Radiation Pattern Behaviour of Reconfigurable Asymmetry Slotted Ultra Wideband Antenna

Yusnita Rahayu
Faculty of Mechanical Engineering
Universiti Malaysia Pahang
Kuantan, Pahang 26600, Malaysia
Email: vannebula2001@yahoo.com

Azlyna Senawi
FIST
Universiti Malaysia Pahang
Kuantan, Pahang 26300, Malaysia
Email: Azlyna@ump.edu.my

Razali Ngah
Faculty of Electrical Engineering
Universiti Teknologi Malaysia
Johor Bahru, 81310, Malaysia
Email: razalin@fke.utm.my

***Abstract*-This paper presents the results of radiation pattern measurement of small reconfigurable slotted ultra wideband (UWB) antennas. The measurements were conducted by using RF measurement and instrumentation facilities, software tools available at WCC of Universiti Teknologi Malaysia. The original antenna's geometry proposed is slotted antenna with L and U slots. Then the slots modifications are applied in order to achieve band-notched characteristics. These proposed antennas are having band notched frequencies at Fixed Wireless Access (FWA), HIPERLAN and WLAN bands. The band-notched operation is achieved by incorporating some small gaps instead of PIN diodes into the slot antenna. It is found that by adjusting the total length of slot antenna to be about a half-wavelength or less at desired notched frequency [1-3], a destructive interference can take place, thus causing the antenna to be non-responsive at that frequency. It was also observed that the measured radiation patterns, H-planes, are omni-directional with slightly gain decreased at boresight direction for measured frequencies. There are also more ripples occurred in the measured pattern compared with the simulated one.**

***Keywords-component; antenna; antenna measurement; radiation pattern; ultra wideband; band-notched antenna*.**

I. INTRODUCTION

This section reviews the concept of reconfigurable antennas that reuse their entire geometry for band-notched frequency applications. Various techniques used have been reported in literature [1-9].

In [1], there are two varieties of slotted antennas which have a frequency notched reported, a triangular notch and elliptical notch. Both antennas have frequency notch characteristics where the arc length of slots form a half wavelength resonance structure at particular frequency, thus a destructive interference takes place causing the antennas to be non-responsive at that frequency. Other types of this kind antenna was reported in [4], a band notched UWB antenna using a slot-type split ring resonator (SRR) was found very effective in rejecting unwanted frequency, such as that for WLAN service, in terms of its selectivity and small dimension. The SRR is composed of two concentric split ring slots and proposed for band stop application, since it provides high Q characteristic. The slotted SRR was positioned near the feeding point to provide more coupling with the field. A multiple band-notched planar monopole antenna using multiple U-shape slots for multi band wireless system was also presented in [5]. The half wavelength U-shape slots were symmetrically inserted in the centre of the planar element. In order to generate the two band-notched characteristics, three U-shape slots were proposed. An alternative antenna design without using slot to obtain band-notched characteristic was proposed in [6]. The antenna consists of two same size monopoles and a small strip bar at the centre showing the band rejection performance in the desired frequency bands. More examples of reconfigurable antenna are available in [7-9].

In this paper, new proposed reconfigurable UWB antennas are designed by adopting the half wavelength slot structure techniques. This paper mainly focuses on reconfigurable notch band through the introduction of new slots, L and U slots, on patch antenna. The current distribution on patch surface is disturbed by the introduction of new slots, which is responsible for the notch in frequency band. Section II will discuss the antenna geometry and the techniques to design new reconfigurable slotted antennas. These proposed antennas are having band notched frequencies. The band-notched operation is achieved by incorporating some small gaps instead of PIN diodes into the slot antenna. The term of small gaps in this paper will refer to switches. The switches are used to short the slot in pre-selected positions along the circumference. The length of the slot antenna can be lengthened or shorted by closing or opening the switches, allowing for a change in the notched frequency. Then the performances of reconfigurable antennas, in terms of VSWR and radiation patterns, will be discussed and evaluated in Section III. Finally, summary will be given in Section IV.

II. ANTENNA GEOMETRY

Fig. 1 shows the original proposed antenna structure printed on the FR4 substrate of $\varepsilon_r = 4.6$. The pentagonal antenna is vertically installed above a ground plane (l_{grd}) of 11 mm. The optimum feed gap (h) to the ground plane is found to be 1.5 mm. The dimension of substrate is chosen to be 30 x 30 mm^2 (W_{sub} x L_{sub}) in this study. Antenna has a pentagonal patch with a width (w) of 15 mm and a length (l) of 12 mm. This shape is as variation of rectangular shape with bevel techniques. The couple slots, L and U, are designed very carefully by studying the current flow distribution which will give input impedance improvement.

The slots proposed on patch effectively change its electrical length over a very wide bandwidth. Slot dimensions of the proposed antenna are listed in Table 1. The slot width is 0.5 mm in order to improve the bandwidth above 10 GHz.

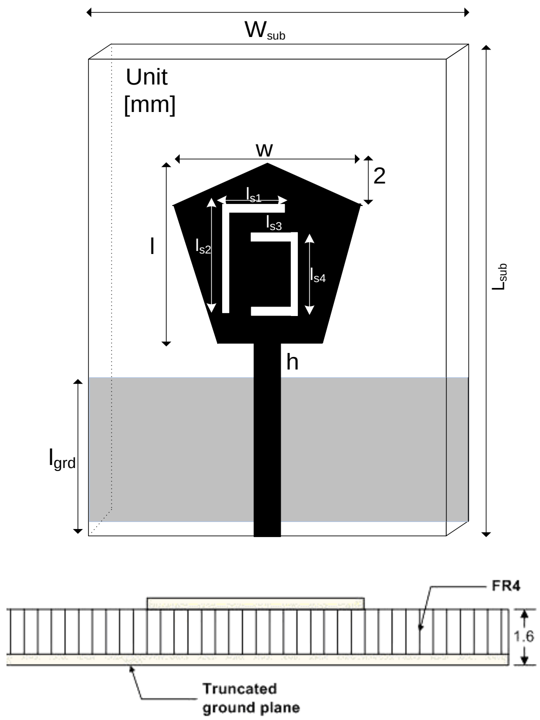

Figure 1. Geometry of L and U slotted antenna

TABLE I DIMENSION OF L AND U SLOT

Description	**L and U Slots**	
	Symbol	***Size [mm]***
Slot length	Is1	6
	Is2	9
	Is3	3
	Is4	6.5

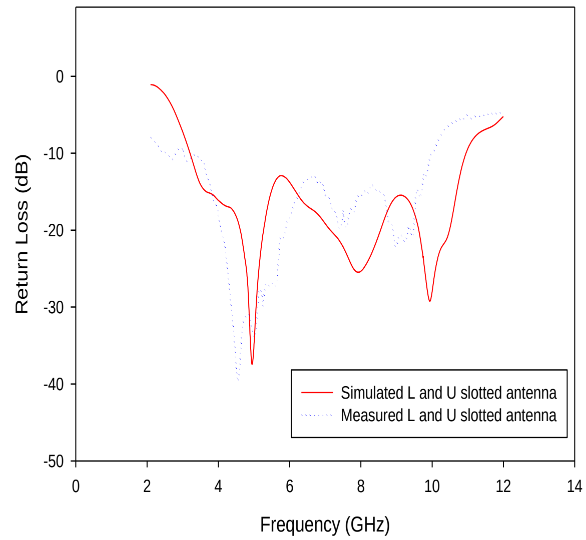

Figure 2. The measured and simulated return loss L and U slotted antenna

The simulated and measured return loss is shown in Fig. 2. The measured return loss is slightly shifted to the simulated one, but they still cover 2.5 GHz to 10.1 GHz as what the UWB required. The length of L slot is 14.5 mm approximately equal to 0.25λ at 5.3 GHz, and the length of U slot is 11.5 mm approximately equal to 0.4λ at 10.3 GHz.

The original geometry of slotted antenna is taken as a reference to form new modified L and U reconfigurable slotted antennas. The modified antennas are designed for having reconfigurable frequency notched at FWA, HIPERLAN, and WLAN as shown in Fig. 3. There are maximum six switches used to provide the reconfigurable function. No especial matching network is used and the matching properties are solely determined by the placement of the switches. The dimensions of antenna and substrate are kept equal to the original model. The length of L and U slots are similar to the previous length, except two additional slot lengths, I_{s20} and I_{s21}. The additional slots are very critically determined by the frequency notched band characteristics.

Licensed band at FWA for point to multipoint radio systems assigned by Malaysian Communications and Multimedia Commissions (MCMC) for 3.4 to 3.7 GHz is considered giving potential interference to UWB application. Therefore, the antenna had notched characteristic at this band is also proposed.

For the simulation purposed, the switches are considered as ideal switches and are modeled as small patches that connect or disconnect the adjacent slot, changing the antennas' slot length.

 ISBN: 978-1-61208-140-3

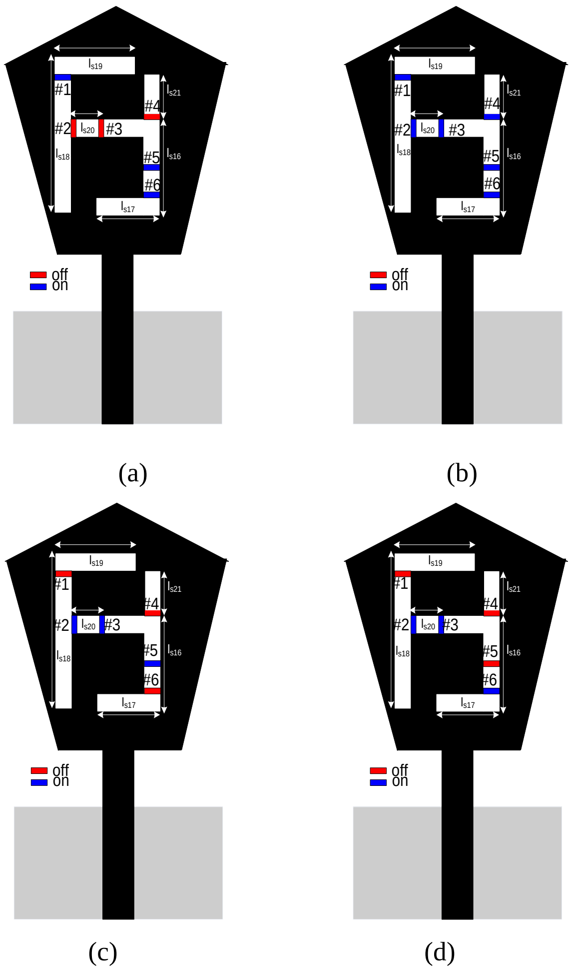

Figure 3. Switching configuration for L and U slotted antennas: (a) without notched, (b) notched at FWA, (c) notched at HIPERLAN, (d) notched at WLAN

For prototype development, the gaps are created in the UWB antenna pattern, which are represented as switches. The selection of PIN diodes as switches is based on their low cost, higher speed and they have better insertion losses at higher frequency than FET switches.

In Fig. 3, the switches have different colors for on and off state condition. Blue color represents the on state condition and red color for the off state condition. In order to provide the UWB characteristic, the switches are placed as shown in Fig. 3(a). Three switches of #2, #3, and #4 are in the off state position. Other switches of #1, #5, and #6 are in the on state condition. When the switches are in the off state condition, the gap between slots occurs and the current flowing to the gap. When the switches are in the on state condition, there is no current flowing to the slots. Thus it forms continuous slots. The switches of #2 and #3 are incorporated to the first additional slot (I_{s20}) which is 3.5 mm of slot length. The switch of #4 is attached to the second additional slot (I_{s21}) which is 2.5 mm of slot length.

The frequency notched characteristic antenna at FWA is shown in Fig. 3(b). All switches are in the on state position (continuous slot). Total slot lengths are 32 mm or approximately equal to 0.4λ at 3.7 GHz. The total slot lengths mean the sum of slot lengths of L, U and additional slots. Fig. 3(c) and Fig. 3(d) present the frequency notched characteristic antenna at HIPERLAN and WLAN, respectively. To reject interference from HIPERLAN, the switches of #1, #4, and #6 are in the off state position while switches of #2, #3, and #5 are in the on state position. It is investigated that by inserting those switches in the off state condition broke the connection between slots. This break connection has reduced the slot length to be 20.75 mm or approximately equal to 0.33λ at 5.2 GHz. Thus, the antenna has frequency notched at HIPERLAN. The total slot length is measured from the length of connecting slots.

The configuration of switches in Fig. 3(d) have resulted an antenna with frequency notched at WLAN. It is shown that the switch of #5 set in the off state position in order to reduce the slot length, while the switch of #6 is set in the on state position. This is the only different while compared to the HIPERLAN configuration. Total slot lengths are 18 mm or approximately equal to 0.33λ at 5.75 GHz and measured from the length of connecting slots.

III. RESULTS AND DISCUSSION

Fig. 4 shows the simulated VSWR for reconfigurable modified L and U slotted antennas. By varying the slot lengths and break the connection between slots using switches, the proposed frequency notched is achieved. The FWA notched band is obtained from 3.57 GHz to 3.86 GHz with the total slot length of 32 mm at 3.7 GHz, which is the centre frequency. While the HIPERLAN and WLAN notched bands are from 4.84 GHz to 5.33 GHz and 5.53 GHz to 6.02 GHz, respectively.

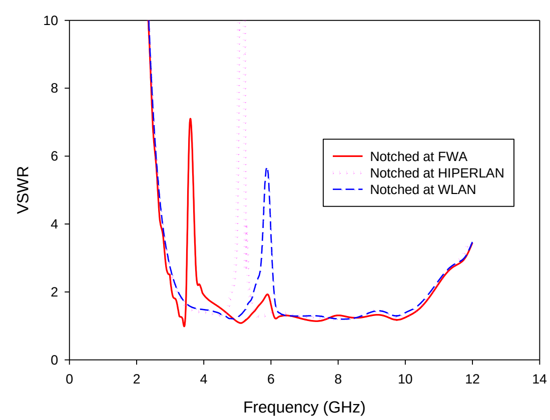

Figure 4 Simulated VSWR for reconfigurable modified L and U slotted antennas

It is noted that beyond the frequency notched bands, the VSWR is kept to be less than 2. With the notched band's characteristic, the antenna has ability to reconfigure its frequency that only responsive to other frequencies beyond the rejection band within UWB bandwidth.

 ISBN: 978-1-61208-140-3

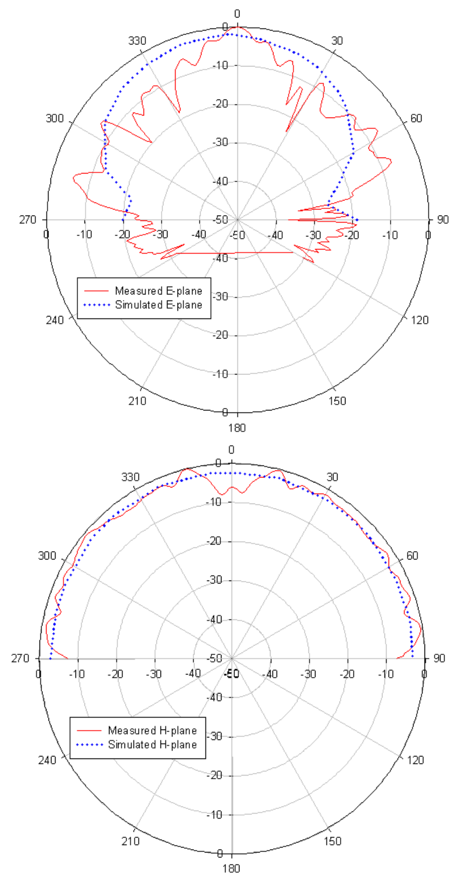

Figure 5. Simulated and measured E and H planes at 4 GHz for antenna notched at FWA

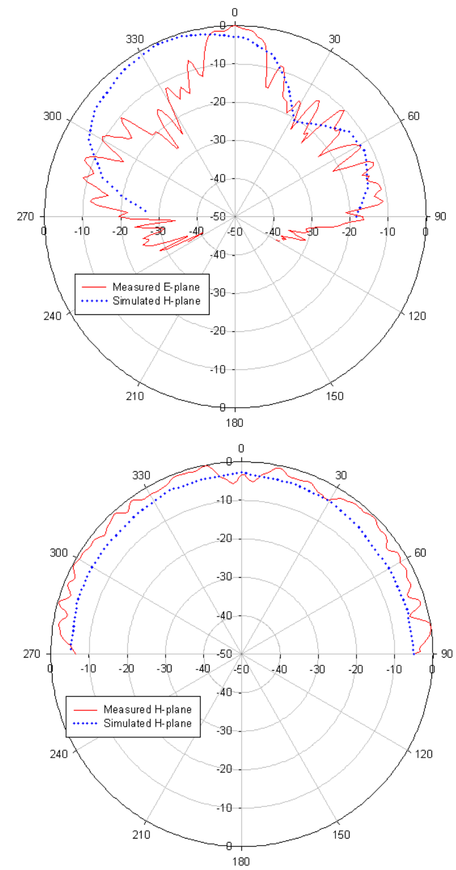

Figure 6. Simulated and measured E and H planes at 5.8 GHz for antenna notched at FWA

Once the resonance frequencies were identified, principal radiation patterns were taken to characterize the operational performance of each antenna. These measurements were conducted in indoor anechoic chamber room. The probes available in the chamber room are in the frequency ranges of 3.95 – 5.85 GHz and 8.95 – 12 GHz, respectively. The existing chamber employed the spherical near field measurement.

Comparison between measured and simulated radiation patterns for these proposed antennas are plotted in Fig. 5 to Fig. 8. All radiation patterns were measured at 4 GHz and 5.8 GHz for both E and H planes. Fig. 5 and Fig. 6 show the radiation patterns of antenna notched at FWA for 4 GHz and 5.8 GHz, respectively.

From Fig. 5 and Fig. 6, there are slightly back-lobes present for the E-planes for both frequencies. Both H-planes are omni-directional with slightly gain decreased at boresight direction. More distortions occur in the measured patterns compared with the simulated ones. This is due to an enhanced perturbing effect on the antenna performance caused by the feeding structure and cable at these frequencies.

During measurement process, several requirements are needed to take into consideration. Obtaining true patterns depends primarily on accurately positioning the probe, accurately measuring the field, and eliminating distortions in the field introduced by the room, tracks, or probe [10]. The room reflections must be lower than the basic side-lobes level and the probe must have low reflections. The probe position must be accurate to give better tolerance corresponding to the side-lobe level. In a spherical near-field range, the spherical measurement surface will be imperfect due to inaccuracies of the positioners and misalignment of these positioners [11].

Fig. 7 shows the radiation patterns for antenna notched at HIPERLAN. The E and H planes measured at 4 GHz and 5.8 GHz.

ISBN: 978-1-61208-140-3

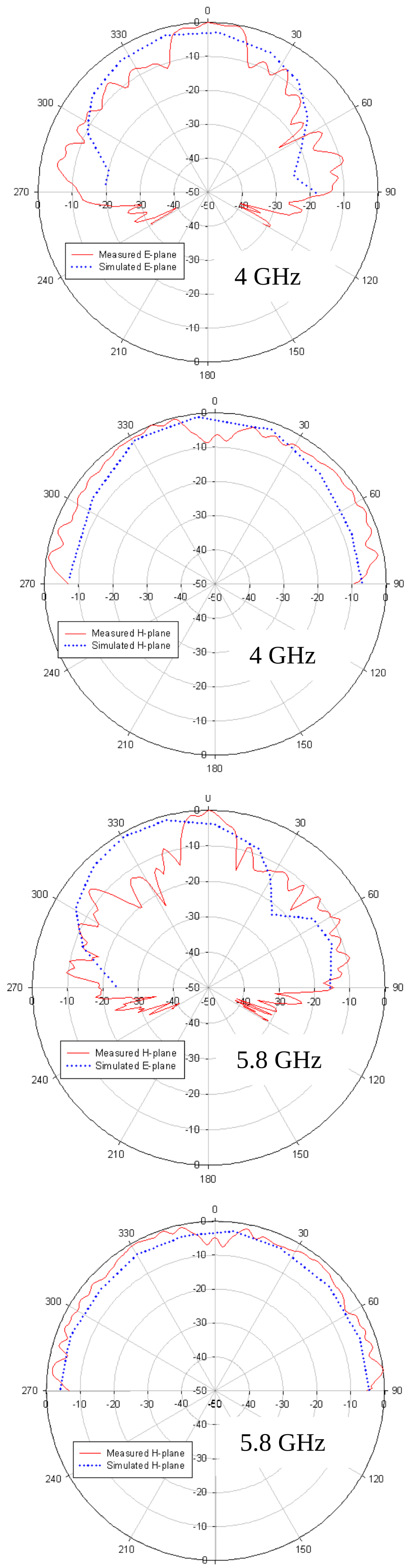

Figure 7. Simulated and measured E and H planes at 4 GHz and 5.8 GHz for antenna notched at HIPERLAN

Fig. 8 and Fig. 9 present the simulated and measured E and H planes for antenna notched at WLAN for both frequencies of 4 GHz and 5.8 GHz, respectively. It is observed that the measured E planes for antenna notched at HIPERLAN broader than the measured E planes for antenna notched at FWA. Both H planes are omni-directional. The overall H-planes patterns retain a satisfactory omni-directionality (less than 10 dB gain variation in most directions) over the entire bandwidth in both simulation and experimental.

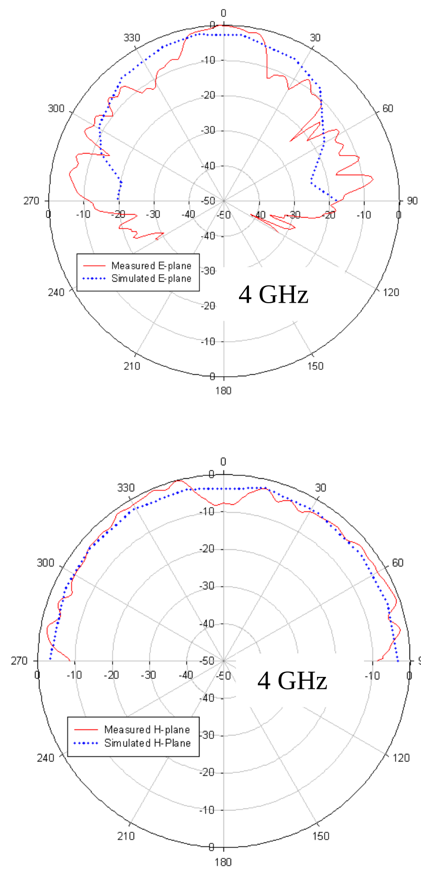

Figure 8. Simulated and measured E and H planes at 4 GHz for antenna notched at WLAN

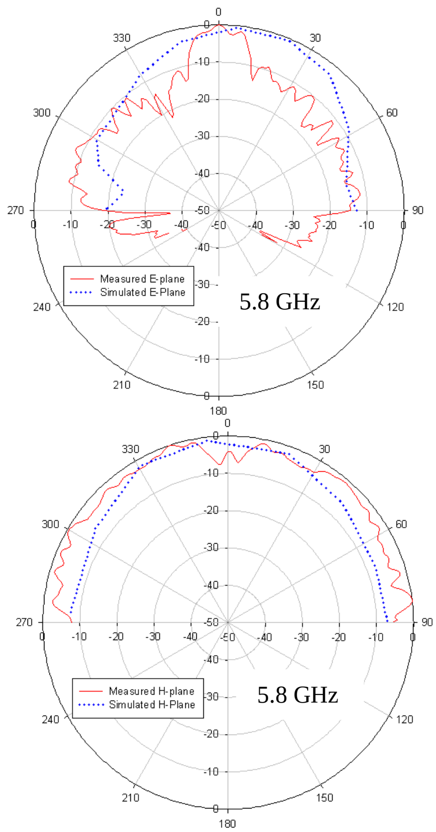

Figure 9. Simulated and measured E and H planes at 5.8 GHz for antenna notched at WLAN

IV. SUMMARY

New slotted reconfigurable antennas with band notched characteristics at FWA, HIPERLAN, and WLAN band have successfully designed and developed. The new models are obtained from modification of previous models without degrading their performance. In order to reconfigure their frequency notched band, six switches are attached to the antenna. It is shown that by varying the slot length, the frequency notched antennas are performed at certain frequency.

Simulated and measured radiation patterns for proposed slotted reconfigurable antennas at 4 GHz and 5.8 GHz have been examined. They show acceptable results where the overall H-planes for both frequencies providing omni-directional patterns. But, more ripples occur in the measured E-planes radiation pattern. This is due to some errors during measurement process.

ACKNOWLEDGEMENT

The authors would like to thank Research and Innovation Department of Universiti Malaysia Pahang for supporting this research and Wireless Communication Centre (WCC) of Universiti Teknologi Malaysia for cooperating and facilitating this research measurement.

REFERENCES

[1] H. G. Schant, G. Wolenec, and E. M. Myszka. Frequency Notched UWB Antenna. Proc. IEEE Conference on Ultra Wideband Sys and Tech. 2003. pp. 214-218.

[2] Y. Kim and D. H. Kwon. CPW-Fed Planar Ultra-Wideband Antenna Having a Frequency Band Notch Function. Electronics Letters. April, 2004. Vol. 40(7): pp. 403-405.

[3] S. W. Su, K. L. Wong, and F. S. Chang. Compact Printed Ultra-Wideband Slot Antenna with a Band Notched Operation. Microwave & Optical Techni. Letters. April, 2005. Vol. 45(2): pp. 128-130.

[4] J. Kim, C. S. Cho, and J. W. Lee. 5.2 GHz Notched Ultra-Wideband Antenna Using Slot-type SRR. Electronics Letters. March 16, 2007. Vol. 42(6).

[5] W. S. Lee, W. G. Lim, and J. W. Yu. Multiple Band-Notched Planar Monopole Antenna for Multiband Wireless Systems. IEEE Microwave and Wireless Components Letters. Sept., 2005. Vol. 15(9).

[6] S. Hong, K. Chung, and J. Choi. Design of a Band-Notched Wideband Antenna for UWB Applications. Antennas and Propagation Society International Symposium. IEEE. 2006.

[7] Kenneth C. L. Chan and Yi Huang. A Compact Semi-Circular Disk Dipole with Notched Band for UWB Applications. The Institution of Engineering and Technology Seminar on Ultra Wideband Systems, Technologies, and Applications. 2006. pp. 226-230.

[8] K. Chung, J. Kim, and J. Choi. Wideband Microstrip-Fed Monopole Antenna Having Frequency Band Notch Function. IEEE Microwave and Wireless Components Letters. November, 2005.Vol. 15(11).

[9] Y. Kim and D. H. Kwon. Planar Ultra Wideband Slot Antenna with Frequency Band Notch Function. Antennas and Propagation Society International Symposium. IEEE. 2004.

[10] Gary E. Evans. Antenna Measurement Techniques. Boston, London: Artech House. 1990.

[11] G. Hindman and Allen C. Newell. Simplified Spherical Near-Field Accuracy Assessment. Technical Paper. Nearfield System, Inc. 2004.

 ISBN: 978-1-61208-140-3