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Wideband G-Shaped Slotted Printed Monopole Antenna for WLAN and WiMAX Applications

Wan Noor Najwa Wan Marzudi[1], Zuhairiah Zainal Abidin[1], Siti Zarina Mohd Muji[1], Ma Yue[2], and Raed A. Abd–Alhameed[3]

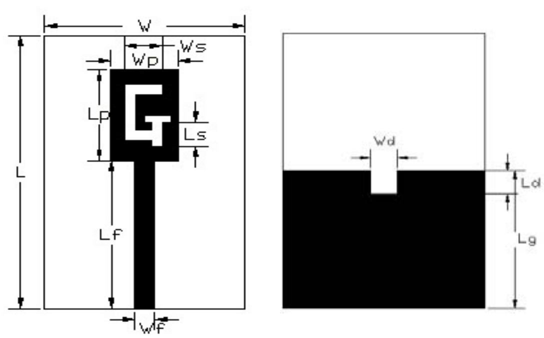
[1]Research Centre for Applied Electromagnetic (EMC),
UniversitiTun Hussein Onn Malaysia, Johor, Malaysia
[2]National Astronomical Observatories, Chinese Academy of Sciences
[3]Mobile and Satellite Communications Research Centre,
University of Bradford, United Kingdom
[1]wannoornajwa@gmail.com, zuhairia@uthm.edu.my, szarina@uthm.edu.my

Abstract: A novel wideband printed monopole antenna is proposed covering frequency spectrum of wireless local area network (WLAN) and the Worldwide Interoperability for Microwave Access (WiMAX). The total antenna size is 30 × 48 × 1.6 mm³ in which it consists of a G-shaped slotted printed antenna and a defected ground plane. Theoretical and experimental characteristics are presented and compared. The antenna yields an achieved impedance bandwidth of 95.1% between 2.374 GHz and 6.682 GHz at a reflection coefficient $|S_{11}| \leq -10$ dB.The results including S-parameters, surface current distribution, VSWR, radiation patterns and antenna gains; in addition to a reasonable and stable radiation pattern and power gain.

Keywords: Ground Plane, Monopole Antennas, Wideband Antennas, WLAN/WiMAX.

1. Introduction

Recently, the trends and demands towards wireless communications such as WLAN and WiMAX have been widely increased and leads to an antenna that has a compact size, light weight, ease of fabrication and large bandwidth. Therefore, various types of antenna have been reported in literature to operate along the WLAN and WiMAX frequency bands [1-9]. Different techniques have been proposed providing dual, triple or four band performances such as parasitic inverted U-shaped [1], paw shaped [2], C- and L- shaped [3], split ring slot [4], T-shaped [5] and umbrella printed dipole [6]. Furthermore, a coplanar waveguide (CPW) fed monopole antenna [1], coupling fed plate [7] and defected ground plane [5, 8] are other methods have been used to improve the impedance bandwidth of the antenna and simultaneously improved the antenna performance. In this article, a wideband G-shaped slotted



(a) (b)

Figure 1. Geometry of the proposed antenna (in mm); (a) Top View, (b) Bottom view.

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printed monopole antenna covering the operating band from 2.37 GHz up to 6.68 GHz is introduced for possible use to satisfy the requirement of WLAN and WiMAX applications. The total dimensions of the proposed antenna are 30 × 48 × 1.6 mm^3. It should be noted that the dimension of the proposed antenna smaller than the previous published work in [9] about 15.68 % improved size. The proposed work has the dimension of 1440 mm^2, compare to previous work in [9] which has the dimension of 1685 mm^2. It is confirmed that new development of G-shaped slotted printed radiator and etching of a defected area on the ground plane, two resonant frequencies and broad impedance bandwidth can be achieved. Details of the proposed antenna design; both experimental and simulated results of the fabricated prototype are presented and discussed in the following sections.

2. Antenna Design

The configuration of the proposed antenna is illustrated in Fig.1. The antenna comprises the G-shaped slotted monopole that is quite similar to the published data in [2].The previous published data in [10] provide dual wideband frequencies which have fluctuation at 4.528 GHz. In this antenna design, an improvement have been made by changing the size of the defected areathat resulted wideband performances.The proposed antenna deployed on an FR4 substrate material with relative permittivity, ε_r = 4.4, thickness, h = 1.6 mm. The radiator is printed on the top side of FR4substrate coveringthe dimension area of 10 × 16 mm^2. Figure 1(a) shows that G-shaped slotted is etched on rectangular patch radiator that is fed by a 26 × 2.96 mm^2 50 Ω micros trip line. Through the simulated results, it is found that the operating frequencies of WLAN and WiMAX obtained after G-slot introduced. The upper arm, W_s and lower arm, L_s of G-shaped slotted are found responsible to resonate the upper and lower frequencies of WLAN and WiMAX respectively. In order to improve the impedance bandwidth of the proposed antenna, the defected area with the size of 4 × 4 mm^2 was etched on the top of the ground plane. The impedance bandwidth of the proposed antenna achieved about 95.1 % from 2.374 – 6.682 GHz compared to previous publish work in [5] which not fully covered the WLAN/WiMAX frequency range. To verify the simulated results, the proposed antenna was fabricated and tested. The physical prototype of the proposed antenna shows in Figure 2.

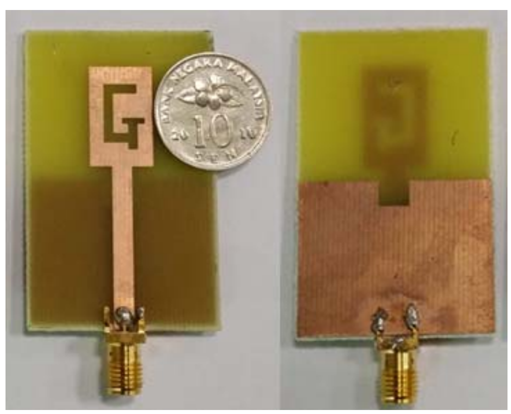


Figure 2. Practical prototype of proposed antenna

3. Parametric Study

A. *Effect of the Width,* W_s *and Length,* L_s *of G-slot*

In order to quantify the effects of the W_s (upper arm) and L_s(lower arm- as shown in Fig. 1) on the proposed antenna, the parametric studies were carried out by using CST Microwave Studio. Figure 3 and Figure 4 exhibit the return losses of various dimensions of W_s and L_s without the existing of the defected area respectively. From Figure 3, it can be seen that by slightly increased the width of W_s, the upper frequency of the proposed antenna will be slightly shifted. It showed that the width of W_s can control the resonant frequency at the upper band.

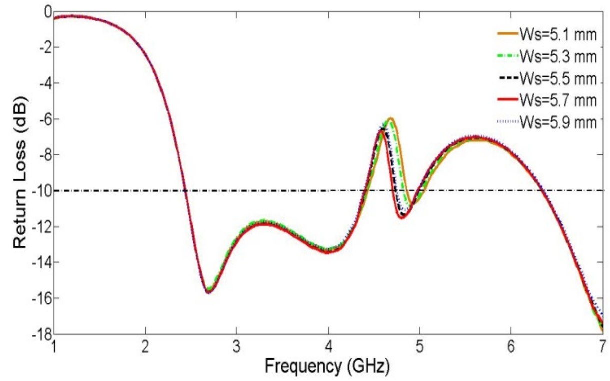


Figure 3. Simulated return loss with various W_s (upper arm)

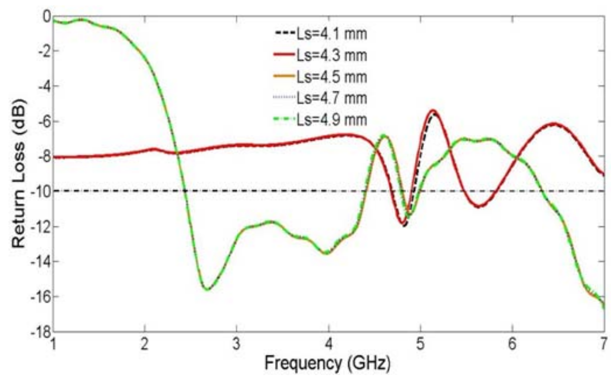


Figure 4. Simulated return loss with various L_s (lower arm)

Meanwhile, Figure 4 depicted the simulated return losses of various dimension of $L_{s.}$ From the figure, it can be observed that when the length of L_s starts to increase from 4.5 mm, the proposed antenna tends to resonate at lower frequency band. This indicates that the lower frequency of the proposed antenna depends on the length of $L_{s.}$ The effect of the W_s and L_s can be observed through the surface current distribution as shown in Figure 9. It can been seen that at the lower frequencies band; 2.4, 2.5, 3.5 GHz and for the upper frequencies band; 5.2/5.5/5.8 GHz, the current has high concentration at L_s and W_s part respectively. It can be concluded, that the upper arm (W_s) of G-slot control the higher frequencies band meanwhile the lower frequencies band was controlled by lower arm(L_s)of G-slot.

B. Effect of the Width, W_d *and Length,* L_d *of Defected Area on Ground Plane*

The width and the length of the defected ground plane areother important design parameters that influenced the performance of the proposed antenna characteristic. These parameters are denoted with "W_d" and "L_d".

Through figure 5 and figure 6, it can be seen that by gradually increased the W_d and L_d, it will affect the impedance bandwidth of the proposed antenna, respectively. Through these parametric studies, it can be observed that by gradually increased the L_d, it will affect the impedance bandwidth. The optimal dimension of L_d was set to 4 mm which gave a relative

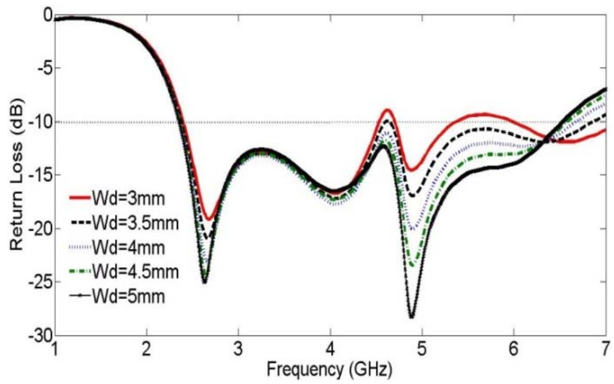


Figure 5. Simulated return loss with various W_d (width of defected ground plane)

bandwidth of 95.1% compared to others value that resulted dual band and decreased the relative bandwidth performances. Meanwhile, the width of defected area W_d was remain intent as in [10] because there is no significant differences in impedance bandwidth for over 4 mm. From these observations, it proves that the defected ground plane is one of the techniques to improve resonant frequency and impedance bandwidth of the antennaas mentioned in [11].To verify the performance of the defected ground plane, the comparison of the simulated return loss, S_{11} with and without defected ground plane of the proposed antenna is shown in Figure 7.

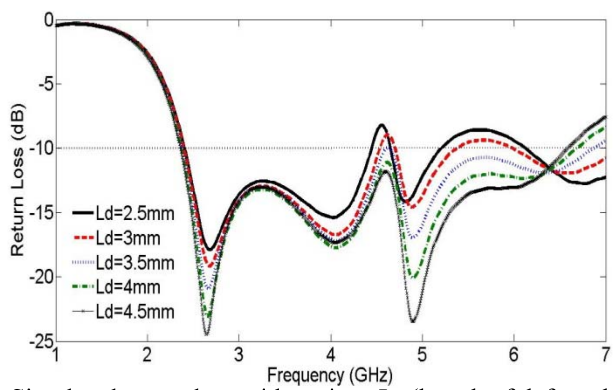


Figure 6. Simulated return loss with various L_d (length of defected ground plane)

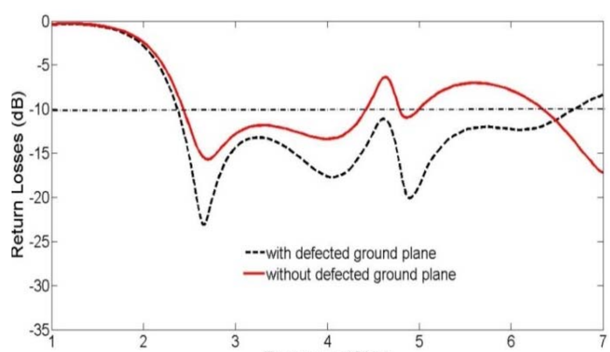


Figure 7. Comparison of return loss, S_{11} with and without defected ground plane.

Table 1. Optimized values of the prototype

Parameter	Values (mm)
W	30
L	48
$\mathbf{L_f}$	26
$\mathbf{W_f}$	2.96
$\mathbf{L_g}$	24
$\mathbf{W_s}$	5.7
$\mathbf{L_s}$	4.5
$\mathbf{L_d}$	4
$\mathbf{W_d}$	4
$\mathbf{W_p}$	10
$\mathbf{L_p}$	16

It is noticed that, when the defected area deployed on the ground plane, it will improve the impedance bandwidth of the proposed antenna. The impedance bandwidth of the proposed antenna increased from 57.4% (over 2.434-4.42 GHz) and 4.2% (over 4.786-4.996%) to 95.1% (over 2.374-6.682 GHz). In summary, the operating frequency band of the proposed antenna were determined by the width, W_s and the length, L_s of the G-shaped slotted. Meanwhile, the width, W_d and length, L_d of defected area on the ground plane were the others parameters that influenced the impedance bandwidth of the proposed antenna. The final optimized dimensions of the antenna parameter are summarized in Table 1.

4. Results And Discussion

A. S-Parameters

The simulated and measured return loss of the proposed antenna is plotted in Figure 8. As can be seen, the result reasonably agrees between simulation and measurement. The measured return loss slightly shifted compared to the simulated ones. This frequency shift is probably caused by the effect of SMA connector and fabrication tolerance. This figure reveals that the measurement result for return loss, S_{11} is less than -10 dB over a bandwidth range of 2.37 up to 7 GHz covering WLAN 2.4/5.2/5.8 and WiMAX 2.5/3.5/5.5 bands.

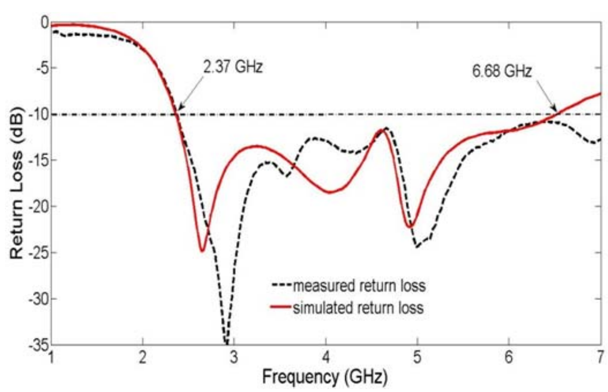


Figure 8. Simulated and measured return loss of the proposed antenna

B. Surface Current Distribution

The surface current distribution of the proposed antenna over different frequencies at 2.4, 2.5, 3.5, 5.2, 5.5 and 5.8 GHz shows in Figure 9. It can be observed that the surface current distributed close to the feed line. At these resonant modes the current started to distribute uniformly to the rectangular patch.

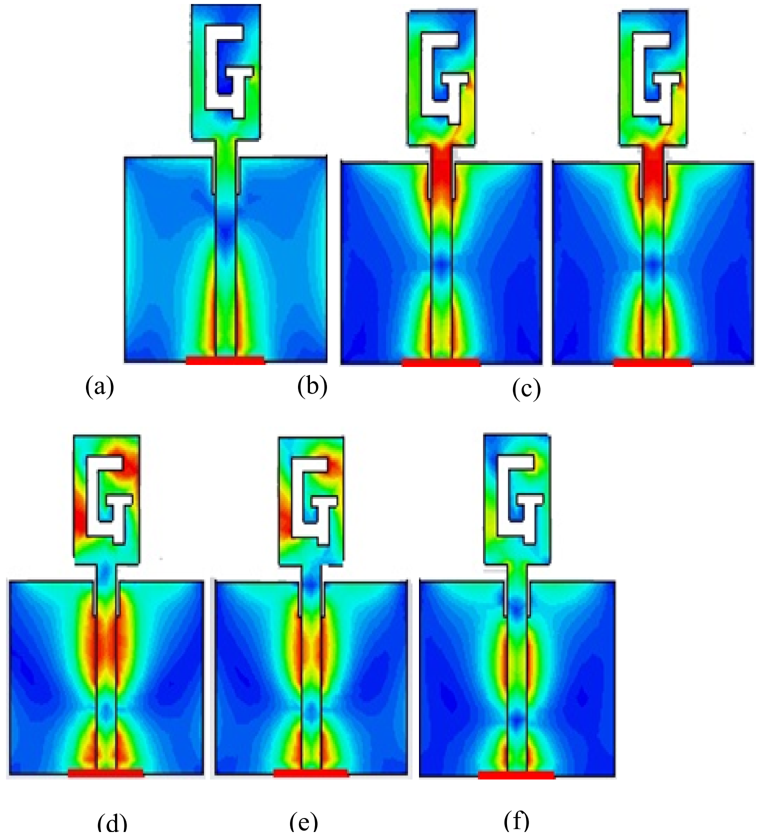


Figure 9. Surface current distribution at (a) 2.4 GHz, (b)2.5 GHz, (c)3.5 GHz, (d)5.2 GHz, (e)5.5 GHz and (f) 5.8 GHz

C. Voltage Standing Wave Ratio (VSWR)

The measured and simulated voltage standing wave ratios (VSWR) for the proposed antenna are shows in Figure 10. There exists a good agreement between simulated and measured results. It can be seen that, lower VSWR which is smaller than 2 achieved over the entire frequency band from 2.4 to 5.8 GHz.

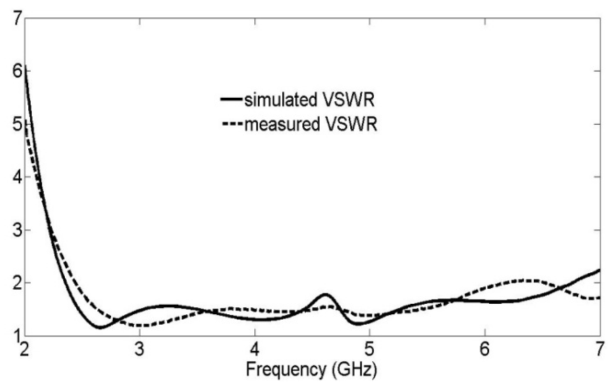
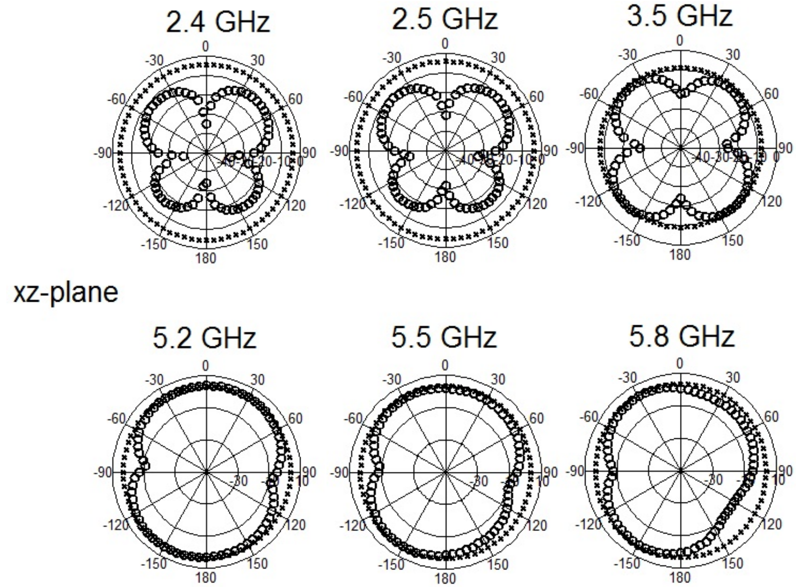


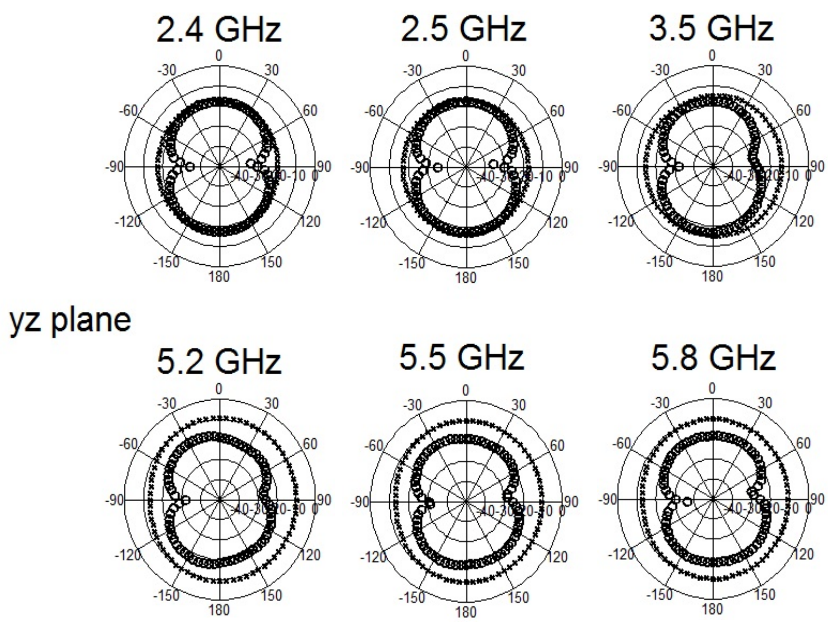
Figure10. Simulated and measured voltage standing wave ratio (VSWR) of the proposed antenna.

D. Radiation Patterns

The simulated far-field radiation pattern on the E-plane (x-z plane) and H-plane (y-z plane) at frequencies of 2.4, 2.5, 3.5, 5.2, 5.5 and 5.8 GHz are plotted in Figure 11. The antenna shows a stable omnidirectional pattern in the E-plane and H-plane, respectively over the Wi-Fi, WLAN and WiMAX spectrum bands.



(a)



(b)

Figure 11. Simulated radiation pattern of the proposed antenna at 2.4, 2.5, 3.5, 5.2, 5.5 and 5.8 GHz in the (a) X-Z plane and (b) Y-Z plane. “xxxx” simulated co-polarization, “oooo” simulated cross-polarization.

E. Antenna Gains

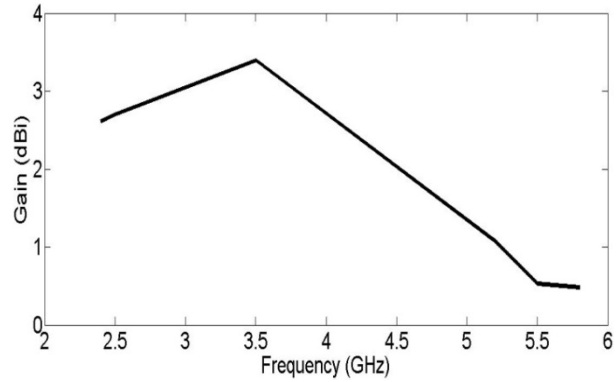


Figure 12. The gain of the proposed antenna.

Figure 12 depictsthe simulated gain of the proposed antenna over the interval frequency band from 2.4 to 5.8 GHz. The antenna gain levels obtained are about 2.6 -3.3 dBi in the range of2.4-3.5 GHz and 3.3 – 0.48 dBi at 3.5 – 5.8 GHz. It can been seen that, the gain at the upper frequencies are lower that the antenna gain at the lower frequencies.This is due to the cross-polarization of upper frequencies in E-plane (x-z plane) as shown in Figure 11 (a)is larger than those of the lower frequencies. Additionally, the radiation efficiency of this proposed antenna is approximately above 90%.

5. Conclusion

A novel wideband G-slotted and defected ground plane printed monopole antenna has been presented as possible candidate for WLAN and WiMAX wireless applications. The optimum dimensions of proposed antenna were found $48 \times 30 \times 1.6$ mm³. The proposed radiating element has achieved stable radiation pattern overall 95.1% operating frequency band extended over 2.374-6.682 GHz. Measurement result showed good agreement with simulated one.

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Wan Noor Najwa Wan Marzudi completed her BSC in Electrical Engineering with Honor in 2013 from Universiti Tun Hussein Onn Malaysia. She is currently pursuing her Masters by Research Degree in Electrical Engineering from Universiti Tun Hussein Onn Malaysia, Johor, Malaysia. Her research interest include design of wideband and MIMO/diversity printed antennas.

Zuhairiah Zainal Abidin was born in Kuala Lumpur, Malaysia, in 1978. She received the B.Eng. from the Universiti Teknologi Malaysia, in 2001, the M.Engfrom the Kolej Universiti Tun Hussein Onn Malaysia, Johor, Malaysia, in 2003,and Ph.D. degree from Bradford University, U.K in 2011. Currently, she was a Senior Lecturer at Universiti Tun Hussein Onn Malaysia. Her current research interests include MIMO antenna design, electromagnetic bandgap (EBG) for wireless and mobile systems and high speed digital circuits.

Siti Zarina Mohd Muji received her M.Sc. degree in Electric and Electronic Engineering from Universiti Sains Malaysia in 2004 and his PhD degree in Electronic Instrumentation at Universiti Teknologi Malaysia in 2012. She is currently a senior lecturer at the Faculty of Electric and Electronic Engineering at Universiti Tun Hussein Onn Malaysia, focusing on Optical Tomography and embedded system applications.

Raed A. Abd-Alhameed received the B.Sc. and M.Sc. degrees from Basrah University, Basrah, Iraq, in 1982 and 1985, respectively, and the Ph.D. degree from the University of Bradford, West Yorkshire, UK, in 1997, all in electrical engineering He is a Professor of electromagnetic and radio frequency (RF) engineering in the School of Engineering and Informatics at the University of Bradford, Bradford, U.K. He has over 25 year research experience in RF designs, antennas and electromagnetic computational techniques and has published over 400 academic journals and referred conference papers. He has led several funded projects from EPSRC, European funds, Health Department, Technology Strategy Board and Industry. His current research interests include hybrid electromagnetic, EMC, low SAR antennas, active antennas, beam steering antennas, MIMO antennas, RF predistorter including biological cell modelling for breast cancer applications. Prof. Abd-Alhameed is the Fellow of the Institution of Engineering and Technology, Fellow of Higher Education Academy, and a Chartered Engineer; in addition he is a senior member of the IEEE. He is also the Chair of several successful workshops on Energy Efficient and Reconfigurable Transceivers (EERT): Approach towards Energy Conservation and CO2 Reduction that addresses the biggest challenges for the future wireless system.

Ma Yue was born in China. She received the Bachelor and Master Degree from University of Bradford University, UK respectively in 2009 and 2010. Her current research interest includes mobile and satellite communication, MIMO mobile handset antenna designs, CPW, UWB, phase array antennas for wireless communication applications, wide band single pixel feed and phased array feed for Square Kilometre Array(SKA) radio telescope. Currently, she is a main researcher for the Chinese Ministry of Science and Technology under the State Key Development Program for Basic Research, National Astronomical Observatories, Chinese Academy of Sciences.