A Study of Carbon Coated Flat Stick Bamboo Microwave Absorber Performance

Azizah Ahmad, Hasnain Bin Abdullah, Linda Mohd Kasim, Noor Azila Ismail, Norhayati Mohamad Noor, and Nazirah Mohamat Kasim
Faculty of Electrical Engineering, Universiti Teknologi MARA, Cawangan Pulau Pinang, Malaysia
Email: {azizah146; hasnain; linda; noorazila687; hayati005; nazirah261}@uitm.edu.my

Abstract—**Electromagnetic radiation can be prevented by using microwave absorber. Microwave absorbers are applied in an anechoic chamber for the electromagnetic compatibility (EMC) and electromagnetic interference (EMI) evaluation on its wall, ceiling, and floor. The purpose of this research is to develop a carbon-coated flat shape of biomass absorbers using an agricultural material. The main material used in constructing the flat absorber is natural bamboo. The flat shaped absorber is selected as it able to meet the specified industry standard and can be used appropriately in the microwave frequency range. Carbon coated cylindrical bamboos with different radiuses have been used for this study. Studies were conducted on two different sizes of the radius that is 0.2 cm for Design 1 and 1 cm for Design 2. The ranges of frequencies are set in the range from 1 GHz to 12 GHz. The result of the microwave absorber is analyzed for its absorption performance. The generated result from the performance shows that the carbon-coated flat stick bamboo microwave absorber operates the best in Design 2 with 45.7% of absorption performance compared with Design 1. The overall results in different angles for both designs are analyzed and compared.**

Index Terms—**Absorption performance, electromagnetic compatibility, electromagnetic interference, microwave absorber, radiation**

I. Introduction

Malaysia is a country that is actively involved in the development of wireless telecommunications technology. With the increasing use of electromagnetic waves, such as in industrial equipment, medical devices and more sophisticated electronic devices, electromagnetic interference (EMI) becomes an important issue that deserves greater attention. Research carried out by [1] shows that 60% of the medical devices tested were affected by the existence of a wireless telecommunication device. EMI not only interferes the performance of the electronic devices, it also affects human health. A long-time usage of mobile phones increases the risk of 40% - 200% for having brain cancer and tumor as stated in the published epidemiological studies by Lin [2]. The specific absorption rate (SAR) is the measurement of electromagnetic (EM) absorption by human tissue when they are exposed to Radio Frequency (RF) and the unit is watts per kilogram, W/kg. A particular safe limit of SAR is selected so that the maximum EM radiation exposure could be sustained without leading to biological changes to human health. These standards regulated by world authoritative bodies comprise the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and Federal Communications Commission, (FCC). According to the ICNIRP standard, the safe SAR limit is 2 W/kg for 10 g of body tissue[3]. The impact of EMI on electronic equipment shown by [4] shows that in the presence of EMI, the equipment should provide the highest reliability and robust operation.

There are four different phenomena regarding electromagnetic compatibility EMC issues, such as Radiated Emission (RE), radiated susceptibility/ immunity (RS/I), Conducted Emission (CE) and Conducted Susceptivity/Immunity (CS/I) emission which is related to the capability of a device to cause interference in its environment. The objective of controlling the level of emissions of a device is to establish a significant electromagnetic environment. The malfunction of a device due to noise is called susceptibility and susceptivity while its opposite is called immunity [5].

There are two ways to protect the electromagnetic field (EMF) exposure that is by using shielding material or the absorbing method. Shielding materials are incapable to eliminate or weaken EMI radiation; even the reflected wave may interact with the incident wave resulting disturbance to other devices. Another way is by using an electromagnetic wave absorbing materials and transferring the electromagnetic energy to other forms[6].

To prevent this from occurring, emissions and immunity play an important role. Emissions from electronic equipment must be controlled so that the electromagnetic environment does not affect the equipment. At the same time, any critical malfunction must be avoided by achieving the equipment immunity when the equipment is working in a typical environment where a certain level of concern occurs. It is essential to measure the compatibility of electronic devices, computers and home appliances on its EMC and EMI tests in an anechoic chamber [7], [8]. This is to ensure that the functions of the device system are not compromised and that the equipment can operate without being affected by the electromagnetic environment.

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Corresponding author: Azizah Ahmad (email: azizah146@uitm.edu.my).

Meanwhile, this technique can decrease maintenance and construction expenses, as well as lessen the complexity of its operating system.

Recently, microwave absorber is an option for the electronic industries to inhibit the radiation in electromagnetic environments. It is impossible to avoid the exposure of high radio frequency radiation in the surroundings. Reduce the duration of exposure in the high radiation working environment or lessen the use of mobile phones is the prevention that people should do.

This research is focused on designing flat bamboo absorber to be located in an anechoic chamber. The use of bamboo in this project can fulfill the need for green technology and economics. Carbon and water element contained in bamboo make this material a good microwave absorber. Carbon is a semiconductor material that allows a low quantity of charge flows through it. From this characteristic, carbon can be used as the material in the making of absorber [9]. Flat stick carbon-coated has been proposed for this research.

The objectives of this project are divided into three steps. The first step is to design and simulate the modeling of the characteristic for flat absorber by using CST software. The second step is to develop a flat shape of biomass absorbers using natural bamboo and coated with carbon. The final step is to analyze the performance of the absorber in terms of its absorption efficiency.

This project intends to examine the suitable dielectric properties value impact from the flat shape of biomass absorbers using agricultural waste materials, which is natural bamboo. The flat shape of the absorber will be used in this research to get a better performance in terms of its absorption efficiency. The principle of this study involves dielectric test, characterization and simulation with different values of dielectric properties and performance measurement. CST software is used to analyze the simulation, modeling and analysis of the properties and characteristics of the natural bamboo absorbers. The important parameters derived from the CST software are the dielectric constant and the reflectivity coefficient using different values of dielectric properties.

Several project implications can be achieved from this project. Flat natural bamboo microwave absorbers can be environmentally friendly radiation-measuring machines. Besides, it can reduce unwanted or lost signals from electronic devices and other equipment. Finally, it provides a good indication of absorption performance.

II. Methodology

Characteristic and several parameters studies have been performed to identify the factors that influence the absorption performance. The basic absorption material used for this study is carbon-coated bamboo. The design was created using the CST Microwave Studio Software as a tool to accomplish the absorption performance.

The microwave absorption performance is measured using a free space arch reflection technique. This technique requires a pair of horn antenna that is attached to arch curvature, Vector Network Analyzer and material measurement software (Agilent 85071E). The structure of the arch curvature is made up of semi-circular wood[10]. The design of the arch will allow horn-type antennas for transmitting and receiving signals. The absorber should be positioned properly in the middle of the arch throughout the measurement process. The position angle of the antenna horns is varied to realize the electromagnetic wave [11]. Measurements are prepared for frequencies between 1 GHz and 12 GHz.

A. Design of Absorber

Cylindrical-shaped bamboo is used for the design of the flat absorber. In this study, flat absorbers are designed in two different radiuses. Both designs are arranged in three layers and the dimension is 60 cm length $\times$ 60 cm width. The purpose of a three-layer arrangement of bamboo is to minimize the gap between the bamboo sticks. Design 1 is shown in Fig. 1 with a radius of 0.2 cm while Design 2 is developed using a bamboo radius of 1 cm as shown in Fig. 2. All absorbers were coated with carbon to enhance absorption performance. Cassava glue is used to attach the bamboo. Tapioca starch that is mixed with hot water is used to make cassava glue to hold the structure of the absorber. Consequently, the construction of the absorbers will be long-lasting and sturdy enough to withstand any applied force.

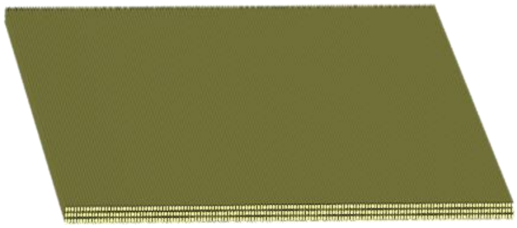

Fig. 1. Design 1: Flat absorber model using CST.

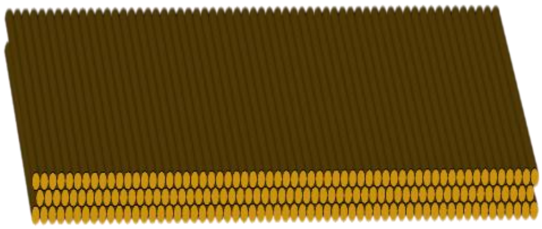

Fig. 2. Design 2: Flat absorber model using CST.

B. Material of Absorber

Bamboo is a rapid growth plant compared to other trees and a sustainable source as the increasing use in various areas of the wood and construction industry [12], [13]. Bamboo has been largely used in building applications such as fences, flooring, ceiling, wall and windows. Based on the diversity of bamboo uses, studies have been conducted to see the ability of bamboo to be a good absorber. Bamboo has the potential to be produced as activated carbon[14]. Carbon is a material that is naturally able to convert microwave energy to thermal energy due to its good semiconductor properties [10]. According to this finding, to enhance the absorption performance of the designed absorber, the flat stick bamboo is coated with carbon made up of bamboo activated carbon as illustrated in Fig. 3 and Fig. 4.

Fig. 3. Design 1: Carbon coated microwave absorber.

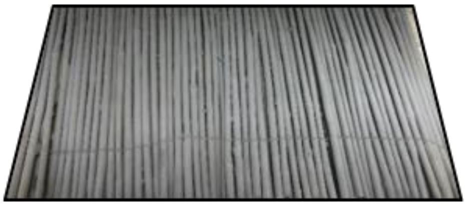

Fig. 4. Design 2: Carbon coated microwave absorber.

C. Dielectric Measurement

Complex permeability and permittivity are two important aspects in determining the capability of microwave absorber absorption [15], [16]. The absorption is attainable if the impedance of free space and the impedance of a material is matched [17]. These two properties can be obtained by determining the dielectric of the material. Dielectric measurement is also compulsory for the multilayer absorber.

III. Result and Discussion

A. Simulation Result

From the simulation result of Design 1 in Fig. 5, the flat absorber shows a minimum absorption at –8 dB at 1 GHz. The maximum absorption hit –60 dB at the frequency of 3.8 GHz. The simulation result of Design 2 shown in Fig. 6 indicates the minimum absorption of –3 dB at 2.5 GHz of frequency, and the maximum absorption is –45 dB in the frequency of 6.7 GHz.

B. Measurement Result

The measurement of the absorber was conducted to determine the absorption performance. Measurement of the absorption is executed in five different angles to observe the influence on the performance of the absorber. Both designs are measured at 0°, 15°, 30°, 45° and 60°.

Fig. 7 shows the measurement result of Design 1 at 0°. At 1 GHz the result shows minimum absorption is –1 dB and the maximum absorption is –19 dB at the frequency of 10.2 GHz. Meanwhile, Design 2, the minimum absorption is –5 dB and maximum absorption is –35 dB at the frequency of 3 GHz and 11.8 GHz respectively. At this angle, Design 2 shows the maximum absorption of 45.7% greater compared to Design 1.

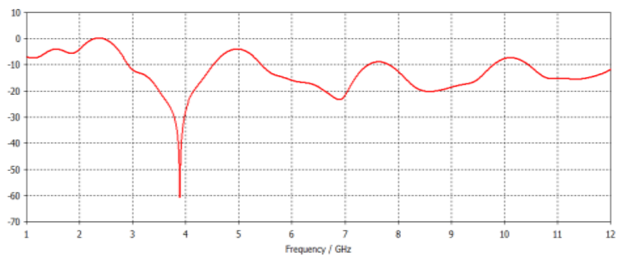

Fig. 5. Simulation result for design 1.

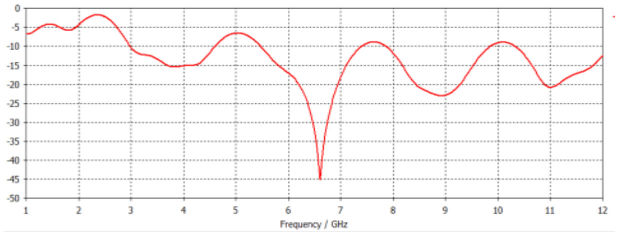

Fig. 6. Simulation result for design 2.

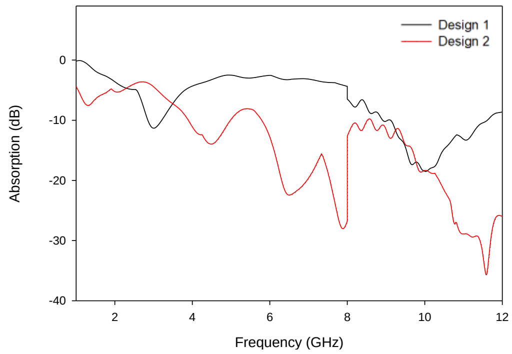

Fig. 7. Measurement result comparison graph for 0 °coated.

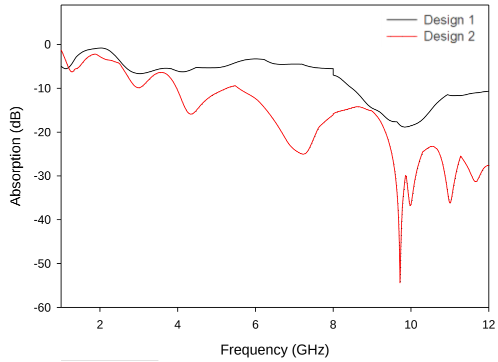

Fig. 8. Measurement result comparison graph for 15 °coated.

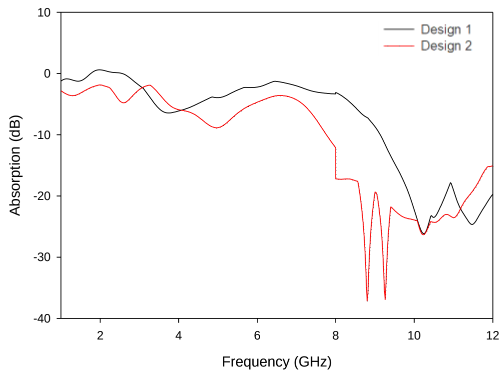

Fig. 9. Measurement result comparison graph for 30 °coated.

From Fig. 8, at 15° the result shows that Design 1 had a minimum absorption at –2 dB at the frequency of 2.2 GHz. The maximum absorption hit –20 dB at 9.9 GHz. For Design 2, it had a minimum absorption at –1 dB at the frequency of 1 GHz. The maximum absorption struck –55 dB at 9.7 GHz. At 15°, Design 2 also indicates 63.6% greater absorption compared to Design 1.

Based on the measurement at 30°, Fig. 9 indicates the minimum absorption of Design 1 is –0.11 dB at 3 GHz while the maximum absorption is –25 dB at the frequency of 10.5 GHz. Meanwhile, for Design 2, the minimum absorption is –2 dB and the maximum absorption is –38 dB at the frequency of 3.2 GHz and 8.8 GHz respectively. The maximum absorption at this angle is 34.2% higher for Design 2 compared to Design 1.

From Fig. 10, at 45° it has been shown that Design 1 had a minimum absorption at –2 dB at the frequency of 3 GHz. The maximum absorption hit –32 dB at the frequency of 11.7 GHz. For Design 2, it had a minimum absorption at –2 dB at the frequency of 1 GHz. The maximum absorption struck –40 dB at frequency 10.1 GHz. At this angle, the maximum absorption of Design 2 compared to Design 1 is 20%. From the result, it has been shown that at this angle, both of the design gives good absorption.

Based on the measurement at 60° for Design 1 in Fig. 11, at 2 GHz the result showed that minimum absorption is –1.5 dB and the maximum absorption value is –13 dB at the frequency of 3.4 GHz. Meanwhile, on Design 2, the minimum absorption is –2 dB and maximum absorption is –21 dB at the frequency of 1 GHz and 7.2 GHz respectively. The maximum percentage of Design 2 is 38.1% higher compared to Design 1.

The measurement results show that the designed absorber can be operated for a broad range of incident angles. Design 2 is more capable to absorb the unwanted signal compared to Design 1 as the percentage of maximum absorption is higher in every angle of measurement.

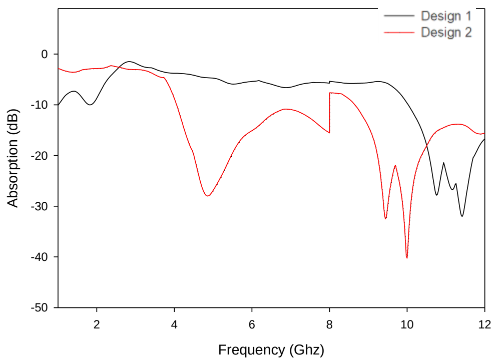

Fig. 10. Measurement result comparison graph for 45 °coated.

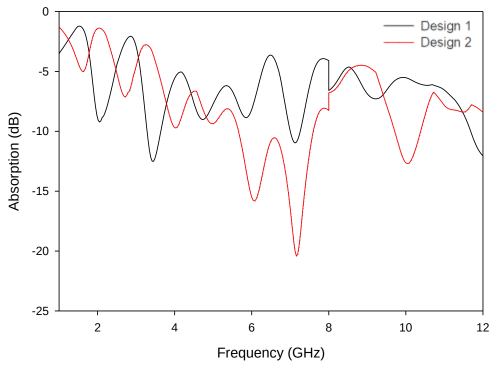

Fig. 11. Measurement result comparison graph for 60 °coated.

Table I shows the comparison of the measurement result between Design 1 and Design 2 carbon-coated flat stick bamboo microwave absorber for 0° to 60° in the frequency band of 1 GHz up to 12 GHz. The result is tabulated according to the IEEE standard frequency band that is L band (1-2 GHz), S band (2-4 GHz), C band (4-8 GHz) and X band (8-12 GHz).

TABLE I. MEASUREMENT RESULT FOR 0° TO 60° OF 1 GHZ-12 GHZ

Design		Absorption (dB)							
		L Band 1 – 2 GHz		S Band 2 – 4 GHz		C Band 4 – 8 GHz		X Band 8 – 12 GHz	
		Min	Max	Min	Max	Min	Max	Min	Max
0°	1	0	-3	-3	-11	-3	-6	-6	-19
	2	-5	-8	-4	-10	-7	-28	-10	-35
15°	1	-1	-7	-1	-8	-2	-5	-8	-20
	2	-1	-8	-2	-10	-10	-25	-13	-55
30°	1	+1	-2	+1	-6	-1	-5	-3	-25
	2	-2	-4	-2	-5	-3	-18	-12	-38
45°	1	-7	-10	-2	-9	-4	-6	-5	-32
	2	-3	-4	-1	-8	-8	-29	-8	-40
60°	1	-3	-9	-2	-14	-3	-11	-5	-12
	2	-1	-5	-1	-10	-7	-20	-5	-13

From the measurement results in Table I, for L band, it has been shown that the flat absorber of Design 1 had a minimum absorption of +1 dB measured at 30° while the maximum absorption reaches the value of –10 dB at the at 45°. For Design 2, minimum absorption of –1 dB occurs at 15° and 60° while the maximum absorption is –8 dB at 0° and 15°. In this band, the maximum absorption of Design 1 is 20% higher compared to Design 2.

For S band, Design 1 showed that minimum absorption is –1 dB occurs at 15° and the maximum value of absorption is –14 dB at 60°. Meanwhile, for Design 2, the minimum absorption is –1 dB at 60° and maximum absorption is –10 dB at the angle of 0°, 15° and 60° respectively. In this band, the maximum absorption of Design 1 is 28.6% higher compared to Design 2.

For C band, the result indicates that the carbon-coated flat absorber of Design 1 had a minimum absorption at –1 dB at 15°. The maximum absorption hit –11 dB at 60°. For Design 2, it had a minimum absorption at -3 dB at 30°. The maximum absorption struck –29 dB at 45°. In this band, the maximum absorption of Design 2 is 62.1% higher compared to Design 1.

For X band, the measurement result for Design 1 shows a minimum absorption at –3 dB at 30° and the maximum absorption is –32 dB at 45°. Meanwhile, Design 2 had the minimum absorption of –5 dB at 60° and maximum absorption of –55 dB at 15°. In this band, the maximum absorption of Design 2 is 41.8% higher compared to Design 1.

From Table I, Design 1 gives a good absorption compared to Design 2 in L band and S band while Design 2 has a good absorption compared to Design 1 in C band and X band. However, by looking at the angle of measurement, Design 2 shows good absorption strength for four frequency bands.

IV. CONCLUSION

The objective of the research is accomplished by referring to the performance of the carbon-coated flat stick bamboo absorber. The result of simulation and measurement shows the carbon-coated flat stick bamboo absorber can absorb unwanted signals excellently.

The best absorption of Design 1 is at –32 dB at a frequency band between 8 GHz and 12 GHz with an angle of 45° while for Design 2 the best absorption is at –55 dB at a frequency band of 8 GHz to 12 GHz with angle 15°. This study proves that the absorption performance is related to different dielectric constants and the radius of the bamboo.

Different radius sizes will create different structural designs. A bigger open surface is created by the bigger sizes of bamboo radiuses. It may affect the absorption of the performance of the microwave absorber since the larger area lets the absorber to accept the high capacity of the transmitted signal. Based on the observation, both designs of the absorber are established in a wide band of frequency. This research proves that the carbon-coated flat stick bamboo is capable as the microwave radiation absorber. The absorption is apparently could be affected by adjusting the radiuses size of the bamboo stick. Activated carbon also plays an important role to enhance the absorption capability of the absorber.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Azizah Ahmad and Hasnain Bin Abdullah wrote the manuscript with input from all authors; Hasnain Bin Abdullah and Linda Mohd Kasim contributed to the design and implementation of the research; Noor Azila Ismail and Norhayati Mohamad Noor processed the experimental data and performed the analysis; Azizah Ahmad and Nazirah Mohamat Kasim performed the measurements. All authors contributed to the final version of the manuscript.

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Azizah Ahmad was born in Penang, Malaysia in 1982. She received her Diploma and B.Eng. Hons in Electrical and Electronics Engineering from Universiti Teknologi MARA in 2003 (UiTM Pulau Pinang) and 2006(UiTM Shah Alam) respectively and M.Sc. in Electronic System Design Engineering from university Sains Malaysia in 2008. In 2009, she joined the Faculty of Electrical Engineering, Universiti Teknologi MARA, Pulau Pinang as a Lecturer and became a Senior Lecturer since 2016. Her current research interests include microwave absorber, software engineering and image processing. Mrs. Azizah is a member of Board of Engineers Malaysia.

Dr. Hasnain Bin Abdullah received his B.Sc. degree in Electrical Engineering and M.Sc. degree in Communication Engineering from Universiti Teknologi Malaysia (UTM) Skudai, Malaysia, in 1996 and 2002, respectively. In 2019, he obtained his Ph.D. in Electrical Engineering from Universiti Teknologi MARA, Shah Alam, Malaysia. He is currently a lecturer in Universiti Teknologi MARA, Pulau Pinang, Malaysia. His current research interests include antenna and propagation, radio frequency, microwave and communication system. Presently, he is a leading design and development of indigenous biomass microwave absorber.

Linda M. Kasim was born in Perlis, Malaysia in 1976. She received her Diploma in Electronics and B.Eng. Hons. Electronics (Microelectronics) from Universiti Teknologi Malaysia, Johor in 1997 and 1999 respectively. She completed her study in MSc in Electronic System Design Engineering from Universiti Sains Malaysia in 2005. In 2001, she joined the Faculty of Electrical Engineering, Universiti Teknologi MARA, Pulau Pinang as a Lecturer and became a Senior Lecturer since 2012. Her current research interests include electromagnetic absorbing material, microwave absorber and power electronics. Mrs. Linda is a member of Board of Engineers Malaysia and Profesional Technologist of Malaysia Board of Technologist.

Noor Azila Ismail was born in Kedah, Malaysia, in 1976. She received the B.Eng. (Hons). in electrical engineering and the M.Eng. Electrical Energy and Power System in electrical engineering from the Universiti Malaya, Malaysia in 2000 and 2006 respectively. In 2006, she joined the Faculty of Electrical Engineering, Universiti Teknologi MARA. Cawangan Pulau Pinang, as a Lecturer, and in 2011 became a Senior Lecturer. Her current research interests include microwave, communication, power electronics and drives. Mrs. Noor Azila is a member of Board of Engineer Malaysia and Profesional Technologies of Malaysia Board of Technologist.

Norhayati M. Noor was born in Kedah, Malaysia in 1975. She received her Bachelor of Electrical Engineering and Master of Electrical Engineering from Universiti Teknologi Malaysia, Johor in 1998 and 2002 respectively. In 2000, she joined the Faculty of Electrical Engineering, Universiti Teknologi MARA, Pulau Pinang as a Lecturer and became a Senior Lecturer since 2010. Her current research interests include Mobile communication and telecommunication. Mrs. Norhayati is a member of Board of Engineers Malaysia.

Nazirah Mohamat Kasim was born in Perak, Malaysia in 1976. She received her Dip.Eng. in electrical engineering and the B.Eng. degree (with honors) in electrical engineering from the Universiti Teknologi Mara, Malaysia, in 1998 and 2001 respectively. She completed her study in M.Sc. degree in microelectronics from the Universiti Kebangsaan Malaysia, Malaysia, in 2005. She joined the Faculty of Electrical Engineering, Universiti Teknologi Mara, Pulau Pinang, Malaysia, in 2001, where she is currently senior lecturer since 2011. Her research interests cover microwave engineering, telecommunication and microelectronic. Mrs. Nazirah is a member of Board of Engineer Malaysia and Profesional Technologies of Malaysia Board of Technologist.

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