International Journal of Advanced Communication Technology
Volume 1, No. 2, December 2021 [17-25]

Feasibility Study on Embroidered Wi-Fi Antenna Performances

Che Muhammad Nor Che Isa[1], Muhammad Syukri Jaafar[2], Zahari Awang Ahmad[2], Amir Nazren Abdul Rahim[3]

[1]Advanced Communication Engineering, Centre of Excellence (CoE), Universiti Malaysia Perlis (UniMAP), Perlis, Malaysia
[2]Facullty of Electronic Engineering Technology, Universiti Malaysia Perlis (UniMAP), Perlis, Malaysia.
[3]Computing Centre of Excellence Advanced Computing (AdvComp), Universiti Malaysia Perlis (UniMAP), Perlis, Malaysia.

Corresponding author: (cmnor@unimap.edu.my).

ABSTRACT Performance of a dual-band coplanar patch antenna with bending and wet condition is described in this paper. The antenna structure is made from common clothing fabrics and operates at the 2.45 and 5 GHz wireless bands. The antenna's radiating element is using Nora Dell serves as a ground plane and Felt as the substrate. The final part carries out the simulation on forward, backward bending, and also the wet condition in CST software. The comparison of two bending conditions is discussed in this report.

KEYWORDS Nora Dell, Felt, CST software, bending.

I. INTRODUCTION

In this modern application, antenna technology exists to promote and enhance the efficiency of our daily life. Over the last few decades, the technology for wearable antennas has grown quickly. By definition, a wearable or an electronic antenna is intended to be part of clothing worn by human or animals. This smart clothing technology will appear in various applications, including sports, emergency workers, military, medical and space apps, or even casual clothing or fashion [1]. The textiles antenna for this monitoring purpose are made using fleece, polyester, denim, felt for all the tracking and rescue activities (Osman et al., 2011). In the 2.4 GHz (2.4-2.484 GHz) and 5.2/5.8 GHz (2.15-5.35 GHz/5.725-5.825 GHz) bands and WiMAX process in the 2.5/3.5/5.5 GHz bands, the latest common designs suitable for WLAN operation have been reported in [2]. However, this concept of this smart clothes will be only being achieved when antennas and all linked components are entirely changed into 100% textile material. This antenna covers the 2.45 GHz and 5 GHz wireless networking frequencies and can be worn under clothing. The antenna is made up of a coplanar stripline feeding a coplanar patch antenna, which allows for a far broader operational bandwidth and more variable band spacing than a dual-band microstrip patch antenna while keeping the front to back ratio.

Due to the fact that these antennas will be placed against the body, it is preferable to limit the amount of backward scattered radiation as much as feasible [3]. The antennas are conformal and made of flexible materials that can easily be concealed or sewed into garments. The materials utilized range from felts and textiles to leather fibers, and are typically seen in apparel products. The conducting components, coplanar feed line, patch antenna, and ground plane, are manufactured from a conducting fabric Nora Dell. For the antenna design process, a layer of thin felt material with 1.1 mm thickness, permittivity, ε_r = 1.38 and tangent loss, tan δ= 0.023 at 2.60-3.95 GHz [4] was chosen and CST Microwave studio software was used simulate the desired design. The results for the antenna bent around two formers in the E-plane and H-plane, as well as antennas mounted on the human body, are shown. Simulations in wet conditions were also carried out.

II. FABRIC CHARACTERIZATION

Following the discovery that a wide range of textiles can be used as antenna substrates, an electrically conductive fabric for the ground plane and antenna patches was required. For the purposes of a textile antenna design, a conductive fabric needs to satisfy the following requirements:

- The material must be uniform throughout the antenna area, with a minor variation in resistance through the material.
- The fabric should be flexible enough to allow the antenna to deform while being worn.
- Elastic fabrics' electrical properties may alter when stretched or bent, hence the fabric should be inelastic.
- A low and stable electrical resistance (1 ohm/square) is desired to minimize losses.

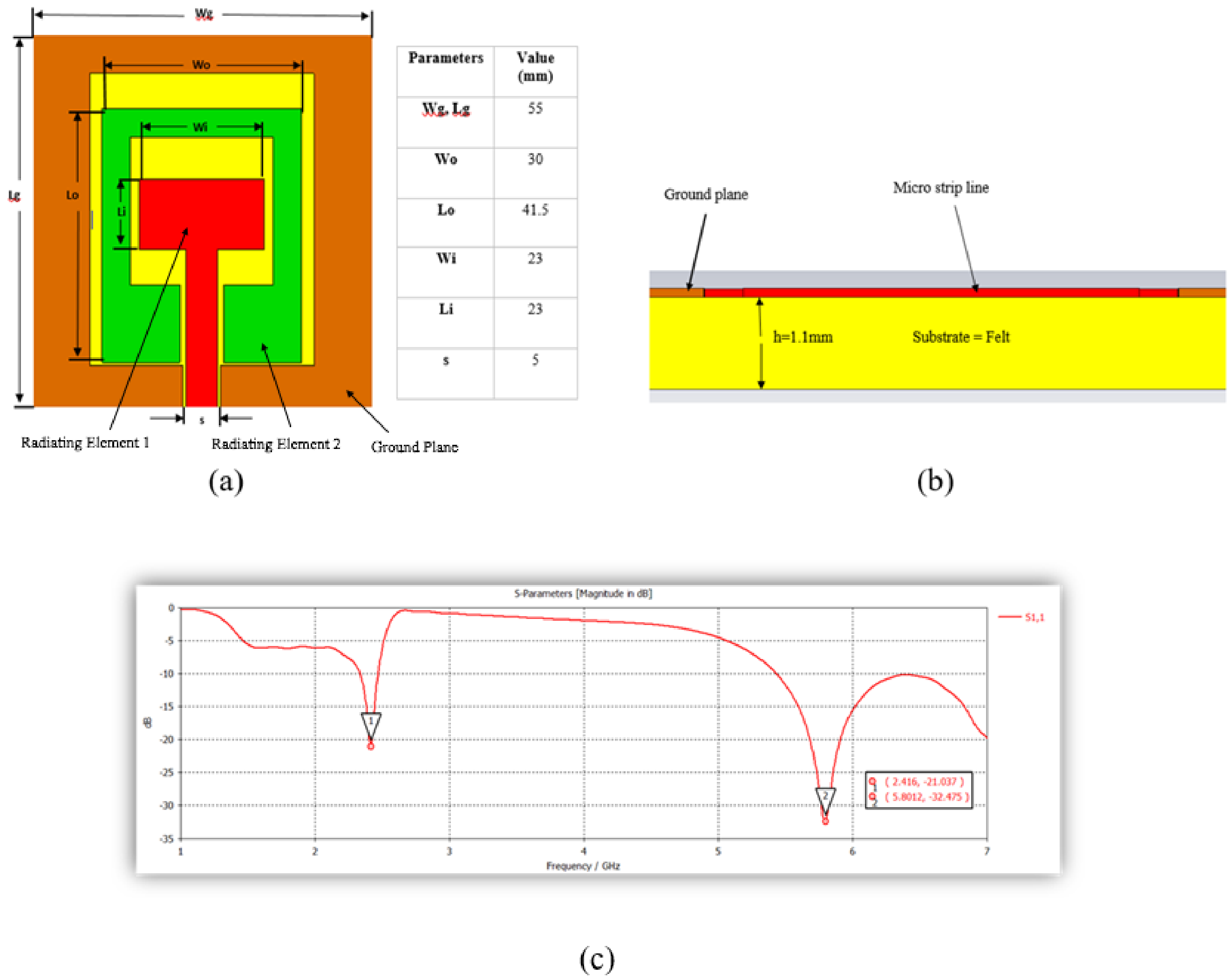
The conducting material Nora Dell has a high-quality nylon-based substrate and is plated with copper and tin with a conductivity of 1.538e+006 s/m. Its thickness is 0.13 mm with a manufacturer's surface resistivity specification lower than 0.01 ohm/square, which is excellent for creating efficient antennas and RF circuits at wireless communication frequencies, also Nora Dell is durable, tear resistant, and is easy to form and handle [5]. Instead of hard circuit boards, felt fabric is employed as the substrate material in this project, while the conductive fabric Nora dell is used as a ground plane. Table 1 shows the details of material specifications in this paper.

Table 1: Material Specifications [4],[6]

Materials	Thickness (mm)	Permittivity
Felt	1.1	1.6
Nora Dell	0.13	1.538e+6

III. DESIGN OF DUAL BAND ANTENNA

To achieve the bandwidth and keep the antenna as thin as possible a coplanar antenna was designed using CST software. Figure 1 shows the antenna uses a felt substrate with 1.1. mm thickness. While the radiating element and ground use Nora Dell material that consists of an inner patch (radiating element 1 in red color) surrounded by a parasitic rectangular ring element (radiating element 2 in green color), and surrounded by the normal ground (brown color). The antenna was 55 × 55 mm in size. A coplanar antenna was chosen over a microstrip patch antenna because it offers a much broader bandwidth [6]. Simulations show the current excitation in Figure 2 at two frequency bands of interest, 2.45 and 5.8 GHz.



Parameters	Value (mm)
Wg, Lg	55
Wo	30
Lo	41.5
Wi	23
Li	23
s	5

Figure 1: (a) Top view of dual band antenna geometry (b) Side view (c) Simulated reflection coefficient of dual band antenna

IV. Bending condition

The bending impact of proposed antenna is studied for seven distinct angles in this project: 20°, 30°, 40°, 50°, 60°, 70°, and 80° for forward and backward bending condition. In order for the antenna to be bent, a nonconductive cylinder is employed as a reference structure. Equation in (1) is used to find the outer radius of the cylinder

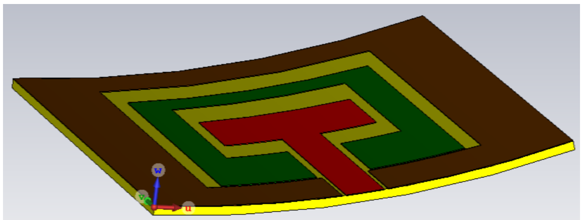
$$S = r\,\theta \tag{1}$$

Where, S = Arc length,
R = Radius of the circle,
θ = Measure of the central angle in radians.

The width of the substrate antenna was used as the arc length, is 60 mm. Based on the equation (1), the cylinder radius value of the intended angle was calculated in Table 2 and 3.

Table 2: Dual band antenna calculations for forward bending purpose

20-degree bending



$$\theta = \frac{20 \times \pi}{180} = 0.349 \text{ (degree in radian)},$$

$$r = \frac{s}{\theta} = \frac{55}{0.349} = 157.59 \text{ mm (radius for bending reference)}$$

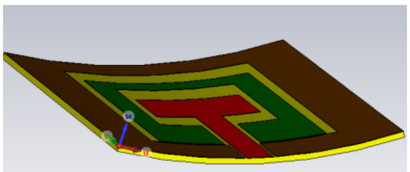
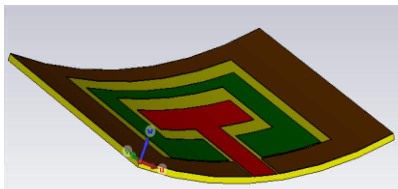
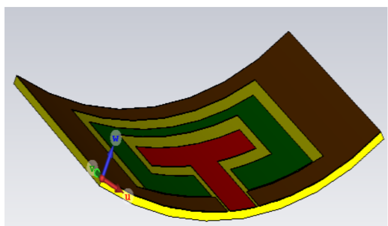
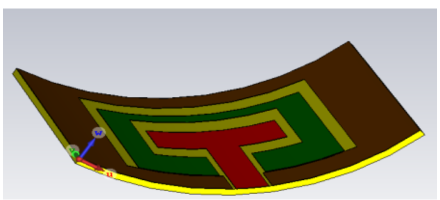
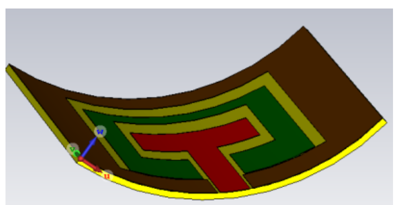
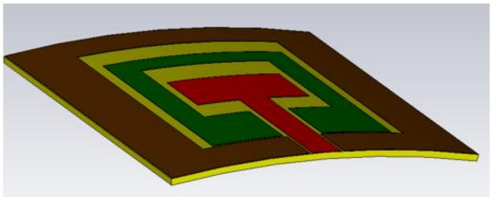
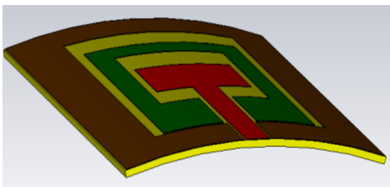
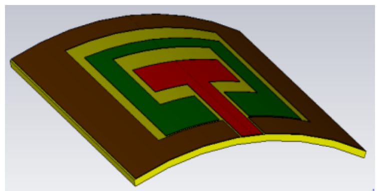
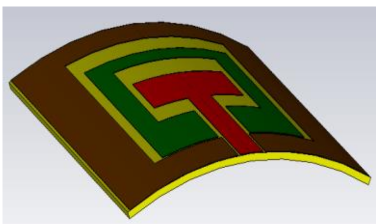
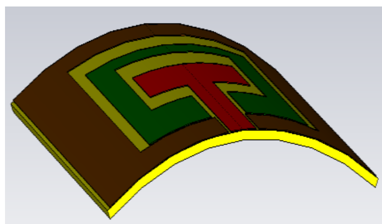
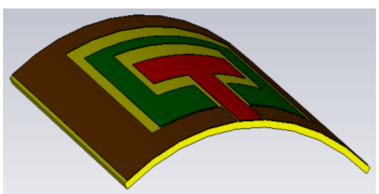
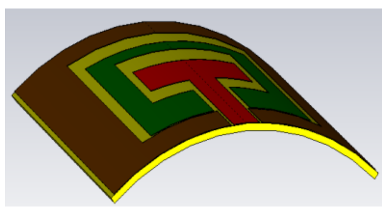
30-degree bending	**40-degree bending**
	
r = 105.16 mm (reference radius)	r = 78.79 mm (reference radius)
50-degree bending	**60-degree bending**
	
r = 63.02 mm (reference radius)	r = 52.52 mm (reference radius)
70-degree bending	**80-degree bending**
	
r = 45.01 mm (reference radius)	r = 39.39 mm (reference radius)

Table 3: Dual band antenna calculations for backward bending purpose

20-degree bending



$$\theta = \frac{20 \times \pi}{180} = 0.349 \text{ (degree in radian)},$$
$$r = \frac{s}{\theta} = \frac{55}{0.349} = 157.59 \text{ mm (radius for bending reference)}$$

30-degree bending	**40-degree bending**
	
r = 105.16 mm (reference radius)	r = 78.79 mm (reference radius)
50-degree bending	**60-degree bending**
	
r = 63.02 mm (reference radius)	r = 52.52 mm (reference radius)
70-degree bending	**80-degree bending**
	
r = 45.01 mm (reference radius)	r = 39.39 mm (reference radius)

V. RESULTS AND DISCUSSIONS

All simulations are done using CST software. The simulated reflection coefficient is done between range 1 GHz to 7 GHz under seven different bending angles of 20°, 30°, 40°, 50°, 60°, 70° and 80° degrees. Figure 2 and 3 show the simulated comparison of reflection coefficient (dB) result for antenna in bend conditions. The antenna shows the similar pattern of reflection coefficient at several degrees of antenna bends. In forward bending, for lower band, the antenna achieved the highest reflection coefficient at 80° with -35.82 dB and highest upper band at 70° with -33.53 dB. In backward bending, for lower band, the highest reflection coefficient at 30° with -25.22 dB and highest upper band at 20° with -47.31 dB.

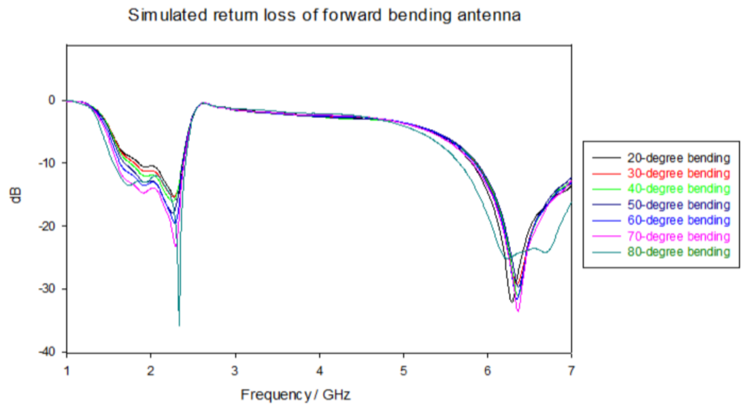


Figure 2: The return loss for dual band antenna for forward bending condition

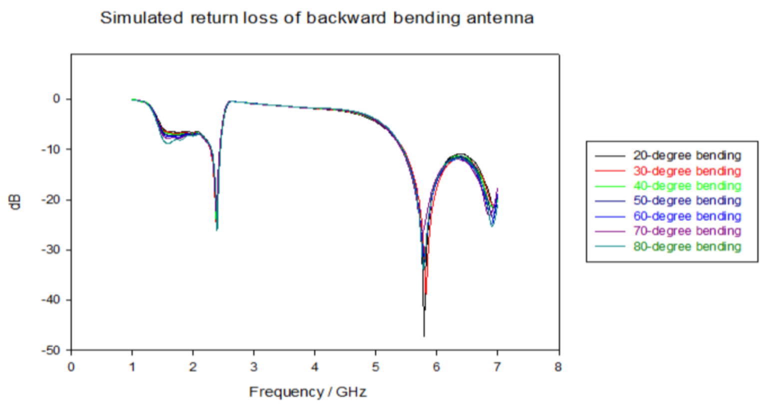
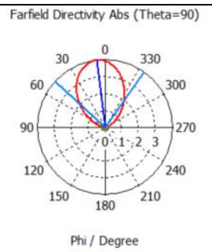
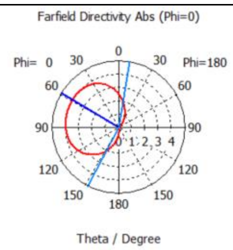
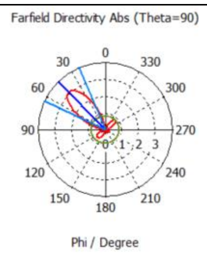
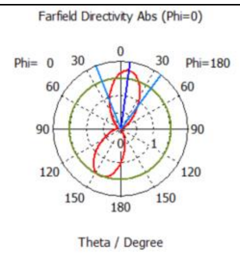
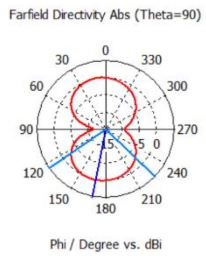
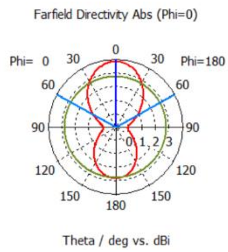
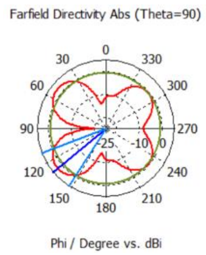
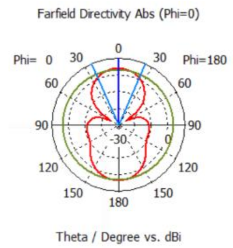


Figure 3: The return loss for dual band antenna for backward bending condition

Table 4 shows 40° forward bending, for 2.4 GHz, for E-plane, Half Power Bandwidth (HPBW) is 81.8° and 109.4° for H-plane. HPBW for 5.8 GHz part is 38.8° and 57.8°, both for E and H-plane. Based on the result, at low degree of bending antenna. For 40° forward bending for 2.4 GHz, for E-plane, HPBW is 101.5° and 122.4° for H-plane. HPBW for 5.8 GHz part is 36.3° and 47.3° for both for E and H-plane. Based on the result, at low degree of bending antenna, the radiation pattern is omnidirectional.

Table 4: The radiation pattern of forward and backward bending condition for 40° bending

Type of bending	2.4 GHz		5.8 GHz	
	E-Plane	**H-Plane**	**E-Plane**	**H-Plane**
Forward				
Backward				

VI. CONCLUSION

Dual band Wi-Fi antenna have been discussed and the proposed antenna design which in antenna was simulated. The wearable textile material, Felt and Nora Dell were chosen to design the antenna, for Wi-Fi spectrum applications, both the impedances matching performances and the radiation properties were capable.

Even though there are shifted frequencies in bending conditions compared to the antenna in flat condition in particular ranges, the antenna still performs properly with a good gain within the desire ranges. The proposed antenna's performance is slightly reduced as the antenna bending degree is increased, but the antenna still operates efficiently at lower and upper resonant frequency.

The simulation results show that wearable textile antennas have a lot of potential to change traditional rigid antennas in different of applications. The complete elastic body worn antenna system may be creating in our daily lives in the future.

VII. ACKNOWLEDGMENT

The authors thankfully acknowledge the help rendered by all lectures and colleague that help in this project. The authors also express their special thanks to the reviewers for the critical and valuable comments. This work was possible due to support from committee of Faculty of Electronic Engineering Technology, Universiti Malaysia Perlis (UniMAP), Perlis, Malaysia.

International Journal of Advanced Communication Technology
Volume 1, No. 2, December 2021 [17-25]

REFERENCES

[1]. A. Dierck, T. De Keulenaer, F. Declercq, and H. Rogier, A wearable active GPS antenna for application in smart textiles, 32nd ESA Antenna Workshop on Antennas for Space Applications, (2010).

[2]. E. Wang, J. Zheng, and Y. Liu, A Novel Dual-Band Patch Antenna for WLAN Communication, Progress in Electromagnetics Research C (2009), p 93-102.

[3]. B. Gupta, S. Sankaralingam, and S. Dhar, Development of Wearable and Implantable Antennas in The Last Decade: A Review, Mediterranean Microwave Symposium, (2010) p 251 –267.

[4]. S. Zhu and R. Langley, Dual-Band Wearable Textile Antenna on an EBG Substrate, IEEE Transactions on Antennas and Propagation, (2009) p. 926-935.

[5]. S. Zhu and R. J. Langley, Dual Band Wearable Antennas Over EBG Substrate, IET Electronic Letter (2007) p. 141–143.

[6]. R. Adhesives, Datasheet Shieldex Nora Dell, (2014).

[7]. L. Liu, S. Zhu, and R. Langley, Dual-band Triangular Patch Antenna with Modified Ground Plane, Electronics Letters (2007) p. 140-141.

AUTHORS BIOGRAPHIES

CHE MUHAMMAD NOR CHE ISA. was born in Kelantan, Malaysia. He obtained his Master of Engineering in Telecommunication Engineering from University of South Australia (UniSA), Australia in 2009. He received the Bachelor of Engineering from University Malaysia Perlis (UniMAP), Malaysia, with Honors, in Communication Engineering, graduating in 2007 and Diploma in Electrical Engineering (Communications) from Universiti Teknologi Malaysia (UTM), Malaysia in 2003.

His research interests include MIMO antennas, mobile terminal antennas and user's interactions as well as dielectric materials.

He is a member of the IEEE, as well as the Malaysia Board of Technologists (MBOT) and the Malaysian Board of Engineers (BEM).

SYUKRI JAAFAR was born in Klang, Selangor, in 1995. He is received B.S. degree in electronic engineering major in telecommunication from Universiti Malaysia Perlis UniMAP in 2021. His research interest includes antenna engineering focuses in advance 5G technology electronics. He is currently pursuing his interest working in telecommunication industry.

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AMIR NAZREN BIN ABDUL RAHIM was born in Perak, Malaysia in February 1989. In 2018, he received his Doctor of Philosophy in Computer Engineering from Universiti Malaysia Perlis (UniMAP), Malaysia. He earned a Bachelor of Engineering in Computer Engineering with honours from Universiti Malaysia Perlis (UniMAP), Malaysia, in 2013 and a Diploma in Computer Engineering from Universiti Malaysia Perlis (UniMAP), Malaysia, in 2010.

Some of his research interests are Image Processing, Artificial Intelligence, Machine Learning, and the Internet of Things (IoT).

He is a member of the IEE, as well as the Malaysia Board of Technologists (MBOT) and the Malaysian Board of Engineers (BEM).

ZAHARI AWANG AHMAD was born and raised in the state of Kedah, Malaysia. Started to get education in primary and secondary school in 1978 to 1988 in the city of Alor Setar.Kedah. Obtained Bachelor of Sciences in electrical engineering degree from the University of Kentucky, Lexington, KY USA in 1994. Then completed Master of Engineering in computer and microelectronics from the Universiti Teknologi Malaysia (UTM), Skudai, Johor, Malaysia in 2008.

He has over 12 years of working experience in industry. He worked with multiple multi-national companies such as Applied Magnetic Corporation, Siemens Opto-semiconductors, and Siemens Opto-semiconductors. He also appointed as General Manager at Pan-Northern Air Services Sdn Bhd, a local aviation company in 2005. Currently working as Lecturer and Researcher at the Universiti Malaysia Perlis (UniMAP).

Ir. Zahari Awang Ahmad is a corporate member of Institute of Engineering Malaysia (IEM) since 2015. He has been awarded a Meritorious Service Medal (PJK) by the Sultan of Kedah in 2011