Empirical measurement for path loss characteristics at multiple frequency bands from 2.2 to 14.6 GHz in chamber room

Atikah Balqis Basri[1], Khairayu Badron[1], Ahmad Fadzil Ismail[1], Abadi Chanik[2]
[1]Department of Electrical and Computer Engineering, Kulliyyah of Engineering, International Islamic University Malaysia (IIUM), Selangor, Malaysia
[2]National Space Agency (ANGKASA), Malaysia Space Centre 42700 Banting, Selangor, Malaysia

Article Info

Article history:

Received Jun 29, 2021
Revised Apr 06, 2022
Accepted Apr 14, 2022

Keywords:

EMC chamber
FSPL
Microwave link
Receiver
Transmitter

ABSTRACT

Free space path loss (FSPL) is the loss of electromagnetic signal strength. This loss is caused by the line-of-sight path through free space. Even in a line of sight (LoS) indoor single layer, as the distance increases, the path loss in the 1 GHz frequency band also exceeds the free space path loss. This is because the first Fresnel zone is shielded by the floor and ceiling. To improve the measurement results, a fully covered anechoic chamber is used in this empirical measurement. The measurement is based on multiple frequency bands from 2.23201 GHz to 14.685 GHz. This article details how to achieve it. Measurements are made to establish the correlation between the power transmit value and the frequency value. This movement involves the establishment of microwave link transmissions. Use a signal generator to control the transmit power and use a vector network analyzer in the electromagnetic compatibility (EMC) room to measure the received power level. Appropriate analysis that determines the correlation. The logarithm function developed based on the empirical experiment conducted, the result suggested the formulation of $L_{FS} = a - b \times ln(x + c)$. These findings enable people to understand the required FSPL value as the power transmission and frequency change during each measurement.

Corresponding Author:

Khairayu Badron
Department of Electrical and Computer Engineering, Kulliyyah of Engineering
International Islamic University Malaysia (IIUM), Selangor, Malaysia
Email: khairayu@iium.edu.my

1. INTRODUCTION

The signal is carried by electromagnetic waves to a receiver in wireless communications, which is now suffering from propagation issues [1]. A transmitter sends out a signal that may travel via many pathways to a receiver at the same time. Multipath is the term for this phenomenon [2]. The successful design and deployment of a wireless system require a full understanding of the propagation characteristics of the channel. Therefore, channel models for various situations have been the subject of research for many years [3]. To analyze the wireless channel, path loss is one of the most important characteristics. Path loss analysis can provide knowledge about the reduction of power density when electromagnetic waves propagate through space in a specific environment, which is very important for analyzing the channel capacity and radio coverage of wireless networks [4].

This article focuses on the measurement of radio wave propagation in indoor environments and applies it to wireless communication systems in the centimeter wave frequency range. There are different methods of predicting path loss [5]. Based on field measurements in various environments, many empirical models of path loss have been derived [6]-[7]. The measurement activities required to derive these models usually mean significant time and labor costs. In addition, the nature of empirical models means that they are only suitable for environments with the same propagation characteristics as those in which the measurements are performed, and are accurate, which limits the use of empirical channel models. Sulyman *et al.* [8] proposed some simple statistical models for the standardization of path loss models, in which it is assumed that the number of rays (plane waves) is limited. Numerous path gain measurement campaigns have been performed at mm/cm wavebands in various types of indoor environments (room-room, around the corner, corridor-room). In these measurements, one end of the link is kept at a fixed location while the other is relocated to hundreds of different places [9]-[22].

In a recent work [23], a theory of room electromagnetics was proposed based on pure diffuse scattering like the theory of “room acoustics”. The theory is inspired by the similarity of the wavelengths of sound waves and microwaves, and the size of the room and the roughness and scattering of the walls are expected to produce similar reverberation effects throughout the room. Since the 1920s, the acoustics community has been using “room acoustics” and basic Sabine equations to predict the indoor sound field. The key idea of this theory is to treat the indoor environment as a lossy cavity, which is characterized by line of sight (LoS) components and scattered scattering components caused by walls and other internal obstacles. Diffuse scattering causes the tail to decay exponentially, when expressed in decibel units, it converts to a linear relationship [24]. This to measure the path loss in the free space condition. The result for this research will include the analysis from the satellite propagation. But for this paper, we focus more on the result for path loss in the condition where free space is applied.

This paper will describe the establishment of microwave link transmissions, which include transmitters, receivers, and related antennas with different displacements. The remainder of this paper is organized as follows. Section two explicates electromagnetic compatibility (EMC) chamber-based prediction approach. Section three introduces the path loss measurement activities and measurement settings. The fourth part discusses the results of path loss measurement activities and the theoretical results obtained from path loss prediction methods. Finally, the conclusion is draw based on the overall result and conclude the process of measurement.

2. EMC CHAMBER-BASED PREDICTION APPROACH

In this section, we derive the expressions of the path-loss based on the EMC chamber measurement. The focus of the evaluation is power transmission, distance, and frequency changes. Assembled and conducted empirical experiments in the EMC room of the National Space Administration in Banting, Selangor. The results obtained have been used to determine the difference between theoretical and empirical values. This is important for evaluating the free space path loss (FSPL) formula under free-space conditions. The flow chart illustrating the methodology or the path loss prediction algorithm is given. The process involves designing the empirical experiment set up based on available equipment and facilities. Towards the designing process, the antenna specifications are checked and chosen based on the different frequencies used in the measurement. Then assemble and carried out the experimental setup for free space condition where EMC chamber is indicated based on their functionality. Afterward followed by calculating the cable loss from both cables and finally calculating the free space path loss value based on the measurement setup design and assembly. Figure 1 illustrates the process for path loss prediction algorithm.

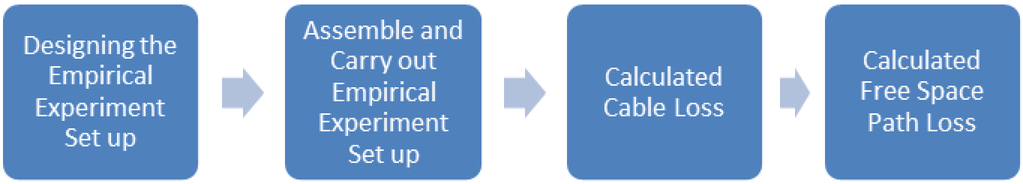

Figure 1. Methodology for path loss prediction algorithm

3. THE PATH-LOSS MEASUREMENT CAMPAIGN

The measurement campaign involved the measurement of antenna voltage standing wave ratio (VSWR) and gain value. All the antenna specifications are categorized in Table 1. Table 2 recorded the transmit and receive gain for each antenna used in the measurement. VSWR as the measurement result is shown in Figure 2. Record the reflection coefficient value of each antenna used in the empirical experimental setup.

Table 1. Antenna specifications

Specifications	Doppel steg horn HF 906 (1-18GHz)	AT4510	AT4003A	AT4004
Frequency range	1 GHz to18 GHz	1 GHz to 4.2 GHz	4 GHz to 8 GHz	8 GHz to18 GHz
Power input	300 watts to 500 watts	900 watts to1500 watts	250 watts	250 watts
Input impedance	50 Ω	50 Ω	50 Ω	50 Ω
Gain	7 dBi to 14 dBi	13 dBi to18 dBi	11.5 dBi to16.9 dBi	11.4 dBi to 20.1 dBi
Connector	N female	N female	N female	WRD 750 waveguide
Temperature range	0 °C to 50 °C	0 °C to 50 °C	0 °C to 50 °C	0 °C to 50 °C
Dimensions	2.9 cm × 2.5 cm × 1.6 cm	46.3 cm × 46.3 cm × 69.2 cm	21.5cm × 21.6cm × 30.5 cm	4.6 cm × 6.1 cm × 6.4 cm
Weight	1.5 kg	6.9 kg	1.6 kg	0.6 kg

Table 2. Transmit and receive antenna gain

Transmit antenna	Gain	Receive antenna	Gain
Doppel steg horn HF 906 (S-band)	9.0 dBi	AT 4510	13.0 dBi
Doppel steg horn HF 906 (C-band)	10.0 dBi	AT 4003A	11.5 dBi
Doppel steg horn HF 906 (X-band)	11.4 dBi	AT4004	11.2 dBi
Doppel steg horn HF 906 (Ku-band)	14.0 dBi	AT 4004	11.2 dBi

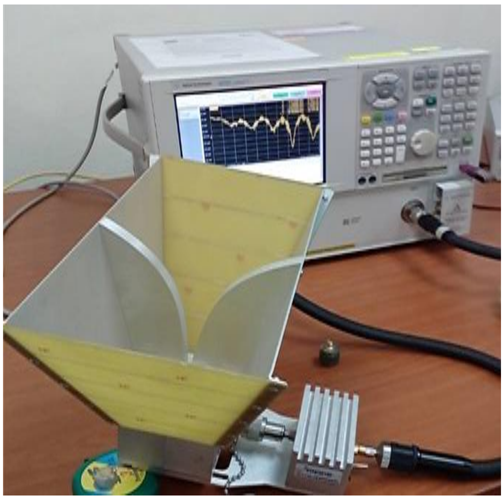

Figure 2. Setup for antenna measurement

The transmit antenna used in the empirical experiment is fixed to doppel steg horn HF 906 (1 GHz to GHz) and transmit antenna S_{11} values are recorded in Table 3 while received antenna S_{11} values is recorded in Table 4. S_{11} value for each frequency band used in the empirical experiment was checked and recorded from the vector network analyzer (VNA). Figure 3 shows the example of the VNA results.

Table 3. Transmit antenna S_{11} values

Doppel steg horn HF 906 (1-18 GH) (transmit antenna)	S_{11} value (dB)
Frequency	Below -10
S-band	-4.7321
C-band	-5.6741
X-band	-5.7963
Ku-band	-7.2228

Table 4. Received antenna S_{11} values

Frequency band	Receive antenna	S_{11} value (dB)
S-band	AT4510	-12.971
C-band	AT4003A	-11.242
X-band	AT4004	-12.231
Ku-band	AT4004	-42.256

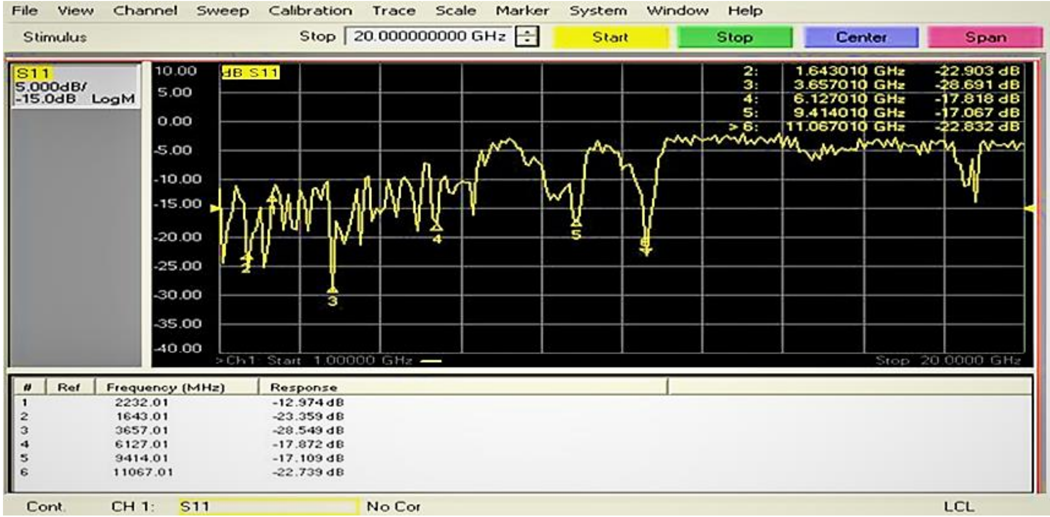

Figure 3. S_{11} results for antenna AT 4510

The cable loss is a factor to be considered in system design [25]. The loss introduced by the cable varies with frequency. Delete the loss to confirm that there is no loss of the collected data. The type of cable used during the measurement is Huber Suhner multiflex 141 50. The cable loss value has been measured using (1). Where a and b are fixed coefficients. The list of cable loss results is shown in Table 5.

$$Attenuation = (a \times f^{0.5} 0.5 + b \times f) \quad (1)$$

Where: $a = 0.3732$
$b = 0.0279$

This value needs to be considered and must be removed from the result acquired in the empirical experiment. By using the related empirical value collected in the empirical experiment, (2) is used:

$$Pr = Pt + Gt + Gr - LFS - LCL \quad \text{in dB} \quad (2)$$

Where: Pr: power received, Pt: power transmitted
Gr: transmitter antenna gain, Gr: receiver antenna gain
LFS: free space path loss (dB)
LCL: cable loss (dB)

Table 5. Cable loss for each frequency used

Frequency (GHz)	Cable loss (dB)
2.232	0.6198
3.753	0.8277
4.185	0.8802
8.181	1.2956
9.019	1.3724
12.201	1.6440
14.685	1.8399

An agilent signal generator to generate the signal was used. The signal generator can generate waveforms between 9 kHz and 20.0 GHz with a resolution of 0.01 Hz. The minimum and maximum transmit power are 0 dBm and 20 dBm respectively. Each subsequent transmission will increase by 1 dBm until the maximum level is reached. For each transmission, the vector network analyzer records the received signal level, the vector network analyzer is used as a spectrum analyzer, marked as the second channel, and the corresponding received signal is measured in dBm. The example of the collected data is shown in Table 6. The transmitting and receiving antennas are in the EMC room in Sungai Lang, Banting. The measurement repeated by varying the distance between transmitter and receiver. The collected data is recorded in Excel. Microwave link data includes transmit power, receive power, frequency, and distance. The overview and scenario of the measurement setup are shown in Figure 4. The collected data interval is 1 dBm. Then analyze the data to find the difference between the theoretical value and the experimental value.

Table 6. Example of collected data

Transmit Power PT (dBm)	Distance = 1 m Received Power S-Band Pr (dBm)		Received Power C-Band Pr (dBm)		Received Power X-Band Pr (dBm)		Received Power Ka-Band Pr (dBm)	
	2.23201	3.753	4.185	6.057	8.1805	9.019	12.201	14.685
0	-18.89	-23.19	-25.31	-23.97	-28.87	-29.21	-33	-37.9
1	-17.89	-22.17	-24.39	-22.83	-28.01	-28.24	-31.85	-36.91
2	-17.11	-21.16	-23.44	-21.84	-26.98	-27.25	-30.91	-35.61
3	-16.88	-20.09	-22.33	-20.82	-25.91	-26.12	-30.07	-34.4
4	-15.86	-19.16	-21.39	-19.82	-25	-25.08	-29.23	-33.21
5	-14.85	-18.14	-20.37	-18.75	-23.91	-24.02	-28.09	-32.33
6	-13.87	-17.11	-19.42	-17.78	-22.94	-23.22	-26.64	-30.99
7	-12.88	-16.15	-18.44	-16.73	-21.95	-22.17	-25.83	-30.36
8	-11.93	-15.17	-17.3	-15.75	-20.94	-21.15	-24.85	-29.25
9	-10.89	-14.17	-16.44	-14.8	-19.97	-20.15	-24.19	-28.28
10	-9.89	-13.16	-15.42	-13.81	-18.97	-19.15	-24.03	-27.43
11	-8.82	-12.14	-14.4	-12.77	-17.98	-18.1	-23.93	-26.31
12	-7.84	-11.19	-13.42	-11.79	-16.98	-17.2	-24.07	-25.52
13	-6.83	-10.19	-12.42	-10.83	-15.99	-16.14	-24.09	-24.64
14	-5.86	-9.17	-11.44	-9.84	-15.01	-15.16	-24.93	-24.75
15	-4.83	-8.18	-10.41	-8.84	-14.01	-14.18	-24.07	-24.88
16	-3.85	-7.17	-9.45	-7.82	-13.098	-13.23	-24.11	-24.71
17	-3.45	-6.18	-8.44	-6.84	-12.01	-12.18	-23.12	-24.88
18	-2.28	-5.15	-7.46	-5.82	-11	-11.22	-24.09	-24.63
19	-2.17	-4.15	-6.46	-4.81	-9.99	-10.23	-24.22	-24.91
20	-1.18	-3.11	-5.41	-3.79	-8.97	-9.11	-24.14	-24.82

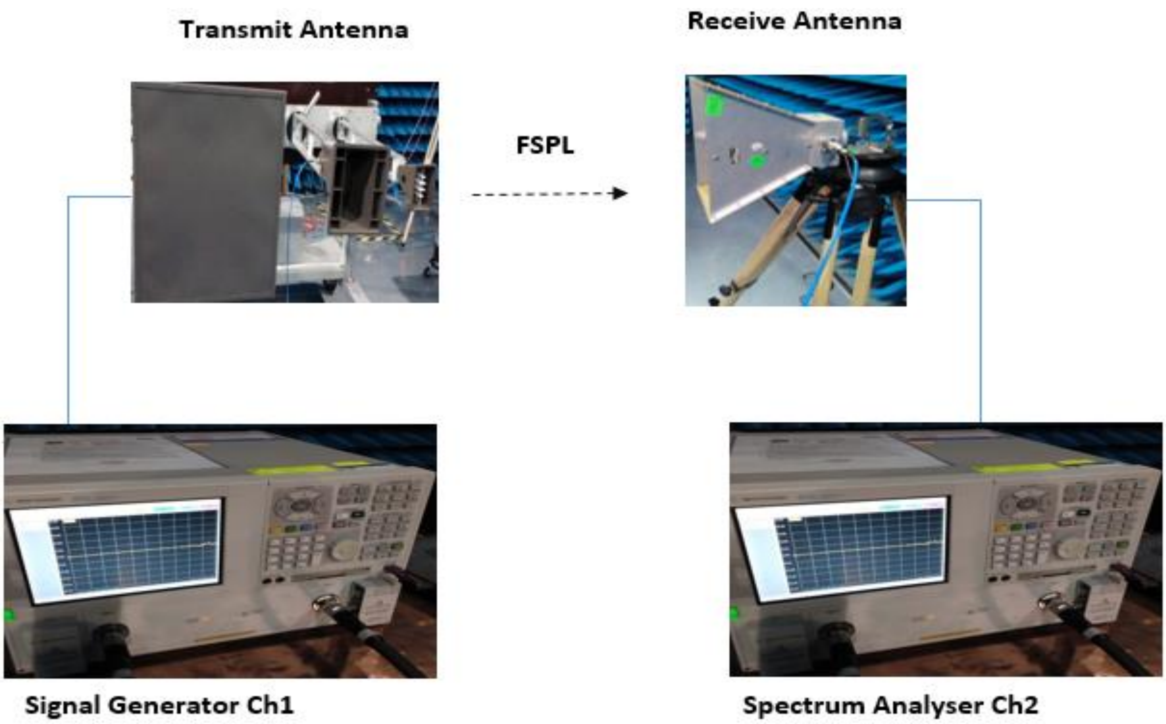

Figure 4. Experimental setup

4. PATH-LOSS MEASUREMENT CAMPAIGN RESULTS

The results collected from the EMC chamber were analyzed, Figure 5 demonstrates the received power versus the transmit power for distance at 1 meter, and a new formula was developed using OriginPro software, in which drawing, and analysis can be performed. The fitting function of nonlinear curve fitting is applied, and the most suitable formula is selected, as shown in Figure 6. Apply the logarithmic function and generate a new formula.

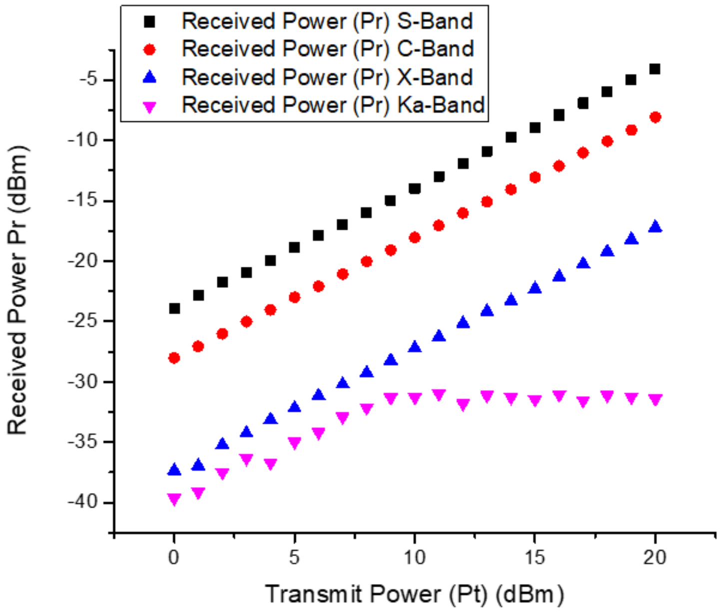

Figure 5. Received power for each frequency at different distances

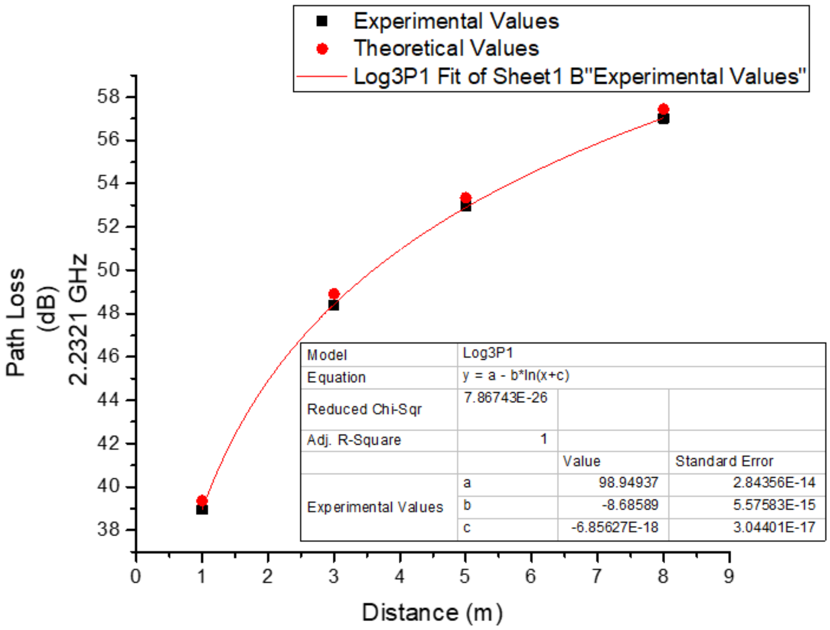

Figure 6. Logarithm function

5. CONCLUSION

Through measurement activities, the required value of the received signal level in multiple frequency bands from 2.2 GHz to 14.6 GHz in dBm has been established. This is achieved through parallel measurements using the tracking receiver and spectrum analyzer in the EMC chamber. Considering all the results collected from the experiment, the most effective way to represent the results of the experiment is to compare the free space formula with the newly derived formula.

The findings of this study, namely the received signal level in dBm, are indeed very useful in the study of microwave propagation. This result is based on the analysis of multiple frequency bands from 2.2 GHz to 14.6 GHz in the chamber room. The effect is taken based on the whole analysis involving the satellite propagation where it is now possible to assess the impact of water vapor condensation on any S-band air-to-ground communication link, where radar is in use in the whole analysis. The process of removing the water vapor for the satellite communication system is shown in detail on paper. However, for this paper, only part of the analysis involving the ground microwave link is shown and discussed. Subsequently, these findings can also provide references for the development of revised free-space path loss formulas for satellites operating in tropical countries.

ACKNOWLEDGEMENTS

All authors would like to thank the International Islamic University of Malaysia (IIUM) and the Research Management Center of the Malaysian Ministry of Education (MOHE) for their financial assistance and support throughout the research process. We have a special recognition of ANGKASA's expertise in exchange for their continuous support. The reported research results are part of the research results funded by the IIUM Research University Program. This research was sponsored by the Ministry of Education of Malaysia under the P-RIGS18-005-0005 research project to generate new theories, concepts, and ideas.

REFERENCES

[1] V. S. Abhayawardhana, I. J. Wassell, D. Crosby, M. P. Sellars, and M. G. Brown, "Comparison of empirical propagation path loss models for fixed wireless access systems," *2005 IEEE 61st Vehicular Technology Conference*, 2005, vol. 1, pp. 73-77, doi: 10.1109/VETECS.2005.1543252.

[2] Y. Singh, "Comparison of Okumura, Hata and COST-231 models on the basis of path loss and signal strength," *International Journal of Computer Applications*, vol. 59, no. 11, pp. 37-41, Dec. 2012, doi: 10.5120/9594-4216.

[3] A. E. Forooshani, S. Bashir, D. G. Michelson, and S. Noghanian, "A survey of wireless communications and propagation modeling in underground mines," *IEEE Communications surveys & tutorials*, vol. 15, no. 4, pp. 1524-1545, 2013, doi: 10.1109/SURV.2013.031413.00130.

[4] I. F. Akyildiz and E. P. Stuntebeck, "Wireless underground sensor networks: Research challenges," *Ad Hoc Networks*, vol. 4, no. 6, pp. 669-686, 2006, doi: 10.1016/j.adhoc.2006.04.003.

[5] V. C. Gungor, B. Lu, and G. P. Hancke, "Opportunities and Challenges of Wireless Sensor Networks in Smart Grid," in *IEEE Transactions on Industrial Electronics*, vol. 57, no. 10, pp. 3557-3564, Oct. 2010, doi: 10.1109/TIE.2009.2039455.

[6] A. Bria *et al*., "4th-generation wireless infrastructures: scenarios and research challenges," in *IEEE Personal Communications*, vol. 8, no. 6, pp. 25-31, Dec. 2001, doi: 10.1109/98.972165.

[7] T. K. Sarkar, Z. Ji, K. Kim, A. Medouri, and M. Salazar-Palma, "A survey of various propagation models for mobile communication," in *IEEE Antennas and Propagation Magazine*, vol. 45, no. 3, pp. 51-82, 2003, doi: 10.1109/MAP.2003.1232163.

[8] A. I. Sulyman, A. Alwarafy, G. R. MacCartney, T. S. Rappaport, and A. Alsanie, "Directional Radio Propagation Path Loss Models for Millimeter-Wave Wireless Networks in the 28-, 60-, and 73-GHz Bands," in *IEEE Transactions on Wireless Communications*, vol. 15, no. 10, pp. 6939-6947, Oct. 2016, doi: 10.1109/TWC.2016.2594067.

[9] C. R. Anderson *et al*., "In-building wideband multipath characteristics at 2.5 and 60 GHz," *Proceedings IEEE 56th Vehicular Technology Conference*, 2002, vol. 1, pp. 97-101, doi: 10.1109/VETECF.2002.1040310.

[10] H. Zhao *et al*., "28 GHz millimeter wave cellular communication measurements for reflection and penetration loss in and around buildings in New York city," *2013 IEEE International Conference on Communications (ICC)*, 2013, pp. 5163-5167, doi: 10.1109/ICC.2013.6655403.

[11] A. Karttunen, K. Haneda, J. Järveläinen, and J. Putkonen, "Polarisation characteristics of propagation paths in indoor 70 GHz channels," *2015 9th European Conference on Antennas and Propagation (EuCAP)*, 2015, pp. 1-4.

[12] O. H. Koymen, A. Partyka, S. Subramanian, and J. Li, "Indoor mm-Wave Channel Measurements: Comparative Study of 2.9 GHz and 29 GHz," *2015 IEEE Global Communications Conference (GLOBECOM)*, 2015, pp. 1-6, doi: 10.1109/GLOCOM.2015.7417720.

[13] R. Mehmood, J. W. Wallace, and M. A. Jensen, "LOS and NLOS millimeter-wave MIMO measurements at 24 GHz in a hallway environment," *2016 IEEE International Symposium on Antennas and Propagation (APSURSI)*, 2016, pp. 325-326, doi: 10.1109/APS.2016.7695871.

[14] R. Mehmood, J. W. Wallace, W. Ahmad, Y. Yang, and M. A. Jensen, "A comparison of 24 GHz and 2.55 GHz MIMO measurements in two indoor scenarios," *2017 IEEE International Symposium on Antennas and Propagation & USNC/URSI National Radio Science Meeting*, 2017, pp. 1411-1412, doi: 10.1109/APUSNCURSINRSM.2017.8072748.

[15] S. Deng, G. R. MacCartney, and T. S. Rappaport, "Indoor and Outdoor 5G Diffraction Measurements and Models at 10, 20, and 26 GHz," *2016 IEEE Global Communications Conference (GLOBECOM)*, 2016, pp. 1-7, doi: 10.1109/GLOCOM.2016.7841898.

[16] J. Ko *et al*., "Millimeter-Wave Channel Measurements and Analysis for Statistical Spatial Channel Model in In-Building and Urban Environments at 28 GHz," in *IEEE Transactions on Wireless Communications*, vol. 16, no. 9, pp. 5853-5868, Sept. 2017, doi: 10.1109/TWC.2017.2716924.

[17] V. Raghavan, A. Partyka, L. Akhoondzadeh-Asl, M. A. Tassoudji, O. H. Koymen, and J. Sanelli, "Millimeter Wave Channel Measurements and Implications for PHY Layer Design," in *IEEE Transactions on Antennas and Propagation*, vol. 65, no. 12, pp. 6521-6533, Dec. 2017, doi: 10.1109/TAP.2017.2758198.

[18] D. Chizhik, J. Du, G. Castro, M. Rodriguez, R. Feick, and R. A. Valenzuela, "Path loss measurements and models at 28 GHz for 90% indoor coverage," *12th European Conference on Antennas and Propagation (EuCAP 2018)*, 2018, pp. 1-4, doi: 10.1049/cp.2018.0375.

[19] J. W. Wallace, W. Ahmad, Y. Yang, R. Mehmood, and M. A. Jensen, "A Comparison of Indoor MIMO Measurements and Ray-Tracing at 24 and 2.55 GHz," in *IEEE Transactions on Antennas and Propagation*, vol. 65, no. 12, pp. 6656-6668, Dec. 2017, doi: 10.1109/TAP.2017.2758390.

[20] S. Geng and P. Vainikainen, "Millimeter-Wave Propagation in Indoor Corridors," in *IEEE Antennas and Wireless Propagation Letters*, vol. 8, pp. 1242-1245, 2009, doi: 10.1109/LAWP.2009.2035723.

[21] F. Huang, L. Tian, Y. Zheng, and J. Zhang, "Propagation Characteristics of Indoor Radio Channel from 3.5 GHz to 28 GHz," *2016 IEEE 84th Vehicular Technology Conference (VTC-Fall)*, 2016, pp. 1-5, doi: 10.1109/VTCFall.2016.7881180.

[22] G. R. MacCartney, S. Deng, and T. S. Rappaport, "Indoor Office Plan Environment and Layout-Based mmWave Path Loss Models for 28 GHz and 73 GHz," *2016 IEEE 83rd Vehicular Technology Conference (VTC Spring)*, 2016, pp. 1-6, doi: 10.1109/VTCSpring.2016.7504287.

[23] V. N. Okorogu, D. U. Onyishi, G. C. Nwalozie, and N. N. Utebor, "Empirical characterization of propagation path loss and performance evaluation for co-site urban environment," *International Journal of Computer Applications*, vol. 70, no. 10, pp. 34-41, 2013, doi: 10.5120/12001-7888.

[24] Y. Ai, J. B. Andersen, and M. Cheffena, "Path-Loss Prediction for an Industrial Indoor Environment Based on Room Electromagnetics," in *IEEE Transactions on Antennas and Propagation*, vol. 65, no. 7, pp. 3664-3674, 2017, doi: 10.1109/TAP.2017.2702708.

[25] W. Tang *et al*., "Wireless Communications with Reconfigurable Intelligent Surface: Path Loss Modeling and Experimental Measurement," in *IEEE Transactions on Wireless Communications*, vol. 20, no. 1, pp. 421-439, Jan. 2021, doi: 10.1109/TWC.2020.3024887.

BIOGRAPHIES OF AUTHORS

Atikah Balqis Basri graduated in 2014 B. Eng, 2017 in MSc and 2021 Ph.D. in Communication from the International Islamic University Malaysia (IIUM). She is currently a Lecturer at the Department of Information Systems Faculty of Information and Communication Technology International Islamic University Malaysia (IIUM). Her research interests are in radar radiometry and wireless communication where involve predictive methods, data mining, and data analysis. She can be contacted at email: atikahbalqis@iium.edu.my.

Khairayu Badron obtained her BEng (2006), Msc (2011) and Ph.D (2016) from International Islamic University Malaysia (IIUM). She is currently one of the faculty members of Faculty of Engineering, IIUM, and recently commenced her research areas in Radar and Radiometry research, quantifying propagation effects on microwave and millimetre wave links. Khairayu is a professional member of IEEE, IEM,BEM and MTSFB. She has published and co-authored more than 30 papers in International Journals as well as Conferences on subjects relating to rain attenuation in the tropical regions. She can be contacted at email: khairayu@iium.edu.my.

Ahmad Fadzil Ismail currently a lecturer at Department of Electrical and Computer Engineering, Faculty of Engineering, International Islamic University Malaysia (IIUM). He completed his bachelor degree studies in Electrical Engineering at Gannon University, Pennsylvania, USA with Cum Laude Latin honors. He holds MSc and PhD from University of Essex, UK and University of Bath, UK, respectively. His research interests include development of active and passive target tracking algorithms, radio frequency and wireless systems and microwave. He can be contacted at email: af_ismail@iium.edu.my.

Abadi Chanik he gained the B.E. degree in electronic engineering from the Universiti Malaysia Sarawak, Malaysia, in 2005. He is currently awaiting the approval for his PhD from the University of Surrey in the field of spacecraft control. He is a member of the Board of Engineers (BEM) Malaysia and since 2006, he is a Research Officer with the Malaysia Space Agency (ANGKASA). His work includes the operation of the Malaysian and other satellites from neighboring country specifically in the ground segments. His research interest includes development of a ground facility for spacecraft test ing and its earth segment. He can be contacted at email: abadi@mysa.gov.my.