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Seasonal and diurnal variations of wet scintillation in tropical region Malaysia

Ibtihal Fawzi El-Shami[1], Jafri Din[2], Ali I. Elgayar[3], Ahlaam Miftah Saed[4]
[1]Department of Electronics Engineering, College of Electrical and Electronics Technology, Benghazi, Libya
[2]Wireless Communication Centre, Faculty of Electrical Engineering, Universiti Teknologi Malaysia (UTM), Johor Bahru, Malaysia
[3]Department of Electrical Engineering, Faculty of Engineering, University of Benghazi, Benghazi, Libya
[4]Department of Electrical and Electronics Engineering, Bright Star University, Brega, Libya

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ABSTRACT

This paper investigates the seasonal and diurnal variations of wet tropospheric scintillation in a tropical region to support the design and optimization of fade margin in satellite communication systems. A one-year Ku-band propagation measurement campaign was conducted in Johor Bahru, Malaysia, using a direct broadcast receiver (DBR) and an automatic weather station (AWS) to capture both signal and meteorological data. A comprehensive signal processing technique was applied to separate scintillation effects from rain attenuation, enabling accurate statistical characterization. The analysis was performed based on monsoon seasons and different time intervals of the day. The results indicate that higher scintillation fades are most likely to occur during the afternoon period, particularly between 3:00 pm and 6:00 pm. In addition, the inter-monsoon season exhibits a higher rate of variation in scintillation intensity due to increased convective activity, whereas the southwest monsoon shows relatively lower variability under drier conditions. The findings also demonstrate that diurnal scintillation behavior is strongly influenced by seasonal patterns, with peak intensity typically observed in the late afternoon across different monsoon periods. Unlike many existing models developed for temperate regions, this study provides experimental insights into scintillation characteristics under equatorial climatic conditions. These results offer valuable guidelines for system designers to improve fade margin allocation and enhance the reliability of satellite links in tropical environments.

Corresponding Author:

Ibtihal Fawzi El-Shami
Department of Electronics Engineering, College of Electrical and Electronics Technology
Benghazi, Libya
Email: ifelshami@ceet.edu.ly

1. INTRODUCTION

Satellite communication systems operating above 10 GHz with low fade margins are highly vulnerable to turbulence-induced fluctuations in the atmospheric refractive index, which result in random signal fading and enhancement at the receiver [1], [2]. In addition to being significantly affected by rain attenuation, these propagation impairments can lead to service interruptions, especially in tropical and equatorial regions [3], [4]. Such impairments are strongly governed by local climatic and topographical conditions, typically marked by high humidity, relatively uniform temperatures, and intense rainfall [5]. In addition to atmospheric and climatic influences, system parameters such as the operating frequency band and elevation angle also significantly affect the severity of tropospheric scintillation.

Scintillation effects generally increase with higher frequency bands, particularly at Ka- and Q-band frequencies, due to their greater sensitivity to small-scale atmospheric fluctuations [6]–[8].

Furthermore, the elevation angle plays a critical role, as lower elevation links experience stronger scintillation due to the longer propagation path through the turbulent troposphere, as highlighted in long-term measurement campaigns at very low elevation angles [9]. These findings emphasize the importance of considering both frequency and elevation angle in the accurate assessment and design of satellite communication systems. Numerous experimental studies on tropospheric scintillation have been conducted in temperate regions, such as in Europe and North America, including long-term measurement campaigns carried out in sites like Rome and other Mediterranean locations. These studies have provided valuable insights into scintillation behavior under moderate climatic conditions and have contributed significantly to the development of prediction models and recommendations for satellite link design [10], [11].

However, atmospheric conditions in equatorial and tropical regions differ significantly from those in temperate climates. Regions near the equator are typically characterized by high humidity, nearly uniform temperatures, and intense convective rainfall, which strongly influence radiowave propagation [12]–[15]. As a result, scintillation and rain attenuation effects in these regions may exhibit different statistical characteristics and higher variability compared with those observed in temperate environments. Therefore, further investigation of scintillation behavior under equatorial climatic conditions is essential for improving the reliability and design of satellite communication systems in such regions.

In fact, yearly rain attenuation and wet scintillation statistics alone are not enough to completely describe the precipitation phenomenon when the quality of services of the satellite system is of interest. The effect of fade on the quality of services is highly dependent on the season and time of day [16], [17]. Therefore, a specific knowledge of seasonal and diurnal variations together with wind direction and wind speed of air flows is desired to estimate the effectiveness of the fade countermeasure application. The most used fade countermeasure is the application of a fade margin [18].

Therefore, understanding signal attenuation based on seasonal and diurnal patterns is crucial for system designers when determining appropriate fade margins. In Southeast Asia, scintillation behavior is strongly influenced by the monsoon cycle, which results from seasonal changes in wind direction. In Malaysia, the annual wind circulation is generally divided into four seasons: the pre-Northeast (pre-NE), Northeast (NE), pre-Southwest (pre-SW), and Southwest (SW) periods. These seasons typically occur during October–November, December–March, April–May, and June–September, respectively [19]. The northeast and southwest Asian Monsoon winds are predictable climate; which brings a wetter and drier season to Malaysia, respectively. The NE monsoon originates from Siberia and it brings stronger precipitation events, especially to the east coast of Peninsular Malaysia; whereas the SW monsoon is relatively drier, as the warm air originates from the Australian deserts.

Besides seasonal changes, diurnal variation is also a key factor in designing mechanisms that maintain the high performance of satellite communication systems. Numerous studies have attempted to predict clear-sky tropospheric scintillation, particularly by analyzing its variation throughout different hours of the day. However, most existing models have been developed using measurement data from temperate regions under clear-sky conditions [20]–[23]. Studies addressing this phenomenon in regions characterized by heavy rainfall remain limited, with only a few exceptions reported in [24], [25].

However, the diurnal variation pattern is not only dependent on local temperature and humidity but also influenced by geographical topographies, as well as the location of interest. Hence, it is worth highlighting that the diurnal variation of wet scintillation in temperate regions does not completely represent the diurnal behaviour in equatorial Malaysia. Despite the extensive studies on tropospheric scintillation, most existing works have focused on temperate regions and clear-sky conditions. Limited attention has been given to the combined seasonal and diurnal behavior of wet scintillation in tropical climates under heavy rainfall conditions.

Therefore, this paper aims to provide a comprehensive measurement-based analysis of wet scintillation in an equatorial region. The main contributions of this work include: (i) long-term experimental characterization of wet scintillation at Ku-band, (ii) investigation of its dependence on monsoon seasons, and (iii) analysis of diurnal variation for improved fade margin design in tropical satellite communication systems.

2. EXPERIMENTAL SETUP

The experimental station, illustrated in Figure 1, was installed on the campus of Universiti Teknologi Malaysia in Johor Bahru. Data were collected over a one-year period from January to December 2013. The site, located at 1.55° N latitude and 103.64° E longitude, included a direct broadcast receiving antenna with a diameter of 90 cm, oriented toward the MEASAT-3 broadcasting satellite at an elevation angle of 75.61°. The satellite signal at 12.2 GHz was monitored and recorded using a spectrum analyzer connected to a data logger. An automatic weather station (AWS) was also installed nearby.

This meteorological station was equipped with several sensors to measure surface parameters such as temperature, humidity, wind speed, and wind direction, along with a tipping-bucket rain gauge positioned close to the receiving antenna.

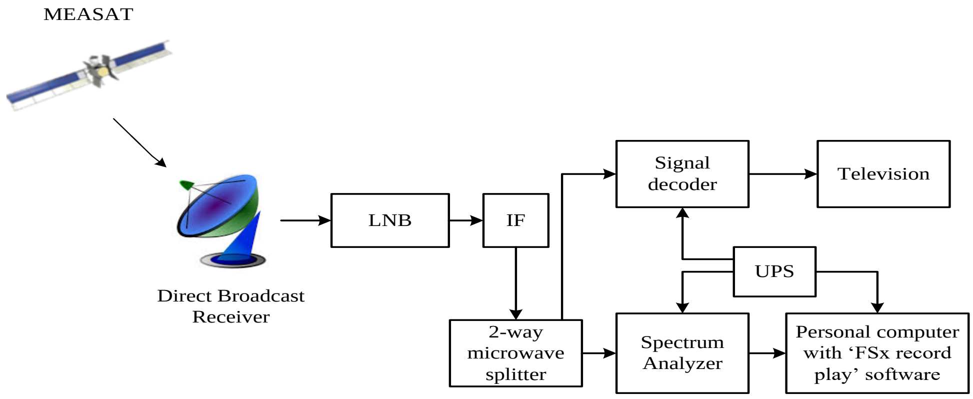

Figure 1. Block diagram of MEASAT satellite receiving system

3. SCINTILLATION SIGNAL PROCESSING AND DATA PREPARATION

The raw received signal level acquired from the direct broadcast receiver (DBR) contains a mixture of different propagation effects, including slow variations due to rain attenuation, rapid fluctuations caused by tropospheric scintillation, and possible non-propagation-related disturbances such as equipment outages or power interruptions. Therefore, a systematic signal processing procedure was applied to extract reliable wet scintillation statistics.

First, a quality control stage was performed to identify and remove abnormal signal behavior not associated with atmospheric effects. Such abnormalities are characterized by sudden and sustained signal drops lasting several minutes, typically caused by power failures or equipment downtime. These events were cross-validated using concurrent rainfall measurements from the AWS. Any abnormal signal segments not correlated with rainfall events were excluded from further analysis to avoid biased scintillation estimation.

Subsequently, the validated signal time series was processed using digital filtering techniques to separate scintillation from rain attenuation. A fifth-order butterworth filter was employed due to its maximally flat frequency response in the passband and its suitability for propagation studies. Based on power spectral density analysis, a cutoff frequency of 0.02 Hz was selected, as it effectively distinguishes between slow-varying rain attenuation components and rapid scintillation fluctuations as shown in Figure 2.

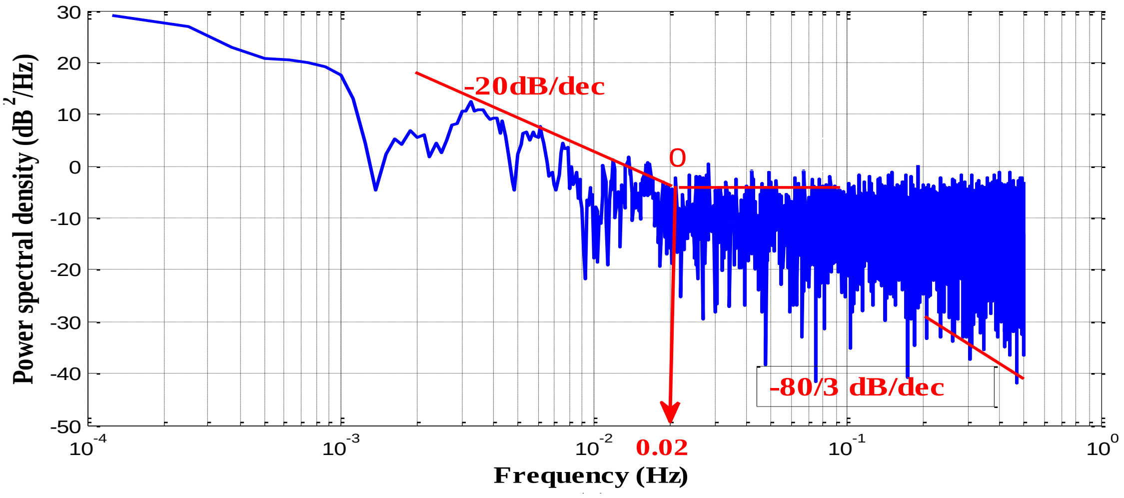

Figure 2. Power spectrum density on 31st December 2013 for MEASAT-3

The low-pass filtered signal (fc = 0.02 Hz) represents the rain attenuation component, while the high-pass filtered signal corresponds to tropospheric scintillation. For scintillation analysis, a band-pass filter in the frequency range of 0.02–0.5 Hz was applied, ensuring the preservation of relevant scintillation dynamics while suppressing noise and long-term trends. MEASAT-3 received signal level as shown in Figure 3. In order to illustrate the effect of without filtering, through the low-pass filtering, and through high pass/band pass filtering, of received signal, as can be observed in Figures 3(a)-(c).

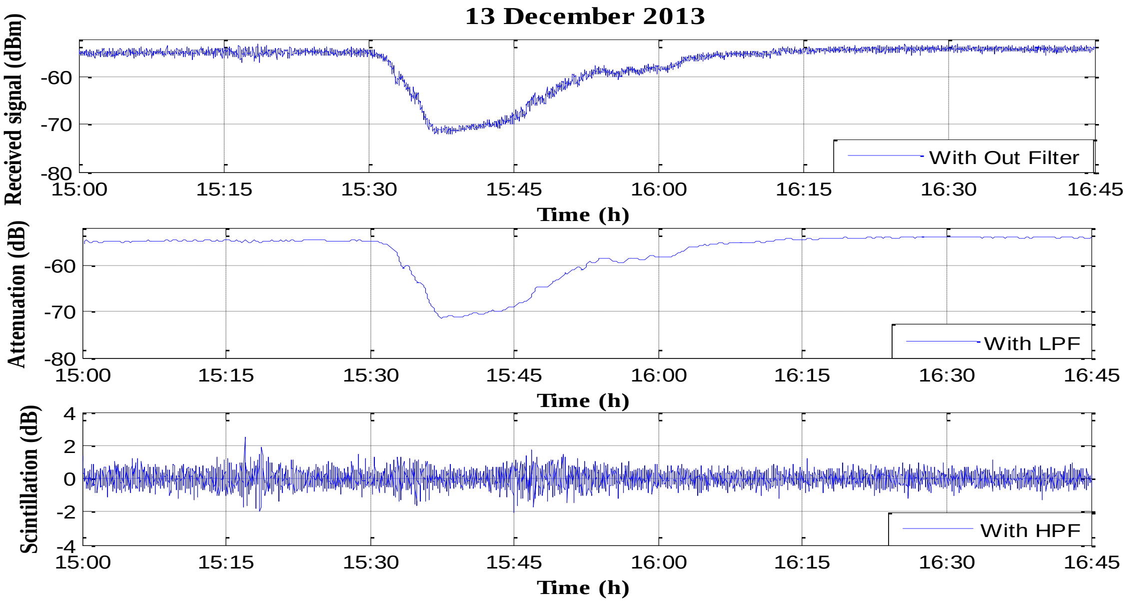

Figure 3. MEASAT-3 received signal level: (a) without filter, (b) with LPF, and (c) with HPF

After filtering, the scintillation signal was normalized by subtracting its local mean value, obtained from the low-pass filtered signal, in order to remove residual slow variations. This normalization ensures that the extracted scintillation fluctuations are zero-mean and suitable for statistical characterization. The processed signal was sampled at 1 Hz, which is sufficient to capture tropospheric scintillation effects whose dominant spectral content lies well below the Nyquist frequency. This sampling rate provides an adequate trade-off between temporal resolution and data volume while maintaining the integrity of scintillation statistics.

4. WET SCINTILLATION DATA ANALYSIS

The knowledge and characteristics of diurnal and seasonal variation of wet scintillation are of great importance for design fade margin system. In this study, a total of 1 year's data is only utilized, that is from January to December 2013. During this observation period, the variations of a meteorological condition such as rain and the wind may be different from time to time on seasonal basis or time of the day. First, the seasonal variation of wet scintillation is analyzed by dividing the year into three main periods: (i) the Northeast monsoon (December–March), (ii) the Southwest monsoon (June–September), and (iii) the inter-monsoon period (April–May and October–November). The statistical distribution of wet scintillation during these seasons can be represented in two ways. The most commonly used approach is the cumulative distribution, which evaluates the probability of occurrence of both fading and enhancement events caused by wet scintillation. The second approach examines the relationship between the scintillation standard deviation and rain attenuation, where wet scintillation data are categorized according to attenuation levels.

In addition to seasonal monsoon effects, diurnal variations in Peninsular Malaysia must also be considered by satellite system operators and radio communication engineers, particularly when designing fade margins in regions with heavy rainfall. To study the daily variability of wet scintillation, the analysis is divided into four non-overlapping time intervals: 00:00–06:00, 06:00–12:00, 12:00–18:00, and 18:00–24:00.

5. SEASONAL VARIATION

In order to recognize the seasonal variation of wet scintillation, cumulative distribution of scintillation fade was categorized based on monsoon season, namely NE, SW, and inter-monsoon (i.e., pre-NE and pre-SW). Figure 4 shows the seasonal complementary cumulative distribution functions (CCDFs) relative to the one-year period. The figure also shows the differences between the South-West season and the other two seasons at 0.01 percentage of scintillation fade (i.e. approximately 0.1 dB).

Aside from seasonal CCDF of scintillation fade, the scintillation standard deviation acted as a function of rain attenuation, which is another parameter to characterize the relation between these two phenomena. Figure 5 presents the seasonal variation of scintillation standard deviation as a function of rain attenuation. The scintillation standard deviation increases nearly proportionally with attenuation levels up to approximately 4 dB. Beyond this threshold, attenuation increases more rapidly. During the southwest monsoon season. However, the scintillation standard deviation demonstrates a lower rate of change relative to rain attenuation. This pattern is likely due to the higher frequency of strong convective activity during the inter-monsoon period, while the southwest monsoon aligns with the driest months, as indicated in Table 1.

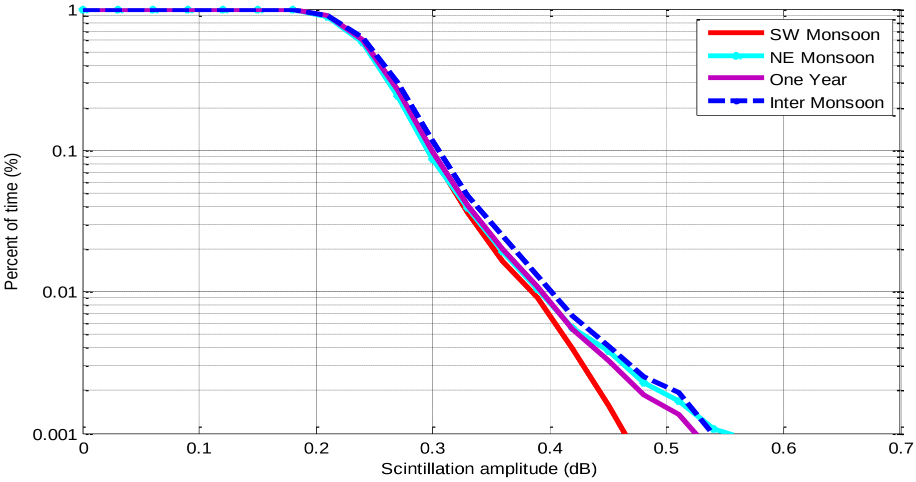

Figure 4. Seasonal CCDFs of scintillation amplitude for different seasons

Table 1. Type of rain event as collected in Johor Bahru

Season	Number of events	
	Stratiform	Convective
Northeast Monsoon	39	52
Southwest Monsoon	27	42
Inter-Monsoon	28	68

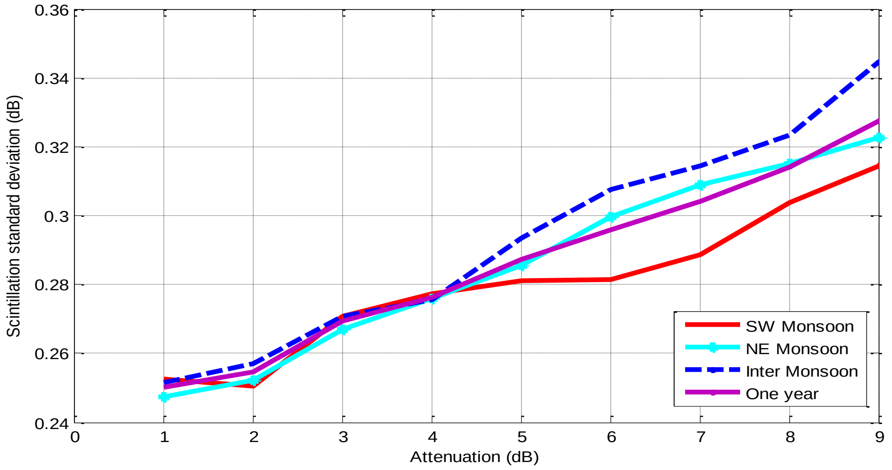

Figure 5. Standard deviation of wet scintillation as a function of attenuation for each season

6. DIURNAL VARIATION

Besides seasonal monsoon variations, the diurnal variations in equatorial Malaysia are also needed to be taken into significance by the satellite operators and radio engineers, such as the fade margin design in this heavy rain region that experiences significantly different precipitation rates at different times of the day. The CCDFs of diurnal wet scintillation fade as reported in Figure 6 confirmed that higher scintillation fade are likely to occur during the evening and late evening period, compared to the other times of the day. Such data gives good understanding for the system operators and service providers who need to undertake the quality of the link services system during the busiest business hours, to suitably design the fade margin based on seasonal and diurnal variations.

Diurnal variation is greatly affected by seasonal changes. Thus, it is important to examine the characteristics of diurnal variation within each season. During the NE monsoon season, higher scintillation intensity is typically observed in the late afternoon, between 4:00 pm and 7:00 pm. The maximum peak typically happens around 5:00 pm, as shown in Figure 7. During the inter-monsoon season, the peak of scintillation intensity was found at 4 pm. Meanwhile, the high scintillation intensity in SW season usually started at 1 pm and continued until 5 pm. Therefore, high scintillation intensity during these periods causes the availability of rainfall in every season.

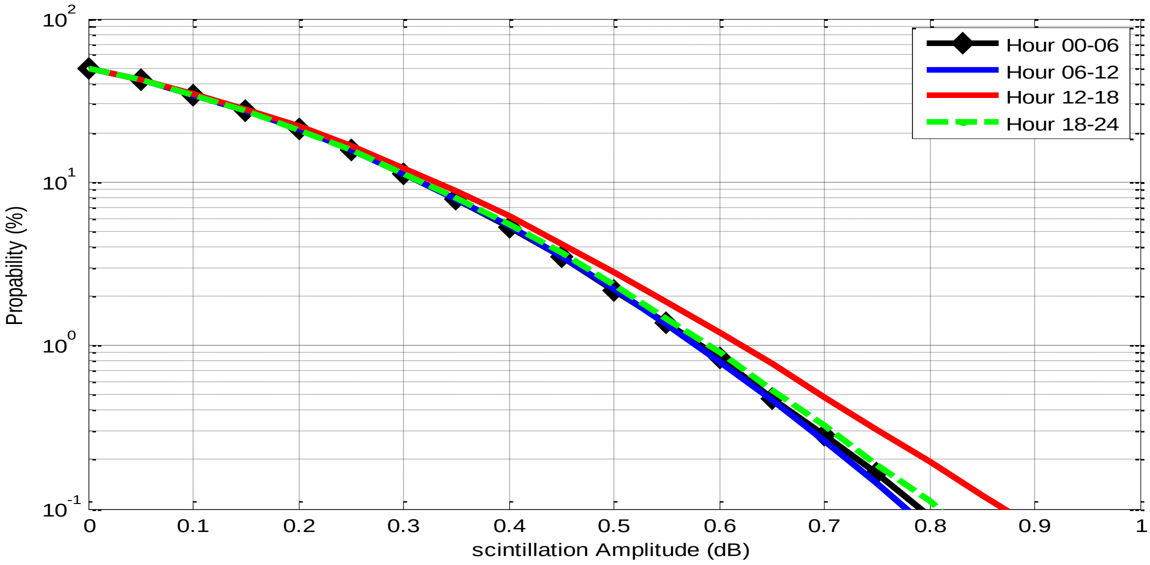

Figure 6. CCDFs of scintillation fade on a diurnal basis in Johor Bahru

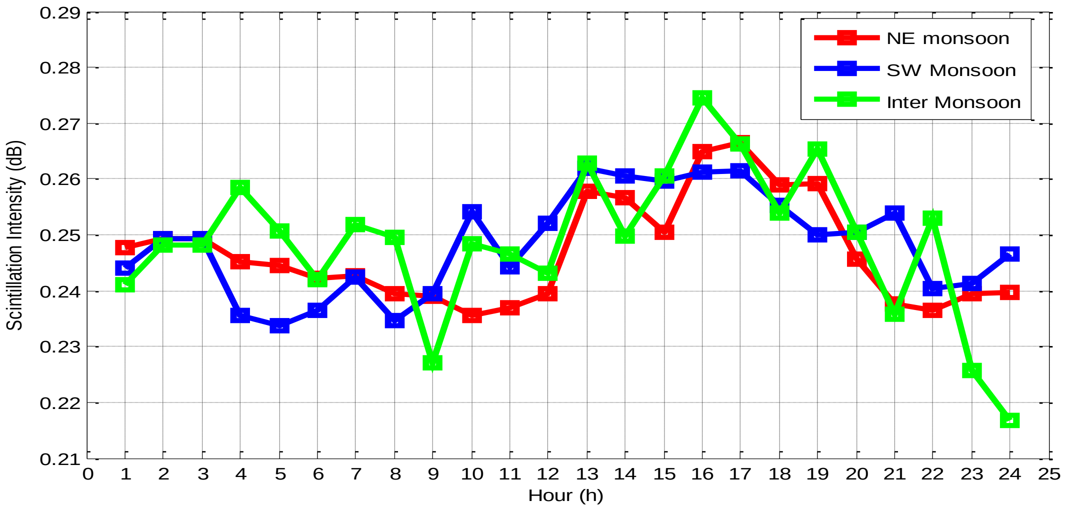

Figure 7. Diurnal variation of scintillation intensity based on seasonal variation

7. CONCLUSION

Seasonal and diurnal variations of wet scintillation and rain attenuation were thoroughly examined. The findings indicate that higher wet scintillation fading is most likely to occur in the afternoon, particularly between 3:00 pm and 6:00 pm. The study also highlights that the climatic characteristics of equatorial regions differ significantly from those of temperate regions, showing higher rain attenuation and stronger wet scintillation effects. It was further observed that heavy rainfall events commonly occur in the afternoon, mainly between 3:00 pm and 5:00 pm, with the NE monsoon identified as the wettest season. In contrast, during the Southwest monsoon, the scintillation standard deviation shows a relatively smaller variation with rain attenuation. This behavior is attributed to the higher occurrence of strong convective activity during the inter-monsoon period, whereas the Southwest monsoon corresponds to the driest months. These findings suggest that adaptive or time-dependent fade margin strategies may be required, particularly during peak scintillation periods in the afternoon, to ensure reliable satellite communication performance in tropical regions.

REFERENCES

[1] I. F. El-Shami, H. Yin Lam, J. Din, and S. L. Jong, “Clear sky diurnal behavior of tropospheric scintillation at Ku-Band satellite communication in equatorial Malaysia,” *Jurnal Teknologi*, vol. 77, no. 10, Nov. 2015, doi: 10.11113/jt.v77.6279.

[2] I. F. El-Shami, A. Yousef, M. Elbarani, and A. I. Elgayar, “Comparison of tropospheric scintillation prediction models of libyan climate,” in *Proceedings of the 6th International Conference on Engineering & MIS 2020*, 2020, pp. 1–7, doi: 10.1145/3410352.3410797.

[3] H. Y. Lam, J. Din, L. Luini, A. D. Panagopoulos, and C. Capsoni, “Analysis of raindrop size distribution characteristics in Malaysia for rain attenuation prediction,” in *2011 XXXth URSI General Assembly and Scientific Symposium*, Aug. 2011, pp. 1–4, doi: 10.1109/ursigass.2011.6050806.

[4] I. Fawzi Elshami, J. Din, L. Hong Yin, and A. I. Elgayar, “Characterization of concurrent ku band tropospheric scintillation and rain attenuation in Malaysia,” *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS)*, vol. 15, no. 2, p. 956, Aug. 2019, doi: 10.11591/ijeecs.v15.i2.pp956-961.

[5] H. Y. Lam, L. Luini, J. Din., C. Capsoni, and A. D. Panagopoulos, “Stratiform and convective rain discrimination for equatorial region,” in *2010 IEEE Student Conference on Research and Development (SCOReD)*, Dec. 2010, pp. 112–116, doi: 10.1109/scored.2010.5703983.

[6] A. Kelmendi, A. Hrovat, A. Svigelj, and M. Mohorcic, “Tropospheric scintillation fading analysis of alphasat satellite measurements in Ka and Q Bands,” in *2022 16th European Conference on Antennas and Propagation (EuCAP)*, Mar. 2022, pp. 1–5, doi: 10.23919/eucap53622.2022.9769659.

[7] N. Sonth and J. Morton, “Tropospheric scintillation fading on L-band signals using mountaintop-based radio occultation measurements,” in *Proceedings of the 2026 International Technical Meeting of The Institute of Navigation*, Feb. 2026, pp. 165–176, doi: 10.33012/2026.20535.

[8] A. Comisso, C. Riva, L. Luini, G. Codispoti, and G. Parca, “Tropospheric scintillation and simultaneous rain attenuation at 19.7 GHz and 39.4 GHz for tito scalo and spino d’Adda,” in *2023 17th European Conference on Antennas and Propagation (EuCAP)*, Mar. 2023, pp. 1–5, doi: 10.23919/eucap57121.2023.10133007.

[9] M. Rytir, “Long-term measurements of tropospheric scintillation at very low elevation angles - initial analysis,” in *2022 16th European Conference on Antennas and Propagation (EuCAP)*, Mar. 2022, pp. 1–5, doi: 10.23919/eucap53622.2022.9769627.

[10] S. Barbieri *et al.*, “Ka-Band tropospheric scintillation and simultaneous rain attenuation measured over rome with alphasat,” in *2025 19th European Conference on Antennas and Propagation (EuCAP)*, Mar. 2025, pp. 01–05, doi: 10.23919/eucap63536.2025.10999792.

[11] L. Luini *et al.*, “The MEKaP project: measuring tropospheric impairments at Ka Band with MEO satellites,” in *2020 14th European Conference on Antennas and Propagation (EuCAP)*, Mar. 2020, pp. 1–5, doi: 10.23919/eucap48036.2020.9135489.

[12] A. S. Akinloye, O. T. Victor, O. I. Enoch, E. M. Eterigho, O. Oluwafunmilayo Oluwayemisi, and A. O. Mustapha, “Impact of tropospheric scintillation models on earth-space path in Southwest, Nigeria,” in *2019 6th International Conference on Space Science and Communication (IconSpace)*, 2019, pp. 5–8, doi: 10.1109/iconspace.2019.8905936.

[13] T. V. Omotosho, S. A. Akinwumi, O. O. Ometan, M. O. Adewusi, J. S. Mandeep, and M. Abdullah, “Earth-Space rain attenuation prediction: its impact at Ku, Ka and V-band over some equatorial stations,” *Journal of Informatics and Mathematical Sciences*, vol. 9, no. 2, pp. 359–374, 2017.

[14] P. Rapaka and T. V Ramana, “Tropospheric scintillation of Ku and Ka-Band satellite signals in South Indian region,” in *2017 IEEE 7th International Advance Computing Conference (IACC)*, Jan. 2017, pp. 188–192, doi: 10.1109/iacc.2017.0051.

[15] K. P. S. Sudarshana and A. T. L. K. Samarasinghe, “Rain rate and rain attenuation estimation for Ku band satellite communications over Sri Lanka,” in *2011 6th International Conference on Industrial and Information Systems*, Aug. 2011, pp. 1–6, doi: 10.1109/iciinfs.2011.6038030.

[16] O. Banjo and E. Vilar, “Measurement and modeling of amplitude scintillations on low-elevation earth-space paths and impact on communication systems,” *IEEE Transactions on Communications*, vol. 34, no. 8, pp. 774–780, Aug. 1986, doi: 10.1109/tcom.1986.1096617.

[17] I. F. Elshami and J. Din, “Seasonal and diurnal variation on tropospheric scintillation at Ku-Band in tropical climate,” *International Journal of Electrical and Computer Engineering (IJECE)*, vol. 6, no. 4, p. 1710, Aug. 2016, doi: 10.11591/ijece.v6i4.pp1710-1716.

[18] I. Elshami, M. Kablan, M. Altorky, S. Elkhabbaz, and A. I. Elgayar, “Seasonal rain attenuation using ITU-R prediction model for Libyan climate,” in *The 7th International Conference on Engineering & MIS 2021*, Oct. 2021, pp. 1–7, doi: 10.1145/3492547.3492619.

[19] S. L. Jong, H. Y. Lam, J. Din, and M. D’Amico, “The relationship between ground wind direction and seasonal variation of rain attenuation at Ku band satellite broadcasting services,” in *2014 XXXIth URSI General Assembly and Scientific Symposium (URSI GASS)*, Aug. 2014, pp. 1–4, doi: 10.1109/ursigass.2014.6929042.

[20] A. Vander Vorst, D. Vanhoenacker, and L. Mercier, “Fluctuations on OTS-Earth copolar link against diurnal and seasonal variations,” *Electronics Letters*, vol. 18, no. 21, pp. 915–917, Oct. 1982, doi: 10.1049/el:19820624.

[21] G. Ortgies and F. Rücker, "Diurnal and seasonal variations of OTS amplitude scintillations," *Electronics Letters*, vol. 21, no. 4, pp. 143–145, Feb. 1985, doi: 10.1049/el:19850102.
[22] I. E. Otung, "Prediction of tropospheric amplitude scintillation on a satellite link," *IEEE Transactions on Antennas and Propagation*, vol. 44, no. 12, pp. 1600–1608, 1996, doi: 10.1109/8.546246.
[23] Y. Karasawa, M. Yamada, and J. E. Allnutt, "A new prediction method for tropospheric scintillation on Earth-space paths," *IEEE Transactions on Antennas and Propagation*, vol. 36, no. 11, pp. 1608–1614, 1988, doi: 10.1109/8.9712.
[24] J. S. Mandeep and Y. Y. Ng, "Satellite beacon experiment for studying atmospheric dynamics," *Journal of Infrared, Millimeter, and Terahertz Waves*, 2010, doi: 10.1007/s10762-010-9658-4.
[25] I. F. El-shami, L. H. Yin, J. Din, A. l Elgayar, and M. Alhilali, "Tropospheric scintillation with rain attenuation of Ku Band at tropical region," *TELKOMNIKA (Telecommunication Computing Electronics and Control)*, vol. 16, no. 5, p. 1982, Oct. 2018, doi: 10.12928/telkomnika.v16i5.10002.

BIOGRAPHIES OF AUTHORS

Ibtihal Fawzi El-Shami received the Ph.D. degree in Wireless Telecommunication Engineering from the University of Technology Malaysia (UTM), Johor Bahru, Malaysia, in 2016, with a dissertation focused on radio wave propagation modeling in tropical environments. She is currently an Associate Professor in the Department of Electrical and Electronics Engineering at the College of Electrical and Electronics Technology (CEET), Benghazi, Libya. She supervises master's and Ph.D. students and has served on academic and scientific committees. Her research interests include wireless communication systems, electromagnetic compatibility (EMC), brain-computer interface (BCI), and the application of deep learning techniques in biomedical signal processing. She has served on the scientific committees of international conferences such as the International Conference on Electrical Engineering and Information Technology (ICEEIT) and the IEEE Maghreb Conference in Engineering and Technology. She can be contacted at: ifelshami@ceet.edu.ly.

Prof. Jafri Din received the B.Sc. degree in electrical engineering from Tri-State University, Angola, IN, USA, in 1988, and the Ph.D. degree from the Universiti Teknologi Malaysia (UTM), Johor, Malaysia, in 1997. From 2008 to 2015, he was the head of Departments, Undergraduate Academic Manager, and the Deputy Dean (Development) of the Faculty of Electrical Engineering (FKE), UTM. He is currently the Director of the Wireless Communication Centre, UTM. His research activities have been correlated to the fields of radio wave propagation, satellite propagation, high-altitude platform station (HAPS), satellite TV broadcasting, weather radar, and sound techniques for fisheries industry. He can be contacted at email: jafri@utm.my.

Ali I. Elgayar is an associate professor in the Department of Electrical Engineering at the Faculty of Engineering, University of Benghazi, Libya. He has over 14 years of academic and research experience in the field of Electrical Engineering. His research interests include power systems, electrical machines, renewable energy integration, and smart grid technologies. Dr. Elgayar is a member of the Arab-German Young Academy of Sciences and Humanities (AGYA), where he actively collaborates on interdisciplinary research and science policy initiatives. He has published numerous research papers in peer-reviewed journals and conferences and is committed to advancing engineering education and research in the region. He also supervises both undergraduate and postgraduate students. He can be contacted at email: ali.elgayar@uob.edu.ly.

Ahlaam Miftah Saed received the B.Eng. degree in Electrical and Electronic Engineering (Telecommunications) from the University of Benghazi, Benghazi, Libya, in 2019, graduating among the top students in her class. She obtained the M.Sc. degree in Artificial Intelligence from the same university in 2023, where her thesis ranked first and was awarded the innovation prize for best scientific research. She is currently a faculty member at Bright Star University and the Libyan International University. Her research interests include artificial intelligence, brain computer interfaces, and intelligent communication systems. She is also passionate about empowering women in STEM fields and advancing research in AI-driven communication technologies. She can be contacted at email: Ahlaam.saed@bsu.edu.