

Rain attenuation prediction for 5G communication links in Minna, Nigeria.

E C Ibekwe, K C Igwe and J O Eichie

Department of Physics, Federal University of Technology Minna Niger State, Nigeria.

ibekwemmanuel@gmail.com

Abstract. Millimeter-wave systems in the near future will provide mobile data rates with higher speeds than the present communication systems in Nigeria but severe signal fading caused by rain is a major disadvantage at these high frequencies. A serious challenge in 5G millimeter wave technology is the accurate estimation of rain-induced attenuation. This study presents statistics of two-years rainfall data for 1-minute rain rate and rain attenuation prediction of 5G communication links propagating at 26 GHz and 38 GHz over a path-length ranging between 1 km and 5 km. A tipping bucket rain gauge type was used, and the data was logged using MadgeTech Rain101A rainfall data logger. From the analysis, a rain rate of 89 mm/hr exceeded at 0.01% of time was obtained. The ITU-R P.530-17 model was used to estimate the path attenuation. The attenuation values at 26 GHz for horizontal polarisation are 19.85 dB, 28.09 dB, 35.28 dB, 41.64 dB and 47.58 dB for 1km, 2km, 3km, 4km and 5 km path-length respectively, while the values for vertical polarisation are 15.94 dB, 22.73 dB, 28.43 dB, 33.59 dB and 38.45 dB respectively for the same path-length. At 38 GHz, the attenuation values for horizontal polarisation are 28.09 dB, 39.91 dB, 49.76 dB, 58.66 dB and 66.97 dB for 1-5 km respectively, while the vertical polarisation predicted attenuation values of 24.25 dB, 34.49 dB, 43.05 dB, 50.79 dB and 58.03 dB for the same path-length. These findings will be valuable for upcoming 5G mm-wave network designers in the study area.

Key words: Fifth-generation (5G), Rain attenuation, Rain rate.

1. Introduction

Increase in the demand for high speed internet and wireless communication networks has motivated research in 5G systems. Migration to a higher bandwidth in the pursuance of 5G wireless networks require the use of higher frequencies beyond the current propagating radio wave frequencies but rain causes the most significant transmission loss of signal strength amongst other atmospheric attenuators at frequencies greater than 10 GHz due to its absorption and scattering of the radio waves [1]. To efficaciously estimate attenuation due to rain along a radio link, rainfall characteristics such as rain rate integration time, average rainfall cumulative statistics and worst-month distribution must be available in the location of interest [2]. According to the International Telecommunication Union - Radio (ITU-R), 1-minute rain rate is the acceptable integration time for the prediction of attenuation due to rain [3]. Therefore, the attenuation caused by rain has to be put into consideration by scientists and radio-engineers in the design of 5G network services [4]. This work studies rainfall statistics in Minna, Nigeria using two years measured rainfall data at an integration time of 1-minute. The study investigates the statistics of rain events and rain rate cumulative distribution with the aim to present detailed information on the 1-minute rain rate and rain attenuation prediction for 5G communication links for the study area.

2. Rain Attenuation Prediction

Rain attenuation can be predicted accurately from point rainfall rate and other pertinent parameters along the link path. Recent attenuation prediction models use empirical procedures which is based on an estimated relationship between rain rate and rain attenuation and also depends on the operating



frequency and polarization type [5]. Total path attenuation is derived by multiplying the specific attenuation α (dB/km) which is dependent on frequency and the effective path-length, d_{eff} . An estimate of path attenuation (dB) using the ITU-R P.530-17 [6] prediction model with rain rate exceeded for 0.01% of time is given by:

$$A_{0.01} = \gamma_R d_{eff} = \gamma_R dr \quad 1$$

where γ represents the specific attenuation α (dB/km), k and a are frequency-dependent coefficients derived from [7], r is the distance factor, and d is the actual link distance.

3. Research methodology

3.1. Data Acquisition

Two years of 1-minute rainfall data measured from 2019 to 2020 was used in this work. The rainfall data was collected using a tipping bucket rain gauge of 0.254 mm per tip connected to a rainfall data logger positioned at the Tropospheric Data Acquisition Network (TRODAN) weather station located at Bosso campus, Federal University of Technology, Minna as shown in Figure 1. The rain gauge scans rainfall data at an interval of one minute along the date and time of each rainfall tip. This prompts an electronic signal that is stored in the data logger. The data logger employed for accurately recording the data is the MadgeTech Rain101A rainfall data logger.



Figure 1: TRODAN weather station at Federal University of Technology, Minna

3.2. Data Analysis

Data logging was done by connecting the logger to a personal computer. The data was saved in a legible format by transferring it to a Microsoft Excel spreadsheet. The collected 1-minute rainfall data was analysed and converted to rain rate so as to compute the cumulative distribution function of the rain rate. The rain rate percentage exceedances were then calculated. The rain rate served as initial input for the ITU-R P 530-17 rain attenuation model to predict rain attenuation for 5G communication links in the study area.

4. Results and discussion

4.1. Average monthly rainfall accumulation

Figure 2 depicts the mean monthly accumulated rainfall over the observed 2-year period. The study area experiences two different seasons annually: dry season stretching from November till April and rainy season from May to October of a year.

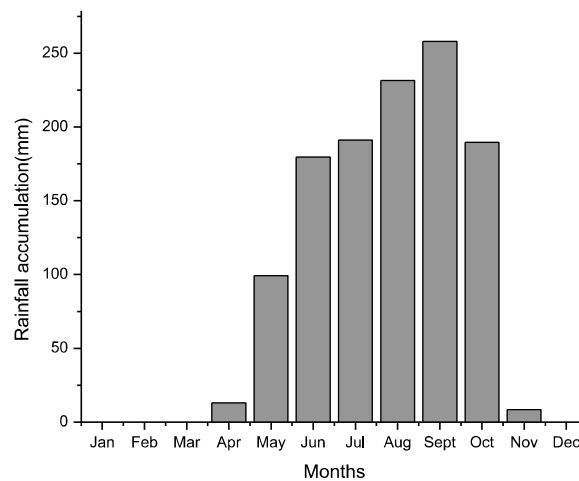


Figure 2: Average monthly rainfall accumulation (mm)

From the result, rainfall accumulation was lowest in November and April for the two-year study. It can be noted that Minna recorded no rainfall in January, February, March and December. The month of September recorded the highest rainfall with a mean monthly accumulated rainfall of 257.91 mm. Data analysis on rain rate further proved the month of September to be the worst month for a radio link in the study area as it recorded the highest rainfall intensity with an average rain rate value of 74.07 mm/hr. Thus, the worst month become an important period to be considered in rain attenuation studies.

4.2 Rain rate cumulative distribution function

Analysis of the measured rainfall data at 1-minute integration time for the 2-year period was carried out with the aim of obtaining the cumulative distribution function. For a better 5G wireless communication service in a medium affected by rain, cumulative distribution is an accurate evaluation technique which determines the percentage of time the rain rate is exceeded. These probabilities enable communication system engineers to design suitable fade margin levels that is required to offset the effects of network outages during rainy season. In general, rainfall rate (mm/hr) value equivalent to 0.01% exceedance commonly referred to as $R_{0.01}$ is the key interest. Figure 3 presents the 1-minute rainfall rate cumulative distribution obtained for Minna.

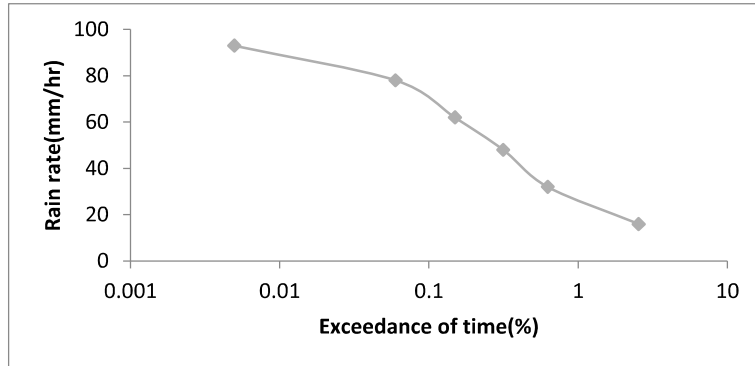


Figure 3: Rain rate cumulative distribution function

The measured rain rate at time percentage exceedance of 0.01% is 89 mm/hr. This is a very vital result. In addition, it was observed that rainfall rate increases when the percentage of time exceedance decreases. For instance, at 0.1% and 1% of time, the recorded rain rate was 70 mm/hr and 26 mm/hr respectively, but as the time percentage exceedance decreased to 0.01%, the rain rate increased to 89 mm/hr.

4.3 Estimation of rain attenuation

The evaluation of the rain attenuation (dB) exceeded for 0.01% of time is derived using the techniques recommended in ITU-R P530-17 model based on rain rate value corresponding to 0.01% of time exceedance which was derived as 89 mm/hr. Frequencies of 26 GHz and 38 GHz are the allocated frequencies for 5G communication systems and was used for this analysis at horizontal and vertical polarisations. The ITU-R P530-17 is designed for communication links with path-length longer than 1 km. Therefore, in this work, the path-length ranges from 1 km to 5 km. Table 1 presents the variation of the rain attenuation at operating frequencies of 26 GHz and 38 GHz with respect to path-length and polarisation types.

Table 1: Rain attenuation values at 0.01 % for 26 GHz and 38 GHz Links

Frequency(GHz)	Path length(km)	Attenuation (dB)	
		Horizontal	Vertical
26	1	19.85	15.94
	2	28.26	22.73
	3	35.28	28.43
	4	41.64	33.59
	5	47.58	38.45
38	1	28.09	24.25
	2	39.91	34.49
	3	49.76	43.05
	4	58.66	50.79
	5	66.97	58.03

Figure 4 presents a graphical representation of the predicted rain induced attenuation at frequencies of 26 GHz and 38 GHz at 0.01 % of time exceeded for the study area derived using recommendation ITU-R P530-17 model.

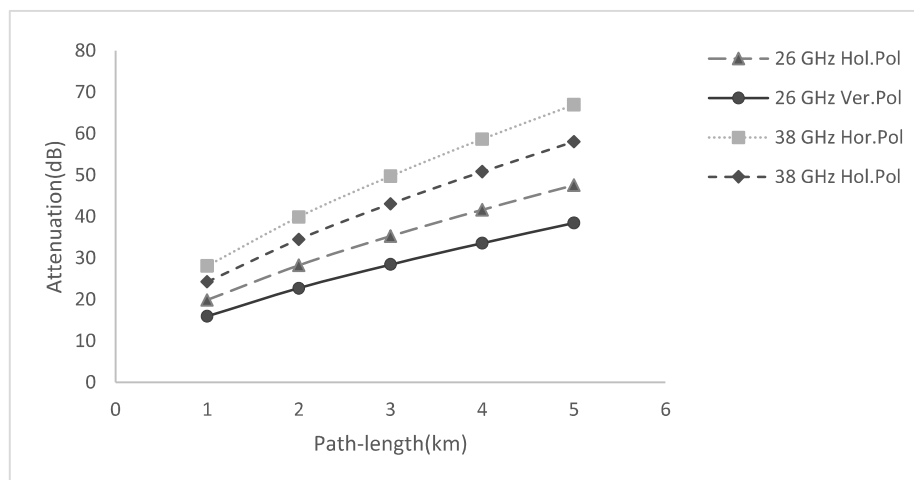


Figure 4: Rain attenuation at 26 GHz and 38 GHz for the study area

From Figure 4, the attenuation values at 26 GHz for horizontal polarisation are 19.85 dB, 28.09 dB, 35.28 dB, 41.64 dB and 47.58 dB for 1km, 2km, 3km, 4km and 5 km path-length respectively, while the values for vertical polarisation are 15.94 dB, 22.73 dB, 28.43 dB, 33.59 dB and 38.45 dB respectively for the same path-length. At 38 GHz, the attenuation values for horizontal polarisation are 28.09 dB, 39.91 dB, 49.76 dB, 58.66 dB and 66.97 dB for 1-5 km respectively, while the vertical polarisation predicted attenuation values of 24.25 dB, 34.49 dB, 43.05 dB, 50.79 dB and 58.03 dB for the same path-length. The analysis show that the attenuation is influenced by the frequency, polarisation type and path length. The attenuation increases with increase in frequency and path-lengths. Above 1 km, there will be a significant decrease in the signal strength due to the high values of attenuation. Therefore, the output power of the transmitter has to be amplified to a value higher than the computed attenuations.

5. Conclusion

Two years of 1-minute rainfall data measured from 2019 to 2020 was used in this work to obtain 1-minute rain rate cumulative distribution function and to predict rain induced attenuation for 5G communication links for the study area. The measured rain rate at 0.01% of time exceedance is 89 mm/hr. The evaluation of rain attenuation at 0.01% of time exceedance was derived using recommendation ITU-R P530-17 model for horizontal and vertical polarisations at 26 GHz and 38 GHz. The path attenuation values at 26 GHz for horizontal polarisation are 19.85 dB, 28.09 dB, 35.28 dB, 41.64 dB and 47.58 dB for 1-5 km path-length, while the values for vertical polarisation are 15.94 dB, 22.73 dB, 28.43 dB, 33.59 dB and 38.45 dB at the same path-length. At 38 GHz, the attenuation values for horizontal polarisation are 28.09 dB, 39.91 dB, 49.76 dB, 58.66 dB and 66.97 dB for 1-5 km path-length, while the vertical polarisation predicted attenuation values of 24.25 dB, 34.49 dB, 43.05 dB, 50.79 dB and 58.03 dB for the same path-length. The results show that the attenuation is influenced by the rain rate, frequency, polarisation type and path length. The results in this research will be useful for efficient and effective design of 5G communication systems in the study area.

References

- [1] D.P. Panagopoulos, D. M. Arapoglou, and G. C. Panayotis, "Satellite communications at Ku, Ka and V bands: Propagation impairments and mitigation techniques," IEEE Communications Surveys and Tutorials, 2004