Predicting Fade Duration Statistics for Microwave Application in Jos, Nigeria

O.M Durodola [(1)], P. David. [(1)], A. Akor[(1)], J.S. Ojo[(2)] and M. O. Ajewole[(2)]
(1)Department of Physics, University of Jos, NIGERIA, e-mail: durotayo@gmail.com,
(2)Department of Physics, Federal University of Tech, Akure, NIGERIA

ABSTRACT

Rain fade is the major challenge to link availability for microwave propagation operating at frequencies above 10 GHz, hence the interest of satellite communication systems designers in the features of rain fade events for the design of link budgets. This paper studies the duration of some rain events as well as the duration rain fades arising there-from. The statistical analysis is based on Year 2015 -2017 rain data collected at Jos Plateau (9°57'N, 8°58'E, 1192 m Altitude above sea level). It was observed that, for a particular value of rain rate R, the number of event N decreases with increase in duration D. ITU-R P.618-12 showed prediction of rain fade levels above 20 dB lasting for more than 20 minutes. Longest durations of rain-fade were experienced in the months of June, July and August. The results of this paper will be useful for the prediction of fade duration statistics which are required for the design of fade mitigation techniques on satellite links during rainfall. It is recommended that the various fade curves be used as inputs in simulation algorithms for mitigating rain fade in the region.

Keywords: Rain-fade dynamics, Rain events, Fade duration, ITU-R, Microwave applications

1.0 INTRODUCTION

As the frequency spectrum becomes increasingly crowded, satellite to ground communication links are shifting to higher frequencies, from C-band to Ku – band and Ka – band. The degradation of communication signal caused by rain fade increases as the number and intensity of heavy rain increases. Fade duration statistics are required for the design of fade mitigation techniques on satellite links. Limited investigation have focused on the analysis of rain fade dynamics in tropical regions.

[1] reported that rain event duration of higher intensity causes signal outage leading to delay of operations in banks, radio signal reception; while event duration of lower intensity causes signal scintillation. They suggested various ways of overcoming fading due to rainfall. The predicted attenuation for Jos at worst month (150mm/h) is about 26.5 dB [2]. This research will reveal the months with such great rain rates capable of squelching communication signals. To model fade duration and rain fade slope analysis, [3] showed that Van de Kamp was best model fit for measured data for two point-to-Point microwave links operating in Ka frequency Band. However, [4] found that a logarithm model was more appropriate than the power-law in modelling rain fade in Ku frequency bands. To analyse the dynamics of rain duration and return period, different conversion factors are required for different locations even within the same climatic regions [5]

1.1 Features characterising Fade dynamics.

Several features that may be used to characterize the dynamics of rain fade are shown in Figure 1, namely: fade depth, fade slope, fade episode, inter-fade interval, fade threshold amongst others. The fade depth is the difference between the maximum and minimum signal strength over a certain interval of time, usually over a very small interval. It is normally used in expressing fading in communication signal [6].

***1.1.1 Fade Duration*:** Fade duration is the time interval between two crossings above the same attenuation threshold. In system design, fade duration is very important to be considered due to the following reasons:- System outage and unavailability, Error Coding and Modulation, and for Fade mitigation techniques. The statistics from fade duration provides information on the number of outages, probability of system unavailability, time durations of the system in a compensation mode, etc. It determines the choice of the coding scheme for forward error correction codes and best modulation schemes. The propagation channel does not produce independent errors but blocks of errors. Fade duration distribution of rain attenuation are often modeled as the sum of two functions – one accounts for short durations (which are caused by scintillation), and the other for long durations (which are caused by rain effects). Fade duration as a function of fade depth is also used to estimate the risks in providing telecommunication services [7].

1.1.2 Inter-fade duration: This is the time interval between two crossings below the same attenuation threshold. The inter fade duration, also called non-fade duration is the complement of fade duration and is used to characterize the time interval between two fades. Essentially, it is the statistics of duration before the occurrence of another fade event which may result in system outage.

***1.1.3 Fade Threshold*:** The fade threshold is the minimum level at which a signal can be received. In the figure 1.0 above, the fade threshold as shown is the fading of signal amplitude as it crosses a certain threshold. The rain fade threshold for this research is the fade level at clear air, when there is no rainfall; which is less than 1 dB [8, 9].

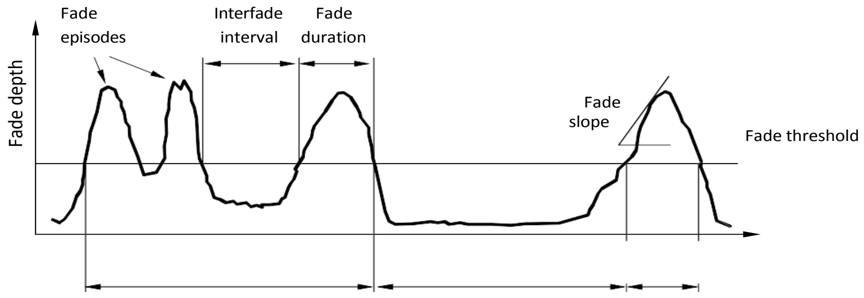


Figure 1: Characteristics of a rain fade event (Source: [6])

1.2.4 Fade Slope: Fade slope is defined as the rate of change of rain attenuation. The fade slope of the received signal is used to predict the short-term propagation conditions of the signals; in order to design a control loop that can follow signal variations. The relevant information is the slope of the slowly varying component of the signal and would require filtering out scintillation and rapid variations of rain attenuation. Apart from climatic parameters and drop size distribution, the fade slope profitability distribution largely depends on the type of rain.

This paper studies monthly and annual rain event duration in Jos plateau state for 3 years (2015 – 2017) through the following specific analyses: Collation of monthly duration statistics of rainfall intensities; Determine monthly variation of rain event duration on graph; and finally, plot Excel graphs were plotted to reveal the parameters and dynamics of each fade event was predicted using ITU-R in [10].

2.0 METHODOLOGY

Rainfall was measured with DAVIS Vantage Vue Integrated Sensor Suite (ISS) weather station set up in Gold and base Jos, Plateau (9°57'N, 8°58'E, 1192 m Altitude above sea level) as described in [11]. One minute rain rates were collected by the wireless console receiver and stored by its automatic data – logger. Rain data from 2015 to 2017 were used.

3.0 RESULT

3.1 Monthly and Annual Duration of Intensities of Rainfall

The monthly graphs in Figures 1 (a-c) present the time duration of rainfall of various intensities collated for the months of June, July, Years 2016 and 2017.

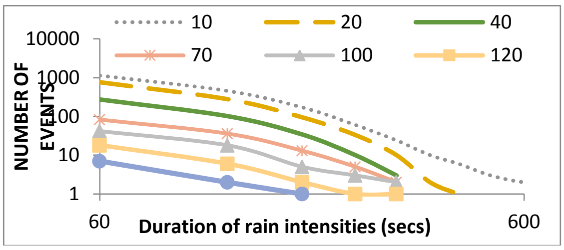
3.2 Duration of Various Rain Events

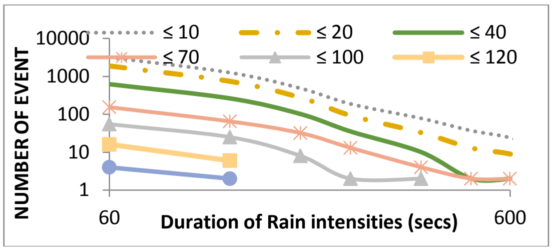
Duration of some rain events in some of the months of 2016 are presented in Figure 3.

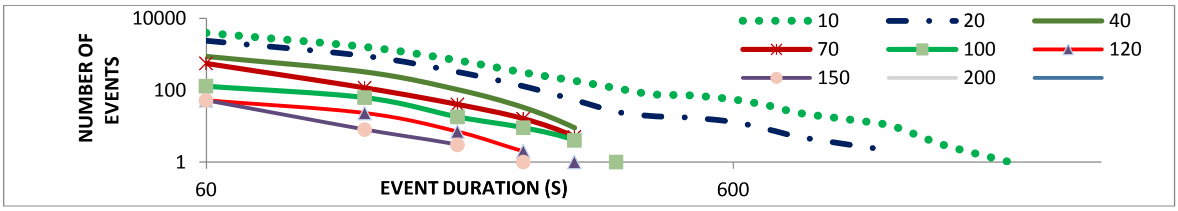
3.3 Prediction of Duration of Rain Fade Events

In Table 1 are the predicted attenuation levels computed using ITU-R prediction model in [10] for the various rain-rates. The graph in Figure 4, derived from Table 1, yields the power-law regression model eqn (1) that was used to predict attenuation at various rain-rates; with a strong regression coefficient of 99%, while The predicted fade duration of a few significant rain events are presented in figures 5 (a –h).

$$A_{(R)} = 0.457R^{0.732} \qquad (1)$$







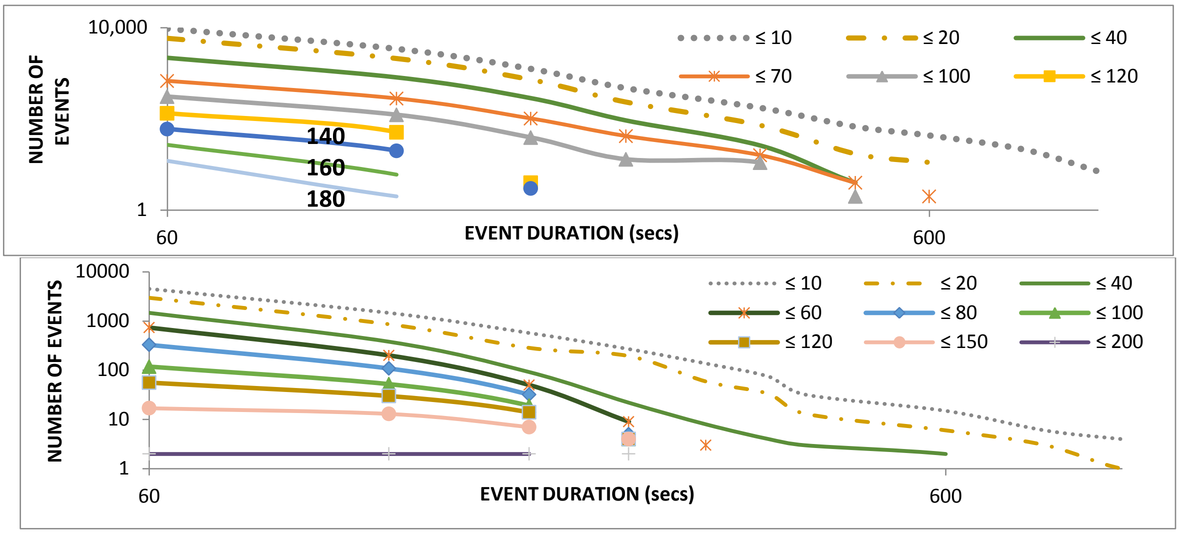


Figure 2: Duration of all rainfall intensities a) June 2016 b) July 2016 c) Yr 2015 d) Yr 2016 e) Yr 2017

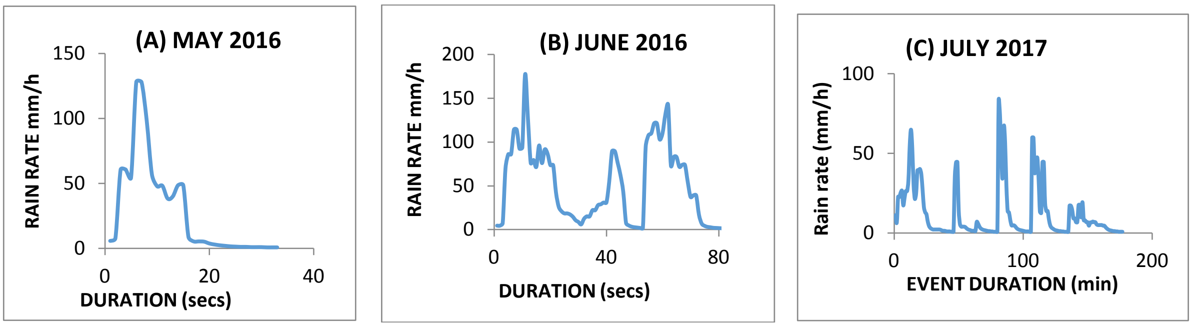


Figure 3: Duration of some rain events in a) May 2016 b) June 2016 c) July 2017

Table 1: ITU-R P.618 (2015) Predicted attenuation for rain rates in Jos.

Rain Rate (mm/h)	2	5	10	20	30	40	50	70	100	120	140	160
Attenuation(dB) ITU-R prediction	0.60	2.05	2.96	3.78	5.40	5.98	7.29	8.85	12.58	16.82	18.15	20.15

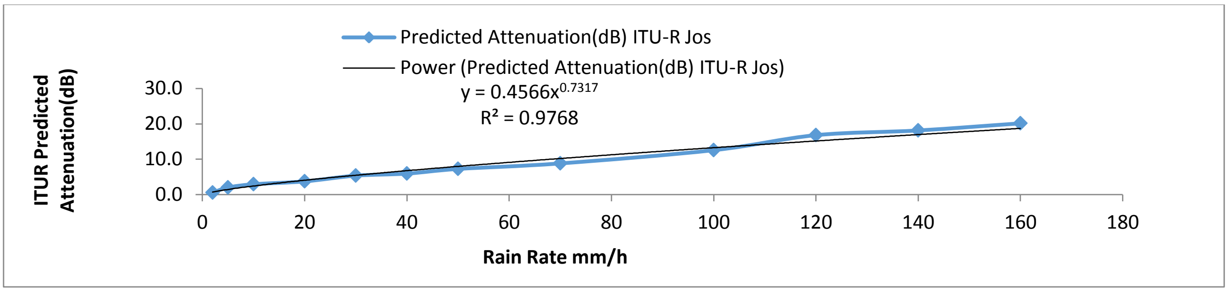


Figure 4: Determination of rain fade model – Power-law regression

4.0 DISCUSSION

4.1 Monthly and Annual Duration of Rainfall Intensities

It is observed that, the number of events N decreases as the rain rate R increases from 2mm/h to 120mm/h, as well as with increase in duration D. For instance, when the rain rate is 10mm/h, the number of events is above 10,000 but the duration was shorter (60 secs). When rain rate is 70mm/h, the number of events is below 1000. This is true for all the different months under investigation. At a rain rate 10mm/h with duration of 60seconds (1minute) the number of events was above 1,000 but as the duration increased to 600 seconds (10minutes) the number of events decreased to

100. Duration decreases with increasing rain rates. The lower rain rates have the longer duration while the higher rain rates have the shorter duration. This indicates that the lower Rain Rates (2- 30 mm/h) can continuously prevail over a longer duration giving rise to scintillations in microwave signals for long period of time while the higher rain rates are confined to a shorter time span resulting in fading of signals for short period of times.

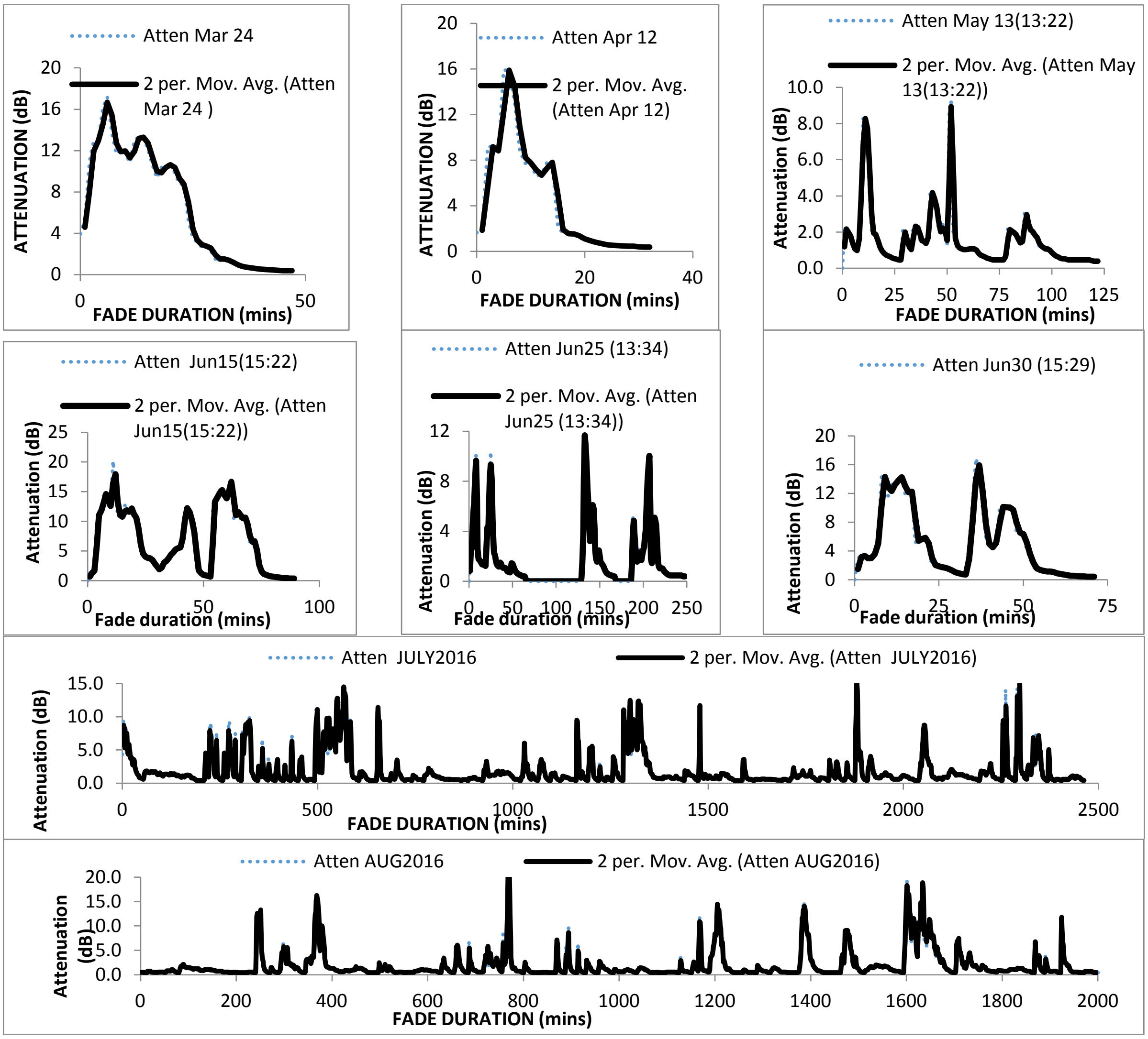


Figure 5: Fade dynamics of some rain events in March through August 2016

4.2 Duration of Various Rain Events

All the months have basically similar results but in some months there are longer duration than others. It was observed that the highest number of rain fall event occurred in the month of August in 2015 and July in 2016 and 2017. The longest rain event duration is observed in the month of July, August and July (over 5,000 seconds) for 2016, 2017. July has been observed to be the worst month with the highest event duration and rain fade [2]. The similarity of graphs for the different rain rates implies that they follow a basic pattern whose parameters depend on the rain climate. Users are advised by this work not to carry out time sensitive events in months like July, August and September which are observed to be more vulnerable to signal fading and scintillations as a result of rain event.

4.3 Dynamics of Rain Fade Events of rain-fade events

A rain event is defined when continuous rain occurs above some predefined rain rate and time threshold [12]. This investigation considered several critical rain events in Jos, Plateau State for each month of study as shown in figure 5. It is observed in March 2016 was the onset of rains in Jos; the rain event was convective. The rain fade crossed the threshold of 4 dB and stayed above the fade threshold at about 10 dB for more than 30 mins. The fade events in July, the worst month, had similar prevalence but with repeated inter-fade durations of 5 mins, 50 mins and 2 mins respectively. This is the general feature of all the rain events as they are inherently random and can be therefore, described by statistical models only [13] (Crane, 1996). The Monthly fade dynamics in the last 2 curves in Fig 5 could serve as input for simulation models and algorithm.

5.0 CONCLUSION

Of interest to communication system designers and planners is the use of the monthly fade dynamics as input for simulation models and algorithm for fade mitigation. The next stage of analysis is to model the various parameters of fades from the fade curves generated in each fade event. These models would then serve as design inputs fro microwave planners in the region.

References

[1] AnimeshMaitra, Saurabh Das and Ashish K Shukla (2009): Joint statistics of rain rate and event duration for a tropical location India; Indian Journal of Radio and space Physics Vol. 38, pp. 353 – 360.

[2] Durodola O.M, Ojo J.S, and Ajewole M.O (2017).Characterization of worst month statistics for satellite – earth links performance in tropical location. *Physical Science International Journal*, 13(3), 1-9.

[3] Sanyaolu, M. E. (2016): Rain fade analysis at C, Ku and Ka bands in Nigeria

[4] Durodola, O. M., Esther M. Fomson and M. M Josiah (2019): Characterization of rain fade in Jos, a semi temperate region; FUPRE Journal of scientific and industrial research Vol. 3, (1), ISSN: 25759-1184 (Print) ISSN: 2578-1129 (Online)

[5] Ojo, J.S and Ajewole, M, O, (2011). Dimensional Statistics of Rainfall Signature and Fade duration for Microwave Propagation in Nigeria.978-1-4244-6051-9/11 © IEEE

[6] Senzo, J.M. (2014): Determination of millimetric signal attenuation due to rain using rain rate and raindrop size distribution models for southern Africa. PhD thesis (Electronics Eng) UKZN, Durban South Africa.

[7] Cheffena, M (2008). Prediction Model for Fade Duration Statistics for Satellite Links between 10-50 GHz Published by IEEE Antennas and Wireless Propagation Letters. (Volume: 7).

[8] Mandeep JS (2009): Comparison of rainfall models with Ku-band beacon measurements, *Acta Astronomical*, Vol. 64(2), pp264-271.

[9] Nalinggam, R; W. Ismail and JS Mandeep (2012): Rain-induced attenuation for Ku-band satellite communications in the West-coast of Peninsular Malaysia, Penang, *Annales des Telecommunications*, Vol. 67(11), pp569-573.

[10] ITU-R P.618-12 (2015): “Propagation data and prediction methods required for the design of earth-space telecommunications systems,” Recommendation, P Series ITU-R, Int. Telecomm. Union, Geneva

[11] Durodola OM, JS Ojo, MO Ajewole; (2017): Performance of Ku-band satellite signals received during rainy condition in two low-latitude tropical locations in Nigeria; Adamawa State University Journal of Scientific Research, Vol.5 (1).

[12] ITU–R P. 530 – 12 (2005): Propagation data and prediction methods required for the design of terrestrial line-of-sight systems.

[13] Crane, R. K., (1996): Electromagnetic wave propagation through rain, Wiley Inter-science, New York.