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# Characterization of Rain Fade in Jos, a Semi Temperate Region

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## Abstract

In a bid to meet the growing demands for mobile satellite applications, communication systems designers have been concerned about how rain attenuation affects satellite communication links especially in tropical region. This study has been conducted to characterize rain fade on satellite communication links in Jos (9.9565$^0$N, 8.8583$^0$E, 1,192 m), a semi-tropical region of Nigeria. The study will avail communication service providers with necessary information to improve the quality of service within the region. Rain data were retrieved from the Davis weather station for a period of one year in 2014. Rain attenuation data were obtained from a Ku-band beacon link set at a look-up angle of 56.5$^0$ on the European Telecommunication Satellite (EUTELSAT W4/W7) orbited on 036E. The different rain rates and their corresponding rain attenuation values were analyzed to obtain basic characteristics of rain fade in the region. The results showed that, as the rain increases in intensity, the measured attenuation increased, indicating that rain fade has direct relationship with rain rate. Also, the maximum level of rain fade for the year 2014 was 30dBm with a maximum rainfall intensity of 160mm/h. For most of the rainy months, the results showed that the logarithm-law, rather than the power-law, is more accurate for the modelling both rain rate and rain attenuation. This suggests that to model rain fade, a logarithm model may be more appropriate than a power law. The average threshold value of rain fade during rainy months was 11 dB; the minimum value was about 4 dB while the maximum was about 21 dB. The usual practice is for designers to provide fade margins based on the maximum rain fade threshold value of 21 dB. These fade levels require that communication system designers explore alternative measures of mitigating the fade levels of 21 dB.

**Keywords: Ku-band, Rain, Rain fade, Fade threshold.**

## 1. Introduction

The increasing demand for up-to-date satellite applications requiring high speed data transmission has created congestion in radio frequency bands lower than 10 GHz; thereby necessitating the increasing need for the higher frequencies. Telecommunication service providers, system designers and operators are forced to migrate to the wider bandwidths available in microwave and millimetre wave frequency bands (3-300 GHz) of the electromagnetic spectrum. However, at frequencies greater than 10 GHz, radio wave propagation is greatly inhibited by hydrometeors, especially rain, which causes attenuation of the signal through heat, absorption and scattering

(Hall, 1989; Ajewole et al, 1999). Rain attenuation is estimated by integrating the specific attenuation along the earth-space path (Malinga, et al; 2013). The specific rain attenuation is mathematically calculated by using empirical parameters such as the cumulative distribution of one-minute rain rate at a given probability of exceedance (ITU-R, 2009; Durodola et al, 2017a).

The impacts of rain rate along the satellite path over mixed climates (such as tropical, sub-tropical and temperate climates) demand special attention in rain attenuation modelling (ITU-R, 2009). Electromagnetic waves passing through raindrops at any of these bands will be absorbed, scattered, or passed through the medium. This scattering and absorption processes are termed rain attenuation (Eze et al, 2014). The attenuation caused by the rain depends on parameters such as the size of raindrops, rain temperature, drop velocity, polarization, rain rate, drop orientation and transmitting frequency (Durodola et al, 2018). Since rain attenuation is the primary obstacle to good quality and availability of signal at these bands, the development of rain attenuation models has been the focus of many researchers such as Ajayi and Olsen, (1985); Adimula, (1997); Ajewole and Adediji, (2004) Ajewole and Ojo,(2005); Omotosho and Oluwafemi, (2009); Semire *et al.*, (2011) and Ojo and Falodun, (2012). In their measurement campaigns, theoretical and analytical models were established. Many rain attenuation models, both of terrestrial and satellite paths, are semi-empirical in nature due to the lack of measurement equipment to study the physics of rain and provide accurate characterization of the various sources that produce the impairments.

In this paper a month by month regression analysis of rain attenuation is presented in order to determine characteristics such as attenuation rate as a percentage of time, noise threshold values for each month, as well as for the year 2014.

## 2. Methodology

Rain attenuation data were obtained using a combo digital SATLINK receiver in form of video clips recorded over a Ku-band link located on European Telecommunication Satellite (EUTELSAT W4/ W7) beacon orbited on 036$^{o}$E at a look-up angle of 56.5$^{o}$. The rain measured data were recorded in EXCEL files database with one-minute integration time using DAVIS ISS weather station (Durodola, 2016). The following parameters were extracted from video clips: Date of the rain data, Time data was obtained, Signal Strength (S), Signal Quality (Q), Bit Error Rate (BER), Power levels (PWR) and Carrier–to-Noise ratio (CN). The video clip display is shown in Figure 1 below.

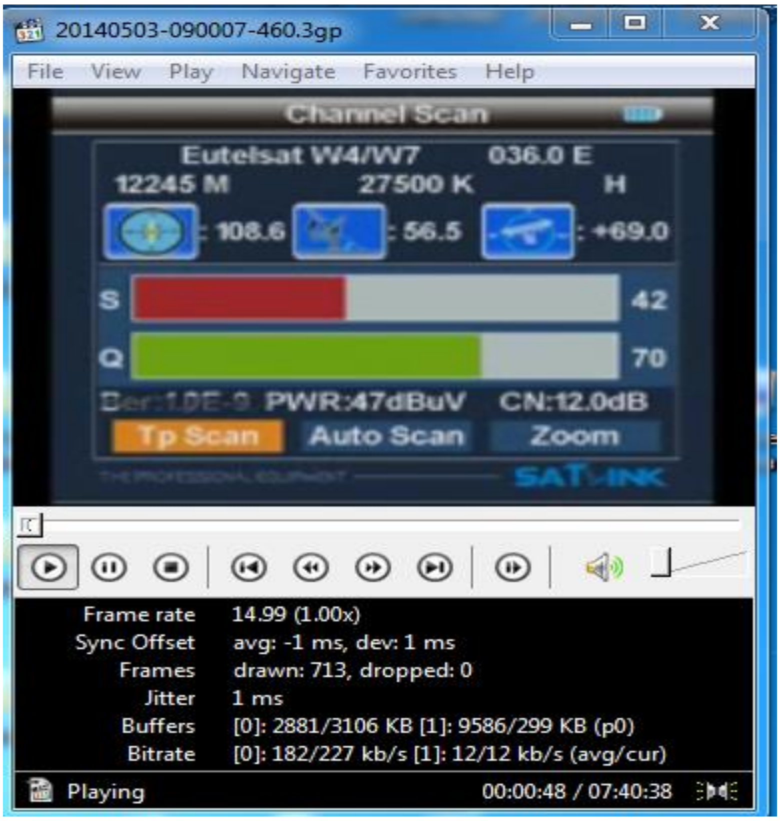


**Figure 1: Video clip display of combo digital receiver and spectrum analyzer**

## 3. Results and discussion

The results of the analysis of Ku-band signal performance during rainfall along Earth-space paths at Jos, a low latitude tropical location in Nigeria are presented. Figures 2 to 8 show the analysis of rain rate and rain attenuation in Jos for the rainy months of April to October 2014 respectively. The trend-lines to characterize the rain fade for the respective rainy months are also presented in Table 1.

### *3.1 Results of the monthly analysis of Rain Rate and Rain Attenuation*

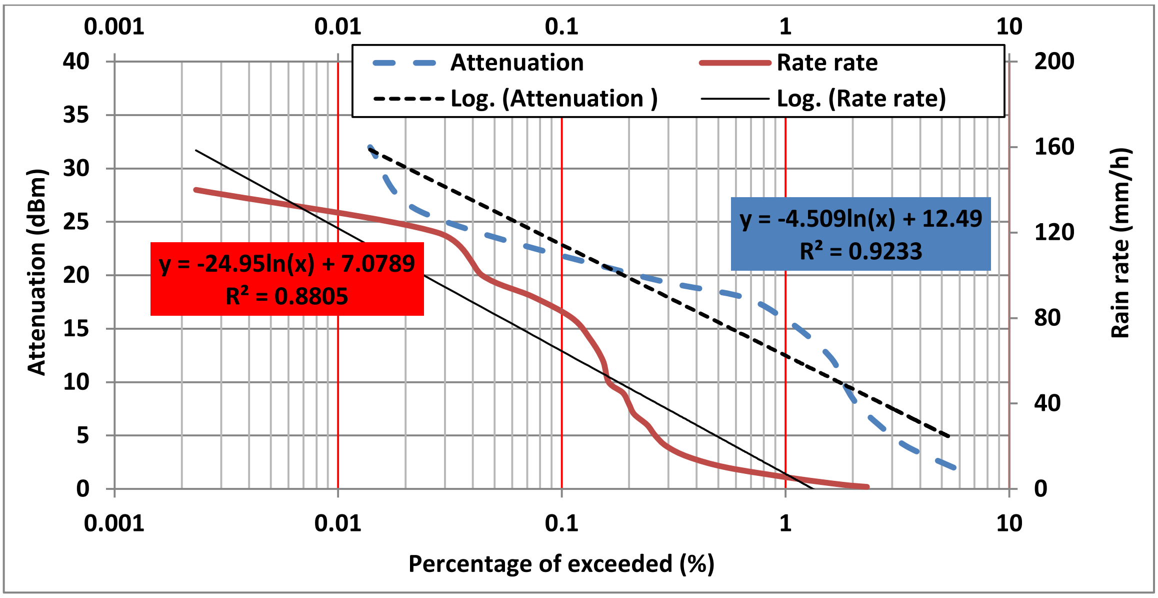


**Figure 2: Analysis of Rain Rate and Rain Attenuation for April, 2014 in Jos.**

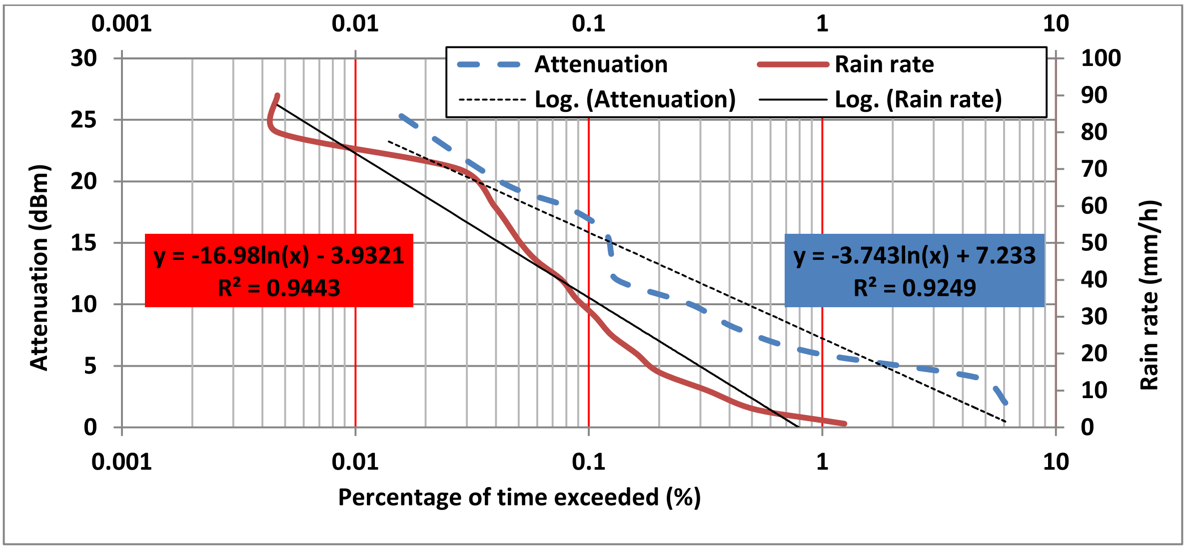


**Figure 3: Analysis of Rain Rate and Rain Attenuation for May, 2014 in Jos.**

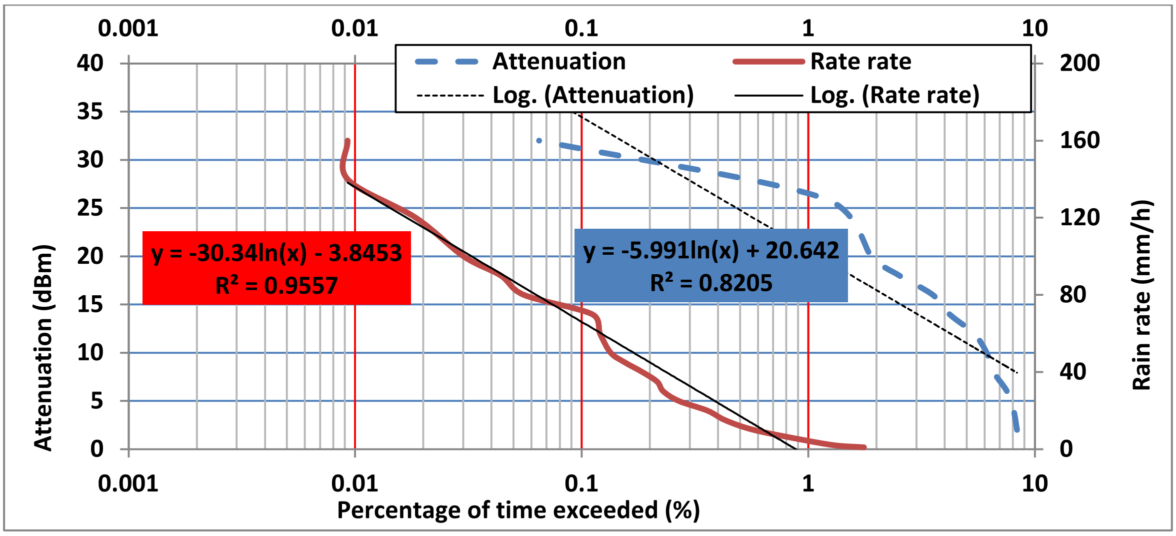


**Figure 4: Analysis of Rain Rate and Rain Attenuation for June, 2014 in Jos.**

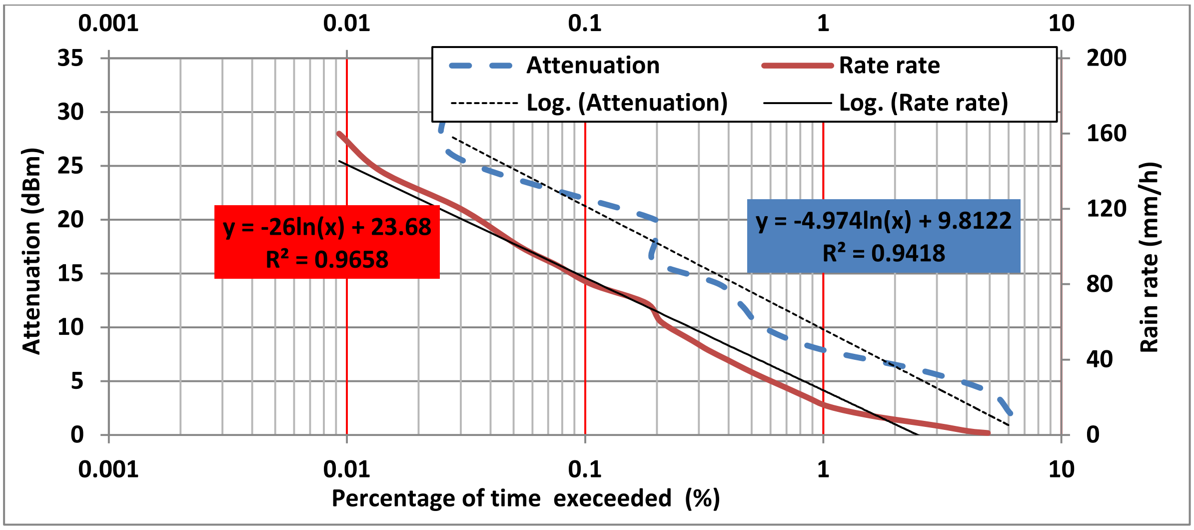


**Figure 5:Analysis of Rain Rate and Rain Attenuation for July, 2014 in Jos.**

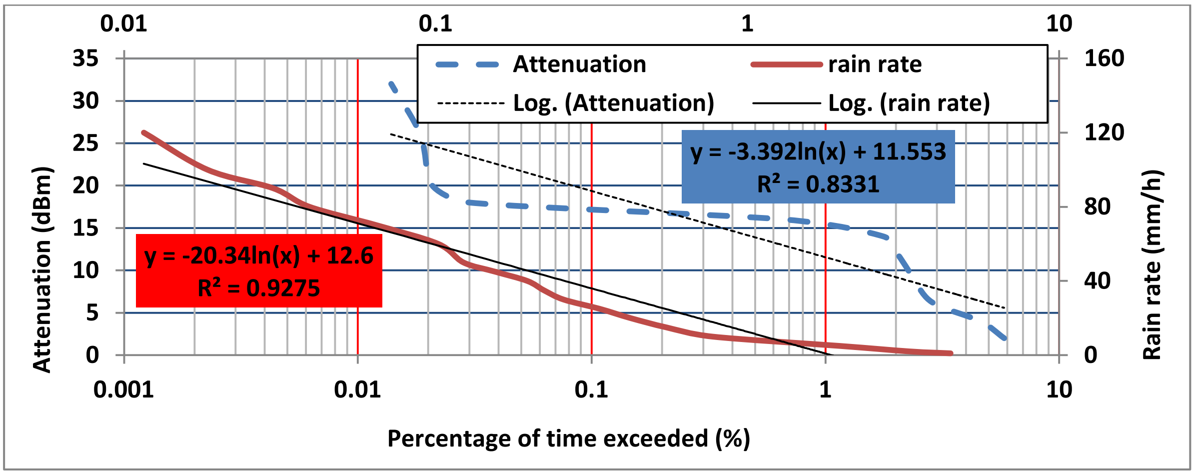


**Figure 6: Analysis of Rain Rate and Rain Attenuation for September, 2014 in Jos.**

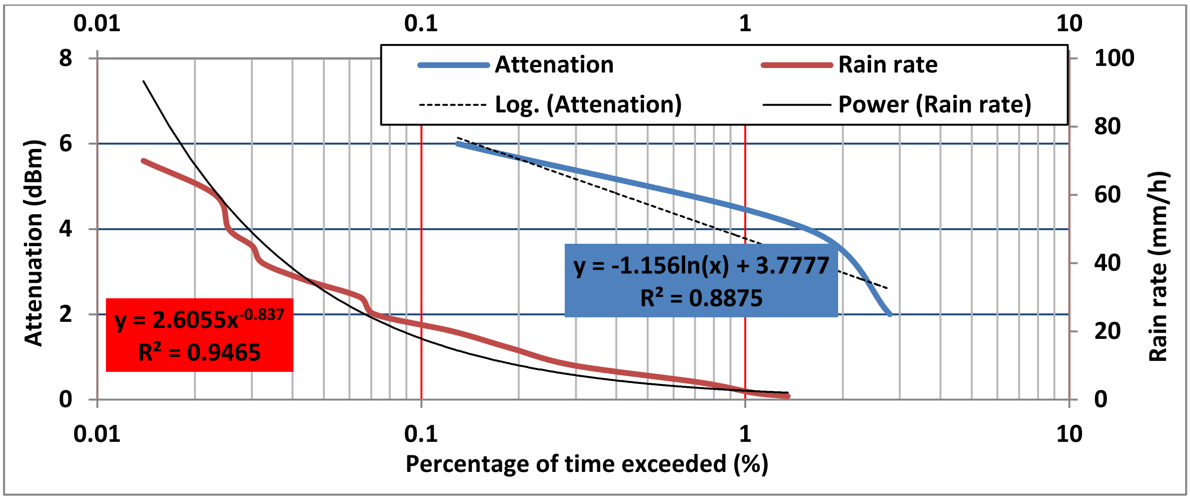


**Figure 7: Analysis of Rain Rate and Rain Attenuation for October, 2014 in Jos.**

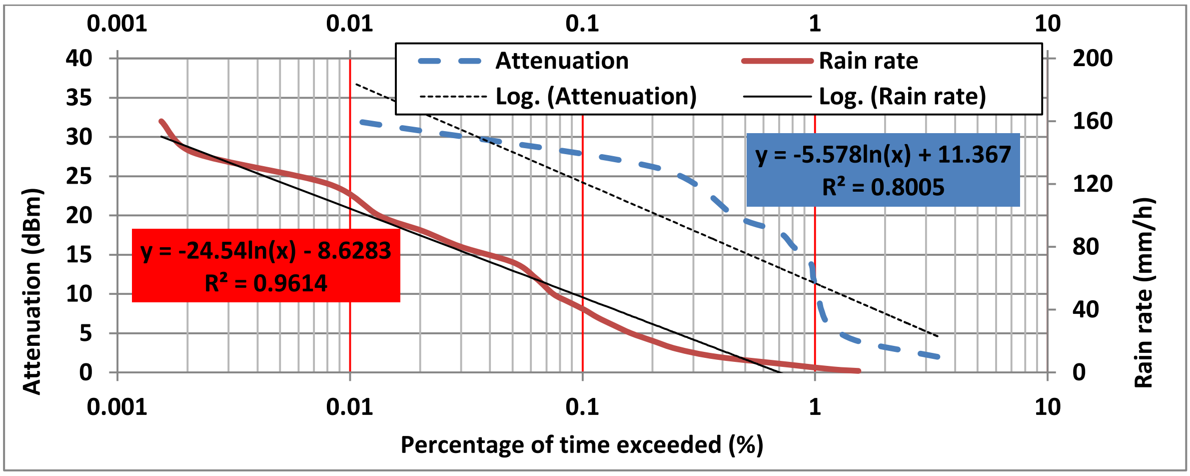


**Figure 8: Analysis of Rain Rate and Rain Attenuation for Year 2014 in Jos**

### *3.1.1 Trend-lines to characterize rain fade*

**Table 1: Characterization of Rain Rate and Rain fade in 2014**

| Month | Regression lines for distribution of Rain Rate (r, mm/h) | | Regression lines for distribution of Rain Attenuation (A, dB) | |
|---|---|---|---|---|
| **April** | r=-24.95In(p)+7.08, | $R^2$=0.89 | A= -4.51In(p)+12.49, | $R^2$= 0.92 |
| **May** | r =-15.98In(p)-3.93, | $R^2$=0.94 | A= -3.74In(p)+7.23, | $R^2$=0.92 |
| **June** | r =-30.34In(p)-3.85, | $R^2$=0.96 | A= -5.99In(x)+20.64, | $R^2$=0.82 |
| **July** | r =-26In(p)=23.68, | $R^2$=0.97 | A= -4.97In(x)+9.81, | $R^2$= 0.94 |
| **September** | r =-20.34In(p)=12.6, | $R^2$=0.93 | A= -3.40In(p)+11.56, | $R^2$= 0.83 |
| **October** | r = $2.61p^{0.84}$, | $R^2$=0.95 | A= 1.16In(p)+3.78, | $R^2$= 0.89 |
| **For Year 2014** | r = -24.5In(p)-8.63, | $R^2$=0.96 | A= -5.57In(p)+11.37, | $R^2$= 0.80 |

### *3.2 Discussion*

### *3.2.1 Monthly and annual Variation of rain fade*

It can be observed from Figure 2 that, as the rain increases in intensity, the measured attenuation also increases. Both rain rate and the attenuation are almost parallel to each other, which indicate that they have similar gradient, and suggests that rain fade has direct relationship with rain rate. Similar trend can be observed for all the rainy months, April through October 2014, as shown in Figures 2 to 8. However, several variations can be observed in the various months in terms of the monthly levels of attenuation and rain rates. The rain attenuation levels for each month showed maximum attenuation levels of 25 to 30 dBm, for the months of April through September; while corresponding rain rate levels were a maximum of 120 mm/h to 160 mm/h. In the month of October both rain rate and attenuation levels were very low with attenuation levels of 6 dBm for a maximum rain rate of 70 mm/h.

The annual distribution of rain fade is presented in Figure 8 where attenuation levels for all the six rainy months are combined. The result shows a maximum attenuation level of 30 dBm for a rain rate of 160mm/h. Therefore, in summary the maximum level of rain fade for 2014 can be taken as 30 dBm while the maximum rainfall intensity for the year is 160 mm/h. These maximum levels were obtained in the months of June and July while the minimum rain fade level for the year was obtained as 6 dBm for a rain rate of 70 mm/h in the month of October. The months of June and July are therefore the worst months for radio-wave propagation in Jos, the study location as observed by Durodola et al. (2017b).

### *3.2.2 Characterization of Monthly and Annual rain fade*

The monthly characteristic of rain fade is shown by the regression lines on the various graphs of Figures 2 to 8 above and summarized in Table 1. It was observed that for all the rainy months except October, the logarithm trend-line gave a higher correlation coefficient than the power law, for both rain rate and rain attenuation. The implication is that for the modelling of rain fade, a logarithm model will be more appropriate than the power law model.

### *3.2.3 Threshold of rain fade for various months*

The trend-line characterization shows that the thresholds of rain fade for the rainy months of April through October in dB are 12.49, 7.23, 20.64, 9.81, 11.56 and 3.78 respectively. An average threshold value of rain rate for the rainy months combined was found to be 11.37 dB. The implication is that the average rain fade margin to be provided by the designers is about 11 dB. The minimum value is about 4 dB while the maximum is about 21dB.The usual practice is for designers to provide fade margins based on the maximum rain fade threshold value of 21 dB. However, if this level of fade margin is provided, it is tantamount to raising the noise floor of the communication system which would be counter-productive for designers. As such service providers must explore alternative measures to mitigate the fade level of 21 dB such as power control techniques at the transponder.

## Conclusion

This study analyzed the characteristics of rain fade within Jos Plateau state, a semi-tropical region of Nigeria. Signal power levels retrieved from the satellite video clips for the rainy days of each month were used to compute the distribution of rain fade. The maximum level of rain fade for 2014 can be taken as 30dBm while the maximum rainfall intensity for the year is 160 mm/h. These maximum levels were obtained in the months of June and July, which were the worst months for the year. The minimum rain fade level for the year was obtained as 6dBm for a rain rate of 70 mm/h in the month of October. From the characterization of rain fade, an average threshold value of rain rate for the rainy months combined was found to be 11.37 dB. The implication is that the average rain fade margin to be provided by the designers is about 11 dB. The minimum value is about 4 dB while the maximum is about 21 dB. These fade levels have shown that communication system designers would need to explore alternative measures of mitigating the fade level of 21 dB such as power control techniques at the transponder. The results obtained in this study can be used for preliminary design of the satellite microwave links, satellite–payload design (satellite-coverage analysis), Earth-segment design and a broad idea of rain attenuation for microwave engineers.

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