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Comparative analysis of rain attenuation models in satellite links

Odo, K.O.[1*]; Okoro, C.K.[2]; Iroegbu, C.[3]; and Ogbonnaya, I.J.[4]

[1,2,3]Electrical and Electronic Engineering Department, Michael Okpara University of Agriculture, Umudike, AbiaState.
[2]Electrical/Electronics Engineering Department, Abia State Polytechnic, Aba, Abia State.
[*]CorrespondingAuthor's E-mail: kayceebby@yahoo.co.uk

Abstract
This study presents the analysis and simulation of rain attenuation models in satellite links in Umuahia metropolis. Rain attenuation is a major source of impairment to signal propagation at microwave and millimeter wavebands. It can cause a distorting effect on signal quality at higher frequencies leading to digital transmission errors. The knowledge of rain attenuation and its performance is essential in order to optimize system capacity and meet quality and reliability. Basic climate data were obtained from the Nigerian Meteorological Agency for a period of Twelve years and Umuahia geographical location was considered in this study. The computer simulation was carried out using Matlab. There are many rain attenuation prediction models for satellite links such as International Telecommunication Union- Recommendation (ITU-R) model, Dissanayake, Allnutt, and Haidara (DAH) model and Ajayi model. The ITU-R model was generally observed in 2016 to have recorded the highest value of rain attenuation of 0.1399dB which was followed by DAH model, 0.2264dB and Ajayi model showed the least value rain attenuation of 0.00371dB of all the models investigated in Umuahia geographical location. Therefore, Ajayi prediction model is overall best model and was closely followed by DAH and ITU-R models, respectively in Umuahia metropolis.

Keywords: Rain attenuation, Rain attenuation models, Satellite links, Quality of signal, Reliability of service.

1. Introduction

Rain attenuation (RA) is major source of impairment to signal propagation at microwave and millimeter wavebands. These impairments become particularly severe at high frequencies, especially above Ku band. As such, it is extremely hard to optimally manage satellite dependent network resources that are impacted by weather attenuations, (Amruta & Patane, 2015). Attenuation due to rain at frequencies above 10 GHz, mainly leads to outages that compromise the availability and quality of service, making this one of the most critical factors in designing microwave link in tropical and subtropical regions. The design of new telecommunication systems requires the knowledge of rain fade in order to optimize system capacity and meet quality and reliability criteria, (Khandaker & Mohammed, 2014). Rain attenuation is defined as the product of specific attenuation (dB/km) and the effective propagation path length (km). The product of path reduction factor and the physical path length of a microwave link are referred to as the effective path length. The strength of satellite signal may be degraded or reduced under rain conditions; in particular radio waves above 10 GHz are subject to attenuation by molecular absorption and rain. Presence of rain drops can severely degrade the reliability and performance of communication links. Attenuation due to rain effect is a function of various parameters including elevation angle, carrier frequency, height of earth station, latitude of earth station and rain fall rate, (Osahenvemwen & Omorogiuwa, 2017).

Satellite communications that operate at high frequencies beyond 10 GHz are expected to deliver a wider bandwidth and a higher data rate for multimedia and broadband services. However, such systems have to cope with strong atmospheric impairments, mainly due to rain. This particular impairment is even worse in the tropical regions, which are mostly characterized by heavy precipitation. In this case, deep signal fading due to rain will definitely affect the quality of analogue transmissions and increase the error rate of digital transmissions, (Idrissa et al, 2016).

Satellite communications system operating in frequency band over 10GHz, is restricted in steady operation due to severe signal attenuation by dispersion and absorption of the air including rainfall (Choi et al, 2011).

1.1 Literature Review

1.1.1 Related Works

Ojo *et al* (2008) predicted rate of rainfall and attenuation due to rain for communication satellite in Ku and Ka bands. The study was based on predictions and no attempt was made by the research to compare rain attenuation using various models in satellite links. Ajewole *et al* (2014), investigated some aspects of rain effects on the performance of Ku-band satellite signals in Akure, Nigeria. The research showed the time series of rainfall during a typical rainy event was the reception pattern at Ku-band that indicated a very strong relationship between the reduction of the satellite signals and the rate of rainfall recorded. Ezeh *et al* (2014) investigated the effects of attenuation due to rain on satellite communication links. They observed that as rain attenuation increases, rainfall rate value also increases but at a rain rate of 112mm/h and above, there was total outage of reception that causes loss of received signal, however, there was no comparison for different rain attenuation models. HamadAmeen, (2018) studied rain effect on Ku-band satellite system. In the research, study and calculation of rain effect was performed. The result of the research showed that the horizontal polarized signals affected greater than that with vertical polarized but he used only ITU-R model for the calculation of rain attenuation.

Osahenvemwen and Omorogiuwa, (2017), described rain attenuation analysis from system operating at Ku and Ka frequency bands. The research showed that attenuation increases as rainfall rate increases and the vertical polarized signal offers less rain attenuation than the horizontal polarized signal at Ku and Ka bands. However, they did not consider using different models for estimating rain attenuation. Immadi*et al* (2017) researched on computation of rain attenuation for Ku band frequencies using Drop Size Distribution for the tropical region. The result showed that rain attenuation plays an important function in receiving any signal transmitted at Ku band and higher frequencies, however, they only adopted drop size distribution which is not a model for estimating rain attenuation. We have identified the knowledge gaps existing among various researchers in their literatures. HamadAmeen, (2018) used ITU-R model only for estimating rain attenuation. Based on this, we have carried out research work on comparative analysis of rain attenuation models in satellite links in Umuahia metropolis using three different models.

1.2 Rain Attenuation Prediction Models

The rapid development of satellite services with higher frequency bands like the Ku band has stated the reason for determining the combined influence of different propagation impairments. It is important to find out and/or predict the overall effect of the attenuation impact within any particular path. Accurate predictions of the propagation impairments that affect link quality are essential for the proper design of satellite communications, (Sanjeev & Madhan, 2011). Rain attenuation plays a more important role in satellite communication than other atmospheric losses when Ku-band is in use especially in tropical and sub tropical regions. Rainfall can result to uncontrolled variations in phase, signal amplitude, polarization and angle of arrival, which result in decreased in the efficiency of analog transmissions and an increase in the bit error rate of digital transmissions.

The evaluation of prediction models for communication satellite and microwave systems requires a detailed knowledge of the attenuation statistics for each ground terminal location at the specific frequency (12/18 GHz) of interest. Due to non availability of Ku- band satellite signal in these footprints, it would obviously be an impossible task to collect experimental data for all the frequencies, regions, and angle of elevation in consideration for functional satellite services. Therefore, a more reasonable approach is to apply the predictive models based on and in agreement with data from various national and international organizations, (Ojo*et al*, 2017). The possibility of estimating attenuation caused by rain statistics on the path from rain rate data has been a subject of interest in the previous researches, and has stimulated a detailed series of experimental and theoretical studies. Attenuation caused by rain may be determined openly through measurement or can be predicted from the rain data, drop size distribution and other significant parameters of radio path. Various models are available for rain attenuation prediction due to rain on earth-space path. These models are used for calculating rain attenuation, in general where ever adequate data is not available. Various prediction models such as ITU-R modelandDissanayake-Allnut-Haidara (DAH) model, and Ajayi model are used in the current study.

The International Telecommunication Union - radio communication sector (ITU-R) model was adjudged the most widely accepted internationally for the prediction of rain effects on communication systems for this reason, most emerging models are compared against it for conformity and reliability; especially for cases where measured data are not available. However, recent researches have shown that some ITU-R models are only suitably reliable in certain geographical areas, (Abayomi et al, 2016). The performances of the following rain attenuation prediction models were investigated in Umuahia geographical location in this study.

ITU-R Model

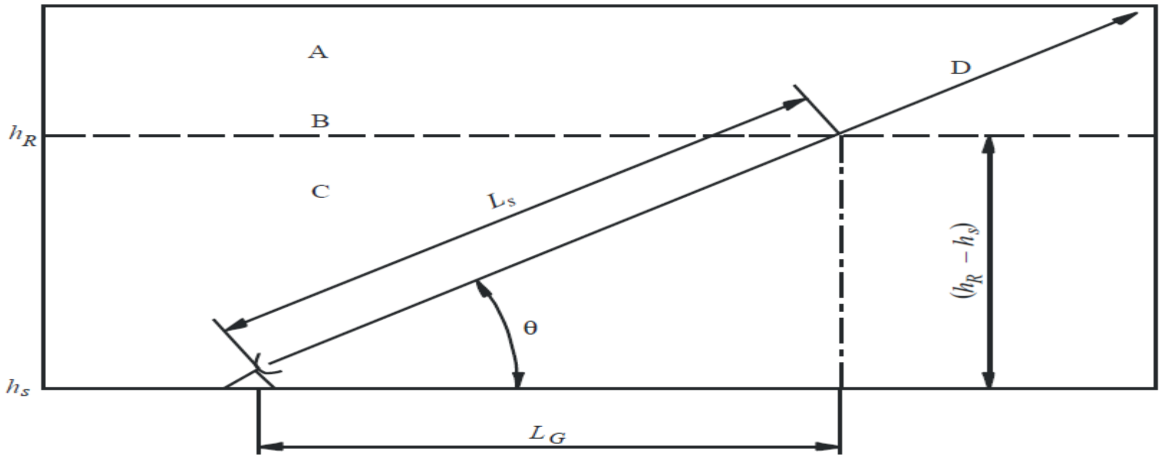

Figure 1: Path diagram of the rain attenuation in satellite link

The ITU-R model is used worldwide, with huge range of frequencies with different elevation angles, for different rain climates. It is the most acceptable model by the international propagation community which is applied for calculating statistics of long term rain attenuation at higher frequencies in most of the regions, (ITU, 2001).

Dissanayake-Allnut-Haidara (DAH) Model

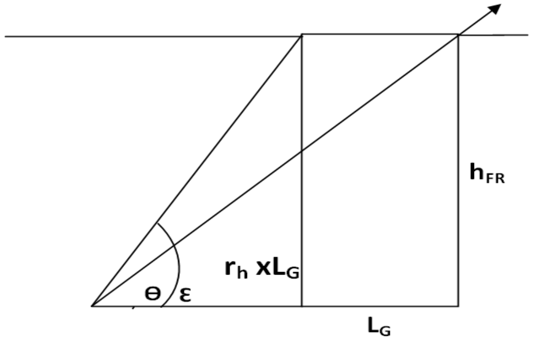

Figure 2:Slant path geometry of Dissanayake-Allnutt-Haidara method

This model was developed by Dissanayake, Allnutt and Haidara in their work. The conversion of the physical path length to the effective path length as applied in the ITU-R method does not often give an exact reduction in path length. Therefore in the DissanayakeAllnuttHaidara method, the conversion factor is called the Adjustment Factor instead of reduction factor. Dissanayake et al (1997) included two adjustment factors, in their method, namely horizontal path adjustment factor and vertical adjustment factor. The horizontal path adjustment factor considers the horizontal inhomogeneity of rain along the propagation path, while the vertical adjustment factor considers the vertical inhomogeneity of the rain. The two adjustment factors were devised by using available slant path attenuation measurement data.

Ajayi Method

This method was proposed by Ajayi. The path reduction factor in the ITU-R prediction method converts a physical path length to an equivalent length along which the rain rate can be assumed constant. Since it turned out that the conversion process does not necessarily always lead to a reduction in path length, Ajayi modified the ITU-R method by introducing two reduction factors namely; the horizontal reduction factor and the vertical reduction factor.

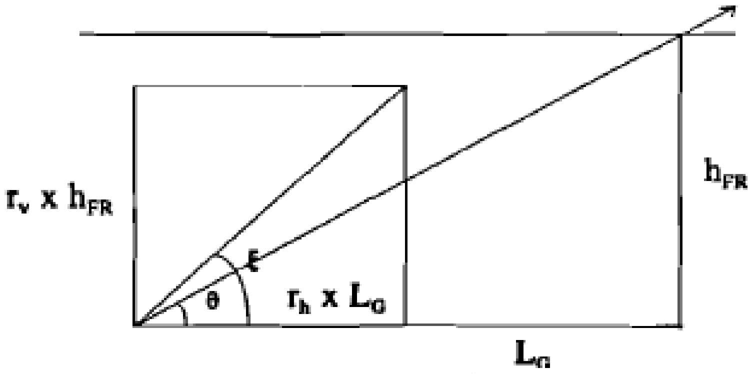

Figure 3: Slant-path geometry for Ajayi model

2.0 Material and methods

The materials used in this research work are rain gauge, stopwatch, compass, Hp Laptop and matlab/Simulink computing software.

2.1 Method

The simulation of different rain attenuation models particularly ITU–R, DAH, and Ajayi in Umuahia metropolis considering the data of Eutelsat satellite has been carried out using MATLAB software. The satellite used for the analysis of different rain attenuation models is Eutelsat (7.492° E) which is a geostationary communication satellite owned by Modern Communication Limited (MCL). Eutelsat exhibits linear polarization and can convey broadband media to small organizations, Internet Service Providers or household housetop antennas. The satellite conveys Direct–To–Home power and execution, and additionally noteworthy inter–regional network. Rainfall data was obtained from the Nigerian Meteorological Agency for a period of twelve years (12 years). After obtaining the data, the data was arranged annually and put in a tabular form showing year, annual rainfall and average annual rainfall. Three models were used to calculate specific attenuation and attenuation for ten years. They are ITU-R model, Dissanayake-Allnut-Haidara model and Ajayi model.

2.1.1 Block diagram of the system

The block diagram of the system is shown in figure 4

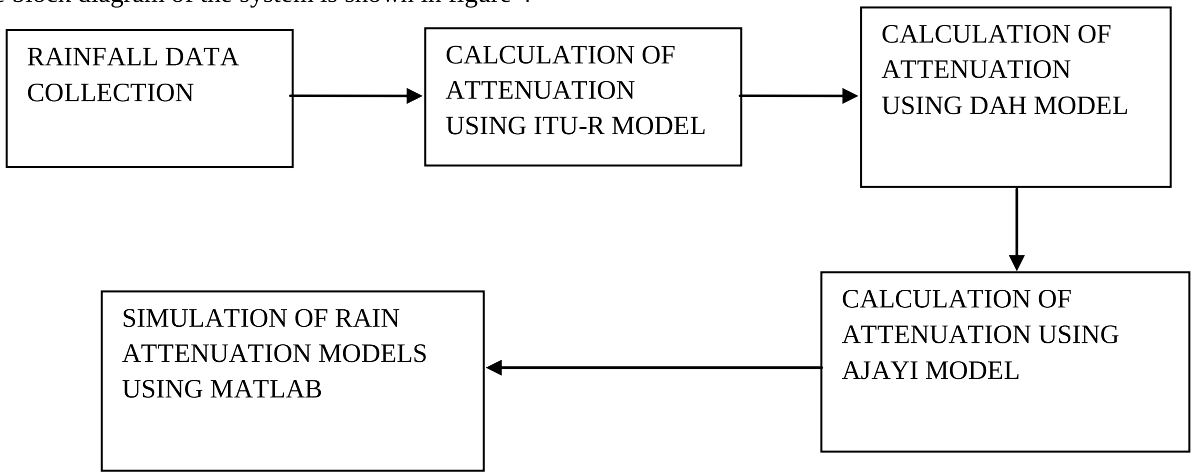

Figure 4: Block diagram of the system

The daily rainfall data was converted to average/mean annual accumulation (M) in mm/year. To estimate rainfall rate with an integration time of one minute, $R_{0.01}$, it is derived from the value of M at the location of interest. Various methods have been described for the calculation of $R_{0.01}$ from the long-term mean annual rainfall. Chebil's model looks suitable and it accepts the use of long-time mean annual accumulation at the location. The power law of the model is given by

$$R_{0.01} = \alpha M^{\beta} \quad (1)$$

where α and β are regression coefficients. In Chebil's model the regression coefficients are defined as $\alpha = 12.2903$ and $\beta = 0.2973$.

Table 1: Average annual rainfall accumulation for twelve years (12 years)

PERIOD (years)	ANNUAL RAINFALL(mm)	NO. OF DAYS	AVERAGE ANNUAL RAINFALL (mm/yr)
2009	2060.1	147	14.0
2010	3350.3	110	30.5
2011	2560.9	120	21.3
2012	3560.8	101	35.3
2013	2135.8	132	16.2
2014	1798.6	135	13.3
2015	2676.6	132	20.3
2016	4322.7	107	40.4
2017	3379.8	115	29.4
2018	2728.6	108	25.3
2019	3472.4	127	27.3
2020	4528.2	119	38.1

2.1.2 International telecommunication union –recommendation (ITU-R) model

The procedure for calculating the prediction of attenuation according ITU-R model is as follows:
Step 1 The effective rain height h_R(km) is calculated from the earth station latitude, $\emptyset$, as shown in equations (2) and (3).

$$h_R = 5.0 \quad \text{for } 0^{\circ} \leq \emptyset < 23^{\circ} \quad (2)$$

$$h_R = 5.0 - 0.075(\emptyset - 23) \quad \text{for } \emptyset \leq 23^{\circ} \quad (3)$$

Step 2 For $\Theta \geq 5°$, the slant-path length, *Ls*, the rain height is calculated using equation (2) and (3).

$$L_S = \frac{h_R - h_s}{\sin\theta} \text{ (km)} \quad (4)$$

whereh_S is the earth station height above mean sea level. For $\Theta < 5°$, the following formula is used.

$$Ls = \frac{2(h_R - h_S)}{\sqrt{\left(\sin^2\theta + \frac{2(h_R - h_S)}{R_e} + \sin\theta\right)}} \quad (5)$$

If $hR - hs$is less than or equal to zero, the predicted rain attenuation for any time percentage is zero.
Step 3 The horizontal projection, L_G, of the slant-path length is calculated using equation (6).

$$L_G = L_S \cos\Theta \text{ (Km)} \quad (6)$$

Step 4 Obtain the rainfall rate, $R_{0.01}$, exceeded for 0.01% of an average year (with an integration time of 1 min). If $R_{0.01}$ is equal to zero, the predicted rain attenuation is zero for any time percentage and the following steps are not required.
Step 5 Obtain the specific attenuation, Υ_R, using the frequency-dependent coefficients given in recommendation ITU-R P.838 and the rainfall rate, $R_{0.01}$, determined from Step 4, by using

$$\Upsilon_R = K (R_{0.01})^{\alpha} \text{ dB/km} \quad (7)$$

where α & k are dependent variables each of which is functions of frequency, elevation angle and polarization tilt angle. K and α is calculated using regression coefficients K_H, K_V, α_H and α_V. These values are provided at the frequency of interest using the following equations:

$$K= [K_H + K_V + (K_H - K_V)\mathrm{Cos}^2\Theta\mathrm{Cos}2г]/2 \qquad (8)$$

where τ is polarization tilt angle (0°, 45°, and 90°) for horizontal, circular and vertical polarization respectively.

$$\alpha = [K_H\alpha_H + K_V\alpha_V + (K_H\alpha_H - K_V\alpha_V)\cos 2_{\Theta} \cos 2г]/2K \qquad (9)$$

Step 6 Calculate the horizontal reduction factor, $\Upsilon_{0.01}$, for 0.01% of the time expressed as:

$$\Upsilon_{0.01} = \frac{1}{1-0.78\sqrt{\frac{L_G\Upsilon_R}{f}}-0.38(1-e^{-2L_G})} \qquad (10)$$

Step 7 Calculate the vertical adjustment factor, $V_{0.01}$, for 0.01% of the time by using

$$V_{0.01} = \frac{1}{1+\sqrt{\sin\theta\left(31\left(1-e^{\left(\frac{\theta}{1+\chi}\right)}\right)\sqrt{\frac{L_R\Upsilon_R}{f^2}}-0.45\right)}} \qquad (11)$$

$$\mathcal{E} = \tan^{-1}\left(\frac{h_R-h_S}{L_G\Upsilon_{0.01}}\right) degree \qquad (12)$$

For $\mathcal{E} > \Theta$,

$$L_R = \frac{L_G\Upsilon_{0.01}}{\cos\theta} km \qquad (13)$$

where L_R is the actual slant path. Else,

$$L_R = \frac{h_R - h_S}{\sin\theta} km \qquad (14)$$

If $|\varnothing| < 36^{o}$, $\chi = 36 - |\varnothing|$ degrees (15)

Else, $\chi = 0$ degrees

Step 8 The effective path length is computed from:

$$L_E = L_R V_{0.01} \text{ km} \qquad (16)$$

Step 9:The predicted attenuation exceeded for 0.01% of an average year is obtained from equation 17

$$A_{0.01} = \Upsilon_R L_E \text{ dB} \qquad (17)$$

2.1.3 Dissanayake-Allnut-Haidara (DAH) model

The procedure for calculating the prediction of attenuation according this model is as follows:

Step 1 Freezing height during rain, hfr (km), is calculated from the absolute value of station latitude, Ø (degrees), as:

$$hfr = 5.0 \quad \text{for } 0^{\circ} \leq \theta < 23^{\circ} \qquad (18)$$

$$hfr = 5.0 - 0.075(\theta - 23) \quad \text{for } \theta \geq 23^{\circ} \qquad (19)$$

Step 2 The slant-path length, Ls, below the freezing height is obtained from

$$\text{Ls} = \frac{h_R - h_s}{\sin\theta}\ (\text{km}) \tag{20}$$

where Θ is the elevation angle and h_S is the station height in km. For elevation angles less than 5°, a more accurate path length estimate can be made using:

$$\text{Ls} = \frac{2\left(h_{fr} - h_S\right)}{\sqrt{\left(sin^2\theta + \frac{2\left(h_{fr} - h_S\right)}{R_e} + \sin\theta\right)}}\ (\text{km}) \tag{21}$$

Step 3 The horizontal projection, Lg, of the slant path length is found from:

$$\text{Lg} = \text{Ls}\cos\Theta\ (\text{km}) \tag{22}$$

Step 4 Obtain the rain intensity, $R_{0.01}$(mm/hr), exceeded for 0.01% of an average year, and calculate the specificattenuation, Υ_R(dB/km), using widely published frequency and polarization dependent coefficients k and α:

$$\Upsilon_R = K(R_{0.01})\alpha \tag{23}$$

where $K = 0.0242$ and $\alpha = 0.0161$

The specific attenuation for each year is obtained in step 4 of ITU-R Model using equation (7).

Step 5 Calculate the horizontal path adjustment factor, $\Upsilon_{h0.01}$, for 0.01% of the time:

$$\Upsilon_{h0.01} = \frac{1}{1+0.78\sqrt{\frac{L_G\Upsilon_R}{f}} - 0.38\left[1-e^{(-2L_g)}\right]} \tag{24}$$

where f is frequency in GHz.

Step 6 Calculate the effective horizontal extent of rain $L_{0.01}$ for 0.01% of the time

$$L_{0.01} = \Upsilon_{h0.01}\text{Lg} \tag{25}$$

Step 7 Calculate the adjusted rainy path length, Lr (km), through rain:

$$\text{Lr} = \frac{h_{fr}\,L_{0.01}}{\cos\theta}\ km \text{ for } \varepsilon > \Theta \tag{26}$$

$$\text{Lr} = = \frac{h_{fr} - h_S}{\sin\theta}\ km \text{ for } \varepsilon < \Theta \tag{27}$$

$$\text{where } \varepsilon = \tan^{-1}\left(hfr/L0.01\right) \tag{28}$$

Step 8: Calculate the vertical adjustment factor, $\Upsilon_{v0.01}$, for 0.01% of the time:

$$\Upsilon_{v0.01} = \frac{1}{1+\sqrt{\sin\theta\left(31\left(1-e^{\left(\frac{\theta}{1+\chi}\right)}\right)\sqrt{\frac{L_R\Upsilon_R}{f^2}} - 0.45\right)}} \tag{29}$$

Step 9 The effective path length through rain, Le (km), is given by:

$$\text{Le} = \text{Lr}\ r_{v0.01}\ (\text{km}) \tag{30}$$

Step 10 The attenuation exceeded for 0.01% of an average year may then be obtained from:

$$A_{0.01} = \Upsilon_R\text{Le}\ (\text{dB}) \tag{31}$$

2.1.4 Ajayi method

The Ajayi method is broken down into steps for simplification.

Step 1: The height of the freezing level, (hfR) during rain,

hfR = 5.0 for $0° \leq \theta < 23°$ (32)
hfR = 5.0 – 0.075(θ – 23) for $\theta \geq 23°$ (33)

The two reduction factors used here are the horizontal reduction factors, *r*h and vertical reduction factor, *r*v.

Step 2:For $\Theta \geq 5°$ compute the slant-path length, *Ls*, below the rain height from:

$$\text{Ls} = \frac{hR-hs}{sin\theta}\ \text{km} \tag{34}$$

For $\Theta < 5°$, the following formula is used.

$$\text{Ls} = \frac{2(hR-hs)}{\left(sin^2\theta+\frac{2(hR-hs)}{Re}\right)½ +sin\theta}\ \text{km} \tag{35}$$

If *hR* – *hs*is less than or equal to zero, the predicted rain attenuation for any time percentage is zero and the following steps are not required.

Step 3:Calculate the horizontal projection, L_G, of the slant-path length from:
$$\text{L}_\text{G} = \text{Lscos}\Theta\ \text{km} \tag{36}$$

Step 4:The reduction factor $\Upsilon_{0.01}$ for 0.01% of the time can be calculated from:

$$\Upsilon_{0.01} = \frac{1}{1+{}^{LG}/_{Lo}} \tag{37}$$

Where Lo = $35exp^{(-0.015R0.01)}$ is the characteristic length of a rain cell.

Step 5:The horizontal reduction, $\Upsilon_{h0.01}$ for 0.01% of the time can be calculated from;

$$\Upsilon_{h0.01} = \frac{1}{1+LG\text{^}0.002(R0.01)\text{^}1.01} \tag{38}$$

Step 6: The vertical reduction factor $\Upsilon_{v0.01}$, for 0.01% of the time can be calculated from;

$$\Upsilon_{v0.01} = \left[\frac{1}{1+\frac{hFR}{5+0.4\emptyset\text{^}1.5}}\right] \tag{39}$$

Step 7: The effective path length through the rain Le can be calculated from:

$$\text{Le} = \frac{LG\gamma h0.01}{cos\theta}\varepsilon > \theta \tag{40}$$

$$\text{Le} = \frac{hFR\gamma v0.01}{sin\theta}\varepsilon \leq \theta \tag{41}$$

Where $\varepsilon = \tan^{-1}\frac{hFR\gamma v.0.01}{LG\gamma h0.01}$ (42)

Step 8: Specific attenuation as a function of $R_{0.01}$ and frequency

$$\gamma_R = K(R_{0.01}) \propto \tag{43}$$

Step 9: The attenuation exceeded for 0.01% of an average year, $A_{0.01}$ is obtained from;

$$A_{0.01} = \Upsilon_R L e \Upsilon_{0.01} \tag{44}$$

Table 2: Rain rate and specific attenuation experienced yearly using the three models

YEAR	RAINRATE (mm/hr)	SPECIFIC ATTENUATION (dB/km)
2009	26.9	0.02252
2010	33.9	0.02260
2011	30.5	0.02257
2012	35.5	0.02262
2013	28.1	0.02253
2014	26.5	0.02252
2015	30.0	0.02256
2016	36.9	0.02264
2017	33.4	0.02260
2018	32.1	0.02259
2019	32.8	0.02560
2020	36.3	0.02564

Table 2: Rain rate and specific attenuation experienced each year using ITU-R, Ajayi and DAH models.

Table 3: Attenuation experienced yearly using the three models

YEAR	**ATTENUATION (dB)**		
	ITU-R MODEL	**DAH MODEL**	**AJAYI MODEL**
2009	0.1392	0.2252	0.004148
2010	0.1397	0.2260	0.004164
2011	0.1395	0.2257	0.004155
2012	0.1398	0.2262	0.004162
2013	0.1393	0.2253	0.004149
2014	0.1392	0.2252	0.004147
2015	0.1394	0.2256	0.004152
2016	0.1399	0.2264	0.004165
2017	0.1397	0.2260	0.004160
2018	0.1396	0.2259	0.004157
2019	0.1396	0.2260	0.004158
2020	0.1399	0.2263	0.004163

Table 3: Attenuation experienced each year using ITU-R, DAH and Ajayi models.

3.0 Results and Discussions

The results present the graphs of rain attenuation models against the number of years, rain attenuation models against rainfall rates and specific attenuation against rainfall rates as shown in figures 4, 5 and 6 respectively**.**

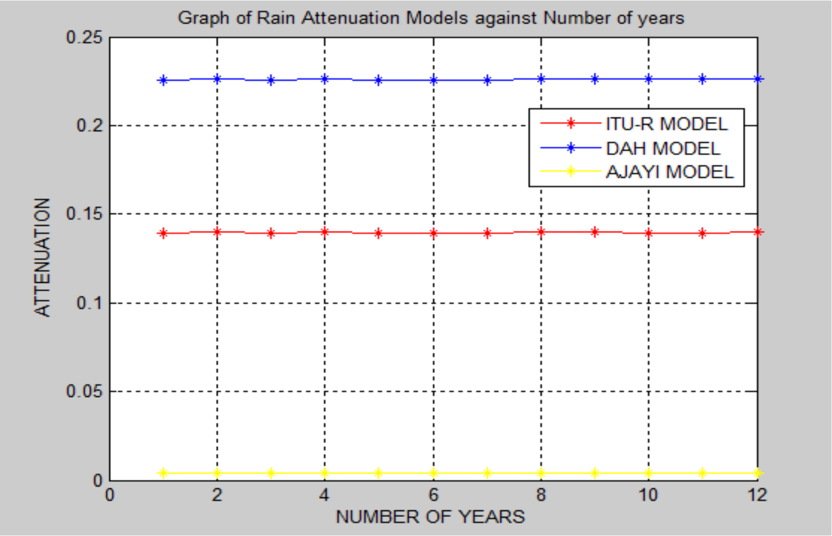

Figure 4: Comparison of rain attenuation models and the number of years

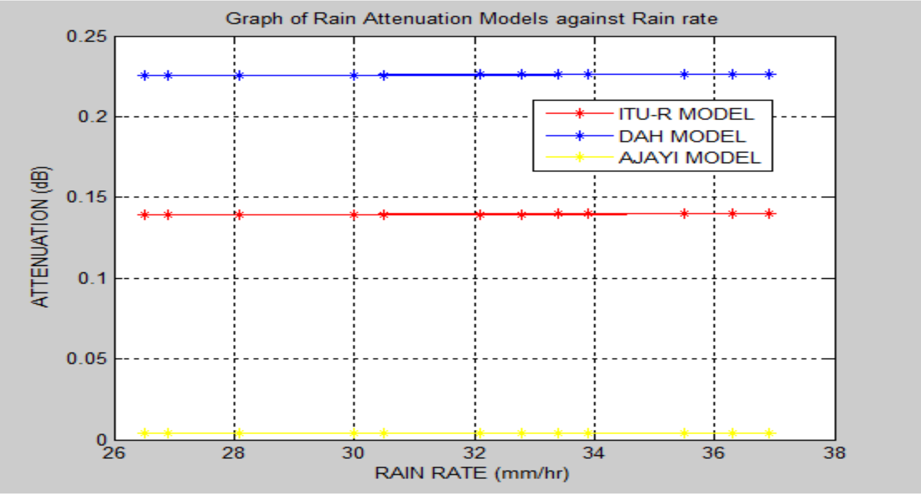

Figure 5: Comparison of rain attenuation models and rain rate

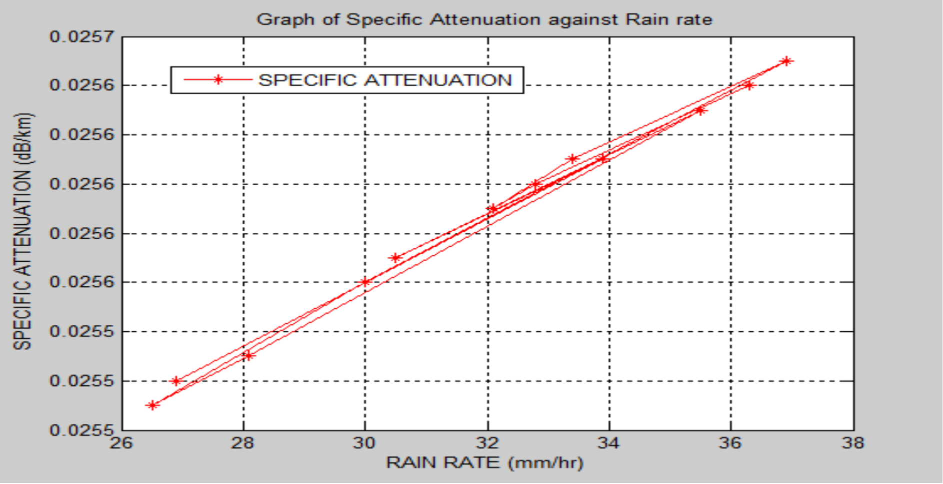

Figure 6: Comparison of specific attenuation and rain rate

Results of the comparison for the ITU-R model and two relevant rain attenuation prediction models for satellite links in Umuahia geographical region were plotted. A glimpse at Figure 4 seems to show that the Ajayi model presented the best performance because the degrees to which radio signals are attenuated vary slightly. For instance, the attenuation exceeded for Umuahia in 2016 are 0.1399dB, 0.2264dB and 0.00371dB for ITU-R model, DAH model and Ajayi model respectively. These can be seen in figures 4 and 5. The ITU-R model was generally observed to have recorded the highest value of rain attenuation which was followed by DAH model and Ajayi model showed the least value of all the models investigated in Umuahia geographical location. It can be seen from table 3 that DAH and ITU-R models recorded higher values than Ajayi model. The effect of attenuation will be higher when predicting rain attenuation in Umuahia using DAH and ITU-R models.

According to the evaluation procedures adopted for comparison of prediction methods by the Recommendations ITU-R P.311-13, the best prediction method produces the smallest values of the statistical parameters. Therefore, Ajayi prediction model is overall best model and was closely followed by DAH and ITU-R models, respectively in Umuahia metropolis. A comparative simulation result is shown in Figure 6 of different specific attenuation calculated from the ITU-R, DAH and Ajayi models with varying rain rates. It was clearly observed that rain attenuation value increases as rainfall rates increase at higher frequencies. Therefore, when communication satellites are being produced for areas with high rainfall rate such as Umuahia, the satellite engineers should put into consideration the differences in degree of attenuation values from one location to another because these values represent an uncertainty in the design of communication link and this affects service availability and can lead to interruption of communication link performance**.**

4.0. Conclusion

This paper presented the findings of the analysis and simulation of rain attenuation models in satellite links in Umuahia geographical location of Abia state, Nigeria. After analyzing and simulating different rain attenuation models in Umuahia metropolis by integrating different parameters, it was observed that rain attenuation models gives results based on the parameters considered and each of the model have their own advantages and limitations. Results of this study suggested that the ITU-R model produced the highest value of rain attenuation in 2016 which was followed by DAH model and Ajayi model produced the least value of rain attenuation. Ajayi model exhibited the overall best performance and was closely followed by DAH model. It is also clear that the rain has negative effect on the received signal and causes decrease in the received signal in satellite links as a result of increase in attenuation values. The poor performance of the ITU-R model may be attributed to the fact that the data used for the formulation of these models are mostly sourced from the tropical climate region. On the other hand, the impressive performances of Ajayi and DAH models can be attributed to its data source, which is Umuahia metropolis; which is tropical station.

5.0 Recommendation

It is recommended that rainfall data should be obtained from other cities in the south eastern part of Nigeria other than Umuahia Metropolis which will be used for the estimation of rain attenuation using different rain attenuation models other than ITU-R, DAH and Ajayimodels.

Acknowledgements

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