Nigerian Journal of Science and Environment 2025 Volume 23 (2) 56 – 64 ISSN: 3043 – 4440
https://doi.org/10.61448/njse232255

ESTIMATION OF RAIN-INDUCED SIGNAL LOSS ON STARTIMES TV COMMUNICATION LINKS IN ABRAKA, DELTA STATE

***[1]Shaka, S.O., [2]Olisenekwu, C., [3]Oyibo, D.P. and [4]Atori, R.**
[1,2,3,4] Department of Science Laboratory Technology, Delta State University, Abraka.
Corresponding Author: shaka4all@delsu.edu.ng

ABSTRACT

Rain-induced attenuation significantly affects the reliability of telecommunication links, particularly in regions such as Abraka, Nigeria. The operation of microwave systems operating at frequencies higher than 10 GHz can be significantly impacted by rainfall. Rain attenuation, often referred to as rain fade, is a phenomenon that causes propagating signals to fade and can seriously impair the dependability and quality of telecommunications networks during wet seasons. This study estimates rain-induced signal losses on StarTimes TV communication links, which operate primarily at Ku-band frequencies. Due to their shorter wavelengths, Ku-band signals are highly susceptible to rain attenuation, causing signal degradation, reduced picture quality, and service interruptions during heavy rainfall. The research employs empirical data collected through concurrent measurements of precipitation using the FJ3390A, A multifunctional professional weather station, and signal strength analysis via a spectrum analyzer manufactured by Weytoll, also known as Weytoll FJ3390A Co., Ltd. **(**Standard Model). Various rain types, including drizzle, widespread rain, showers, and thunderstorms, were categorized, and their impact on signal losses was computed. The results reveal that while drizzle had minimal impact on signal strength, widespread rain and showers resulted in moderate signal losses, and thunderstorms caused severe attenuation, with signal losses reaching up to 125.754 dB during peak events. The study underscores the inadequacy of generalized rain attenuation models in accurately predicting signal degradation in tropical regions, emphasizing the need for localized models tailored to Abraka's unique rainfall patterns, accounting for Average Annual Rainfall of approximately 2,446 mm (96.3 inches) and rainy days: Around 278 days per year with at least 1 mm (0.04 inches) of precipitation. The findings provide StarTimes with critical insights to optimize their broadcasting infrastructure, ensuring more reliable service delivery and reducing customer dissatisfaction caused by weather-related signal disruptions.

Keywords: Rain attenuation, Telecommunication links, StarTimes TV, Tropical climate, Signal loss

INTRODUCTION

Television broadcasting systems, particularly those operating in tropical and equatorial regions, are highly susceptible to signal degradation due to atmospheric factors, such as high solar radiation, low-pressure systems, global wind patterns, and rainfall (Adetan *et al.,* 2021; Ahmed *et al.,* 2022). The impact of rain on electromagnetic wave propagation has been extensively studied in the field of telecommunications, as it is a primary factor contributing to signal attenuation, particularly in the microwave and millimetre-wave bands commonly used for digital broadcasting services like those provided by StarTimes (Adetan *et al.,* 2021). Signal attenuation, or "rain fade," occurs as raindrops absorb and scatter the energy in a transmitted signal, weakening the signal strength before it reaches the receiver (ITU-R, 2019; 2020; Zhimwang *et al.,* 2023)

In Nigeria, rainfall characteristics vary widely due to geographical and seasonal factors, with areas like Delta State experiencing high annual precipitation. Such environmental conditions make communication links in regions like Abraka prone to disruptions in service quality. Rain-induced attenuation is particularly impactful in satellite and terrestrial broadcasting systems in such high-rainfall zones, as it causes degradation in signal-to-noise ratio (SNR), leading to picture loss or signal interruptions (Ajayi & Ofoche, 2004; Samuel *et al.,* 2023; Zhimwang *et al.,* 2022a)

In the context of StarTimes, a major digital terrestrial television (DTT) and satellite TV provider in Nigeria, understanding rain attenuation is crucial to improving the quality and reliability of service delivery. StarTimes utilizes the Ku-band frequencies for satellite transmissions, which are more susceptible to rain-induced signal losses compared to lower frequency bands like C-band. This increased vulnerability stems from the fact that shorter wavelengths, such as those in the Ku-band, experience higher attenuation when they encounter raindrops that are similar in size to the signal's wavelength (Emiliani *et al.,* 2000; Evans *et al.,* 2005). Rain-induced attenuation poses substantial technical and operational challenges for digital television services in Nigeria. Without adequate forecasting and mitigation strategies, signal degradation can result in increased service interruptions, customer dissatisfaction, and financial losses for providers (Igbekele *et al.,* 2024; Zhimwang *et al.,* 2022b). This research aims to address these challenges by providing an empirical estimation of rain-induced signal losses on StarTimes communication links in Abraka, contributing to the broader body of knowledge on rain attenuation in tropical regions and offering practical insights for improving service reliability in similar climates.

In regions with high rainfall intensity, such as Abraka in Delta State, Nigeria, digital terrestrial and satellite television signals are often compromised by rain-induced attenuation. StarTimes, a key provider of digital television services in Nigeria, relies heavily on Ku-band frequencies, which are especially vulnerable to signal degradation due to rain. During heavy rainfalls, signal attenuation can lead to degraded picture quality, interruptions in service, and an overall reduction in the quality of customer experience (Ojoba *et al.,* 2024a). Despite the critical nature of this issue, there is a lack of localized studies that quantify the extent of rainfall-induced signal losses specifically for StarTimes broadcasting infrastructure in Abraka. Existing general models, such as ITU-R P.838-3, provide rain attenuation predictions but may not account for the unique rainfall characteristics and intensity patterns in the region. Consequently, StarTimes lacks a tailored approach to mitigate rain-induced signal losses, leading to frequent disruptions in service.

This study aims to fill this gap by providing an empirical estimation of signal losses due to rainfall on StarTimes communication links in Abraka. By quantifying rain-induced attenuation, this research will offer StarTimes critical insights to adapt their broadcasting infrastructure for improved reliability during adverse weather, ultimately enhancing the service quality for users in the region.

Abraka, located in Delta State, has a tropical monsoon climate, which results in frequent and intense rain events during the wet season (Ojoba *et al.,* 2024b). This climate presents unique challenges for DTT and satellite communication providers, as the frequency and intensity of rainfall directly impact link performance. Studies have shown that rain attenuation in tropical regions is significantly higher than in temperate climates due to larger raindrop sizes and higher rainfall rates, which lead to more pronounced scattering and absorption effects (Isabona *et al.,* 2022; Chakraborty *et al.,* 2020). This has led telecommunications providers to consider rain attenuation models that are tailored to tropical climates when designing and optimizing communication infrastructure.

Rainfall Types

Rainfall is generally categorized into two main types:

1. Stratiform Rain (Drizzle and Widespread Rain)
2. Convective Rain (Shower and Thunderstorm Rain**)**

Stratiform rain is typically associated with low-intensity, widespread precipitation, often resulting in minimal signal degradation. Drizzle, a subset of stratiform rain, consists of tiny raindrops with diameters less than 1 mm. It commonly occurs in damp conditions and originates from shallow cloud layers. Drizzle exhibits very low rainfall rates, generally not exceeding 5 mm/h, and its impact on high-frequency telecommunication signals is relatively minor. Widespread rain, another form of stratiform precipitation, develops through sublimation and coalescence processes within stratiform cloud systems. This type of rainfall typically has an intensity between 5 mm/h and 25 mm/h and may persist for several hours. Unlike drizzle, widespread rain can sometimes extend to the Zero-Degree Isotherm (ZDI) height, where ice-phase processes contribute to raindrop formation. While widespread rain may cause signal attenuation, its gradual and consistent nature allows for better predictability in telecommunication system adjustments (Ajewole, 2011; Hossain *et al.,* 2010).

Convective rain, in contrast, is associated with high-intensity rainfall that significantly impacts radio wave propagation. Shower rain, originating from cumuliform clouds, is characterized by intense but short-lived precipitation. Raindrop sizes typically exceed 2 mm in diameter, with rainfall intensities ranging between 25 mm/h and 50 mm/h. This type of rain forms below the ZDI height through the process of accretion, and its intensity largely depends on factors such as cloud thickness and updraft strength (Durodola, 2016). The most severe form of convective rain is thunderstorm rain, which develops within cumulonimbus cloud systems. Thunderstorms contain multiple active cells driven by strong vertical air currents, leading to substantial raindrop growth and frequent lightning activity. As these precipitation particles increase in size, they eventually become too heavy to be sustained by the upward air currents, resulting in intense rainfall. Raindrop diameters typically exceed 3 mm, and rain rates can range between 50 mm/h and 240 mm/h in tropical regions, including Abraka. Thunderstorm rain poses the greatest challenge for telecommunication reliability due to its high intensity, rapid fluctuations, and strong signal attenuation effects (Ajewole, 2011; Ogungbenro and Morakinyo, 2014). Given the varying characteristics of these rainfall types, their impact on telecommunication links differs significantly. While stratiform rain contributes to gradual and predictable attenuation, convective rain, especially thunderstorm activity, introduces severe signal degradation, making accurate prediction models essential. This research seeks to enhance rain attenuation prediction by incorporating localized rainfall characteristics in Abraka, thereby improving the reliability of high-frequency telecommunication links.

Table 1: Classification of rain types from rain rates

Rain Type	Range of Rain Rate (mm/h)
Drizzle	≤5
widespread	>5≤25
Shower	>25≤50
Thunderstorm	>50

Source: Ajewole, 2011

MATERIALS AND METHODS

Data Collection

The precipitation and Startimes signal measurements were collected in Abraka using a professional-grade device such as a spectrum analyzer or a digital signal meter (2.8-inch vector Network analyzer S-A-A-2), tuned to the frequency range used by Startimes (UHF band for DTT). Rain data was measured using a FJ3390A weather station, Abraka, while Startimes signals were obtained using a spectrum analyzer. The down-converted Startimes signal was fed into the digital satellite meter and a spectrum analyzer for signal level analysis, logging, and recording samples of viewed spectrum over finite periods on a computer system. Both satellite signal and precipitation measurements were done concurrently. The measurement of precipitation was done using the FJ3390A weather station, which logs rain rate and other meteorological parameters at a one-minute integration time. The FJ3390A weather station has an Integrated Sensor Suite (ISS), which is co-located with the outdoor unit of the beacon setup, that is, the offset parabolic antenna.

Estimating the impact of Rain-induced Signal Loss on StarTimes Links

The signal losses were determined using equation (1): (Hossain *et al.*, 2010)

$$A(dB) = KR^{\propto}L_{eff} \quad (1)$$

With $L_{eff} = rl$ (2)

where l (km) is the actual path length, L_{eff} is the effective path length, and r is a reduction coefficient given by

$$r = \frac{1}{1+CL^{m}} \quad (3)$$

The losses A (dB) and the 1-minute rain rate R (mm/h) are calculated for the same time percentage; k and α are regression coefficients depending on frequency (12.52 GHz) and polarization (Horizontal). C and m were derived using the experimental data obtained from the microwave channel at 12.52 GHz band range with a path length of 20 km. It was found that C depends on the probability level p (in percentage) of interest for which data are available, and m depends on the radio channel path length and its frequency. The resultant formula for the path length reduction factor is given by (Moupfouma and Martin, 2005) as

$$r = \frac{1}{1+0.03(\frac{p}{0.01})^{-\beta lm}} \quad (4)$$

$$m(f,l) = 1 + \varphi(f)log_{e}l \quad (5)$$

Where:

m(f,l): A function that depends on both frequency f and distance l. It could represent a modification factor, attenuation multiplier, or signal correction parameter.

φ(f): A frequency-dependent coefficient. It tells us how strongly the logarithmic term influences the value of mmm, and it varies with frequency.

$log_e l$: The natural logarithm (log base *e*) of distance l, which models how effects like attenuation or signal variation scale logarithmically with distance.

$$\varphi(f) = 1.4 \times 10^{-4}f^{1.76} \quad (6)$$

Nigerian Journal of Science and Environment 2025 Volume 23 (2) 56 – 64 ISSN: 3043 – 4440
https://doi.org/10.61448/njse232255

Where:

f is the frequency in GHz, and the coefficient, β, is given based on the value of l

φ(f): A function of frequency f (usually in MHz or GHz), which represents a frequency-dependent attenuation factor or correction coefficient.

$f^{1.76}$: The frequency raised to the power 1.76, indicating a nonlinear relationship as frequency increases, φ(f)increases rapidly.

When $l < 50km$

$\beta = 0.45, for\ 0.001 \leq p \leq 0.01$

$\beta = 0.6, for\ 0.01 \leq p \leq 0.1$

When $l \geq 50km$

$\beta = 0.36, for\ 0.001 \leq p \leq 0.01$

$\beta = 0.6, for\ 0.01 \leq p \leq 0.1$

For example

Using F =12.5GHz, equation (7) becomes

$\varphi(f) = 1.4 \times 10^{-4} 13^{1.76} = 0.013$

Putting the value of $\varphi(f)$ into equation (6)

$m(f, l) = 1 + 0.013 log_e l$

where $log_e l = log_e 20 = \frac{\log_{10} 20}{\log e} = \frac{\log_{10} 20}{\log 2.71} = \frac{1.301}{0.432} = 3.011$

$m(f, l) = 1 + 0.013 \times 3.011 = 1.039$

Putting the value of $m(f, l)$ into equation (4) for drizzle rain type either ≤ 5mm/hr at 2.979% for April 2024

$r = \frac{1}{1+0.03(\frac{p}{0.01})^{-\beta lm}} = \frac{1}{1+0.03(\frac{2.979}{0.01})^{-0.45\times20\times1.039}} = 1.052$

Putting the value of r into equation (3), then

$L_{eff} = 1.052 \times 20 = 21.04$

Putting the value of L_{eff} into equation (2)

$A(dB) = 0.0341 \times (5)^{1.1586} \times 21.04 = 3.358$

RESULTS

Table 2: Computation of Signal strength, BER, and Signal losses for April 2024

Rain Type	Rain Duration (hour)	BER	Signal Strength (%)	Signal Losses (dB)
Drizzle (≤5)	14.8	1.00E-06	70	3.358
Widespread (>5≤25)	5.0	1.00E-08	62	23.291
Shower (>25≤50)	0.8	1.00E-09	51	56.519
Thunder (>50)	0.9	1.00E-07	67	17.656

Table 3: Computation of Signal strength, BER and Signal losses for May 2024

Rain Type	Rain Duration (hour)	BER	Signal Strength (%)	Signal Losses (dB)
Drizzle (≤5)	25.9	1.00E-07	67	3.324
Widespread (>5≤25)	7.2	1.00E-08	62	22.918
Shower (>25≤50)	1.6	1.00E-09	50	54.032

Thunder (>50)	2.4	1.00E-08	62	21.011

Table 4: Computation of Signal strength, BER and Signal losses for June 2024

Rain Type	Rain Duration (hour)	BER	Signal Strength (%)	Signal Losses (dB)
Drizzle (≤5)	38.5	1.00E-06	69	3.304
Widespread (>5≤25)	9.4	1.00E-08	58	22.816
Shower (>25≤50)	2.2	1.00E-09	50	54.397
Thunder (>50)	1.2	1.00E-09	48	101.005

Table 5: Computation of Signal strength, BER and Signal losses for July 2024

Rain Type	Rain Duration (hour)	BER	Signal Strength (%)	Signal Losses (dB)
Drizzle (≤5)	65.1	1.00E-07	69	3.282
Widespread (>5≤25)	15.2	1.00E-09	52	22.528
Shower (>25≤50)	4.3	1.00E-09	49	52.920
Thunder (>50)	2.4	1.00E-09	45	125.754

Table 6: Computation of Signal strength, BER and Signal losses for August 2024

Rain Type	Rain Duration (hour)	BER	Signal Strength (%)	Signal Losses (dB)
Drizzle (≤5)	61.8	1.00E-08	66	3.286
Widespread (>5≤25)	12.5	1.00E-09	54	22.666
Shower (>25≤50)	2.8	1.00E-09	46	53.805
Thunder (>50)	1.6	1.00E-09	44	98.920

DISCUSSION

Table 2 presents the computation of Signal strength, BER and Signal losses for April 2024. From the result obtained, shower (>25≤50) recorded the highest signal losses of 56.519 dB and low signal strength of 51% with a BER of 10^{-9}, while drizzle, widespread, and thunderstorm recorded higher signal strength with BER less than 10^{-9}

Table 3 presents the computation of Signal strength, BER, and Signal losses for May 2024. From the result obtained, shower (>25≤50) recorded the highest signal losses of 54.032dB and low signal strength of 50% with a BER of 10^{-9}, while drizzle, widespread, and thunderstorm recorded higher signal strength with BER less than 10^{-9}

Table 4 presents the computation of Signal strength, BER and Signal losses for June

2024. From the result obtained, shower (>25≤50) and thunder (>50) recorded the highest signal losses of 54.397dB and 101.005dB with low signal strength of 50% and 48% respectively and BER of 10^{-9} while drizzle and widespread recorded higher signal strength with BER less than 10^{-9}

Table 5 presents the computation of Signal strength, BER and Signal losses for July 2024. From the result obtained, Widespread (>5≤25), shower (>25≤50) and thunder (>50) recorded the highest signal losses of 22.528dB, 52.920dB and 125.754dB with low signal strength of 52% , 49% and 45% respectively and BER of 10^{-9} while drizzle recorded higher signal strength with BER less than 10^{-9}

Table 6 presents the computation of Signal strength, BER and Signal losses for August 2024. From the result obtained, Widespread (>5≤25), shower (>25≤50) and thunder (>50) recorded the highest signal losses of 22.66dB, 53.805dB and 98.920dB with low signal strength of 54%, 46% and 44% respectively and BER of 10^{-9} while drizzle recorded higher signal

CONCLUSIONS

This study focuses on estimating a suitable model capable of enhancing the utilization of channel capacity of a microwave link under rain. The results obtained revealed that higher signal strength and lower signal losses were obtained under the various rain types. As it can be seen from the results, the impact of drizzle (≤5mm/hr) on the Startimes link is not significant regardless the duration of rainfall for all the months and years under study. The results also revealed that severe signal losses recorded under shower (>25≤50mm/hr) and thunderstorm (>50mm/hr) were due to a greater value of BER (≥10^{-9}) which affected and reduced the level of the received signal as such limiting the performance of the Startimes link under rain. This is because, for a satisfactory performance of the channel capacity, the BER has to be less than 10^{-9} as recommended by ITU-R. The results further revealed that widespread rainfall (>5≤25mm/hr) that prevailed for a longer period also causes severe signal losses. This is to say that lower rain rate of about 25mm/hr that prevailed for a very long time have significant effect on microwave link.

REFERENCES

Adetan, O. A., Morakinyo, T. E. and Akinbode, O. M. (2021). Analysis of rain attenuation on terrestrial line-of-sight microwave links in Nigeria. Journal of Atmospheric and Solar Terrestrial Physics, 218, 105566.

Ahmed, T., Jabir, M. R. and Khan, N. A. (2022). Rain attenuation prediction in tropical environments using machine learning techniques. IEEE Access, 10, 58000-58011.

Ajayi, G. O. and Ofoche, E. B. (2004). Some tropical rainfall rate characteristics at Ile-Ife for microwave and millimeter wave applications. Journal of Climate and Applied Meteorology, 23 (4), 562-567.

Ajewole M. O. (2011) Radio and rain: Friends and foes 62nd inaugural lecture delivered at Federal University of Technology, Akure; June 21, 2011.

Chakraborty, S., Chakraborty, M. and Das, S. (2020). Experimental studies of slant-path rain attenuation over tropical and equatorial regions: A brief review. *IEEE Antennas and Propagation Magazine, 63*(3), 52-62.

Durodola, O. M. (2016). The Characterization Attenuation of Ku-band signals along two tropical regions during rainfall. A Ph.D thesis submitted to the Department of Physics, Federal University of Technology Akure, Nigeria

Emiliani, L. D., Luini, L. and Capsoni, C. (2000). A new prediction model of rain attenuation that jointly accounts for path length and frequency. IEEE Transactions on Antennas and Propagation, 48 (5), 716-725.

Evans B., Werner M., Lutz, Bousquet, M., Corazza G.E., Maral G., and Rumeau R. (2005). Integration of satellite and terrestrial systems in future multimedia communication, IEEE wireless communication. Vol 12, no.5, pp. 72-80.

Hossain Md.M, Rahman. Md.m and Alim Md. A (2010). performance analysis of uplink and downlink Transmission in CDMA system, journal of telecommunication volume 1(1) page 84. (Not cited in the write up)

Igbekele, O., Zhimwang J. T., Ogherohwo E. P and Kwaha, B. J. (2024). Impact of Altitude and Weather Conditions on Cellular Networks: A Comprehensive Analysis of Quality of Service. International Journal of Advanced Networking and Applications, 15(06), 6169–6173. https://doi.org/10.35444/IJANA.2024.15603

International Telecommunication Union (ITU-R P.838-3). (2005). Specific attenuation model for rain for use in prediction methods. Geneva: ITU.

Isabona, J., Imoize, A. L., Rawat, P., Jamal, S. S., Pant, B., Ojo, S. and Hinga, S. K. (2022). Realistic prognostic modeling of specific attenuation due to rain at microwave frequency for tropical climate region. *Wireless Communications and Mobile Computing*, *2022*(1), 8209256.

ITU-Recommendation (2002). Propagation data and prediction methods required for the design of earth space telecommunication system. P.618-7.

Moupfouma, F. and Martin, L. (2005). Modeling of the rain attenuation in terrestrial and satellite links. IEEE Transactions on Antennas and Propagation, 43 (10), 971-975.

Ogungbenro, S. B. and Morakinyo, T. E. (2014). Rainfall distribution and change detection across climatic zones in Nigeria. Weather and Climate Extremes, 5, 1-6.

Ojoba C.K., Zhimwang J.T., Ogherohwo E.P. and Anaibe E. (2024a). Impact of Elevation Angle on Cross Polarization Discrimination for Telecommunication Application In Warri, Delta State, Nige**ria.** *Int. J. Advanced Networking and Applications*. 15(5), 6090-6093. https://doi.org/10.35444/IJANA.2024.15402

Ojoba, C. K., Zhimwang, J. T., Ogherohwo, E. P. and Enaibe, E. (2024b). Estimating the Effect of Copolar Attenuation Caused by Rain Events on Radio Wave Propagation. Asian Journal of Research and Reviews in Physics, 8(2), 21–26. https://doi.org/10.9734/ajr2p/2024/v8i2161

Samuel, S. O., Zhimwang J. T., Ojoba, C. K., and Ikhioya, L. (2023). Temperature's Impact on the Physical Properties of Rare Earth Element Doped SrS for Optoelectronic Use. *Journal of Engineering in industrial Research,* 4(3), 147–156. https://doi.org/10.48309/JEIRES.2023.3.2

Zhimwang J.T, E. P. Ogherohwo, A. A. Alonge, A. O. Ezekiel and S. O. Samuel, (2023). Effect of the Variation of Atmospheric Refractive Index on Signal Transmission for Digital Terrestrial Television in Jos, Nigeria, *2023 IEEE AFRICON, Nairobi, Kenya*, pp. 1-4, http://dx.doi.org/10.1109/AFRICON55910.2023.10293714

Zhimwang J.T, Shaka Oghenemega Samuel, Frank Lagbegha-ebi Mercy, Ibrahim Aminu, and Yahaya Yunisa, (2022a). Analysis of Frequency and Polarization Scaling on Rain Attenuated Signal of a KU-Band Link in Jos, Nigeria. *Int. J. Advanced Networking and Applications*. 14(1). https://doi.org/10.35444/IJANA.2022.14111

Zhimwang J.T., Shaka Oghenemega Samuel, Frank Lagbegha-ebi Mercy, Ibrahim Aminu, and Yahaya Yunisa, (2022b). Categorization of Measured Rainfall Rates and Estimation of their impact on Radio Wave Propagation at Higher Frequency Band (12.5 GHz) in Wukari, Taraba State, *Nigerian Journal of Physics.* 31(2)