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Mitigation of Rain Fade Effect at the Ku Band Using Site Diversity Techniques

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Abstract:- At the Ku band frequencies, the signal is oftentimes influenced by numerous deteriorating factors like rain attenuation, cloud attenuation, and tropospheric scintillation. Among other propagation impairment, rain attenuation is the most common and critical, because of its effects on the transmitted signal. These include loss of signal strength at the receiving station, wastage of transmission power in a bid to overcome the attenuation. The need to mitigating the effect of rain attenuation of signals at this band by gaining the diversity and improving the factor is of paramount importance that is addressed by this paper. The improvement factor and the diversity gain needed to compensate for the attenuation were obtained from data collected from three weather stations in the tropical region, after which a rain attenuation model was proposed. The results obtained from the several simulations using different diversity gain in single site attenuation shows that there has been a significant decrease in root-mean-square and standard deviation as a prediction error compared with existing standard models. This model (site diversity prediction) was built with respect to baseline orientation angle, frequency of operation, site separation distance, and elevation angle, and it performed better for elevation angle, and site separation distance.

Keywords:- *Ku band frequency**,** Signal, Attenuation**,** Mitigation, Diversity.*

I. INTRODUCTION

Satellites provide three essential communication servic es, namely telecommunication, broadcasting, and data communications. There has been great advancement in the use of satellite technology today in many sectors, namely; satellite internet service provider (ISPs), governments, military, and medical [5]. One of the primary disadvantages of using satellites (K-bands) at frequencies greater than 10 GHz gets affected by beam spread, rain, and snow which are examples of atmospheric disturbance. The higher the frequency, the more severe the attenuation (signal fading) that occurs by these atmospheric disturbances (Palmer, 2014). To transmit and receive signals in satellite communication, the frequency of 1-50 GHz L (1-2 GHz), are 2-4 GHz), C (4-8), X (8-12 GHz), Ku (12-18 GHz), Ka (20-30 GHz) and V (40-50) [4]. The frequency ranges or bands GHz) L, S, and C bands are in the lower range and have low power transmission, as such, require a larger dish of about 4feet (1.2m) to receive these signals more so, the size of the dish shrinks as the power increases. The antenna's dish element collects incident waves across a large area and concentrates them onto the receiving element. If the waves are more powerful, fewer of them must be gathered to attain the same strength at the receiving element. As a result, the parabolic reflectors become more efficient in focusing them as the frequency increases. The Ku, Ka, X, and V bands are at the higher end of the frequency spectrum, requiring more power for transmission. Dishes as tiny as 45 cm in diameter can receive signals.[12]. Even when the terrestrial systems collapse due to disasters such as earthquakes, volcanic eruptions, floods, droughts, cyclones, landslides, and diseases, satellite communication can provide ongoing communication. Long-distance education, often known as online education or Tele-education, and telemedicine in the field of medical sciences are two other areas where satellite communication is used [5]. Satellite communication, on the other hand, does not necessitate large-scale infrastructure investments, making it perfect for underserved and isolated locations with dispersed populations. [2]. Ku band uplinks frequency is (13.25 - 14.50 GHz) and downlinks (11.7 - 12.2 GHz), these separate frequencies are to ensure that the signals do not interfere with each other. A wavelength of the signal at this frequency is (2.5 cm-1.67 cm) though more powerful and direct but more likely to be affected by atmospheric conditions unlike the C-band satellite service having a wavelength of 7.5 – 3.75 cm [7]. These atmospheric conditions cause attenuation when radio wave propagates through them. The most prevailing problem is usually rain fades [10], which are caused by rain. Rainfall is convective, with strati generating rain, while rainstorms are convective. Vertical atmospheric motions cause vertical transport and mixing, resulting in the former. The flow takes place in a cell with a horizontal extent of several kilometers, which can be isolated or embedded in a thunderstorm zone linked with a passing weather front. The latter on the other hand has widespread continuous precipitation which occurs when there is a large-scale ascension as a result of frontal or topographic lifting, or large-scale horizontal air convergence. Other factors are primarily to blame, such as wind or breeze. It is also characterized as a medium or moderate rain rat that falls for a longer time and covers a wide area. Fade Mitigation Techniques (FMT) could be used to provide a high percentage of system availability during rain events, allowing a good design of the Satellite Communication network to limit the influence of rain on propagated signals. This difficulty, on the other hand, might be mitigated in a number of ways, including the implementation of a power control system (allocating a higher power consumption to compensate rain fade loss), frequency diversity, adaptive coding modulation, site diversity, time diversity and Reconfigurable Antenna Pattern (RAP) among others to compensate for the rain fade loss [11]. But this paper focused on mitigating the rain fade effect using the site diversity technique.

II. RAIN AND DIVERSITY GAIN

The scattering or absorption of radio waves by raindrops, which occurs when the wavelength of signals being conveyed is shorter than the raindrop diameter, reduces system availability and reliability., otherwise known as signal attenuation. The degree of severity of rain distortion increases as frequency increases [8]. Raindrop scattering is also known as signal depolarization, and it is generated by differential attenuation and differential phase shift caused by differing raindrop diameters. In horizontal polarization, differential attenuation and phase shift are stronger at low frequencies, and vice versa. Estimating the forward scattering of a raindrop yields the aforementioned scattering characteristics. [3].

$$\Delta A = 8.686 \times I_m(K_h - K_V)L \qquad (2.1)$$

$$\Delta\emptyset = \left[\frac{180}{\pi}\right] \times Re(K_h - K_V)L$$

A=8.686I m (K h-K V) is the differential attenuation (A). The L (2.1) differential phase shift is determined by: = [180/] Re (K h-K V)L
(2.2)

where, the horizontal component of propagation constant is given by K_h and the vertical component of propagation constant is given by K_V. The length of the passage across the medium is denoted by L. The real and imaginary components are referred to as Re and I m, respectively. According to [3,] the length of this path is 5.4 km, and the expression for these parameters is

$$K_{h,v} = \left(\frac{2\pi}{K}\right)\int f_{h,v}\, n(a)da \qquad (2.3)$$

Where $f_{h,v}$ denotes the forward scattering amplitudes in both horizontal and vertical direction for raindrops with $n(a)$ and a the equi-volumetric radius of a raindrop in mm.

To estimate accurately the effect of rainfall on wireless signal transmitted, the relationship between the fall velocity of rain molecules, the height of the rain and the diameter of the rain were derived. Using the generalized form, in which the height dependent density correction for the fall velocity $dv(h)$ is defined in equation (2.4) as:

$$v(D)\, m/s = (9.65 - 10.3\exp(-0.6D))\partial v(h) \quad \text{For } 0.109 \le D \le 6mm \qquad (2.4)$$

Using the America Standard Atmosphere conditions for the height dependence of air density and making use of the relation of $\partial v(h)$ under these assumptions is defined as in equation (2.5)

$$\partial v(h) = [1 + 3.68 \times 10^{-5}h + 1.71 \times 10^{-9}h^2] \qquad (2.5)$$

Where h is given as height

The spectra reflectivity can also be calculated from the drop diameter using the expression given in equation (2.6)

$$\eta(D_{nn}) = \eta(f_{D,nn})\frac{\partial f_D}{\partial v}\frac{\partial v}{\partial D} \qquad (2.6)$$

Where

$$\frac{\partial f_D}{\partial v} = 160.1973m^{-1} \qquad (2.7)$$

and

$$\frac{\partial v}{\partial D}(ms^{-1}mm^{-1}) = 6.18 \times exp(-0.6D)v(h) \qquad (2.8)$$

Substituting 6.18exp(-0.6D) v(h) equations (2.8) and (2.7) into (2.6) gives the expression in equation (2.9)

$$\eta(D_{nn})m^{-1}mm^{-1} = \eta(f_{D,nn}) \times 990.02 \times \exp(0.6mm^{-1}D) \qquad (2.9)$$

Dividing equation (2.9) by $\sigma(D_{nn})$ gives the expression in equation (2.10)

$$N(D_{nn}) = \frac{\eta(D_{nn})}{\sigma(D_{nn})} \qquad (2.10)$$

where $N(D_{nn})$
$\sigma(D_{nn})$, is he drop size distribution which can be substituted, and the single-particle backscattering cross-section of rain-drop of diameter D_{nn}. [1]

And diversity gain is the difference between the route attenuation associated with a single terminal and diversity modes of operation. as given in equation (2.11)

A S (P) - A j (P) = G (D, A S) (dB)
(2.11)

Aj is the joint site attenuation after applying the selection combination, and A (S) is the attenuation suffered by the single site reference station. The minimal attenuation of the reference site and the diversity site are chosen for the selection combination. The difference between the equi-probability attenuation of A S and A j at the temporal probability level P is the site diversity gain, and D is the site separation distance in kilometres between the sites. The gain in the system is G (D, A S). To maintain system availability of P percent, a single site running at the location of interest would require an A S margin. When more than one site is used, the margin required for each site is lowered to A j dB, which is equivalent to lowering the antenna gains at each site by G (D, A S) dB for the same performance. The site separation distance is the most important component in determining the amount of improvement obtained by diversity operation in a diversity configuration. When it is raised, the diversity gain increases as well, up to around the intense rain cell's average horizontal extent. There is a slight improvement in diversity operation at separation distances much beyond the normal horizontal extent. However, if the distance between sites is too high, diversity gain may be reduced since a second cell may become engaged in the propagation channels. Figure 2.1 presents a typical illustration of site diversity gain.

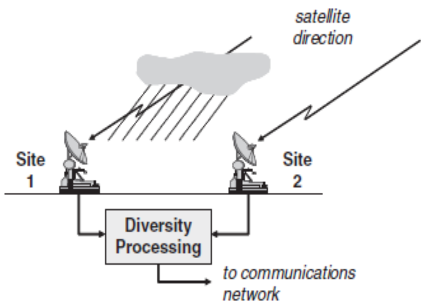

Figure 2.1: Site diversity concept (source: Ippolito, 1986*)*

III. METHODOLOGY

Southwestern monsoon winds from the ocean combine with dry northwest winds from the Sahara Desert to create Akure. It has the typical tropical climate's rainy and dry seasons. It has the typical tropical climate's rainy and dry seasons. The wet season lasts from April to October, whereas the dry season lasts from November to March, with an average annual rainfall of 1500 mm. Temperatures range from 28 to 31 degrees Celsius, with an annual relative humidity of around 80%. The city is located in the rain forest region of Nigeria's south western region. [9]. This work makes use of data obtained from each of the sites to estimate rain-induced attenuation for path and site diversity using a generalized ITU-R model. A 2-year archived rain data (2012-2014) from three weather stations located within Akure campus of the Federal University of Technology (Lat: 7.17 N, Long: 5.18 E, Alt: 358 m). Tropospheric Data Acquisition Network (TRODAN) garden, Communication Physics Research Observatory at Physics building Oba-Kekere, and West African Science Centre for Climate Change and Adapted Land Use (WASCAL), Oba-Nla Staff Quarters is the three study locations. However, for data homogeneity among the study sites, this study covers a 2-year rainy period (2012-2014). Figure 3.1 show the study sites in FUTA while Table 3.1 shows the characteristics of the sites.

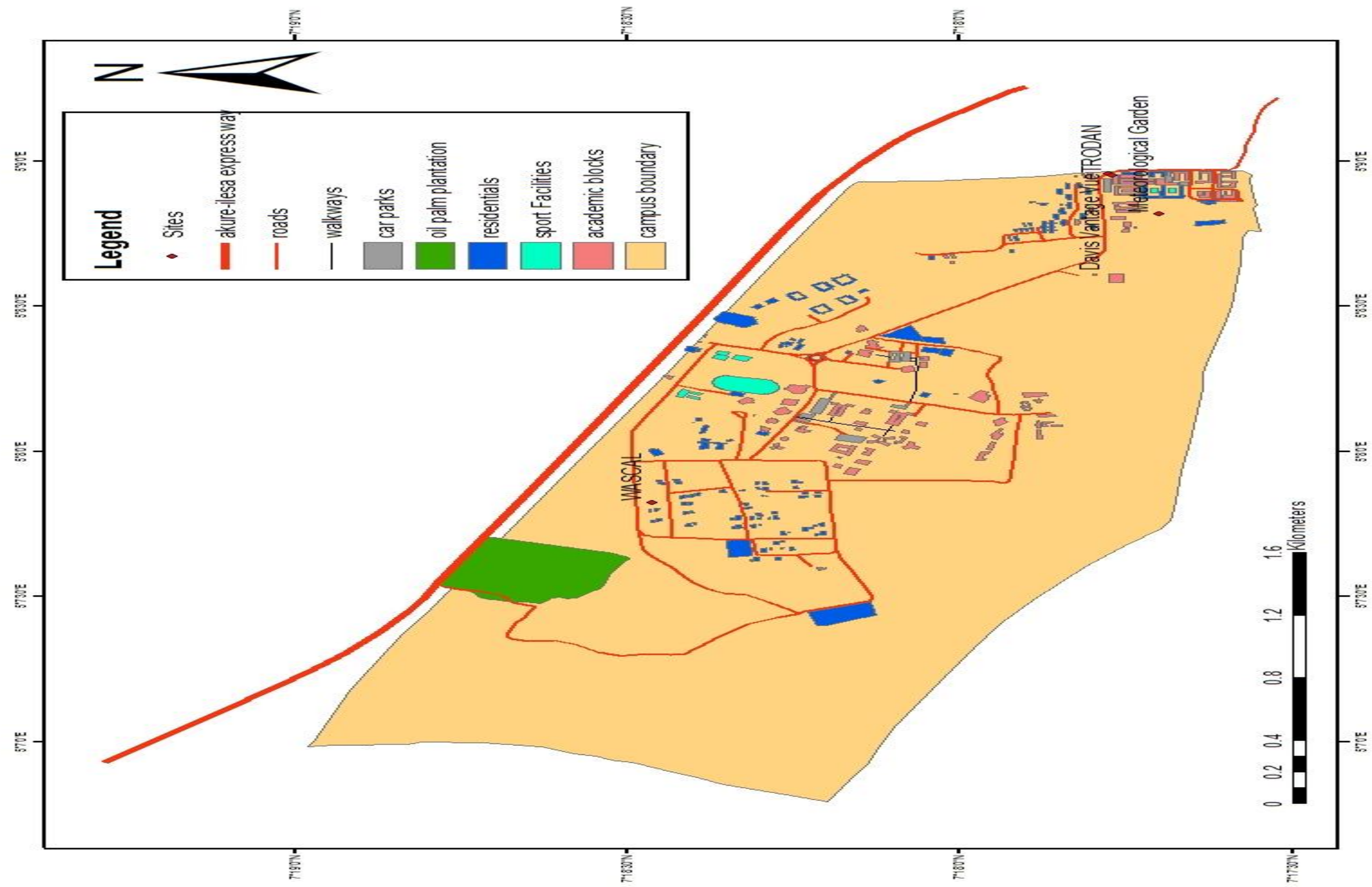

Figure 3.1: Map of FUTA showing the study site

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Table 3.1: Characteristics of the study sites.

Name of the location	Latitude \s(N)	Longitude \s(E)	above Sea Level Height (m)	Distance away from the reference site (km)
TRODAN garden	07^o 17.779′	05^o 8.958′	370	Reference site.
Communication Physics Research Observatory	07^o 17.753′	05^o 8.911′	376	0.014
WASCAL Garden at FUTA Staff Quarters Oba-NLA.	07^o 18.458′	05^o 7.818′	390	2.452

IV. RESULT AND DISCUSSION

The Bar chart showing the mean monthly accumulated rainfall (mm) for the three sites is given in figure 4.1. This is the amount per month of the year, as well as the time period during which the signal level deteriorated. During the rainy season, heavy rainfall is common in all three areas (April-October).

It's clear that the effects of the Inter-Tropical Discontinuity's movement have an impact on monthly rainfall (ITD). Figure 4.1 shows that during July, the WASCAL locations received the highest average monthly rainfall accumulation of roughly 227.4 mm. However, due to the ITD's movement, there is continual rainfall in this region, even throughout the dry season, with the exception of December (which is rather minor) for the years under consideration. As a result, the hardest months are between June and August. As a result, the months with the worst weather are between and. WASCAL Staff Quarters in April and October.

In addition, as shown in Figure 4.1, the average monthly rainfall accumulation for the two years of measurement was taken into account for the TRODAN garden location. the average monthly rainfall accumulation for the two years of measurement was taken into account for the TRODAN garden location.

It can be seen that the monthly rainfall is influenced by the effects of the ITD's movement. The ITD travels across the country during the rainy season due to the abundance of rain. According to observations, the site received its highest average monthly rainfall accumulation of roughly 85.1 mm in July. It's also worth noting that the hardest months are April through October. Nigeria has two distinct seasons: the dry season, which lasts from November to early February/early March, and the wet season, which lasts from March to October. April is often seen to be the start of the rainy season, however rainfall does not become strong until June to October, therefore April and May have sporadic rainfall patterns.

Observation showed that September was the month with the highest average monthly rainfall accumulation of 234 mm at the Physics building site. It's also worth noting that the hardest months are from May through October. Even around the same location, this shows the dynamism of the rain pattern.

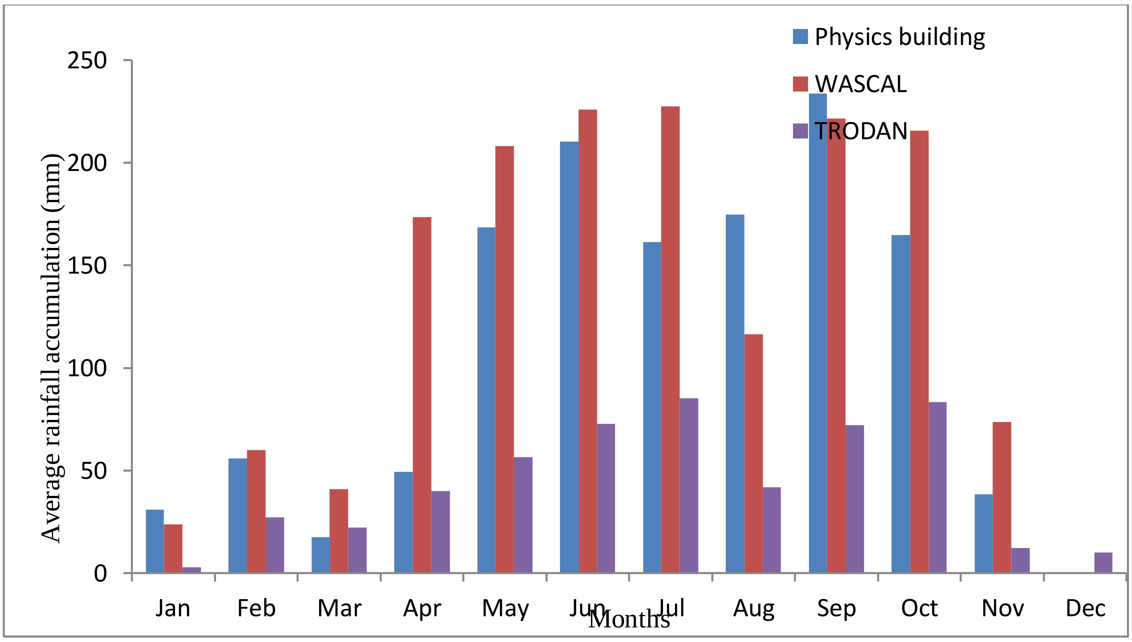

Figure 4.1: Bar chart showing the mean monthly accumulated rainfall (mm) for the three sites

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The average rain cell size distribution for the year under review within the region of interest (ROI) is presented in figure 4.2. It can be shown that the cell diameter was highest in June and September which indicates that the attenuation is higher for those specified months. Hence, it becomes imperative that the link be optimized extensively for the months when the attenuation is highest. By comparing the chart, it is observable that rain cell size was highest during June and September hence, it can be deduced that there is no direct relationship sufficient enough to predict the size of rain cell from the rain rate. it can be suggested that attenuation mostly depends on the rain cell diameter, that is, the rain cell size at the instance of rain.

The cumulative distribution of the recorded one-minute rain rate observed in the Physics building department is shown in Figure 4.3. It can be seen that larger rain rates (more than 50 mm/hr.) occur at smaller percentages of time. For the ITU-R model, the estimated measured rainfall rate surpassed 0.01 percent of the time is about 120 mm/h, whereas the corresponding estimate for the same time percentage is about 94 mm/hr.

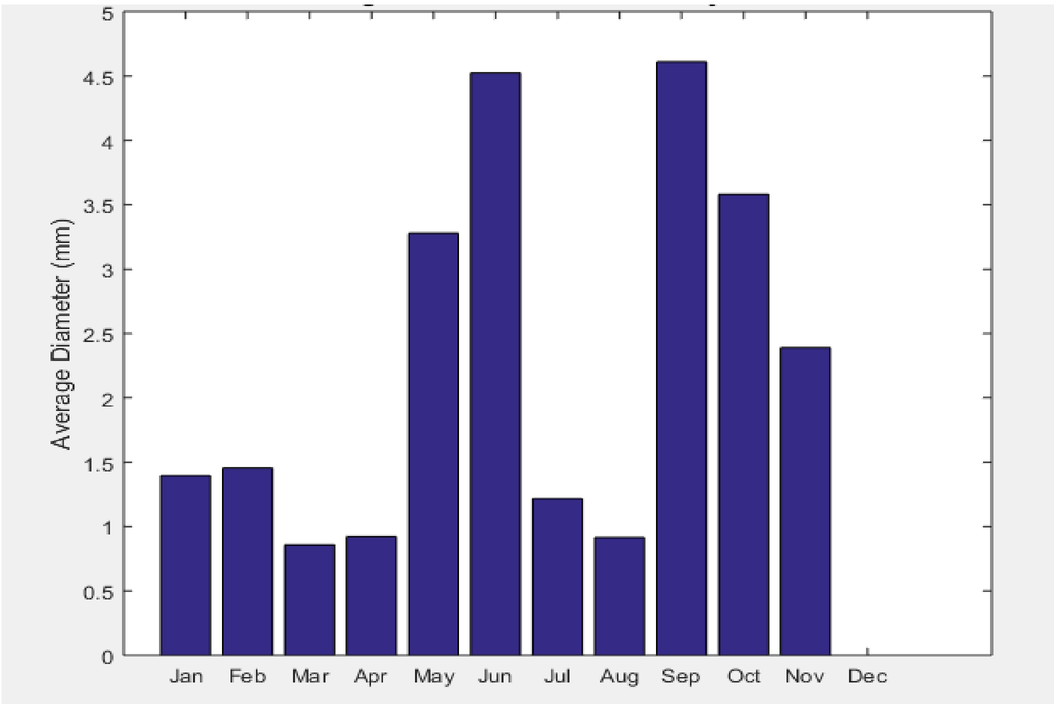

Figure 4.2: The chart of average rain diameter corresponding to the months

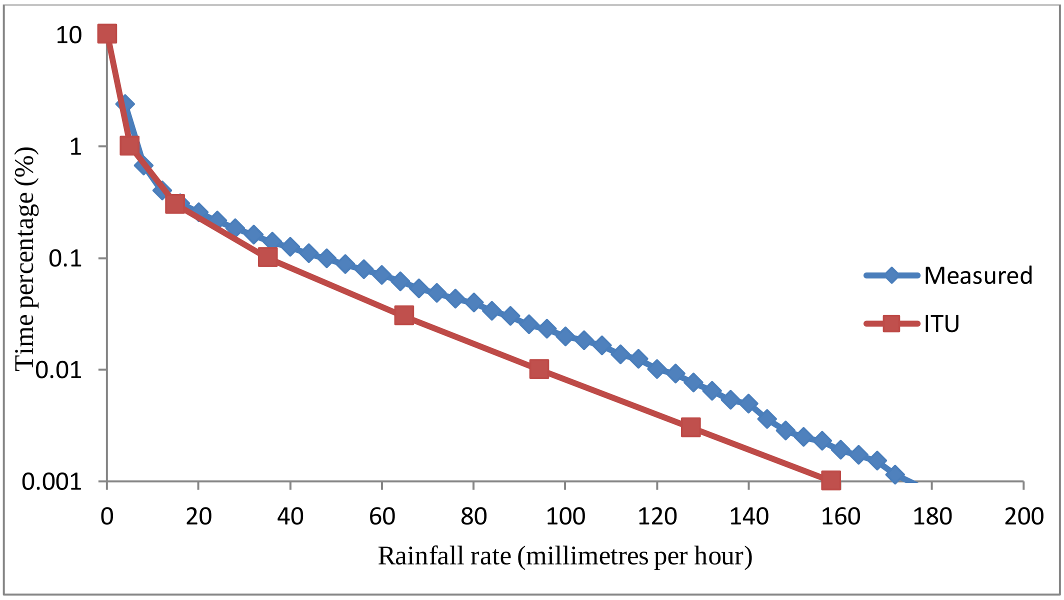

Figure 4.3: Rain rate cumulative distribution in the Physics department.

V. CONCLUSION

Using rain data from three rain stations at Federal University of Technology, Akure, this study offered a new technique for estimating diversity gain (FUTA). The rain attenuation exceedance at the three sites was plotted to assess the diversity gain at various distances, while rain fade was observed to be minimized by the technique described above. The findings demonstrate that site diversity gain is strongly influenced by site separation distance and elevation angle, but frequency and polarisation angle of site diverse stations are less influenced.

REFERENCES

[1]. K. F. Akingbade, and O. O Alo,. (2017). ' Rain attenuation modelling and mitigation over Ku-band signal propagation using Adaptive modulation technique'. International Journal of Exploring Emerging Trends in Engineering (IJEETE). Vol. 04, Issue 03, pp. 145-155.

[2]. G. Akkor, S. B., John, M. Hadjitheodosiou, (2005). 'A multiple subset sum formation for feedback implosion suppression over Satellite Network'. IEEE Globecom., pp 3226-3230.

[3]. M. Animesh, and A. Arpita, (2011). 'Ku-Band signal depolarization over Earth-Space path Scattering of Raindrops at Tropical Locations'. IEEE.

[4]. D. P. Athaonasios, (2004). 'Satellite Communication at Ku, Ka and V bands: Propagation Impairments and Mitigation Techniques'. IEEE Communications Survey and Tutorial, Third Quarter 6(3), pp. 2-14.

[5]. M. Dawidziak, (1984). 'Satellite TV dishes getting good Reception'. Akron Beacon Journal. Proceedings of the IEEE, 85, 6, pp. 959-969

[6]. G. B. Foote, and D. S. DuToit, (1969). 'Terminal Velocity of Raindrops'. *Journal of Meteorology*, Vol 8, pp. 249-253.

[7]. A. J. Jalal, (2015). 'Rain effect on Ku-Band Satellite System'. Electrical and Electronics Engineering International Journal 4(2), pp. 13-15

[8]. A. Maitra, (2004). 'Rain Attenuation Modelling from the measurement of drop size distribution in the Indian Region'. IEEE Antennas and Wireless Propagation Letters 3, pp. 180-181.

[9]. J. S Ojo, and C. R. Okeowo, (2015). 'Diurnal and Seasonal Variations of Rain Rate and Rain Attenuation on Ku-Band Satellite Systems in a Tropical Region: A Synthetic Storm Techniques Approach'. Journal of Computer and Communications., Vol. 3, No.5, pp. 1-10.

[10]. J. Palmer, (2014). Satellite Podcast.

[11]. F. A. Semire, Mohd-Moktar, W Ismail.., N. Mohamad, and J . S. Mandeep, (2015, February 15). 'Modelling of rain attenuation and site diversity prediction for tropical regions'. Annales Geophysics., Vol 33, No 10.51, pp. 321-331.

[12]. H. Somerfield, (2014). 'Satellite dishes getting smaller, sharper in future'. The Tuscaloosa News (Tuscaloosa Alabama).