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EVALUATING THE EFFECT OF RAINFALL ON SIGNAL RECEPTION OF DIRECT-TO-HOME (DTH) SATELLITE SYSTEM IN NORTH CENTRAL, NIGERIA

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ABSTRACT: *This research work examines the effects of rain attenuation on signal reception of Direct-to-Home (DTH) satellite on Ku-Band in north central, Nigeria. Data used were obtained through experimental approach of recording both rainfall and the quality of signal received from DTH at 12.519 GHz at regular interval of one hour covering Rainy season (April to October) in 2018. The data obtained from field was used, daily and monthly averages were evaluated thereof. The work used experimental as well as statistical correlation to establish the effect of rainfall on signal reception. The results obtained showed a gradual increase in the mean monthly rainfall from April and got to its peak in August or September of the season as the case may be and gradual decrease in September ending and October, as rainfall picks gradually in April along the months, quality of signal reception gradually declines as the rainfall increase. Linear correlations between the rainfall and signal quality reception reveal strong negative mean correlations coefficient (r) and coefficient of determination (R^2) values of -0.855 and 0.737 respectively for north central states, Nigeria. The result reaffirmed that the rain rate is inversely proportional to the quality of signal reception at frequency above 10 GHz at Ku-band.*

KEYWORD: Signal Attenuation, Direct-To-Home, Signals Quality Reception, North Central States, Ku-Band.

INTRODUCTION

Direct-To-Home (DTH) satellite service refers to the satellite television (TV) systems in which the subscribers or end users receive signal directly from the geostationary satellite orbit (GEO) dedicated for such purposes. These signals are broadcast in digital format at microwave frequencies (Elbert, 2008). The service providers make use of satellite link to transmit their signal to the entire world through space known as atmosphere consists of a mixture of ideal gases with molecular nitrogen and oxygen as predominant in volume, while carbon-dioxide, water vapour and ozone as minor constituents play crucial roles, is the thin layers of gases, commonly referred to as air that surround the earth and retained by the earth's gravity; seals the planet and protects us from the vacuum and electromagnetic radiations given off by the sun (David, 2010).

Rain on the transmission path is the major weather effect of concern for earth-space communications operating in the frequency bands above 3GHz (Ojo & Ajewole, 2008). The rain problem is particularly significant for frequencies of operation above 10GHz. Raindrops absorb and scatter radiowave energy, resulting in rain attenuation (a reduction in the transmitted signal amplitude), which can degrade the reliability and performance of the communications link (Mukesh *et al*., 2015). The non-spherical structure of raindrops can also change the polarization characteristics of the transmitted signal, resulting in rain depolarization (a transfer of energy from one polarization state to another) (Jalal, 2015). Rain effects are dependent on frequency, rain rate, drop size distribution, drop shape (oblateness), and to a lesser extent, ambient temperature and pressure as well as canting angle (Ippolito, 2008).

The attenuating and depolarizing effects of the troposphere, and the statistical nature of these effects, are affected by macroscopic and microscopic characteristics of rain systems. The macroscopic characteristics include size, distribution and movements of rain cells, the height of melting layers, and the presence of ice crystals. The microscopic characteristics include the size distribution, density, and oblateness of both raindrops and ice crystals (Imarhiagbe, & Ojeh, 2018). The combined effect of the characteristics on both scales leads to the cumulative distribution of attenuation and depolarization versus time, the duration of fades and depolarization periods, and the specific attenuation/depolarization versus frequency.

Bruce (2008) averred that the most detrimental atmospheric effect above 4 GHz is rain attenuation, which is a decrease of signal level due to absorption of microwave energy by water droplets in a rainstorm. Due to the relationship between the size of droplets relative to the wavelength of the radio signal, microwave energy at higher frequencies is absorbed more heavily than that at lower frequencies. Rain attenuation is a serious problem in tropical regions of the world with heavy thunderstorm activity, as those storms contain intense rain cells.

MATERIALS AND METHODS

The equipment used for this work includes: Rain gauge for recording the intensity of rainfall shown in figure 1 and a complete set of direct-to home satellite kit (Antenna, signal Decoder and Scopes) shown in figure 2and 3 for the observation of the signal responses as a result of rainfall.

Figure 1: Rain Gauge for Measuring Amount Precipitation / Rainfall.

Figure 2: Parabolic Antenna

Figure 3 TV Setup for Observation

The work deploys experimental as well as statistical correlation in the evaluation of the impact of rainfall on signal reception. The data obtained from field were compared to that obtained from Nigeria metrological Agency (Nimet), Abuja. The signal receptions were collected at regular interval one hour throughout the raining season (April-October, 2018) across the entire study area, while that of the secondary data were at interval 5 minutes. In each case, daily and monthly mean were evaluated for each location. The mean values were used for the correlation between rainfall and signal quality reception.

Geographical Location of Study Area

This research covers the north central states of Nigeria -viz, Niger, Kogi, Kwara, Plateau, Benue, Nasarawa and the Federal Capital Territory (FCT) Abuja. They represent one of the six geo-political zones in Nigeria. These states are located in the tropical region marked by two distinctive seasons: viz: Dry Season spanning November – March and Rainy Season which spans April – October of each year with August as the peak month of rainy season.

Figure 4 shows the study area of the research, the north central states showing the state capitals, some major towns and cities and particular towns to be covered by the research. Three towns from each state were mapped out as the study area with at least one from each senatorial district of the state as represented in Table 1 with their respective coordinates and altitudes.

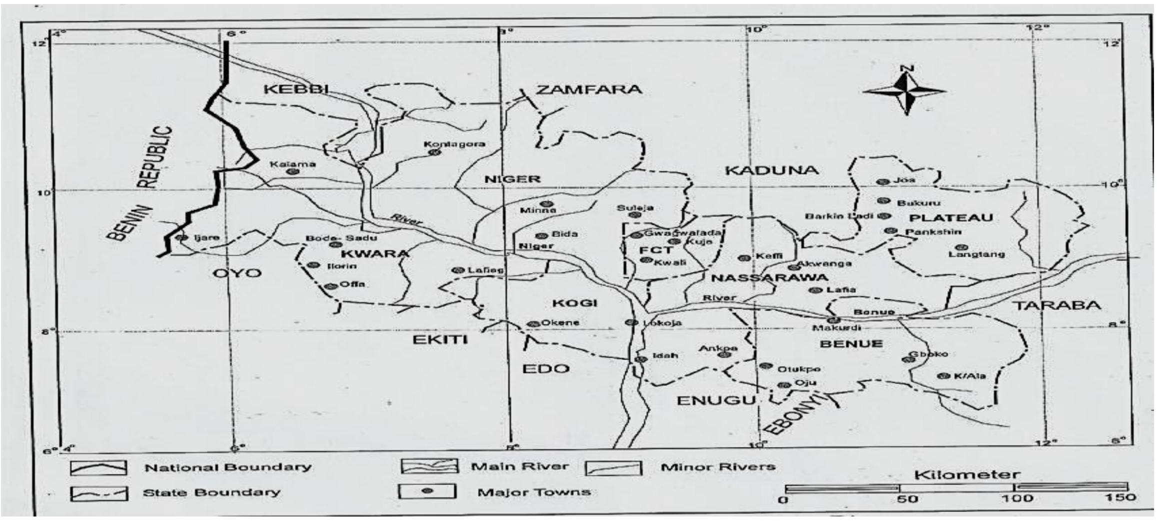

Figure 4: Map of North central states showing the study area (NASDRA, 2013)

Table 1: Towns under the study area and their locations

SNO	STATE	TOWN	LOCATION	ALTITUDE(m)
1	BENUE	Gboko	7.325^{o}N / 9.005^{o}E	335
		Makurdi	7.741^{o}N / 8.512^{o}E	104
		Otukpo	7.333^{o}N / 8.750^{o}E	127
2	KOGI	Ankpa	7.300^{o}N / 7.633^{o}E	70
		Lokoja	7.800^{o}N / 6.740^{o}E	55
		Okene	7.550^{o}N / 6.233^{o}E	270
3	KWARA	Bode-Sadu	8.933^{o}N / 4.783^{o}E	152
		Ilorin	8.500^{o}N / 4.540^{o}E	290
		Lafiagi	8.867^{o}N / 5.418^{o}E	74
4	NASARAWA	Akwanga	8.917^{o}N / 8.367^{o}E	359
		Keffi	8.843^{o}N / 7.871^{o}E	338
		Lafia	8.492^{o}N / 8.517^{o}E	290
5	NIGER	Bida	9.083^{o}N / 6.017^{o}E	152
		Kontagora	10.400^{o}N / 5.467^{o}E	335
		Minna	9.614^{o}N / 6.557^{o}E	299
		Lapai	9.625^{o}N / 6.570^{o}E	162
6	PLATEAU	Jos	9.933^{o}N / 8.883^{o}E	1,208
		Langtang	9.133^{o}N / 9.783^{o}E	430
		Pankshin	9.333^{o}N / 9.450^{o}E	1371
7	FCT	Abuja	9.058^{o}N / 7.489^{o}E	840

(Nimet, 2015).

RESULTS

The results obtained were as depicted in the figures listed. The mean monthly values of rainfall and signal quality over the study area are as shown in Figure 5 and 6 respectively, while Figure 7 and 8 shows the mean monthly rainfall and signal quality per state record respectively. Figure 9 -15 shows the correlation between the mean values of the rainfall and the signal quality at 12.519 GHz for Benue, Kogi, Kwara, Nasarawa, Niger, Plateau and FCT respectively.

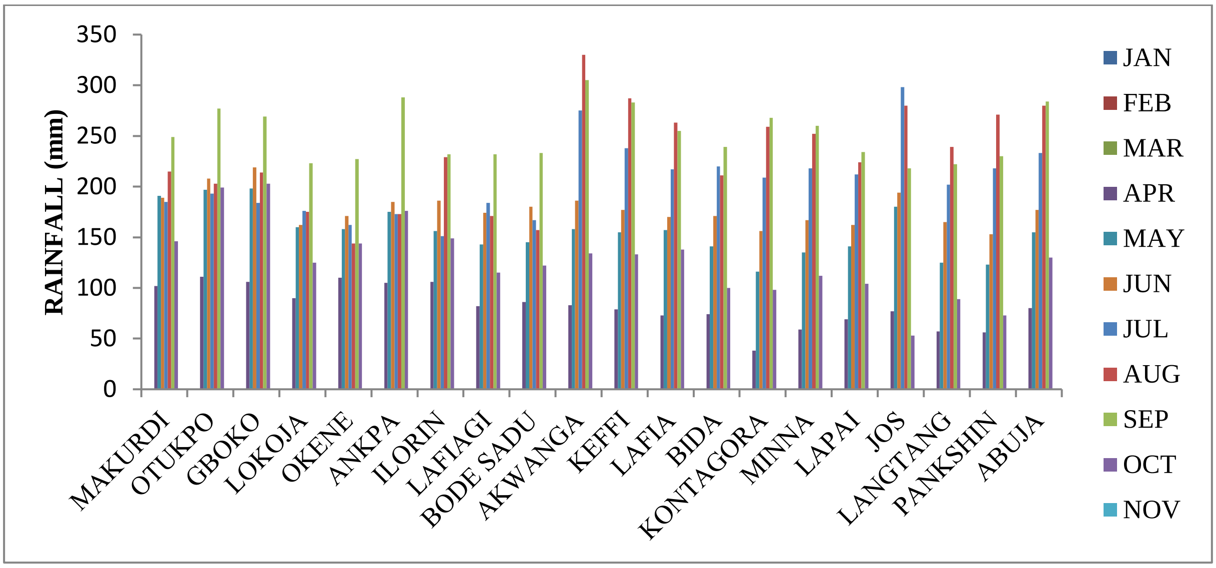

Figure 5: Mean value of Rainfall over the Study Area

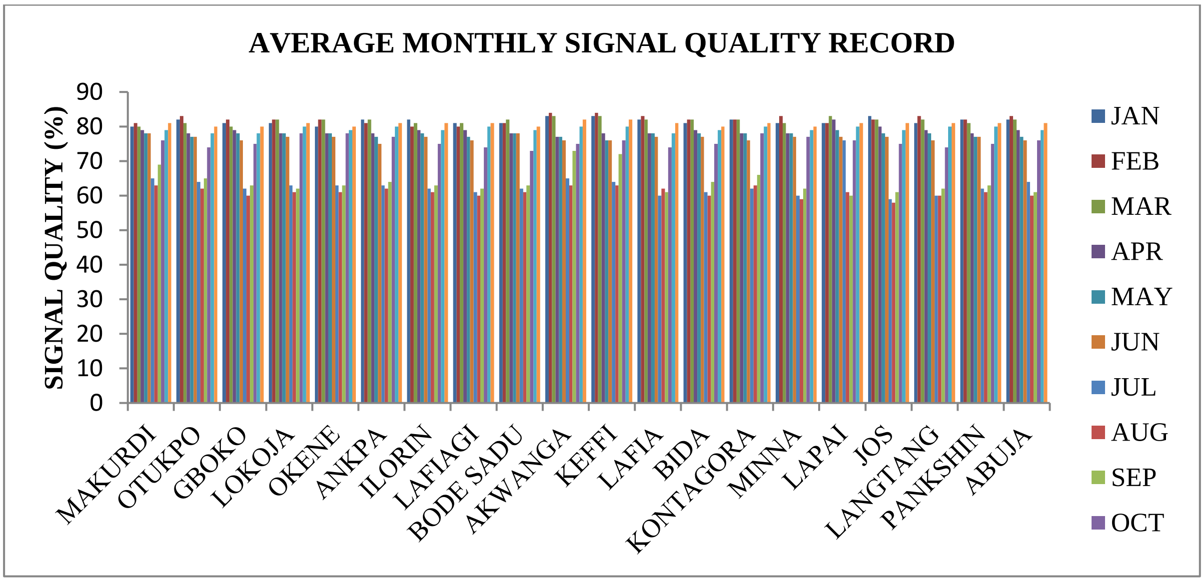

Figure 6: Mean values of Signal Quality over the Locations

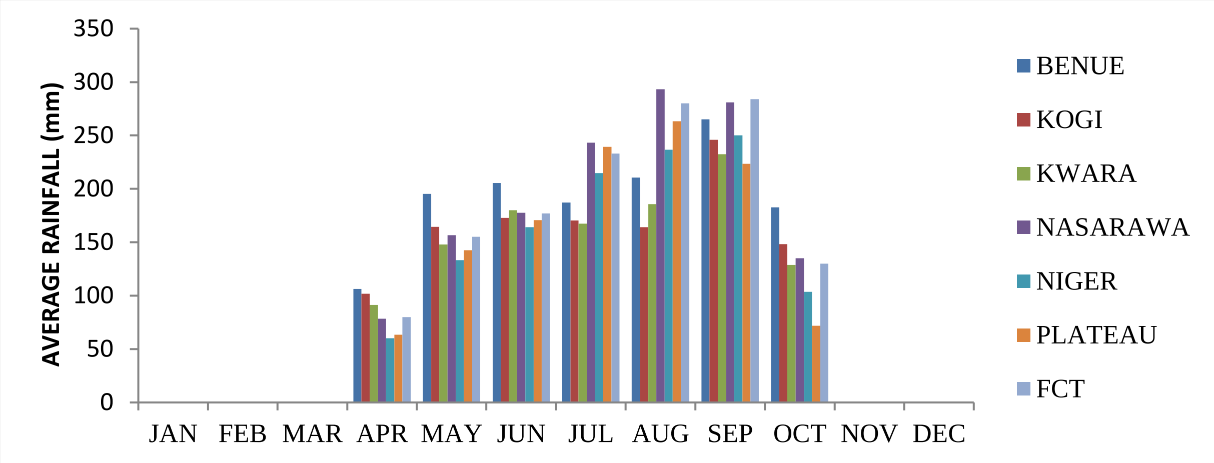

Figure 7: Mean value of Rainfall per state of the Study Area

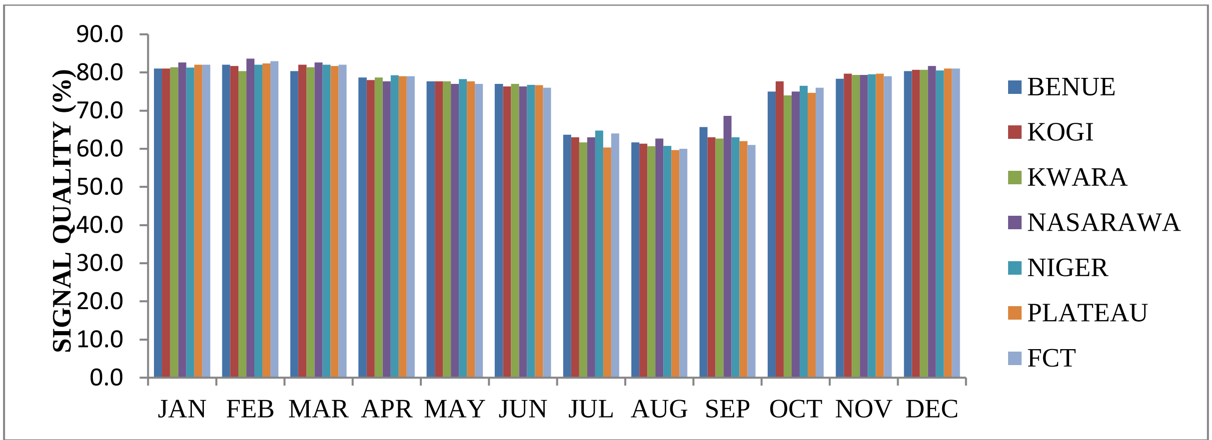

Figure 8: Mean value of Signal Quality per State under the Study Area

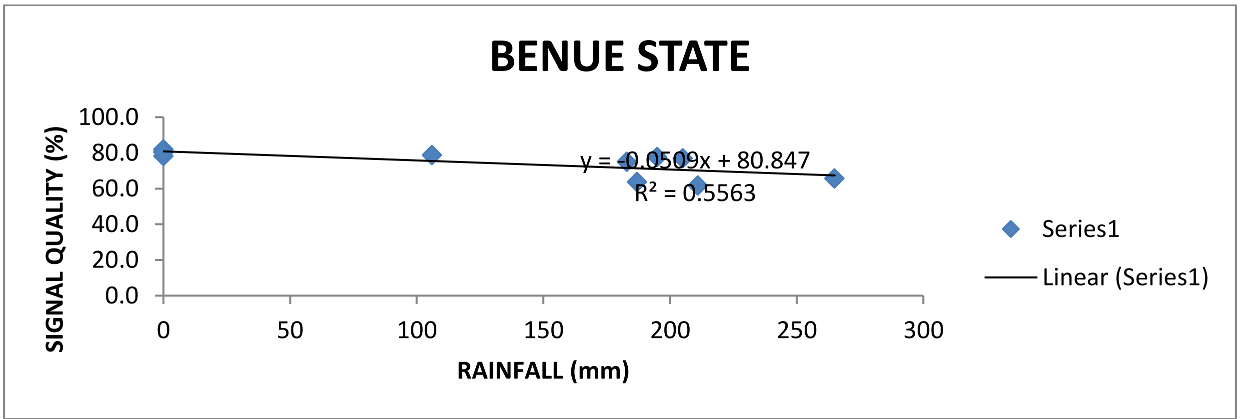

Figure 9: Correlation between Signal Quality and Rainfall for Benue State.

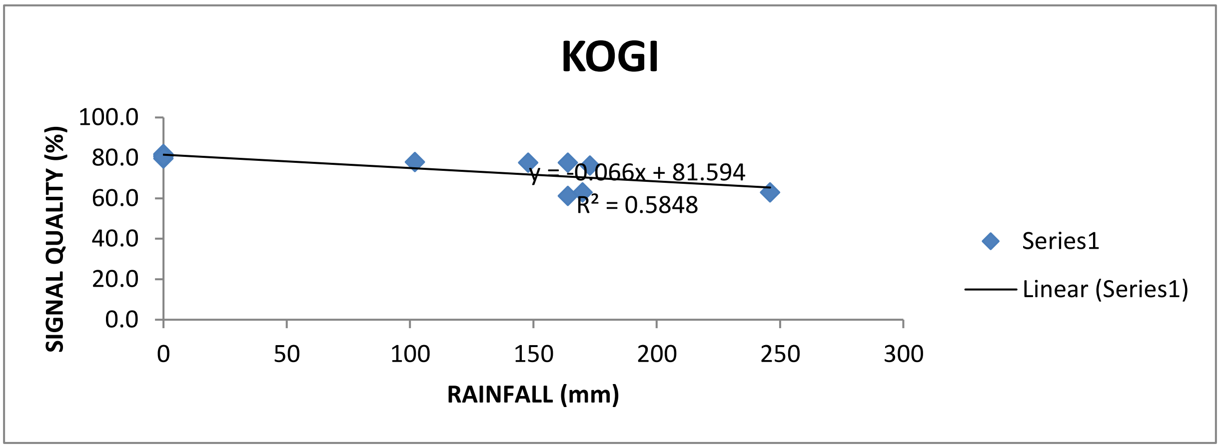

Figure 10: Correlation between Signal Quality and Rainfall for Kogi State.

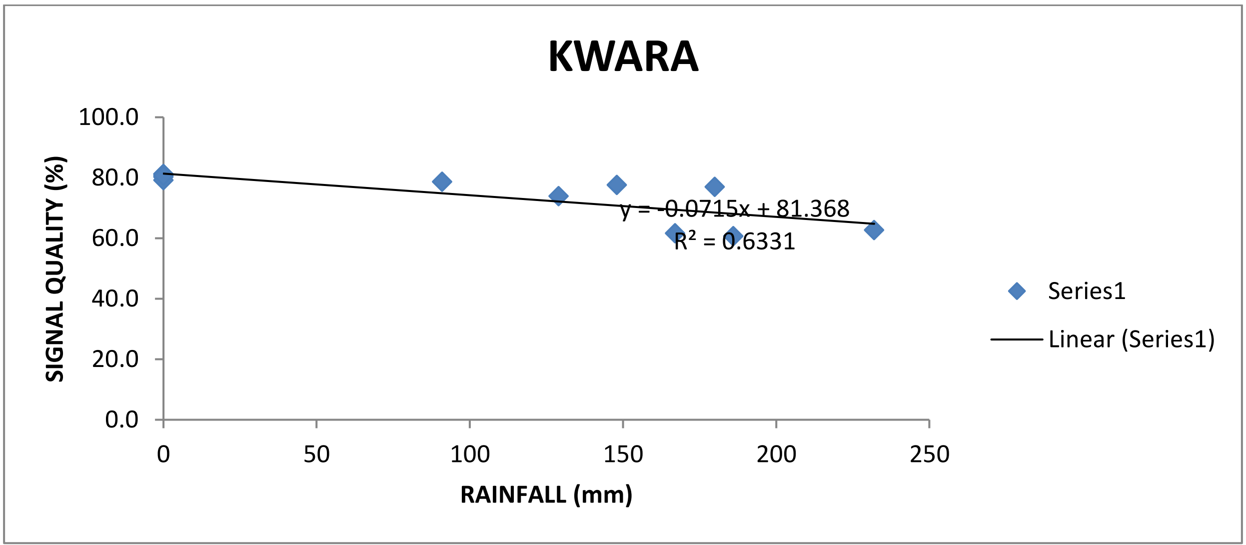

Figure 11: Correlation between Signal Quality and Rainfall for Kwara State.

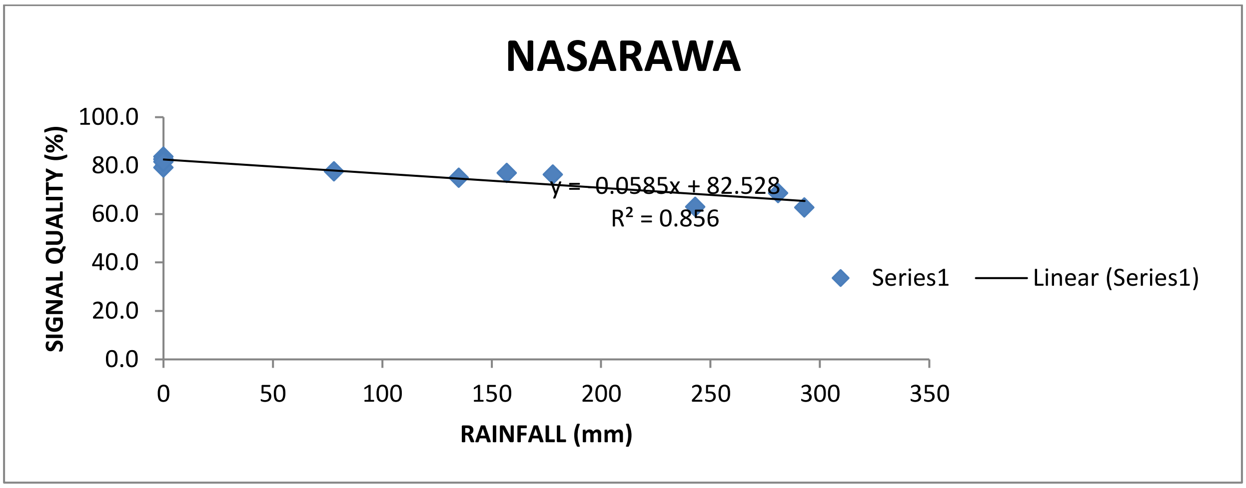

Figure 12: Correlation between Signal Quality and Rainfall for Nasarawa State.

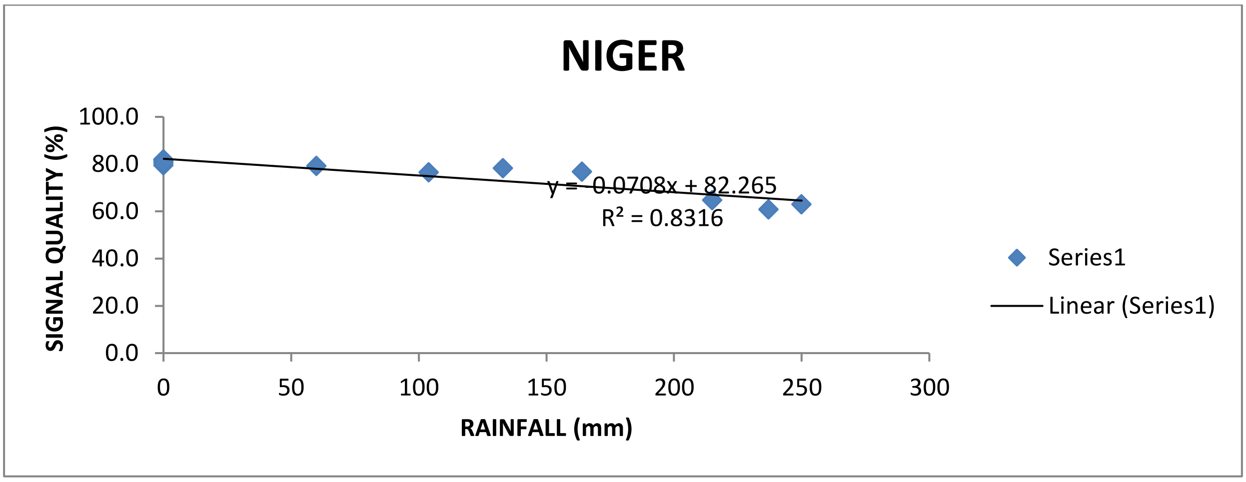

Figure 13: Correlation between Signal Quality and Rainfall for Niger State.

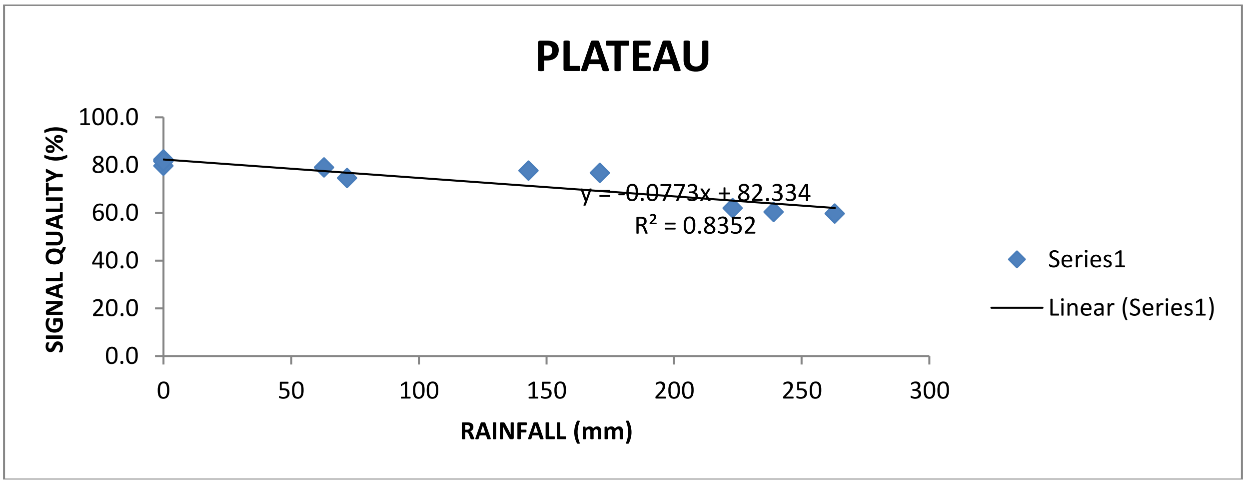

Figure 14: Correlation between Signal Quality and Rainfall for Plateau State.

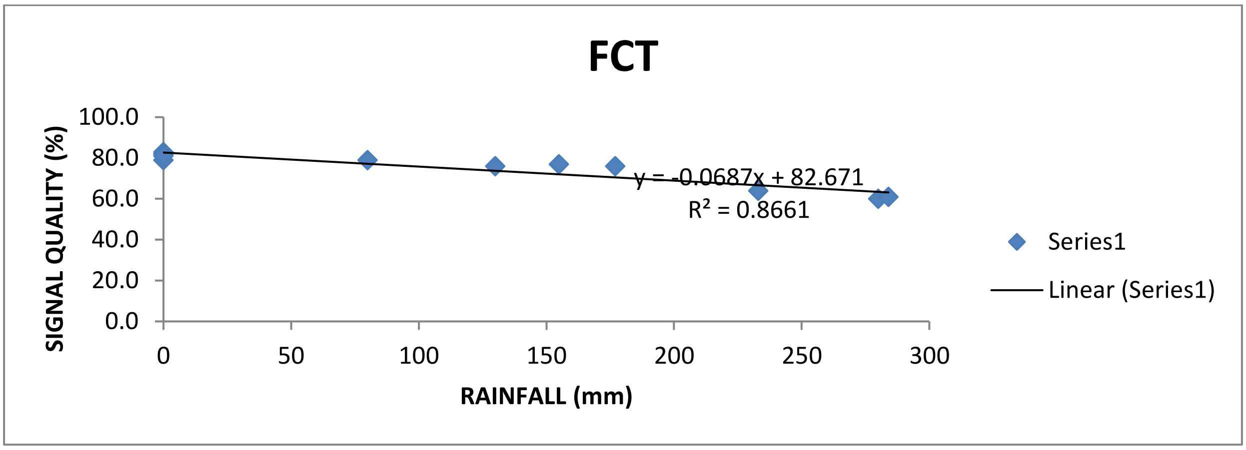

Figure 14: Correlation between Signal Quality and Rainfall for FCT, Abuja.

Table 2: Summary of Relationship between Rainfall and the Quality of Signal at 12.519 GHz Received per State of the Study Areas.

State	Correlation Coefficient (r)	Coefficient of Determination ($R^{2)}$	Remarks
Benue	-0.746	0.556	good
Kogi	-0.765	0.584	good
Kwara	-0.796	0.633	good
Nasarawa	-0.925	0.856	very good
Niger	-0.912	0.831	very good
Plateau	-0.914	0.835	very good
FCT	-0.931	0.866	very good
Mean Value	**-0.855**	**0.737**	

Note: the negative sign associated with the correlation coefficient indicate the trend of the slope and by implication mean inverse correlation between the parameters under consideration.

DISCUSSION

Data obtained revealed that, the amount of rainfall increased gradually from the month of April and got to its peak in month of August or September as the case may be and gradually fade out in the month of October or November. The assertion of gradual increase in the rainfall is depicted in Figure 5, 6 and 7. The data also shows that Nasarawa State experienced the highest amount of rainfall in the period under study with a value of 1365mm, closely followed by Benue State with a value of 1352mm, while Kwara State experienced the least amount of rainfall with a value of 1133mm. On the basis of towns under the study area, Akwanga in Nasarawa State experienced the highest amount of rainfall with a value of 1471mm, while, Bode-Sadu in Kwara State experienced the lowest amount of rainfall with a value of 1090mm.

The rate of rainfall (rain rate) rises gradually from 0.1mm/Hr in April, across the study area and got to its peak with a value of 0.5mm/Hr in the month of August and gradually declined downward to 0.15mm/Hr in October, while on the other hand, the signal decreases gradually as the rainfall (rain rate) increases. The month of August experiences more days of rainfall, while, the month of September experiences more volume of rainfall. The attenuation caused by rain leads to scattering or absorption of signals by water molecules, scattering remains the predominant factor. This finding was corroborated by Omotosho, (2013)

Figure 9 to 15 show that there exists a linear correlation between Rainfall and received Signal quality. The correlation shows a significant correlation between the two variables when fitted into linear regression equations, with r and R^2 values as shown table 2 indicating the degree and percentage values of correlation respectively. The correlation between the two parameters has negative correlation coefficients and by implication means a very good or excellent correlation. This correlation implies that, the higher the Rain rate, the lower the quality of the signal received.

CONCLUSION

The trend of the results obtained shows that as rainfall increases gradually from April the quality of Ku-band signal received decreases gradually too. Considerable reduction in the quality of signal reception was observed within the study area. The correlation between rainfall and the signal quality shows linear correlations, with mean r and R^2 values of -0.855 and 0.737 for rainfall when correlated with signal quality. This value is likely going to increase as time passes by, due rising activities on earth through pollution leading to gradual depletion of the Ozone layer through global warming, the likelihood of the rainfall under study to also rise is

Conclusively, the result obtained and analyzed shows that variation in rainfall has 73.7% effect on the signal reception. This effect on the signal reception thus summed up into the proposition that, the quality of signal received is inversely proportional to the variations in rainfall.

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