

Impact of Climate Change on Communication Link in Nigeria

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Abstract

In the recent time, the issue of climatic change and its adverse effect on mankind as well as on communication links has become a global concern. This paper examines effect of climate on radio communication focusing on rainfall being the major climatic element that hampers signal availability. Time series data were collected and analyzed with descriptive statistics and curve fitting regression. Result shows a steady rise in rainfall trend over the year but with slightly unstable volume variation in the study area.

Keywords

Rain rate; Attenuation; Climate change; Communication

I. Introduction

Over the years rainfall has been recognized as the main hydrometeor parameters that has most significant adverse effect on radio wave propagation at frequency above 10 GHz. The more intense the rainfall, the higher the attenuation. In the recent time, the issue of climatic change and its adverse effect on mankind as well as communication links has become a global concern. Therefore, the inconsistency in climatic conditions has motivated the need to observe trend and variability in climate change for future prediction of rain attenuation on microwave links. The International Telecommunication Union - Radio (ITU-R) rain climatic zones classification have been designed following the characteristics of precipitation measurement taken mostly in temperate region and has been reported unsuitable for tropical microwave link design [1-4].

This paper presents results from analysis of 32 years long term rain data from Abeokuta, Nigeria. The analysis concentrates on the useful rain rate information employed in microwave link budget design. The rain rate exceeded at 0.01% of an average year employed in attenuation prediction has been reported to have increased over the years all over the globe [5-8] particularly in the rain forest region under which the region of this work focuses. Quite a number of research studies have examined the impact of climate variations on communication systems using statistical analysis and simulation models. These studies clearly demonstrated the sensitivity of both temperate and tropical communication systems to climate changes. Mamen and Tjelta [9-10] analyzed the trends in light of climate change using tipping bucket rain gauge data for Norway which falls under temperate region. Their study focused on Norwegian long-term rain rate data analysis from Blindern station to indicate climate change and found that the rain rate varies considerably from year to year. The work showed that $R_{0.01}$ has significant increased in all parts of the country from where long-term data existed. Similar works of importance are Vilar and Burgueño [6], Kvicera [7], Fiser [8] in the Czech Republic, and Paulson [11-12]. Their analyses show that a 7 year to 10 year period preferably is needed for a stable estimate of the average rainfall but not suitable for prediction of systematic change of climate. Hence, the need to observe the trend and variability of rain

rate derived from long-term measurement in Nigeria. This paper is organized in four sections. Section II presents background of study area and data collection while the results and discussion are presented in section III. The conclusion of the work is presented in section IV.

II. Background of Study Area and Data Collection

Abeokuta, the capital city of Ogun state, is located in the south western region of Nigeria on the West Africa coast. It lies within the 7°8'N and 7°21'N latitude and 3°20'E and 3°55'E longitude, having a ground level elevation varying from +30.00m to +153.00m as referred to on the national grid datum. Abeokuta is situated within the confines of rocks on the plateau of Egba division of Ogun State, lying along the water shed of Ogun River and having a rugged and undulating topography. The town lies within the rain forest climatic zone of Nigeria with two major seasons; the wet season and the dry season. The annual mean temperature varies during the day from 20° to 34° with its relative humidity ranging between 65% and 75% and rainfall from 928mm to 3240mm per year. For the study areas, the climate is determined by the movement of two air masses – dry tropical coherent Air mass (CT), this originate from the Sahara Desert and is responsible for the dry season and the most tropical marine (MT), from the Atlantic Ocean, which is responsible for the rainy season. The rainy season is interrupted by short breaks which usually occur in August, but heavy rain in September [13] hence having tropical rainfall pattern with seasonal distribution. The parameters of the station under consideration are 1982, 2014, 33 for first, last and number of years of measurement used for the trend analysis, respective.

Rainfall data for the period of 33 years (1982-2014) were collected both at Nigeria Meteorological station, Osodi, Lagos and Ogun-Osun River Basin Development Authority, Nigeria (OORBDA), Ogun state. The rain gauge has a bucket size of 0.1mm to 0.5 mm per tip. The rain gauge records the number of tipping in 1-minute integration time. No data is recorded if the bucket does not tip which means there is no or very little rain i.e. less than 0.5 mm/minute or 30 mm/h. The accuracy of the rain gauge is above 90% and the period of the equipment down time is less than 5%. The accuracy of the rain gauge is measured based on calibration records done at every 6-month interval. The readings for one minute were averaged and recorded every minute by the data logging system. Data were extracted from the rain logger into Microsoft Excel for statistical processing. Rain rates at different percentages of time are estimated from the data using Macro Excel program to extract the number of times different rain rate occur and then the complementary rain rate cumulative distribution (ccdf) is obtained for each year.

The Coefficient of Variation (CV) used for the analysis is given as;

$$CV = \frac{\sigma}{\bar{R}} \times 100\% \quad (1)$$

where \bar{R} the mean of the entire rain rate series and σ is the standard

deviation from the mean of the series.

The correlation coefficient (r) used is also defined as;

$$r = \frac{\sum(Y \cdot R) - N(\bar{Y} \cdot \bar{R})}{\sqrt{(\sum Y^2 - N\bar{Y}^2)(\sum R^2 - N\bar{R}^2)}} \quad (2)$$

where r is correlation coefficient, N is total number of observations in the series, R is the observation in the series, Y is the time in years, σ_Y is the standard deviation of Y and σ_R is the standard deviation of R.

III. Results and Discussion

Annual rainfall shows a large variability from year- to- year with a general increase although with occasional gentle decline in total annual accumulation. Annual rainfall is averaged to be 1288.895 mm within the period under consideration. There was sharp increase in rainfall recorded in 2011 and 2012 as shown in fig. 1 with corresponding percentage overshoot of 234% and 251.6% respectively. The simulated rain rate averaged over Abeokuta shows a definite increasing trend, and analysis suggests tendencies of occasional extreme rain events. Also, the distribution of rain rate exceeded at 0.01% of the year varies considerably from year to year as shown in fig. 2.

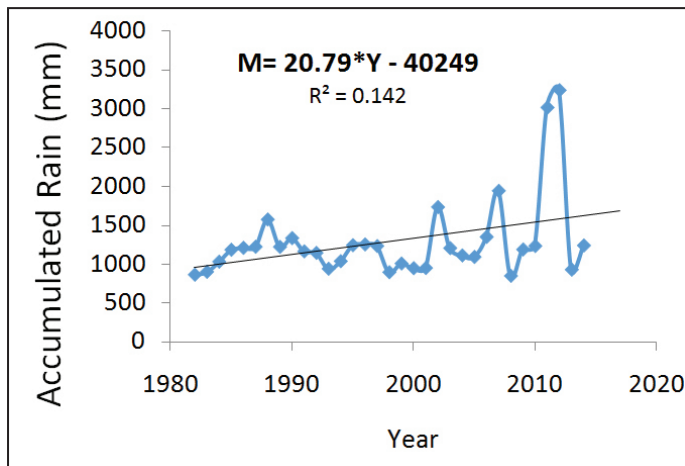


Fig. 1: Plot of Annual Precipitation for the Period of 33 years

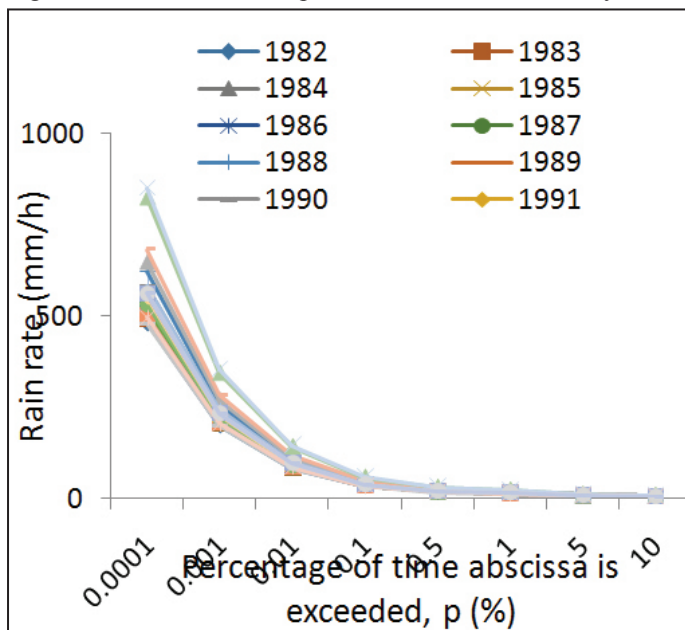


Fig. 2: Percentage of time abscissa is exceeded, with its corresponding Rainfall rate distributions

Fig. 3 shows the yearly distribution with the range between 89.71695mm/h and 158.6318mm/h, indicating significant increase of 68.91485 mm/h over the 33 years of data. In-homogeneities observed were very likely related to the long term fluctuations and trends, which are accepted within other non-randomness characteristics of the series of climatological observations [14]. For the station under consideration, it is seen from fig. 1 that the rain rate follows an increasing trend in the period 1982 to 1988 with declining trend for the next five years. The fluctuation errors follow a normal distribution with standard deviation $\sigma = 12.26154$ mm/h or $\sigma = 0.106515$ if $\log_e R_{0.01}$ is considered.

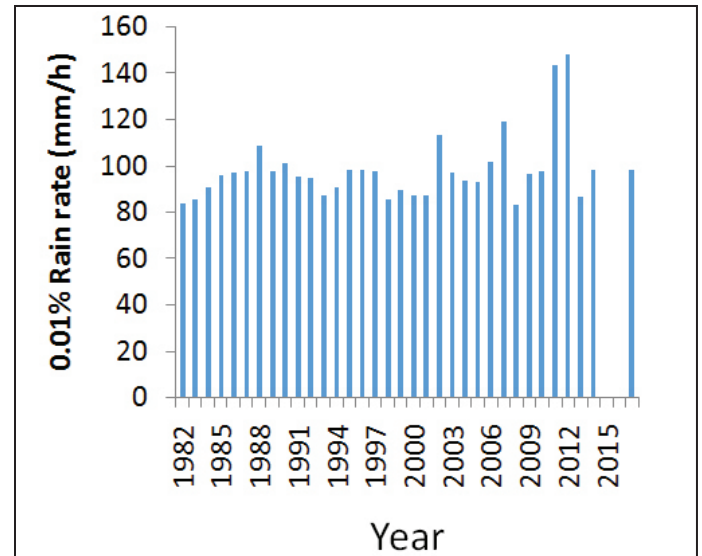


Fig. 3: Annual Rain rate exceeded at 0.001% of year

The measured rain rate exceeded for 0.01% of time for 33 years was regressed on time as shown in fig. 4 with simple regression analysis carried out to obtain the equation of the line of best fit as:

$$R_{0.01} = -1010 + 0.554 \cdot \text{Year} \quad (1)$$

where $R_{0.01}$ is the actual rain rate exceeded for 0.01%. The result of regression analysis shows that rainfall significantly affected the value of rain rate. Regression trend line for estimating accumulated yearly rain as shown in fig. 4 for Abeokuta is obtained as

$$M = 20.79 \cdot Y - 40249 \quad (2)$$

where M is Accumulated Rain, and Y is Year. The Standard Deviation σ is 12.26.

From the trend line equation, it observed that the stations had a positive slope, i.e., $a > 0$ for both annual precipitation and rain rate. For the annual accumulated rainfall, the trend gradient coefficient is 20.79 and the intercept is -40249 as shown in equation(2) which conforms with the same pattern in temperate region [15] but higher in value due to higher rain intensity in the tropical region under consideration. The coefficient of variation (C.V) fluctuates, being higher as the modeled rain rate deviates from the actual value, shows variability with the yearly trend. Also, the Correlation Coefficient (r) is 34349.0106; the value being positive indicating upward trend in the time series analysis.

In the result overview, there is an increase in rain rate when the entire 33 years were analyzed, but the rate observed in shorter intervals in between varies much.

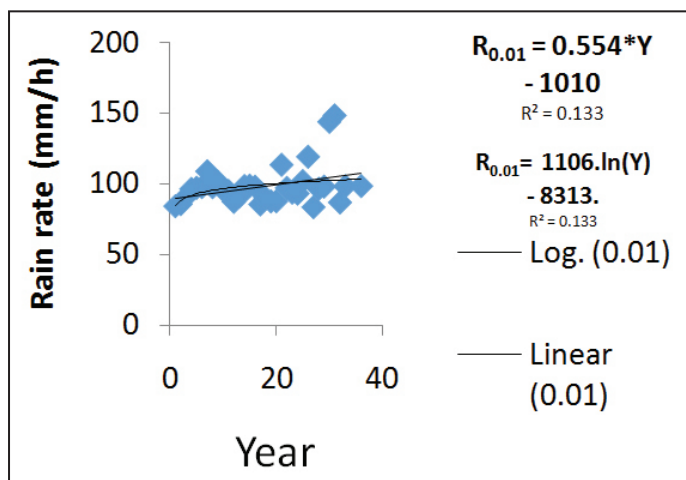


Fig. 4: Rain rate exceeded at 0.01% of year

IV. Conclusion

This study reveals that Abeokuta in Nigeria is experiencing a rise in rainfall intensity implying susceptibility to the attendant consequences of signal outage. The increase in total rainfall suggested a change in the corresponding rainfall rate distribution. Therefore, rise in rain event trend will result in increase in signal attenuation experienced by earth-space communication systems. These climatic changes will certainly have significant effect on the performance of existing radio systems, and hence need to be taken into cognizant consideration when planning future systems.

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