Seasonal Variation of Radio Refractivity in Calabar, Nigeria

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ABSTRACT
Seasonal variation of radio refractivity in Calabar in the year 2016 was investigated. The daily averages of radio refractivity were calculated from the temperature, relative humidity and atmospheric pressure data obtained from the Nigeria Meteorological Agency (NIMET). In order to get the seasonal radio refractivity, daily averages of refractivity for each of the six months of the dry season (i.e. January, February, March, October, November and December) and six months of the rainy season (i.e. April, May, June, July, August and September) were calculated. Result shows that radio refractivity was higher in rainy season than dry season in Calabar in the year 2016.This we assume is due to the difference in the moisture content of the atmosphere in the two seasons.

Keywords - *Refractivity, seasonal, Weather, Atmospheric refraction.*

1. INTRODUCTION
Atmospheric refraction affects propagation of electromagnetic waves and this effect has been studied from the beginnings of radio wave technology. It has been shown that the path bending of electromagnetic waves due to inhomogeneous spatial distribution of the refractive index of air causes adverse effects such as multipath fading and interference, attenuation due to diffraction on the terrain obstacles or radio holes. These effects impede radio communication, navigation and radar Systems. Fluctuation of atmospheric parameters cause the refractive index of the air in the troposphere to vary from one point to the other. Consideration of the refractive properties of the lower atmosphere is important when planning and designing terrestrial communication systems mainly because of multi-path fading and interference due to trans-horizon propagation. Several studies have shown that radio refractivity affects signal propagation (e.g.; [1], [2], [3], [4] etc.). Hence the significance of the study of refractivity. Radio signals are affected mostly by variability in radio refractivity which leads to a decrease in their speed or rate of propagation which eventually cause propagation delay or attenuation in the troposphere.

Calabar, located in the southern part of Nigeria experiences a rare type of climate known as the tropical monsoon climate, Calabar is on Latitude 4°57'06"N and longitude 8°19'19"E at an elevation of 42m above sea level. It experiences precipitations almost throughout the whole year except in the core months of the dry season which occurs in two short periods of January to March and October to December during a calendar year. Accordingly, we have focused on the first period of January to March and October to December as representing the dry season while the rainy season is considered for the months of April to September of the 2016 calendar year.

2. THEORY OF REFRACTIVITY
The refractive index of the atmosphere is approximately unity and the variation is so small, which make it difficult to work with. A more convenient variable to use when modeling the variation of refractive index in the atmosphere is the refractivity, N which is defined as [5]:

$$N = (n-1) \times 10^6 \qquad (1)$$

where n is the refractive index of the atmosphere.
Refractivity and meteorological parameters such as the atmospheric pressure, temperature, vapor pressured are related by:

$$N = \frac{77.6}{T}\left(P + 4810\frac{e}{T}\right) = 77.6\frac{P}{T} + \left(3.732 \times 10^5 \frac{e}{T^2}\right) \qquad (2)$$

Where;
P: Atmospheric Pressure (hPa)
e: Water vapour pressure(hPa)
T: Absolute temperature (K)
Refractivity of the lower atmosphere (troposphere) is divided into two compositions; the dry and the wet composition. The dry term contributes a greater percentage, about 70% to the total value of the refractivity in the atmosphere. The dry term is proportional to the density of the gas molecules in the atmosphere and changes with their distribution. The dry term of refractivity, which is fairly stable, can be modeled with an accuracy of about 20% using surface

measurements of pressure, P (hPa) and temperature, T (Kelvin) as:

$$N_{dry} = 77.6\frac{P}{T} \quad (3)$$

Conversely, the wet term contributes the major variation of refractivity in the atmosphere. Wet term is due to the polar nature of the water molecules and is given by:

$$N_{wet} = 3.732 \times 10^5 \frac{e}{T^2} \quad (4)$$

3. METHODOLOGY

Maximum and Minimum temperature data, as well as, those for average daily relative humidity and average daily atmospheric pressure in Calabar for the twelve month of 2016 were obtained from the Nigeria Metrological Agency(NIMET). These were analysed to evaluate the monthly radio refractivity variations, using well known relations. The temperature averages are obtained from averaging the average daily temperatures, according to;

$$T_{avg} = \frac{T_{min} + T_{max}}{2} \quad (5)$$

T_{avg} = Average daily temperature in degree Celsius

T_{min} = Minimum daily temperature in degree Celsius.

T_{max} = Maximum daily temperature in degree Celsius.

The daily variations in the metrological parameters are evaluated, starting from the partial pressure of water (e) in air

$$e = \frac{e_s H}{100} \quad (6)$$

where

H: Relative Humidity

e_s: Saturated vapour pressure, e_s is calculated using Clausius-clapeyron relation;

$$e_s = 6.11\ exp\left(\frac{17.26(T-273.16)}{T-35.87}\right) \quad (7)$$

T: Temperature in Kelvin.

The radio refractivity for each day within the month is then calculated using equation (2) as in [4].

The recorded data for the refractivity for each of the months in the dry season and rainy season where plotted against the days of each month respectively on same graph

The second step involved calculating the daily averages of refractivity for each of the six months of the dry season (i.e. January, February, March, October, November and December) and daily averages for each of the six months of the rainy season (i.e. April, May, June, July, August and September) to get the overall average of refractivity for the dry season and the rainy season respectively.

4. RESULTS

The results are as shown in the graphs below, Fig's.1 and 2 show the radio refractivity variation for the first and second periods of the dry season of 2016. Fig 3 shows the mean variation profile of the radio refractivity for the dry season. Fig's. 4a and 4b show the mean radio refractivity variation for the dry season and the driest month of 2016. Fig.5 shows the mean radio refractivity variation for the rainy season of 2016. Fig's. 6a and 6b show the mean radio refractivity variation for the rainy season and the rainiest month of 2016. Fig's. 7a and 7b shows a comparative plot of radio refractivity variations for the dry and rainy seasons of 2016.

The compact nature of the plots in Fig's.4a, 6a and 7a prompts the plots of Fig's. 4b, 6b and 7b in order to bring out the distinction between the seasonal radio refractivity in Calabar more discerning. It is clear that the average rainy season radio refractivity is a little higher than the dry season mean. By calculation it is found that;

Average Rainy Season Refractivity =377.5

Average Dry Season Refractivity = 376.5

results which confirm the graphical results.

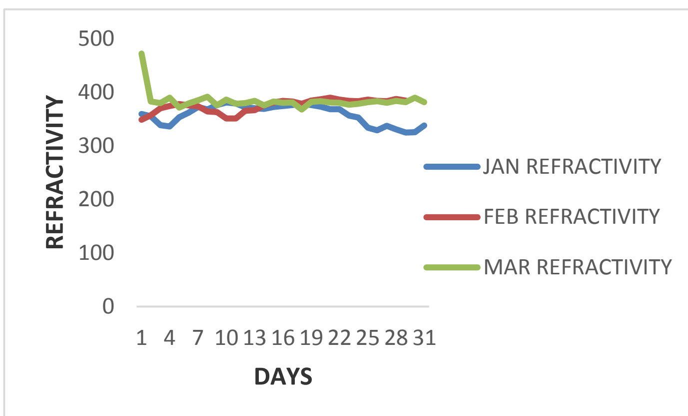

Figure 1; Radio Refractivity Variation for the first dry season of 2016 (January to March).

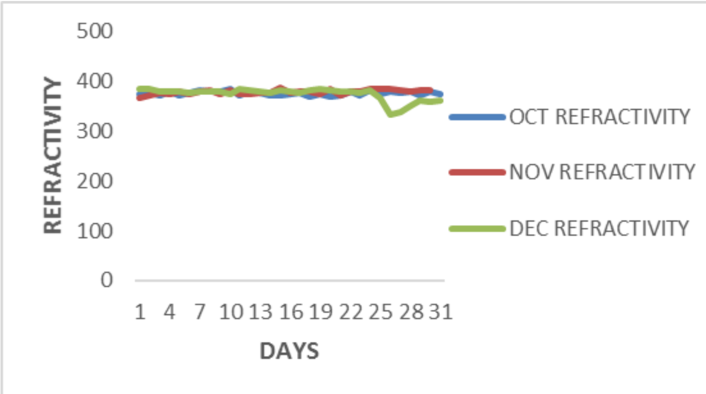

Figure 2; Radio Refractivity Variation for the second dry season of 2016 (October to December).

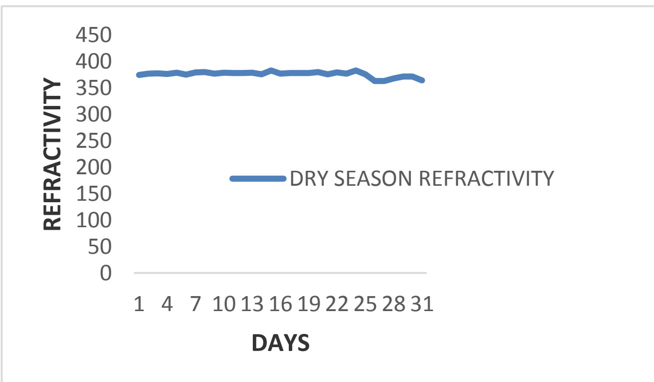

Figure 3; Mean Radio Refractivity Variation for the dry season of 2016

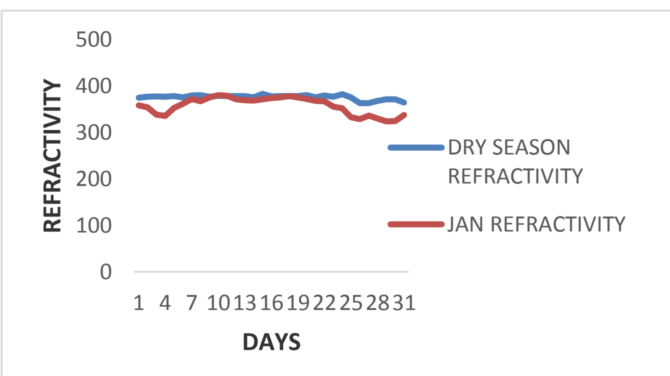

Figure 4a; Mean Radio Refractivity Variation for the dry season and the driest month of 2016

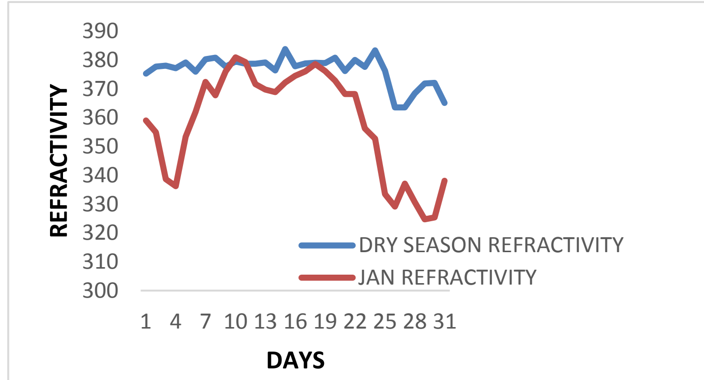

Figure 4b; Mean Radio Refractivity Variation for the dry season and the driest month of 2016

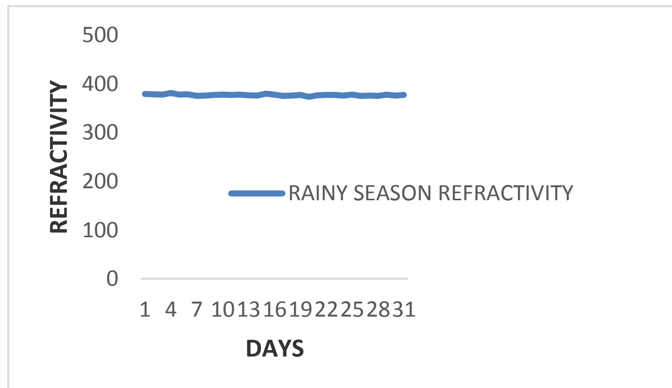

Figure 5; Mean Radio Refractivity Variation for the rainy season of 2016 (April to September)

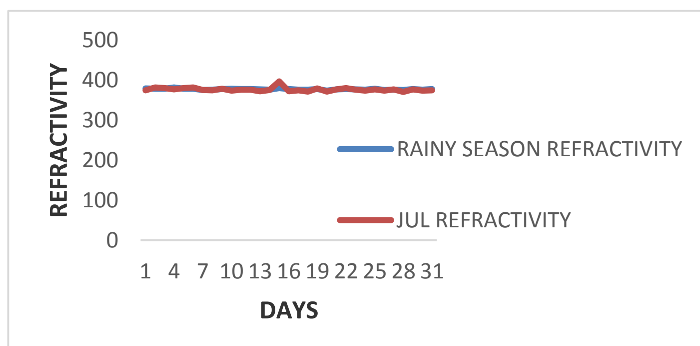

Figure 6a; Mean Radio Refractivity Variation for the rainy season and the rainiest month of 2016

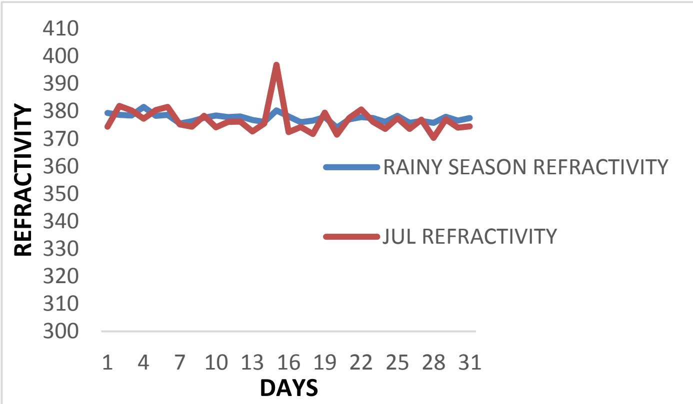

Figure 6b; Mean Radio Refractivity Variation for the rainy season and the rainiest month of 2016

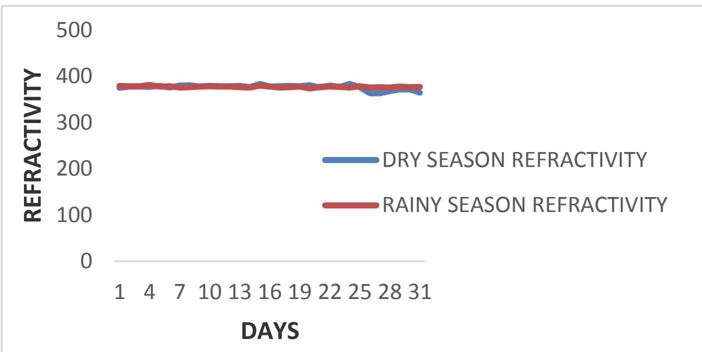

Figure 7a; Radio Refractivity Variations for the dry and rainy seasons of 2016

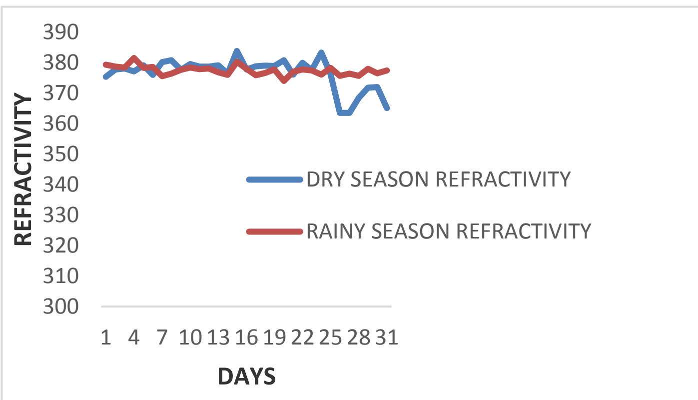

Figure 7b; Radio Refractivity Variations for the dry and rainy seasons of 2016

5. DISCUSSION

From the results of Fig.1-7 respectively it is seen that there is very little variation in the seasonal radio refractivity for both seasons. Again, there is very little difference between the rainy and dry season refractivity due to the fact that Calabar experiences an almost uniform weather through-out the year. This agrees with the findings of earlier studies by [4]. The fact that the radio refractivity here is averagely slightly higher in the rainy season than in the dry season has to do with more moisture content in the lower atmosphere, which makes it denser than in the dry season. Waves travelling through a dense medium experience greater delay than through a less dense medium.

6. CONCLUSION

Our conclusion here that the mean radio refractivity in Calabar is higher in the rainy season than in the dry season confirms with what obtains in some other cities or location in Nigeria, e.g., Jos-Plateau [6]

7. ACKNOWLEDGEMENT

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