Monthly Variation of Radio Refractivity in Calabar, Nigeria

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ABSTRACT
Monthly 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). This was analysed for twelve months in year 2016 and radio refractivity was calculated. The maximum value of 472.0 was obtained in March and the minimum value is about 324.78 which was obtained in January. Results show that radio refractivity pattern variation in Calabar in 2016 varied slightly due to the almost uniform weather condition of Calabar. The radio refractivity data obtained in this study will provide radio engineers with adequate information relevant for the design of communication systems in Calabar.

Keywords - *Refractivity, Signal, Troposphere, Weather, relative humidity.*

1 INTRODUCTION

The propagation of electromagnetic waves in the atmosphere specifically the troposphere is greatly affected by the composition of the atmosphere. This is due to the fluctuations of atmospheric parameters like temperature, pressure and relative humidity primarily at the troposphere which is normally referred to as “the lower” part of the earth. Variations of temperature and moisture in the propagation path cause local refraction of the signal, resulting in signal loss and increase of noise.

Several works on refractivity and its effects on radio wave propagation have been carried out in some selected locations in Nigeria using radiosonde and in situ data [1], [2], [3] and [4]. [5] studied the variation of tropospheric surface refractivity at Nsukka. Data were collected over a twelve-month period using the Vantage PRO II Automatic Weather Station. Results of their analysis showed that the surface refractivity is generally higher in the wet season than in the dry season.

It is shown that a change in temperature influences refractivity much more than a change in either humidity or pressure.

Calabar, located in the south-south part of Nigeria experiences a rare type of climate known as the tropical monsoon climate, which is slightly different from what obtains in Nsukka. 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 is very short and sometimes experiences sporadic rainfalls [6].

[7] did a research in this location where they observed the pattern of variation in dry season refractivity. The result was that slight variations occur in February compared to other dry season months. This, the thought, was because it is the closest dry season month to the rainy season.

[8] also investigated the pattern variation during the rainy season. The result was that there was no significant variation in the rainy season refractivity except partial changes in July where temperatures and relative humidity are usually a little higher at the beginning of the month. [9] examined the effects of temperature, relative humidity and atmospheric pressure on the tropospheric radio refractivity in the rainy and dry season in Calabar, Cross River State of Nigeria. They also investigated the variation in the refractivity between the two seasons. Results obtained from their study indicate that the average monthly Radio Refractivity for rainy season is higher than that of the dry season for a greater part of the year. However, there were no discernable differences between the radio refractivity for the two seasons, indicating that the climatic condition of Calabar contributes to only a little deviation of variation in season refractivity. Studies carried out in other parts of the country clearly show some difference between dry and rainy season refractivities.

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 [10]:

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

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:

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

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:

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

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;

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

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

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

Where
H: Relative Humidity
e_s: Saturated vapour pressure, e_s is calculated using Clausius-clapeyron relation;

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

T: Temperature in Kelvin.
The radio refractivity for each day within the month is then calculated using equation (2).
The recorded data for the refractivity for each of the month of the year was plotted against the days of each month respectively on same graphs.
In order to estimate the pattern variations, the mean refractivity for each January to December is calculated as

$$\bar{N} = \frac{\sum N}{n} \qquad (8)$$

Where
$\sum N$: Sum of daily refractivities
n: Number of days in the month
$\bar{N}$ = monthly average refractivity

The standard deviation of refractivity for each month is calculated as [8]

$$S = \sqrt{\frac{\sum N^2}{n} - \bar{N}^2} \qquad (9)$$

4 RESULTS

The results are as shown in the graphs below in Fig.1-14. Fig 13 shows the variation pattern of refractivity for all months of the year under investigation. The maximum value of 472.0 is obtained for daily refractivity in March and the minimum value of about 324.78 was obtained for daily refractivity in January. Averaging the refractivity across each month, January has the lowest average refractivity of 358.25 ± 18.40 and March has the highest average refractivity of 383.95 ± 17.05 .

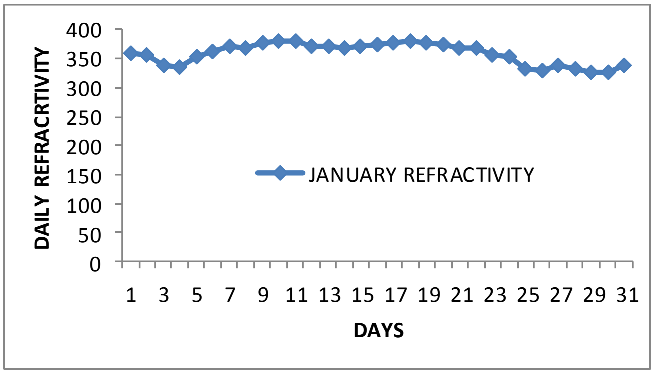

Fig. 1: Daily Variation of Radio Refractivity for January

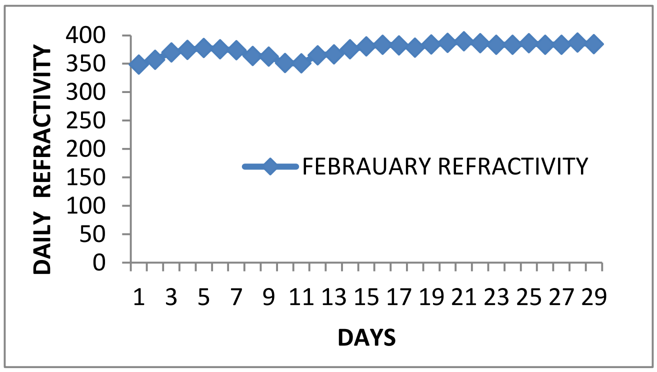

Fig. 2: Daily Variation of Radio Refractivity for February

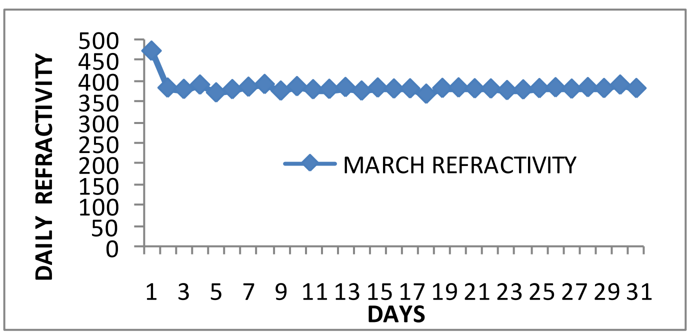

Fig. 3: Daily Variation of Radio Refractivity for March

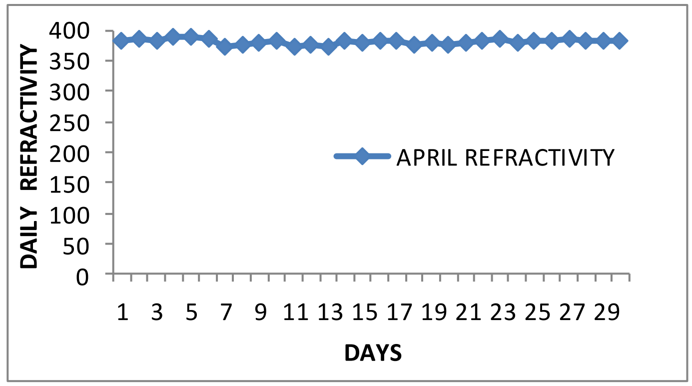

Fig. 4: Daily Variation of Radio Refractivity for April

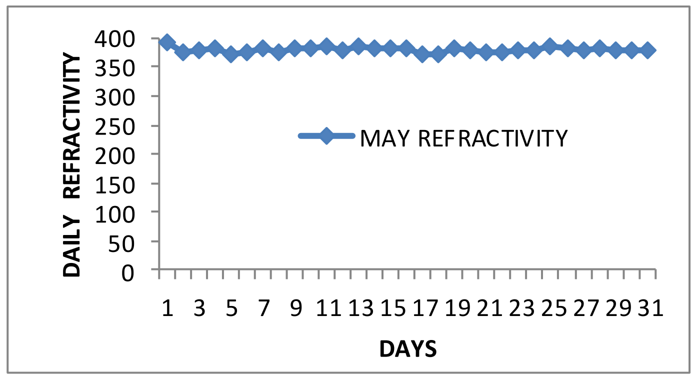

Fig. 5: Daily Variation of Radio Refractivity for May

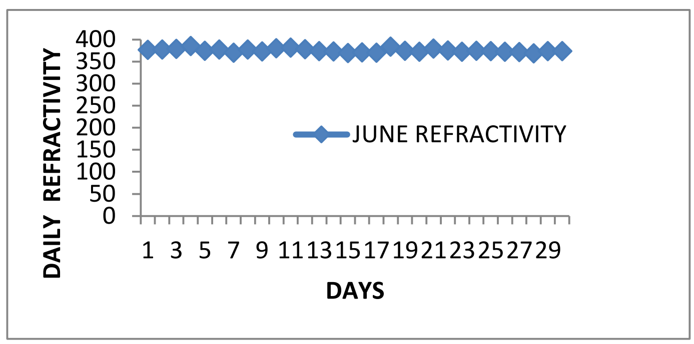

Fig. 6: Daily Variation of Radio Refractivity for June

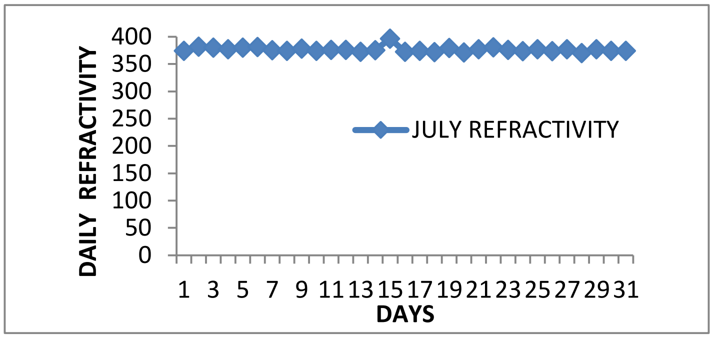

Fig. 7: Daily Variation of Radio Refractivity for July

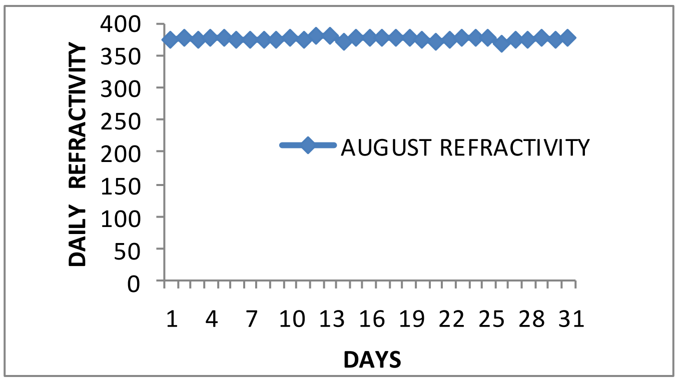

Fig. 8: Daily Variation of Radio Refractivity for August

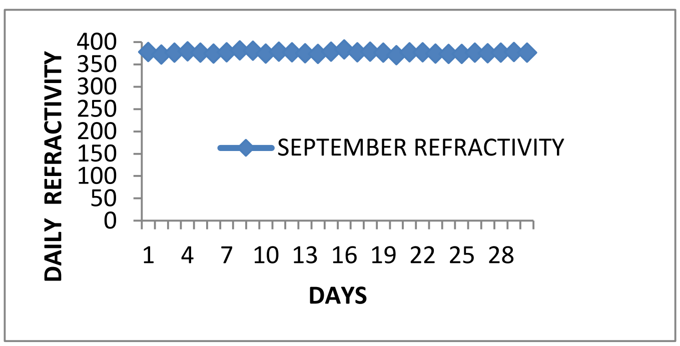

Fig. 9: Daily Variation of Radio Refractivity for September

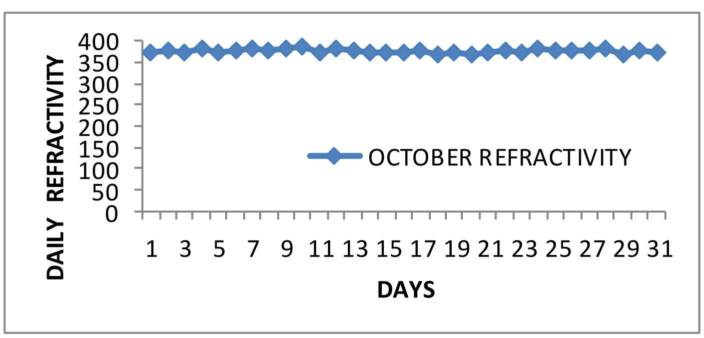

Fig. 10: Daily Variation of Radio Refractivity for October

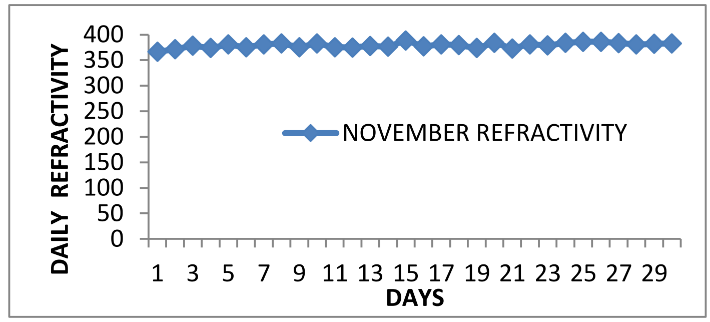

Fig. 11: Daily Variation of Radio Refractivity for November

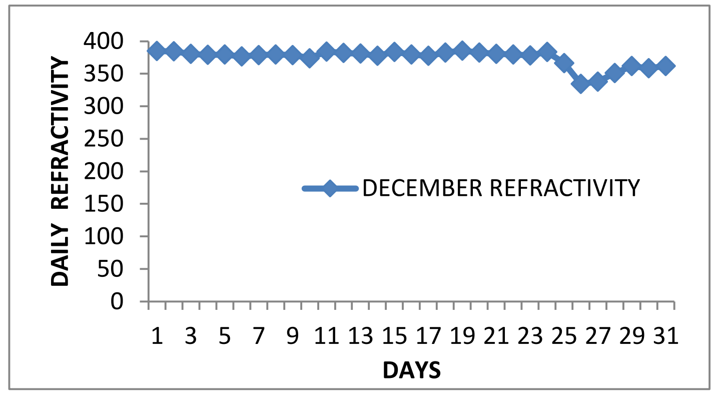

Fig. 12: Daily Variation of Radio Refractivity for December

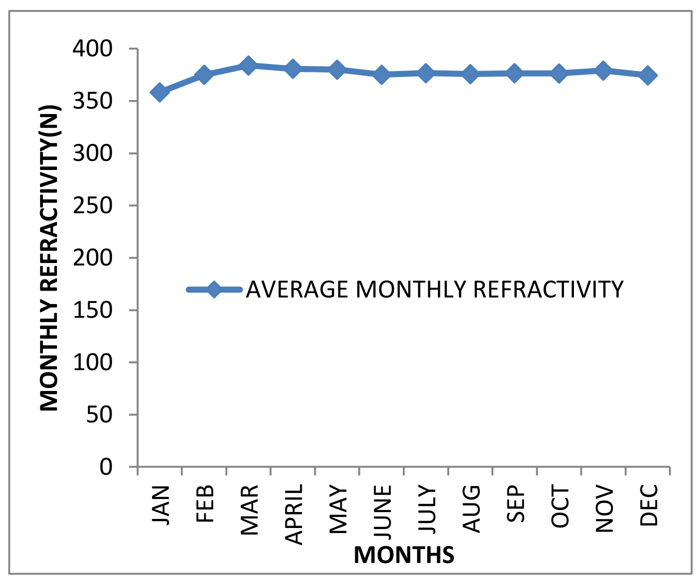

Fig. 13: Average Radio Refractivity Variation for all months of the year

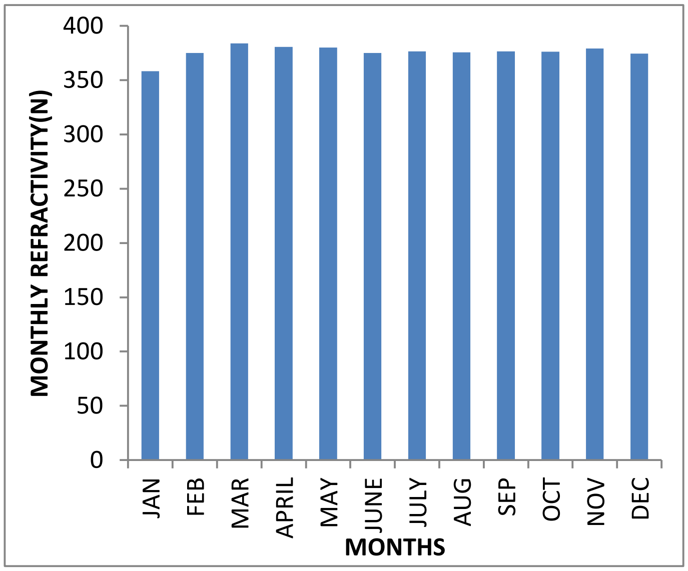

Fig. 14: Average Radio Refractivity Variation for all months of the year

5 DISCUSSION

The standard deviations for the daily refractivity for each month are evaluated using equation (9) and it is observed that August has the lowest standard deviation of 2.6 with percentage of 0.69% which is in agreement with earlier studies by [8], while the highest standard deviation is obtained in the month of January 18.4 with percentage of 5.13%. August standard deviation validates the fact that atmospheric metrological parameters are almost stable in the month of August compared to other months in the rainy season.

From the results of Fig.1-14 respectively it is seen that there is very little variation in the monthly refractivities. Obviously, there is very little difference between the rainy and dry season refractivity due to the fact that Calabar experiences an almost uniform weather.

Under Köppen's climate classification [6], Calabar features a tropical monsoon climate with a lengthy wet season spanning ten months and a short dry season covering the remaining two months. The harmattan, which significantly influences weather in West Africa, is noticeably less pronounced in the city. Temperatures vary very little throughout the year, with average high temperatures usually ranging from 25 to 28 degrees Celsius. There is also little variation between daytime and nighttime temperatures, as temperatures at night are typically only a few degrees lower than the daytime high temperature. Calabar averages just under 3,000 millimetres of precipitation annually.

6 CONCLUSION

The monthly variation of refractivity in Calabar in the year 2016 is not significantly different from results of preceding years. It is seen to be very little above. This may be due to the observed small increase in the tropospheric temperature and humidity and it therefore resulted to very high radio refractivity within the year.

7 ACKNOWLEDGEMENT

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8. REFERENCES

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