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Comparative Analysis of Tropospheric Radio Refractivity during Rainy Season in Calabar, Nigeria

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Abstract: This research paper evaluates the variations in radio refractivity in Calabar, Cross River State, Nigeria. The research work was carried out from data obtained from the Nigeria Meteorological Agency (NIMET) for a period of 10 years (2010 to 2019) within the rainy season from March to October. The yearly averages of refractivity were calculated from meteorological parameters provided. The analysis carried out generally shows slight variations in refractivity during this period with the highest value occurring during the wet season in 2016 and the least value occurring in 2014. The study also showed a linear relationship between water vapour pressure and refractivity, with an R^2 value of 0.9902 while the relationship between refractivity and temperature had an R^2 value of 0.8442.

Keywords: Meteorological parameters, Radio refractivity, Rainy season, R^2 value, Water vapour pressure.

I. INTRODUCTION

Radio communication is one major means of sharing and receiving information. As these signals travel from one point to another they tend to experience certain degree of energy loss due to several factors. Since radio signals are propagated by carrier waves traveling through the earth's atmosphere it becomes imperative to understand the wave's mechanism of propagation through different environments and their conditions [1]. The degree of atmospheric effects on radio signals depends mainly upon the frequency, power of the signal and on the state of the troposphere through which the radio wave propagates [2]. Temperature is one major meteorological parameter in determining refractivity. Therefore evaluating temperature variation is important in predicting radio signal propagation [3]. It is widely agreed that variations in pressure, temperature and relative humidity within the troposphere causes changes in the refractive index of air which can affect the propagation of signals [4].

There are several researches on the variation of radio refractivity in Nigeria. [4] Investigated the radio refractivity in Akure, south west Nigeria and concluded that the refractivity gradient was greater than zero and vary slightly throughout the months of the year. [2] Studied surface radio refractivity in Akwa, south eastern Nigeria. From the analysis it was seen that surface refractivity in Awka varies with seasons and with high values during rainy season and low values during dry seasons. In his work on seasonal variation of surface radio refractivity and water vapour density, results showed that surface refractivity and water vapour density generally have higher values during the rainy season than dry season at all stations studied [5]. [6] and [7] also carried out similar researches on seasonal variations of radio refractivity in Calabar, south south Nigeria. In both studies there were variations in rainy and dry season refractivity. This research is aimed at comparing radio refractivity in Calabar during the wet season, from 2010 to 2019, to ascertain the degree of changes in radio refractivity over the said period and to also compare, refractivity with temperature and water vapour pressure.

II. METHODOLOGY

Meteorological data such as atmospheric temperature, relative humidity and water vapour pressure of Calabar from 2010 to 2019 were obtained from Nigeria Meteorological Agency (NIMET) at Calabar airport.

The data were analysed to determine the degree of changes in refractivity. For all the years under consideration, the refractivity during the rainy season were calculated using standardized relationships and compared with the average temperature and water vapour pressure during the period under review. The atmospheric radio refractivity index n , was calculated using

$$n = 1 + N \times 10^{-6} \quad (1)$$

Where the radio refractivity, N is:

$$N = 77.6 \frac{P}{T} + 3.73 \times 10^5 \frac{e}{T^2} \quad (\text{N-units}) \quad (2)$$

The dry term of the radio refractivity, N_{dry} is:

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

For the wet term of the radio refractivity, N_{wet}

$$N_{wet} = 3.73 \times 10^5 \frac{e}{T^2} \tag{4}$$

Where

e : Water vapour pressure (hpa)

P : Atmospheric pressure (hpa)

T : Average temperature (K)

The water pressure (e) in air was computed from

$$e = \frac{e_s H}{100} \tag{5}$$

Where H : Relative Humidity, e_s saturated vapour pressure (hpa).

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

T = temperature in kelvin. [8], [9].

The mean refractivity for each year was calculated using $\bar{N} = \frac{\sum N}{n}$

Where

$\sum N$: Sum of monthly refractivity

N : number of months

\bar{N} : Yearly average refractivity

III. RESULTS AND DISCUSSION

Meteorological parameters, gotten from NIMET were used for this research. The average monthly parameters were used to calculate for the yearly refractivity using eq. (2). The refractivity for each year is plotted against the years, as shown in the graph below.

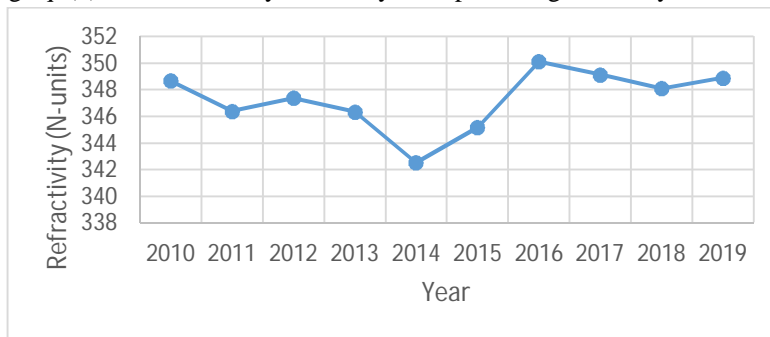


Fig 1: Yearly variation of Refractivity

From Fig. 1 it is seen that during the rainy season of the years evaluated, the highest refractivity occurred in 2016, and the lowest refractivity occurred in 2014. This variation is due to the difference in temperature and relative humidity during these years. The results also show a slight variation in refractivity all through the period considered. This indicates that the meteorological parameters in Calabar have been relatively stable during this period.

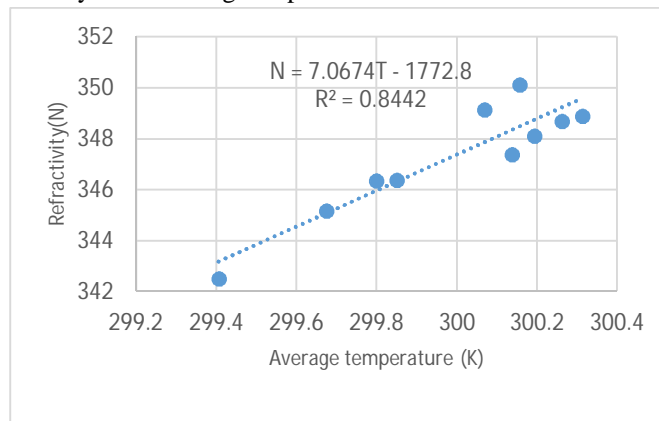


Fig. 2: Linear relationship between refractivity variations and average temperature

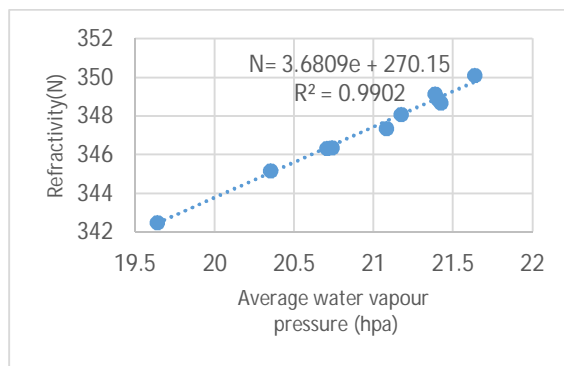


Fig. 3: Linear relationship between refractivity variations and average water pressure

In Fig. 2 refractivity was observed to increase as temperature increases, with some exceptions. For instance, the highest refractivity in the period considered was in 2016 while the highest temperature was in 2019. It was also observed in Fig. 3 that refractivity increases linearly as water vapour pressure increases. The highest and least refractivity and water vapour pressure both occurred in the same years.

Fig. 1 and Fig. 2 show a strong correlation between refractivity and temperature and between refractivity and water vapour pressure respectively. The regression equations derived from the study are given as:

Relationship between refractivity and temperature

$$N = 7.0674T - 1772.8 \quad (6)$$

$$R^2 = 0.8442 \quad (7)$$

Relation between refractivity and water vapour pressure

$$N = 3.6809e + 270.15 \quad (8)$$

$$R^2 = 0.9902 \quad (9)$$

Where

N = Refractivity (N –units)

T = Average temperature (K)

e = Water vapour pressure (hpa)

R^2 = Coefficient of determination (R-squared value).

IV. CONCLUSION

This study on refractivity shows that meteorological parameters contributes to radio refractivity. It has also shown that the highest and least refractivity during these periods occurred in 2016 and 2014 respectively. Because of the slight changes in refractivity during the period under review, it is safe to conclude that the meteorological parameters in Calabar have been quite stable.

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