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Influence of Weather Variables on Atmospheric Refractivity over Auchi Town, Edo State, Nigeria

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ABSTRACT: In this study, atmospheric variables such as air temperature, relative humidity and atmospheric pressure were evaluated in order to determine the atmospheric refractivity over Auchi town in Edo State, Nigeria using a portable weather monitoring system. The data revealed that, the average atmospheric refractivity was 354.31 N-units. It was observed that air temperature, relative humidity and atmospheric pressure were having significant influence on the atmospheric refractivity during all the months in 2017. This influence was much during the months with higher rainfall (wet season), than the months with lesser rainfall (dry season). The air temperature was having the higher influence compared to that of the relative humidity and the atmospheric pressure. This study will assist the management of radio communication systems for enhancement and improvement purposes.

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The electromagnetic waves that are propagated in the lower atmosphere (troposphere) are mainly influenced by the different components that made up the atmosphere, as a result of the variations of the some major atmospheric weather variables which includes; atmospheric temperature, atmospheric pressure and relative humidity in the troposphere (Korak, 2003; Agbo, *et al.,* 2013; Ukhurebor and Azi, 2018). The variations in these atmospheric weather variables cause the refractive index of the air in this region of the atmosphere (troposphere) to differ from place to place. It is obvious that the path bending of electromagnetic waves as a result of the inhomogeneous spatial distribution of the refractive index of air causes hostile effects such as multipath fading and interference, attenuation due to diffraction on the terrain obstacles which is also known as the radio holes (Martin and Vaclav, 2011). The variation in refractivity in the troposphere is a function of weather variables (Agbo, *et al.,* 2013; Ayantunji, *et al.,* 2011; Okoro, *et al.,* 2012; Ukhurebor and Azi, 2018).

The refractivity in the atmospheric depends on some physical variables of the air such as air temperature, atmospheric pressure and water content. It varies in space and time as a result of the physical processes that take place in the atmosphere which are often not too easy to describe in a deterministic manner and have to be considered in most cases as random with its probabilistic characteristics (Martin and Vaclav, 2011; Ukhurebor and Azi, 2018). The various phenomena in the wave propagation like ducting, scintillation, refraction, fading of electromagnetic waves, range and elevation errors in radar acquisition are as a result of refractivity (Martin and Vaclav, 2003). Refractive characteristics are very crucial in the planning and designing of terrestrial communication systems, due to multi-path fading and interference due to trans-horizon propagation. Recent researches on atmospheric refractivity effects uses both the experimental results obtained from in situ measurements of atmospheric refractivity and the computational methods to simulate the refractivity related propagation effects (Martin and Vaclav, 2011). Refractivity variation studies are relevant in telecommunication network, navigation and surveillance systems in order to mitigate with the problems that may occur as a result of anomalous radio wave propagation and unpredicted path loss that affects the performance of these systems (Ukhurebor and Azi, 2018). These unpredicted radio wave propagations can cause intense effects to the extent of complete breakdown of communication between the transmitters and the receivers or even make radar to completely miss its intended target (Alam, *et al.,* 2016; Ukhurebor and Azi, 2018).

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In this study the measurement of three atmospheric weather variables (atmospheric temperature, relative humidity and atmospheric pressure) were made at 50 m height above ground level at the Administrative building of Edo University Iyamho, Auchi area of Edo State, Nigeria for a period one year (January to December, 2017) using a self-designed cost effective portable weather monitoring systems. The measured weather variables were used to calculate the atmospheric refractivity variation and seasonal transaction characteristics over Auchi area, South-South, Nigeria and the results would be useful to the management of radio communication systems for enhancement and improvement purposes.

MATERIALS AND METHODS

Mathematical Information: It has been shown that the electromagnetic waves that are passing through the atmosphere bends, due to the various layers of the atmosphere and its permittivity, but it would have otherwise travel in a straight path if it was homogeneous; as a result of this spatial distribution of the refractive index of the air which causes hostile effects (Martin and Kvicera, 2011; Ukhurebor and Azi, 2018). The atmosphere's refractive index, n and the relative permittivity, $\mathcal{E}_r$ can be connected with (Adediji, *et al.,* 2011; Alam, *et al.,* 2016; Ukhurebor and Azi, 2018);

$$n^2 = \mathcal{E}_r \quad (1)$$

Since the value of the atmospheric refractive index is close to one and the variation is infinitesimal. A suitable parameter that can be used when modeling the variation of the atmospheric refractive index is the refractivity, N which is defined as;

$$N = (\boldsymbol{n} - 1) \times 10^6 \quad (2)$$

The Refractivity, N and atmospheric weather variables such as the air temperature, atmospheric pressure, vapor pressured are connected by;

$$N = \frac{77.60}{T}\left(P + 4810\frac{E}{T}\right) \quad (3)$$

The atmospheric refractivity, N can thus, be expressed as (ITU-R, 2004);

$$N = 77.60\frac{P}{T} + \left(3.73 \times 10^5 \frac{E}{T^2}\right) \quad (4)$$

The troposphere refractivity can be divided into two proportions, namely; the dry proportion and the wet proportion. The dry proportion contributes about 70% of the total refractivity in the troposphere. This dry proportion increases with increasing density of the gas molecules and changes with their distribution. It is normally stable and can be calculated from the measured air temperature and atmospheric pressure with an accuracy of about 20% (Agbo, *et al.,* 2013) using;

$$N_d = 77.60\frac{P}{T} \quad (5)$$

Where P is barometric pressure (millibars) and T is absolute temperature in Kelvin.

On the other hand, the wet proportion which is as a result of the polar nature of water molecules, contributes the main variation of refractivity in the atmosphere and can be calculated (Agbo, *et al.,* 2013) using;

$$N_w = 3.73 \times 10^5 \frac{E}{T^2} \quad (6)$$

Where E is partial pressure of water vapor (millibars) and can be calculated from;

$$E = \frac{RH}{100} \times E_s \quad (7)$$

Where RH is the relative humidity (%) and E_s which is the saturated vapor pressure (millibars) by;

$$E_s = 6.11 \times 10^{\frac{17.27\,(T-273.15)}{T-35.85}} \quad (8)$$

Area of Study: The measurements of the atmospheric weather variables were done at the administrative building block of Edo University Iyamho, Auchi area of Edo State, South-South, Nigeria which is located within Latitude 7.07°N and Longitude 6.27°E of the Greenwich Meridian. This area experiences the humid tropical climate, which is characterized by wet and dry seasons. The vegetation of the area is that of the Savannah, with mostly open grassland and few scattered fire resistant trees. The topography is relatively undulating and it slopes from the north of the area to the south (Ojeifo and Akhimien, 2013; Ukhurebor and Azi, 2018).

Material and Method of Measurements: A self-designed inexpensive portable weather monitoring system was used for the measurements of the various atmospheric weather variables used for this study. The weather monitoring system measure atmospheric weather variables and store them on a micro SD card. Details of the system design and implementation including its validity is contained in Ukhurebor *et al.*, (2017a).

The fixed measuring method by placing the weather monitoring system on the 50 m above ground level was employed for the measurements of the atmospheric weather variables of air temperature, atmospheric pressure, relative humidity and light intensity at the administrative building block of Edo University Iyamho, Auchi area of Edo State, Nigeria for continuous measurement of these weather variables. The measured weather variables are then copied from the weather monitoring system to the computer from the micro SD card. The measurements of the atmospheric variables were made for a period of one year (January to December, 2017). The weather variables were collected and the records cover twenty four hours each day from 00 hour to 2300 hours local time at intervals of one hour. Although, the weather monitoring system measures about four atmospheric weather variables as stated earlier, only the daily records of air temperature; which is defined as the measure of temperature at different levels of earth's atmosphere which is expressed in degree Celsius (^{o}C), atmospheric pressure; which is defined as the force exerted on unit surface area on the earth by the weight of earth's atmospheric air above its surface which is often expressed in (mbar/hPa) and relative humidity (%); which is defined as the ratio of the amount of water vapor in the air at any given temperature to the maximum amount of water vapor that the air can hold (Ukhurebor *et al.*, 2017a; Devaraju, 2015), were used for this part of the research.

RESULTS AND DISCUSSION

The analysis for this study was done procedurally via calculation of the atmospheric refractivity from the measured atmospheric weather variables (air temperature, relative humidity and atmospheric pressure). Some statistical analysis was also done so as to determine their variability as shown in Figure 1. Comparisons of the various measured atmospheric variables and the calculated atmospheric refractivity values were also done graphically. The results are presented in the various plots of measured weather variables against the calculated atmospheric refractivity during the various months (January to December) in 2017 as shown in Figures 2-4.

The calculated atmospheric refractivity values for the months (January to December) in 2017 range from 316.00 N-units to 370.00 N-units with an average value of 354.31 N-units. These calculated results agree very well with the results of Adedeji*et al.*, (2011) and Falodun and Ajewole (2006) were they obtained the average surface refractivity values of 366 N-units and 369 N-units for Akure, Ondo State, Nigeria, respectively. Both results are in conformity with the results of Bean and Dutton (1968) where they obtained an annual average value of surface refractivity for subtropical savannah as 350–400 N-units with an annual range of 30–60 N-units.

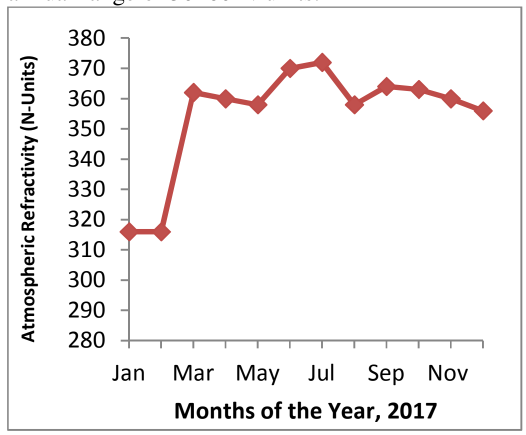

Fig. 1: Monthly Variations of Atmospheric Refractivity

In Figure 1 the calculated atmospheric refractivity variations for the one year period under consideration (January to December, 2017) on monthly basis which were obtained from the monthly records are shown. It was observed that the values are higher during the months of March, April, May, June, July, August, September and October which happens to be the period of much rainfall and are occasioned by very high air humidity values; while, the values were lower in the months of November, December, January and February which happens to be the dry period were rainfall are limited and are occasioned by very low air humidity.

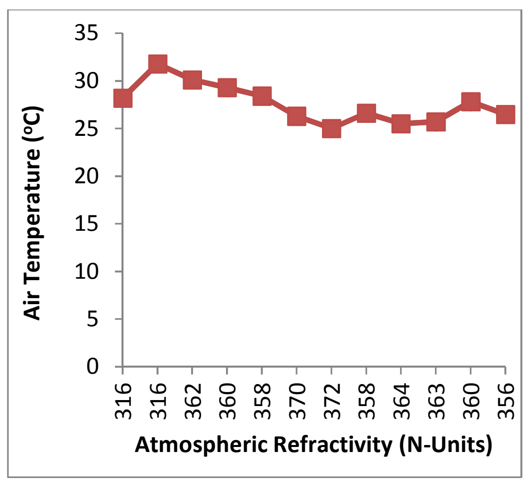

Fig. 2: Air Temperature with Atmospheric Refractivity

Figure 2 shows the plot of the measured air temperature against the calculated atmospheric refractivity during the various months (January to December) in 2017.

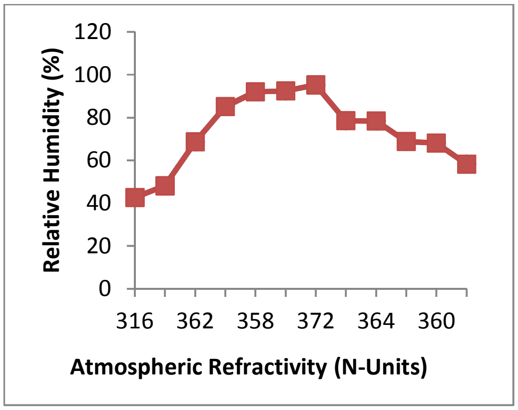

Fig. 3: Relative Humidity with Atmospheric Refractivity

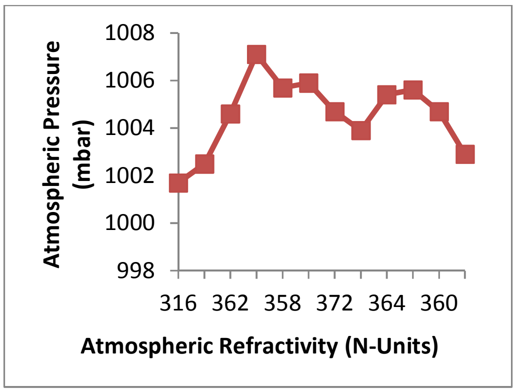

Fig. 4: Atmospheric Pressure with Atmospheric Refractivity

Figure 3 shows the plot of the measured relative humidity against the calculated atmospheric refractivity during the various months (January to December) in 2017, while Figure 4 shows the plot of the measured atmospheric pressure against the calculated atmospheric refractivity during the various months (January to December) in 2017. It was observed that these measured weather variables were having significant influences on the calculated atmospheric refractivity during all the months in 2017, and these influences were more pronounced during the months with much rainfall that is; March, April, May, June, July, August, September and October (rainy season), compared with the months with lesser rainfall that is; November, December, January and February (dry season).

In all, the measured air temperature was seen to be having much influence on the calculated atmospheric refractivity all through the months in 2017, this again affirm that fact that air temperature have significant influence on other weather variables (Ukhurebor *et al.*, 2017b).

Conclusion: From the results obtained from this study, it was inferentially concluded that the measured air temperature, relative humidity and atmospheric pressure were having significant influence on the calculated atmospheric refractivity during all the months in 2017 and these influences were much during the months with higher rainfall (wet season) while the measured air temperature was having much influence on calculated atmospheric refractivity all through the months in 2017. The results from this study will assist the management of radio communication systems in improving their quality of service.

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