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ATMOSPHERIC REFRACTIVITY OVER ABUJA, NIGERIA

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ABSTRACT: *Atmospheric refractivity at Abuja was investigated for disturbed days and quiet days during dry and rainy season. The result of the investigation showed that refractivity variation for disturbed and quiet days during dry and wet season over Abuja are governed by the changes in atmospheric parameters which conversely cause changes in refractive index. The correlation of refractivity with pressure, temperature and relative humidity for disturbed and quiet days indicated that relative humidity and pressure as well as temperature have great correlation effect for disturbed and quiet day in wet season as well as in dry season.*

KEYWORDS: Atmospheric parameters, refractivity, correlation

INTRODUCTION

The propagation of electromagnetic waves in the atmosphere (mainly the troposphere) is greatly affected by the composition of the atmosphere (Korak, 2003). 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. Troposphere extends from the earth surface to an altitude of about 10km at the earth poles and 17km at the equator (Hall, 1979). These fluctuations of the atmospheric parameters cause the refractive index of the air in this layer to vary from one point to the other. Refractivity is responsible for various phenomena in the wave propagation such as ducting and scintillation, (Martin, and Vaclav, 2003) refraction and fading of electromagnetic waves, (Steven, 1996) range and elevation errors in radar acquisition (Anthony, *et al.,* 2003). Consideration of the refractive properties of the lower atmosphere is of certain importance when planning and designing terrestrial communication systems mainly because of multi-path fading and interference due to trans- horizon propagation. Several works carried by many researchers showed that the refractivity fluctuation in the lower atmosphere (troposphere) is a function of atmospheric parameters. Agbo *et al* (2009), studied variation of troposheric refractivity at Nsukka in South Eastern Nigeria. Ayantunji *et al* (2011), studied diurnal and seasonal variation of surface refractivity over Nigeria. Norland (2006), in his work stated that even small changes of temperature, humidity and partial water vapor pressure lead to changes in the atmospheric refractive index. Short time variation of the refractive index over line-of-sight paths of approximately 3 km in mountainous coastal waters using X-band was presented by Norland (2006). Salema, (2003) stated that seasonal variation of refractivity gradient could cause microwave systems unavailability. Okoro *et al* (2012) studied the effect of variation of meteorological parameters on the tropospheric radio refractivity for Minna, Nigeria.
Abuja, the capital city of Nigerian is situated in the North central of Nigeria with total population of 776.29, (2006 Census). It is located at latitude of 9^{o}326 N (9.05735) and longitude of 7^{o}2923E

(7.48976). Abuja being a tropical region features distinct climate; wet and dry climate. The territory experiences three weather conditions annually. This includes, a warm, humid (raining season) and blistering (dry season). The wet season is characterized with heavy down purr (rainfall). It falls between the months of April and October. The dry season, on the other hand, is characterized with scanty or no rainfall and dry dust laden atmosphere. The season lies between the month of November and March.

Considering September and November for wet and dry season respectively, this work, therefore, investigates the atmospheric refractivity variation over Abuja using atmospheric parameters, and as well determines the transition characteristics between dry and wet seasons.

THEORY OF REFRACTIVITY

The refractive index of the atmosphere is close to 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:

$$N = (n-1)x10^6 \quad (1)$$

where n is the refractive index of the atmosphere.

Refractivity and meteorological parameters such as the atmospheric pressure, temperature, vapor pressured are related by:

$$N = \frac{77.6}{T}(P + 4810\frac{\ell}{T}) = 77.6\frac{P}{T} + \left(3.732x10^5\frac{\ell}{T^2}\right) \quad (2)$$

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:

$$N_{dry} = 77.6\frac{P}{T}$$

(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:

$$N_{wet} = 3.732x10^5\frac{e}{T^2}$$

(4)

e is water vapor pressure and can be computed with the following set of equations.

$$x = \frac{17.2694(T-273.15)}{T-35.85} \quad (5)$$

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

$$e_s = 6.11 \text{ x } exp(\text{x})(\text{mbars}) \quad (7)$$

where:

P=Barometric pressure in millibars, T = Absolute temperature in Kelvin, e =Partial pressure of water vapor in millibars, e_s = Saturated Vapor pressure in millibars.

MATERIALS AND METHOD

This work was carried out by launching of meteorological balloons and also by the use of radiosounde to get the atmospheric parameters which aided in the calculation of refractivity. The measured parameters are temperature and relative humidity at constant pressure levels. The measured atmospheric parameter values were classified according to observation hours, days of the year, and pressure levels. After a preliminary day-by-day statistical process according to the standard deviation of each pressure level, the data were cleared from any, unrealistic values. Before calculating the refractivity indices, interpolation procedures were followed to fill in missing values. The first interpolation procedure was made in a day-by-day manner according to the reference pressure levels and was the most important in the sense that it was applied directly to the initial measured data and provided most of the interpolated values, forming smoothed and enriched curves of temperature, relative humility and height versus pressure. The next interpolation procedure was also applied each day. Its purpose was to transform the data according to a reference height, common for the whole dataset. This procedure also enriched the low altitude values and also detected and corrected days where abnormal fluctuations of the original data where present. After the analysis of data according to the above procedures, the refractivity N was calculated using equation (2) represented as follow:

$$N = \frac{77.6}{T}(P + 4810\frac{\ell}{T}) = 77.6\frac{P}{T} + \left(3.732x10^5 \frac{\ell}{T^2}\right) \quad (8)$$

where all the parameters still maintains their standard value as defined in the previous pages.

RESULTS AND DISCUSSION

The data of daily atmospheric observations performed at fixed time of 00 and 1200 hours in Abuja was used. The analysis of the data by means of procedures and calculation of refractivity were followed by a statistical evaluation in order to assess their variability. In other to achieve this, graphical comparisons of the measured atmospheric parameters and refractivity were employed. The results are shown in different plots of refractivity against atmospheric parameters during the two seasons (dry and wet seasons) as represented in the following figures (Fig: 1- 12). Figures 1-3 show the plots of atmospheric parameters with refractivity for disturbed day in November, 2009

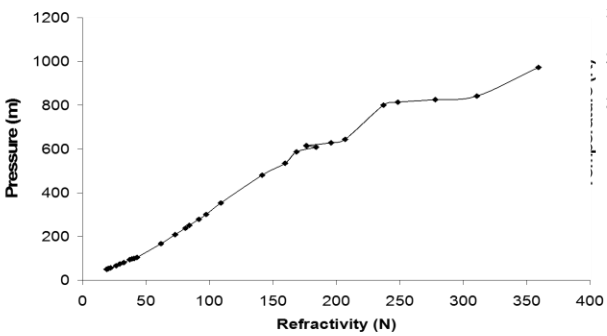


Figure1: Refractivity variation with pressure

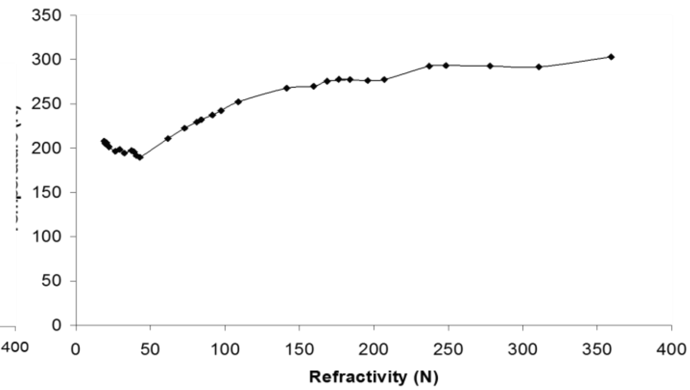


Figure2: Refractivity variation with temperature

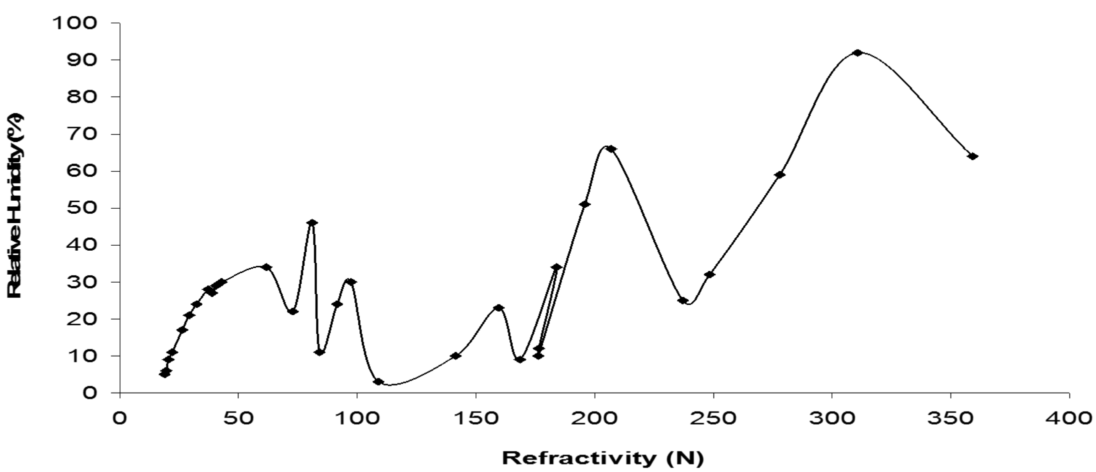
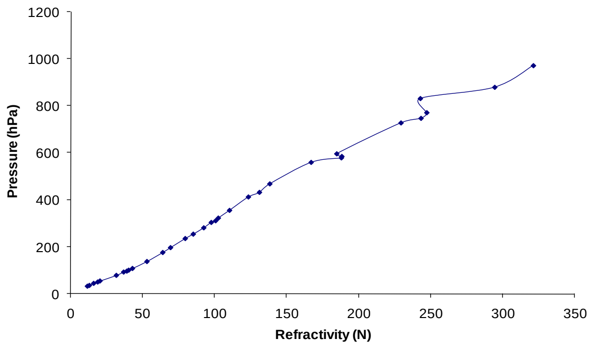


Figure3: Refractivity variation with relative humidity

Figures 4-6 show the plots of atmospheric parameters with refractivity for quiet day in November, 2009



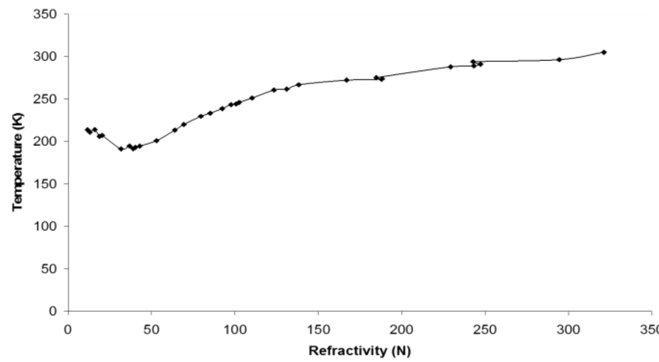


Fig 4: Refractivity variation with pressure **Fig 5: Refractivity variation with temperature**

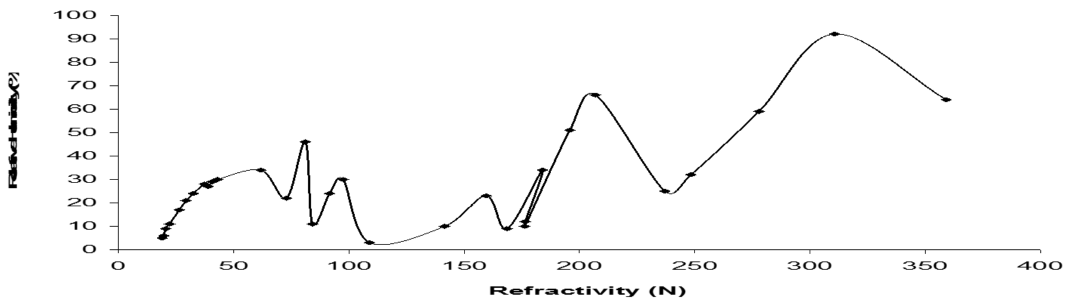


Fig 6: Refractivity variation with relative humidity

In fig 1-3 and fig 4-6, the plots of atmospheric parameters with refractivity during disturbed and quiet days display almost similar characteristics in their variations. The plots of pressure against refractivity (fig 1 and fig 4) were observed to increase progressively from 0 hPa to about 600 hPa where it started showing a concurrent decrease and increase until about 1000 hPa where their maximum peak occurred for disturbed and quiet days. Fig 2 and fig 5 (plots of temperature against refractivity) also follow the same trend. At about 180K and 50N-unit, there is a minimum decrease in temperature. Thereafter, the temperature increased steadily as refractivity increases during quiet and disturbed days. In the case of relative humidity, there are more pronouncing randomness in the change of relative humidity with refractivity for both disturbed and quiet days. This characteristic is normal as it shows the inception of dry season from November.

Figures 7-9 show the plots of atmospheric parameters with refractivity for disturbed days in September, 2009

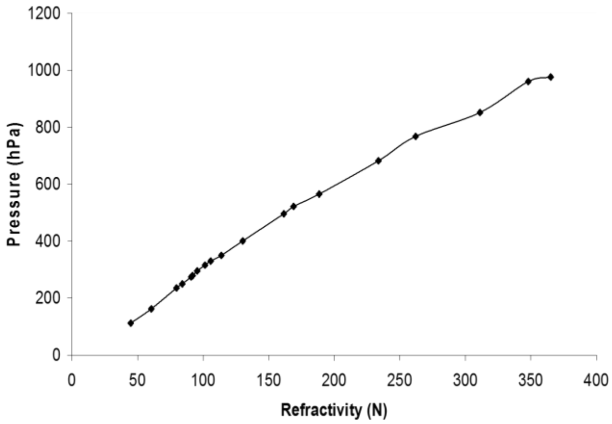


Fig 7: Refractivity Variation with pressure

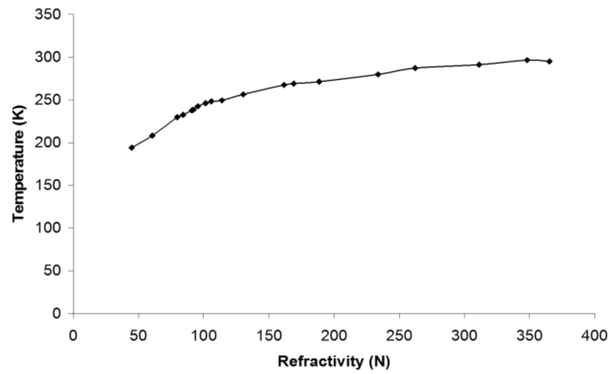


Fig.8: Refractivity Variation with temperature

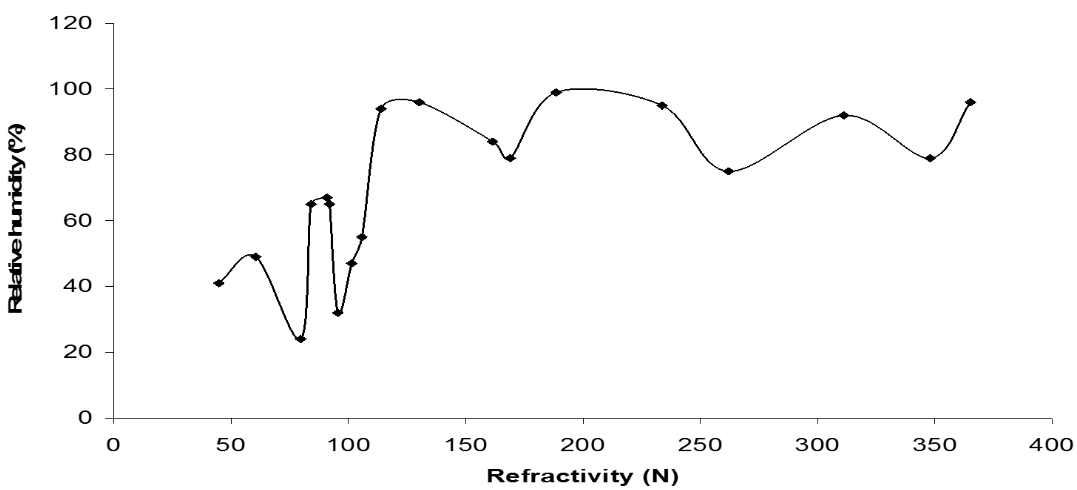


Fig 9: Refractivity Variation with relative humidity

Figures 10-12 show the plots of atmospheric parameters with refractivity for quiet days in September, 2009

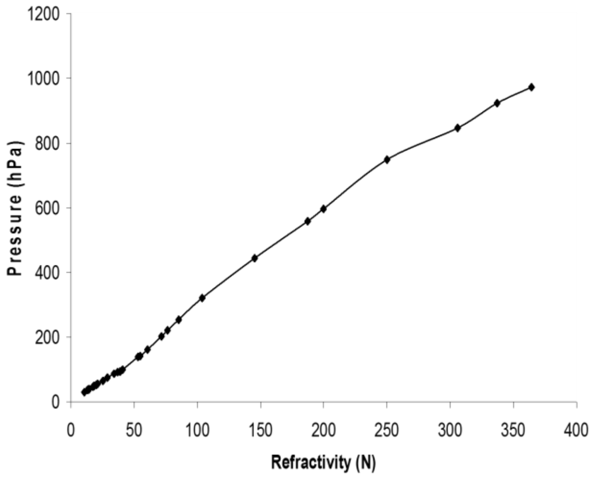


Fig 10: Refractivity variation with pressure

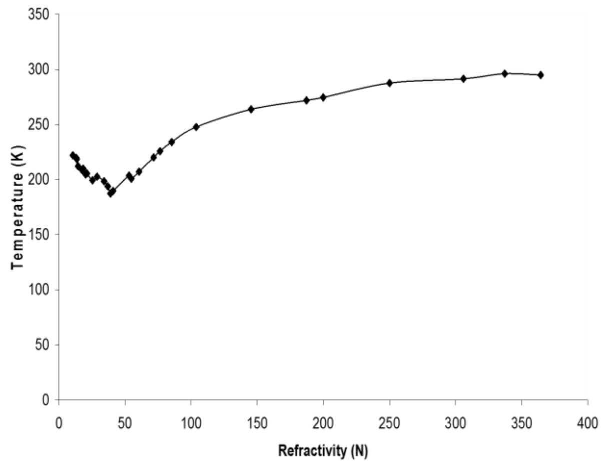


Fig 11: Refractivity Variation with relative humidity

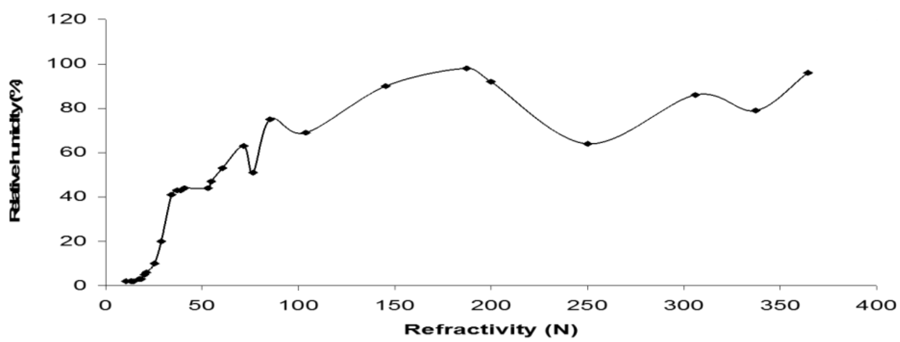


Fig 12: Refractivity variation with relative humidity

In contrast, it is clearly noticed in figs. 7-12 that pressure appears higher in wet season than it is in dry season, both on disturbed and quiet days. Temperature appears higher in dry season than in wet season on both disturbed days and quiet days. Relative humidity is higher on disturbed days in dry season and lower on quiet days in dry season than in wet season. This means that pressure in wet season affect refractivity more than in dry season. Once more, temperature variation in the atmosphere is greater in dry season than it is in wet season. This is obvious during dry season as the atmosphere is heated up more by the solar radiation. During disturbed days, relative humidity become more pronounced in dry season than in wet season, while on quiet days, it's greater in wet season than in dry season. It is observed to be increasing steadily as refractivity increases, though there is still some randomness in its variations.

Table 1: Refractivity Correlation on Pressure, Temperature and Relative humidity for November, 2009 (dry season)

Parameters	Correlation values	
	Disturbed day	**Quiet day**
Pressure (hPa)	0.98765	0.93673
Temperature(K)	0.943812594	0.947844
Relative humidity (%)	0.63733	0.59915

Table 2: Refractivity Correlation on Pressure, Temperature and Relative humidity for September, 2009 (wet season)

Parameters	Correlation values	
	Disturbed day	**Quietist day**
Pressure(hPa)	0.991625	0.99763
Temperature(K)	0.91860053	0.92692
Relative humidity (%)	0.633535327	0.79085

In Tables 1 and 2, respectively, it is clearly observed that pressure and relative humidity have high correlation values for both disturbed and quiet days during rainy season than in the dry season. On the other hand, temperature has high correlation values for both disturbed and quiet days during dry season. Therefore, the atmospheric refractivity can be calculated with about 63.7%, 59.9% of relative humidity respectively for disturbed and quiet days in November and also in September, the values are 63.4% and 79.1% respectively for both disturbed and quiet days. This implies that relative humidity has more precision level in September (wet season) than in November (dry season).

CONCLUSION

Atmospheric refractivity over Abuja, Nigeria, has been investigated. The analysis showed that all the atmospheric parameters, have significant influence on refractivity over Abuja for both disturbed and quiet days during dry and rainy seasons. Relative humidity and pressure as well as temperature were found to have greater influence during wet season while temperature has great influence on refractivity during dry and wet seasons as displayed in the correlation values.

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