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# Contribution of Some Meteorological Parameters in the Variation of Tropospheric Radio Refractivity in Yola, Nigeria

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**Abstract**

The contribution of some meteorological parameters such as temperature, relative humidity and pressure in the variation of tropospheric radio refractivity in Yola using surface data is investigated. Three years (January 2011-December 2013) data were collected using Campbell Scientific Automatic Weather Instrument. The CR1000 data logger type is used for measurement, and data storage is for five minute update cycle. The data were analyzed using Excel and Matlab Softwares. The results reveal that variation of these three meteorological parameters (temperature, relative humidity and pressure) in the troposphere contributes reasonably well to the tropospheric radio refractivity variation in Yola. The results of the analyses also show that the mean diurnal and seasonal refractivity variations were due to contribution from both dry and wet terms of refractivity. The multiple regression analysis shows that 99.5% of the refractivity variation at Yola is due to meteorolgical parameters, for the period investigated. These results are evidence that variations of these parameters in the troposphere caused tropospheric radio refractivity variation in Yola, Nigeria.

***Keywords:*** *Troposphere, Meteorological parameters, Refractivity, Surface data and Regression.*

**Highlight**

- The variation of refractivity in Yola, Nigeria was attributed to variations of the three meteorolgical parameters (temperature, relative humidity and pressure).
- The diurnal and seasonal refractivity variations were results of the contributions of both the wet and dry terms of refractivity.
- The regression model is used to predict the dependent variable (refractivity) from the independent variables ((temperature, relative humidity and pressure).

## Introduction

The three main divisions of communication systems include the receiver system, the propagation channel and the transmitter system. The integrity of the information received at the receiver depends on how much the signal is distorted in the propagation channel. The propagation channel which is important in any communication system could be fibre optic, coaxial cable or the atmosphere. Refraction in the lower atmosphere called the troposphere relies on the variations in space of the refractive index. The radio refractive index is defined as the ratio of the speed of propagation of radio energy in a vacuum to the speed in a specified medium. The radio wave propagation is determined by changes in the refractive index of air in the troposphere (Adediji and Ajewole, 2008). Temperature, relative humidity and atmospheric pressure are among the factors which influence the radio wave signal propagation or radio frequency in the troposhere. Therefore, refractivity variation in the troposphere is a function of temperature, relative humidity and pressure (Saha, *et al.*, 2005; Tomar, 2012).

The study of the tropospheric radio refractivity has stimulated much interest because of its influence on radio wave communication in the lower atmospheric layer called troposphere. Hall (1979) defined troposphere as part of the atmosphere where changes in meteorological parameters such as temperature, humidity, pressure and other factors like clouds and rain contribute to the variation of radio wave propagation from one place to another.

The dependence of refractivity on atmospheric parameters such as pressure, humidity and temperature in Jos, Nigeria was investigated by Agbo (2011). He revealed that both hourly and diurnal surface refractivity are highly dependent on humidity and that there is a negative correlation relationship between the surface refractivity and temperature. Studying the diurnal and seasonal variation of surface refractivity over Nigeria, Ayantunji, *et al.* (2011a and b) observed that diurnal variation is mainly driven by the dry component of refractivity in the rainy season and wet component in the dry season. They also concluded that refractivity shows a seasonal variation with high value in the rainy season and low value in the dry season. The variation in the tropospheric surface radio refractivity over Makurdi was investigated by Isikwue, *et al.* (2013).

Their results revealed that the dry term of refractivity, influenced by high pressure value contributes to the variation of radio refractivity at Makurdi. Bawa, *et al*. (2015) studied the average hourly variations of radio refractivity variations across some selected cities in Nigeria including Yola. The results of their investigations among others revealed that the diurnal variation of refractivity over Yola is attributed to the wet term of refrativity. Tyabo, *et al.* (2018) on investigating the diurnal and seasonal variation of surface refractivity in Minna and Lapai concluded that the surface diurnal refractivity was higher in the early and night hours and lower values occurred during the day.

The advent of mobile communication in Nigeria and the increase in the number of Television (TV) and Frequency Modulation (FM) stations operating in the very high frequency (VHF) and ultra high frequency (UHF) bands has increased the complexity of frequency allocation. Therefore, it is essential to study the radio refractive index in the troposphere for adequate coverage and reduction in interference of signals. However, this study focuses on contribution of temperature, relative humidity and pressure in variation of tropospheric radio refractivity in Yola, Nigeria using surface data.

**Materials and Methods**

The data used in this study were meteorological ground data collected from the Centre for Atmospheric Research, (CAR), Anyigba, Kogi State University, under the supervision of National Space Research and Development Agency (NASRDA), Abuja, Nigeria. The hourly, monthly and seasonal variations of tropospheric radio refractivity in Yola, Nigeria using January 2011 – December 2013 surface data collected by means of the Campbell Scientific Automatic Weather Instrument was studied. The CR1000 data logger type is used for measurement and data storage was five minute update cycle. The records cover 24 hours each day from 00:00 hours to 23:00 hours local time. The data collected were averaged over each hour to give twenty four data points representing diurnal variations for each day. The hourly data for each day is further averaged to give a data point for the day and the average was taken over the month to give a data point for each month. This was then used to determine the monthly and seasonal (dry and rainy) variations for each year. The Excel and Matlab softwares were used for the analyses.

The refractive index of the troposphere is tremendously important in predicting performance of terrestrial radio links. The variation of refractivity in the troposphere is determined by the variations of temperature, relative humidity and pressure. The temperature in degree Celsius ($^0$C), relative humidity in percentage (%) and pressure in millibar (mb) were the input parameters used to calculate the radio refractivity (N-units).

The atmospheric radio refractivity can be computed using the ITU-R (2016): formula

$$N = N_{dry} + N_{wet} = \frac{77.6}{T}\left(P + 4810\frac{e}{T}\right)(N - units) \quad ...(1)$$

The dry term, $N_{dry}$, of radio refractivity is given by:

$$N_{dry} = 77.6\frac{P}{T} \quad ....(2)$$

and the wet term, $N_{wet}$, by:

$$N_{wet} = 373256\frac{e}{T^2} \quad ....(3)$$

where P is the pressure in mb, e is the water vapour pressure in hPa, and T is temperature in Kelvin (K).

The conversion factor from degree Celsius ($^0$C) temperature to Kelvin (K) is given as

$$T(K) = T_c + 273.15 \quad ....(4)$$

where T (K) is temperature in Kelvin (K) and $T_C$ is temperature in degree Celsius ($^0$C)

The water vapour pressure, e is given by

$$e = \frac{RHe_s}{100} \quad ....(5)$$

The saturated vapour pressure, $e_s$ is given by

$$e_s = 6.1121exp\left\{\frac{17.502t}{t+240.97}\right\} \quad ....(6)$$

where t is the value of the temperature in degree Celsius ($^0$C).

The refractive index, n and refractivity, N are related by the equation (7), ITU-R (2012).

$$n = \left(N \times 10^{-6}\right) + 1 \quad ....(7)$$

**Results**

The results of the investigation are graphically presented in Figures 1-5. Figure 1 presents the mean diurnal variation of refractivity, humidity, temperature and pressure over Yola. The mean seasonal variation of refractivity, humidity, temperature and pressure over Yola for dry season is depicted in Figure 2. Figure 3 presents the mean seasonal variation of refractivity, humidity, temperature and pressure over Yola for rainy season.

Furthermore, Figure 4 depicts the mean monthly variation of surface refractivity over Yola. Finally, Figure 5 presents the mean hourly and seasonal variations of surface refractivity over Yola.

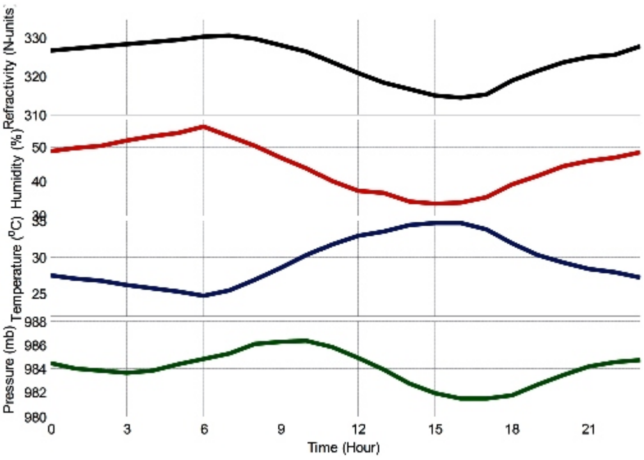


**Fig. 1:** Mean Diurnal Variation of Refractivity, Humidity, Temperature and Pressure over Yola.

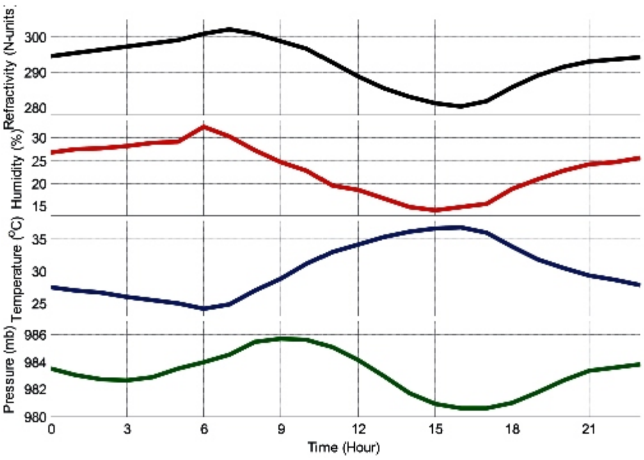


**Fig. 2:** Mean Seasonal Variation of Refractivity, Humidity, Temperatureand Pressure over Yola for Dry Season.

## Discussion

### *Mean Diurnal Variation of Refractivity, Humidity, Temperature and Pressure over Yola*

The average hourly variation of refractivity, humidity, temperature and pressure plotted against time for January 2011 – December 2013 is presented in Figure 1. The plot shows that the parameters exhibit day – night

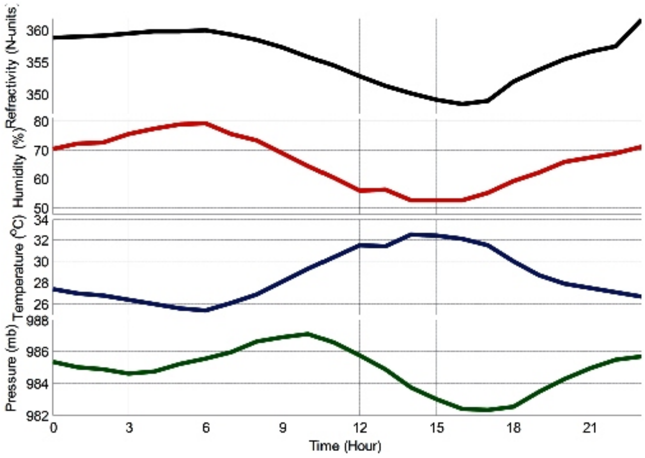


**Fig. 3:** Mean Seasonal Variation of Refractivity, Humidity, Temperature and Pressure over Yola for Rainy Season.

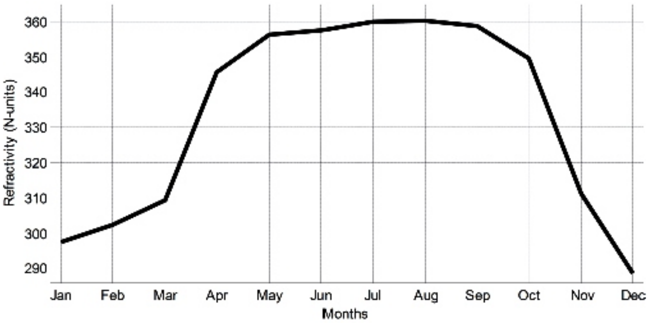


**Fig. 4:** Mean Monthly Variation of Surface Refractivity over Yola.

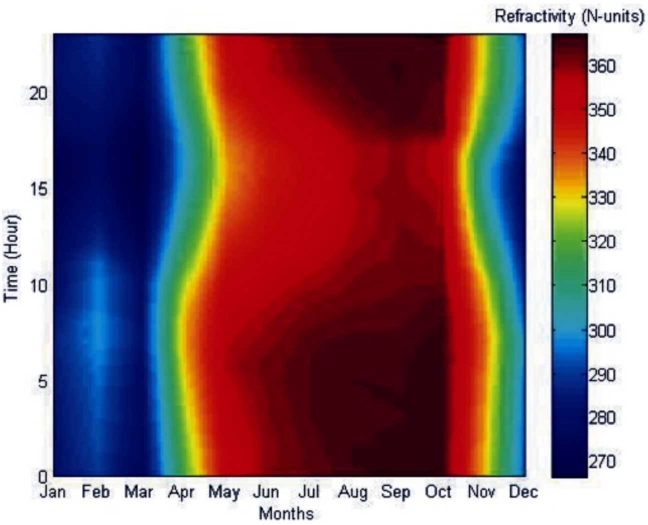


**Fig. 5:** Mean Hourly and Seasonal Variations of Surface Refractivity over Yola.

cycles. The refractivity plot (Figure 1) shows a steady rise from 00:00 hours until it peaked to about 332 N units around 07:00 hours. It thereafter decreases steadily from then until it reaches a minimum of about 316 N units around 16:00 hours from which it rises to complete the day's cycle.

Visual inspection of the humidity plot (Figure 1) shows that the pattern of variation of humidity follows the same pattern as that of refractivity. Temperature variation plots (Figue 1) shows that temperature follows opposite to that of humidity. The diurnal variation of pressure plot (Figure 1) shows that pressure contributed to the variation of refractivity after around 10:00 hours till it completes the day's cycle. However, the results of pressure and temperature do not maintain the ideal gas relation which says that pressure is proportional to temperature because the volume is not fixed.

The diurnal variation of refractivity at Yola exhibits a daily cycle and is affected by the meteorological parameters such as humidity, temperature and pressure. The percentage contribution of the wet term of refractivity ($N_{wet}$) and the dry term of refractivity ($N_{dry}$) is 23% and 77%, respectively. This result suggests that the $N_{dry}$ is highly variable; it is three times as large as $N_{wet}$.

From the above analysis, it could be said that refractivity in Yola is highly dependent on humidity with little contribution from temperature and pressure. Therefore, the variation of refractivity at Yola is a contribution of both the dry and wet terms of refractivity. This does not agree with the findings of Bawa, *et al*. (2015) who carried out a similar investigation. Bawa, *et al.* (2015) found out that the diurnal refractivity variation over Yola is atributed to the wet term of refractivity.

***Mean Seasonal Variation of Refractivity, Humidity, Temperature and Pressure over Yola***

The mean seasonal variation of radio refractivity, humidity, temperature and pressure over Yola plotted against time for January 2011 – December 2013 is presented in Figures 2 and 3, respectively.

The refractivity variation in dry and rainy seasons (Figures 2 and 3) shows low values at early hours and post noon and highest values in the morning around 07:00 hours and late in the night around 23:00 hours. The highest and lowest values for dry season were about 297 N units and 278 N units, respectively while the highest and lowest values for rainy season were about 360 N units and 345 N units, respectively.

The variations of humidity, temperature and pressure for dry and rainy seasons also plotted in Figures 2 and 3, respectively can be used to understand the refractivity variation in Yola. It was observed that the temperature was lowest around 06:00 hours from which it steadily rise to maximum around 15:00 hours before dropping for the rest of the day. The variation of humidity followed opposite trend as that of temperature with highest and lowest values around 06:00 hours and 15:00 hours, respectively. The pressure variation shows early hours decrease to around 03:00 hours. It thereafter increases slightly from then till around 09:00 hours local time from which it steadily drops to minimum around 16:00 hours before rising for the rest of the day.

The combination of these meteorological parameters can be used to explain the seasonal (rainy and dry seasons) variation of refractivity at Yola. The humidity showed a synchronized pattern with the refractivity in both seasons and pressure shows its contribution from 11:00 hours till the end of the day. The percentage contribution of the $N_{wet}$ and $N_{dry}$ is 23% and 77%, respectively. Therefore, the seasonal variation of refractivity is a contribution of both the dry and wet terms of refractivity. The results also revealed that radio refractivity have the highest and lowest values during the rainy and dry seasons, respectively. The highest value is about 360 N units and the lowest value is about 278 N units.

***Mean Monthly Variation of Surface Radio Refractivity over Yola***

The mean monthly variation of radio refractivity over Yola presented in Figure 4 shows high values of refractivity in the months of May to October and the period coincided with the rainy season period in Yola. The minimum and maximum value of refractivity was observed in the months of January and September, respectively. The value of refractivity increases from a minimum of about 280 N units in January to a maximum at about 363 N units in September.

***Mean Hourly and Seasonal Variations of Surface Radio Refractivity over Yola***

The contour plot in Figure 5 presents the summary of the mean hourly and seasonal variations of surface radio. It can be clearly seen from the plot that the high values of refractivity occur between May and October which shows the period of rainy season. The highest refractivity value was identified to be in the month of September (Figure 4). This result suggests that refractivity is mostly affected in the month of September. Thus attenuation of radio wave is high.

***Regression Statistical Analyses***

The results of the regression statistical analyses of refractivity as a function of the meteorological parameters (temperature, humidity and pressure) for the period under investigation were considered. This was done in order to estimate the extent to which these three parameters correlate with the refractivity. The multiple correlation coefficient was determined to be 0.998. This indicates a good level of prediction of refractivity by the independent variables (temperature, humidity and pressure). The value of the coefficient of determination is 0.995. This result suggests that the variables (temperature, humidity and pressure) explain 99.5% of the variability of refractivity in Yola for the period investigated.

**Conclusion**

The contribution of some metorological parameters such as temperature, humidity, and pressure over Yola for January 2011 – December 2013 was investigated. The analysis of the results revealed that the radio refractivity is higher in the rainy season than dry season. The three parameters contributed to the variation of radio refractivity in Yola. However, the results of the mean diurnal and seasonal variations of refractivity revealed that both dry and wet terms of refractivity contributed to the diurnal and seasonal variations of radio refractivity in Yola. The results from the multiple regression analysis show that the relationship of the meteorological parameters (temperature, humidity and pressure) in generating the refractivity at Yola gives a better correlation. Thus the variables explain 99.5% of the variability of refractivity in Yola for the period investigated. This revealed that variations of these parameters in the troposphere caused tropospheric radio refractivity variation in Yola, Nigeria.

**Declaration of Authors Contributions**

**GA** proofread the work, **LO c**ontributions include; presenting the title, writing and analysing the results, **DO** contribution was writing the computer programs

**Conflict of Interest**

Authors declined there is no conflict of interest.

**Acknowledgement**

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