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Variation of Meteorological Parameters and their Influence on Tropospheric Surface Radio Refractivity in Minna and Yola, Nigeria

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Abstract

The variation of meteorological parameters and their influence on tropospheric surface radio refractivity in Minna (middle belt) and Yola (north east), Nigeria was investigated. The results show that variation of each meteorological parameter (temperature, humidity and pressure) contributed to the diurnal and seasonal variations of tropospheric surface radio refractivity at Minna and Yola. The wet term of refractivity (N_{wet}) and dry term of refractivity (N_{dry}), contributed 24% and 76%, respectively at Minna and 23% and 77%, respectively at Yola. The regression model shows that there is strong positive correlation between refractivity and each meteorological parameter (humidity, temperature and pressure).The results revealed that humidity, temperature and pressure, respectively contributed approximately 89%, 84% and 55% of refractivity variation, in Minna and 93%, 92% and 54% of the refractivity variation in Yola.

Keywords: *Meteorological Parameter, Regression, Refractivity, Diurnal and Seasonal*

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INTRODUCTION

The troposphere is the region of circulating air extending from the earth's surface to where the air stops becoming colder with height. Its thickness is thin at the poles and thicker at the equator but varies seasonally. It is within the troposphere that weather (clouds, rain, snow, thunderstorms, etc) occurs, that is, it contains all the weather familiar with life on earth. 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 the troposphere. Hall (1979) stated that the tropospheric refractive index variations affect radio frequencies above $3 \times 10^7 Hz$ which is observed only at frequencies greater than $10 \times 10^7 Hz$. This implication implies that at these frequencies the refractive index of the troposphere is essential in the propagation of radio waves. The variation of refractivity has been observed as the primary cause of bending of radio signal as it continually moving through the troposphere. Hence, the propagation of waves inside the troposphere is an important function of refractive index value because it influences radio propagation to distant places on the Earth.

Tropospheric refraction 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. Adediji and Ajewole (2008) [1-5] revealed that change in the index of refraction of air helps to determine the radio wave propagation in the troposphere. The radio frequency or radio wave signal propagation in the troposphere is influence by some factors. They include temperature, relative humidity and air pressure.

Relative humidity can be defined as the ratio of actual amount of water vapour present in the air to the saturation point at the same temperature, usually expressed as a percentage (%). The atmospheric pressure is defined as the force per unit area exerted by the atmosphere on a surface by virtue of its weight. It is measured in Pascal. Temperature is a measure of the relative coldness or hotness at different levels of the earth's atmosphere measured in Kelvin (K).

Radio propagation in a terrestrial environment is complex making its properties very difficult to predict. This is confirmed at very high frequency (VHF), ultra high frequency (UHF), and super high frequency (SHF) where the clutter of hills, trees, and houses and the dynamic atmosphere provide scattering obstacles with sizes of the same order of magnitude as the wavelength (Hagn, 1980). The increase in mobile communication, Television (TV) and Frequency Modulation (FM) stations operating in the VHF and UHF band has increased the complexity of frequency allocation in Nigeria (Onuorah et al., 2019). Therefore, it is essential to continuously study the tropospheric radio refractivity variation to enable the industry to design sustainable and suitable radio communication systems. Owolabi and Ajayi (1981) highlighted some of the likely local problems of radio propagation in the troposphere and demonstrated that propagation of radio waves in the VHF, UHF and SHF bands are affected by meteorological parameters of pressure, temperature and relative humidity. Bawa et al. (2015) on studying the average hourly variations of radio refractivity variations across some selected cities in Nigeria, including Yola. Their results showed that the wet term which is a function of humidity is the major driving force influencing diurnal and seasonal variations of refractivity over Yola. Ibeh and Agbo (2012) after estimating the tropospheric radio refractivity and its variation with meteorological parameters over Minna discovered from the correlation coefficient results that relative humidity has more effect on refractivity than temperature and pressure. The results of the effect of variation of meteorological parameters on the tropospheric radio refractivity at Minna by Okoro and Agbo (2012) show that increase in humidity and temperature during the rainy season caused weather variation that attributed to high refractivity within the season. Adeyemi (2006), Willoughby et al. (2008), and Agbo et al. (2013) on investigating the atmospheric refractivity of various locations in Nigeria showed that meteorological parameters such as atmospheric pressure, temperature and relative humidity caused the refractivity and water vapour density to fluctuate in the lower troposphere. However, the atmospheric radio refractivity is generally high during the rainy [6-9]season at all the levels of the atmosphere while its values fall during the dry season and harmattan periods. 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. They also concluded that the seasonal variation of the surface refractivity ranges between 270 N-units and 350 N-units in wet and dry seasons in both stations.

Most reviewers on the tropospheric surface radio refractivity in some locations in Nigeria observed that the refractivity variation is attributed to the meteorological parameters and wet term or dry term of refractivity or both terms without stating the percentage contribution of each term in the refractivity variation (Ayantunji et al., 2011a and b; Okoro and Agbo, 2012; Ibeh and Agbo, 2012; Bawa et al., 2015; Tyabo et al., 2018). This serves as a contribution to the present work.

DATA

The data used for this work were obtained from the Centre for Atmospheric Research (CAR), Kogi State University Campus, Anyigba, which is an activity centre of the National Space Research and Development Agency (NASRDA), Abuja, Nigeria. We studied the influence of relative humidity, temperature and pressure and its contribution to variation of tropospheric radio refractivity in Minna (middle belt), and Yola (north-east), Nigeria using January 2014 – December 2016 surface data. The data collected shows that the data collection was done at a five-minute interval. The records cover 24 hours each day starting from 00 hours to 23:55 hours local time.

THEORETICAL BACKGROUND

The saturation vapour pressure, p_s, is the pressure in the saturated air which increases as temperature increases. Thus, the saturationvapour pressure, p_s is calculated using the ITU-R (2016) formula as

$$p_s = 6.1121exp\left\{\frac{17.502 \times t}{t+240.97}\right\} \quad (1)$$

wheret is the value of the temperature in degree Celsius (^oC).

The relative humidity, RH (%) and water vapour pressure, p_w is related by:

$$p_w = \frac{RHp_s}{100} \quad (2)$$

wherep$_s$ is the saturation vapour pressure.

The dry term ofradio refractivity, N_{dry}, is given by:

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

and the wet termof radio refractivity, N_{wet}, by:

$$N_{wet} = 373256\frac{p_w}{T^2} \quad (4)$$

Where P is the pressure in millibar (mb), p_w is the water vapour pressure in hectopascal (hPa), and T is temperature in Kelvin (K).

The sum of N_{dry} and N_{wet} give the result of the atmospheric radio refractivity computed using the ITU-R (2016) formula

$$N = \frac{77.6}{T}\left(P + 4810\frac{e}{T}\right)(Nunits) \quad (5)$$

The refractive index, n and refractivity, N are related by the equation:

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

METHODS

Meteorological data such as temperature, relative humidity and pressure values collected from January 2014 - December 2016 were used to calculate the tropospheric surface radio refractivity value using the expressions in equations 1-5 above. Twenty - four (24) data points representing hourly radio refractivity values for each day of the year were determined. The hourly data for each day is averaged to give a data point for the day and the hourly averages were further averaged in daily bins to obtain the daily values of tropospheric radio refractivity over all the years investigated. Furthermore, the daily averages were averaged in monthly, and then seasonal bins, and these were used to investigate the monthly and seasonal variations of the radio refractivity parameter over Minna and Yola.

A correlation between the tropospheric radio refractivity and each of the meteorological parameters namely; humidity, temperature and pressure were done using regression analysis model on the excel software. This was achieved by using the regression model on the data analysis tool, taking the measured radio refractivity value as the input Y range and each of the parameter values as the input X range. The software is then requested to compute the correlation coefficients, R and the coefficients of determination, R^2. The correlation results were determined and presented in a tabular form. The analyses were all achieved using Microsoft excel and Matlabsoftwares.

RESULTS AND DISCUSSION

The variation of temperature, humidity and pressure and its influence on tropospheric radio refractivity for a period of three years; from January 2014 – December 2016 at Minna (middle belt), and Yola (north-west) within Nigeria were utilized for the analysis.

The diurnal variations of refractivity, temperature, humidity and pressure versus time over Minna, respectively are depicted in Figures 1 - 3. The graphs show a sine wave pattern with refractivity and each meteorological parameter.

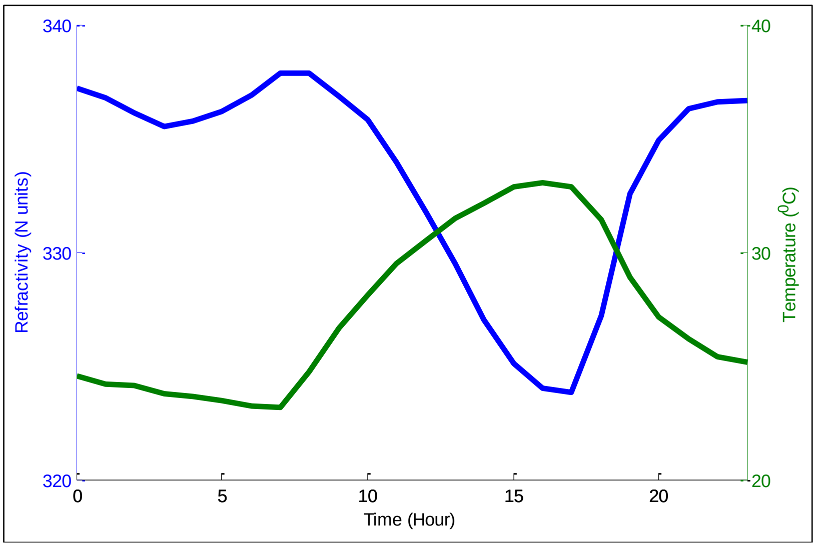

Fig. 1: *Mean Diurnal Variation of Refractivity and Temperature versus Time over Minna.*

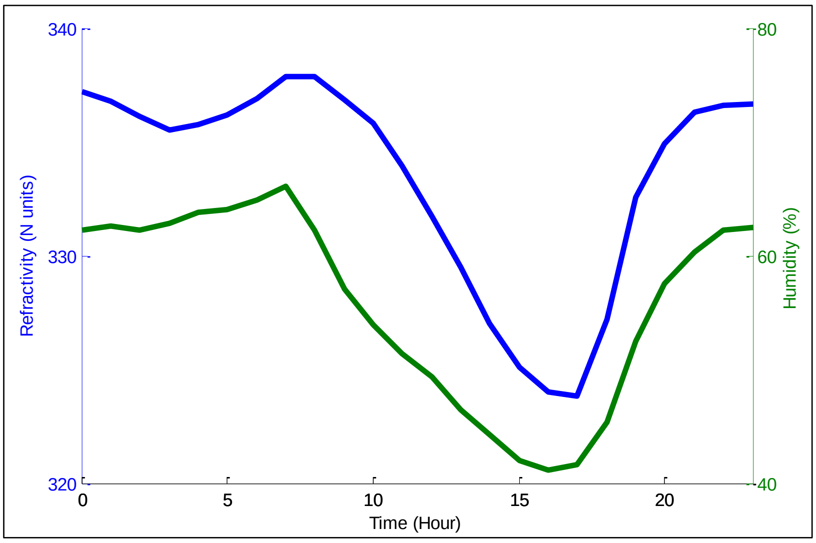

Fig. 2: *Mean Diurnal Variation of Refractivity and Humidity versus Time over Minna.*

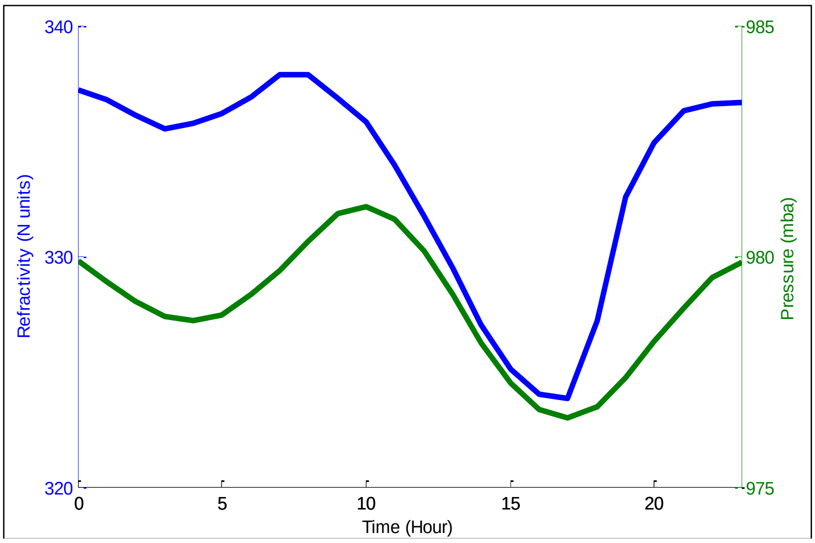

Fig. 3: *Mean Diurnal Variation of Refractivity and Pressure versus Time over Minna.*

The refractivity displays double peaks (morning and late night hours) and double dips (a weak dip in the morning hour and a strong dip in the post noon hours). The temperature displays a dip in the morning hour with a peak in the post noon hour. The humidity shows double peaks (morning and late night hours) with a strong dip in the post noon hour. The pressure displayed double dips (weak in the morning hour and strong in the post noon hours) with a peak in the morning hour.

The value of refractivity showed a steady decrease from 00 hours local time until it falls to a dip of about 335.5 N units around 0300 hours local time. It rises from then to a peak value of about 337.9 N units around 0800 hours local time from which it suddenly falls again to a strong dip of about 323.8 N units around 1600 hours local time. It thereafter increases until it completes a day's cycle with a peak value of about 336.6 N units at 2300 hours local time. The refractivity ranges from 323.8 N-units to 337.9 N-units with an average value of 330.9 N-units.

The temperature value at Minna (Figure 1) gradually fell from 00 hours local time to a dip value of about 23^{o}C around 0700 hours local time. It rises from then to a peak value of about 33^{o}C around 1600 hours local time before it dropped until it completed a day's cycle. The humidity followed opposite pattern as that of temperature. The humidity value at Minna (Figure 2) rises from 00 hours local time to a peak value of about 66% around 0700 hours local time. It gradually falls from then until it reached a strong dip value of about 41% around 1600 hours local time before rising to another peak value of about 63% at 2300 hours local time to complete a day's cycle. The pressure value at Minna (Figure 3) gradually fell from 00 hours local time to a dip value of about 979 mb around 0400 hours local time. It rises from then to a peak value of about 981mb around 1000 hours local time from which it falls again to a strong dip with a value of about 976mb around 1700 hours local time before rising to complete a day's cycle.

Generally, the diurnal variation of refractivity over Minna exhibits a daily cycle and is affected by each meteorological parameter (temperature, humidity and pressure). While the decrease in refractivity value from 00 hours local time to 0300 hours local time can be attributed to the decrease in temperature, humidity and pressure values, the falling in humidity value caused the refractivity value to fall from 0800 hours local time - 1000 hours local time. The rise in refractivity value from 0300 hours local time - 0800 hours local time is attributed to rise in humidity and pressure values. The variation of refractivity at other hours of the day is influenced by the contribution of humidity and pressure variations. The percentage contribution of the wet term of refractivity (N_{wet}) and dry term of refractivity (N_{dry}) is 24% and 76%, respectively.

From the above analysis, it could be said that the highly dependent of refractivity on temperature, humidity and pressure is a good evident to conclude that the variations of each meteorological parameter contributed to the diurnal variation of refractivity at Minna.

The seasonal variation of refractivity, humidity, temperature and pressure versus time over Minna, respectively is depicted in Figures 4 – 9. Figures 4 – 6 present the variations of refractivity, humidity, temperature and pressure versus time over Minna, respectively for dry season. The graphs show that the variation of refractivity, humidity, temperature and pressure also has a sine wave pattern. The refractivity displayed double peaks which occurred in the morning and late evening hours with two dips that occurred early morning and post noon hours. The humidity also displayed double peaks that occurred in the morning and late evening hours with a weak and strong dip that occurred early morning hour and post noon hour, respectively. The temperature displays a dip in the morning hour with a peak in post noon hour. The pressure displayed a weak dip early morning hour and strong dip at post noon hour with a peak in the morning hour.

The variation of refractivity shows high value of about 309.3 N units at 00 hours local time. It steadily falls to a weak dip at about 305.7 N units around 0300 hours local time from which

It slightly rises to a peak value of about 309.4 N units around 0800 hours local time. It thereafter decreases from then to a strong dip of about 290.4 N units around 1700 hours local time from which it rises again to another peak value of about 310.0 N units around 2100 hours local time before dropping till it completed a day's cycle.

The humidity variation (Figure 4) shows a zigzag pattern between 00 hours local time and 0700 hours local time. It falls from 00 hours local time till it reaches a value of about 43% around 0200 hours local time from which it slightly rises to about 45% around 0400 hours local time. It slightly falls and rose to a peak value of about 48% around 0700 hours local time from which it decreased to a dip value of about 25% around 1600 hours local time. It thereafter increases to another peak value of about 47% around 2200 hours local time before slightly dropping to complete the day's cycle. Figure 5 shows that temperature value falls from 00 hours local time till it reached a dip of 23^{o}C around 0700 hours local time. It thereafter increases until it peaked at about 35^{o}C around 1600 hours local time before dropping till it completed a day's cycle. It is very surprising to observe that temperature variation does not follow the zigzag pattern seen in the humidity between 00 hours local time to 0700 hours local time.

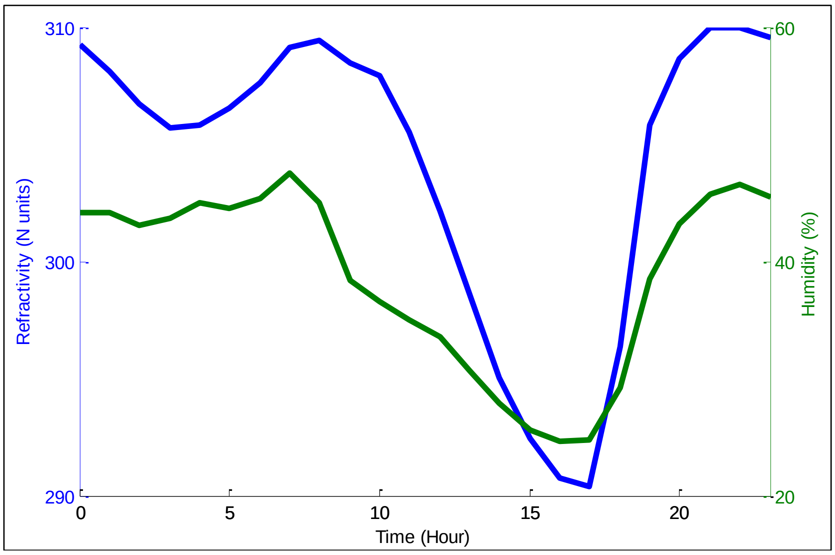

Fig. 4: *Mean Variation of Refractivity and Humidity versus Time over Minna for Dry Season.*

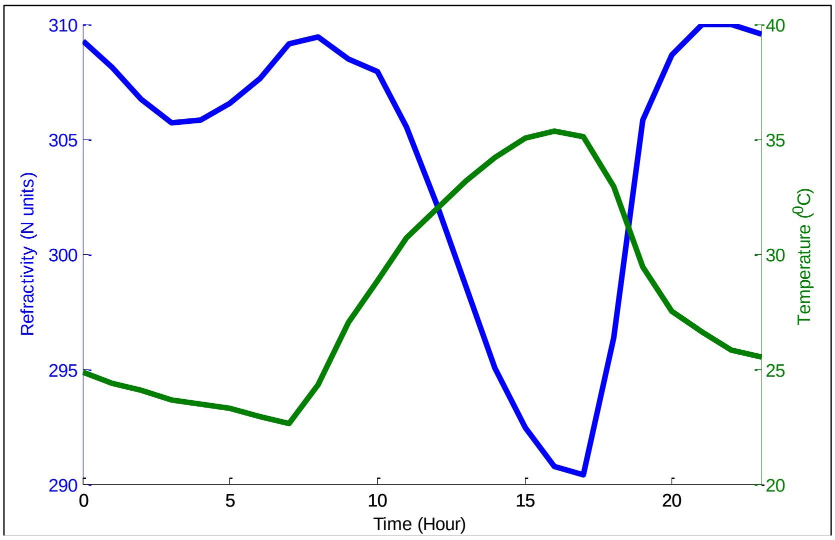

Fig. 5: *Mean Variation of Refractivity and Temperature versus Time over Minna for Dry Season.*

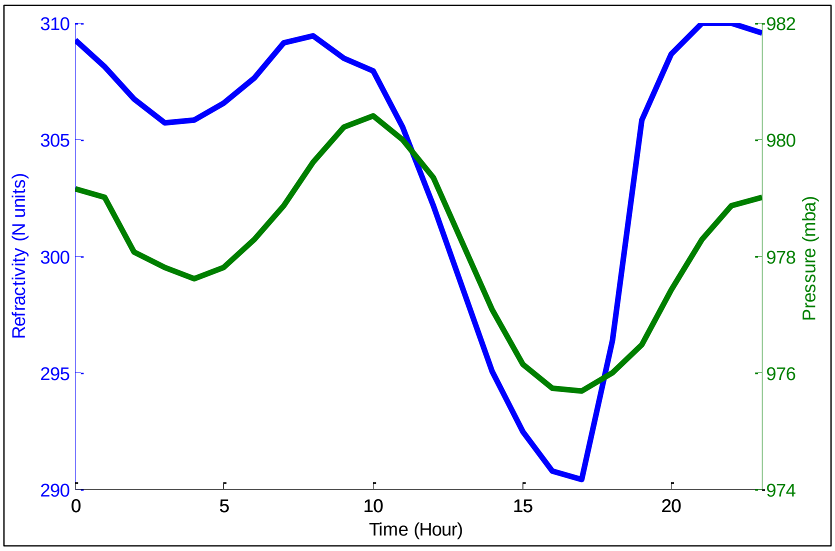

Fig. 6: *Mean Variation of Refractivity and Pressure versus Time over Minna for Dry Season.*

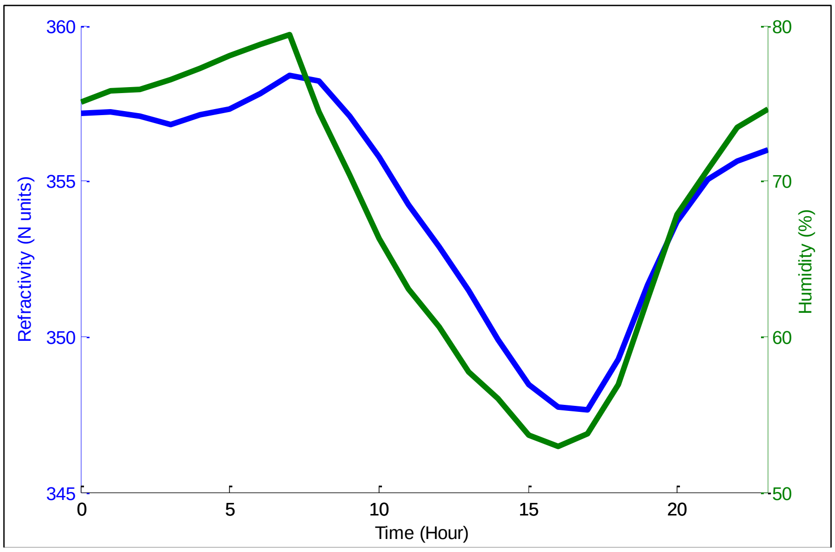

Fig. 7: *Mean Variation of Refractivity and Humidity versus Time over Minna for Rainy Season.*

The pressure variation (Figure 6) shows almost a similar pattern with that of refractivity. The discrepancy was observed between 0300 hours local time and 1000 hours local time. The variation of pressure decreases from early hours local time till it reached the first dip at about 978 mb around 0400 hours local time. It thereafter increases until it peaked to about 980 mb around 1000 hours local time from which it dropped to a strong dip at about 976 mb around 1700 hours local time before rising until it completed the day's cycle.

The variations of refractivity, humidity, temperature and pressure versus time during the rainy season as depicted in Figures 7 - 9 also followed a sine wave pattern. The refractivity displayed double dips which occurred in the morning and evening hours with a peak in the morning hours. The humidity displayed a peak and strong dip that occurred in the morning and post noon hours, respectively. The temperature displays a dip in the morning hour with a peak in post noon hour. The pressure displayed a weak dip early morning hour and strong dip at post noon hour with a peak in the morning hour.

The variation of refractivity shows high value of about 357.2 N units at 00 hours local time. It steadily dropped to the first dip at about

356.8 N units around 0300 hours local time. It slightly increased from then to a peak at about 358.4 N units around 0700 hours local time from which it decreased to a strong dip to about 347.6 N units around 1700 hours local time. It thereafter increases till it completed the day's cycle. The value of humidity (Figure 7) increased from 00 hours local time till it peaked to 79% around 0700 hours local time from which it decreased to a dip at about 53% around 1600 hours local time. It thereafter increases from then until it completed the day's cycle. The variation of temperature followed opposite trend with that of humidity. The temperature plot (Figure 8) shows that the dip and peak value of about 24°C and 31°C, respectively occurred around 0700 hours local time and 1600 hours local time. The variation of pressure (Figure 9) shows a similar pattern with that of refractivity. The discrepancy occurred between 0300 hours local time and 1000 hours local time. The value of pressure decreases from 00 hours local time till it reached the first dip at about 979 mb around 0400 hours local time. It thereafter increases until it peaked to about 982 mb around 1000 hours local time from which it dropped to a strong dip at about 977 mb around 1700 hours local time before rising until it completed the day's cycle.

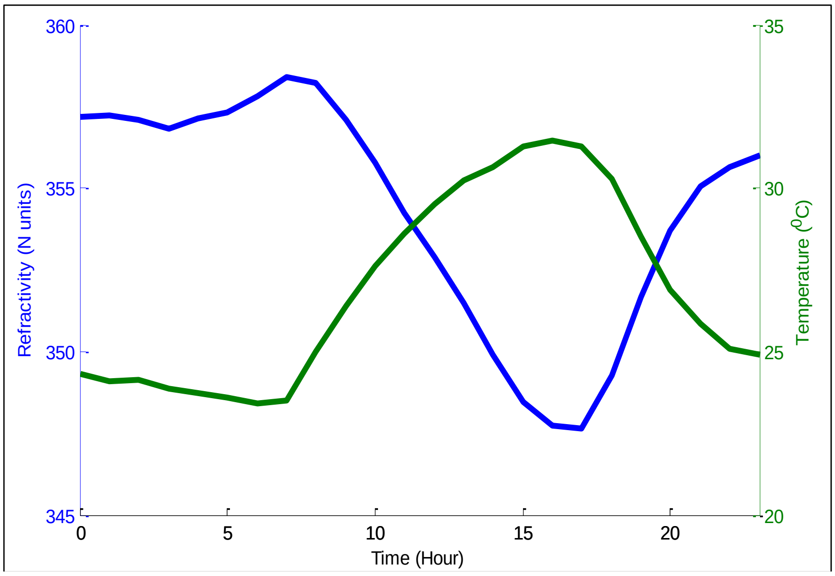

Fig. 8: *Mean Variation of Refractivity and Temperature versus Time over Minna for Rainy Season.*

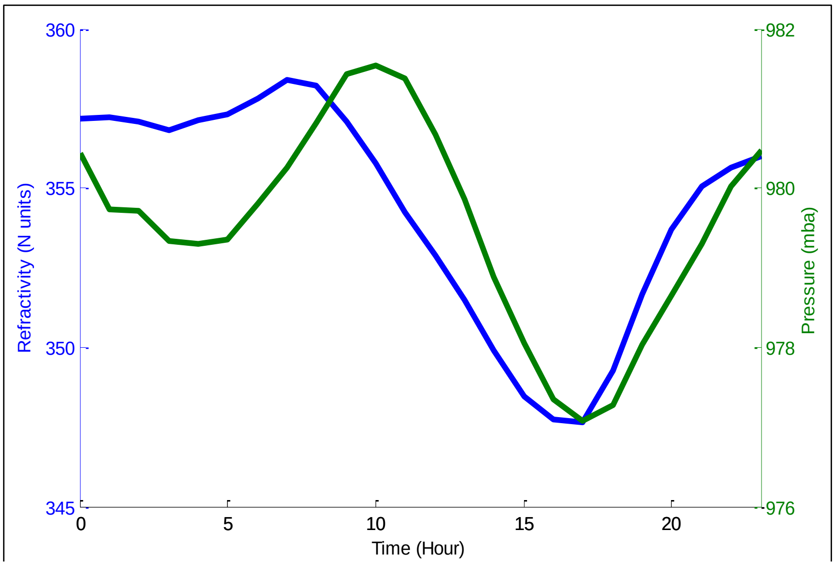

Fig. 9: *Mean Variation of Refractivity and Pressure versus Time over Minna for Rainy Season.*

Theseasonal variation of refractivity at Minna can be understand by the combination of the meteorological parameters. While the slight drop and rise in refractivity observed in the dry season between 00 hours local time and 0800 hours local time is attributed to the influence of combination of each meteorological parameter (humidity, temperature and pressure), the variations of refractivity between 0800 hours local time and 1000 hours local time is influenced by the variation of humidity. The variation of refractivity at other hours of the day is a contribution of the humidity and pressure variations. The percentage contribution of N_{dry} and N_{wet} in the dry season is 83% and 17%, respectively and during the rainy season is 72% and 28%, respectively. This evidence shows that the seasonal variation of refractivity is influenced by the contribution of the variations of each meteorological parameter (humidity, temperature and pressure).This result is in line with the result of Ibeh and Agbo (2012), who found that each meteorological parameter contributed to the variation of refractivity in Minna.

The average diurnal variation of refractivity, humidity, temperature and pressure at Yola plotted against time is depicted in Figures 10 - 12. The plots show that refractivity value increases steadily from the 00 hours to 0700 hours local time. After reaching a peak value of 330.8 N units at the 0700 hours local time, it started decreasing uniformly to about 1600 hours local time reaching a minimum value of 314.4 N units and after which it rose steadily till it completes the day's circle at 2300 hours local time.

Visual inspection of the humidity plot (Figure 10) shows that the pattern of variation of humidity is in phase with that of refractivity. The little difference observed was a shift at the peak and minimum hour. While the peak and minimum hour for refractivity occurred around 0700 hours local time, and 1600 hours local time, respectively, humidity peak and minimum values occurred around 0600 hours and 1500 hours local time at a value of 56% and 33%, respectively.

It could observe that variation of temperature (Figure 11) follows opposite pattern with that of humidity. The plot of temperature shows gradually decrease from 00 hours local time to 0600 hours local time and thereafter increased steadily before reaching a peak at 1500 hours local time. From the peak value, it dropped until it reached its night-time level.

The variation of pressure (Figure 12) shows decrease from 00 hours local time to 0300 hours local time from which it rose to a peak at 1000 hours local time. It thereafter decreased gradually to another minimum at 1700 hours local time before rising to the end of the day.

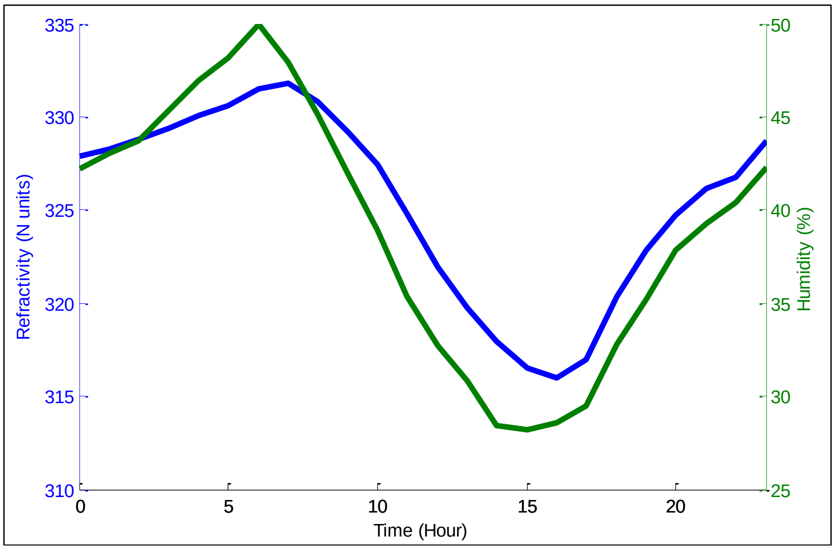

Fig. 10: *Mean Diurnal Variation of Refractivity and Humidityversus Time over Yola.*

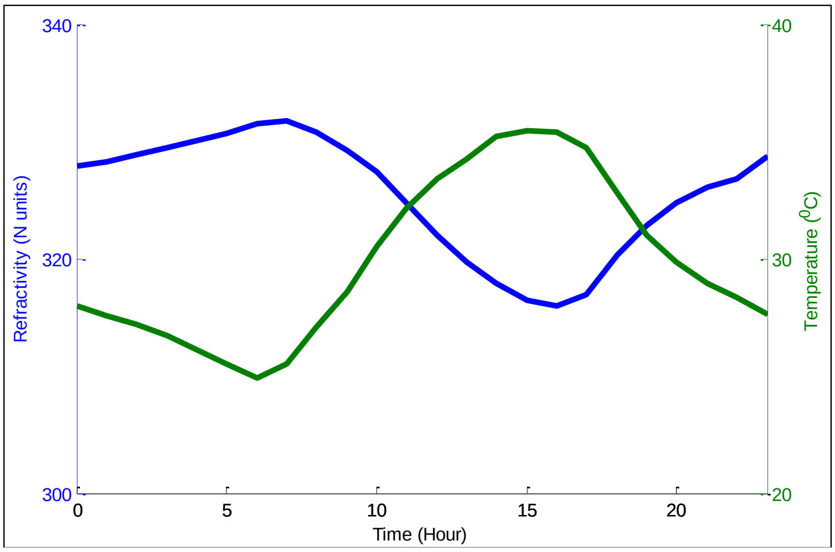

Fig. 11: *Mean Diurnal Variation of Refractivity and Temperature versus Time over Yola.*

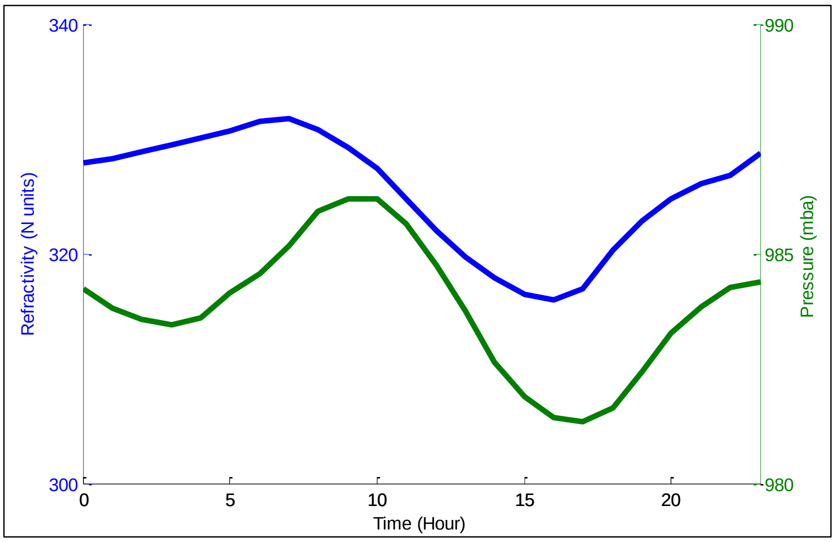

Fig. 12: *Mean Diurnal Variation of Refractivity and Pressure versus Time over Yola.*

It is interesting to observed that the minimum value of refractivity, humidity and pressure occurred between 1500 – 1700 hours local time (Figures 10 and 12). On the other hand, the temperature is a maximum at about the same time (Figure 11).

From the results we observed that the little different between refractivity variation and that of humidity is as a result of increase and decrease in pressure at the time of the day. It is also quite interesting to observe from the pattern of pressure that only pressure completed one period (T) within 24 hours of the day. The percentage contribution of the wet term of refractivity (N_{wet}) and dry term of refractivity (N_{dry}) is 23% and 77%, respectively. Therefore, we concluded from the analysis that refractivity in Yola is highly dependent on humidity and pressure with little contribution from temperature. This result does not agree with the findings of Bawa et al., (2015), who found that humidity is the major driving force influencing diurnal refractivity variation over Yola.

The mean seasonal variations of refractivity, humidity, temperature and pressure over Yola plotted against time for January 2014 – December 2016 are presented in Figures 13 - 18, respectively. Figures 13 - 15 show the mean variation of refractivity, humidity, temperature and pressure over Yola for dry season. The refractivity shows a steady increase from early hours of the day until it peaked at about 302 N units around 0700 hours local time. It thereafter decreases from then to minimum at about 280 N units around 1600 hours local time from which it rises till the end of the day.

The variation of humidity (Figure 13) shows almost a similar pattern with that of refractivity. The discrepancies were observed at the maximum (peak) and minimum values. While refractivity maximum and minimum values occurred around 0700 hours and 1600 hours local time, respectively, maximum and minimum values of humidity, respectively occurred around 0600 hours and 1500 hours local time. The variation of temperature (Figure 14) shows opposite pattern to that of humidity with minimum and maximum values that occurred around 0600 hours and 1500 hours local time. The pattern of pressure (Figure 15) is identified with two troughs and one crest. The first and second minimum values (first and second troughs), respectively occurred around 0300 hours and 1600 hours local time. The maximum value (the crest) occurred around 0900 hours local time.

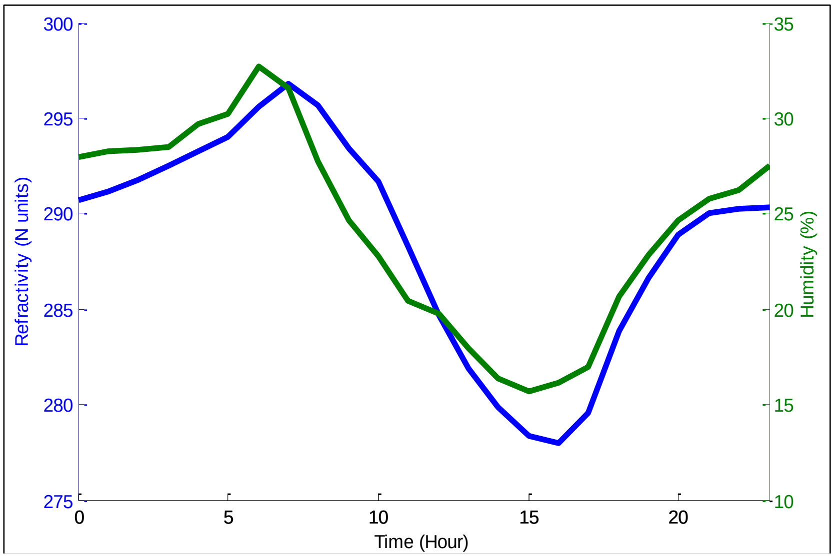

Fig. 13: *Mean Variation of Refractivity and Humidity versus Time over Yola for Dry Season.*

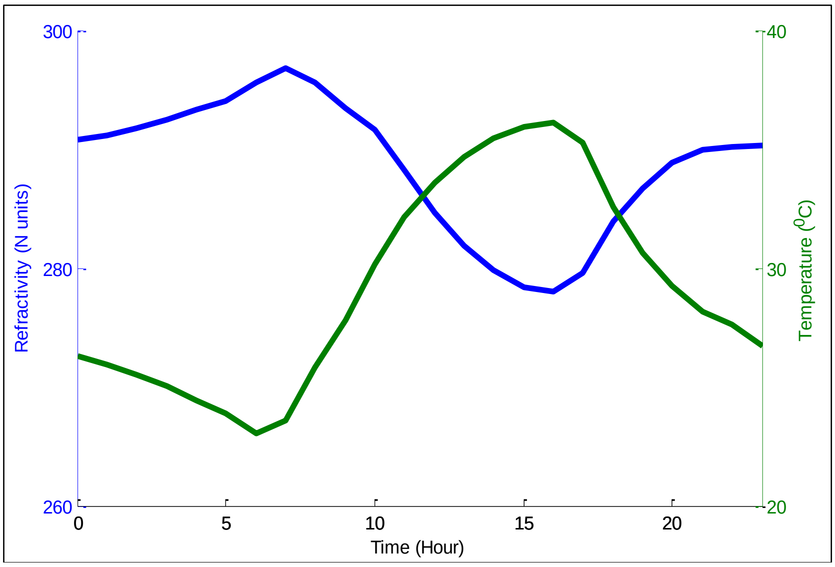

Fig. 14: *Mean Variation of Refractivity and Temperature versus Time over Yola for Dry Season.*

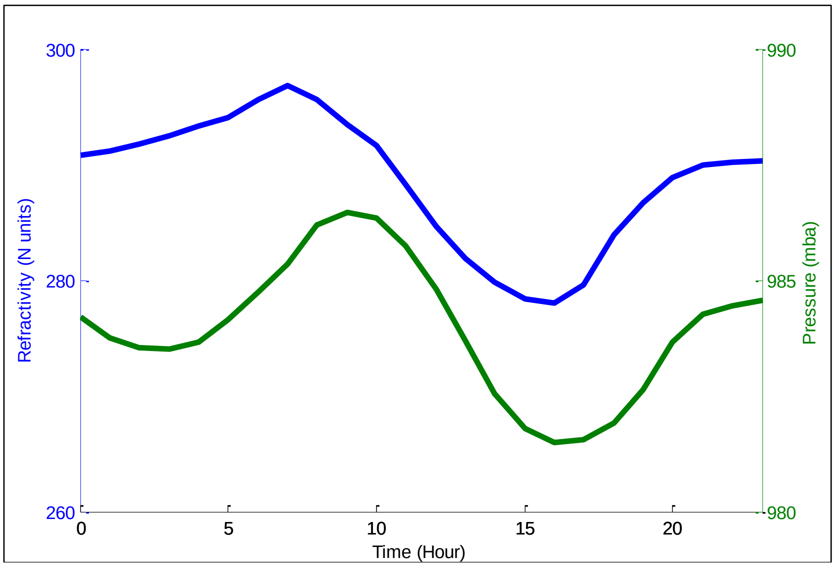

Fig. 15: *Mean Variation of Refractivity and Pressure versus Time over Yola for Dry Season.*

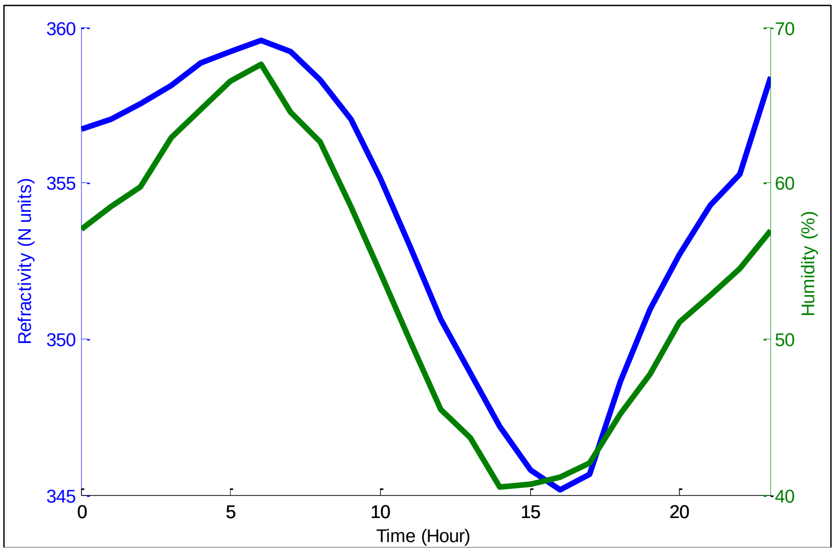

Fig. 16: *Mean Variation of Refractivity and Humidity versus Time over Yola for Rainy Season.*

The average variation of refractivity, humidity, temperature and pressure over Yola for rainy season is depicted in Figures16 - 18. The refractivity showed a steady increase from early hours until it peaked at about 360 N units around 0600 hours local time. It thereafter decreases from then until it reaches a minimum value of about 348 N-units around 1600 hours local time before rising till it reaches a higher value of 362 N units at 2300 hours local time that completes a day's cycle. The variation of humidity during the rainy season also followed the same pattern with the refractivity (Figure 16). Their discrepancies occurred at 1300 hours local time. While the refractivity decreases steadily from 0600 hours local time to around 1600 hours local time, humidity shows a slight increase at 1300 hours local time before it decreases to a minimum around 1600 hours local time. The variation of temperature during the rainy season also shows opposite pattern to that of humidity (Figure 17). The minimum and maximum values of temperature respectively occurred around 0600 hours and 1600 hours local time with a slight decrease at 1300 hours local time. Figure 18shows the variation of pressure during the rainy season that identifies with two minimum values (troughs) and one peak (crest). The observed troughs were around 0300 hours and 1700 hours local time and the crest occurred around 1000 hours local time.

In the dry and rainy seasons, refractivity displays one cycle per day over 24-hour period. These are affected by each of the meteorological parameter. In the dry season the percentage contribution of N_{dry} and N_{wet} is 71% and 29%, respectively. The percentage contribution of N_{dry} and N_{wet} during the rainy season is 85% and 15%, respectively.

The high pressure value always caused the dry term of refractivity (N_{dry}) to have higher value than that of wet term of refractivity (N_{wet}) which depend on humidity value. It can be clearly seen from Figures 13 and 16 that the humidity variation showed a pattern that is almost similar with the refractivity variation. The discrepancy is at 0600 hours local time and 0700 hours local time (in the dry season) and at 1300 hours local time (in the rainy season) which are influenced by pressure. This evidence shows that the variation of radio refractivity does not always depend only on the high percentage contribution value of the dry term of refractivity which is a function of pressure.

Thus, the seasonal variation of radio refractivity in Yola is influenced by the contributions of each meteorological parameter (humidity, temperature and pressure). This result is not in line with the findings of Bawa et al., (2015), who found that humidity is the major driving force influencing seasonal refractivity variation over Yola[10-12].

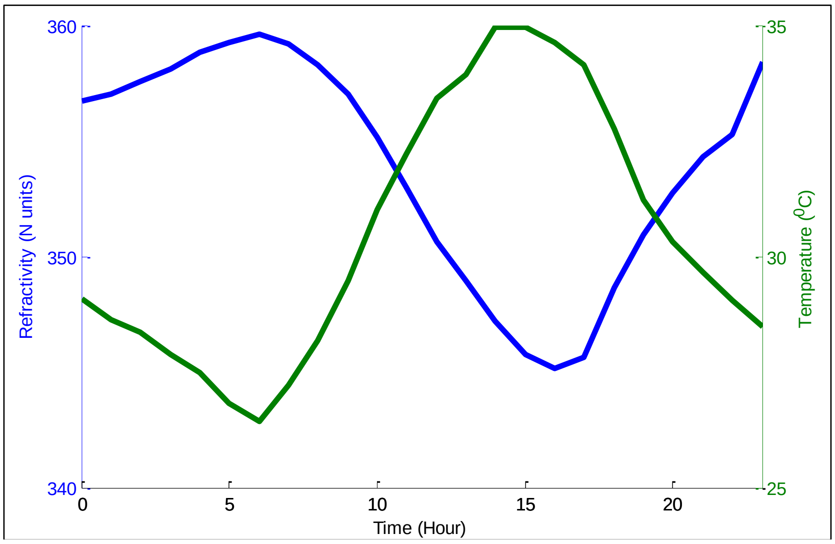

***Fig. 17:** Mean Variation of Refractivity and Temperature versus Time over Yola for Rainy Season.*

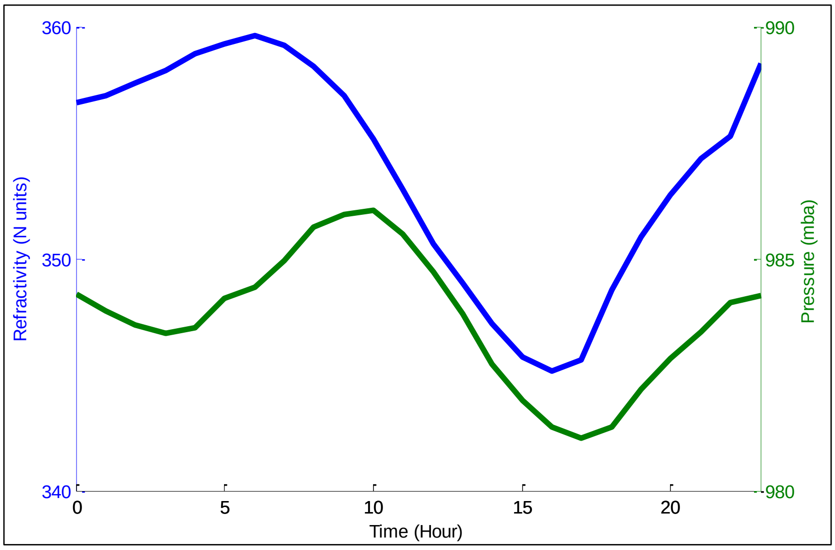

***Fig. 18:** Mean Variation of Refractivity and Pressure versus Time over Yola for Rainy Season.*

The contour plots in Figures 19 and 20, respectively present the average hourly and seasonal variations of radio refractivity over Minna and Yola with the colourbar representing refractivity values. It can be clearly seen from the contour map (Figure 19) that the low values of refractivity were observed in the dry season which occurred in the months of November to March at Minna. The high values of refractivity at Minna occurred during the rainy season, which falls between the months of April and October, with the highest value in August. Figure 20 shows that the low values of refractivity occurred in the months of November to April, which is referred as the dry season period in Yola. The high values of refractivity occurred from the month of May to October, which is known as the rainy season period in Yola, with the highest value in September (Figure 20).

The results suggest that refractivity is mostly affected in the month of August and September, respectively at Minna and Yola. Thus, the month of highest refractivity corresponds to the month with the mostattenuation of radio waves.

Tables 1 and 2, respectively present the results of the regression analysis model of refractivity as a function of each meteorological parameter (humidity, temperature and pressure). This was done in order to estimate the extent to which each meteorological parameter influenced the variation of refractivity by the means of correlation. The correlation coefficients (R), the coefficient of determination (R^2) show the output of regression analysis and the percentage of coefficient of determination (R^2) shows the percentage contribution of each meteorological parameter to variation of refractivity.

Table 1: *Result of Regression Analysis Model for Minna.*

Meteorological Parameter	**Correlation Coefficient, R**	**Coefficient of Determination, R^2**	**Coefficient of Determination, R^2 (%)**
Relative humidity	0.943	0.889	88.9
Temperature	0.918	0.842	84.2
Pressure	0.743	0.552	55.2

Table 2: *Result of Regression Analysis Model for Yola.*

Meteorological Parameter	**Correlation Coefficient, R**	**Coefficient of Determination, R^2**	**Coefficient of Determination, R^2 (%)**
Relative humidity	0.962	0.926	92.6
Temperature	0.959	0.920	92.0
Pressure	0.732	0.536	53.6

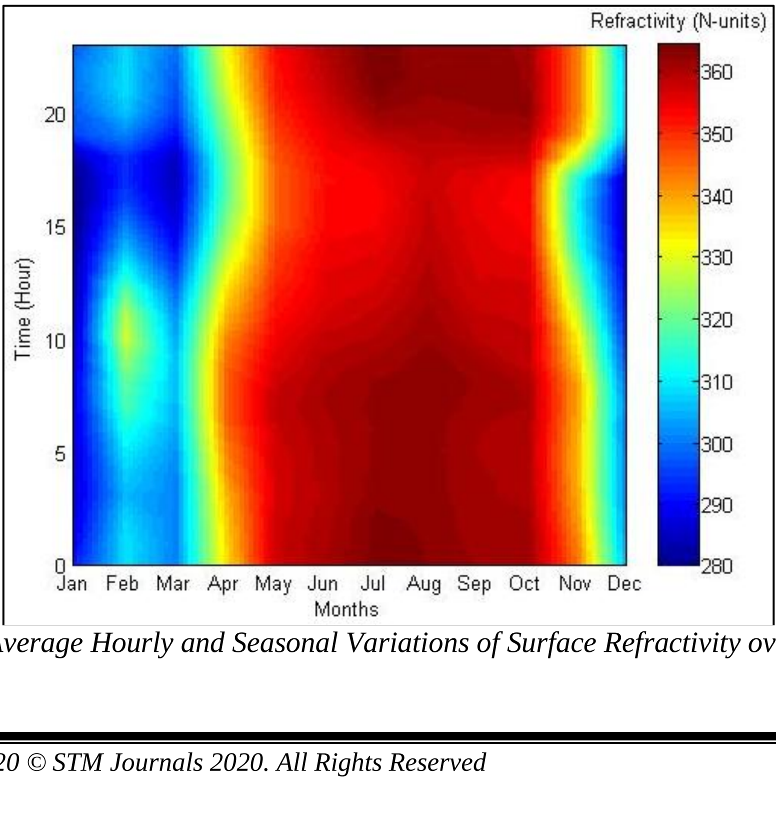

Fig. 19: *Average Hourly and Seasonal Variations of Surface Refractivity over Minna.*

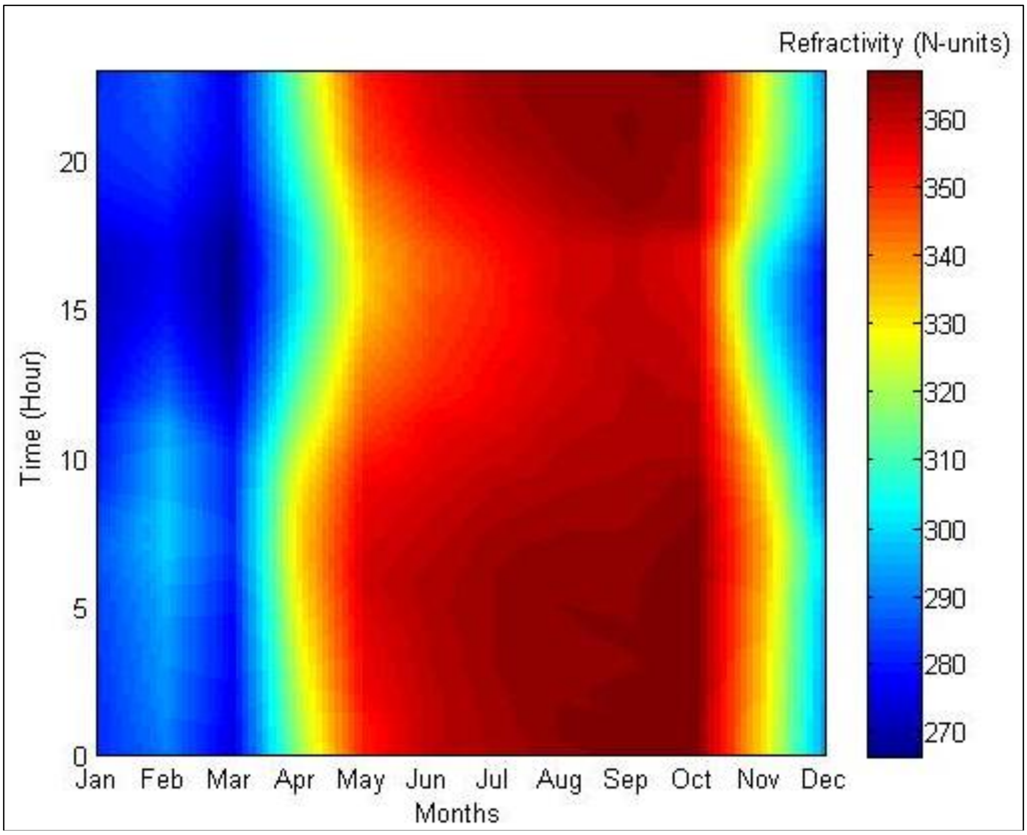

Fig. 20: *Average Hourly and Seasonal Variations of Surface Refractivity over Yola.*

A strongly positive correlation was observed between refractivity and each parameter (humidity, temperature and pressure) at Minna and Yola. The percentage contributions from R^2 for each of the parameter shows that humidity, temperature and pressure, respectively contributed approximately 89%, 84% and 55% of the variation of refractivity in Minna and 93%, 92% and 54% of the refractivity variation in Yola [14-16].

CONCLUSION

The analysis of the results revealed that each of the meteorological parameters (humidity, temperature and pressure) contributed to the variation of radio refractivity in Minna and Yola. The results also show that change in each meteorological parameter (humidity, temperature and pressure) influences variation of refractivity in Minna and Yola. The wet term of refractivity (N_{wet}) and dry term of refractivity (N_{dry}) contribution was 24% and 76%, respectively at Minna and23% and 77%, respectively at Yola. The results of regression analysis model revealed that strong positive correlation exist between refractivity and each meteorological parameter (humidity, temperature and pressure). It was also revealed that humidity, temperature and pressure, respectively contributed approximately 89%, 84% and 55% of refractivity variation, in Minna and 93%, 92% and 54% of the refractivity variation in Yola. However, it was also found that the high value of pressure did not influence the refractivity variation in both stations.

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