ESTIMATING THE VARIATIONS OF TROPOSPHERIC RADIO REFRACTIVITY TREND OVER ANYIGBA, NORTH CENTRAL NIGERIA USING NECOP DATA.

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Abstract: The hourly and seasonal variation of radio refractivity was studied using NECOP (Nigeria Environmental Climate Observing Program) data in Anyigba station north central Nigeria. Also, a harmonic analysis model was used to predict hour-to-hour radio refractivity in the station considered. This study uses the 5 minutes data obtained from campbell Automatic Weather Stations located in Kogi State University, Anyigba at latitude 7°17ʹ55.90ʹʹN, longitude 6°49ʹ47.02ʹʹE and altitude of about 420 m above sea level. The results of the investigation showed that the value of surface refractivity varies from 325.27 N-units in dry season to 359.59 N-units in wet season; which indicates that the wet season refractivity is greater than the dry season refractivity. This could be attributed to the amount of water vapour or relative humidity being high during the wet season in the atmosphere. Furthermore, the result of the harmonic analysis showed that the model estimate is a good fit to the surface refractivity as it produces very close value of average mean and standard deviation of the actual value of refractivity in Anyigba. Therefore, knowledge of refractivity trend in wet season and dry season is very significant in designing efficient and effective radio communication links in regions with similar climatic characteristics.
Keywords: Atmospheric, Climate, Harmonic Analysis, Radio Communication, Radio Refractivity, Weather

Introduction

Refractivity is defined as the physical property of a medium as determined by its index of refraction and it is responsible for the different phenomena in radio wave propagation (Akpootu and Rabiu, 2020). Variations in surface refractivity pose a major setback to modern communication systems globally; the possible effects range from abrupt break in existing radio links to extension of signal beyond normal radio horizon. (Oyedum and Gambo, 1994). More importantly, the strength of signal transmission which conveys information to people varies with time of the day because of the variations in meteorological parameters such as temperature, relative humidity and pressure, these are associated with the change in weather in different seasons of the year. These meteorological parameters change considerably hourly and seasonal in the tropics, an up-to date knowledge of the surface refractivity variation is very essential in designing reliable and efficient radio communication both terrestrial and satellite system.

The characterization of the seasonal variation in radio signal fading and its dependence on meteorological parameters provide the way to improve transmission performance. The interaction between some tropospheric factors and radio frequencies greater than 30 MHz, exposes the signal to important propagation characteristics which often degrades communication links especially at higher frequencies (Oyedun, 2007).

The increasing concern about the transient changes in weather and climate necessitate an up- to date information on the space and time distributions of meteorological parameters as they affect the environment. The identification of methods that will effectively enhance the study of hourly radio refractivity has posed serious challenges over time. This study is aim at estimating the trend in variations of the tropospheric radio refractivity over Anyigba in Kogi State, using Necop Data.

The data span a period from 2011 to 2017. The result from this work will show an up to date trend in variations of hourly and seasonal tropospheric radio refractivity over Anyigba. It will also show the number of harmonics by which the hourly refractivity fluctuates across the stations. Finally, a harmonic analysis model will be used to predict hour-to-hour radio refractivity in this station under study.

Theory of refractivity

Refractivity is a function of pressure, temperature, and vapour pressure. Refractivity near the earth's surface normally varies between 250 and 400 N-Units (ITU-R, 2003). The smaller the N-value, the faster the propagation. Refractivity values become smaller with decreasing pressure and decreasing moisture, but larger with decreasing temperature. Refractivity and meteorological parameters are related by equation (1) (Hall, 1979).

$$N = 77.6\frac{P}{T} + 3.75 \times 10^5 \frac{e}{T^2} = N_d + N_w \quad (1)$$

where P, e and T depict Atmospheric pressure (HPa) Water vapour pressure (HPa) and Absolute temperature (K) espectively; N_d is the dry term; N_w the wet term; N is the Radio Refractivity.

The relationship between water vapour pressure, e and relative humidity is given by equation (2) (Adeyemi and Emmanuel, 2011).

$$e = \frac{He_s}{100} \quad (2)$$

Where:

$$e_s = \alpha \, exp\left(\frac{\beta t}{t+\gamma}\right) \quad (3)$$

H is the relative humidity(%), t is the Celsius temperature (℃), and e_s is the saturation vapour pressure (HPa) at the temperature t, in (℃). The values of the coefficients α, β and γ for water and ice are given as 6.1121, 17.502 and 240.97 respectively, and are valid between −20 and +50 ℃ with an accuracy of ±0.20%, these coefficient are used in calculating the values of refractivity. Hence, using the relevant constants, e_s which is the maximum (or saturated) vapor pressure at a given air temperature t may be obtained as shown in equations (4) and (5) (Ayantunji *et al.*, 2011).

$$e_s = 6.11 \, exp\left[\frac{17.502t}{(t+240.97)}\right] \quad (4)$$

Hence equation (3) becomes

$$e = \frac{H \times 6.11 \exp\left[\frac{17.502t}{(t+240.97)}\right]}{100} \quad (5)$$

Harmonic Analysis

According to Kristina and Sultan (1989), Harmonic analysis is commonly applied to study periodic variations. In general, if the number of observations is N, the number of harmonics is N/2. It is not always required to determine all the N/2 harmonics; usually the first two, or at most three, harmonics describe the variation of the periodic function sufficiently well. Simply, the formula for the series is given by equation (6) (Panofsky and Brier, 1960):

$$X_N = \overline{X} + \sum_{i=1}^{N/2}[A_i Sin(\frac{360}{P}it) + B_i Cos(\frac{360}{P}it)] \quad (6)$$

Where X_N is the time series, $\overline{X}$ is arithmetic mean, and P depicts the period of observation, A_i and B_i are coefficients, while X_N, t and i depict the observed value, time and the number of harmonics.

Materials and Method

Sources of Data

The data used for this research are real time data obtained from Nigerian Environmental and climatic Observing Program (NECOP) database. The data consist of hourly air temperature, pressure and relative humidity measured with the period of measurement, Anyigba (1/1/2011-2/7/2017). The data are 5 minutes data.

Methods of Data analysis

The measured data were averaged over each hour to give a data point for each day. The mean monthly values of the data were obtained; each monthly average were further averaged over the years under study to give a seasonal data point. The averaged data were then divided into wet months (May-August) and dry months (November-February). Nigeria being a tropical region has two seasons – the wet and the dry. The wet season falls from the months of April to October. But according to the International Telecommunication Union Recommendation (ITU-R), May to August represent wet season. The dry season, on the other hand, falls from the months of November to March. The ITU-R representative months are November to February (Agbo, 2011). Hence the months, March, April, September and October are called transitional months. Equation (4) was used to compute the values of the saturated vapor pressure e_s, which was then substituted into equation (5) to obtain the value of the water vapor pressure, e. The values of e, P and T were then substituted into equation (1) to obtain the refractivity values for the station. The dry and wet term contributions (N_d and N_w, respectively) were also obtained from equations (1).

The result obtained from the run of harmonic analysis program on the average N obtained from equation (1) is summarized in Table 1 and 2. Using the average hourly surface refractivity of 359.59 N-unit and 325.27 N-unit for wet and dry seasons respectively. The period functions X_{NW} and X_{ND} for the hourly refractivity for Anyigba station are obtained using extracts from equation (6) as:

$$X_{NW} = 359.59 + \sum_{i=1}^{3}[A_i Sin(15it) + B_i Cos(15it)] \quad (7)$$

$$X_{ND} = 325.27 + \sum_{i=1}^{3}[A_i Sin(15it) + B_i Cos(15it)] \quad (8)$$

Equations (7) and (8) were used in the harmonic analysis program so as to make a six days forecast of the hourly average surface refractivity for Anyigba Station. The displayed results of the forecast with the corresponding actual and model estimates of hourly surface refractivity are shown in Tables 1 and 2

Results and Discussion

Figure 1 presents the variations in hourly surface refractivity in wet and dry season in Anyigba, while the contributions of wet and dry term in hourly surface refractivity in wet season for the station is shown in Figure 2. Similarly, in the dry season, there are contributions of wet and dry terms of the refractivity as shown in figure 3. Finally, Figures 3 and 4 present actual values and model estimate plot.

Anyigba Station

From Figure 1, the fluctuations in the surface refractivity, for both dry and wet seasons are obvious. Hence, both graphs show that surface refractivity is high in the evening and morning hours. This could be attributed to the presence of water vapour in the atmosphere at those periods. For the wet season, the high values of refractivity occurred between 12 mid-night and 11 am, with the peak of about 362.824 N-units occurring at 1 a.m and the lowest of about 354.11 N-units at 1 p.m. In the dry season, the highest refractivity value of about 336.17 N-units occurred at 9 a.m, while the lowest refractivity value of about 310.74 N-units occurred at 4 p.m.

It is important to note here that, the low values of refractivity occurred at the periods when the air temperatures are supposed to be high (Okoro and Agbo, 2016). Secondly both the dry and wet term graphs exhibit signatures similar to dry season plots as shown in Figures 3 and 4. This confirms the fact that the wet and dry term parameters are the main processor for wet and dry season refractivity respectively. In Anyigba station, the dry term percentage contribution to the total refractivity value in dry season is about 70 %, while in wet season the percentage contribution of dry term to total refractivity value is more than 75%.This is in agreement with the result by Adeyemi and Emmanuel (2011).

Results from Tables 1 and 2, show that the 1st harmonics has the highest percentage periodicity. Hence, in Anyigba; the dry season refractivity shows the highest contribution of 73.57% periodicity and the wet season is 65% contribution. This implies a higher fluctuation of refractivity in dry season than in the wet season at Anyigba.

In Figures 4 and 5, the trends in variations between actual and estimated (harmonics) values of refractivity are almost similar in both Figures. Hence, the signatures of both the actual and estimated (harmonic) values of refractivity are almost in phase in both seasons, with the highest refractivity of about 336.17 and 335.04 N-units both occurring at 9 a.m and lowest N of 310.73 and 310.825 N-units occurring at 4 p.m and 3 p.m for actual and estimated values respectively in dry season. For the wet season, the highest refractivity are 362.82 and 361.92 N-units both occurring at 1 a.m and the lowest refractivity are 354.11 and 355.04 occuring at 1 p.m and 3 p.m for actual and estimated values respectively. This implies that refractivity is higher in wet season than the corresponding dry season. Finally, the coefficient of determination (R-squared) shows that in wet season, the actual and estimated (harmonic) values have about 87% relationship with each other, while in dry season it is about 98%. This implies that the model is more efficient in dry season than wet season in Anyigba.

Conclusion

Refractivity for hourly and seasonal variation has a similar trend for both wet season and wet term of refractivity, it also has a similar signature for both dry season and dry term of refractivity in Anyigba. The trend is more stable in dry season and dry term component of the refractivity, this is due to absence of much moisture in the atmosphere at those periods. The rainy season and wet term components of refractivity has a very unstable trend which could be as a result of high amount of water vapour in the atmosphere.

Recommendation

1. A monthly variation in refractivity across Anyigba should be considered using the three atmospheric parameters.
2. Harmonic analysis for the monthly and yearly refractivity should also be established for the atmospheric parameters to ascertain how each parameter vary monthly and even yearly in the station.

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