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Diurnal Variation of Surface Refractivity over Anyigba and Bauchi

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ABSTRACT

The results of the annual mean variation of surface refractivity based on measurement of atmospheric pressure, temperature and relative humidity made across two selected locations within Nigeria; Anyigba (7°.4934) and Bauchi (10°.3010) is presented in this study. This research utilized three years of meteorological data measured from January 2013 to December 2015 using the Center for Atmospheric Research High Precision Telemetry Weather Monitoring Station installed in Anyigba. The data were obtained in five minutes interval, sorted and average into hourly data using MATLAB. The average data was then used to calculate surface refractivity according to the ITU Model. From the research work it is noted that the two stations under study exhibit the same pattern of surface refractivity in the three years of high solar activity studied. Though Anyigba has higher levels of Surface Refractivity compared to Bauchi.

Keywords: surface refractivity, atmospheric pressure, temperature, relative humidity, radio wave propagation, meteorology.

1:0 INTRODUCTION

Refractivity is the physical property of a medium, determined by its index of refraction. It is responsible for various phenomena in radio wave propagation such as; ducting and scintillation, refraction and fading, range and elevation errors[1,2]. The way by which radio signals travel from the transmitters to receiver is of great importance when planning a radio communication network. This is governed to a certain extent by the conditions of the atmosphere through which the waves transverse[3]. Thus, the study and use of atmospheric parameters with regard to radio communication require the knowledge of radio refractivity to characterize the atmosphere for terrestrial and earth-satellite communication purposes.

Knowledge of the refractivity is essential in order to design reliable and efficient radio communication (terrestrial and satellite) systems. Similarly, to estimate the performance of terrestrial radio links, the refractive index of troposphere is equally a very important parameter to be considered[4]. The study of the surface radio refractivity is necessary, especially in this part of the world. Due to the fact that radio wave propagation difficulty is common in this region, tropospheric properties in the troposphere cannot be modified, therefore the need for adequate understanding of the response of radio signals to variation in the tropospheric condition are inevitable[5]. Most of the equipment used by the communication and broadcasting industries in Nigeria are not designed based on our local terrain Data. The refractivity conditions of our environment are not fully understood. Therefore, the need to know the refractivity condition of our immediate atmosphere that is dynamic in nature plays a crucial role in our day-to-day communications became necessary.

2:0 DATA AND METHODS

2:1 Study Area

This research work was conducted over two different locations in Nigeria namely; Anyigba a tropical hinterland, and Bauchi, a tropical climate.

2:2 Anyigba

The study is Anyigba in Eastern part of Kogi State in Dekina Local Government Area. Anyigba lies between longitude 7°1736 N at East of the Greenwich Meridian and latitude 7°4934N of the Equator. It is on the south eastern direction of Lokoja (capital city of Kogi State) and the bearing of Anyigba from Lokoja is 13°5. Like most parts of Kogi State, the climate of Anyigba lies within tropical hinterland. The climate region is characterized partly by double and single maximum rainfall patter with about four months of dry season. In the mornings, Relative Humidity generally rises to over 80% and falls between 50% - 70% in the afternoon during the wet season. Rainy season occur between April through October and the peak is September. Rainfall in Anyigba is seasonal which means, it is not all the year round. Extreme variations in total rainfall for July and August are also general characteristic of rainfall here. Heavy rains of conventional type falls here and this sometimes amount up to about 978.5mm, but may be more. The mean rainy days in there are approximately 73.90days. In general, rainfall decreases inland from the southern part of the region. This area comes under the trade wind for part of the year. Temperature is therefore very high. The mean monthly temperature ranges between 210C and 320C. The daily range in temperature is amount 60C and the annual variation is about 30C in some years (CRIN, 1987). The highest temperature occurs just before the rainy season begins. Anyigba falls into the lowland area and specifically, it is the lowland scabland of the south eastern Nigeria. It lies at the western part of Enugu where the two plateaus are separated by Anambra and Udi River Line.

2:3 Bauchi

Bauchi state, a state located between latitude ($10°.3010$) and north and longitude ($9°.8237$) in the north eastern part of Nigeria has a total land area of 49,119km^2 representing about 5.3% of the country's total land mass and extents two distinct vegetation ones namely the Sudan savannah and the Sahel savannah. The Sudan savannah type of vegetation covers the southern part of the state with the vegetation getting richer and richer towards the south. The Sahel type of vegetation becomes manifest from the mid of the state as one moves from south to northern part of the state. The characteristics of this type of vegetation comprises of isolated stands of thorny shrubs. On the other hand, the southern part of the state is mountainous as a result of the continuation of the Jos-Plateau, while the northern part is generally sandy. The rainfall in Bauchi state ranges between 1300mm per annum in the south and 700mm per annum in the extreme north.

Research Site	Longitude	Latitude
Anyigba	$7°.1736N$	$10°.3010$N
Bauchi	$10°.3010$N	$9°.8237E$

Table: i; longitude and latitude of the study area

2:4 Data and Instrumentation

The measured daily climate data of atmospheric pressure, relative humidity and temperature utilized in this present paper were obtained directly from the Center for Atmospheric Research, National Space Research and Development Agency. These meteorological parameters were measured using the CAR NASRDA High Precision Telemetry Weather Monitoring Station.

2:5 Methodology

The five minutes interval data were averaged into hourly data. The study area under investigation is Anyigba (Latitude; $10°.3010$N) and Bauchi ($9°.8237E$) and longitude ($7°.1736N$) and ($10°.3010$N) respectively. To avoid possible misleading indications related to yearly variation in weather condition, the period under focus is three years (2013-2015) in order to obtain a good climatologically average. The quality assurance of the meteorological measurements was determined by checking the overall consistency of the monthly average of the climatic parameters used in the study area. The refractive index of the atmosphere is dependent upon three factors, the atmospheric pressure, temperature and relative humidity (water vapour content).

Radio Refractive Index

$$T(K) = 273.15 + t[\quad] \tag{1.0}$$

Where, T temperature in Kelvin K and t is temperature in degree Celsius.

The saturated vapour pressure is the vapour pressure that the air would have if it were saturated. Different methods exist for the evaluation of this parameter, usually expressed in hPa. For instance, the saturated vapour pressure can be determined from the relative humidity, H expressed in percentage, and from the water vapour partial pressure (e_s) expressed in hPa using the following expressions [6,7]

$$e = \frac{He_s}{100} \tag{1.1}$$

Where e_s is defined as;

$$e_s = EF.a.exp\left\{\frac{\left(b-\frac{t}{d}\right)t}{t+c}\right\} \tag{1.2}$$

And $EF_{water} = 1 + 10 - 4[7.2P(0.000320 + 5.9.10^{-6}.t^2)]$ (1.3)

ITU-RP.453-13

Where $e_s$is the water vapour partial pressure, t is the temperature in Celsius, H is the humidity, and constants for water are $a = 6.1121$, $b = 18.678, c = 257.14$, and $d = 234.5$.

These coefficients constants are obtained from experiment involving application of standard temperature and pressure (STP) and the formula is empirical. Thus, accurate empirical relations are more often used to determine the saturation vapour pressure.

According to ITU-R P. 453-13, the atmospheric refractive index, n can be computed using equations 1.4, (Bean and Dutton, 1968) and refractivity, N using equation 1.5, (Smith and Weintraub, 1953) respectively[8].

$$N = \langle n-1\rangle \times 10^{-6} \tag{1.4}$$

Where N is radio refractivity expressed by[9,10];

$$N = N_{dry} + N_{wet} = 77.6\frac{P_d}{T} + 72\frac{e}{T^2} + 3.75\times 10^{-5}\frac{e}{T^2} \tag{1.5}$$

With the dry term of radio refractivity given by;

$$N_{dry} = 77.6\frac{P_d}{T} \quad (1.6)$$

And the wet term given by;

$$N_{wet} = 72\frac{e}{T^2} + 3.75 \times 10^{-5}\frac{e}{T^2} \quad (1.7)$$

Where P is atmospheric pressure (hPa), e is water vapour pressure, (hPa) and T is absolute temperature (K).

This expression may be used for all radio wave frequencies (for frequencies up to 100GHz; the error is less than 0.5%) for representative profiles of temperature, pressure and water vapour pressure (ITU-R P.453-13**).**

3:0 RESULTS AND OBSERVATIONS

Fig 4.1 shows the daily mean annual average variations of surface refractivity observed for Anyigba station for 3 years (2013-2015) of high solar activity occurrence. It is clearly shown from the plots that surface refractivity exhibits a consistent maximum diurnal variation during the hours of little or no solar radiation 06:00 to 09:00 am, with magnitude of 254 to 278N, drops slowly to a maximum after sunset between (6pm to 12am). Large variations in surface refractivity are observed when no record of solar activity, while a daytime, surface refractivity is at its minimal.

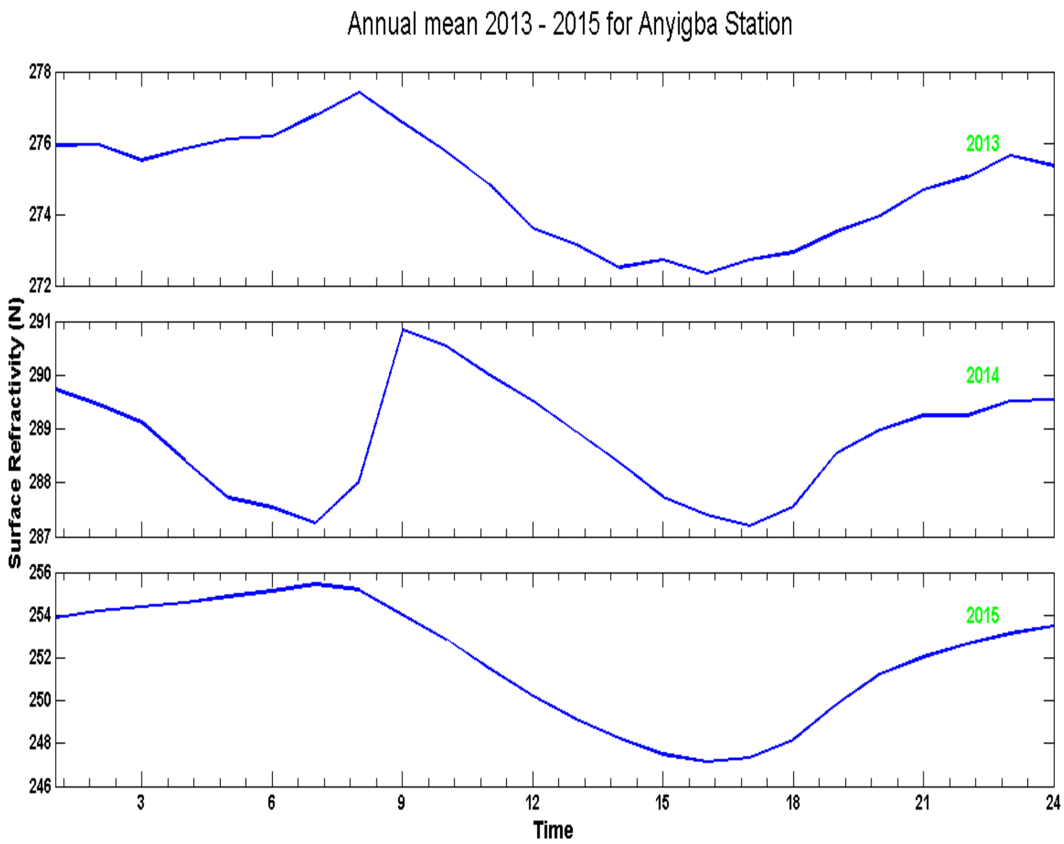

Fig. 4.1 Annual mean 2013 – 2015 for Anyigba Station

For Bauchi, it is observed from the plot that form the three years (2013-2015), surface refractivity is at its maximum with value of surface refractivity of (248N) for three years and surface refractivity is at its minimum with surface refractivity value of (240N) for the three years of study.

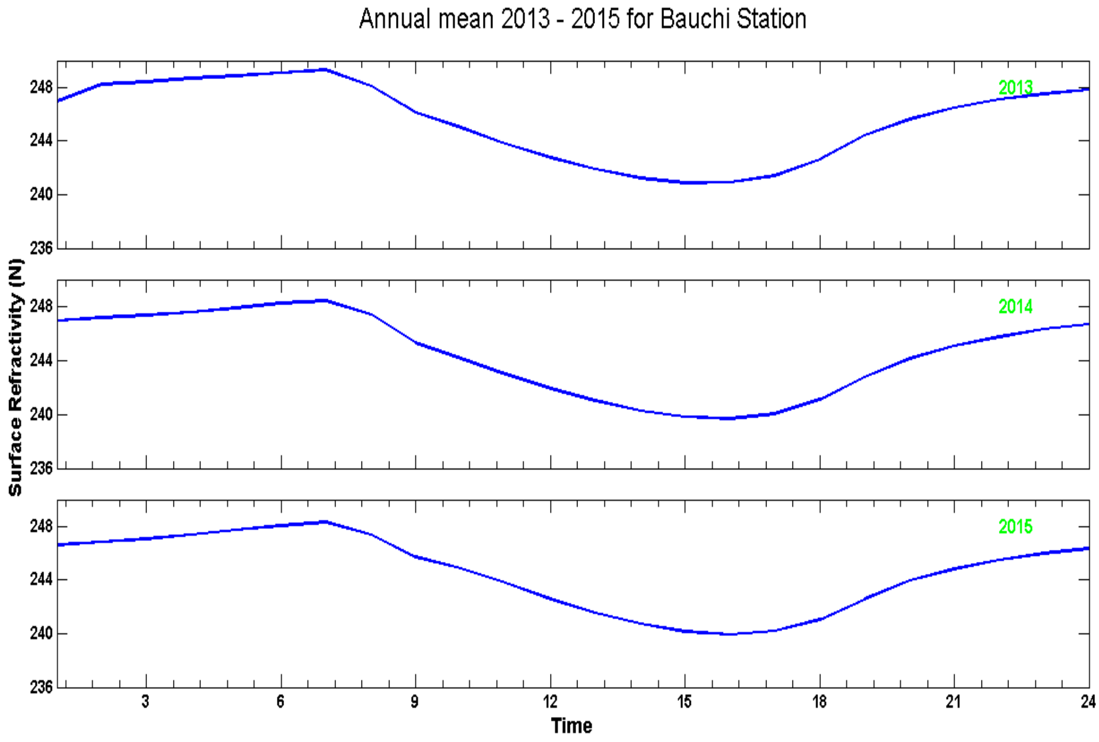

Fig. 4.2 Annual mean 2013 – 2015 for Bauchi Station

Fig 4.2 shows daily mean annual variation of surface refractivity observed for Bauchi stations for three years (2013-2015) of high solar activity occurrence. From the plots shown above, there is a steady maximum increase in surface refractivity between the hours of 07:00 to 09:00 with magnitude ranging between 244 – 248N. It then falls to its minimum between 12:00 and 6:00 pm with magnitude 234 – 236N. It then rise to its maximum between 6pm to 12am surface refractivity increase in its values at nighttime and decrease its value at daytime when solar radiation is at its peak.

4:0 DISCUSSION

Fig 4.1 and Fig. 4.2 show the mean annual plots of surface refractivity in the study areas of Nigeria using Anyigba and Bauchi stations. Surface refractivity is at its minimum in its value at both stations when solar radiation is at its peak. The night time and morning period when no activity of solar radiation is recorded, surface refractivity is at its peak.

Increase in surface refractivity is dependent on the intensity of solar radiation.

From fig 4.1 for Anyigba station, for the years (2013, 2014, 2015), the plot shows that surface refractivity increase with value range of (254, 290, 276)N within the time frame of 3am to 9am,and it's at its peak at 9am as revealed from the graph above. The rise in surface refractivity for the three years varies with range of values of 254N for 2013, 290N for 2014 and 276N for 2015 as seen respectively from the plot.

From the year 2013, as observed from the plot, surface refractivity is at a high peak between the hours of 3-9am when there is little or no solar radiation with surface refractivity value of 276-278N and drops gradually when solar radiation is intense between the hours of 12-6pm with surface refractivity value of 274-273N, then gradually increase at sunset between the hours of 6pm-12am.

Also, the 2014 annual mean surface refractivity variation for the Bauchi station, shows that is at a value above 289N and reduces gradually between 3- 8am, then rises to a peak at 9am and gradually decreases also between 12-6pm, when solar radiation is intense and gradually rises at sunset between the hours of 6pm-12am.

Observing also for the year 2015, surface refractivity is above has similar occurrence record with 2013 when surface refractivity is at its maximum between 3-9am, and reduces gradually to its minimum between 12-6pm when solar radiation is intense and rises steeply between 6pm-12am at sunset.

From Fig. 4.2 for the Bauchi station, surface refractivity is at its maximum between 3-9am, reduces gradually to its minimum between the hours of 12-6pm when solar radiation is at its peak and rises at sunset for the three years observed in Bauchi station (2013-2015).

Observing the two stations (Anyigba and Bauchi), for the three years of study of the mean annual surface refractivity, Bauchi which is located at the North Central region in Nigeria has record of high surface refractivity then Anyigba which is located at the central region of Nigeria (middle belt) has record of surface refractivity but not as that recorded in Bauchi station.

5:0 CONCLUSION

From the research work it is noted that the two stations under study exhibit the same pattern of surface refractivity in the three years of high solar activity studied. Though Anyigba has higher levels of Surface Refractivity compared to Bauchi.

The surface refractivity across both stations demonstrates consistent minimum annual variations during the hours of high solar radiation between (12-6) pm. Generally, the hours of little or no solar radiation surface, refractivity occurs at its maximum then the period of high solar radiation which is between the hours of (3-9) pm.

6:0 RECOMMENDATION

From this research work carried out, it is recommended that further studies be carried out to compare surface refractivity with sunspot number to ascertain the correlation between the two parameters.

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