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EFFECT OF SECONDARY RADIOCLIMATIC VARIABLES ON SIGNAL PROPAGATION IN NSUKKA, NIGERIA

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ABSTRACT: *This study presents the effects of Radioclimatic variables on signal propagation in Nsukka, Nigeria. The primary Radioclimatic data used in the study include temperature, pressure and humidity or water vapour pressure, while secondary radioclimatic data includes refractivity (N), refractive index (n) and effective earth's radius (k-factor). The measurements of the primary variables were made at time interval of 30 minutes daily from August 2013 to July 2014. The results obtained show seasonal variation of the temperature and relative humidity. This leads to the increase in the values of radio refractivity and refractive index. The results also, show that the k-factor values for those months were at the range 1.555 – 1.653. This high values of k-factor is an indicator to the possible causes of signal interference in the study area.*

KEYWORDS: Refractivity, refractive index, k-factor, Nsukka.

INTRODUCTION

It has been established that a good knowledge of secondary Radioclimatic data especially the surface refractivity as well as the diurnal and seasonal variability amongst other factors, are useful tools in planning terrestrial radio links mainly because of multi-path fading and interference effects. Tropospheric surface refractivity poses a major setback to the phenomenon of communication globally. Research done by Oyedun (2007), indicate that the interaction between some tropospheric factors and radio frequencies > 30 Mhz, exposes the signals to important propagation characteristics which often degrades communication links especially at higher frequencies. Korak, (2003) opined that the propagation of electromagnetic waves in the atmosphere (especially the troposphere) is greatly influenced by the composition of the atmosphere, and attributed it to the fluctuations of atmospheric parameters such as; temperature, pressure and relative humidity. Other important variable, "the tropospheric refractive index" is also a function of pressure, temperature and humidity and this implies that fluctuations of these atmospheric parameters (pressure, temperature and humidity) do cause significant variation in the refractive index of the air in the troposphere. The consequences of this scenario lies in the fact that the signal propagating through the troposphere does not arrive at its destination with the same amount of energy with which it was propagated from the source. According to Hall (1980), the troposphere can be defined as that region which extends from the earth surface to an altitude of about 10km at the earth poles and 17km at the equator. Nsukka is located at latitude 6^o 45N and longitude 7^o 30E, South –Eastern Nigeria. The period of investigation spans across the two major seasons (wet and dry) in Nigeria. This paper aims to investigate the effects of Radioclimatic variables on signal propagation in Nsukka, with a view to establish potential pathways to improve radio/communication signal reception in the study area.

MATERIALS AND METHODS

In this study, indirect means of measuring the atmospheric profiles were employed using the fixed measuring method. It involves the use of a tower equipped with meteorological measuring instrument at ground level and also, the sensor was fixed at surface level at center for basic space science (CBSS) at the University of Nigeria, Nsukka. The instrument is a wireless vantage pro 2 automatic weather station which consists of integrated sensor suit (ISS), wireless console with a storage device known as the data logger and laptop computer for data downloading.

Fig. 1. Picture of Davis Wireless Vantage Pro2 and Fan-Aspirated Radiation Shield (model 6153).

Fig. 1 gives a picture of the complete set of wireless Davis Vantage Pro2 instrument installed at CBSS, University of Nigeria, Nsukka observatory. The model 6153 includes Vantage Pro2 console/receiver, integrated sensor suite (ISS), and mounting hardware. The ISS includes rain collector, temperature and humidity sensors, anemometer, 12 m anemometer cable, and a solar panel. Temperature and humidity sensors are enclosed in patented solar-powered 24-hour fan-aspirated radiation shield.

The method of measurement was by fixing the integrated sensor suit (ISS) at surface level at the centre for basic space science (CBSS) mast in Nsukka for the measurement of the weather parameters in the region. The method adopted for this work provides an accurate measurement of parameters required for the estimation of refractive index, effective earth radius (k-factor) and radio refractivity for twelve months. By this method the sensor was positioned upward on the tower while the console is positioned on the ground. The signals from the sensor were transmitted to the receiver (console) by radio waves. The data is stored on the data logger attached to the console located on the ground from which the data are then copied to the computer. The in-situ measurements of meteorological parameters of temperature in (^{o}c), Pressure in hpa and relative humidity in percentage from the data collected for 24 hours each day from zero hour to 23:00 hours local time at intervals of 30 minutes from August 2013 to July 2014. However, the data covers both wet and dry seasons in Nsukka region. The dry season is mainly from November to March while the wet season starts from April to October in the region.

RESULTS AND DISCUSSION

Fig. 1 gives the variations of pressure and temperature with months (August 2013 – July 2014) in the study area. From Fig. 1, a maximum pressure of 1015 Mbar was recorded in December 2013 while the minimum value of the pressure was recorded in April 2014. This could be attributed to the weather conditions of the study area within those months. The increase in the pressure values between April to July was due to the difference in season (wet season). As indicated in Fig. 1, the temperature increased steadily from August 2013, and attained maximum values at the month of December 2013 and February 2014 respectively. The temperature then decreased thereafter. The fall in temperature in January 2013 was attributed to the peak harmattan influence in the study area within that period. The values of the temperature and pressure obtained in this study is in close agreement with the research work by other authors in the literature (Adeyemi and Emmanuel, 2011; Isikwue et al, 2013; Agbo 2011; Ekpe et al., 2010).

Fig. 2 gives the variations of humidity with months from August 2013 to July 2014. The behavior of the plot is in line with the changing seasons of the study area. As indicated earlier, the wet seasons normally last from April to October while the dry season is from November to March, hence the maximum value of the humidity was recorded in August 2013 while the minimum value was recorded in February 2014.

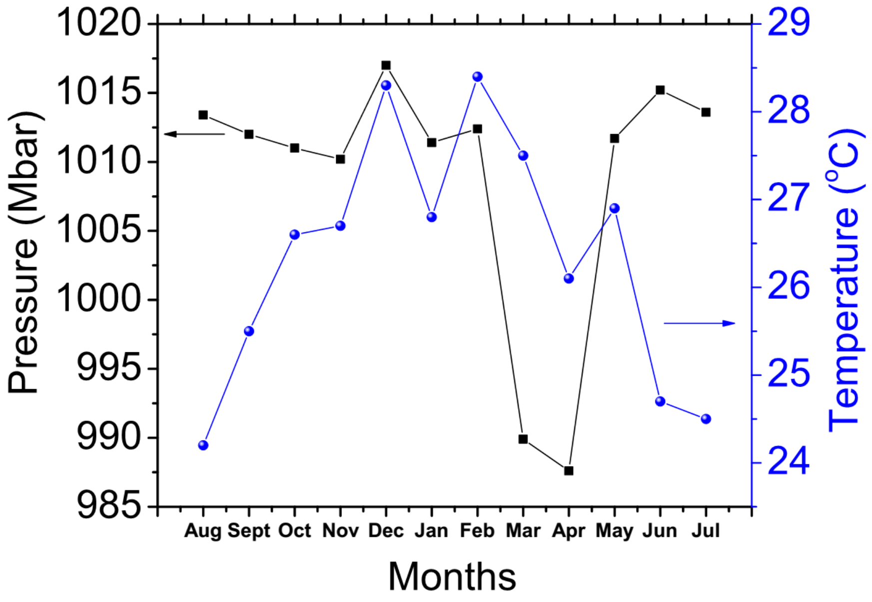

Fig. 1: Variations of pressure and temperature with months (August 2013 – July 2014)

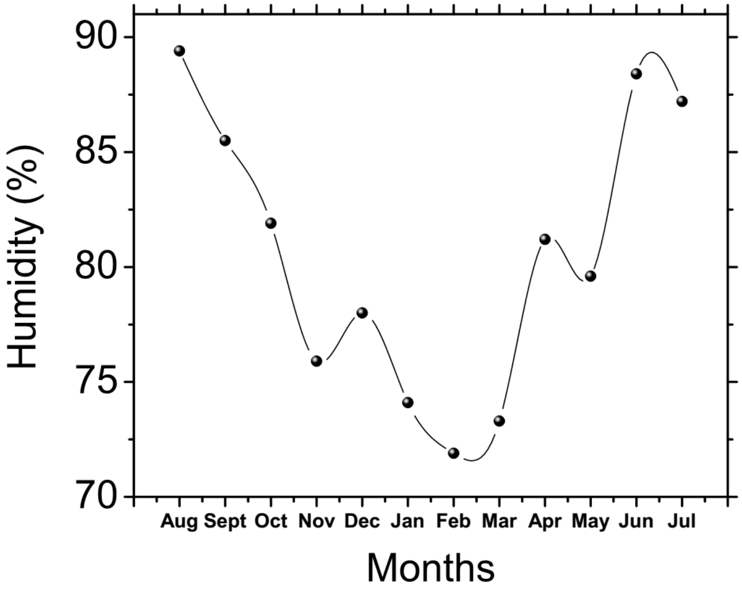

Fig. 2: Variations of humidity with months (August 2013 – July 2014)

Fig. 3 shows the variation of the water vapour e_s, with months (August 2013 – July 2014). The plots indicate that the water vapour pressure increased from August 2013 and attained a maximum value in the months of December 2013 and February 2014. The values then decreased thereafter. This behaviour is due to the effect the prevailing

seasons at the period of the measurements. Other authors have reported similar findings (Agbo, 2011).

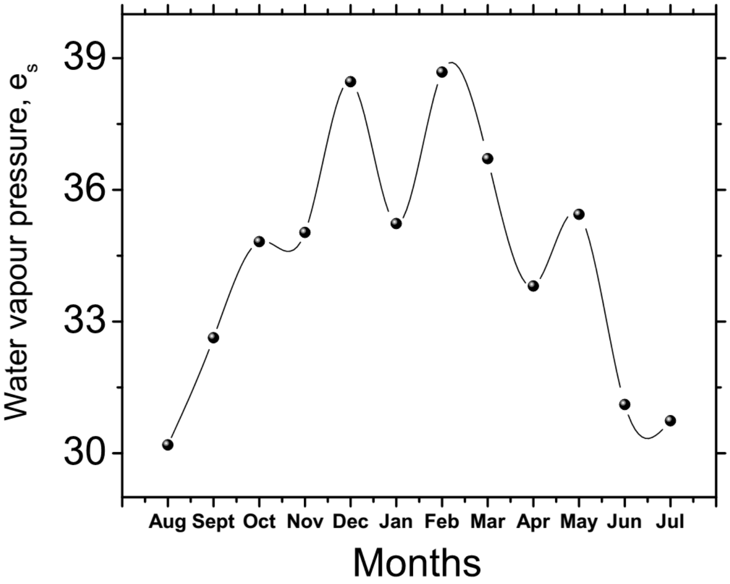

Fig. 3: Change of water vapour pressure with months (August 2013 – July 2014)

The secondary data can be estimated from a relevant primary data which include; temperature, pressure and humidity or water vapour pressure, while secondary radioclimatic data includes; refractivity (N), refractive index (n) and effective earth's radius (k-factor).The secondary Radioclimatic data were obtained from the primary data by employing relevant equation from the literature. The surface refractivity was deduced using the relation given in Bech et al (2000). The parameters; temperature, T(°c) and the relative humidity, RH(%) extracted from the daily records were converted to water vapour pressure, e (hpa). The data were then used to compute the refractivity using the relation (Bech et al., 2000, Hall and Barclay, 1989);

$$N = (n-1)\, x\, 10^6 = \frac{77.6}{T}\left(P + \frac{4810\, e}{T}\right) \qquad 1$$

where P is the atmospheric pressure (hPa), e is the water vapour pressure (hpa), n is the refractive index and T is the absolute temperature (K) at surface level considered for this study. Equation 1 is valid at surface level and for radio frequencies between 1 GH_Z and $100GH_Z$ (Bech et al., 2000). Alternatively, equation 1 can be rewritten as (Smith and Weintraub, 1953; ITU-R, 2003, Ayatunji et al, 2011);

$$N = \frac{77.6\,P}{T} + \frac{3.73\,x\,10^5\,e}{T^2} \qquad 2$$

Where N, P, T, and e, in equation 2 retains their usual meanings.

However, the relationship between saturated vapor pressure and relative humidity is used to calculate the water vapor pressure using the expression given in the literature (Ayatunji et al, 2011):

$$e_s = \frac{100\,e}{H} \qquad 3$$

In general, it has been established that e_s can be expressed in the relationship with temperature as (Ayatunji et al, 2011);

$$e_s = 6.1121\exp\left(\frac{17.592\,t}{t + 240.97}\right) \qquad 4$$

where t is the temperature in degree Celsius (^{0}C) and e_s is the saturated vapor pressure (hpa) at the temperature t (^{o}C).

The data from the computations using equation 1 and equation 2 was used to plot the variations of surface refractivity, N_S, with months (August 2013 – July 2014). Fig. 4 gives that variations of the surface refractivity, N_S, with months (August 2013 – July 2014). As indicated in the plot (Fig. 4), the surface refractivity displayed a maximum in December 2013 and a minimum value in March 2014. However after the minimum value, the surface refractivity increased thereafter. Other research groups have observed similar findings. Research work by Ayatunji et al., (2011), indicate that surface refractivity show a seasonal variation with high value in the rainy season and low value in the dry season.

The k-factor was determined using the relation discussed in the literature (International Telecommunication Union – Recommendations ITU-R, 2000; ITU-R, 2009; Agunlejika, and Raji, 2010), hence:

$$k = \frac{1}{1 - {}^{a}\!/_{\rho}} \qquad 5$$

Where a is the earth radius given as 6375 km and ρ is further related to the surface refractivity as;

$$\rho = \left(\frac{a}{1 - 0.04665\, e^{0.005577 N_S}} \right) \qquad 6$$

where a and Ns retains their usual meanings.

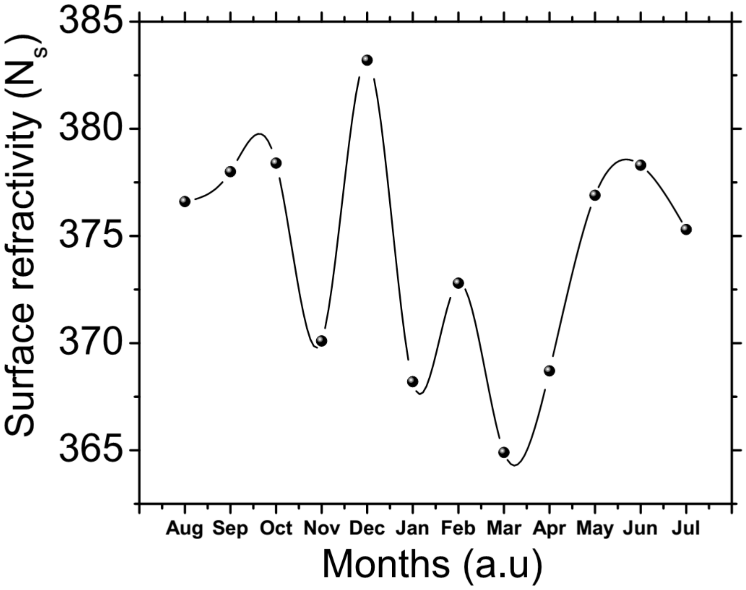

Fig. 4: Variations of surface refractivity, N_S, with months (August 2013 – July 2014)

Fig. 5 gives the change of k-factor with months (August 2013 – July 2014). The values of the k-factor were very high and in the range 1.555- 1.653. The behaviour of the k-factor is relatively similar to that of the surface refractivity in that it exhibited a maximum value at the month of December in 2013 and also showed a minimum at the month of March 2014. This behaviour is very close to the observation of other research groups in the literature (Okoro and Agbo, 2012).

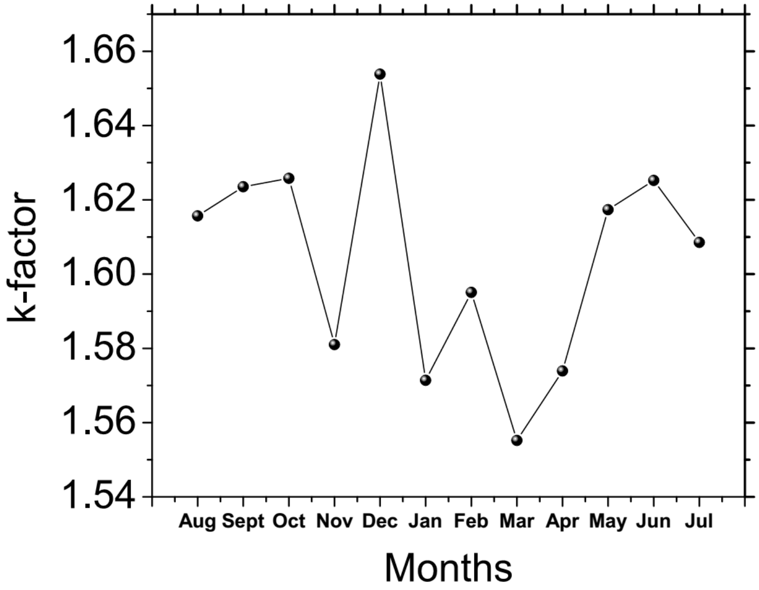

Fig. 5: Change of k-factor with months (August 2013 – July 2014)

CONCLUSION

The effects of radioclimatic variables on signal propagation in Nsukka, Nigeria has been investigated. The results show that there is an increase in the values of the effective earth radius (k-factor) and radio refractive index (n) in the region. It was also observed that there was a significant increase in the atmospheric temperature during the dry season and as well an increase in the months of the rainy season due to the rise in the atmospheric moisture content in the region. All these variations affects the microwave propagation in the area, especially the rise in the values of k-factor above the global standard value of 1.333. The effect of this result (large k-factor value) is that it will lead to major propagation condition known as super- refraction which mostly affects radio waves and then lead to signal interference over Nsukka area.

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