Caliphate Journal of Science & Technology (CaJoST)

ISSN: 2705-313X (PRINT); 2705-3121 (ONLINE)

Research Article

Article Info

Received: 26th September 2019

Revised: 9th February 2020

Accepted: 13th February 2020

Effects of Radio-Climatic Variables on Signal Propagation in Kebbi State

Iliyasu Usman, Mohammed N. Ibrahim, Lukman S. Akeem and Anas Shehu

Department of Physics,
Sokoto State University, Sokoto.

***Corresponding author's email:**

usman.iliyasu@ssu.edu.ng

Cite this: *CaJoST,* 2020, 1, 18-24

This study presents the effects of Radio-climatic variables on signal propagation in Kebbi State of Nigeria. The primary Radio-climatic data used in the study include temperature, pressure and relative humidity. The analysis was focused on the study area in question which spans across all major signal propagation in the study area. The measurements of the average monthly primary variables (temperature, relative humidity and air pressure) were made from January 2016 to December 2016. In this work, mathematical model were used using an excel spread sheet to compute the secondary radio-climatic variables which also include graphical representation (Surface Refractivity, Refractive Index (n), and Effective Earth Radius (k-factor). The results obtained shows seasonal variation of the temperature and relative humidity. The k-factor calculated has a value which ranges from 1.77 to 2.33 in the Months of January and April respectively. The higher the value of k-factor greater than 1.33 is an indicator of possible causes of signal interference in the study area. The correlation between the primary and secondary radio-climatic variables were not affected except for the refractive index (n) which increases to a maximum value of 1.0005 slightly greater than the recommended value as the temperature increases. The results compared well with other literature.

Keywords: Temperature, Pressure, Relative humidity, Surface refractivity, Refractive index, K-factor and Radio-climatic variables.

1. Introduction

Kebbi is a state in North-Western Nigeria with its capital at Birnin Kebbi. The state was created in 1991 out of a part in Sokoto State. It is located at a Coordinates - 11°30′N 4°00′E, which cover a total area of 36,800 km^2. The part of the atmosphere most closely related to human life is the troposphere with altitude ranges from about 10 km at the earth's poles and 17 km at the earth equator [3]. Since the temperature decreases with altitude in the troposphere, warm air near surface of the earth can rapidly rise replacing the cold dense air at the upper part of the temperature [5]. Radio communication is not the same at all hours of the day or at all times of the year. Despite the fact that radio waves and the atmosphere are above the Earth, they are invisible, the atmosphere plays an important role in radio communications. Solar events, such as sunspots several million miles away, have a direct effect on communications. Since propagation usually takes place within the earth's atmosphere, it is necessary to establish a basic understanding of the air around and above us and also the wave length of the propagating site [16].

Radio signals can be reflected, refracted, scattered, and absorbed by different atmospheric properties. However, the degree of atmospheric effects on radio signals depends mainly upon the frequency, power of the signal and on the state of the troposphere through which the radio wave propagates. The characterization of tropospheric variability has great significance to radio communications, aerospace, environmental monitoring, disaster forecasting etc [7]. The earth's atmosphere has a complex structure, which may significantly impact radio wave propagation, causing such effects as smooth refraction, scatter and energy absorption of the radio wave. Variations of the electro-magnetic parameters of the atmospheric air are highly dependent on its gaseous composition, pressure, humidity and ionization

It has been established that a good knowledge of secondary Radio-climatic 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 [2]. The structure of the

Radio-refractive index, n, at the lower part of the atmosphere is a very important parameter in the planning of the communication links. It is defined as a ratio of the radio wave propagation velocity in free space to its velocity in a specified medium. Radio–wave propagation is determined by changes in the refractive index of air in the troposphere. Changes in the value of the Radio-refractive index in the troposphere can curve the path of the propagating radio wave. The atmosphere Radio-refractive index depends on air temperature, humidity, atmospheric pressure and water vapor pressure. Even small changes in any of these variables can make a significant influence on radio-wave propagation, because radio signals can be refracted over the whole signal path [8]. Refractive index is not constant in the atmosphere and its space-time distribution results in scattering, sub-refraction, super-refraction, ducting and absorption phenomena [8].

The variation of refractive-index is due to various phenomena affecting the propagation of radio signal, which for instance include refraction, bending, ducting and scintillation, range and elevation errors in radar acquisition and radio station interference [13]. The variation of refractive index as well as specific attenuation of micro/radio wave may be estimated indirectly with the measurement of temperature, pressure and relative humidity [17]. The effect of temperature and relative humidity on specific attenuation of microwave was studied by different researchers. The establishment of a Radio-refractive index database is necessary because the knowledge of Radio-refractive index is always required when measurements are made in air. Several research work on radio-refractivity for different regions and climates using measured local meteorological data have been investigated in Nigeria and other parts of the world [17].

Radio waves like light wave are affected by the phenomena of reflection, refraction, diffraction, absorption, polarization and scattering [10], to understand the effects of varying conditions on Radio Propagation has many practical applications, from choosing frequencies for international shortwave broadcasters, to designing reliable Mobile Telephone Systems, to Radio Navigation, to operation of Radar Systems. When an electromagnetic wave is transmitting from an antenna, the radiated energy gets transmitted through reflection, refraction, diffraction and scattering in the free space. [14] Affirmed that the tropospheric surface refractivity poses a major setback to the phenomenon of communication globally. Research done by [15] indicates that the interaction between some tropospheric factors and radio frequency > 30MHz, which often exposes the signals to important propagation characteristics which often degrades communication links especially at higher frequencies.

2. Materials and Methods

In this work, indirect means of measuring the atmospheric profiles were employed using the fixed measuring method. It involves the use of tower equipped with meteorological measuring instrument fixed with sensor at the sea level at Kebbi State University of Science and Technology. The instrument is a wireless vantage PRO 2 automated weather station which consist of integrated sensor suit (ISS) wireless console with a data logging system. The in-situ measurements of the meteorological parameters of average monthly data for temperature (°C), pressure (hpa**)** and relative humidity (Percentage) which spanned from January 2016 to December 2016. The extracted data (temperature, pressure and relative humidity) from the monthly records were converted to water vapor pressure (hpa)**.** The data were then used to compute the refractivity using the relation ([8], [11]:

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

Where P is the atmospheric pressure (hpa), e is the water vapor pressure (hpa), n is the refractive index and T is the absolute temperature (K) at surface level considered for the study. Equation 1 is valid at surface level and for radio frequencies between 1 GHz and 100GHz [8]. Alternatively, equation 1 can be rewritten as:

$$N = \frac{77.6\,P}{T} + \frac{3.73 \times 10^5 e}{T^2} \quad (2)$$

However, the relationship between saturated vapor pressure and relative humidity is used to calculate the water vapor pressure using the expression given

$$e_s = \frac{100e}{H} \quad (3)$$

Where e_s is saturated vapor pressure given by:

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

Where t is the temperature in degree Celsius (°C) and e_s is the saturated vapor pressure (hpa) at the temperature t (°C) [6].

The k-factor is determined using the relation discussed in the literature [12] as:

$$K = \frac{1}{1 - \frac{d}{P}} \quad (5)$$

The numerical value of the air refraction index is fairly close to unity. Since for the troposphere, it usually doesn't exceed unity by more than about 0.05 to 0.1 percent [4] and for conveniences refractivity is given as:

$$N = (n - 1) \times 10^6 \qquad (6)$$

Table 1 below depict the measurements obtained for the primary variables (temperature, relative humidity, air pressure and water vapor pressure) with respect to months for the period of January 2016 to December 2016.

Table 1. Average monthly Primary Climatic Variables at KSUSTA, Aliero from January 2016 to December 2016

Months	Temperature (°C)	Relative humidity (%)	Air pressure (Mbar)	Water vapor pressure (hpa)
January	30.36	27.20	921.40	43.33
February	35.37	22.94	982.70	57.40
March	42.36	38.64	948.43	80.17
April	41.57	64.79	979.89	80.17
May	38.13	75.57	1012.34	66.73
June	33.74	87.72	1310.53	52.44
July	30.45	96.69	950.84	43.55
August	31.60	97.24	985.62	46.50
September	31.77	98.63	1015.43	46.95
October	33.71	85.51	980.88	52.34
November	38.34	53.54	948.53	67.49
December	36.79	31.90	982.35	62.05

3. Results and Discussion

3.1 Presentation of monthly secondary radio-climatic variable

(i) Surface Refractivity (N_s)

The results from primary climatic variables were used in computing the values for the surface refractivity, N_S, using equation (2). The result of the surface refractivity is graphically represented as shown in Figure 1. As shown in the figure, the surface refractivity increases from lowest value 412.26 N unit in January and reaches a maximum value of 545.54 N unit in April but a sudden decrease was observed in May which increased to 540.55 N unit in June. However, similar decrement was observed in July of a value 420.51 N unit which is perhaps lower than that observed in May. After July value 420.51 N unit, the surface refractivity increased thereafter. The zigzag nature of surface refractivity observed may result from intertwined rainy and little dry period experienced in the year. It can be further inferred that the value of the surface refractivity changes constant with climatic condition (variation in weather). [1] Affirmed that surface refractivity shows a seasonal variation, and has high value in the rainy season and low value in the dry season.

(ii) Refractive Index (n)

The refractive index of each month was computed using equation 6. The results obtained are as shown in Figure 2. We can infer from Figure 2 that there is a variation in the refractive index of the study area. This form the fact that the tropospheric refractive index is a function of primary radio-climatic variables. (Variation in seasonal Temperature, Pressure, Relative Humidity and water vapor cause significant effect on it) [13]. The consequence of this effect is that the strength of radio wave propagation will decrease with distance as described by inverse square law.

(iii) The Effective Earth Radius (K-Factor)

The Effective Earth Radius, K-Factor, obtained from the study area using equation (5) are graphically represented in the Figure 3. From the figure, it was observed that the highest value (2.33) of the effective earth radius was in April and the lowest value (1.77) was in January. This behavior is very close to the observations of other research groups in the literature [14], [5].

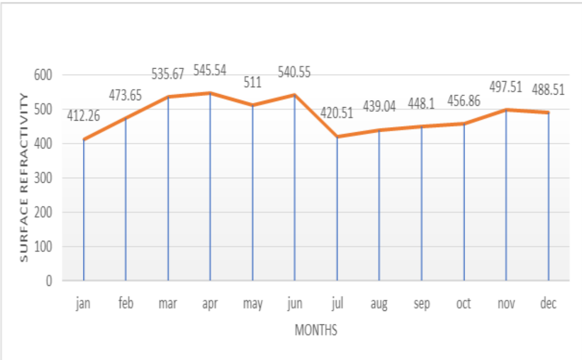

Figure 1. Surface Refractivity Variation with Respective Months

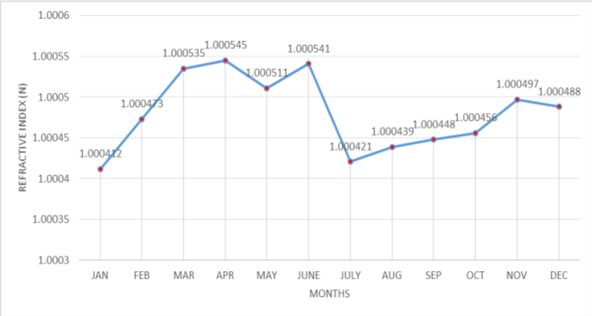

Figure 2. Graphical representation of refractive index with their respective month

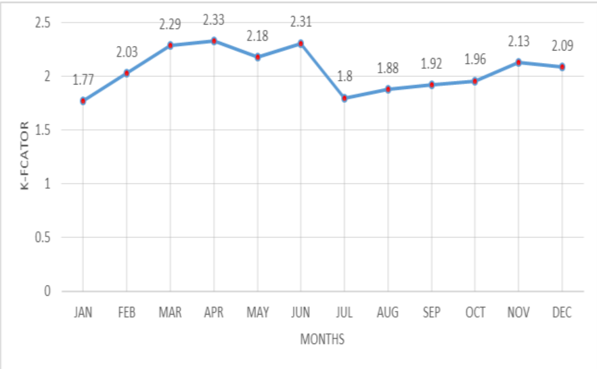

Figure 3. Variation of K-Factor with respect to months.

3.2 Results of correlations between primary's and secondary's Radio-climatic variables

(i) Correlation between Temperature with respect to Surface refractivity, K-Factor and Refractive Index

Figure 4a shows that the refractivity increases linearly from January as the lowest (412.26) to a higher value (545.54) in April which correspond to the increase in temperature from January to April. The effective K-factor is also a function of temperature as the highest value of the K-factor (2.33) in Figure 4b were in April and the lowest value (2.77) were in January respectively. In Figure 4c, the refractive index increases with temperature as the highest value (1.00055) were recorded in the month of April with a value slightly greater than the recommended value of (1.0003) and the lowest value were 1.0041 in the month of January respectively.

(ii) Correlation between relative humidity with respect to surface refractivity, refractive index and K-factor

Figures 5a, 5b, and 5c shows the correlation between relative humidity with Surface Refractivity, Refractive Index and Effective Earth Radius (K-factor)

The lowest value of the relative humidity were recorded at the month of January 27.2 % and increased steadily to 98.63 % in the month of September and slowly decrease to 31.9% in the month of December. The surface refractivity, Refractive index and effective earth radius (K-factor) were not affected by the relative humidity as shown in the figures above

(iii) Correlation between Air Pressure with respect to surface refractivity, refractive index and K-factor

Figures 6a, 6b, and 6c depict the graphical representation of the correlation between Relative Humidity with Surface Refractivity, Refractive Index (n) and Effective Earth Radius (K-factor).
The figures show the correlation between air pressure with surface refractivity, Refractive Index and Effective Earth Radius (K-factor)
The lowest value of the air pressure were recorded in the month of January 921.4 Mbar and increased steadily to a highest value of 1310 Mbar in the month of June. The surface refractivity, Refractive index and effective earth radius (K-factor) were not affected by the air pressure as shown in the figures above

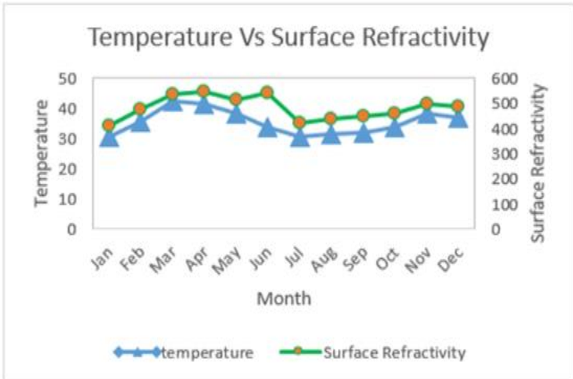

Figure 4a. Graph of Correlation between Temperature and Surface Refractivity

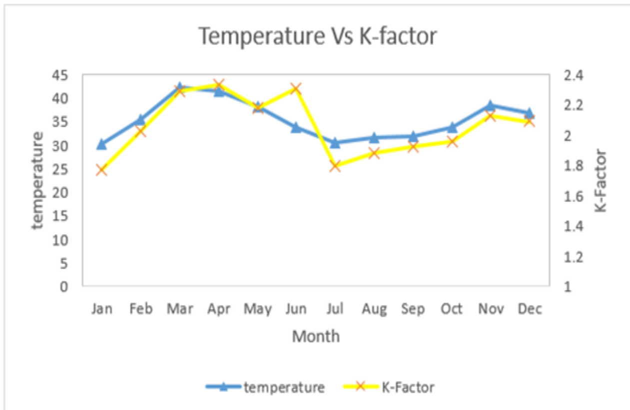

Figure 4b. Graph of Correlation between Temperature and Effective Earth Radius (K-Factor)

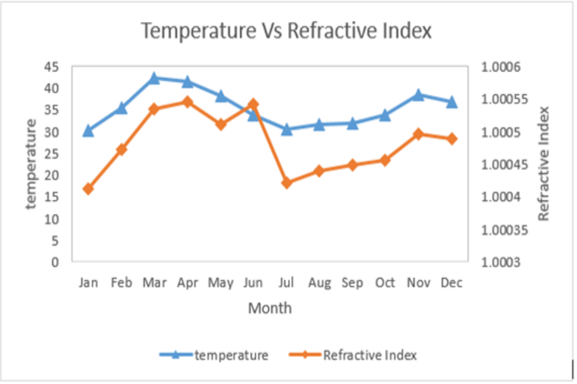

Figure 4c. Graph of Correlation between Temperature and Refractive Index (n)

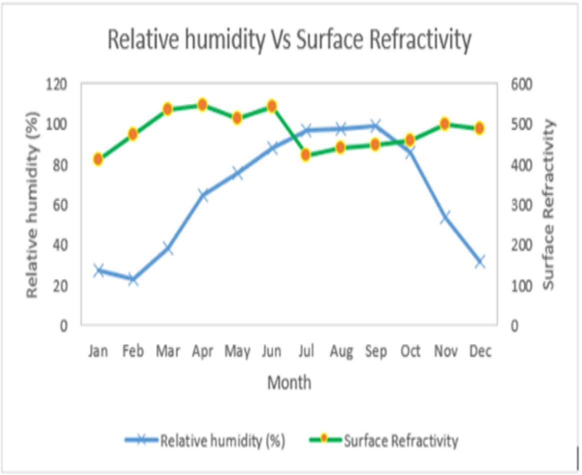

Figure 5a. Graph of correlation of relative humidity and surface refractivity

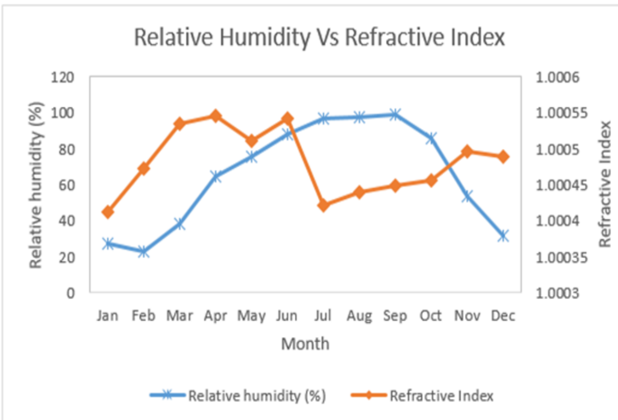

Figure 5b. Graph of correlation of relative humidity and Refractive Index (n)

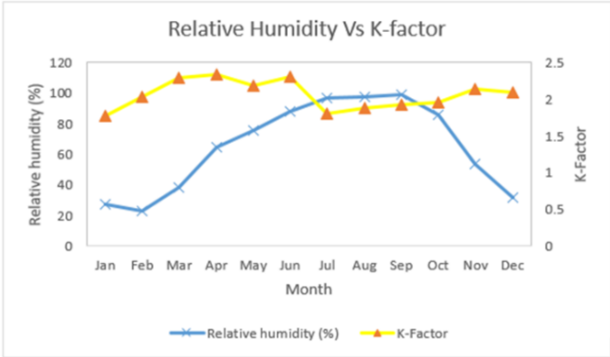

Figure 5c. Graph of correlation of relative humidity and Effective Earth Radius (K-factor)

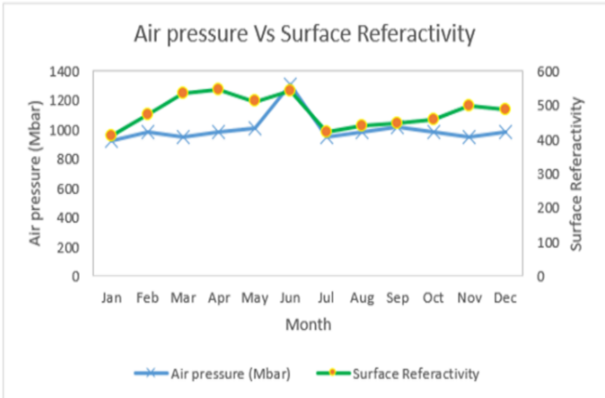

Figure 6a. Graph of correlation between Air Pressure and surface refractivity

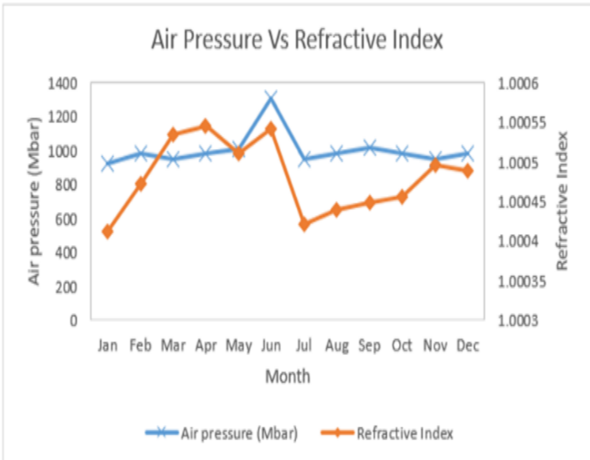

Figure 6b. Graph of correlation between Air Pressure and Refractive Index (n)

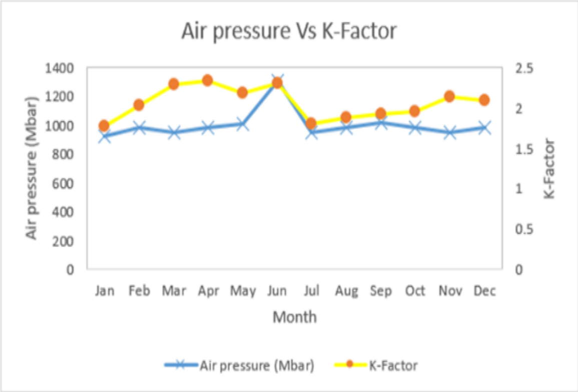

Figure 6c. Graph of correlation between Air Pressure and Effective Earth Radius (K-Factor)

4. Conclusion

The effects of radio climatic variables on signal propagation in Kebbi, Nigeria have been investigated. The results shows that there were increased in the values of the effective earth radius (k-factor) and radio refractive index (n) in the region. It was also observed that there were significant increases in the atmospheric temperature during the winter and as well in the months of the summer 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 affects radio waves and then lead to radio-signal lost or interference over some area in Kebbi. The correlation between the primary and secondary radio-climatic variables were not affected except for the refractive index (n) which increases to a maximum value of 1.0005 slightly greater than the recommended value of 1.0003 as the temperature increases The study shows that the surface refractivity varies with season of the year. Therefore, the slightly increased in refractivity should be compensated for during designing of wireless communication links in this environment.

Acknowledgement

We are thankful to the Department of Soil Science, Kebbi State University of Science and Technology Aleiro, for providing the meteorological data used in this study

Conflict of interest

The authors declare no conflict of interest.

References

[1] Adeyemi, B and Emmanuel, I (2011). Monitoring tropospheric radio refractivity over Nigeria using CM – SAF data derived from NOAA – 15, 16 and 18 satellites. *Indian Journal of Radio and Space Physics*, (40), 301 – 310.

[2] Alam, I., Mufti, N., Shah, S. A. A. and Yaqoob, M. (2016). The Effect of Refractivity on Propagation at UHF and VHF Frequencies. *International Journal of Antennas and Propagation.* Volume 2016**.**p. 8

[3] Agbo, G. A. (2011). Tropospheric Refractivity Dependence on Atmospheric weather conditions in Jos – *Nigeria. Journal of Basic Physical Research*, *Vol.* 2 (2) 2 - 6.

[4] Agunlejika, O and Raji, T. O. (2010). Empirical evaluation of wet – term of refractivity in Nigeria. *International Journal of Engineering and Applied Sciences, Vol.*2(2), 63 – 68

[5] Akpootu, D. O. and Iliyasu, M. I. (2017). Estimation of Tropospheric Radio Refractivity and Its Variation with Meteorological Parameters over Ikeja, Nigeria. *Journal of Geography, Environment and Earth Science International. Vol.*10 (1). pp. 1-12.

[6] Ayatunji, B,G,. P. N. and Urama, J.O., (2011). Seasonal variation of surface refractivity over Nigeria, *Advances in space Research Vol.* 48, pp 2023-3037

[7] Barr, R. Llanwyn J, Rodger C.J. (2000). ELF and VLF radio waves, *Journal of Atmospheric and Solar-Terrestrial Physics. Vol.* 62 (2000) 1689-1718.

[8] Bech, J., Sairouni, A., Codina, B. Lorente, J. and Bebbington, D., (2000). Weather Radar anaprop conditions at a Mediterranean coastal site. Physics and Chemistry of the Earth, Part B; Hydrology, Oceans and Atmosphere. 25(10-12), 829-832.

[10] Ekpe, O. E., Agbo, G. A., Ayantunji, B. G., Yusuf, N and Onugwu, A. C. (2010). Variation of tropospheric surface refractivity at Nsukka in South – Eastern Nigeria*. Nigerian Journal of Space Research*. *Vol.* 7, 42 – 48.

[11] Hall, M. P. M. and Barclay, L. W. (1989). Radio wave propagation. NASA STI/Recon Technical Report A, 90, 45603.

[12] International Telecommunication Union – Recommendations. In: Encyclopedia ITU-Recommendation Assembly, Geneva, Computer Language Company Inc. 2000, Radio refractive index: its formula and refractivity data pp. 453-7.

[13] Korakshaha, P.N. (2003). The physics of the earth and its atmosphere, John Wiley and sons Inc., New York, USA.

[14] Okpani. P. E., Nwofe, P. A. and Chukwu, N. O. (2015), effects of radio-climatic variable on signal propagation in Nsukka, *Nigeria, International Research Journal of Natural Sciences Vol*.3, No.2, pp.9-17

[15] Oyedun, O.D. (2007). *Nigerian Journal of Space Research Vol.*3, Pp.78 –97.
[16] Okoro O. N. and Agbo G. A., (2012). The Effect of Variation of Meteorological Parameters on the Tropospheric Radio Refractivity for Minna. *Global Journals Inc. (USA), Vol.*12 (2), 1.
[17] Yu, S. M., Yee, H. L., and Boon, C. N. (2009). The Effects of Tropical Weather on Radio-Wave Propagation over Foliage Channel. IEEE Transactions on Vehicular Technology, vol. 58, no. 8. pp. 2-9.