International Journal of Electronics and Communication Engineering.
ISSN 0974-2166 Volume 5, Number 4 (2012), pp. 498-503

http://www.irphouse.com

Characterization of Nsukka, Nigeria Radio Space

O. L. Daniyan and C. I. Ani

ETF Centre of Excellence in Communication Networks, Department of Electronic Engineering, University of Nigeria, Nsukka
E-mail: mailto:cosmas.ani@unn.edu.ng

Abstract

Currently, radio network providers and radio space refractivity researchers in Nigeria use data provided by International Telecommunication Union for Radio (ITU-R). The data was obtained from the characterization of radio space outside Nigeria. Such data do not produce the expected results in the performance of radio networks since they are extrapolated to cover Nigeria radio space. Therefore, there is the need to directly characterize Nigeria radio space for accurate and effective radio network design and management.

This paper, therefore, presented the data generated from direct radio space measurement of related meteorological variables for period spanning from November 2007 through November 2010 at Nsukka, Enugu State location - South–East of Nigeria. The radio space was characterized using general refractivity model. The model's main refractivity constants were determined from the data measured. The resultant value for surface refractivity over Nsukka proved that using ITU-R data on the entire Nigeria is erroneous. It has 13.05% deviation at Nsukka location

Introduction

Propagation of radio waves through the troposphere is influenced by the parameters that characterize the behaviour of atmosphere within the tropospheric layer [1]. The wave propagation through the troposphere may be properly and accurately analyzed if the layer is characterized with high level of precision. Such characterization is currently receiving great attention from researchers at different countries and zones on the earth surface [2].

Currently, in Nigeria, radio network planning and refractivity studies are based on the data provided by the International Telecommunication Union for Radio (ITU-R) [3]. The data is basically the results of tropospheric layer characterization conducted outside Nigeria and extrapolated to cover Nigeria radio space. Nigeria has a very large expanse of land and very unique weather conditions. Nigeria has three weather seasons – rain, dry and harmattan seasons. These imply that Nigeria radio space is unique and therefore requires direct characterization. Even if a location is directly characterized in Nigeria it may not be able to accurately represent the entire nation's radio space. The least that can be done for Nigeria is directly characterize the radio spaces at each of the six geo-political zones since it has been shown that radio network planning and refractivity studies in Nigeria require data obtained from direct characterization. In this work, radio space was characterized using a general and popular refractivity model with defined refractivity constants [4].

This paper, therefore, presented the data generated from the characterization of the radio space of a location (Nsukka, south–east of Nigeria) out of several locations distributed within the nation. The radio space was characterized through practical approach which involved direct measurement of related meteorological variables such as temperature, relative humidity and pressure. The measurements were conducted using for period spanning from November 2007 to November 2010 with an update cycle of five minutes. The instruments were configured to measure and log data every five minutes. This produced 288 data sets every day for the period covering all weather conditions (dry, wet and harmattan) experienced in a year. The relatively small update cycle of five minutes allows for the recognition and capture of minute changes in the tropospheric conditions.

The radio space was characterized using a general refractivity model [3]. The main refractivity constants were determined using the measured data. The resultant value for surface refractivity determined over Nsukka proved that ITU-R data on the entire Nigeria is erroneous. Nsukka location has 13.05% deviation, which is relatively significant.

Characterization Process

The general and popular refractivity model employed in the process of tropospheric characterization was given by equation (1) [3].

$$N = K_1 \frac{P}{T} + K_2 \frac{e}{T} + K_3 \frac{e}{T^2} \quad (1)$$

Where,
N – Refractivity
P – Atmospheric pressure
T – Absolute Temperature (Kelvin)
e – Water Vapour Partial Pressure
K_1, K_2 and K_3 – refractivity constants

The model is comprised of two components – the dry and wet components as represented in equations (2) and (3) respectively.

$$N_1 = \mathrm{K}_1 \frac{\mathrm{P}}{\mathrm{T}} \quad (2)$$

$$N_2 = K_2 \frac{e}{T} + K_3 \frac{e}{T^2} \tag{3}$$

Therefore $N = N_1 + N_2$. The refractivity constants could be defined along the separation illustrated in equations (2) and (3) if the respective refractive indices are known. Then the constant K_1 could be defined using equation (2) while constants K_2 and K_3 could be defined using equation (3). Mathematically, it is practically difficult to define values for coefficients K_1, K_2 and K_3 at a location without knowing the value of N. It was found, in this work, that the above difficulty could be avoided by playing down on the influence of one of the three coefficients. Then the effect of K_2, which is minor, was determined indirectly using the ITU-R standard refractivity values and in conjunction with measured values.

In this work, therefore, the two constants, K_1 and K_3, were determined using equation (1) while the ITU-R value for K_2 was retained [3]. Practically, K_2 has very little influence on the wet component and consequently on the total refractivity constant (N). K_2 makes below 2% contribution to the total refractivity constant. Therefore, the value of K_2 was chosen to be retained knowing that it would not make significant difference on the total refractivity constant value. Equation (1) is a function of temperature (T), pressure of the atmosphere (P) and water vapour pressure (e). Direct measurements of T and P parameters were conducted while e parameter was determined indirectly. As stated in equation (4), e is a function of saturation vapour pressure (e_s), relative humidity (H) and temperature (T^1 °C). Relative humidity and temperature were measured directly. All measurements were carried out every five minutes interval for the period of three years. Recorded data for T, P and H were plotted in Figures 1 – 3 just to show the pattern of the variation of the parameters.

The measured data were grouped and processed statistically year by year to produce three groups of data for each parameter measured. Statistical average, maximum and minimum values were calculated for each such parameter.

Figure 1 illustrates the pattern of behavior of atmospheric absolute temperature. In the period of observation, each year has statistical average, maximum and minimum absolute temperature values recorded as shown in table 1.

Table 1: Statistical values for absolute temperature

	1-st year	2-nd year	3-rd year
Maximum value	306.68	309.98	303.98
Average value	298.804	299.173	297.171
Minimum value	290.93	291.60	292.7

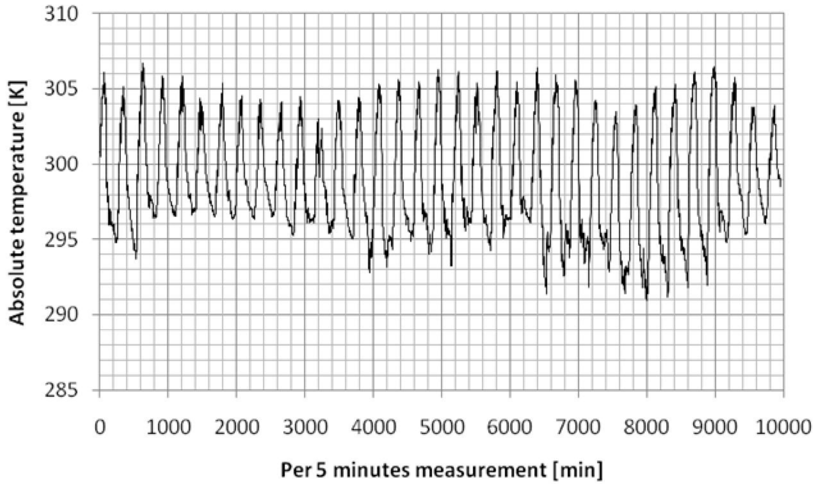

Figure 1: Temperature variation pattern

Figure 2 shows the pattern of behavior of atmospheric pressure. Table 2, shows the year by year statistical average, maximum and minimum absolute temperature values recorded during the period of observation.

Table 2: Statistical values for atmospheric pressure

	1-st year	2-nd year	3-rd year
Maximum value	1009	1006	1003
Average value	955.1264	956.2269	958.4051
Minimum value	916	920	928

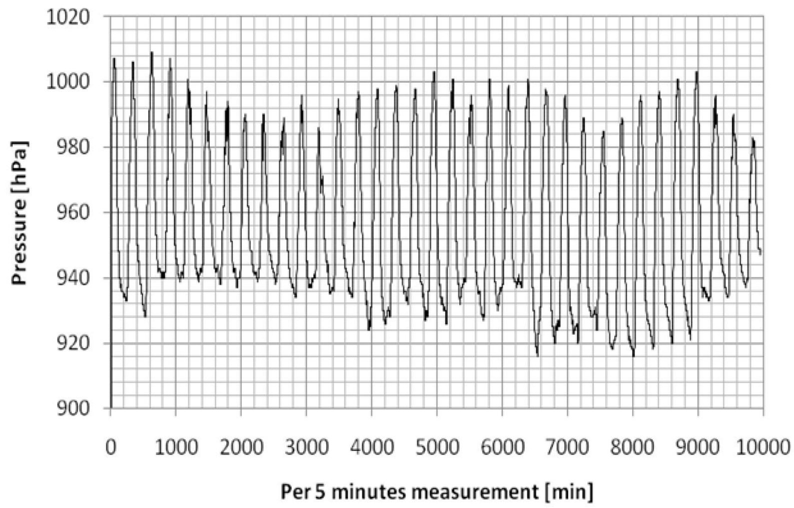

Figure 2: Pressure variation pattern

Figure 3 shows the pattern of behavior of atmospheric relative humidity. The statistical average, maximum and minimum absolute temperature values recorded for each year are shown in table 3.

Table 3: Statistical values for relative humidity

	1-st year	2-nd year	3-rd year
Maximum value	95.6	95.1	95.8
Average value	60.1007	44.0864	77.8806
Minimum value	13.97	8.26	36.02

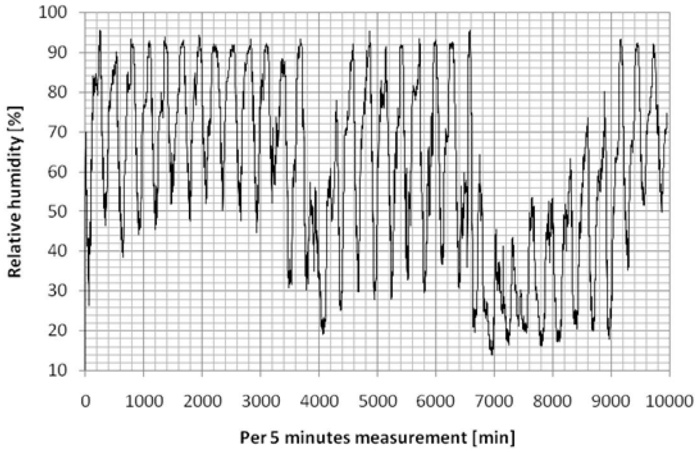

Figure 3: Relative Humidity variation pattern

Water vapour pressure, e, was represented by equation (4) [3]. e was calculated using directly measured parameters such as H and T^l.

$$e = \frac{He_s}{100} = \frac{H}{100} a \exp\left(\frac{bT^1}{T^1 + c}\right) \tag{4}$$

Where,
H = Relative Humidity (%)
e_s = Saturation vapour pressure (hpa)
T^l = Temperature (^{o}C)
a = 6.1121
b = 17.502
c = 240.97

The K_1 and K_3 constants were defined from the statistical averages presented in the tables 1 – 3 for water vapour pressure, e(hPa), atmospheric pressure, P(hPa), and absolute temperature, T(K).

Equation (1) was employed, as earlier stated, for the determination of the two constants, K_1 and K_3, while K_2 was defined using ITU-R standard refractivity value. The application of the standard refractivity value on the measured data resulted in K_2 = 1011K/mbar. This approach reduced the unknown parameters in equation (1) from four to three unknown parameters. Therefore, three equations were employed in determining the unknowns - N, K_1 and K_3. The equations (5) – (7) below came from substituting each year's measured parameters averages, as tabulated in tables 1 – 3, into equation (1) separately for the three years.

$$N = 3.33K_1 + 66.147 + 2.19x10^{-4} K_3 \tag{5}$$

$$N = 3.196K_1 + 67.4 + 2.228x10^{-4} K_3 \tag{6}$$

$$N = 3.225K_1 + 83.103 + 2.766x10^{-4} K_3 \tag{7}$$

Solving for the constants (N, K_1 and K_3) simultaneously would produce the sort-for expressions and the consequent values:

$$K_1 = \frac{(b_1 - b_2)(c_3 - c_2) - (c_2 - c_1)(b_2 - b_3)}{(a_2 - a_1)(c_3 - c_2) - (c_2 - c_1)(a_3 - a_2)} \tag{8}$$

$$K_3 = \frac{(b_1 - b_2)(a_3 - a_2) - (a_2 - a_1)(b_2 - b_3)}{(a_3 - a_2)(c_2 - c_1) - (c_3 - c_2)(a_2 - a_1)} \tag{9}$$

where,

$$a_1 = 3.33;\ a_2 = 3.196;\ a_3 = 3.225$$

$$b_1 = 66.147;\ b_2 = 67.4;\ b_3 = 83.103$$

$$c_1 = 2.19x10^{-4};\ c_2 = 2.228x10^{-4};\ c_3 = 2.766x10^{-4}$$

Then, K_1 = 67.22K/mbar, K_2 = 1011K/mbar and K_3 = 328136.247K^2/mbar. Therefore, the ideal, refractive index for Nsukka, Nigeria is defined against that which was given by the ITU-R. The refractive index for Nsukka, N = 355.344, was defined using equation (1). Hitherto, it was required that the measured data be applied to the ITU-R constants in equation (10) with K_2 completely neglected [3].

$$N = \frac{77.6}{T}\left(P + 4810\frac{e}{T}\right) = 77.6\frac{P}{T} + 373256\frac{e}{T^2} \tag{10}$$

Therefore, applying the measured data on equation (10) resulted in $N = 77.6 * 3.196 + 373256 * 2.228x10^{-4}$ = 331.171. In the same vein, using the defined constants, without reference to the ITU-R data, the refractive index was determined to be equal to 287.944. This gives a 13.05% deviation from what it was when using ITU-R data.

Conclusion

The behaviour of radio waves in the troposphere is greatly influenced by the parameters that characterize the region [5]. It is practical that the radio path or propagation medium be accurately characterized in order to adequately set up an effective and efficient communication network.

In this work, the meteorological variables of the troposphere over Nsukka, South-East of Nigeria were measured over the period of three years and the data generated on temperature, relative humidity and pressure presented. the refractivity constants K_1, K_2 and K_3 that define the surface refractive index, N, were calculated. The results of this research work show that beyond determining the refractive index at a location, the refractivity constants K_1, K_2 and K_3 are essential factors that should be taken into consideration before estimating any refractivity value and consequently embarking on radio network planning over a location. Several authors have realized the imperativeness in generating such values for radio space and for locations of their interests in order to precisely estimate the refractive index.

Nsukka radio space was directly measured and the data generated processed and used in the calculation of the refractivity constant. The results obtained are based on data from direct measurement of radio meteorological parameters in Nsukka using Campbell Scientific Instrument. This is ideal for radio communication planning, design and refractivity estimation in Nsukka region. The hitherto used values such as the ITU values do not represent our radio space and cannot give the true condition of Nsukka radio space. The resultant value for surface refractivity over Nsukka proved that using ITU-R refractivity constants on the entire Nigeria is erroneous. It showed 13.05% deviation at Nsukka location.

Acknowledgement

The authors are grateful to other Networks Research Team members for their ever constructive comments. Authors are grateful to the University of Nigeria, Nsukka for providing the enabling environment and the Federal Government of Nigeria for endowing the University with Centre of Excellence in Networking.

References

[1] H.J. Liese, G.A. Hufford "Modelling Millimeter wave propagation effects in the atmosphere"
[2] Bean B. R. and Dutton E. J., "Radio Meteorology" 1996.
[3] ITU-R P.453-7, "The Radio Refractive Index: Its Formula and Refractivity Data," International Telecommunication Union (ITU), pp 1-10, 1999
[4] T. Bayong, S. Djakawinata, "The Influence of Meteorological Factors on Tropospheric Refractive Index over Indonesia" JMS Vol.4, No 1, April 1999.
[5] E. Valma et al. "Determination of Radio Refractive Index Using Meteorological Data"