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MONTHLY AVERAGE ESTIMATION OF RADIO REFRACTIVITY OF ADO-EKITI, SOUTH-WESTERN NIGERIA

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ABSTRACT

For optimal performance of communication system links, reliable information about the effects of the medium between the transmitter and receiver is of great importance to the radio links engineers. Microwave/radio signal propagating through the troposphere is affected by variations in meteorological parameters which affects the refractivity of the troposphere. This often led to anomalous propagation conditions such as sub-refraction, super-refraction and ducting. The changes in radio refractivity of an area also affect the strength of radio signals transmitted and received in the area because refractivity is related to signal strength. This paper investigates the tropospheric radio refractivity of Ado-Ekiti, Ekiti State, South Western Nigeria (7°38′N, 5°13′E and 461m) due to meteorological parameters for a period of two (2) years using the method recommended by the international telecommunication union (ITU). The result obtained shows a lower value of radio refractivity during the dry season, and higher value during the wet season in the study area. The implication is that radio signal propagated in the atmosphere will travel a longer distance with fidelity during the dry season than the wet season.

KEYWORDS: Meteorological; Parameters; Radio; Refractivity; Troposphere; Propagation

INTRODUCTION

Propagation of radio signal from transmitter to receiver is of great importance when planning a radio communication networks because they are significantly affected by the atmospheric conditions of the medium through which it is propagated. However, the degree of atmospheric effects on radio signals propagation depends mainly upon the frequency, power of the signal and on the state of the atmosphere through which the radio wave propagates (Akpootu & Iliyasu, 2017; Chima, et al., 2019; Enyenihi, et al., 2019).

In radio communications, two layers of the atmosphere are of great importance. The first is the troposphere which extends from the earth surface to an altitude of about 10 km at the earth poles and 17 km at the equator and tends to affect radio frequencies above 30MHz. The second is the ionosphere which is a region that extends from around 60 km up to 700 km producing ions and free electrons which affect radio signals at certain frequencies; typically, those below 30MHz (Adediji, 2017).

Signal propagation in the troposphere is affected by many factors caused by variations of meteorological parameters of humidity, temperature and pressure. Variations in these parameters within the troposphere cause changes in the refractive index of air and large scale changes of refractive index with height will cause radio waves to be refracted and the effect can be quite significant at all frequencies. Refraction is defined as the change in direction of signal as it passes from one medium to another of different densities. It causes degradation in communication signal strength as well as loss in point to point communication links because change in atmospheric refractive index will cause the radio horizon to appear to be 1.33 times further away than the geometric horizon; hence transmitted signal will not reach the desired destination. The ratio of the velocity of the radio propagation in free space to that in medium is called refractive index. Refractive index is small at the earth's surface (about 1.0003), and as a result, it becomes convenient to use refractivity, N when modeling variation of refractive index in the atmosphere. Refractivity, N is related to refractive index, n as in (ITU-R, 2015).

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

More so, the use of atmospheric parameters to analyze the behavior of radio communication in the troposphere requires the knowledge of radio refractivity to characterize the atmosphere for terrestrial and earth – satellite communication purposes.

Radio refractivity is defined as the product of the refractive index minus one unit and one million. Refractivity is one of the factors which affect the transmission of radio signal operating within the troposphere. It is the physical property of a medium as determined by its index of refraction and it is responsible for various phenomena in radio wave propagation such as ducting and scintillation, refraction and fading, range and elevation errors in radar acquisition (Adediji, 2017).

Surface radio refractivity N_s is known to have high correlation with radio field strength values, thus knowing the radio refractivity of a place especially how it varies with some meteorological parameters will help in planning of communication systems (Abdullahi, 2017). This research work is aimed at using a two year meteorological datasets of temperature, pressure and relative humidity to investigate the effects of radio refractivity to radio communication and to bridge the location gap in radio refractivity in Ado-Ekiti.

Radio Refractivity Estimation Efforts in Nigeria

Significant efforts have been expended by various researchers in investigating the characteristics and pattern of radio refractivity for different regions and climate using measured local meteorological data in Nigeria and other parts of the world. The results of their works have been made known to radio link designers for optimal radio/micro wave link design. Most recently, Akeem, et al., (2022) in their study, opined that a low value of radio refractivity gradient was prevalent during the raining season as compared to the dry season of year 2020. They further pointed out that higher signal strength propagation beyond the line of sight distance is probably in Oyo metropolis in the period under study. Mmahi et al., (2021) showed that there is higher radio wave signal attenuation during the wet season than the dry season and in Ilorin as compared to Abuja. Abimbola et al., (2020) also in their research work opined that radio refractivity decreases exponentially with height and from the coast towards the desert. They observed sub-refraction dominating the dry season and super-refraction dominating most part of the wet season.

Falodun et al., (2019) in their research work used five years data of air temperature and relative humidity at two pressure levels and compared the results obtained across the sixteen locations used in the study. The result showed similar trends on daily and seasonal basis at both pressure levels with higher values of modified radio refractivity gradient at 700hPa pressure level at morning and night hours of the day at all locations. The coastal region of Port Harcourt has the highest value of modified radio refractivity.

Adediji (2017) made use of an in situ measurement of atmospheric pressure, temperature and relative humidity from a wireless weather station over Akure in the Southwest, Minna in North central and Nsukka in Southeastern Nigeria. The results showed that radio refractivity various daily and seasonally and a function of variation of meteorological parameters. He observed highest values in the morning and evening across the three locations with highest values occurring in the Southern part of Nigeria.

MATERIALS AND METHOD

The monthly average meteorological parameters of air temperature, atmospheric pressure and relative humidity covering two years (2020-2021) used in this research work were obtained from weather online at www.weatheronline.com/ado-ekiti. Data obtained were extracted from the datasets and prepared into tables using excel workbook. The recommendation of the International Telecommunication Union (ITU-R) 2017 was used to calculation various parameters of radio refractivity using excel workbook formulas.

To ensure the validity and correctness of the downloaded data, datasets from average weather in Ado-Ekiti from weatherspark and climate Ado-Ekiti from meteoblue for the parameters studied and for the year under study were used to validate or check for consistency of the data used.

The parameters calculated are:

a. **Saturated Vapour Pressure (e_s)**: the saturated vapour pressure is the pressure of a liquid when it is in equilibrium with the liquid phase. It can be express as;

$$e_s = 6.112 exp\left[\frac{17.502t}{t+240.97}\right] \quad (2)$$

where exp. is exponential (= 2.718), t is the temperature in Kelvin (k) and e_s = saturated vapour pressure in hectoPascal (hPa).

b. **Vapour Pressure (e)**: is the measurement of the amount of moisture in the air. It is expressed as;

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

where R_h is the relative humidity in percent (%). e is the vapour pressure in hectoPascal (hPa) and e_s is the saturated vapour pressure (hPa).

c. **Radio refractivity N**: Is a derived quantity used for convenience in most scientific studies when modeling variation of refractive index in the atmosphere. It is expressed mathematically as;

$$N = (n-1) \times 10^6 \quad (4)$$

Radio refractivity is expressed meteorologically as;

$$N = 77.6\frac{P}{T} + 3.73 \times 10^5 \frac{e}{T^2} \cong \frac{77.6}{T}\left(P + 4810\frac{e}{T}\right) \quad (5)$$

$$N = N_{dry} \quad (6)$$

where the "dry term (N_{dry})"is given by;

$$N_{dry} = 77.6\frac{P}{T} \quad (7)$$

and, the "wet term(N_{wet})"is given by;

$$N_{wet} = 3.73 \times 10^5 \frac{e}{T^2} \quad (8)$$

where n is the refractive index of the atmosphere, N is the radio refractivity in N-unit, T is the air temperature in Kelvin, p is the atmospheric pressure in hectopascal (hPa) and e is the vapour pressure in hectopascal (hPa).

RESULTS AND DISCUSSION

Table 1 shows the monthly average of radio refractivity at Ado-Ekiti for the year 2020. In Year 2020, especially in the month of August there was drop in the value of relative humidity which impact on the radio refractivity of the study area. From table 1, the radio refractivity increases rapidly from the lowest value of 308.52N-units in the Month of January which happens to be a harmattan period to 320.85N-units in the Month of February with sharp incremental value of 12.33N-units. The radio refractivity then continues to increases steadily at a slow rate from the Month of March to the highest value of 365.15N-unit in the Month of June and then decreases to a lower value in August. It again increases much slowly from September to a very low value in December, though, not the lowest value for the year under study. From table 1, the relative humidity was at its lowest values of 38%, 47% and 69% in the Months of January, February and December (Harmattan periods) respectively which explains the increased values of radio refractivity in these Months. The low value obtained in August was probably due to the prolong August break. It can be said that from figure 1, that the Monthly average variations in radio refractivity for the year under study was mostly due to variation in relative humidity.

Table 2 shows the monthly average of radio refractivity for the year 2021. The result obtained shows a slow decrease in the value of refractivity in the Month of February. The radio refractivity then increases sharply in the Month of March to the highest value of 362.77N-units in Month of October due to the decrease in relative humidity, though, temperature and pressure also contributed to this occurrence. The value then decreases to a lower value of 325.61N-units in the month of December. The increase in radio refractivity in the Month of March was as a result of the commencement of rain season window while the decrease in the value in November was as a result of the starting of harmattan in the study area. The highest values of radio refractivity observed in the Months of August through October were as a result of the gradual decrease in the value of relative humidity as shown in Table 2.

CONCLUSIONS AND RECOMMENDATIONS

The results obtained show a monthly and seasonal variation in radio refractivity. These variations were mostly due to the changes in relative humidity, although other factors (temperature and pressure) also contributed to this occurrence. Lower values of radio refractivity were observed during the dry season and higher values in the wet season (Abdullahi, 2017; Akeem, et al., 2022; Mmahi et al., 2021). The implication of the above is that, radio signal could travel much longer distance with stronger signal strength with less or no attenuation in dry season.

These findings will be of benefits to radio communication designers in predicting the extent to which a communication signal will cover in the study area, since there is a high correlation between signal strength and radio refractivity and will also bridge the location gap in radio refraction in the study area.

The data used for this study were sourced from online. It is therefore, recommended that for further research work in the study area;

i. An in-situ measurements of the radio meteorological parameters be obtained and used to estimate the radio refractivity.

ii. Measurement should be made at two heights above the ground level to evaluate the gradient of radio refractivity which gives an insight to the occurrence on the wave front and the path clearance.

iii. Radio Link designers are encouraged to explore the results herein for an efficient link in Ado-Ekiti Metropolis.

iv. The transmitter power level could be increased or more repeaters can be deployed during the period of low (raining season) radio refractivity for communication fidelity.

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Table 1: Monthly average data of temperature, relative humidity, pressure and radio refractivity for year 2020

Months	T (℃)	T (K)	Rh (%)	P (hPa)	*N*
Jan	31	304	38	1010.5	308.5245
Feb	32	305	47	1009.8	320.8477
Mar	29	302	75	1008.8	354.5232
Apr	29	302	79	1009.4	359.7605
May	27	300	85	1010.9	364.1278
June	25	298	89	1012.2	365.1518
July	23	296	91	1012.1	362.8661
Aug	23	296	87	1012.8	358.7625
Sept	23	296	93	1012.0	364.9834
Oct	26	299	86	1010.9	363.3931
Nov	29	302	72	1010.1	351.0449
Dec	29	302	69	1009.8	347.1555

Table 2: Monthly average data of temperature, relative humidity, pressure and radio refractivity for year 2021

Months	T (℃)	T (K)	Rh (%)	P (hpa)	N
Jan	31	304	61	1009.4	336.8432
Feb	31	304	58	1009.4	332.8511
Mar	29	302	73	1008.4	349.8683
Apr	29	302	75	1009.5	352.6901
May	27	300	82	1011.4	358.5894
June	25	298	86	1012.8	359.8408
July	23	296	90	1014.7	360.3978
Aug	23	296	92	1014.1	362.3848
Sept	24	297	90	1013.2	362.2775
Oct	26	299	87	1011.9	362.7692
Nov	28	301	78	1010.5	355.1578
Dec	30	303	53	1010.0	325.6145

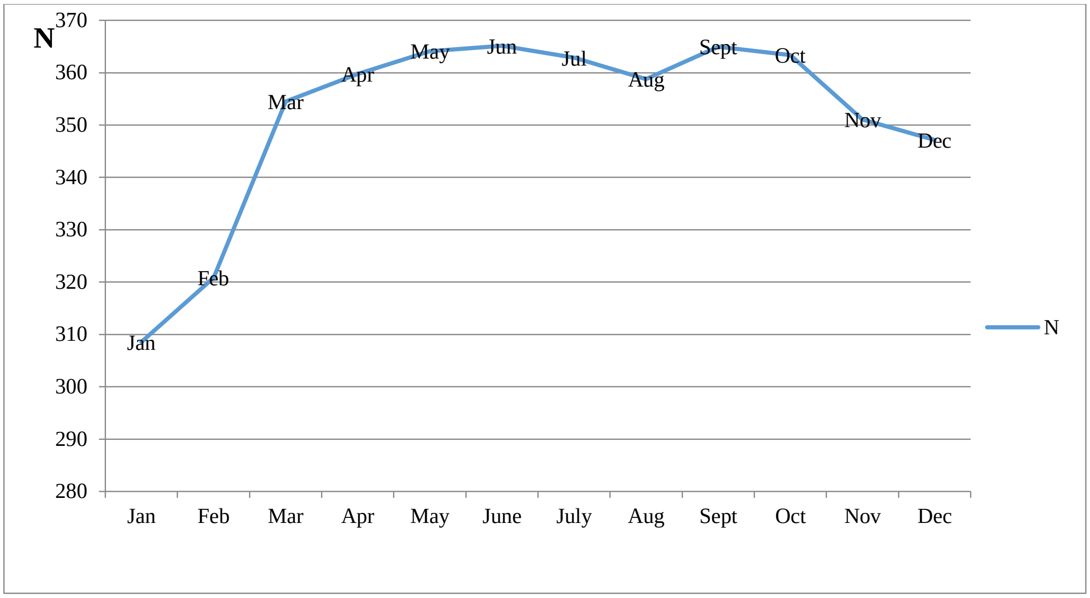

Figure 1. Graph of radio refractivity variation with Months for year 2020.

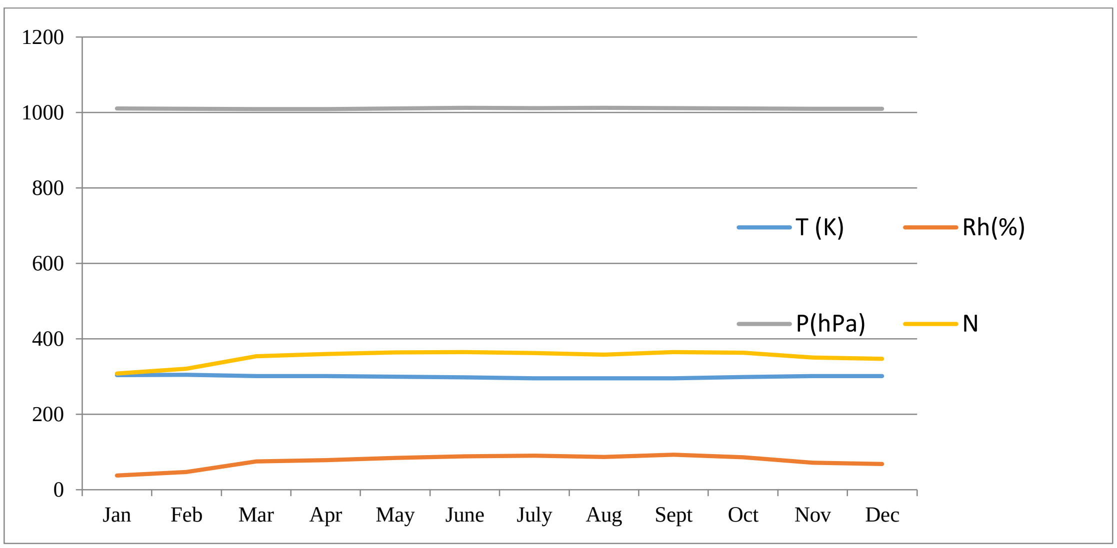

Figure 2. Graph of refractivity and radio climatic parameters for 2020

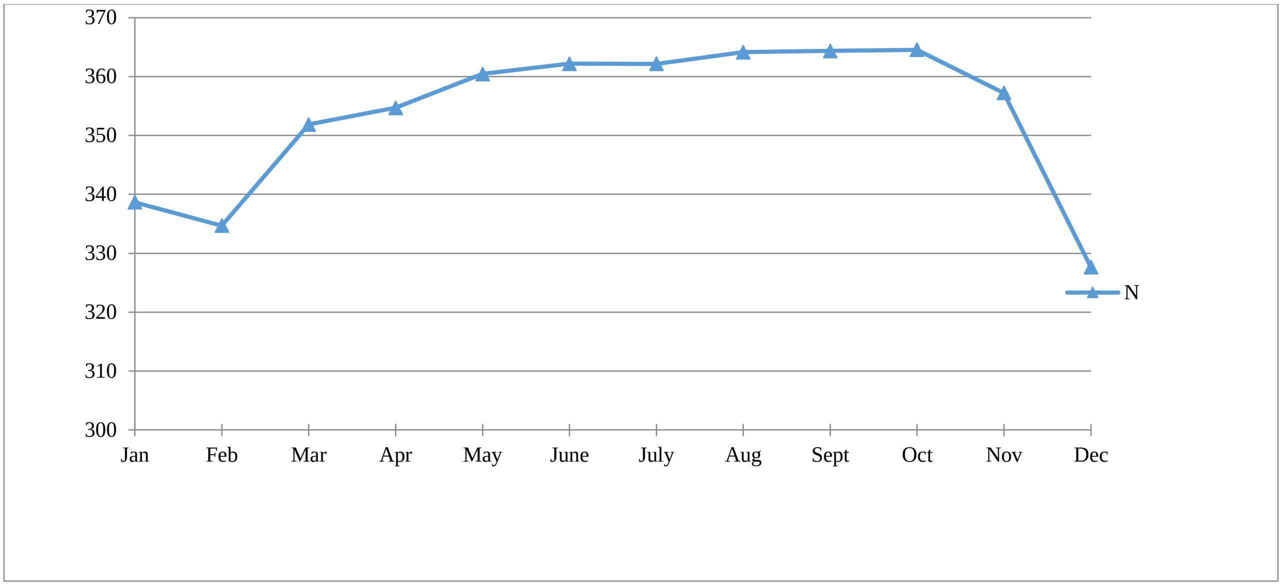

Figure 3. Graph of radio refractivity variation with Months for year 2021.

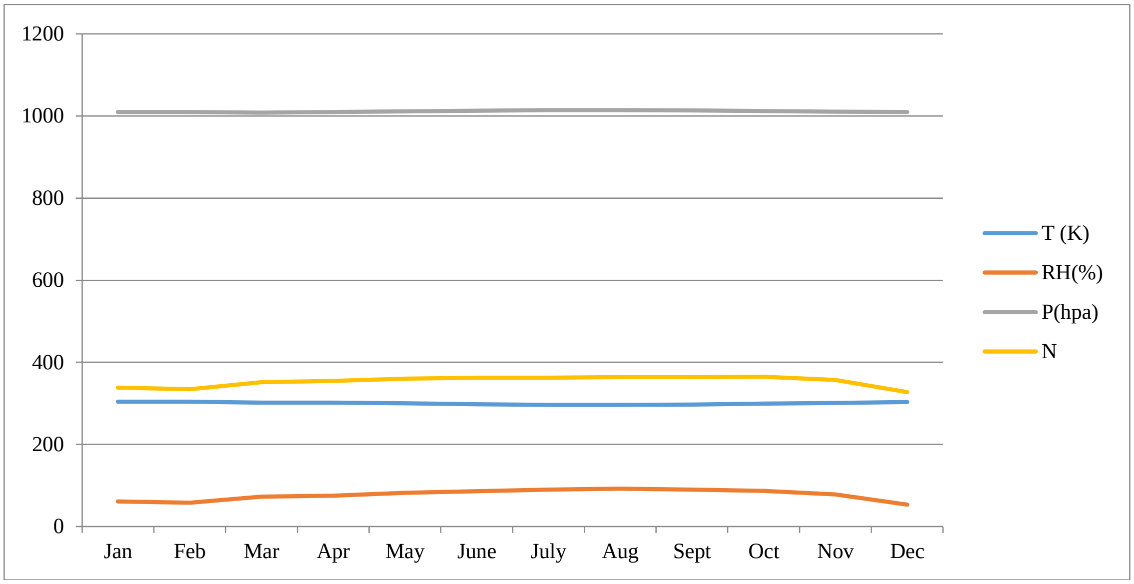

Figure 4. Graph of refractivity and radio climatic parameters for 2021