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VARIATION IN METEOROLOGICAL PARAMETERS ON THE TROPOSPHERIC RADIO REFRACTIVITY OVER LAPAI, NIGER STATE, NIGERIA

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ABSTRACT

The study of radio refractivity has aroused considerable interest primarily because of its influence on radio wave communication in the lower atmosphere. There is little or no need to over emphasize the effects of the parameters concerned with this research, temperature, pressure, and relative humidity on the various weather conditions experienced in Lapai town, which is the study area. Various weather conditions experienced also have their features which bring about their effects on the weather. The fact that these parameters stated above are subject to fluctuation gives them this ability to cause variations in the weather. This change in the weather on the other hand has a great effect on the rate of propagation of radio signals. The aim of this work is to examine the variations in meteorological parameters (Temperature, Atmospheric pressure, and Relative humidity) on the surface radio refractivity '*N*' in Lapai town, Niger state of Nigeria, with focus on the wet and dry seasons. Lapai town is located within latitude 9º 02□ N and longitude 6º 34□ E. The Meteorological data were obtained from the Nigerian Meteorological Agency (NIMET), and used to compute the mean monthly refractivity for each month of the six years under review. The results obtained showed that the refractivity values are lower in the dry season months (January, February, November and December) due to lower relative humidity, as compared to the wet season months (March, April, May, June, July, August, September and October), which are characterized by higher refractivity values, and it could be attributed mainly to high relative humidity values. The result also indicated that month of January for the year 2018 has the minimum refractivity value of 325 N-units, while the month of April, 2018 with *N* value of 444 N-units has the maximum value of refractivity. The k-factor obtained from the radio refractivity gradient (RRG), $\left[\frac{\mathrm{dN}}{\mathrm{dh}}\right]$ was used to establish the fact that the study area has been found to be super refractive during both seasons, with values of 1.5 and 1.87 for dry and wet seasons respectively. The results provide useful information needed by radio engineers to set up new terrestrial radio propagation links or to improve on the existing ones especially at VHF, UHF in Lapai, as recommended by ITU-R.

The research therefore concludes that meteorological parameters put into focus for this work contribute noticeably to the radio refractivity, and subsequently the k-factor of Lapai, therefore, it affects the radio wave propagation. It has also established the fact that there exists a significant variation in the wet and dry season refractivity, with dry seasons having lesser *N* values due to low relative humidity as the major driving force. More so, the wet seasons are characterized by higher refractivity values due to higher values of relative humidity. Consequently, both seasons for the study area have been found to be super refractive, with the wet season having an increased super refractivity as compared to the dry season.

KEYWORDS: Relative humidity, Atmospheric pressure, Temperature, Radio Refractivity Gradient,*k*-factor

INTRODUCTION

Refractivity is described as a physical property of a medium dictated by its index of refraction, and it is responsible for a variety of phenomena in radio wave propagation, including refraction and fading, ducting and scintillation, range and elevation errors in radar acquisition, and so on (Akpootu & Iliyasu, 2017). The troposphere is the lowest layer of the earth's atmosphere and the location of all weather in the cosmos. It is the component of atmosphere that comes closest to human life in terms of proximity. It extends 10 kilometers above the earth's poles, the North and South Poles, and 17 kilometers above the equator (Akpootu & Rabiu, 2019). Because of persistent electric dipoles of water vapour molecules, radio signal transmissions in the troposphere at frequencies above 30 MHz are sensitive to weather and climatic variations, resulting in the atmosphere having a complicated dielectric constant and thus a complex refractive index (Muhammad *et al.*, 2020). The study of radio refractivity has aroused considerable interest primarily because of its influence on radio wave communication in the lower atmosphere. In particular, the manner in which refractive index changes with height has much consequence for radio wave propagation at frequencies greater than 30 MHz, although these effects become significant at frequencies greater than 100 MHz in the lower atmosphere (Ayantunji *et al.*, 2011). Hence, the refractive index, *‘n’* of the troposphere is of major concern in the propagation of radio waves at these frequencies. The value of refractive index at the earth’s surface is slightly greater than unity and gradually decreases towards unity with increase in altitude. At the earth’s surface, radio refractive index is usually between 1.00025 and 1.00035 (Muhammad *et al.*, 2020). This study presents an easy method for calculating radio refractivity and how it enhances signal variations between the dry and wet seasons in Lapai Niger State of Nigeria.

THEORETICAL BACK GROUND

The radio refractivity index is defined as the ratio of radio energy propagation velocity in a vacuum to velocity in a given medium. Its value 'n' tends to drop from locations near the earth's troposphere surface of roughly 1.0003 to the top of the earth's atmosphere, i.e. free space, where the value unity ($n = 1$) is found (Chinelo & Chukwunike, 2016). For easy understanding of concept, the refractive index is expressed in terms of a dimensionless parameter known as the refractivity, N, which is defined as the measure of the refractive index's divergence from unity in parts per million. It can be expressed as:

$$N = (n-1)10^6 = \frac{77.6}{T}\left(\frac{P+4.810e}{T}\right) \qquad (1)$$

P stands for atmospheric pressure in mill bar (mb), e for water vapor pressure in millibars, and T for absolute temperature in Kelvin. When expanded, equation (1) can be rewritten as:

$$N = 77.6\frac{P}{T} + \frac{3.37\times10^5}{T^2}e \qquad (2)$$

Changes in temperature, T, atmospheric pressure, P, and water vapor, e, in general, produce changes in radio refractivity, N.

Consequently, the relationship between water vapor e and relative humidity $R.H$ is given by:

$$e = \frac{RHe_s}{100} \qquad (3)$$

where e_s is the saturation vapor pressure determined by Clausius- Clapeyron equation given by:

$$e_s = 6.11\, exp\left(\frac{19.7t}{t+273}\right) \tag{4}$$

where t is the temperature in °C

The vertical radio refractivity gradient (*G)* (N-units/km) at the surface level is expressed as:

$$G = \frac{dN}{d\square} = -7.32\, exp(\,0.005577N_S) \tag{5}$$

where N_s is the value of surface radio refractivity, these parameters were calculated using equations (6) to (10):

$$N = 77.6\frac{P}{T} + \frac{3.37\times10^5}{T^2}e \tag{6}$$

$$e = \frac{RHe_S}{100} \tag{7}$$

$$e_s = 6.11\, exp\left(\frac{19.7t}{t+273}\right) \tag{8}$$

$$n = 1 + N \times 10^{-6} \tag{9}$$

The refractivity gradient G may be given according to Muhammad (2019) as:

$$G = \frac{dN}{d\square} = -7.32\, exp(\,0.005577N_S)(N - units/km) \tag{10}$$

where N is the radio refractivity, P *is* the atmospheric pressure, T *is* the absolute temperature in Kelvin, t is temperature in degree Celsius, e is the vapor pressure, e_s is the saturated vapor pressure, n is the refractive index and G is refractivity radio gradient (RRG). Partial pressure of water 'e' was also determined. Finally, *k*- factor and radio refractivity gradient 'RRG' were calculated. The RRG is the determining factor for super refractivity, sub refractivity, or ducting based on the following criteria:

- Sub-refraction: $\frac{dN}{dh} \square - 40$ (11)

In this condition, N increases with height and in this case of sub-refraction, the radio wave moves away from the earth’s surface and the line of propagation decrease accordingly.

- Super refraction: $\frac{dN}{dh} \square -40$ (12)

In this case, electromagnetic waves are bent in a downward direction towards the earth. The degree of bending depends on the super refractive condition.

- Ducting: $\frac{dN}{dh} < -157$ (13)

During ducting process, the waves tend to bend downwards with a curvature greater than that of the earth. Radio energy bent downwards can become trapped between two boundaries in the troposphere. In this propagation which, like a wave guide, very high signal strengths can be obtained at very long range and the signal strength may exceed its free-space value (Oyedum *et al*., 2016).

In a vacuum, electromagnetic waves propagate along straight lines at *C* (velocity of light in vacuum). Light has slightly different electromagnetic characteristics than a vacuum. They are defined at each point by the refractive index, n = c/v, where v is the propagation velocity of electromagnetic waves. Clear – air effects are atmospheric effects that do not involve condensed water vapor but do contain the impacts of dry and dust particles (Oyedum *et al*., 2013 and Oyedum *et al*., 2016). In designing a radio communication network, it is of great importance to know the radio refractivity index of the atmosphere. The propagation of radio waves in the troposphere modifies the refractive index of air, which is the focus of this study. The changes observed in the troposphere radio refractive index can cause the path of a propagating radio wave to be bent (Adisa, 2015). Dipole moments exist in water molecules in the atmosphere. Every other gas in the atmosphere is non-polar in nature. When electromagnetic radiation passes through them, however, dipole moments produce dipole moments in their molecules. As a result, changes in the radio refractive index ‘n’ occurs, resulting in reflection, polarization, and scattering of incident radiation (Olorode & Adeniji, 2013). Gradients in refractivity alter with time, resulting in unusual propagation conditions. When the path profile is plotted, there is a convenient artifice that is utilized to account for the problem of refraction, this is refers to the effective earth radius factor *'k'* (Otasowie & Edeko, 2015).

STUDY AREA

Niger state is located in northern Nigeria and is the largest; it was called after the river Niger, and its capital is Minna. Between latitudes 8°20'N and 11°30'N and longitudes 3°30'E and 7°20'E, Niger state is located. To the north, the state is surrounded by Zamfara, to the northwest by Kebbi, to the south by Kogi, and to the southwest by Kwara, while to the northeast and southeast, the state is bordered by Kaduna and the Federal Capital Territory, respectively (Dangana *et al.*, 2015)

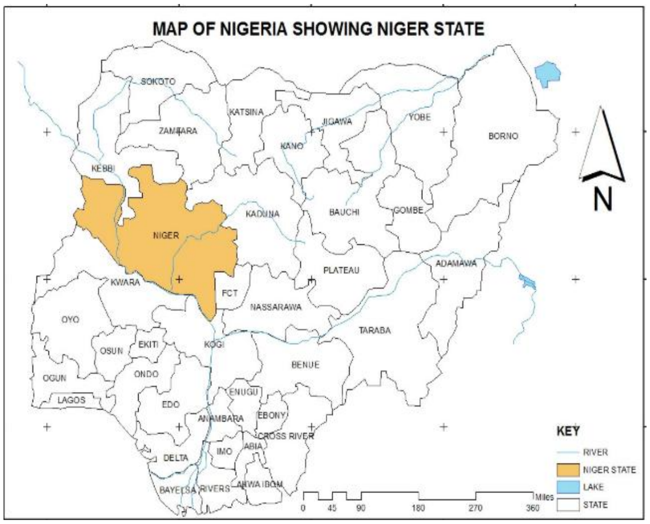

Figure 1. Map of Nigeria showing the location of Niger state and its borders

Source: (Dangana *et al.*, 2015)

More so, it shares a common international boundary with the republic of Benin. In general, Niger state covers a total land area of 76,363 square km, or about 9 % of the total land area of the country, which makes it the largest. It has a population of 3,950,249 (2006 population census) and a population density of 52 square Lapai area of Niger state, being the study area, is located within latitude 9º 02" N and longitude 6º 34" E and is 18 km west of the old Lapai, near Gurara River, along Suleja road and about 56 km east of Minna, Niger state capital. Lapai covers an area of 3,730 square km with a population of about 53,687 (National Population Commission, 2006). Lapai local government area is one among the twenty-five local governments in Niger state.

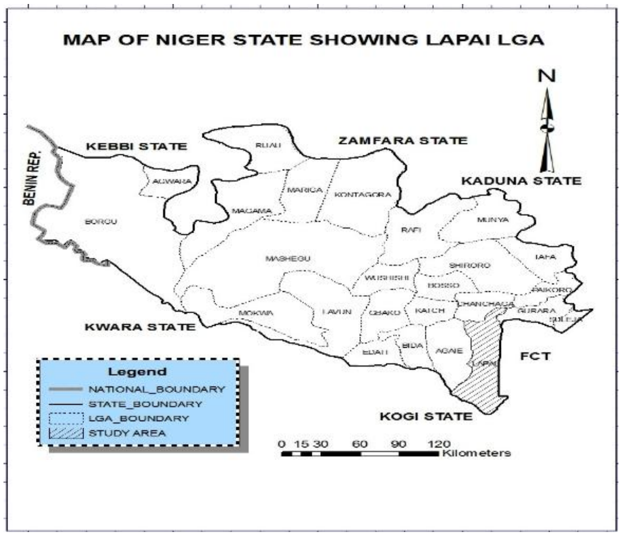

Figure 2. Map of Niger state showing the position of the study area (Lapai)

Source: (Dangana *et al*., 2015)

The research area is characterized by a tropical environment with two distinct seasons per year, namely dry and wet seasons. The area is defined by annual rainfall of less than 1000 mm, with the rainy season lasting from April to September and peaking between October and March (Dangana *et al*., 2015). Naturally, the area's vegetation is classified as parkland guinea savanna, which is characterized by a variety of trees, shrubs, and tall grasses that forms a natural ecosystem and contributes to the area's stunning land scale and beauty. Melina, locust beans, and shea butter are all examples of trees that are widely found in this area. Numerous years of agriculture and the impacts of soil erosion have significantly diminished the plant cover's density.

DATA COLLECTION AND ANALYSIS

The parameters used, temperature, pressure, and relative humidity, are monthly data spanning the six-year period (2015 - 2020) obtained from the Nigerian Meteorological

Agency's (NIMET) data collection center, which maintains observatory stations in each state of the country, commonly referred to as data points. On the other side, these data points contain instruments for monitoring meteorological parameters such as rain gauges, thermometers, barometers, and hygrometers for detecting relative humidity. Upon collection of data, processing/analysis was carried out. The refractivity and refractive index were considered individually on a monthly basis from the mean monthly data obtained for Lapai town using the following equations

$$N = 77.6\frac{P}{T} + \frac{3.37\times10^5}{T^2}e \qquad (14)$$

$$n = 1 + N \times 10^{-6} \qquad (15)$$

The refractivity values vary with season that is, the dry and rainy seasons. The values tend to go higher in the rainy season due to higher humidity values as compared to the dry season with lower values of the humidity. Monthly mean surface refractivity was calculated using excel and also computed for each year and analyzed using the ‘Origin’ software. Similarly, the annual mean surface refractivity was also computed for the six- year period (2015 – 2020).

RESULTS AND DISCUSSION

Average Monthly Refractivity and Refractive Index

In the first stage of results obtained, the calculated values of radio refractivity and the refractive index have been illustrated in Tables 1 to 6 for the study area and years under review (2015-2020). Tables 1, 2, 3, 4, 5 and 6 values were used to plot the corresponding Figures 3, 4, 5, 6,7 and 8, for the years 2015, 2016, 2017, 2018, 2019 and 2020 respectively.

Table 1: Average Monthly data, refractive index and radio refractivity over Lapai town for 2015

Months	Temperature °C (AVG)	Relative Humidity % (AVG)	Atmospheric Pressure (HPA)	Refractivity (N-units)	Refractive index(n)
JAN	27.8	22	1011.1	330	1.000330
FEB	30.7	26	1010.7	346	1.000346
MAR	32.5	62	1008.8	442	1.000442
APR	32.4	63	1009.1	443	1.000443
MAY	29.3	75	1011.3	436	1.000436
JUN	27.5	80	1012.3	436	1.000436
JUL	27.1	81	1012.8	436	1.000436
AUG	26.8	84	1012.5	438	1.000438
SEP	27.1	84	1013.0	441	1.000441
OCT	28.3	79	1011.7	443	1.000443
NOV	29.4	57	1010.3	405	1.000405
DEC	28.7	36	1010.1	359	1.000359

Table 2: Average monthly data, refractive index and refractivity over Lapai town for 2016

Months	Temperature °C (AVG)	Relative Humidity % (AVG)	Atmospheric Pressure (HPA)	Refractivity (N-units)	Refractive Index
JAN	27.9	21	1011.1	344	1.000344
FEB	30.8	25	1010.7	367	1.000367
MAR	32.6	61	1008.8	400	1.000400
APR	32.5	62	1009.1	399	1.000399
MAY	29.4	74	1011.3	414	1.000414
JUN	27.6	80	1012.3	417	1.000417
JUL	27.2	80	1012.8	423	1.000423
AUG	26.9	83	1012.5	419	1.000419
SEP	27.2	84	1013.0	418	1.000418
OCT	28.4	79	1011.7	398	1.000398
NOV	29.5	57	1010.3	364	1.000364
DEC	28.8	36	1010.1	346	1.000346

Table 3: Average monthly data, refractive index and refractivity over Lapai town for 2017

Months	Temperature °C (AVG)	Relative Humidity % (AVG)	Atmospheric Pressure (HPA)	Radio Refractivity (N-units)	Refractive index
JAN	29.0	31	1011.4	350	1.000350
FEB	30.6	33	1009.6	360	1.000360
MAR	33.1	47	1009.5	408	1.000408
APR	32.8	46	1009.1	403	1.000403
MAY	29.7	57	1010.8	408	1.000408
JUN	28.2	67	1012.1	417	1.000417
JUL	27.6	73	1013.3	424	1.000424
AUG	26.7	75	1013.1	421	1.000421
SEP	27.1	72	1013.2	418	1.000418
OCT	28.6	56	1012.3	399	1.000399
NOV	29.5	37	1010.8	364	1.000364
DEC	28.9	31	1011.5	350	1.000350

Table 4: Average monthly data, refractive index and refractivity over Lapai town for 2018

Months	Temperature °C (AVG)	Relative Humidity % (AVG)	Atmospheric Pressure (HPA)	Radio Refractivity (N-units)	Refractive index
JAN	27.8	20	1008.5	325	1.000325
FEB	31.7	47	1005.4	397	1.000397
MAR	32.2	61	1005.9	434	1.000434
APR	32.5	65	1005.6	444	1.000444
MAY	29.0	73	1007.3	434	1.000434
JUN	27.7	80	1009.3	437	1.000437
JUL	26.9	84	1009.9	437	1.000437
AUG	26.6	84	1009.8	435	1.000435
SEP	26.9	81	1008.4	431	1.000431
OCT	27.9	78	1008.2	435	1.000435
NOV	28.8	59	1007.0	405	1.000405
DEC	27.7	35	1009.0	353	1.000353

Table 5: Average monthly data, refractive index and refractivity over Lapai town for 2019

Months	Temperature °C (AVG)	Relative Humidity % (AVG)	Atmospheric Pressure (HPA)	Radio Refractivity (N-units)	Refractive index
JAN	29.5	26	1008.5	341	1.000341
FEB	29.4	35	1007.2	359	1.000359
MAR	29.2	54	1006.1	397	1.000397
APR	29.4	55	1005.4	399	1.000399
MAY	28.5	65	1006.7	415	1.000415
JUN	27.0	74	1009.4	419	1.000419
JUL	27.1	78	1009.0	428	1.000428
AUG	26.0	79	1009.7	422	1.000422
SEP	26.7	77	1008.8	423	1.000423
OCT	26.5	68	1007.3	404	1.000404
NOV	28.5	48	1006.4	379	1.000379
DEC	28.8	33	1007.4	353	1.000353

Table 6: Average monthly data, refractive index and refractivity over Lapai town for 2020

Months	Temperature °C (AVG)	Relative Humidity % (AVG)	Atmospheric Pressure (HPA)	Radio Refractivity (N-Units)	Refractive index
JAN	27.9	22	1011.1	342	1.000342
FEB	30.8	26	1010.7	333	1.000333
MAR	32.6	62	1008.8	405	1.000405
APR	32.5	63	1009.1	430	1.000430
MAY	29.4	75	1011.3	438	1.000438
JUN	27.6	80	1012.3	441	1.000441
JUL	27.2	81	1012.8	436	1.000436
AUG	26.9	84	1012.5	429	1.000429
SEP	27.2	84	1013.0	438	1.000438
OCT	28.4	79	1011.7	436	1.000436
NOV	29.5	57	1010.3	358	1.000358
DEC	28.8	36	1010.1	378	1.000378

Dry and wet seasons refractivity (N_{dry} and N_{wet}) for 2015 - 2020

Figure 3 presents the mean monthly variation of radio refractivity for the study area for the year 2015. It was observed that there were variations in the monthly radio refractivity. The months of January has the least refractivity value of 344 N-units, followed by December, 346 N-units, then November, 364 N-units and February 367 N-units having the highest values during the dry seasons. Thus, these refractivity values are lower, as compared to the wet seasons. This is as a result of lower relative humidity recorded during the dry season. Consequently, the months of March, April, May, June, July, August, September and October are characterized with the following refractivity values of 400 N-units 399 N-units, 414 N-units, 417 N-units, 423 N-units, 419 N-units, 418 N-units, 398 N-units respectively, with the wet seasons months having higher refractivity values; this is due to higher relative humidity. The month of July has the maximum value of refractivity of 423 N-units and January has the minimum value of 344 N-units for the year 2015, which are wet and dry seasons respectively. The results presented are in agreement with work of Oyedum *et al.* (2016), who reported a mean surface refractivity of Lapai and Makurdi as 342 and 343 N-units respectively

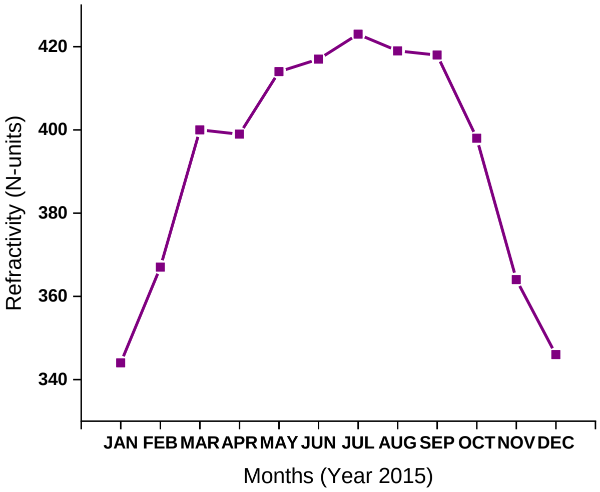

Figure 3: Average monthly refractivity for 2015

Figure 4 presents the mean monthly variation of radio refractivity for the study area for 2016. It has been observed that there was a variation in the monthly radio refractivity. The months of January, February, November and December are characterized by the following refractivity value of 330 N-units, 346 N-units, 405 N-units, 359 N-units respectively. The refractivity values of the dry seasons are lower, as compared to the wet months seasons this is as a result of lower relative humidity recorded for the season. Consequently, the months of March, April, May, June, July, August, September and October are characterized with following refractivity values 442 N-units, 443 N-units, 436 N-units, 436 N-units, 436 N-units, 438 N-units, 441 N-units, 443 N-units respectively, with the wet season months having the higher refractivity values. The month of October has the maximum refractivity value of 443 N-units and January has the minimum refractivity value of 330 N-units for the year 2016. This result is inline obtained by Muhammad *et al.* (2020) who reported the mean surface N of 342 N-units and refractivity gradient of -46 N/Km.

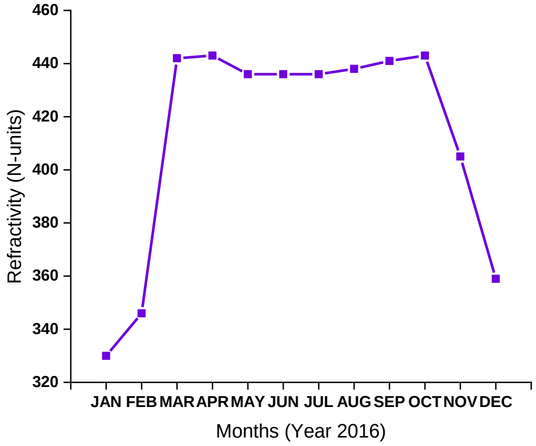

Figure 0: Average monthly refractivity for 2016

Figure 5 presents the mean monthly variation of radio refractivity for the study area for 2017. It has been observed that there was a variation in the monthly radio refractivity. The computed refractivity values obtained for the months of January, February, November and December are 350 N-units, 360 N-units, 364 N-units, 350 N-units respectively for the dry seasons, during which refractivity values are lower, as compared to the wet seasons. This is as a result of lower relative humidity recorded for the season Consequently, the refractivity values for the months of March, April, May, June, July, August, September, and October, are 408 N-units and 403 N-units, 408 N-units, 417 N-units, 424 N-units, 421 N-units 418 N-units, 399 N-units respectively for the dry seasons, having higher refractivity values, this is due to high relative humidity. The month of July has the maximum value refractivity of424 N-units and January and December have a joint minimum refractivity value of 350 N-units, for the year 2017, which are wet and dry season months respectively,

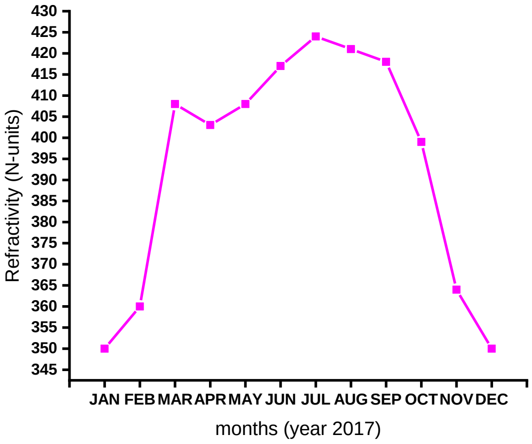

Figure 5: Average monthly refractivity for 2017

Figure 6 presents the mean monthly variation of radio refractivity for the study area for 2018. It has been observed also that there was a variation in the monthly radio refractivity. The months of January, February, November and December are characterized by the following refractivity value of 325 N-units, 397 N-units, 405 N-units, and 353 N-units for the dry season months, during which refractivity values are lower, due to recorded values of lower relative humidity as compared to the wet season. Consequently, the months of March, April, May, June, July, August, September and October are characterized with following refractivity values 434 N-units, 444 N-units, 434 N-units, 437 N-units, 437 N-units, 435 N-units 431 N-units, 435 N-units respectively, for the dry season months, having higher refractivity values. The month of April has the maximum refractivity value of444 N-units and January has the minimum refractivity value of 325 N-units for the year 2018. This result is in correspondence with the work of Muhammad *et al.* (2020), who work on the study of study of surface refractivity over North-Central Nigeria, and reported the mean refractivity over Lapai to be 344 N-units.

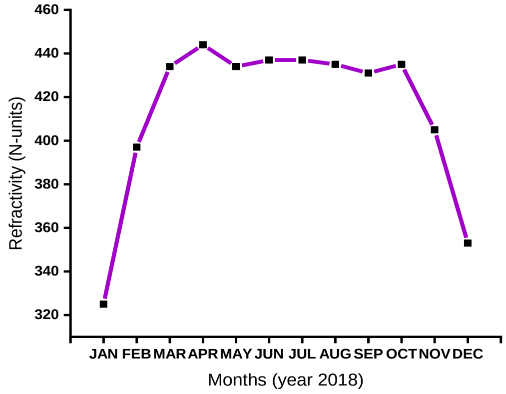

Figure 6: Average monthly refractivity for 2018

Figure 7 presents the mean monthly variation of radio refractivity for the study area for 2019. The curves have shown variations in the monthly refractivity values for the year under review. The months of January, February, November and December are characterized with following refractivity values 341 N-units, 359 N-units, 379 N-units, 353 N-units respectively, for dry season months, during which refractivity values are lower, due to low relative humidity values as compared to the wet seasons. Consequently, the months of March, April, May, June, July, August, September and October are characterized with following refractivity values 397 N-units 399 N-units, 415 N-units, 419 N-units, 428 N-units, 422 N-units 423 N-units, 404 N-units respectively, for the wet seasons having higher refractivity values. The month of July has the maximum refractivity value of 428 N-units, and January has the minimum refractivity value of 341 for the year 2019. These results are in agreement with the work of Muhammad *et al.* (2020).

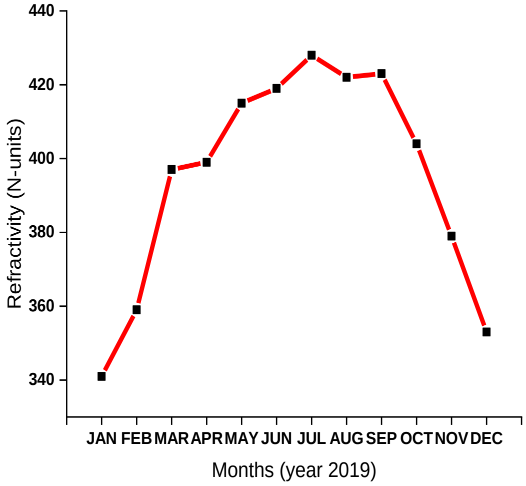

Figure 7: Average monthly refractivity for 2019

Figure 8 presents the mean monthly variation of radio refractivity for the study area for 2020. The curves have shown variations in the monthly refractivity values for the year under review. The months of January, February, November, and December, are characterized with following refractivity values of 342 N-units, 333 N-units, 388 N-units, 378 N-units respectively for the dry season months, during which refractivity values are lower due to lower values of relative humidity as compared to the wet seasons. Consequently, the months of March, April, May, June, July, August, September and October are characterized with following refractivity values 405 N-units, 430 N-units, 438 N-units, 441 N-units, 436 N-units, 429 N-units 438 N-units, and 436 N-units respectively, with the wet season months having higher refractivity values. The month of June has the maximum refractivity value of 441 N-units and February has the minimum refractivity value of 333 N-units for the year 2020. The result shows that station is remain under the same climate condition as influenced by the N-S migration of the ITD.

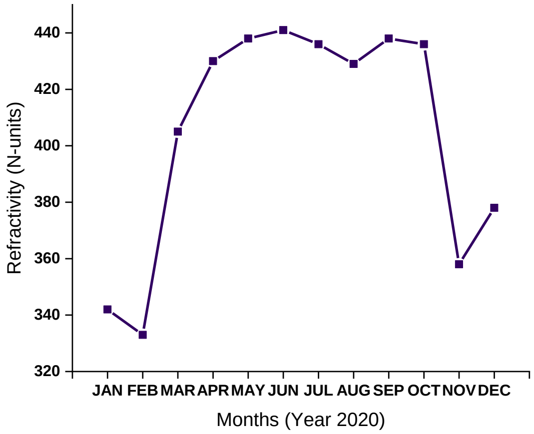

Figure 8: Average monthly refractivity for 2020

Computation of RRG and the effective earth radius, *K*

The effective earth radius factor, *k* can also be used to characterize refractive conditions as either normal, sub or super refraction and ducting as the case may be. Therefore, *k* is expressed in terms of RRG. The *k* factor is expressed as: (Muhammad, 2020).

$$k \approx \left[1 + \frac{\left(\frac{dN}{d\square}\right)}{157}\right]^{-1} \qquad (11)$$

The RRG has been calculated using equation (12) as:

$$G = \frac{dN}{d\square} = -7.32\, exp(\, 0.005577 N_S)(N - units/km) \qquad (12)$$

For the dry season, the RRG has been evaluated to be -54 N-units/km which gives an effective earth radius of 1.5. This is greater than 1.33 and by implication, super refraction occurs in dry season, thereby causing radio waves to propagate abnormally towards the earth’s surface, thus extending the earth’s horizon. Subsequently, RRG for the wet season was also obtained. A value of -73 (N-units/km) was obtained, which gives a *k*-factor of 1.87, which is much greater than 1.3 as compared to the obtained value for the dry season.

Consequently, increased super-refraction occurs in wet season and it causes radio waves to propagate better towards the earth's surface, thus extending the radio horizon distance much more than the dry season. The variations of radio refractivity and refractive index, are being estimated with the measurement of temperature, atmospheric pressure, and relative humidity. The effect of such parameters, which leads to estimation of RRG and *k*-factor has been studied by different researchers. The results reported in this study are in line with works of (Oyedum *et al*., 2016) and (Muhammad *et al.*, 2020). The authors did work on both Northern and Southern parts of Nigeria.

CONCLUSIONS

The need to study variations of meteorological parameters over Lapai town of Niger state, as these parameters affects the transmission of radio signals, necessitated this research It was observed that the refractivity values are lower in the dry season months due to lower relative humidity, as compared to the wet season. On the other hand, the wet season months characterized by higher refractivity value can be attributed mainly to high relative humidity values. The result showed that the month of January for the year 2018 has the minimum refractivity value of 325 N-units while the month of April, 2018 with *N* value of 444 N-units has the maximum value of refractivity. Finally, the RRG and *k*-factor for both seasons have been evaluated, ie -54 N-units/km and 1.5 respectively for dry season, and -73 N-units/km and 1.8 respectively for the wet season, which implies that both seasons are super-refractive, with the wet season more super refractive than the dry season. This research concludes that meteorological parameters put into focus for this work contribute noticeably to the radio refractivity, and subsequently the *k*-factor of Lapai, therefore, it affects the radio wave propagation. It has also established the fact that there exists a significant variation in the wet and dry season refractivity, with dry seasons having lesser *N* values due to low relative humidity as the major driving force. More so, the wet seasons are characterized by higher refractivity values due to higher values of relative humidity.

Consequently, both seasons for the study area have been found to be super refractive, with the wet season having an increased super refractivity as compared to the dry season.

The study recommends that

1. There is a need for more data measurement and acquisition centers in the study area to enable researchers get access to the process involved in the acquisition of data and to make the research a lot less stressful.
2. Future research should be focused on looking into a possibility of making radio refractivity high and efficient regardless of the season.

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