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The Seasonal Variations of Radio Refractivity over Abuja, Nigeria

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Abstract: The variation of radio refractivity affects the strength as well as the distance that can be covered by any transmitted signal in that area at any point in time. When there is high refractivity, the strength of signal travelling from one point to the other will reduce faster as the signal has to travel through different obstacles making it to bend in many different directions before reaching any destination. This work is aimed at determining how radio refractivity of Abuja varies with rainy and dry seasons. The work employs mathematical computation to determine the radio refractivity of the study area. It was discovered that radio refractivity of Abuja is higher in rainy season and lower in dry season.

Keywords: *Refractivity, Temperature, Vapour pressure, Frequency, Propagation.*

I. INTRODUCTION

Atmospheric or meteorological parameters are dynamic and under changes from time to time. These meteorological parameters, viz pressure, temperature, and relative humidity have serious effect on radio wave propagation at UHF and microwave frequencies. These effects are analyzed from the study of radio refractive index derived from these meteorological parameters (Bean and Dutton, 1966).

The propagation of electromagnetic waves in the atmosphere (mainly the troposphere) is greatly affected by the composition of the atmosphere (Korak, 2003). These components of the atmosphere that majorly affect the propagation of electromagnetic waves in the atmosphere are temperature, relative humidity and pressure. If the refractivity property of the atmosphere is known, it will aid in the design of wireless communication systems in the country (Adediji and Ajewole, 2008).

The refractive index of the atmosphere is close to unity and the variation is so small, which make it difficult to work with [Agbo et al., 2013]. A more convenient variable to use when modeling the variation of refractive index in the atmosphere is the refractivity, N. Radio refractivity is represented mathematically as:

$$N = (1 - n) \times 10^6 \quad \text{--------------------} \; 1$$

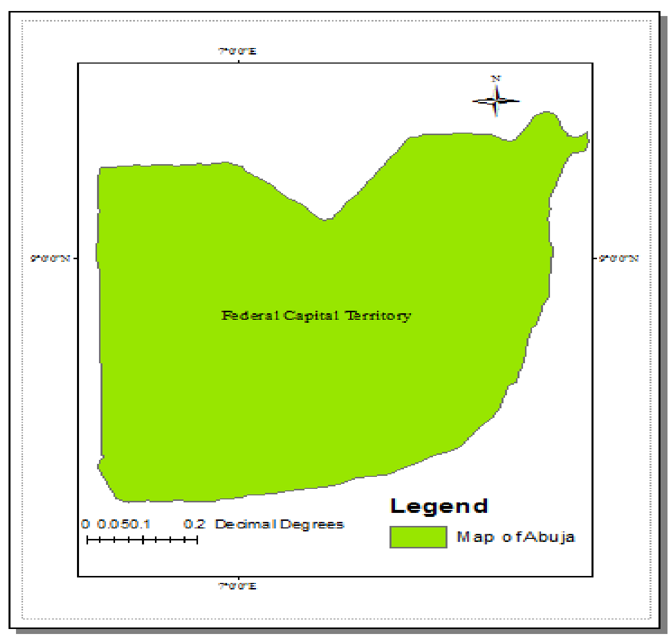
Where N = Radio Refractivity and n Refractive Index of air.

Radio refractivity is very important in design of telecommunication systems. The characterization of tropospheric, N variability has great significance to radio communications, aero-space, environmental monitoring, disaster forecasting, etc. (Ali, et al., 2012). One significant effect of the refractivity is the fact that it creates a multipath effect as a result of the variation of the refractive index at different layers of the atmosphere, hence signal propagation tends to take different trajectories as they travel in the atmosphere; the result is that the different signals will arrive at different time to the receiver or interfere with each other at the atmosphere (Emmanuel and Adebayo, 2013).

Similar works have been carried out by some researchers in some parts of the country. Isikwe et al., 2013 carried out such a research in Makurdi, North Central Nigeria. In their work, it was observed that there is a significant variation in rainy and dry season refractivity. In 2012, Okoro, and Agbo in their work in Minna, it was observed that there was a clear variation between refractivity for rainy season and dry season.

Daniel et al., 2015 carried out similar work in Calabar south-south Nigeria and found out that although the rare climatic conditions like that of Calabar City might distort this clear variation in some percentage but at the end, there was still a variation between dry and rainy season refractivity. Ayegba, et al., 2016, did a similar work in Lagos state, Nigeria. It was discovered that the radio refractivity in area in rainy season is higher than in dry season. This work is carried out for Abuja, the Federal Capital of Nigeria.

II. STUDY AREA



The study area of this research is Abuja, the Federal Capital Territory of Nigeria which is located between latitude 8.250 and 9.200 North of the equator and longitude 6.450 and 7.390 East of the Greenwich meridian. It was formed in 1976 from parts of Kogi state, Nasarawa state and Niger state. It has the land area of about 7315km2 , and bounded by Niger state to the West and North, Kaduna to the Northeast, Kogi to the south west and Nasarawa to the east and south. The rainy season is between April- September and dry season is between October -March.

Figure 1: Map of the study area

III. MATERIALS AND METHOD

i. Materials: The materials used for this work is a secondary data of temperature, pressure and relative humidity for the months of February and June 2016, obtained from the archive of weather online. The data for the month of June if for rainy season while that of February is for the dry season. Other materials the ArcGIS 10.1 software which was used for creating the map of the study area and Microsoft excel package used for the computation of the parameter and the plotting of graphs.

ii. Methods: The calculations of various parameters were done in Microsoft excel workbook using their various formulas. Various parameters are calculated before the determination of the radio refractivity. These procedure or steps are shown below.

a. Calculation of 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 depends mainly on the temperature of the vapour or air. It is determined using the formula given as;

$$e_s = 6.11\exp\left[\frac{17.26(T-273.16)}{T-35.87}\right] \quad \text{---- 2}$$

Where T is the air temperature in Kelvin (K), e_s is the saturated vapour pressure in hectopascal (hpa) and $\exp$ is exponential given by a constant value of 2.718.

b. Calculation of vapour pressure (e): Vapour pressure is defined as the measurement of the amount of moisture in the air. Vapour pressure is determined using the formula given as;

$$e = e_s \text{ x } \frac{H}{100} \quad \text{--------------------- 3}$$

Where H is the relative humidity in percent, e is the vapour pressure in hectopascal (hpa) and e_s is the saturated vapour pressure calculated from (2) above.

c. Calculation of Radio Refractivity (N): Radio refractivity is the physical property of the medium as determined by its index of refraction. It is the product of the refractive index less than one unit and one million. The ratio of the velocity of the radio propagation in free space to that in medium is called refractive index. Radio refractivity is calculated using the formula;

$$N = 77.7\frac{P}{T} + 3.73 \text{ x } 10^5 \frac{e}{T^2} \quad \text{----- 4}$$

Where P is the air pressure in (hpa), e is the vapour pressure in hectopascal (hpa) and T is the air temperature in Kelvin (K).

Table 1: Atmospheric data for February, 2016

Days	T (^{0}c)	P (hpa)	H (%)
1	33.3	1014.0	12.00
2	34.0	1012.0	12.00
3	34.5	1012.0	15.00
4	35.0	1013.0	15.00
5	35.1	1013.5	13.00
6	35.3	1014.0	11.00
7	34.8	1015.0	10.00
8	32.0	1016.0	15.00
9	33.9	1015.0	15.00
10	33.7	1015.0	10.00
11	34.8	1012.0	10.00
12	33.0	1014.0	10.00
13	34.0	1013.0	10.00
14	34.0	1012.0	23.00
15	34.0	1011.0	35.00
16	34.8	1011.5	30.00
17	37.0	1012.0	25.00
18	36.0	1011.0	35.00
19	35.0	1010.0	9.00
20	37.7	1011.0	9.00
21	36.0	1011.5	9.50
22	35.0	1012.0	10.00
23	35.5	1012.0	10.00
24	34.6	1012.0	18.00
25	32.1	1012.0	10.00
26	36.0	1012.0	15.00
27	35.0	1010.0	30.00
28	38.0	1010.0	40.00
29	35.0	1012.0	45.00

Table 2: Atmospheric data for June, 2016

Days	T (^{0}c)	P (hpa)	H (%)
1	30.8	1015	65
2	32.2	1015	57
3	27.5	1017	70
4	28	1016	68
5	28.4	1015	65
6	27.5	1014.5	68
7	27	1014	70
8	29	1015	60

9	30.1	1014	73
10	29	1015	70
11	29.2	1015	72
12	29.5	1015	70
13	29.5	1016	67
14	29.7	1017	65
15	24.7	1017	86
16	27.5	1018	75
17	27.5	1018	65
18	30.3	1015	60
19	28.4	1016	64
20	26.5	1017	63
21	27	1016	71
22	27.6	1015	69
23	28.4	1016	65
24	27.2	1015	68
25	28	1015	65
26	21	1017	90
27	27.5	1017	82
28	29	1017	71
29	29	1016	72
30	29	1017	68

III. RESULTS AND DISCUSSIONS

A. Results

Table 3: Calculated refractivity for dry season

Days	T (^{0}c)	P (hpa)	H(%)	Ndry
1	33.3	1014.0	12.00	281.18
2	34.0	1012.0	12.00	280.95
3	34.5	1012.0	15.00	287.60
4	35.0	1013.0	15.00	288.23
5	35.1	1013.5	13.00	284.01
6	35.3	1014.0	11.00	279.79
7	34.8	1015.0	10.00	277.69
8	32.0	1016.0	15.00	286.96
9	33.9	1015.0	15.00	287.92
10	33.7	1015.0	10.00	277.46
11	34.8	1012.0	10.00	276.93
12	33.0	1014.0	10.00	277.09
13	34.0	1013.0	10.00	277.01
14	34.0	1012.0	23.00	304.00
15	34.0	1011.0	35.00	328.89
16	34.8	1011.5	30.00	320.39
17	37.0	1012.0	25.00	313.94
18	36.0	1011.0	35.00	334.76
19	35.0	1010.0	9.00	274.27
20	37.7	1011.0	9.00	275.07
21	36.0	1011.5	9.50	275.97
22	35.0	1012.0	10.00	276.98
23	35.5	1012.0	10.00	277.11
24	34.6	1012.0	18.00	294.15
25	32.1	1012.0	10.00	276.47
26	36.0	1012.0	15.00	288.80
27	35.0	1010.0	30.00	320.49
28	38.0	1010.0	40.00	353.74
29	35.0	1012.0	45.00	354.00

Table 4: Calculated refractivity for rainy season

Days	T (^{0}c)	P (hpa)	H (%)	Nrainy
1	30.8	1015	65	375.39
2	32.2	1015	57	367.32
3	27.5	1017	70	368.27
4	28	1016	68	367.24
5	28.4	1015	65	364.09
6	27.5	1014.5	68	364.60
7	27	1014	70	365.22
8	29	1015	60	358.63
9	30.1	1014	73	385.49
10	29	1015	70	374.94
11	29.2	1015	72	379.23
12	29.5	1015	70	377.46
13	29.5	1016	67	372.70
14	29.7	1017	65	370.55
15	24.7	1017	86	377.17
16	27.5	1018	75	376.07
17	27.5	1018	65	360.98
18	30.3	1015	60	364.21
19	28.4	1016	64	362.77
20	26.5	1017	63	353.76
21	27	1016	71	367.21
22	27.6	1015	69	366.70
23	28.4	1016	65	364.35
24	27.2	1015	68	363.41
25	28	1015	65	362.34
26	21	1017	90	364.54
27	27.5	1017	82	386.38
28	29	1017	71	377.08
29	29	1016	72	378.45
30	29	1017	68	372.19

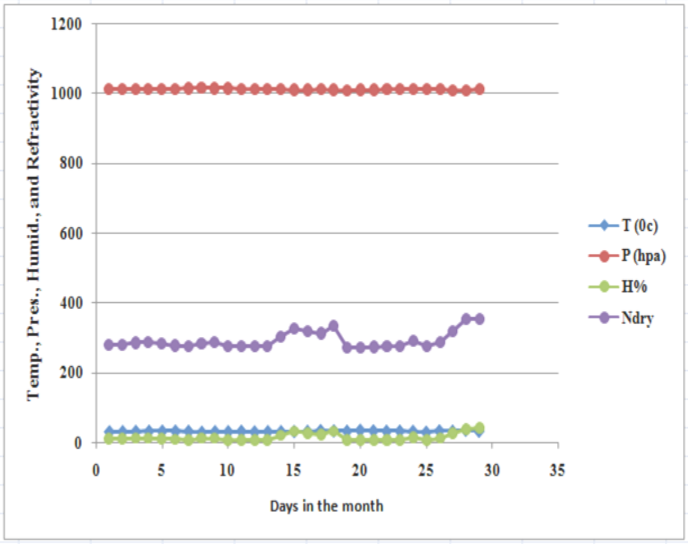


Figure 1: Graph of temperature, pressure, relative humidity and radio refractivity for dry season.

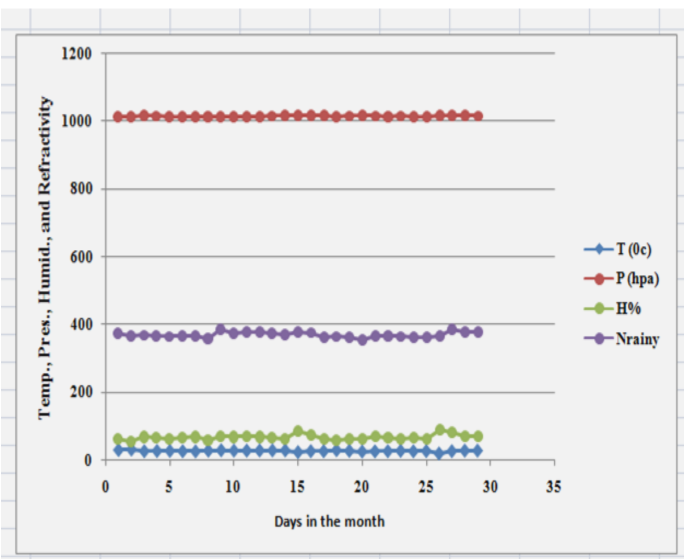


Figure 2: Graph of temperature, pressure, relative humidity and radio refractivity for rainy season.

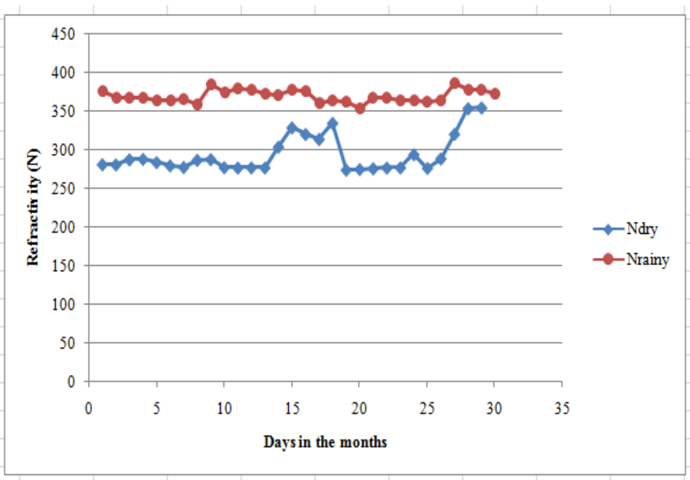


Figure 3: Graph of radio refractivity for both dry and rainy seasons.

B. Discussions

Figure 1 shows the graph of temperature, pressure, relative humidity and radio refractivity for dry season which was plotted from table 3. The data of the month of February is used in this research work as the dry season data as shown in table 1. The calculated radio refractivity for dry season is shown in table 3. The dry season has the maximum and minimum refractivity of 354 N-units and 274.3 N-units respectively, and an average refractivity of 294.2 N-units.

Table 4 shows the calculated refractivity for rainy season, in which the data for June was used. In rainy season, the maximum and minimum refractivity are 386.4 N-units and 353.8 N-units respectively, and an average refractivity of 369.5 N-units.

In the two figures- figures 1 and 2, the radio refractivity is said to vary with the relative humidity as it can be noticed in their curves. Although, the temperature and pressure may have effect on the radio refractivity, their influence is not clearly noticed in this work.

Also, figure 3 is the representation of the comparison of the dry and rainy seasons refractivity. It can be seen that the radio refractivity for dry season is less than that for rainy season. Although at some point in dry season, the refractivity values were close to that of rainy season due to higher values of relative humidity at those points, the rainy season refractivity was greater than the dry season one all through. Also, from the average refractivity values, the average refractivity for rainy season-369.5 N-units is higher than the average refractivity for dry season, which is 294.2 N-units. This confirms the work of Ayegba, et al., 2016, which was done in Lagos state where it was observed that the radio refractivity for dry season was less than that for rainy season.

CONCLUSION

The data of temperature, pressure, and relative humidity for the months of February and June, 2016 obtained from the archive of weather online limited was used to determine the radio refractivity for dry season and rainy season. The rainy season has the maximum and minimum refractivity of 386.4 N-units and 353.8 N-units respectively, while dry season has the maximum and minimum refractivity of 354 N-units and 274.3 N-units respectively.

From the result, it can be stated that the radio refractivity for both dry season and rainy season vary with relative humidity. Also, it can be further concluded that radio refractivity is higher in rainy season than in dry season.

Recommendation

In this work, the data for one month in each of the dry and rainy seasons is used. It is hereby recommended that about five months data for rainy season and dry season each be used for this same work.

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