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International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Exploring the Relationship between Radio Refractivity Trends and Atmospheric Parameters in Osogbo, Nigeria.

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A B S T R A C T

This study presents the relationship between radio refractivity and atmospheric parameters in Osogbo, Nigeria. The atmospheric parameters are temperature, pressure, and saturation vapour pressure (SVP). The radio refractivity over Osogbo, Nigeria, was estimated to range between 370 – 390N-units and 300 – 380N-units for 2021 and 2022, respectively. It was shown that the radio refractivity over Osogbo is influenced by atmospheric moisture and temperature, resulting in higher values during the rainy season and lower values during the dry season. Understanding the seasonal variations of radio refractivity is essential for optimising the design and performance of radio communication systems in the region, ensuring reliable and efficient transmission of information.

Keywords: Radio refractivity, Atmospheric parameters, Osogbo, Nigeria

1. Introduction

Atmosphere – the layer of gases that covers the Earth is important for life, the regulation of climate and protection of the Earth from radiation that emanates from the sun. The atmosphere has distinct layers, including the troposphere, stratosphere, mesosphere, and others. One of the layers of the atmosphere that is important for the transmission of radio signals is the troposphere [1-2]. The troposphere contains about 75–80% of the total mass of the atmosphere and nearly all of its water vapour, clouds, and weather activity. The behaviour of the weather that occurs at an instant of time affects the transmission of radio signals through the atmosphere. The different variations of temperature, pressure and relative humidity cause refraction of radio signals, which has a significant effect on telecommunications [3-5]

Diverse studies have been carried out on the propagation of radio signals for different regions of Nigeria [6-10]. [11] examined instantaneous GSM signal strength variations with weather and environment. They observed that rain, high humidity, and temperature extremes caused noticeable signal attenuation. [12] investigated characteristics of surface radio refractivity over Ilorin, Nigeria, pointing out pronounced seasonal variability, with high values during the wet season as a result of the influence of humidity. It was also reported by [9] that temperature and humidity variation that occurs early in the mornings and late in the evenings has an influence on refractivity, with higher values of radio refractivity during the wet seasons. Also, atmospheric parameters such as temperature and pressure experience seasonal changes, which have implications on the radio refractivity of a given location [13-16]. Anomalous microwave propagation in the first 100m altitude was examined by [15]. They reported that super-refraction and ducting were frequent during wet season mornings, while dry season conditions leaned toward standard refraction. [16] showed that coastal and southern regions exhibited the highest refractivity and largest fade depths, while arid northern zones had lower values. Fade depth was more severe in the wet season, especially in high-humidity zones. The radio refractivity gradient in Akure, Nigeria, was examined by [6]. They discovered that the wet season usually produced super-refraction, while dry season conditions approached normal refraction. The researchers concluded that the climate of a specific region can significantly impact radio refractivity, which in turn affects radio signal transmission. This finding highlights the importance of considering local climate patterns in designing and deploying radio communication systems, as they can hurt transmission quality and reliability.

The investigation of radio refractivity is very necessary since such knowledge is needed in the development of effective communication systems, climate studies and disaster management [2, 11, 17]. This study aims to investigate the variation of radio refractivity with atmospheric parameters of temperature, pressure and saturated vapour pressure over Osogbo, Osun State, Nigeria.

2. Methodology

The daily data of temperature (T), Atmospheric pressure (P) and dew point temperature (Td) for the years 2021 and 2022 were obtained from the archive of ERA5. The area under investigation is Osogbo, Osun State, Nigeria. Osogbo is the capital city of Osun State, Nigeria, which lies between latitude 7.78 °N and longitude 4.45 °E. Osogbo is a major commercial and agricultural trade hub, particularly for yams, cassava, maize, beans and cotton. The city also has a booming arts and crafts economy. Osogbo has two major seasons, which are the wet (April to October) and dry (October to March) seasons.

Osogbo experiences a tropical savanna climate with a yearly temperature and precipitation of 25 °C and 1241 mm, respectively [18]. The daily data were averaged into monthly data, and computational analysis was carried out. The radio refractivity was computed using the expression given by

$$N = 77.6\frac{P}{T} + 3.75 \text{ x } 10^5 \left(\frac{e}{T^2}\right) \qquad (1)$$

where P is the atmospheric pressure in hPa, T is the absolute temperature in Kelvin, and e is the partial pressure due to water vapour in hPa. Where e is given as

$$\mathbf{e = 6.11exp\left(\frac{7.5Td}{237.3 + Td}\right)} \qquad (\mathbf{2})$$

3. Results and Discussion

The monthly radio refractivity of Osogbo, Nigeria, was estimated for the years 2021 and 2022. The radio refractivity (N) and saturation vapour pressure (SVP) were computed using (1) and (2), respectively and the results are presented in Tables 1 and 2.

Table 1: Monthly estimated values of radio refractivity (N) and atmospheric parameters for the year 2021

Months	T(K)	P(hPa)	SVP (hPA)	N (N-units)
Jan	299.00	976.17	29.46	376.93
Feb	300.24	973.14	29.46	374.06
Mar	299.70	974.90	33.24	391.19
Apr	299.08	974.61	30.27	379.78
May	297.49	976.03	29.79	380.84
Jun	296.15	978.74	26.29	368.88
Jul	296.39	980.42	27.54	374.28
Aug	297.12	976.21	28.86	377.54
Sep	296.41	977.5	28.55	377.76
Oct	297.14	978.05	29.83	382.12
Nov	296.85	975.67	29.63	381.13
Dec	298.27	976.85	28.09	372.53

Table 2: Monthly estimated values of radio refractivity and atmospheric parameters for the year 2022

Months	T(K)	P(hPa)	SVP (hPA)	N (N-units)
Jan	295.48	975.74	9.49	297.02
Feb	299.43	975.67	31.45	384.38
Mar	297.64	973.98	29.33	378.08
Apr	297.69	977.09	31.14	386.49
May	295.79	977.28	26.86	371.51
Jun	294.50	978.80	25.46	367.99
Jul	295.13	978.80	25.63	367.69
Aug	295.49	977.53	26.94	372.44
Sep	296.01	977.20	26.83	371.01
Oct	297.76	976.27	28.94	376.82
Nov	297.71	974.58	27.68	371.15
Dec	297.87	976.97	8.13	288.90

Figure 1a shows the monthly trend of radio refractivity and temperature. From the plot, it can be seen that radio refractivity (red line) fluctuates between 370–390 N-units, high in March–April and lowest around June, then slightly recovers in the second half of the year. Temperature (Blue line) peaks around March, drops sharply to a minimum in June. Remains relatively low from July to October, with small oscillations, then rises again slightly in December. This shows that there is a strong relationship between radio refractivity and temperature. When the temperature drops between April and June, radio refractivity also drops. This shows temperature plays a more dominant role in radio refractivity variation. However, the recovery of radio refractivity in the late months, while temperature stays nearly constant, again implies the effect of moisture and seasonal air mass changes. Figure 1b shows that the radio refractivity (red line) peaks sharply around February – March, decreases gradually from April to September and rises slightly in October–November, then drops sharply in December. Temperature (blue line) is highest around February but steadily declines from March to July, reaching a minimum in June–July. Rises again toward September–November, and slightly drops in December. From the plot, an inverse relationship is noticeable, as temperature decreases (March–July), radio refractivity remains relatively high, then starts dropping as temperature stabilises. This suggests refractivity here is not solely driven by temperature and is likely also influenced by humidity and pressure, which dominate radio refractivity during the wet season. The sharp fall of refractivity in December could indicate the transition into the dry season, which is a harmattan effect in West Africa.

The trend in radio refractivity for Figure 2a (red line) is the same as that of Figure 1a, showing significant fluctuations in the year 2021. But the trend for pressure (blue line) shows the lowest values around February–March, then rises steadily to peak in July, followed by mild fluctuations toward the end of the year. There is an inverse relationship in many months. For example, in March, radio refractivity is very high while pressure is low. In June–July, the pressure peaks while radio refractivity dips to its lowest. This suggests that higher atmospheric pressure tends to suppress radio refractivity values, and vice versa. The plot of radio refractivity for Figure 2b (red line) is the same as that of Figure 1b (red line), showing moderate fluctuations. The plot of pressure (blue line) shows a low in February – March, rises steadily to a maximum in June–July, and then decreases toward October–November before slightly rising again in December. The **r**elationship between radio refractivity and pressure shows an inverse correlation, that is, radio refractivity is highest when pressure is lowest (February – March). Pressure is highest when radio refractivity has slightly declined (June–July). However, in mid-to-late months (August – October), both pressure and radio refractivity remain moderately high, suggesting the inverse relation is not strict but seasonal.

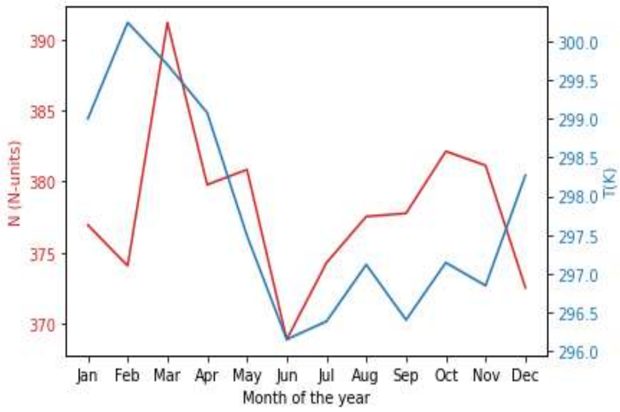


Figure 1a: Variation of radio refractivity and temperature for 2021

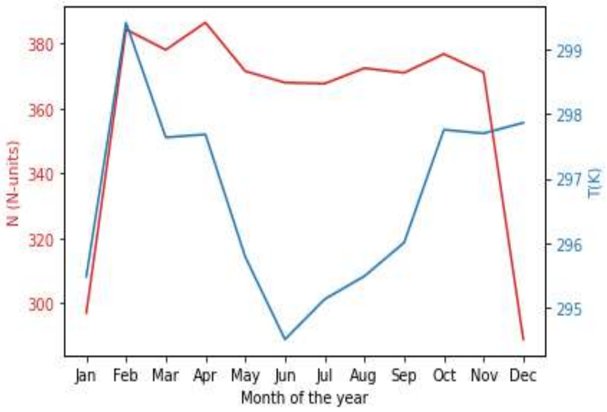


Figure 1b: Variation of radio refractivity and temperature for 2022

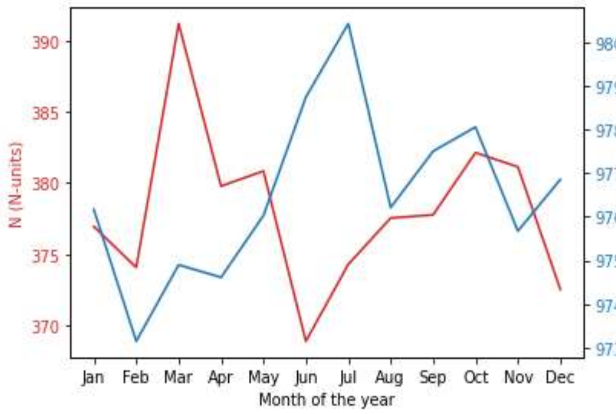


Figure 2a: Variation of radio refractivity and pressure for 2021

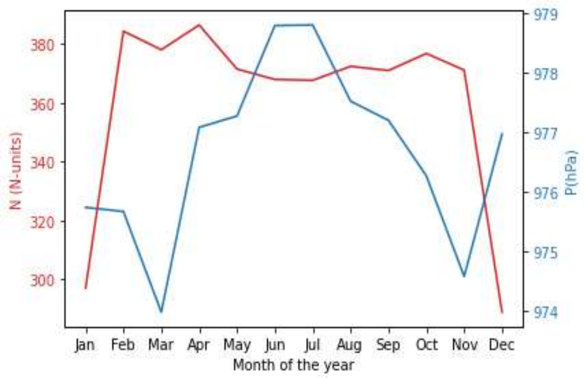
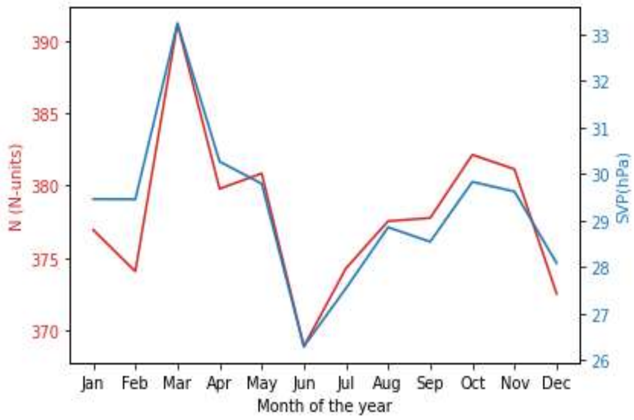


Figure 2b: Variation of radio refractivity and pressure for 2022



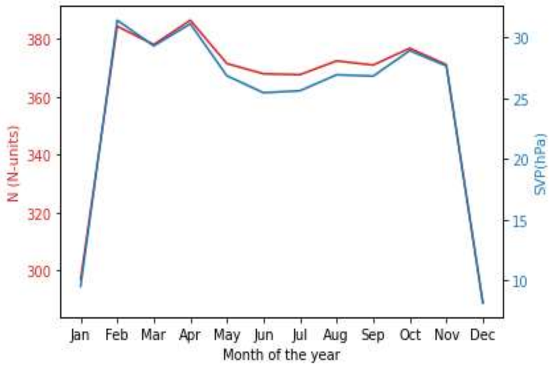


Figure 3a: Variation of radio refractivity and saturated vapour vapour Pressure for 2021

Figure 3b: Variation of radio refractivity refractivity and saturated vapour Pressure for 2022

In Figure 3a, both radio refractivity (N) and saturated vapour pressure (SVP) show similar seasonal variations, indicating a strong relationship. A sharp rise occurs around March–April, and then a steep decline in June–July. Afterwards, both gradually increase again through October–November before declining in December. When SVP rises (higher atmospheric moisture content), refractivity increases. The minimum in June–July suggests the dry season has a low vapour content and less radio refractivity. Peaks in March–April and October–November coincide with higher humidity, which is the wet season transition. The patterns in Figure 3b have a trend with less fluctuation. Both radio refractivity and SVP are relatively high and stable between February and October, with small dips around June and July. A sharp drop occurs in December, showing significantly lower SVP and refractivity (very dry conditions). The stability from February to October shows a long period of relatively moist atmosphere, keeping N values high. The sharp decline in December suggests extremely low vapour pressure, strongly reducing radio refractivity.

4. Conclusion

In this study, the radio refractivity of Osogbo, Nigeria, was computed and analysed. The result obtained shows that local atmospheric conditions (seasonal temperature & humidity cycles) play a big role in modulating refractivity alongside pressure. Also, radio refractivity depends on the atmospheric parameters in Osogbo, Nigeria. The result obtained is very helpful in the planning and designing of radio communication systems for the area of study and for regions that have similar climates. Future research is centered on the spatial analysis of radio refractivity over Nigeria.

Acknowledgements

Thanks to the European Centre for Medium-Range Weather Forecasts (ECMWF) for granting access to the ERA5 reanalysis data.

Funding: Not applicable

Conflict of Interests: The author declares no conflict of interest.

Data Availability: The data used for this study are available at https://cds.climate.copernicus.eu/cdsapp#!/dataset/reanalysis-era5-single-levels

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