



Assessment of Meteorological Drivers of Surface Radio Refractivity For Terrestrial Communication Planning In Jos, Plateau State

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ABSTRACT

This study focuses on the Statistical Assessment of Meteorological Drivers of Surface Radio Refractivity for Terrestrial Communication Planning in Jos, Plateau State, Nigeria. Ten years (2011–2020) of satellite-derived meteorological data, including air temperature, atmospheric pressure, relative humidity, and rainfall, were used to compute monthly, seasonal, and annual surface refractivity values. The results show that refractivity is consistently higher during the wet season than the dry season, with mean values of about 275.00 N-units and 200.00 N-units, respectively. Minimum refractivity values ranged from 289.84 to 320.30 N-units, while maximum values varied between 351.53 and 374.01 N-units over the study period. Higher refractivity during the wet season indicates increased signal attenuation due to enhanced atmospheric moisture. Correlation analysis reveals a negative relationship between refractivity and temperature, a mixed response to atmospheric pressure, and positive correlations with relative humidity and rainfall. These findings are significant for radio frequency planning and can aid in optimizing power budgets and improving the reliability of terrestrial radio communication systems in Jos and similar climatic regions.

Keywords: Refractivity, Terrestrial, Communication, Meteorological, Planning

INTRODUCTION

Radio communication systems rely on the propagation of electromagnetic waves through the Earth's atmosphere, where the troposphere plays a dominant role in determining signal behavior. Variations in meteorological parameters such as air temperature, atmospheric pressure, relative humidity, and rainfall modify the tropospheric refractive index, thereby influencing signal amplitude, phase, and propagation path. These effects can degrade transmission quality and increase propagation losses, particularly at very high frequency (VHF), ultrahigh frequency (UHF), and super high frequency (SHF) bands (Usman et al., 2023). The troposphere extends from the Earth's surface to approximately 10–17 km in altitude (Ref?) and is characterized by random spatial and temporal fluctuations in refractivity (Ref?). Such variability gives rise to scattering, absorption, scintillation, and anomalous propagation phenomena, which may result in signal fading and co-channel interference (Usman, et al., 2024). These effects are generally more pronounced in tropical regions due to high humidity levels and frequent intense rainfall.

MATERIALS AND METHODS

Study Area

Jos is located on the Jos Plateau in Plateau State, north-central Nigeria, at approximately 9.93° N, 8.89° E, with a mean elevation of about 1,217 m above sea level (Ref?). It serves as the administrative capital and largest urban center in the state, with an estimated population of about 9.0×10^5 (Ref?). The city's elevated terrain gives rise to climatic conditions that are markedly cooler than those of the surrounding lowland regions. The climate of Jos is classified as tropical savanna (Köppen: Aw), modified by altitude. Mean monthly temperatures typically range between 21–25 °C, while nighttime temperatures during the dry season (November–

January) can fall to about 7 °C. The coolest months record average temperatures of approximately 15.5–18.5 °C, whereas the hottest months experience temperatures in the range of 27.5–30.5 °C. Occasional hailstorms may occur during the rainy season due to convective activity and orographic lifting over the plateau. Jos receives a mean annual rainfall of about 1,400 mm, with spatial variability across the city ranging from approximately 2,000 mm yr⁻¹ in the southwest to $\leq 1,500$ mm yr⁻¹ in the northeastern sector. Rainfall is highly seasonal, occurring mainly between June and September, with July–August as the peak months. Precipitation is largely driven by moist southwesterly winds and enhanced by orographic effects on the windward slopes of the plateau (Adewale, et al., 2013). Relative humidity is generally high during the wet season.

Source of Data Used for This Study

Ten years (2011-2020) of satellite data of weather parameters, temperature, pressure, humidity, and amount of rainfall at the surface above ground level were obtained from the European Center for Medium-Range Weather Forecast (ECMWF, 2022) in January 2022. The European Center for Medium-Range Weather Forecasts (ECMWF)-ERA5 is an independent intergovernmental organization established in 1975. They have scientific and technical research to develop numerical models and data assimilation systems (ECMWF, 2022). They generate data and provide numerical weather predictions on a global scale. The world's largest supercomputer facilities and meteorological data archives are found at this site for users worldwide. They generated a global numerical weather forecast. Medium-range, monthly, and seasonal weather forecasts in addition to climate change and Copernicus atmosphere monitoring. Their forecasts are intended to illustrate the most likely course of the weather, and the center generates an ensemble of forecasts that displays the climatic

re-analysis, re-forecast, forecast, analysis, and multi-model database in real-time and in the past (ECMWF, 2021). One interesting feature of this study is recent satellite atmospheric

data (2011–2020) over Jos, utilizing an ITU-recommended approach to generate secondary data.

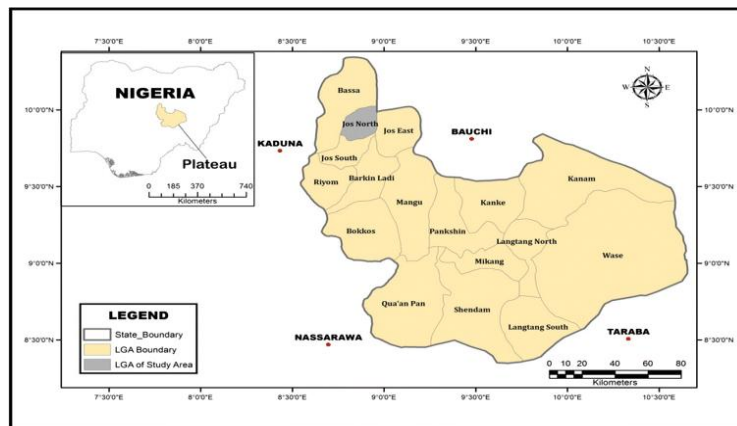


Figure 1: Map of Nigeria Showing The Study Area Adapted from Paramallam and Hoomlong, (2017)

Data Sorting and Empirical Tools

The data set was divided into monthly, seasonal, and annual formats for ease of analysis and result discussion. (1) (ITU-R, P.453, 2003, P.453-14, 2017); (Adediji and Ajewole, 2008; Ayantuji et al., 2011) provides the universal radio refractivity equation: Surface radio refractivity, or N_{sf} and N100, is the refractivity at the atmosphere's surface determined by surface meteorological factors. The surface radio refractivity was calculated using equations (1) through (4) (Usman et al., 2023).

$$N = 77.6 \frac{Pd}{T} + 72 \frac{e}{T} + 3.75 \times 10^5 \frac{e}{T^2} \text{ (N-units)} \quad (1)$$

$$e = 100 \frac{H.es}{100} \quad (2)$$

$$es = EF.a.exp \left[\frac{\left(\frac{b - t}{d} \right) t}{t + c} \right] \quad (3)$$

And:

$$EF = 1 + 10^{-4} [7.2 + P.(0.0320 + 5.9 \times 10^{-6} T^2)] \quad (4)$$

Where:

T: temperature (^oC)

P: total atmospheric pressure (hPa)

H is relative humidity (%),

e_s : Saturation vapor pressure (hPa) at the temp t (^oC)
 $a=6.1121$
 $b=18.678$
 $c=257.14$
 $d=234.5$ (ITU-R, 2021).

Where, e_s is the maximum (or saturated) vapour pressure at the given air temperature t (^oC) and H (%RH) is the humidity. P is the air pressure (hPa), T is the temperature (K), and e, is water vapour pressure (hPa). Generally, P and e decrease rapidly with height, whereas T, decreases slowly with height (Adediji and Akinbolati, et al., 2024). To determine the degree of relationship between the variables, Karl Pearson's product correlation coefficient used for continuous data as presented in equation (4) was used.

$$r = \frac{n \sum xy - \sum x \sum y}{\sqrt{[n \sum x^2 - (\sum x)^2] [n \sum y^2 - (\sum y)^2]}} = \frac{cov XY}{\sqrt{var X.var Y}} \quad (4)$$

RESULTS AND DISCUSSION

Figure 2 shows the monthly variation of surface radio refractivity (N-units) in Jos, Plateau State for the years under study (2011-2020). Table 1 presents the average seasonal variation for dry season and wet season

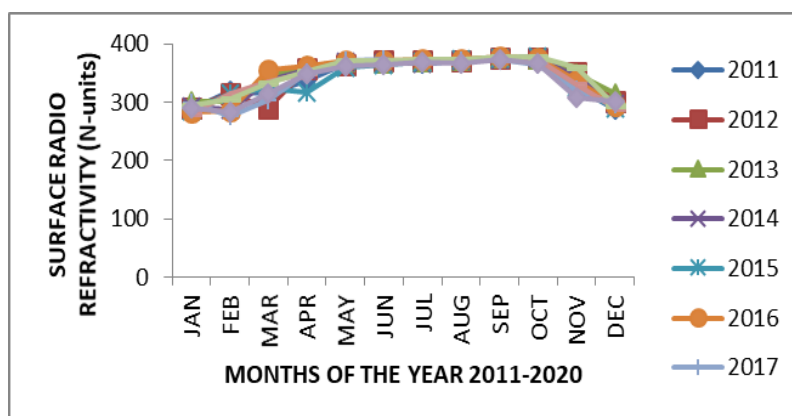


Figure 2: Variation of Surface Radio Refractivity for The ten Years (2011-2020) over Jos, Plateau State

Figure 2 shows the monthly variation of surface radio refractivity (N-units) in Jos, Plateau State over ten years (2011-2020). Surface radio refractivity is an important atmospheric parameter that affects radio wave propagation, communication signals, and radar transmission. The graph shows that surface radio refractivity generally increases gradually from January to October and then decreases toward December. Values start at about 290-310 N-units in January,

then rise steadily through the months, and reach a peak of about 410-430 N-units around September to October. After October the refractivity drops sharply in November and December to around 360-380 N-units.

Average Seasonal Variations of Surface Radio Refractivity

Table 1: Showing the Average Seasonal Variation for Dry Season and Wet Season

Years	Dry (N-units)	Wet (N-units)
2011	304.880	367.864
2012	314.128	369.274
2013	316.141	369.110
2014	304.936	368.474
2015	303.682	366.302
2016	299.590	371.550
2017	298.017	369.989
2018	303.970	368.136
2019	313.223	371.323
2020	295.135	364.931
Mean	305.370	368.695

As seen in Figure3 below, During the dry season Table 1, Surface Radio Refractivity had a minimum value of 304.880 (N-units) in the first year (2011), increased to 314.128 (N-units) in the following year (2012), and then rapidly increased to its highest value of 316.141 (N-units) in the year (2013) before declining in the following year (2014). After that, it abruptly rises to 313.223 (N-units) in 2019 and then falls to 295.135 (N-units), the first lowest value, in 2020. However, the value of refractivity in the WET season Table 1 was measured in the first year of 2011 at 367.864 (N-units). It then slightly increased to 369.274 (N-units) in the following year, 2012, and it also slightly decreased in the following years,

2013, 2014 and 2015, with values of 369.110 (N-units), 368.474 (N-units) and 366.302 (N-units), respectively. After that, it increased gradually in 2016 to 371.550 (N-units) which is the peak value. It has been noted that 2016 had the highest value of 371.550, while 2020 had the lowest value of 364.931 (N-units). Because the lower atmosphere is denser during the wet season due to increased moisture content, radio refractivity is often slightly higher here than during the dry season. When waves pass through a dense material, they move more slowly than through a less dense one (Usman et al., 2026). Figure3's findings demonstrate that the seasonal radio refractivity for both seasons varies relatively little.

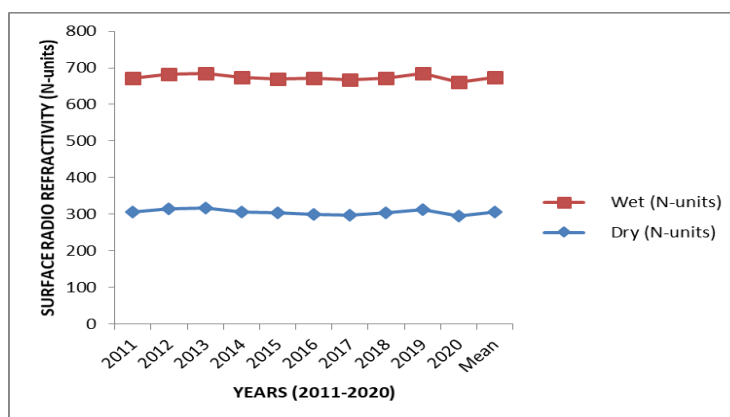


Figure 3: Average Seasonal Variation for Dry and Wet Season For the Years (2011-2020)

Evaluated Degree of Relationship between Radio Refractivity and Atmospheric Variables (Correlation Coefficients)

Statistical analysis utilizing a correlation coefficient on Table 2 was conducted to determine the degree of relationship between radio refractivity Ns and atmospheric variables of temperature, humidity, pressure, and rainfall. According to the results in 2015, the correlation coefficients between the degree of correlation between of radio refractivity Ns and atmospheric variables, temperature, humidity, pressure, and rainfall amount, for 2016 was determined. The results showed

that Ns and temperature, pressure, humidity, and rainfall had correlation coefficients of -0.51, -0.15, 0.84, and 0.64, respectively. Additionally, in 2017, the following year, the Ns were found to be -0.49, -0.28, 0.75, and 0.73 in relation to temperature, pressure, humidity, and rainfall amount, respectively. In contrast, the relationship between Ns and temperature, pressure, humidity, and rainfall amount was found to be -0.48, -0.08, 0.84, and 0.58 in 2018 and -0.46, -0.11, 0.77, and 0.51 in 2019, respectively. The remaining years have similar trends.

Table 2: The Correlation Coefficients between Surface Radio Refractivity and Temperature, Atmospheric Pressure, Relative Humidity, and Amount of Rainfall

Years	Temperature (K)	Pressure (hPa)	Relative Humidity (%)	Amount of Rainfall (mm)
2011	-0.335	0.104	0.905	0.358
2012	-0.384	0.382	0.907	0.341
2013	-0.434	0.384	0.929	0.439
2014	-0.235	0.263	0.897	0.534
2015	-0.179	0.254	0.901	0.521
2016	-0.483	-0.109	0.908	0.364
2017	-0.392	0.213	0.895	0.148
2018	-0.987	0.363	0.996	0.463
2019	-1	1	1	1
2020	0	0	0	0

The negative correlation between temperature and surface radio refractivity means as temperature rises, radio refractivity reduces and vice versa. Similarly, a negative atmospheric pressure suggests that surface radio refractivity increases when atmospheric pressure falls.

Statistical analysis was conducted using the Pearson correlation coefficient to quantify the relationship between

surface radio refractivity (N-units) and key atmospheric variables: air temperature (T, K), atmospheric pressure (P, hPa), relative humidity (RH, %), and rainfall (R, mm). Table 2 presents the correlation coefficients computed annually from 2011 to 2020.

Table 3: Correlation Coefficients between Surface Radio Refractivity and Atmospheric Variables

Year	Temp (K)	Press (hPa)	RH (%)	Rainfall (mm)
2011	-0.34	0.10	0.91	0.36
2012	-0.38	0.38	0.91	0.34
2013	-0.43	0.38	0.93	0.44
2014	-0.24	0.26	0.90	0.53
2015	-0.18	0.25	0.90	0.52
2016	-0.48	-0.11	0.91	0.36
2017	-0.39	0.21	0.90	0.15
2018	-0.49	0.36	0.95	0.46
2019	-0.46	0.11	0.93	0.51
2020	-0.44	0.13	0.92	0.48

The results indicate consistent trends as shown in table 3 above

Temperature (T): Negative correlations with Refractivity (≈ -0.44 to -0.49) suggest that surface radio refractivity decreases as temperature increases. Physically, warmer air has lower density, reducing the refractive index.

Pressure (P): Weak positive or slightly negative correlations (≈ -0.11 to 0.38) reflect that higher atmospheric pressure slightly increases refractivity, but the effect is smaller compared to humidity.

Relative Humidity (RH): Strong positive correlations (≈ 0.90 – 0.95) indicate that increasing moisture content in the air enhances refractivity, as water vapor contributes significantly to the refractive index.

Rainfall (R): Moderate positive correlations (≈ 0.15 – 0.53) show that periods of higher precipitation generally coincide with elevated refractivity, reflecting the combined effects of increased humidity and tropospheric moisture.

Overall, the analysis demonstrates that humidity and rainfall are the dominant atmospheric drivers of surface radio refractivity, while temperature inversely affects refractivity, and pressure plays a secondary role. These insights are crucial for radio link design, coverage prediction, and power budgeting in Jos and similar tropical highland environments.

CONCLUSION

This study deals with Statistical Assessment of Meteorological Drivers of Surface Radio Refractivity (12 m) above ground level on a monthly, seasonal, and annual basis,

as well as the correlations between surface radio refractivity and atmospheric variables such as temperature, pressure, relative humidity, and rainfall for Terrestrial Communication Planning in Jos, Plateau State, Nigeria. Using the ITU-R standard, the propagation effects of the secondary radio climatic parameters were calculated. Compared to the dry season months, higher values of radio refractivity were generally recorded during the wet season months covering all years. Furthermore, during the years 2011 through 2020, average values of surface radio refractivity of 307.741 (N-Units) were obtained during the dry season. In addition to the average values of surface radio refractivity, which were recorded during the wet season months for the years 2015 to 2020, the minimum and maximum values of 301.509 and 314.088 (N-Units) during the dry season months were recorded in the years 2015 and 2017, respectively. 2018 and 2020, respectively, had the lowest and greatest values of 322.712 and 324.826 (N-Units) during the wet season. Compared to the dry season months, higher values of radio refractivity were generally recorded during the wet season months covering all years. Furthermore, during the years 2015 through 2020, average values of surface radio refractivity of 307.741 (N-Units) were obtained during the dry season. In addition to the average values of surface radio refractivity, which were recorded during the wet season months for the years 2015 to 2020, the minimum and maximum values of 301.509 and 314.088 (N-Units) during the dry season months were recorded in the years 2015 and 2017, respectively. 2018 and 2020, respectively, had the lowest and greatest values of

322.712 and 324.826 (N-Units) during the wet season. The monthly fluctuations in refractivity during the dry season are primarily caused by changes in the wet (Humidity) component of refractivity, whereas both the wet (Humidity) and dry (Pressure) components of refractivity contribute to the monthly variations during the rainy season. Over the city of Jos, refractivity shows seasonal fluctuations, with high values during the rainy season and low values during the dry season.

- i. Radio engineers will have access to sufficient data from this study's surface radio refractivity measurements to aid in designing communication systems at the sites.
- ii. It will be crucial in establishing the sites' VHF, UHF, and microwave signal coverage and quality.
- iii. To compensate for potential losses from high refractivity, owners of communication systems using the VHF and UHF bands are encouraged to boost their output power during the rainy season. The necessity for this kind of study is even more pressing now that communication channels have expanded. Thus, efforts should be made to connect with research participants to obtain funding to purchase more advanced equipment.

REFERENCES

Adediji, A. T. and M. O. Ajewole, Vertical profile of radio refractivity gradient in Akure South-west Nigeria, Progress In Electromagnetic Research C, Vol. 4, 157-168, 2008.

Ajewole, M. O., et al., (2013) Spatial variability of VHF/UHF electric field strength, in Niger State, Nigeria, International Journal of Digital Information and Wireless Communications (IJDWC) 3(3): 26-34 The Society of Digital Information and Wireless Communications, 2013 (ISSN: 2225-658X).

Akinbolati et al., (2024). The Investigation of Surface Radio Refractivity over Lokoja, Kogi State Nigeria, UMYU Scientific, Vol. 3 NO. 1, March 2024, Pp. 144 – 156

(ITU-R, P453, 2003, P453-14, 2017); (Adediji and Ajewale, 2008; Ayantuji: et al., 2011 provides the universal (ITU-R, 2021)

Para-Mallam, F.J., and Hoomlong, K. (2017). A critical investigation into the role of security sector agencies in Jos conflict: issues and strategies for institutional/ security sector reform. Research report.

Usman S.L., et al., (2023). Exploring vertical gradients of radio refractivity and their significance for radio wave propagation in abuja, jos and makurdi of north-central nigeria science world journal vol. 19(no 1) 2024 <https://dx.doi.org/10.4314/swj.v19i1.8>

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Usman S.L., et al., (2024). Studies on surface radio refractivity and its effects on radio wave propagation over abuja, nigeria aan journal of sciences, engineering and technology vol. 2, issue 2, pp. 16-29, july 2024

Usman S.L., et al., (2026). "Long-Term Characterization of Vertical Radio Refractivity Gradients and Tropospheric Propagation Conditions over North Central Nigeria Using ERA-5 Reanalysis Data" published in the latest issue of Physics Access, Vol. 6, and Issue 1.



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