JOURNAL OF SCIENCE TECHNOLOGY AND EDUCATION 13(3), SEPTEMBER, 2025
E-ISSN: 3093-0898, PRINT ISSN: 2277-0011; Journal homepage: www.atbuftejoste.com.ng

Investigation of Variability of Tropospheric Radio Refractivity and Field Strength over Gusau Town, Zamfara State, Nigeria

Ibrahim Lugga Abubakar
Department of Physics, School of Science (Education)
College of Education Maru, Zamfara State Nigeria

ABSTRACT

This study investigates the variability of tropospheric radio refractivity and examines how these variations impact radio field strength over Gusau town, Zamfara state. The measurement of tropospheric parameters was made using a Davis Wireless Vantage Pro2 Weather Station, which was installed on the ground surface under study. The study utilized data measurement for six (6) months (from January 2025 to June 2025). The variable was computed using the Recommendation of the International Telecommunication Union (ITU-R Model). Also, regression analysis was carried out to ascertain the degree of influence of surface refractivity and field strength variability. The result shows that the average value of radio refractivity showed seasonal variations with high values during the early rainy season and with an increase in the value of radio refractivity from 295N to a maximum value of 356N units. Therefore, the researcher recommended that the study serve as an important parameter in determining the coverage and quality of tropospheric refractivity and field strength variability in Gusau Town of Zamfara State, Nigeria.

ARTICLE INFO
Article History
Received: April, 2025
Received in revised form: May, 2025
Accepted: August, 2025
Published online: September, 2025

KEYWORDS
Refractivity, Temperature, Atmospheric Pressure, Relative Humidity.

INTRODUCTION

The performance of radio communication systems is fundamentally determined by the characteristics of the propagation medium linking the transmitter and the receiver. Unlike wired channels, which are relatively stationary and predictable, wireless communication systems rely on the atmosphere, which is inherently dynamic and highly variable. Atmospheric conditions—such as temperature, pressure, humidity, hydrometeors, suspended particles, and gaseous constituents—play a critical role in determining electromagnetic wave propagation and add to the complexity of predicting signal behavior (Margarita, 2005). Radio wave propagation is typically influenced by two broad categories of losses: free-space loss, which arises from the geometric spreading of electromagnetic waves, and medium loss, which results from interactions between the wave and the propagation environment (Adediji et al., 2014; Oyedum, 2009). In particular, the troposphere exhibits spatial and temporal variations in its refractive index due to the non-homogeneous distribution of its molecular constituents, leading to fluctuations in signal strength and coverage (Tanko et al., 2018). As a result, understanding the variability of tropospheric refractivity is essential for the design, deployment, and optimization of reliable wireless communication systems.

The objective of this study is to investigate the variability of tropospheric radio refractivity and field strength over Gusau Town, Zamfara State, Nigeria. Field strength, defined as the magnitude of the received electromagnetic field at an antenna, determines receiver performance and the reliability of communication links. This research utilizes meteorological parameters—atmospheric pressure, temperature, and relative humidity—computed according to the International Telecommunication Union's Recommendation ITU-R P.453 (ITU, 2013) to derive refractivity values and corresponding field

Corresponding author: Ibrahim Lugga Abubakar
iblugga9@gmail.com
Department of Physics, School of Science (Education) College of Education Maru, Zamfara State Nigeria.

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strength levels. By examining seasonal and diurnal variations, the study provides a quantitative framework for assessing the influence of atmospheric conditions on radio signal behavior within the study area.

Despite the importance of atmospheric parameters, knowledge of radio propagation in tropical regions remains limited. Historically, the lack of region-specific measurements led to reliance on propagation curves and models developed predominantly from studies in temperate climates, such as Europe, North America, and Japan (ITU-R, 1994–2012). For instance, ITU-R P.370-7, which provides propagation curves for frequencies between 30 MHz and 1000 MHz, has been widely used in sub-Saharan Africa despite climatic and geographical differences that reduce its accuracy in predicting signal behavior under tropical conditions (Ayatunji et al., 2011). Recognizing this limitation, the ITU initiated a radio propagation measurement campaign in Africa in 1984 (ITU, 2004). However, the availability of long-term, location-specific propagation data remains inadequate, particularly in Nigeria, underscoring the need for targeted studies on radio refractivity and field strength in diverse climatic settings.

To address this gap, the present study employs a computational approach based on ITU recommendations to analyze the impact of meteorological variables on tropospheric refractivity and corresponding field strength. Meteorological observations for Gusau are systematically processed to derive refractivity profiles, which are then examined on daily and seasonal scales. This approach not only enhances the understanding of propagation conditions in the study area but also provides empirical evidence that can inform the adaptation of existing propagation models to local tropical climates.

The outcomes of this research are expected to provide valuable inputs for frequency planning, system design, and performance optimization in both terrestrial and satellite communication systems across Nigeria and the broader sub-Saharan African region. By generating reliable, location-specific data on tropospheric radio refractivity and field strength, the study addresses a critical knowledge gap and contributes to improving the robustness of communication infrastructure. In doing so, it supports the broader aim of enhancing wireless communication reliability in environments where climatic variability presents significant challenges (Bean & Dutton, 1966).

METHODOLOGY

This study employed field-based measurements of meteorological parameters in Gusau, Zamfara State, using the Davis Vantage Pro2 automatic weather station. The instrument consists of two main components: the Integrated Sensor Suite (ISS) and the console receiver. The ISS was installed in an open area free from obstructions to ensure accurate atmospheric measurements. It was mounted at a standard height above ground level in order to minimize interference from surface heating and surrounding structures.

The ISS was equipped with a set of calibrated sensors for measuring temperature, atmospheric pressure, relative humidity, rainfall, wind speed, solar radiation, and ultraviolet radiation. The temperature, pressure, and humidity sensors were housed in a passive radiation shield to reduce errors caused by direct solar heating. Weather data captured by the ISS were transmitted wirelessly via radio signals to the Vantage Pro2 console. The console was connected to a personal computer fitted with a data logger, where all observations were automatically stored at regular intervals.

Field data collection was carried out continuously over a six-month period, covering both the dry harmattan season and the onset of the rainy season. The system was routinely inspected to ensure that the sensors remained functional and unobstructed throughout the study period. In addition, periodic calibration checks were performed to maintain data accuracy. Collected data included temperature (°C), relative humidity (%), and atmospheric pressure (hPa), which were subsequently used to compute surface radio refractivity values based on the

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iblugga9@gmail.com
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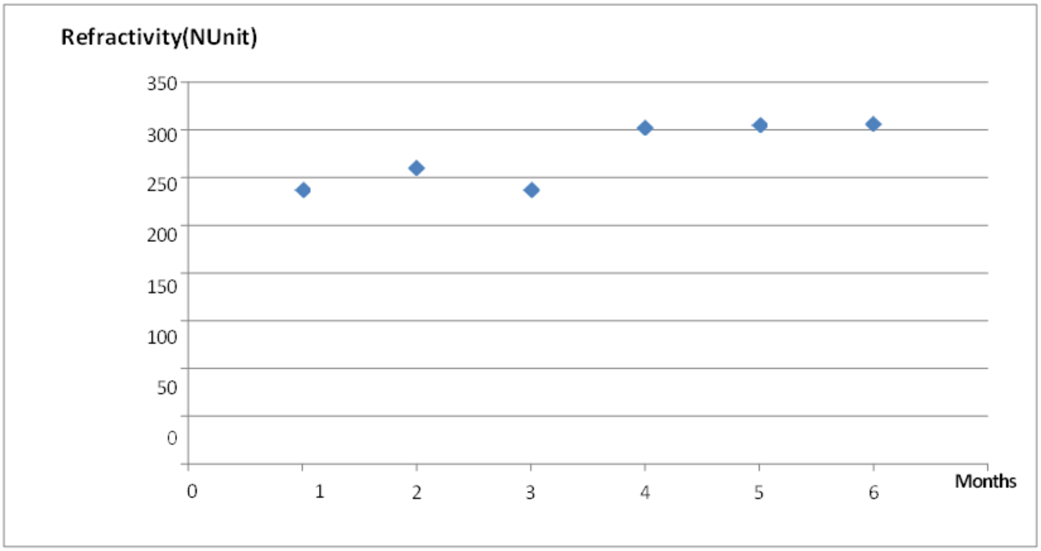
International Telecommunication Union's Recommendation ITU-R P.453 (ITU, 2013).

The refractivity values derived from the field data were analyzed to determine seasonal and diurnal variability. Specifically, monthly averages were computed and compared to identify trends across harmattan and rainy seasons. Field strength was then estimated from the refractivity data to evaluate the implications for radio wave propagation and communication reliability in Gusau.

In summary, the methodology combined systematic field observations using a high-precision weather station with standardized computational procedures. This ensured that the data collected were both reliable and representative of the prevailing atmospheric conditions in the study area.

Results and Discussions



The seasonal variation of surface radio refractivity over Gusau provides valuable insight into the atmospheric conditions that directly influence radio wave propagation and the reliability of communication systems in the region. The results demonstrate a clear distinction between the dry harmattan season and the humid rainy season, each presenting unique challenges and opportunities for wireless communication and broadcasting services.

During the harmattan period, refractivity values were at their lowest, with a minimum of 287 N-units recorded in January. This low refractivity is linked to the dominance of dry northeasterly winds, which travel across the Sahara Desert and strip the air of much of its moisture. For the people of Gusau, this season is well known not only for its dusty air and reduced visibility but also for its impact on communication systems. Low refractivity implies weaker bending of radio signals back toward the earth's surface, leading to reduced coverage areas for broadcasting stations and possible signal fading. In practical terms, residents may experience poor radio and television reception, interrupted mobile phone connectivity, and reduced reliability of microwave or satellite links. These disruptions are particularly concerning during harmattan when critical information, such as weather alerts or security broadcasts, needs to reach communities across rural and urban areas.

By contrast, the rainy season brings about a dramatic increase in refractivity, with values peaking at 352 N-units in May, 355 N-units

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iblugga9@gmail.com
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in April, and 356 N-units in June. The higher values are driven largely by the sharp rise in relative humidity as rainfall saturates the atmosphere with water vapor. From a communication standpoint, high refractivity enhances the bending of radio waves, sometimes extending signal coverage beyond the normal line-of-sight. For instance, rural communities on the outskirts of Gusau may receive stronger FM radio or mobile signals during the wet season than in harmattan. However, this benefit comes with a trade-off: high atmospheric moisture also increases the risk of signal attenuation and scattering, especially at higher frequencies used by satellite television, 4G/5G mobile networks, and internet services. Residents may thus notice intermittent signal losses during heavy downpours—a familiar experience in Gusau households during the rainy months.

The human dimension of these variations cannot be overstated. Reliable communication systems are the backbone of modern life in Gusau, supporting education, business, health services, security operations, and social interactions. Farmers rely on weather forecasts transmitted over radio to plan planting and harvesting schedules, students and teachers depend on mobile data for online learning, and traders in the Gusau central market use mobile phones to negotiate prices with partners in distant towns. Interruptions to these services—whether due to low refractivity in harmattan or high attenuation in the rainy season—directly affect livelihoods and development.

From a technical perspective, the findings underscore the importance of climate-aware communication planning. Service providers in Gusau need to design and optimize their infrastructure with seasonal refractivity variations in mind. For example, during the harmattan, signal boosters and repeaters may be required to maintain coverage in areas affected by weak propagation, while in the rainy season, network designs should account for moisture-induced losses by employing adaptive technologies such as error correction codes, frequency diversity, and smart antennas.

In summary, the seasonal pattern of refractivity in Gusau highlights the deep interconnection between atmospheric conditions and communication systems. Low refractivity during the harmattan season and high refractivity during the rainy season both present distinct challenges to signal strength and reliability. By understanding these dynamics, policymakers, engineers, and service providers can develop strategies to ensure more resilient communication systems that support not just technology, but also the daily needs and aspirations of the people of Gusau.

CONCLUSION

This study examined how variations in tropospheric radio refractivity influence radio field strength in Gusau, Zamfara State, using six months of meteorological data. Results show that refractivity decreases during the harmattan season, reaching 287 N-units, which weakens radio signals and reduces coverage, while during the rainy season it rises to 356 N-units, enhancing wave bending but also causing attenuation and scattering from heavy rainfall. These seasonal fluctuations demonstrate that the atmosphere is a critical factor in communication reliability, and recognizing such patterns is essential for engineers, policymakers, and service providers to design climate-aware networks that ensure consistent and resilient communication services in the region.

RECOMMENDATIONS

Based on the findings, telecommunication systems in Gusau should be planned with seasonal climate variations in mind, accounting for low refractivity during harmattan and high attenuation during the rainy season. Service providers can enhance reliability by adopting adaptive technologies such as smart antennas, frequency diversity, and error correction codes, while also deploying repeaters and signal boosters to maintain coverage during harmattan. Continuous monitoring across longer periods and wider locations is necessary to generate more robust data for network optimization. Furthermore, collaboration between meteorological agencies,

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iblugga9@gmail.com
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service providers, and regulators is essential for integrating climate-sensitive knowledge into system design. Finally, public awareness campaigns should be encouraged to help users understand weather-related impacts on communication and prepare accordingly.

REFERENCES

Adediji, A. T., Ajewole, M. O., & Falodun, S. E. (2014). Distribution of radio refractivity gradient and effective earth radius factor (k-factor) over Akure, South Western Nigeria. *International Journal of Atmospheric Sciences*, 2014, 1–7. https://doi.org/10.1155/2014/938487

Ayatunji, B. G., Mandeep, J. S., Abdullah, M., & Adekola, A. S. (2011). Seasonal variation of radio refractivity gradients in Nigeria. *International Journal of Physical Sciences*, 6(23), 5435–5441. https://doi.org/10.5897/IJPS11.1180

Bean, B. R., & Dutton, E. J. (1966). *Radio meteorology*. U.S. Department of Commerce, National Bureau of Standards.

International Telecommunication Union. (2004). *Handbook on radio wave propagation information for designing terrestrial point-to-point links*. ITU Radiocommunication Bureau.

International Telecommunication Union. (2013). *Recommendation ITU-R P.453-12: The radio refractive index: Its formula and refractivity data*. ITU Radiocommunication Bureau.

International Telecommunication Union Radiocommunication Sector. (1994–2012). *Recommendation ITU-R P.370-7: VHF and UHF propagation curves for the frequency range from 30 MHz to 1000 MHz broadcasting services*. ITU.

Margarita, A. (2005). *Radio wave propagation: Principles and techniques*. McGraw-Hill.

Oyedum, O. D. (2009). Variation of surface radio refractivity and radio field strength over Minna, Nigeria. *Nigerian Journal of Physics*, 21(1), 45–51.

Tanko, D., Emmanuel, I., & Adamu, M. (2018). Diurnal and seasonal variations of surface radio refractivity over Sokoto, Northwestern Nigeria. *Journal of Atmospheric and Solar-Terrestrial Physics*, 179, 310–317. https://doi.org/10.1016/j.jastp.2018.08.002.

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iblugga9@gmail.com
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