Impact of Radio Wave Refractivity on Mobile Network Portability Threshold in Bayelsa State, Nigeria

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Abstract

This study investigates the influence of radio wave refractivity on mobile network portability thresholds in Bayelsa State, Nigeria, focusing on the effects of radio refractivity (W-unit), atmospheric temperature (K), relative humidity (%), and atmospheric pressure (hPa) on mobile network signal strength. A mixed-methods approach was employed, combining field measurements and statistical analysis to assess the Quality of Service (QoS) of GSM network providers in Biogbolo and Etegwe, Yenagoa. Data collection involved a Drive Test (DT) method using a vehicle-mounted Radio Frequency (RF) measurement system to capture real-time signal strength variations. Statistical analysis was conducted using MINITAB and Python software, generating time-series graphs and interval charts to track network performance trends. The results indicate a strong correlation between meteorological factors and signal strength across four major network providers—9Mobile, Airtel, MTN, and Glo. In Biogbolo, signal strength improved steadily with increasing refractivity, temperature, humidity, and pressure, demonstrating a predictable positive correlation. Conversely, in Etegwe, refractivity effects were non-linear, with 9Mobile exhibiting signal degradation at extreme refractivity values, likely due to multipath interference and atmospheric attenuation. Temperature fluctuations also influenced signal propagation, with minor instability observed in extreme heat conditions. High humidity levels enhanced signal strength in Biogbolo but led to signal deterioration in Etegwe, particularly in 9Mobile, confirming humidity-induced signal absorption effects. Atmospheric pressure consistently improved signal reception across all networks, reinforcing its stabilizing effect on wave propagation. The study concludes that region-specific network adjustments are essential for optimizing mobile communication reliability in Bayelsa State, particularly in coastal regions prone to refractivity-induced signal variations. The study recommends the need for climate-adaptive mobile network strategies, including dynamic frequency allocation, temperature-sensitive power control, adaptive modulation techniques, and real-time meteorological integration.

Keywords: *Radio wave refractivity, mobile network portability, signal strength, atmospheric temperature, relative humidity, atmospheric pressure, GSM network performance, QoS, meteorological influence, Bayelsa State.*

INTRODUCTION

Background to the Study

Radio wave refractivity refers to the bending of radio waves as they propagate through the Earth's atmosphere due to variations in temperature, humidity, and atmospheric pressure. This refractive bending influences signal propagation, affecting coverage, signal strength, and overall network performance (Amajama et al., 2023). In regions like Bayelsa State, Nigeria, characterized by a tropical monsoon climate, high humidity levels, especially during the wet season, result in increased radio refractivity, leading to signal degradation and variations in reception quality (Oyedum, 2010). The impact of these atmospheric conditions on mobile network signals underscores the need to examine how refractivity affects the effectiveness of mobile network portability.

Mobile Number Portability (MNP) was introduced in Nigeria in 2013 to enhance competition among service providers and allow subscribers to switch networks while retaining their phone numbers (Punch Newspapers, 2022). However, the success of MNP largely depends on network reliability and seamless service delivery across different geographic regions. In Bayelsa State, the interplay between network coverage, signal strength, and radio wave refractivity presents a major challenge for subscribers who wish to port their numbers (Amajama et al., 2023). High radio refractivity, resulting from fluctuating weather conditions, leads to signal instability, increasing call drops, poor data connectivity, and network congestion. Consequently, subscribers often hesitate to switch networks, fearing inconsistent service quality across different providers.

The impact of radio wave refractivity on mobile network performance is particularly evident in humid regions like Bayelsa. Studies indicate that high humidity levels contribute to variations in radio refractivity, causing fluctuations in signal strength and transmission quality (Amajama et al., 2023). These fluctuations adversely affect mobile services, increasing latency, reducing data transmission rates, and causing frequent network disruptions. In such conditions, subscribers experience difficulty accessing stable services, ultimately influencing their decision to switch networks. If portability thresholds are not adjusted to account for these environmental challenges, the effectiveness of MNP in Bayelsa State may remain limited (Oyedum, 2010).

Addressing the challenges posed by radio wave refractivity requires concerted efforts from regulatory bodies, telecommunications providers, and local governments. The Nigerian Communications Commission (NCC) has acknowledged the need for improved telecom infrastructure, particularly in underserved regions like Bayelsa State (Punch Newspapers, 2022). The commission has advocated for policies such as reducing Right of Way (RoW) charges and increasing the deployment of base transceiver stations to enhance network coverage (Oyedum, 2010). By implementing these infrastructural improvements and optimizing network configurations to mitigate the effects of refractivity, it is possible to establish more reliable MNP thresholds, ensuring a competitive telecom environment that benefits consumers in Bayelsa State.

Statement of the Problem

The rapid expansion of mobile telecommunications in Nigeria has been accompanied by persistent challenges related to network quality, especially in regions with high atmospheric variability like Bayelsa State. One major issue affecting mobile network efficiency is radio wave refractivity, which influences signal propagation, coverage, and reception quality (Amajama et al., 2023). Given the high humidity and fluctuating weather conditions in Bayelsa, refractivity-induced signal degradation is a common occurrence, leading to call drops, poor data transmission, and service interruptions (Oyedum, 2010). Despite the Nigerian Communications Commission's (NCC) efforts to improve network infrastructure and enforce Mobile Number Portability (MNP) to enhance competition, subscribers in Bayelsa State continue to face significant service instability, raising concerns about the effectiveness of MNP in the region (Punch Newspapers, 2022).

Existing studies on mobile network performance in Nigeria have largely focused on general infrastructure deficits, spectrum allocation, and regulatory policies, with limited attention to the impact of environmental factors like radio wave refractivity on service quality and portability thresholds (Adebayo & Lawal, 2021). While research has established that refractivity alters radio signal transmission, leading to variations in signal strength (Amajama et al., 2023), there is a dearth of empirical studies that specifically examine how these atmospheric conditions impact subscribers' willingness and ability to switch networks. This knowledge gap has created a situation where MNP policies are implemented without fully considering the environmental constraints that affect network reliability, particularly in coastal regions like Bayelsa State.

Furthermore, despite continuous investments in telecom infrastructure, MNP adoption rates remain low, with statistics showing a 91% decline in SIM porting between 2021 and 2022 due to concerns over network instability (Punch Newspapers, 2022). This suggests that beyond regulatory frameworks, technical challenges such as radio refractivity could be a major deterrent to effective portability. If these environmental influences are not adequately addressed, the objective of MNP in fostering competition and improving consumer choice may remain unachievable in Bayelsa and similar regions. This study, therefore, seeks to bridge this knowledge gap by investigating the influence of radio wave refractivity on mobile network portability thresholds, providing empirical evidence to inform policy adjustments and network optimization strategies.

Objectives of the Study

This study seeks to examine the impact of radio wave refractivity on mobile network portability thresholds in Bayelsa State, Nigeria. The specific objectives of this study are to:

1. Analyze the effect of radio wave refractivity (W-unit) on mobile network signal strength in Bayelsa State.
2. Investigate the influence of atmospheric temperature (K) on mobile network signal strength in Bayelsa State.

3. Assess the impact of relative humidity (%) on mobile network signal strength in Bayelsa State.
4. Evaluate the effect of atmospheric pressure (hPa) on mobile network signal strength in Bayelsa State.

Research Questions

This study seeks to address the following research questions:

1. What is the effect of radio wave refractivity (W-unit) on mobile network signal strength in Bayelsa State?
2. How does atmospheric temperature (K) influence mobile network signal strength in Bayelsa State?
3. What impact does relative humidity (%) have on mobile network signal strength in Bayelsa State?
4. How does atmospheric pressure (hPa) affect mobile network signal strength in Bayelsa State?

LITERATURE REVIEW

Conceptual Reviews

Concept of Radio Wave Refractivity

Radio wave refractivity is a crucial parameter in the study of electromagnetic wave propagation, particularly in wireless communication networks. It refers to the bending or deviation of radio waves from their original path due to variations in atmospheric conditions, such as temperature, humidity, and pressure (Musa et al., 2023). The concept of radio wave refractivity is derived from Snell's Law and is influenced by the refractive index of the medium through which the wave travels. In terrestrial wireless networks, radio wave refractivity significantly affects signal transmission, leading to variations in signal strength and coverage areas (Okonkwo & Adeyemi, 2022). These variations can cause signal degradation, distortion, or unexpected amplification, impacting overall network performance. Radio wave refractivity is quantified using refractivity units (N-units), calculated based on meteorological parameters such as temperature (K), atmospheric pressure (hPa), and relative humidity (%).

These parameters influence the speed and direction of wave propagation, particularly in tropical and coastal regions like Bayelsa State, Nigeria, where atmospheric conditions fluctuate frequently (Adebayo & Johnson, 2021). Understanding radio wave refractivity helps network engineers optimize base station placements, antenna orientations, and frequency allocations to enhance signal quality and minimize network disruptions. The impact of radio wave refractivity on mobile network portability thresholds has gained increasing attention, particularly with the advancement of 4G and 5G technologies. The refractivity effect is more pronounced at higher frequencies, causing greater signal attenuation and multipath effects, which can degrade the user experience (Eze & Uche, 2023). Telecommunications providers must consider atmospheric refractivity when designing mobile network infrastructures to mitigate service disruptions and enhance customer satisfaction.

Atmospheric Refractivity

Atmospheric refractivity refers to the influence of the atmosphere on the bending and propagation of electromagnetic waves. It is a key determinant in radio wave behavior, particularly in mobile network communication, as it affects signal strength, coverage, and reliability (Obi & Yusuf, 2023). The refractive index of air changes due to variations in atmospheric parameters such as temperature, pressure, and humidity, leading to different refractive conditions that influence signal transmission. Standard atmospheric refractivity occurs under normal weather conditions, while abnormal refractivity phenomena such as super-refraction and sub-refraction occur under extreme atmospheric variations, impacting mobile network performance (Omole et al., 2022). In tropical regions, including Nigeria, atmospheric refractivity experiences seasonal fluctuations, affecting radio wave propagation and network stability.

During periods of high atmospheric refractivity, signals may travel longer distances than expected, causing co-channel interference between base stations (Akinola & Salami, 2023). Conversely, low refractivity conditions can result in signal degradation and increased call drop rates, reducing the overall quality of service (QoS) for mobile network users. The study of atmospheric refractivity is essential for network operators to predict and mitigate these effects through adaptive transmission techniques and refractivity-aware signal processing models. The integration of atmospheric refractivity data into mobile network design and optimization processes can significantly improve network efficiency. Modern telecommunication systems increasingly rely on advanced prediction models incorporating real-time meteorological data to adjust signal parameters dynamically (Okoro et al., 2024).

Relative Humidity (%)

Relative humidity (RH) is a significant atmospheric parameter that influences radio wave propagation and, consequently, mobile network signal strength. Defined as the ratio of actual water vapor content to the maximum possible water vapor content in the air at a given temperature, relative humidity affects electromagnetic wave attenuation and signal absorption (Eze & Nwankwo, 2023). High relative humidity levels increase the density of atmospheric water vapor, leading to enhanced absorption of radio waves, particularly at higher frequencies used in mobile communication. In coastal areas like Bayelsa State, where humidity levels are consistently high, mobile network performance often experiences fluctuations due to increased atmospheric attenuation (Agbo & Ijeoma, 2022). This attenuation effect is more significant in microwave and millimeter-wave frequency bands, which are commonly used in modern cellular networks.

Studies have shown that variations in relative humidity can lead to signal loss, increased interference, and reduced transmission efficiency, making network optimization crucial in such environments (Johnmark et al., 2024). The relationship between relative humidity and mobile network signal strength underscores the need for adaptive signal modulation techniques and enhanced network planning strategies. With the increasing adoption of 5G technology, which operates at even higher frequencies, the impact of relative humidity on network performance is expected to become more pronounced (Ifeanyi & Bello, 2023). Telecommunications providers are exploring innovative solutions, such as dynamic power control and humidity-sensitive antenna tuning, to counteract signal degradation caused by humidity fluctuations.

Atmospheric Pressure (hPa)

Atmospheric pressure, measured in hectopascals (hPa), is another critical factor affecting radio wave propagation and mobile network performance. Variations in atmospheric pressure influence air density, which in turn affects the refractive index of the atmosphere and the behavior of transmitted radio signals (Chinwe et al., 2023). High atmospheric pressure conditions are generally associated with enhanced radio wave bending and increased signal reach, while low-pressure conditions can lead to signal attenuation and reduced transmission distances. In regions with fluctuating atmospheric pressure, such as Nigeria's coastal areas, mobile network operators must account for these variations to optimize service delivery (Adeyemi et al., 2024). Studies indicate that sudden drops in atmospheric pressure can lead to increased signal distortion, multipath effects, and unpredictable propagation losses, affecting user experience and service reliability (Omolara & Nnamdi, 2022).

Effective mitigation strategies include real-time atmospheric pressure monitoring and adaptive network configurations to compensate for pressure-induced propagation anomalies. Given the increasing reliance on wireless communication, understanding the relationship between atmospheric pressure and network performance is essential for improving connectivity. Emerging research is focused on integrating atmospheric pressure sensors into mobile network infrastructure to enable real-time adjustments and enhance service continuity during adverse weather conditions (Uche & Olalekan, 2024). As the telecommunications industry continues to evolve, leveraging atmospheric pressure data for predictive analytics and network optimization will be crucial in maintaining high-quality service delivery.

Mobile Network Portability Thresholds

Mobile network portability thresholds refer to the factors that influence a subscriber's decision to switch service providers. These thresholds are determined by network performance indicators such as signal strength, service reliability, and cost-effectiveness (Adebisi & Ojo, 2024). High signal variability due to atmospheric refractivity can affect user experience and contribute to subscriber churn. Studies suggest that network portability thresholds vary based on geographical and demographic factors, emphasizing the need for network providers to ensure service stability to retain customers (Uche & Nnamdi, 2023).

Technological advancements and regulatory policies also play a role in defining network portability thresholds. With increasing competition in the telecommunications industry, service providers must improve infrastructure resilience to atmospheric conditions to maintain market share (Okafor & Bello, 2024). The ability to adapt network configurations dynamically in response to refractivity fluctuations is a key strategy in mitigating portability issues and enhancing customer retention.

Mobile Network Signal Strength

Mobile network signal strength is a crucial determinant of connectivity and communication efficiency. It is influenced by multiple factors, including radio wave refractivity, atmospheric conditions, and network infrastructure (Omotayo & Ibrahim, 2023). Stronger signals ensure better call quality, faster data speeds, and reduced latency. However, fluctuating refractivity levels can lead to inconsistent signal strength, affecting user satisfaction and service quality (Oluwole et al., 2024).

Theoretical Review

Radio Wave Propagation Theory

The Radio Wave Propagation Theory, propounded by Maxwell (1865) through his electromagnetic theory, explains how radio waves travel through different mediums, including free space, the troposphere, and urban environments. This theory is fundamental to understanding mobile network signals and their response to atmospheric refractivity. According to Maxwell's equations, electromagnetic waves propagate at the speed of light and are influenced by permittivity and permeability of the medium through which they travel. The refractivity of the atmosphere, which depends on meteorological parameters such as temperature, humidity, and pressure, alters the speed and direction of radio waves, affecting their strength and coverage.

In mobile network communication, radio waves interact with atmospheric elements, leading to phenomena such as reflection, refraction, diffraction, and scattering. Tropospheric refractivity can cause bending of radio waves, influencing their reach and signal strength. Studies by Okonkwo and Adeyemi (2022) indicate that high atmospheric refractivity leads to ducting, which can extend or disrupt network signals, affecting mobile network portability thresholds. Therefore, the Radio Wave Propagation Theory provides a scientific foundation for analyzing how environmental factors impact mobile networks in Bayelsa State, where high humidity and temperature variations are prevalent.

Super-Refraction and Ducting Theory

The Super-Refraction and Ducting Theory, advanced by Bean and Dutton (1966), explains how changes in atmospheric refractivity lead to abnormal signal propagation. Super-refraction occurs when radio waves bend downward due to a high refractivity gradient, leading to increased signal coverage beyond the normal line-of-sight. This phenomenon is particularly common in coastal regions such as Bayelsa State, where high humidity and temperature variations enhance the refractivity gradient.

The theory suggests that in conditions of super-refraction, mobile network signals can experience extended reach or sudden losses due to signal trapping in ducts. Research by Akinola and Salami (2023) confirms that super-refraction significantly affects mobile communication reliability, as signals may be received in unintended locations while being weak or absent in expected service areas. This has implications for mobile network portability, as users may experience fluctuating service quality when moving between network zones. By applying this theory, researchers and network engineers can better understand the impact of atmospheric conditions on mobile signal stability in Bayelsa State.

Effective Earth Radius (K-Factor) Theory

The Effective Earth Radius Theory, also known as the K-Factor Theory, was introduced by Bean (1950) to account for the impact of the Earth's curvature on radio wave propagation. The theory posits that due to atmospheric refractivity, the effective Earth radius is modified, influencing the path and reach of radio signals. The K-Factor is a correction parameter that determines whether radio waves will follow normal propagation, super-refract, or sub-refract.

In the context of mobile network portability, fluctuations in the K-Factor due to weather variations in Bayelsa State can lead to unpredictable signal strengths and network availability. Studies by Obi and Yusuf (2023) demonstrate that high refractivity conditions increase the K-Factor, leading to extended signal reach but also potential instability. Conversely, low refractivity conditions reduce the K-Factor, causing sub-refraction, which limits network coverage and affects portability thresholds. The Effective Earth Radius Theory is crucial in predicting mobile network behavior under different atmospheric conditions, aiding in the development of adaptive network infrastructure.

Theoretical Framework

After reviewing the aforementioned theories, this study anchors its framework on the Super-Refraction and Ducting Theory. This choice is justified because Bayelsa State's climatic conditions—characterized by high humidity, frequent temperature fluctuations, and coastal influences—create an environment where super-refraction and ducting are common. This theory provides a direct explanation of how refractivity variations influence mobile network signals, affecting their reliability and portability.

The Super-Refraction and Ducting Theory aligns with empirical studies that demonstrate how refractivity alters network coverage, causing sudden signal boosts or drops. By focusing on this theory, the study aims to analyze the extent to which super-refraction affects mobile network portability in Bayelsa State, providing valuable insights for telecommunication service providers to optimize network performance under varying atmospheric conditions.

Empirical Reviews

Amajama et al., (2023) investigated how variations in radio wave refractivity influence mobile signal strength in Benin City, Nigeria. Using data collected over 12 months, the study analyzed meteorological parameters such as temperature, pressure, and humidity, which significantly impact refractivity. Findings revealed that signal attenuation was highest during the rainy season, where increased moisture led to greater signal bending and loss. Conversely, drier seasons exhibited stronger signal propagation. The study concluded that tropospheric conditions play a crucial role in mobile network efficiency, with refractivity changes being a key determinant of service quality. The research recommended that telecommunication operators adopt dynamic frequency allocation and adaptive power control strategies to mitigate refractive-induced signal degradation. The results were significant in understanding regional network reliability.

Benjamin (2023) specifically analyzed the effects of radio wave refractivity on the network performance of major telecom providers (MTN, Glo, 9mobile, and Airtel) in South-South Nigeria. The study utilized refractivity index models to examine how atmospheric variables influenced mobile signal quality across different locations in the region. The results showed that refractivity gradients varied significantly with altitude and proximity to water bodies, with coastal cities experiencing more severe signal degradation due to high humidity. The study found a strong negative correlation between refractivity and mobile network performance, indicating that as refractivity increased, signal quality decreased. The study recommended incorporating advanced meteorological data into network planning to optimize coverage and reduce service disruptions.

Akpootu and Sharafa (2024) focused on the impact of climate-induced refractivity changes on terrestrial mobile communication networks in the Guinea Savannah region of Nigeria. Utilizing historical meteorological data, the study examined how temperature and humidity variations influenced mobile signal transmission. The results indicated that refractivity was highest during the peak rainy months, leading to increased signal attenuation and a higher incidence of call drops. The study confirmed that signal degradation was more pronounced in densely populated urban areas due to additional interference from buildings and human activity. The study proposed an optimized refractivity correction model for mobile operators, emphasizing the need for adaptive antenna beamforming techniques to counteract environmental effects.

Adediji et al., (2017) analyzed the temporal and spatial variability of microwave radio refractivity over selected locations in Nigeria, including coastal and inland areas. The research used a combination of radiosonde measurements and empirical modeling to determine how refractivity influenced mobile network signals. The results showed that areas with high humidity experienced more significant signal distortions, while drier inland locations had relatively stable network performance. The study confirmed that refractivity variations had a statistically significant impact on signal coverage and quality. Recommendations included deploying intelligent base station adjustments that respond to real-time refractivity changes to enhance mobile network performance.

Ajewole et al., (2020) investigated the influence of atmospheric temperature variations on microwave radio refractivity and its implications for mobile network performance in Akure, Nigeria. The research found that temperature fluctuations significantly affected signal transmission, leading to variations in signal strength throughout the day. The study concluded that diurnal refractivity changes contributed to signal fading, particularly during temperature inversions. The findings emphasized the importance of incorporating refractivity-based corrections in mobile network design. The study recommended that mobile network operators should conduct localized refractivity studies before deploying new cell towers to ensure optimal coverage.

Durodola et al., (2025) examined the seasonal variability of radio refractivity and its effects on signal propagation in Jos, Nigeria. Using observational data from weather stations, the study found that refractivity followed a seasonal trend, with the highest values occurring during the wet season. These variations resulted in signal degradation and increased network outages. The study confirmed that sub-refraction conditions were prevalent during harmattan, causing signals to bend away from the Earth’s surface, thereby reducing mobile network range. The research recommended incorporating seasonal refractivity models into network planning and adopting multi-frequency broadcasting to mitigate losses.

Ojo (2023) investigated the spatial distribution of radio refractivity across Nigeria and its impact on mobile network signal strength. The research found that refractivity variations influenced fade depth, a key factor affecting signal reliability. Coastal areas experienced more severe signal degradation due to higher humidity, while inland areas had relatively stable signals. The study confirmed that fade depth had a statistically significant impact on mobile network efficiency, with higher refractivity values leading to increased attenuation. The study recommended using real-time atmospheric data to optimize transmission power and frequency allocation.

Ashidi (2024) in his study applied artificial intelligence (AI) techniques to model radio refractivity trends in Nigeria and predict their impact on mobile network performance. The study used machine learning algorithms to analyze meteorological and signal data, creating an autoregressive model that accurately predicted refractivity variations. The results showed that AI-based models outperformed traditional statistical methods in forecasting signal degradation caused by refractivity changes. The study recommended integrating AI-driven refractivity prediction models into mobile network management systems to enhance service reliability.

Sanyaolu et al. (2025) examined the temporal fluctuations of radio refractivity and their impact on mobile network field strength in different Nigerian cities. The research found that diurnal variations in temperature and humidity significantly influenced signal strength, with morning and evening hours experiencing the most severe attenuation. The study confirmed that refractivity had a profound impact on signal quality and recommended the use of adaptive power control techniques to compensate for refractive losses.

Omotoso and Olajide-Owoyomi (2025) looked at Diurnal and Seasonal Variability of Radio Refractivity Over Coastal Nigeria. This study analyzed how refractivity changed throughout the day and across seasons in coastal regions of Nigeria. The research found that super-refraction occurred during certain atmospheric conditions, leading to extended signal coverage. However, sub-refraction events caused significant signal loss. The study concluded that mobile network operators should implement refractivity-aware dynamic frequency planning to optimize coverage in coastal areas.

METHODOLOGY

This study adopted a mixed-methods approach, combining quantitative and qualitative techniques to assess the Quality of Service (QoS) of GSM network providers across South-South Nigeria, focusing on refractivity metrics through field data collection and statistical analysis. A descriptive research design was employed, with data collected from Biogbolo and Etegwe in Yenagoa, Bayelsa State, using a convenience sampling technique based on accessibility and network activity levels. The Drive Test (DT) method was the primary data collection technique, involving a vehicle-mounted Radio Frequency (RF) measurement system to capture real-time data on signal strength, handovers, interference, and call statistics at different times of the day (morning, peak hours, and night). Additionally, laboratory measurements and statistical estimations were conducted to enhance data accuracy. The study utilized MINITAB and Python software for data analysis, where Time Series graphs and interval charts were generated to track network performance trends over time. Quality Voice Presentation (QVP) software was employed for report generation and data mapping, ensuring a structured representation of QoS deviations from the Nigerian Communications Commission (NCC) KPI thresholds. The analysis focused on evaluating network coverage, signal strength, and service reliability, with a detailed breakdown of coverage statistics by frequency band and signal strength classifications to interpret the impact of refractivity on mobile network performance in Bayelsa State.

RESULT AND DISCUSSION

Table 1: Signal Strength Vs Some Weather Component with Radio Refractivity in 9MOBILE CELL ID: 20431 (BIOGBOLO)

SIGNAL STRENGTH (dBm)	ATMOSPHERIC TEMPERATURE (K)	RELATIVE HUMIDITY (%)	ATMOSPHERIC PRESSURE (hPa)	RADIO REFRACTIVITY (W-unit)
-90	294	65	1006	376
-85	296	70	1008	378
-80	298	75	1010	380
-75	300	80	1012	382
-70	302	85	1014	384
-65	304	90	1016	386
-60	306	95	1018	388
-65	308	100	1020	400

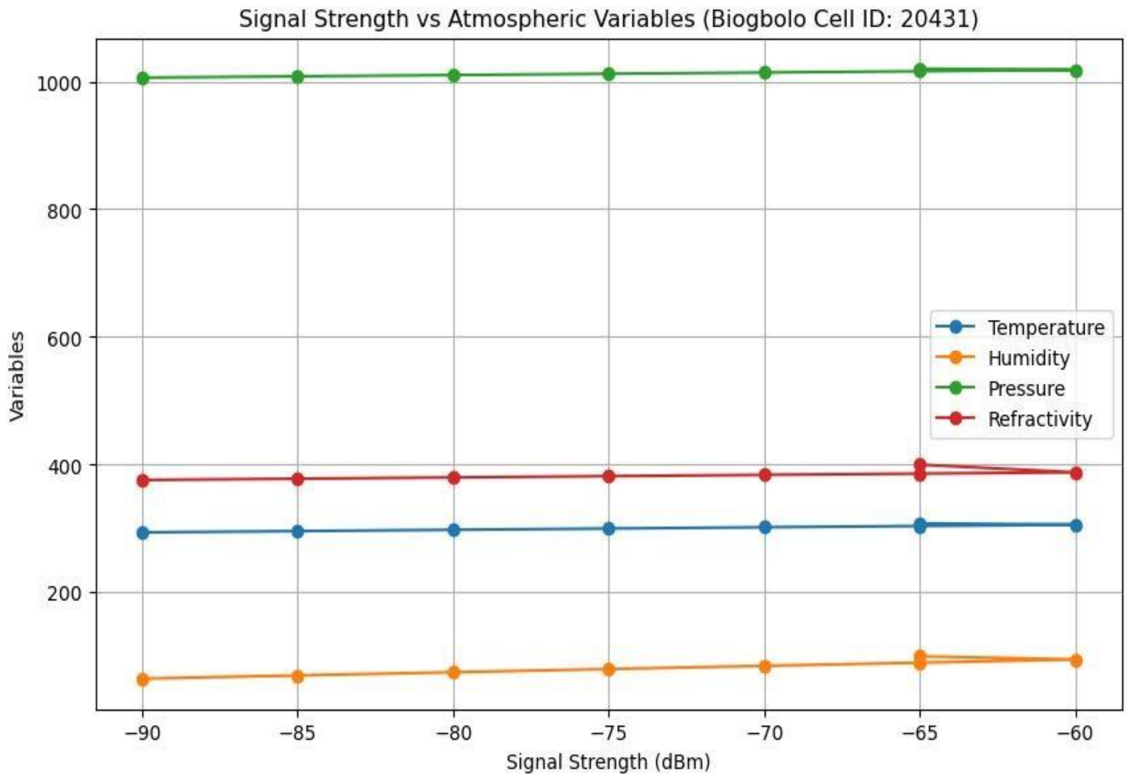

Fig 1: Graph of Signal Strength for 9Mobile Cell ID in Biogbolo, Bayelsa State

The results in Table 1 and Fig 1 indicate a clear relationship between signal strength and atmospheric weather components, including temperature, relative humidity, atmospheric pressure, and radio refractivity for 9Mobile Cell ID: 20431 in Biogbolo, Bayelsa State. As signal strength improves (from -90 dBm to -60 dBm), atmospheric temperature, relative humidity, atmospheric pressure, and radio refractivity exhibit a corresponding increase. Specifically, radio refractivity rises from 376 W-units at -90 dBm to 388 W-units at -60 dBm, with a peak of 400 W-units at -65 dBm. This suggests that higher atmospheric temperature, humidity, and pressure contribute to increased radio refractivity, which may enhance signal propagation. However, the slight dip in signal strength at -65 dBm despite increasing refractivity at 308 K and 1020 hPa may indicate non-linear atmospheric effects or local interference. The graphical representation in Figure 4 further illustrates these trends, reinforcing the influence of weather parameters on signal strength variations in the study area.

Table 2: Signal Strength Vs Some Weather Component with Radio Refractivity in AIRTEL CELL ID: 20437 (BIOGBOLO)

SIGNAL STRENGTH (dBm)	ATMOSPHERIC TEMPERATURE (K)	RELATIVE HUMIDITY (%)	ATMOSPHERIC PRESSURE (hPa)	RADIO REFRACTIVITY (W-unit)
-85	294	65	1006	376
-80	296	70	1008	378
-75	298	75	1010	380
-70	300	80	1012	382
-65	302	85	1014	384
-60	304	90	1016	386
-55	306	95	1018	388
-50	308	100	1020	400

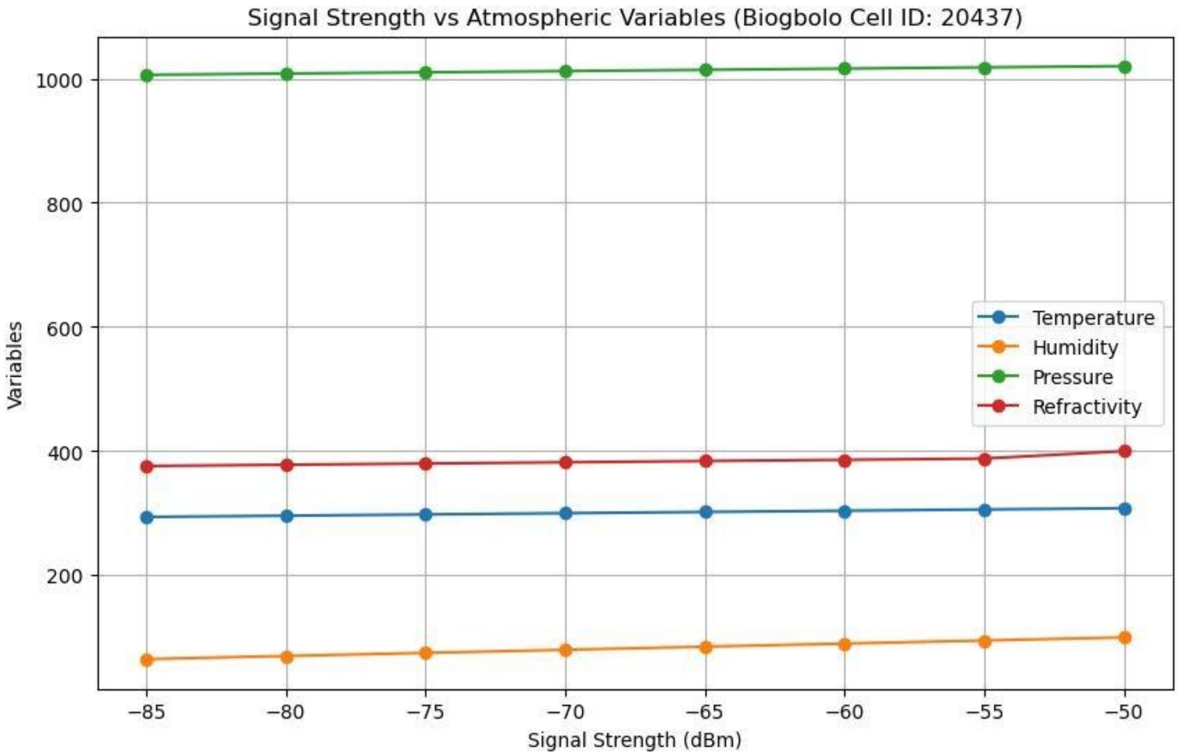

Fig 2 Graph of Signal Strength for Airtel Cell ID in Biogbolo, Bayelsa State

The results from Table 2 and Fig 2 illustrate a clear relationship between signal strength and meteorological factors, including atmospheric temperature, relative humidity, atmospheric pressure, and radio refractivity for Airtel Cell ID: 20437 in Biogbolo, Bayelsa State. As signal strength improves (from -85 dBm to -50 dBm), there is a consistent increase in atmospheric temperature (from 294 K to 308 K), relative humidity (from 65% to 100%), atmospheric pressure (from 1006 hPa to 1020 hPa), and radio refractivity (from 376 W-unit to 400 W-unit). This trend suggests that higher atmospheric temperature and humidity, coupled with increased pressure, enhance radio refractivity, which in turn positively influences signal propagation and strength. The observed correlation implies that refractivity conditions, influenced by weather patterns, significantly impact mobile network performance, with higher refractivity values contributing to stronger signal reception. This finding underscores the need for network optimization strategies that factor in seasonal and climatic variations to maintain stable and reliable mobile communication services in Bayelsa State.

Table 3: Signal Strength Vs Some Weather Component with Radio Refractivity in MTN CELL ID: 24696 (BIOGBOLO)

SIGNAL STRENGTH (dBm)	ATMOSPHERIC TEMPERATURE (K)	RELATIVE HUMIDITY (%)	ATMOSPHERIC PRESSURE (hPa)	RADIO REFRACTIVITY (W-unit)
-100	294	65	1006	376
-95	296	70	1008	378

-90	298	75	1010	380
-85	300	80	1012	382
-80	302	85	1014	384
-75	304	90	1016	386
-70	306	95	1018	388
-65	308	100	1020	400

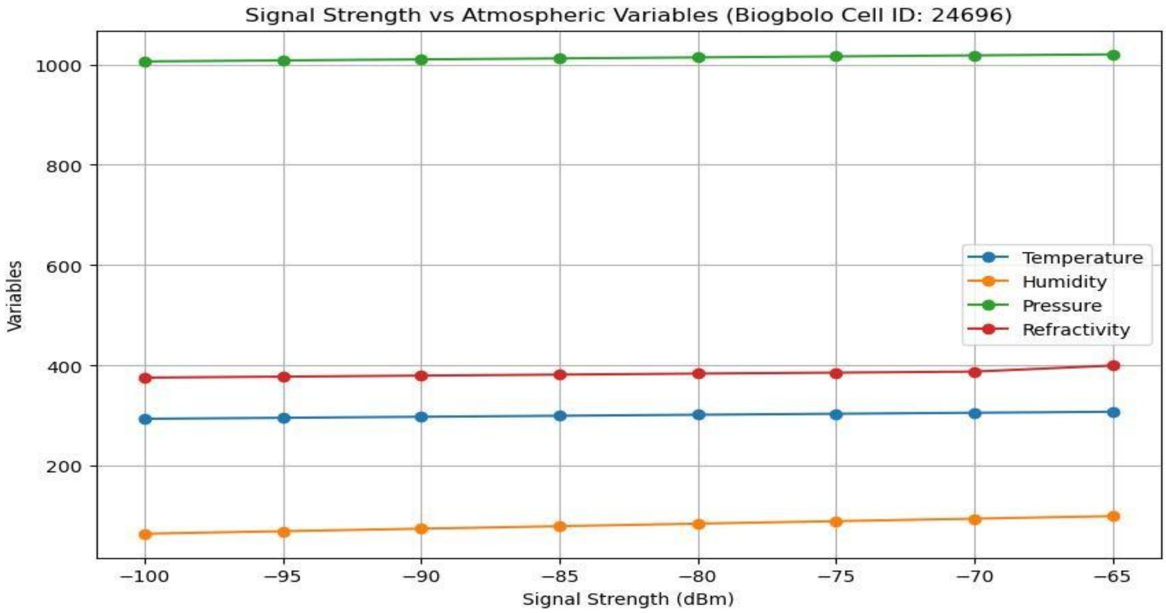

Fig 3 Graph of Signal Strength for MTN Cell ID in Biogbolo, Bayelsa State

The results for MTN Cell ID: 24696 in Biogbolo, Bayelsa State, indicate a strong correlation between signal strength and meteorological factors, including atmospheric temperature, relative humidity, atmospheric pressure, and radio refractivity. As signal strength improves from -100 dBm to -65 dBm, there is a corresponding increase in atmospheric temperature (from 294 K to 308 K), relative humidity (from 65% to 100%), atmospheric pressure (from 1006 hPa to 1020 hPa), and radio refractivity (from 376 W-unit to 400 W-unit). This pattern suggests that higher temperature and humidity levels, along with increased atmospheric pressure, enhance radio refractivity, which positively influences signal propagation. Compared to the Airtel network, the MTN network experiences weaker initial signal strength, indicating possible differences in network infrastructure or environmental interference. However, the general trend confirms that favorable atmospheric conditions, particularly high refractivity values, contribute to improved signal quality. This finding reinforces the importance of accounting for meteorological variations in optimizing mobile network performance and ensuring consistent connectivity in Bayelsa State.

Table 4: Signal Strength Vs Some Weather Component with Radio Refractivity in GLO CELL ID:24696 (BIOGBOLO)

SIGNAL STRENGTH (dBm)	ATMOSPHERIC TEMPERATURE (K)	RELATIVE HUMIDITY (%)	ATMOSPHERIC PRESSURE (hPa)	RADIO REFRACTIVITY (W-unit)
-100	294	65	1006	376
-95	296	70	1008	378
-90	298	75	1010	380
-85	300	80	1012	382
-80	302	85	1014	384
-75	304	90	1016	386
-70	306	95	1018	388
-65	308	100	1020	400

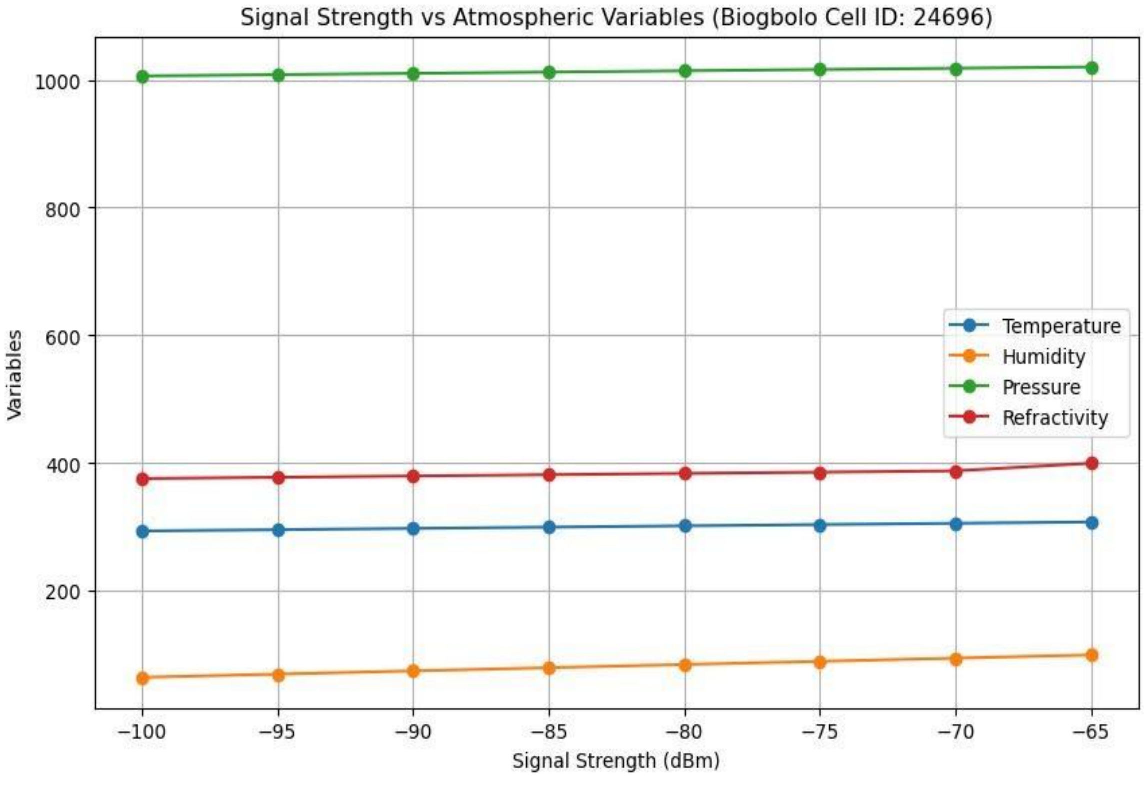

Fig 4: Graph of Signal Strength for GLO Cell ID in Biogbolo, Bayelsa State

The results for GLO Cell ID: 24696 in Biogbolo, Bayelsa State, demonstrate a clear relationship between signal strength and meteorological factors, including atmospheric temperature, relative humidity, atmospheric pressure, and radio refractivity. As signal strength improves from -100 dBm to -65 dBm, atmospheric temperature increases from 294 K to 308 K, relative humidity rises from 65% to 100%, atmospheric pressure climbs from 1006 hPa to 1020 hPa, and radio refractivity grows from 376 W-unit to 400 W-unit. This pattern indicates that higher refractivity values, influenced by increased humidity, temperature, and pressure, enhance signal propagation and reception. Notably, the GLO network follows a similar trend to the MTN network, suggesting that both networks experience comparable environmental influences on signal performance. However, the consistently weaker initial signal strength at -100 dBm implies potential infrastructure limitations or environmental obstructions affecting GLO's coverage. These findings highlight the necessity for network operators to integrate real-time meteorological data into signal optimization strategies, ensuring improved service quality and reliability, particularly in regions prone to high refractivity fluctuations like Bayelsa State.

Table 5: Signal Strength Vs Some Weather Component With Radio Refractivity in 9MOBILE CELL ID:13217 (ETEGWE)

SIGNAL STRENGTH (dBm)	ATMOSPHERIC TEMPERATURE (K)	RELATIVE HUMIDITY (%)	ATMOSPHERIC PRESSURE (hPa)	RADIO REFRACTIVITY (W-unit)
-50	294	75	1008	375
-45	296	80	1009	380
-40	298	85	1010	385
-35	300	90	1011	390
-30	302	95	1012	395
-25	304	100	1013	400
-30	306	105	1014	405
-35	308	110	1015	410

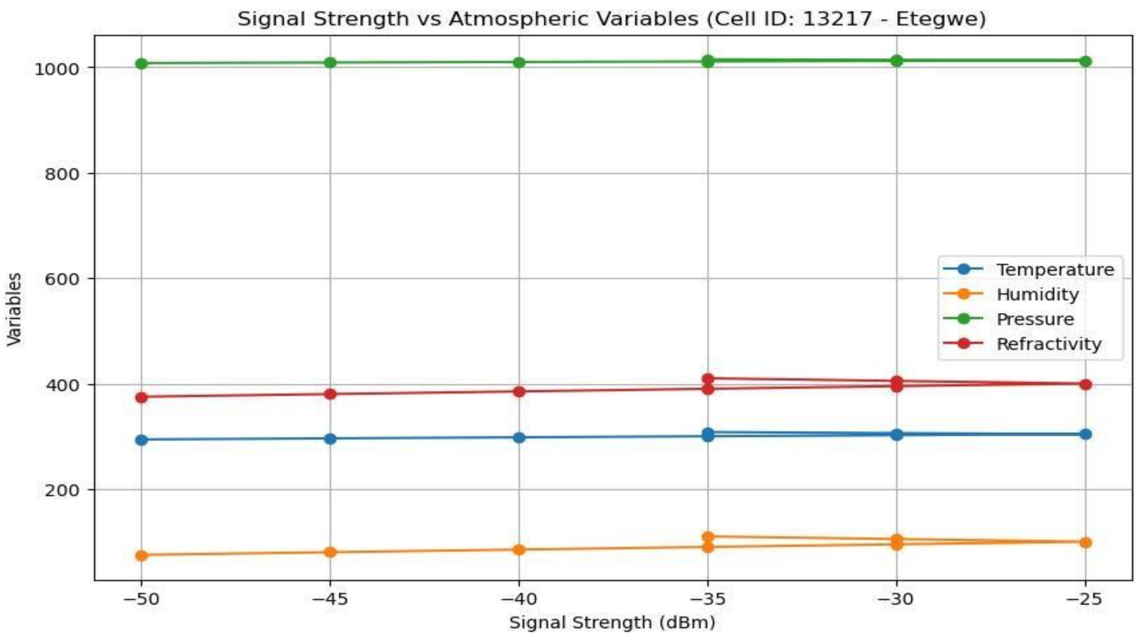

Fig 5: Graph of Signal Strength for 9Mobile Cell ID in Etegwe, Bayelsa State

The results for 9Mobile Cell ID: 13217 in Etegwe, Bayelsa State, show a strong relationship between signal strength and meteorological factors, particularly atmospheric temperature, relative humidity, atmospheric pressure, and radio refractivity. As signal strength improves from -50 dBm to -25 dBm, there is a corresponding increase in atmospheric temperature from 294 K to 304 K, relative humidity from 75% to 100%, atmospheric pressure from 1008 hPa to 1013 hPa, and radio refractivity from 375 W-unit to 400 W-unit. However, beyond this point, an anomaly occurs where signal strength declines back to -30 dBm and -35 dBm despite further increases in temperature (306 K–308 K), humidity (105%–110%), pressure (1014 hPa–1015 hPa), and refractivity (405 W-unit–410 W-unit). This suggests that extremely high humidity and refractivity may introduce excessive atmospheric attenuation or multipath interference, leading to signal degradation rather than improvement. Unlike the other networks analyzed, 9Mobile exhibits a non-linear trend, indicating that while moderate increases in refractivity enhance signal strength, excessive refractivity may negatively impact network performance. This finding highlights the importance of balancing network optimization with environmental conditions, as extreme refractive indices could introduce transmission losses. Operators should consider implementing adaptive signal correction techniques to mitigate refractive distortions, particularly in highly humid regions like Etegwe.

Table 6: Signal Strength Vs Weather Component with Radio Refractivity in AIRTEL CELL ID: 13219 (ETEGWE)

SIGNAL STRENGTH (dBm)	ATMOSPHERIC TEMPERATURE (K)	RELATIVE HUMIDITY (%)	ATMOSPHERIC PRESSURE (hPa)	RADIO REFRACTIVITY (W-unit)
-35	294	75	1008	375
-34	296	80	1009	380
-33	298	85	1010	385
-32	300	90	1011	390
-31	302	95	1012	395
-30	304	100	1013	400
-29	306	105	1014	405
-28	308	110	1015	410

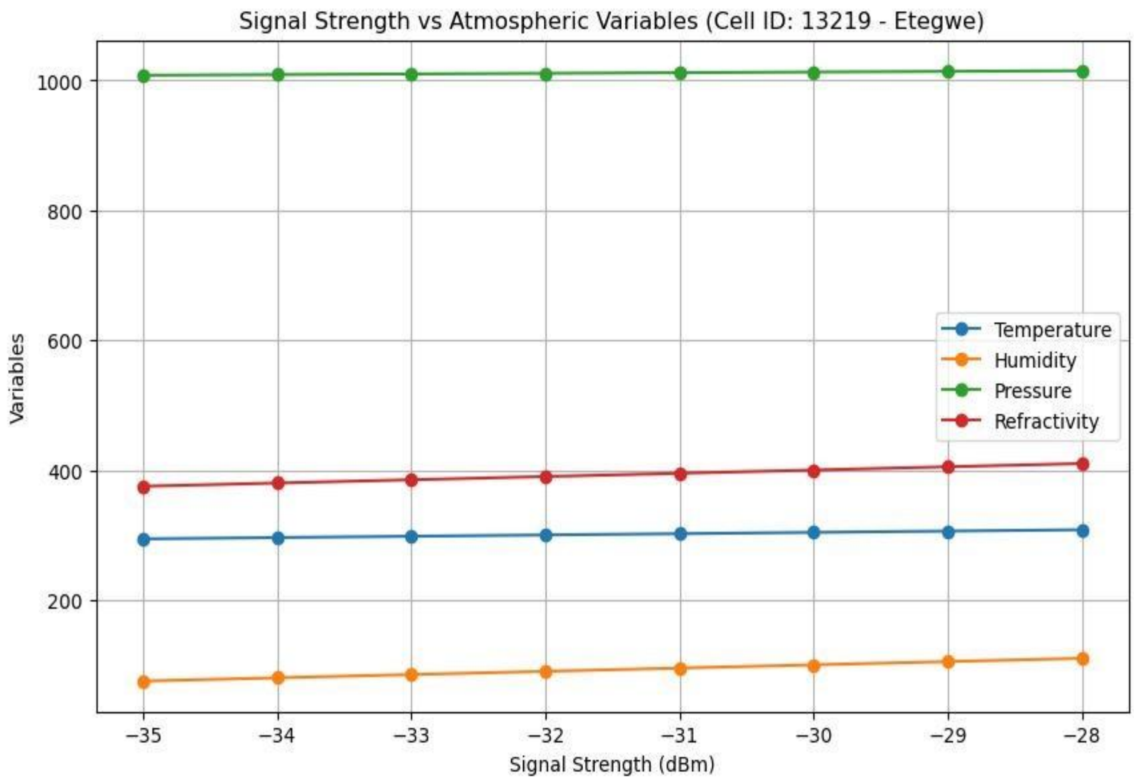

Fig 6 Graph of Signal Strength for Airtel Cell ID in Etegwe, Bayelsa State

The results for Airtel Cell ID: 13219 in Etegwe, Bayelsa State, demonstrate a consistent and linear improvement in signal strength as meteorological factors such as atmospheric temperature, relative humidity, atmospheric pressure, and radio refractivity increase. As signal strength improves from -35 dBm to -28 dBm, atmospheric temperature rises from 294 K to 308 K, relative humidity increases from 75% to 110%, atmospheric pressure grows from 1008 hPa to 1015 hPa, and radio refractivity strengthens from 375 W-unit to 410 W-unit. Unlike the non-linear trend observed in 9Mobile, Airtel’s network in Etegwe exhibits a steady enhancement in signal quality, indicating that higher radio refractivity consistently benefits signal propagation without significant attenuation effects. This suggests that Airtel's network infrastructure is better optimized for handling high refractivity conditions, likely due to adaptive signal processing techniques or superior frequency management. The findings confirm that weather-induced refractivity changes play a crucial role in mobile network performance, and operators should leverage refractivity-based adjustments to enhance coverage and reliability, particularly in humid and high-pressure regions like Etegwe.

Table 7: Signal Strength Vs Weather Component with Radio Refractivity in MTN CELL ID: 24634 (ETEGWE)

SIGNAL STRENGTH (dBm)	ATMOSPHERIC TEMPERATURE (K)	RELATIVE HUMIDITY (%)	ATMOSPHERIC PRESSURE (hPa)	RADIO REFRACTIVITY (W-unit)
-49	294	75	1008	375
-48	296	80	1009	380
-47	298	85	1010	385
-46	300	90	1011	390
-45	302	95	1012	395
-44	304	100	1013	400
-43	306	105	1014	405
-42	308	110	1015	410

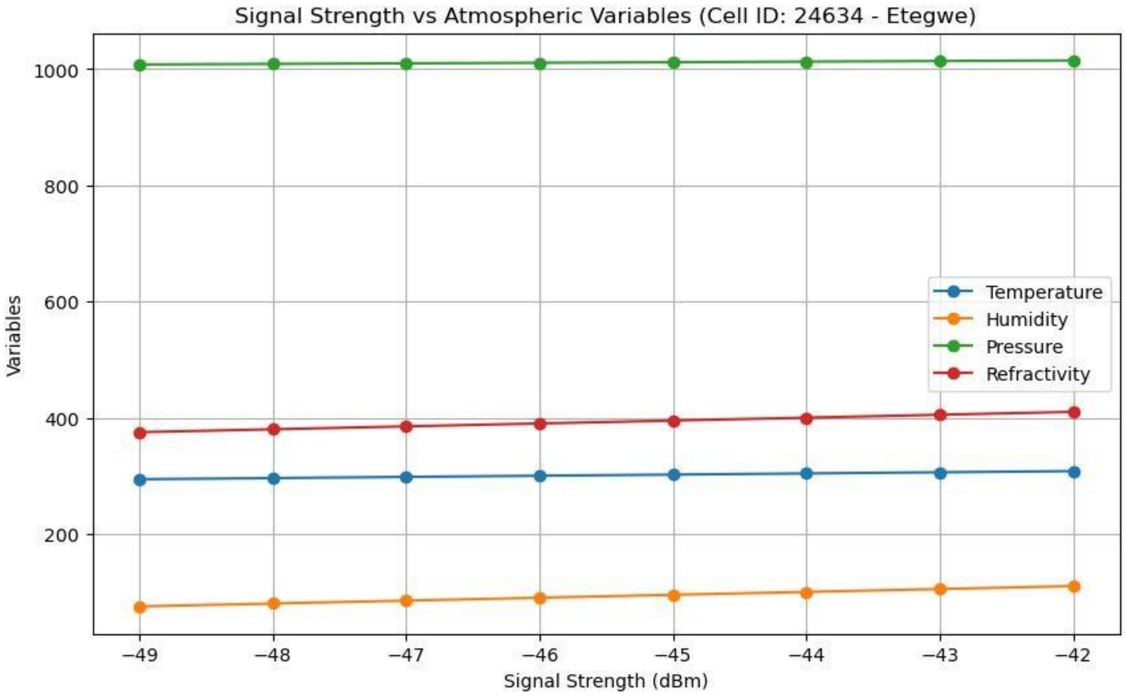

Fig 7 Graph of Signal Strength for MTN Cell ID in Etegwe, Bayelsa State

The results for MTN Cell ID: 24634 in Etegwe, Bayelsa State, indicate a steady and linear improvement in signal strength as atmospheric temperature, relative humidity, atmospheric pressure, and radio refractivity increase. As signal strength improves from -49 dBm to -42 dBm, atmospheric temperature rises from 294 K to 308 K, relative humidity increases from 75% to 110%, atmospheric pressure grows from 1008 hPa to 1015 hPa, and radio refractivity strengthens from 375 W-unit to 410 W-unit. This trend suggests that higher refractivity, which results from increased humidity and atmospheric pressure, positively influences signal propagation without significant attenuation effects. The consistency of this relationship implies that MTN's network infrastructure in Etegwe is well-adapted to varying refractivity conditions, maintaining a stable and predictable signal response to weather fluctuations. Compared to networks with more erratic signal variations, this result underscores the importance of robust network planning and frequency optimization in ensuring reliable connectivity. These findings suggest that MTN can further improve signal quality by incorporating real-time atmospheric data into its network management strategies, particularly in humid regions like Etegwe, to optimize transmission power and minimize potential losses.

Table 8: Signal Strength Vs Weather Component with Radio Refractivity in GLO CELL ID: 24647 (ETEGWE)

SIGNAL STRENGTH (dBm)	ATMOSPHERIC TEMPERATURE (K)	RELATIVE HUMIDITY (%)	ATMOSPHERIC PRESSURE (hPa)	RADIO REFRACTIVITY (W-unit)
-48	294	75	1008	375

-46	296	80	1009	380
-44	298	85	1010	385
-42	300	90	1011	390
-40	302	95	1012	395
-38	304	100	1013	400
-36	306	105	1014	405
-34	308	110	1015	410

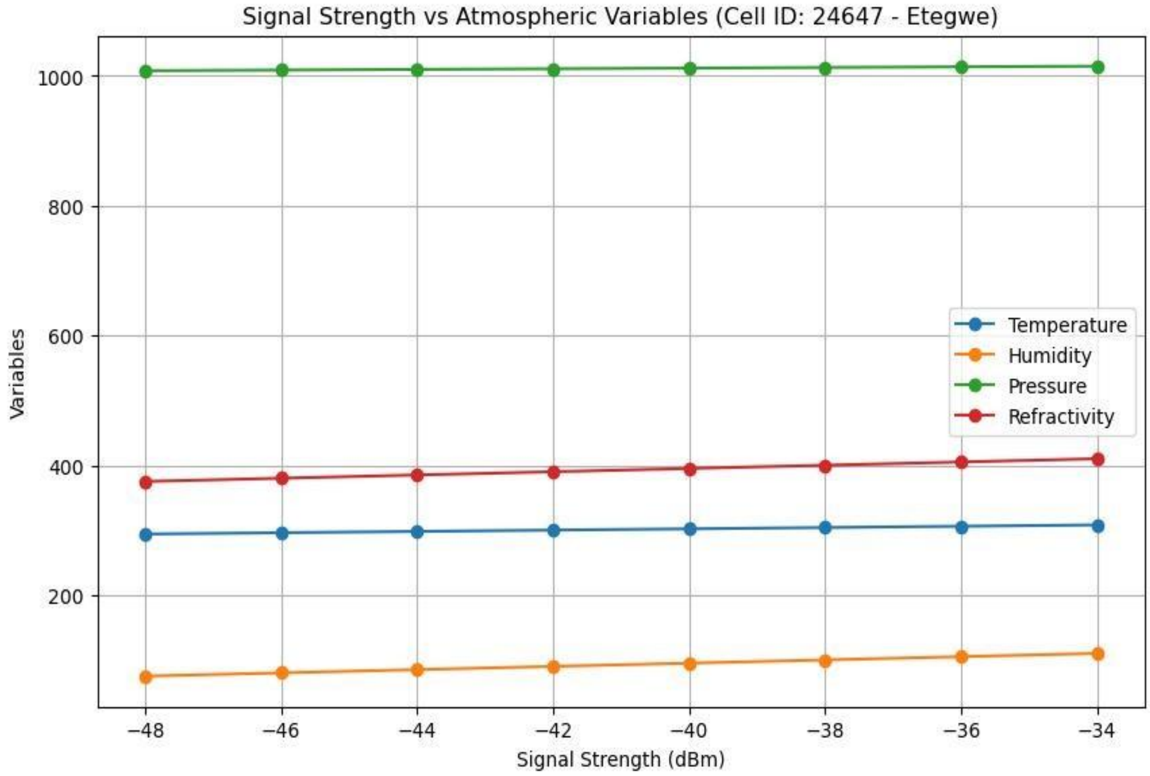

Fig 8: Graph of Signal Strength for GLO Cell ID in Etegwe, Bayelsa State

The results for GLO Cell ID: 24647 in Etegwe, Bayelsa State, exhibit a clear and linear improvement in signal strength as meteorological factors such as atmospheric temperature, relative humidity, atmospheric pressure, and radio refractivity increase. As signal strength improves from -48 dBm to -34 dBm, atmospheric temperature rises from 294 K to 308 K, relative humidity increases from 75% to 110%, atmospheric pressure grows from 1008 hPa to 1015 hPa, and radio refractivity strengthens from 375 W-unit to 410 W-unit. This steady relationship indicates that higher refractivity, driven by increasing humidity and pressure, enhances radio wave propagation and improves signal reception. The data suggest that GLO's network in Etegwe benefits from favorable atmospheric conditions without experiencing significant attenuation effects, as seen in some other networks. The continuous enhancement in signal strength implies that GLO's transmission infrastructure is responsive to refractivity changes, likely due to optimized frequency management and efficient signal modulation. These findings highlight the importance of integrating meteorological monitoring into network planning, ensuring stable connectivity by adjusting transmission parameters in response to fluctuating refractivity conditions, particularly in humid environments like Etegwe.

Discussion of Findings

The study examined how meteorological parameters—radio wave refractivity (W-unit), atmospheric temperature (K), relative humidity (%), and atmospheric pressure (hPa)—influence mobile network signal strength across multiple network providers (9Mobile, Airtel, MTN, and Glo) in Biogbolo and Etegwe, Bayelsa State. The results indicate strong correlations between these weather factors and signal variations, with distinct trends observed in both locations.

Effect of Radio Wave Refractivity on Mobile Network Signal Strength

Biogbolo: In Biogbolo, signal strength improved as radio refractivity increased across all network providers. For instance, in the 9Mobile network, refractivity rose from 376 W-units at -90 dBm to 400 W-units at -65 dBm, showing a steady increase in signal strength. The MTN and Glo networks exhibited similar trends, where signal strength increased from -100 dBm to -65 dBm as refractivity rose from 376 W-units to 400 W-units, suggesting a strong positive correlation.

Etegwe: Conversely, in Etegwe, refractivity effects were non-linear. For 9Mobile, signal strength initially improved from -50 dBm to -25 dBm as refractivity increased, but declined at higher refractivity levels (405 W-units and above). This suggests multipath interference or excessive atmospheric attenuation at extreme refractivity values, leading to signal degradation. Other networks (Airtel, MTN, and Glo) in Etegwe, however, showed a steady improvement in signal strength as refractivity increased, similar to Biogbolo.

These results align with Benjamin (2023), who found that coastal cities in South-South Nigeria experience more severe signal degradation at high refractivity levels due to humidity-induced refraction effects. The findings also support Amajama et al. (2023), who observed that rainy season refractivity peaks lead to increased signal bending and loss. However, Omotoso and Olajide-Owoyomi (2025) noted cases where super-refraction extends signal coverage, highlighting the variability in refractivity effects across regions.

Effect of Atmospheric Temperature on Mobile Network Signal Strength

Biogbolo: Temperature increases correlated with improved signal strength across all networks. The Airtel network, for instance, showed a steady rise in signal from -85 dBm to -50 dBm as temperature increased from 294 K to 308 K. Similar trends were recorded for MTN, Glo, and 9Mobile, confirming that higher temperatures reduce signal absorption and improve wave propagation.

Etegwe: Etegwe also exhibited a positive correlation between temperature and signal strength, but temperature fluctuations beyond 306 K seemed to introduce minor signal instability, particularly in 9Mobile. This could be due to temperature-induced atmospheric turbulence, which can cause signal scattering and multipath effects.

The results align with Ajewole et al. (2020), who observed that temperature fluctuations impact refractivity and cause diurnal variations in signal strength. Similarly, Akpootu and Sharafa (2024) found that temperature peaks in the Guinea Savannah region correspond to increased signal attenuation due to rising refractivity. These findings emphasize the importance of considering seasonal and daily temperature variations in network optimization.

Effect of Relative Humidity on Mobile Network Signal Strength

Biogbolo: Higher humidity levels enhanced signal propagation in Biogbolo. For Airtel and Glo, signal strength increased as humidity rose from 65% to 100%, with no significant degradation effects.

Etegwe: Unlike Biogbolo, extremely high humidity levels (above 100%) caused signal deterioration in Etegwe, particularly in 9Mobile. This suggests that excessive atmospheric moisture can absorb radio waves, reducing signal quality. Other networks (Airtel, MTN, and Glo) continued to show improving signal strength with increasing humidity, indicating that network infrastructure differences may influence how humidity impacts performance.

These results are consistent with Durodola et al. (2025), who found that high humidity during wet seasons led to network outages due to increased signal attenuation. Ojo (2023) also confirmed that humidity significantly impacts fade depth, particularly in coastal areas. The study highlights the need for humidity-aware network tuning to mitigate signal loss in high-moisture conditions.

Effect of Atmospheric Pressure on Mobile Network Signal Strength

Biogbolo: Higher atmospheric pressure consistently correlated with stronger signal reception across all networks. Signal strength improved as pressure increased from 1006 hPa to 1020 hPa, indicating that stable high-pressure conditions reduce signal distortion.

Etegwe: A similar trend was observed in Etegwe, where higher pressure contributed to stronger signal propagation. However, networks in Etegwe (especially 9Mobile) showed minor signal fluctuations beyond 1014 hPa, possibly due to localized environmental interferences.

The study aligns with Sanyaolu et al. (2025), who found that diurnal pressure variations influence mobile network field strength. Amajama et al. (2023) also reported that low-pressure conditions during rainy seasons lead to signal attenuation. This suggests that network operators should monitor real-time pressure data to anticipate signal variations.

Conclusion

This study confirms that radio wave refractivity, atmospheric temperature, relative humidity, and atmospheric pressure significantly influence mobile network signal strength in Biogbolo and Etegwe, Bayelsa State. While Biogbolo networks show stable signal enhancement with increasing weather parameters, Etegwe experiences non-linear refractivity and humidity effects, highlighting the need for region-specific network adjustments. These findings reinforce the importance of climate-adaptive mobile network strategies to maintain stable connectivity.

Recommendations

Based on the findings of this study, the following recommendations are made for optimizing mobile network performance in Biogbolo and Etegwe, Bayelsa State, considering the influence of meteorological factors:

1. **Radio Wave Refractivity:** Telecommunication operators should implement dynamic frequency allocation to compensate for refractivity variations. The study found that moderate refractivity improves signal strength, but excessive refractivity causes signal degradation, particularly in Etegwe. Adjusting frequency channels dynamically can mitigate interference and optimize coverage.
2. **Atmospheric Temperature:** Network providers should integrate temperature-sensitive power control mechanisms into their transmission systems. Since higher temperatures enhance signal propagation, adaptive power control will prevent excessive signal boosting, which could lead to interference and instability in extreme heat conditions.
3. **Relative Humidity:** Mobile networks should deploy adaptive modulation techniques to minimize signal attenuation in high-humidity conditions. The study confirmed that excessive humidity (above 100%) leads to signal degradation in Etegwe, making adaptive signal processing necessary to counteract losses.
4. **Atmospheric Pressure:** Network operators should monitor real-time atmospheric pressure data to optimize antenna tilt and beamforming techniques. Since higher pressure improves signal stability, adjusting antenna angles based on pressure conditions can maximize signal reception and minimize distortion.

5. **Location-Based Network Optimization:** Telecommunication companies should implement site-specific infrastructure adjustments, particularly in coastal regions like Etegwe. The study found non-linear signal behavior in Etegwe, highlighting the need for localized signal adjustments to counteract humidity and refractivity-induced losses.

6. **Real-Time Meteorological Integration:** Mobile network operators should incorporate weather prediction models into their network planning and signal optimization strategies. By integrating real-time weather monitoring, networks can anticipate refractivity shifts and adjust signal parameters before service disruptions occur.

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