FUDMA Journal of Sciences (FJS)
ISSN online: 2616-1370
ISSN print: 2645 - 2944
Vol. 10 No. 1, January, 2026, pp 194 – 202
DOI: https://doi.org/10.33003/fjs-2026-1001-4534

EMPIRICAL ASSESSMENT OF FM RADIO SIGNAL STRENGTH VARIATIONS WITH DISTANCE AND WEATHER CONDITIONS IN WARRI, NIGERIA

[*1]Ohworho Akpevwe Ejiro, [2]Vwavware Jude Oruaode and [1]Abriku, Ezekiel Onoriode

[1]Department of Physics, Delta State University, Abraka, Delta State, Nigeria.
[2]Department of Physics, Dennis Osadebay University, Asaba, Delta State, Nigeria.

*Corresponding authors' email: aeohworho@delsu.edu.ng; Phone: +234 8138090736

ABSTRACT

Reliable frequency modulation (FM) broadcast coverage depends significantly on signal strength variations with distance and short-term environmental conditions. This study presents an exploratory field investigation of Received Signal Strength Indicator (RSSI) variations from four FM radio stations - Mega FM, Crown FM, Current FM, and DBS Warri - in Warri, Delta State, Nigeria. Observational field measurements were obtained at distances between 1 km and 10 km during morning, afternoon, and evening periods in a one-day pilot campaign conducted in June 2024. Alongside RSSI, temperature and humidity were recorded to examine their associations with short-term signal propagation. The results show a clear decay of RSSI with increasing distance and consistent diurnal variability across all stations. Correlation analysis indicates that humidity exhibits a stronger negative association with RSSI (–0.45 to –0.61) t han temperature (+0.12 to –0.22). To further quantify these relationships, a pooled ordinary least squares regression incorporating station-specific effects was performed. Distance emerged as a statistically significant predictor of RSSI, while humidity showed a weak negative influence and temperature was not statistically significant within the short observation window. Station-dependent differences in RSSI were also evident, reflecting variations in transmitter characteristics. As a temporally limited pilot study, the findings indicate associations rather than causal relationships, but they demonstrate the value of combining distance-based measurements with environmental parameters and station-specific effects in FM propagation analysis within tropical urban environments. The study provides a foundation for extended multi-day measurements and future predictive modelling of FM broadcast signal behaviour.

Keywords: FM Radio Propagation, Received Signal Strength (RSSI), Weather-Induced Signal Variation; Temperature and Humidity; Tropical Climate Propagation; Warri, Nigeria

INTRODUCTION

FM radio remains an important broadcast medium in many developing regions, particularly where internet penetration is limited and access to digital services is uneven. Despite the growth of new media platforms, FM broadcasting continues to play a significant role in information dissemination across sub-Saharan Africa due to its accessibility, affordability, and operational resilience (Usama *et al.*, 2024; NEXUS-IBA, 2025). In Nigeria, FM radio supports wide-area communication and remains relevant for community outreach and public information delivery (Ojebode *et al.*, 2022).

From a propagation perspective, however, the reliability of FM broadcast coverage depends fundamentally on the behaviour of radio waves along the transmission path. Signal quality is strongly influenced by distance from the transmitter, transmission power, antenna characteristics, terrain, and atmospheric conditions (Ohworho and Ossai, 2023; Samson *et al.*, 2022). In the VHF band used for FM broadcasting, environmental factors such as temperature and humidity can modify radio wave propagation through changes in absorption, scattering, and near-surface refractive conditions, thereby affecting the received signal strength indicator (RSSI) at different locations (Khan *et al.*, 2020; Hassan *et al.*, 2017). In the lower troposphere, variations in temperature and humidity influence the refractive index of air and the dielectric properties of the propagation medium. Elevated humidity levels increase atmospheric water vapour content, which can enhance signal attenuation and variability, while temperature gradients contribute to changes in refractivity that affect signal bending and multipath behaviour. These mechanisms are particularly relevant in humid tropical coastal environments, such as the Niger Delta, where high moisture content, rapid temperature fluctuations, and atmospheric instability are common and can introduce short-term variability in FM signal reception.

Although weather-induced attenuation has been extensively studied for microwave and satellite links using established models such as ITU-R P.676 and P.837 (ITU, 2021; Samson *et al.*, 2022), comparatively fewer field-based investigations have focused on FM signal propagation in tropical climates. This represents an important research gap, as intense humidity fluctuations and convective weather patterns typical of tropical regions may influence VHF signal behaviour differently from temperate environments (Okoro *et al.*, 2021; Chibuzor, 2023). Existing studies have highlighted the need for localized experimental data to improve understanding of FM coverage in Nigeria. For example, Ajewole *et al.* (2020), Roshidat *et al.* (2020), and Amajama *et al.* (2023) reported that humidity-driven refractivity variations significantly alter FM coverage zones in southwestern Nigeria, while Abayomi-Shonuga *et al.* (2022) and Ukhuerebor *et al.* (2020) emphasized the importance of empirical measurements for urban planning, spectrum management, and quality-of-service assurance.

Despite these efforts, limited attention has been given to the combined effects of diurnal temperature and humidity variations on FM signal attenuation in the Niger Delta region. Accordingly, this study presents a one-day exploratory field investigation of FM radio signal strength in Warri, Delta State, Nigeria. Using RSSI measurements obtained from four FM stations across multiple distances during morning, afternoon, and evening periods. The study aims to:

i. examine distance-dependent variations in FM signal strength,

ii. assess diurnal differences in RSSI behaviour, and
iii. explore the association between RSSI, temperature, and humidity in a humid tropical coastal environment.

MATERIALS AND METHODS

Materials

The materials used for this study included a mini tinySA spectrum analyser for measuring received signal strength indicator (RSSI), Google Maps for estimating distances along the signal propagation paths, and a GPS locator app for recording the latitude and longitude of the four FM transmission stations.

i. Mini tinySA spectrum analyser: This portable handheld device was used to measure RSSI from the transmission stations.
ii. Weather Data: Ambient temperature and relative humidity data were obtained from the Nigerian Meteorological Agency (NiMet). Measurements were synchronized with RSSI recordings at each data collection point.
iii. Google Maps: Distances along the propagation path from each transmitter were estimated using Google Maps, with an approximate error margin of ±3-5 m.
iv. GPS Locator: Latitude and longitude coordinates of the FM stations were recorded using a mobile GPS app to ensure accurate mapping of the propagation path.

Study Area

The study was conducted in Warri, Delta State, Nigeria (Latitude: 5.5°N - 5.8°N, Longitude: 5.3°E - 5.6°E). It is a coastal city in the Niger Delta region characterized by a humid tropical climate. Warri lies approximately 6-10 m above sea level, with flat terrain and moderate urban density in close proximity to the Atlantic coast. The city experiences high relative humidity (70 - 95%), daily temperatures ranging from 25 - 32 °C, and frequent convective rainfall events, particularly during the wet season (NiMet, 2023). These conditions make Warri suitable for studying FM radio signal propagation under varying atmospheric conditions in a tropical environment.

Measurement Procedure and Data Collection

This study was conducted as a one-day pilot field investigation, with field measurements taken in a drive-test campaign covering four FM radio stations (Table 1): Mega FM, Crown FM, Current FM, and DBS Warri, operating within the 88 - 91 MHz frequency band. For each station, three diurnal time slots were considered: morning (07:30 - 10:00), afternoon (12:00 - 13:30), and evening (17:00 - 19:00), to capture variations in RSSI with time of day. At each measurement point along the propagation path (1 - 10 km from the transmitter), two measurement readings were obtained:

i. RSSI (dB): measured using the mini tinySA spectrum analyser, and
ii. GPS coordinates: recorded at each point to track distance and location accurately.

Temperature (°C) and relative humidity (%) data were obtained from NiMet.

The RSSI measurements were obtained with the mini tinySA handheld spectrum analyser operated in spectrum mode and tuned to the centre frequency of each FM station. Default manufacturer-recommended settings were used for VHF measurements, and peak signal levels were recorded. The analyser's built-in telescopic monopole antenna was oriented vertically to match the polarization of the FM broadcast signals, with the antenna positioned at approximately 1.5 m above ground level. No external calibration was performed beyond factory calibration; however, a consistent measurement configuration was maintained throughout the campaign to ensure reliable relative comparisons. Measurements were taken from a moving vehicle following the propagation path; vehicle motion was maintained at moderate urban driving speeds, and care was taken to minimize obstruction by large buildings or other obstacles to approximate line-of-sight conditions.

These procedures ensured synchronized observations of environmental conditions and FM signal strength across stations, distances, and time of day.

Table 1: FM Stations used in the Study

Station Name	Frequency (MHz)	Latitude	Longitude
Mega FM	89.1	5.7396	5.5175
Crown FM	89.9	5.4542	5.3229
Current FM	90.7	5.7735	5.5279
DBS Warri	88.6	5.7603	5.5442

The dataset therefore provides a synchronized observation of environmental conditions and FM signal strength across stations, distances, and time of day.

RESULTS AND DISCUSSION

Overview of Measurements and Environmental Conditions

Table 2 presents the RSSI field measurement data obtained for the various times of day (morning, afternoon and evening), data collection distances from transmitters, temperature and humidity field measurements. as observed from the table, across all stations, RSSI generally decreased with increasing distance. Temperature values ranged from 24°C to 36°C (afternoon/evening), while relative humidity was generally high, ranging from 70% to 93%, with comparatively lower values observed in the afternoon.

Table 2: Measurements Taken from the Four FM Stations for the Study

Time of Day	Distance (km)	Station Name	Temp (°C)	Hum. (%)	RSSI (dB)	Station Name	Temp (°C)	Hum. (%)	RSSI (dB)	Station Name	Temp (°C)	Hum. (%)	RSSI (dB)	Station Name	Temp (°C)	Hum. (%)	RSSI (dB)
Morning (07:30 – 10:00)	1	Mega FM	27	88	-65.2	Current FM	25	93	-70.0	Crown FM	24	93	-54.2	DBS Warri	25	93	-70.0
	2		27	88	-69.7		25	91	-77.2		24	93	-58.2		25	91	-77.2
	3		28	87	-54.5		26	91	-79.2		24	93	-54.7		25	91	-79.2
	4		28	87	-48.2		26	86	-80.2		24	93	-51.2		26	86	-80.2
	5		28	87	-64.7		28	86	-81.7		24	93	-55.2		26	86	-81.7
	6		28	87	-49.2		28	77	-82.7		25	91	-59.2		28	77	-82.7
	7		28	87	-52.7		28	77	-81.7		25	91	-62.7		28	77	-81.7
	8		28	87	-50.2		28	77	-79.7		27	83	-57.2		28	77	-79.7
	9		28	87	-62.7		29	68	-81.7		27	83	-60.2		29	68	-81.7
	10		28	86	-72.7		29	68	-82.9		27	83	-57.9		29	68	-82.9
Afternoon (12:00 – 13:30)	1		28	82	-55.3		26	71	-74.2		33	53	-44.3		26	71	-74.2
	2		28	82	-69.5		29	71	-79.2		33	53	-60.1		26	71	-79.2
	3		28	81	-54.7		29	69	-83.2		33	53	-70.1		29	69	-83.2
	4		29	81	-58.7		29	69	-84		33	53	-64.7		29	69	-84
	5		29	81	-45.7		29	69	-83.7		33	53	-57.1		29	69	-83.7
	6		29	81	-50.2		29	69	-83.2		33	53	-61.1		29	69	-83.2
	7		29	81	-52.7		28	77	-90.2		33	53	-65.0		28	77	-90.2
	8		29	81	-58.2		28	77	-80.2		32	54	-68.7		28	77	-80.2
	9		29	82	-64.2		28	77	-81.7		32	54	-61.5		28	77	-81.7
	10		29	83	-77.7		27	83	-81.7		32	54	-67.4		27	83	-81.7
Evening (17:00 – 19:00)	1		31	70	-60.7		24	90	-68.2		26	85	-47.4		25	91	-68.2
	2		31	71	-54.0		24	91	-67.3		26	85	-55.5		24	92	-67.3
	3		31	71	-57.0		24	92	-77.5		26	85	-61.0		24	92	-77.5
	4		36	76	-42.0		24	92	-75.7		26	85	-63.1		24	93	-75.7
	5		36	72	-52.3		24	93	-81.7		26	85	-65.4		24	93	-81.7
	6		36	72	-64.0		24	93	-80.5		26	85	-71.7		24	93	-80.5
	7		36	72	-48.0		24	93	-82.2		26	86	-60.1		24	94	-82.2
	8		31	72	-50.0		24	84	-80.2		26	86	-58.6		24	84	-80.2
	9		31	72	-61.0		25	84	-80.7		26	86	-71.7		25	84	-80.7
	10		31	73	-57.0		25	89	-77.9		26	86	-64.1		25	89	-77.9

Station Characteristics and RSSI Range

Table 3 presents the transmission characteristics of the four FM stations investigated, including operating frequency, transmitter power, strongest and weakest recorded RSSI values and measurement distances. The results show noticeable inter-station variability in RSSI levels, reflecting differences in transmitter power, operating frequency, and site-specific propagation conditions.

Table 3: Summary of FM Stations and Signal Strength

Station	Frequency (MHz)	Transmitter Power (kW)	Strongest RSSI (dB)	Weakest RSSI (dB)	Transmission Distance (km)
Mega FM	89.1	6.0	-42.0	-77.7	1 – 10
Crown FM	89.9	5.0	-51.2	-62.7	1 – 10
Current FM	90.7	1.5	-56.7	-68.7	1 – 10
DBS Warri	88.6	2.5	-55.7	-72.5	1 – 10

Distance-Dependent RSSI Behaviour

Figures 1a and 1b illustrate the relationship between RSSI and distance for all four FM stations. A general decrease in RSSI with increasing distance from the transmitter is observed across stations, although deviations from a smooth decay are evident at several locations.

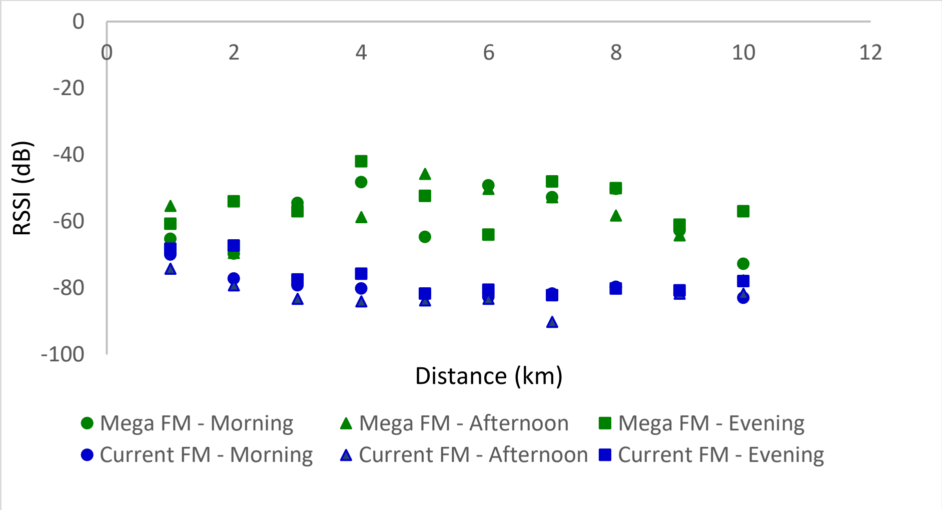

Figure 1a: Plot of RSSI vs Distance for Mega and Current FM Stations

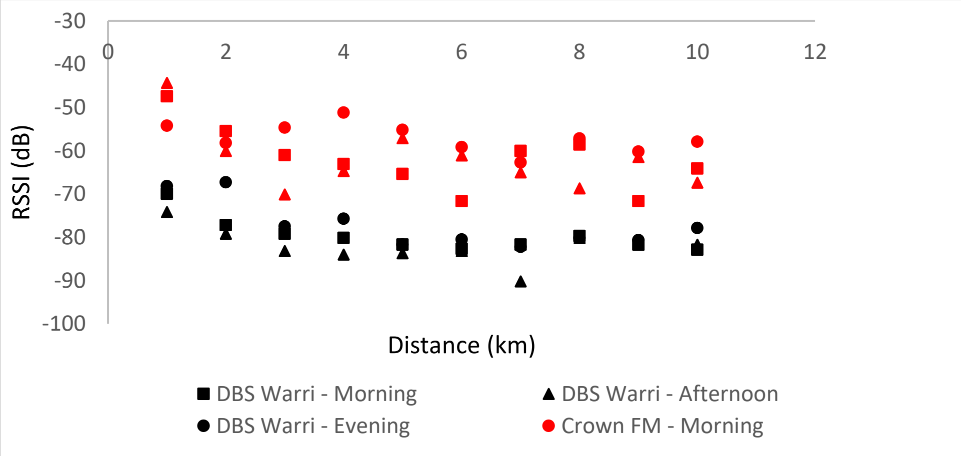

Figure 1b: Scatter Plot of RSSI vs Distance for Crown FM and DBS Warri

Relationship Between RSSI and Environmental Variables

Scatter plots illustrating the relationships between RSSI and temperature are shown in Figures 2a and 2b, while Figures 3a and 3b present RSSI as a function of relative humidity. Visual inspection suggests weak to moderate associations between RSSI and the environmental variables, with humidity exhibiting a more pronounced inverse relationship than temperature for most stations.

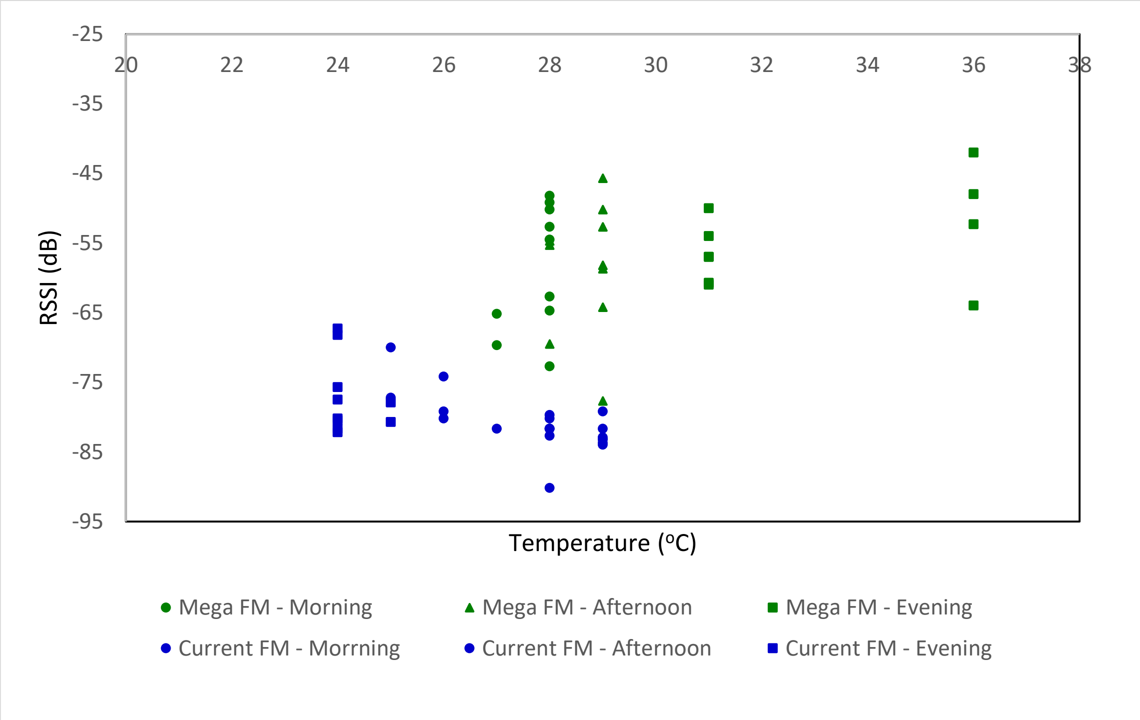

Figure 2a: Scatter Plot of RSSI vs Temperature for Mega and Current FM Stations

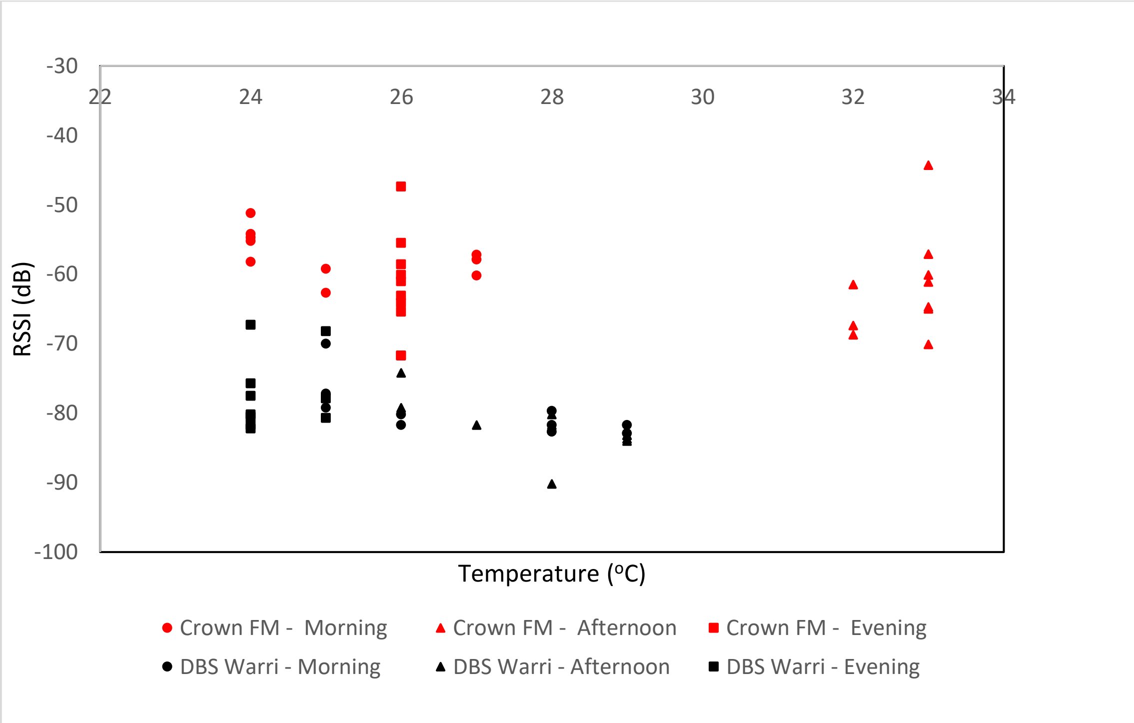

Figure 2b: Scatter Plot of RSSI vs Temperature for Crown FM and DBS Warri

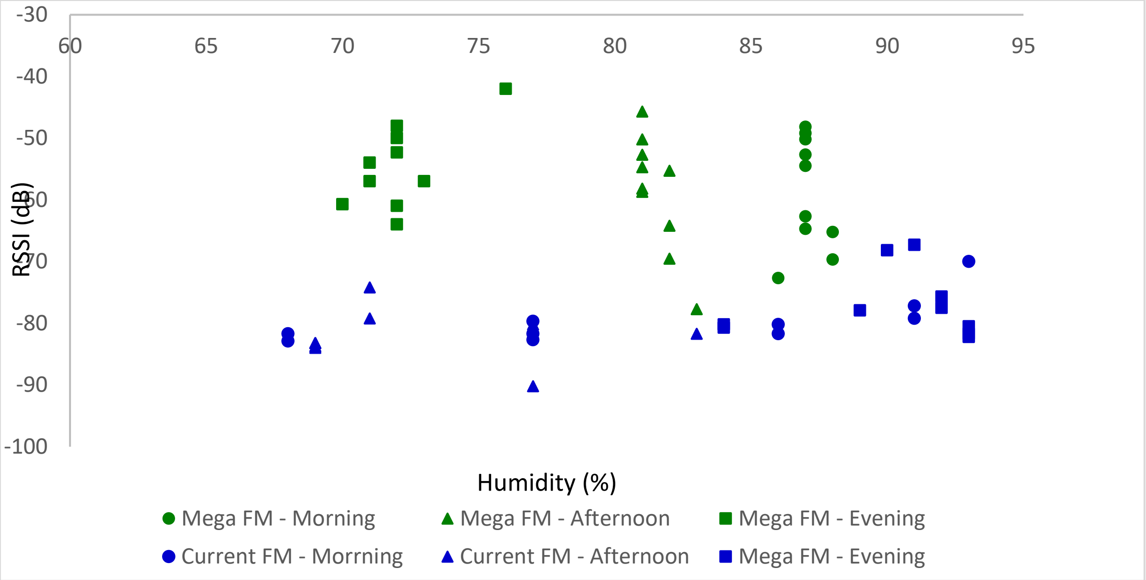

Figure 3a: Scatter Plot of RSSI vs Humidity for Mega FM and Current FM Stations

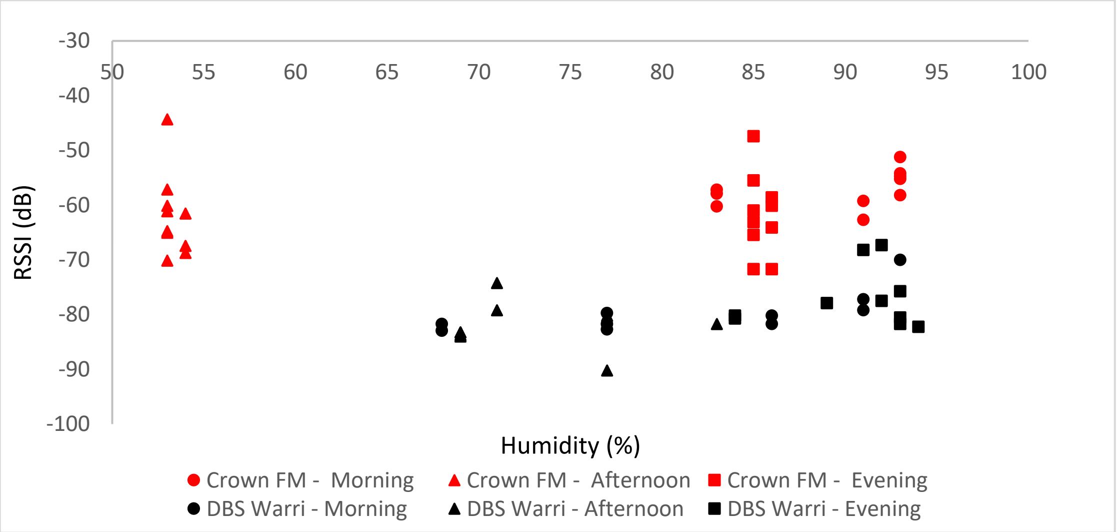

Figure 3b: Scatter Plot of RSSI vs Humidity for Crown FM and DBS Warri

Pearson correlation coefficient was computed to quantify the relationships between RSSI, temperature, and humidity. The correlation results as presented in Table 4 indicate a generally negative moderate correlation between RSSI and relative humidity, both at the individual-station level and when data are pooled. Correlations between RSSI and temperature are weaker and less consistent in signs across stations.

Table 4: Pearson Correlation between Rssi and Environmental Variables

Station	RSSI-Humidity Correlation	RSSI-Temperature Correlation
Mega FM	- 0.45	+ 0.12
Crown FM	- 0.53	- 0.22
Current FM	- 0.61	- 0.18
Overall	- 0.52	- 0.08

Multivariate Regression Analysis Controlling for Distance and Station Effects

To separate geometric path loss from atmospheric effects, a multivariate ordinary least squares (OLS) regression model was performed with RSSI as the dependent variable and distance, temperature, humidity, and station identity as predictors. Station identity was included as a categorical variable to account for transmitter-specific offsets. The regression results as summarized in Table 5, shows that the regression model explains approximately 78% of the total variance in RSSI (R^2 = 0.78, adjusted R^2 = 0.77), and the overall model is statistically significant ($p < 0.001$). Distance from the transmitter emerged as the dominant predictor of RSSI, with signal strength decreasing by approximately 0.82 dB per kilometre ($p < 0.001$).

Table 5: Multivariate Linear Regression Results for RSSI

Predictor	Coeff. (β)	Std. Error	t-value	p-value
Intercept	-58.57	13.70	-4.28	< 0.001
Distance (km)	-0.82	0.19	-4.32	< 0.001
Temperature (°C)	-0.01	0.33	-0.04	0.966
Relative Humidity (%)	0.04	0.07	0.59	0.553
Station: Mega FM	2.74	1.75	1.56	0.121
Station: Current FM	-19.52	1.55	-12.57	< 0.001
Station: DBS Warri	-19.62	1.55	-12.62	< 0.001

Table 6: Model Statistics

Metric	Value
R^2	0.780
Adjusted R^2	0.768
F-statistic	66.60 (p < 0.001)
Durbin–Watson	1.36

Dependent variable: RSSI (dB)
Model: Ordinary Least Squares (OLS)
Number of observations: 120
(Reference station: Crown FM)
Statistical significance assessed at $\alpha = 0.05$.

The station-specific effects are also statistically significant for some stations, reflecting differences in transmission characteristics and local propagation conditions as shown in table 5. Current FM (-19.52) and DBS Warri (-19.62) exhibit significantly lower RSSI values relative to the reference station, while Mega FM exhibited a positive but statistically insignificant offset (2.74). These station-level differences exceed the magnitude of any short-term meteorological effects detected in the regression analysis. In contrast, after controlling for distance and station effects, neither temperature ($p = 0.97$) nor relative humidity ($p = 0.55$) exhibited a statistically significant independent influence on RSSI ($p > 0.05$), in the multivariate model.

Current FM was used as the reference station to provide a stable baseline for comparison of station-specific RSSI variations. It was selected due to its moderate transmission power and representative signal characteristics, allowing meaningful comparison with both higher- and lower-power stations. The Durbin–Watson statistic was used to verify that residual autocorrelation did not substantially bias the regression estimates. The Durbin–Watson statistic indicated mild positive autocorrelation, which is expected given the ordered nature of distance-based and diurnal field measurements. However, the value does not suggest severe dependence that would invalidate the regression estimates.

Distance and Station-dependent Effects

The results confirm that distance from the transmitter remains the dominant factor influencing FM signal strength across all four stations. As shown in Figures 1a and 1b, RSSI generally decreases with increasing distance, consistent with free-space path loss and additional attenuation due to ground reflections and urban clutter. This observation aligns with established VHF propagation behaviour reported in earlier studies and provides empirical context for FM broadcast performance under tropical atmospheric conditions (Yabwa, *et al.* 2023; Matthew *et al.* 2018; Timtere *et al.* 2020). The multivariate regression analysis (Table 5) further quantifies this relationship, indicating a statistically significant negative distance coefficient (-0.82 dB/km, $p < 0.001$), after controlling for station identity and atmospheric variables. This confirms that the observed decay is not merely descriptive but remains robust under basic inferential testing, even within the constraints of a one-day pilot dataset.

Deviations from smooth monotonic decay were observed at some locations, particularly within the first few kilometres from the transmitters. Such deviations are plausibly attributable to multipath propagation and localized obstructions common in dense urban environments (Khan *et al.*, 2020; Adeyemi *et al.*, 2023; Hassan *et al.*, 2017). However, detailed quantitative characterization of urban morphology and obstruction geometry was not performed. These explanations are therefore offered as plausible but not definitive and are framed accordingly to avoid overinterpretation.

Influence of Humidity and Temperature on RSSI

Correlation analysis (Table 4) shows that relative humidity exhibits a moderate negative association with RSSI across stations, with coefficients ranging from −0.45 to −0.61. On the other hand, temperature shows weaker and inconsistent correlations with RSSI for all four FM stations (r = –0.22 to –0.08 and +0.12), suggesting minimal influence within the one-day measurement period.

Afternoon and evening temperature measurements (Table 2 and Figures 2a, 2b) show temperature-driven variations, with atmospheric heating contributing to refractive effects and occasional improvements in signal strength at certain distances. Humidity measurements (Table 2 and Figures 3a, 3b) show higher humidity levels (above 85%) are associated with weaker signals, this is due to increased absorption and scattering of VHF waves in moist tropical air, thus resulting in weaker signals emanating from the water molecules. Similar temperature variations and humidity-driven attenuation patterns have been reported in tropical environments, where high moisture content alters near-surface refractive conditions (Ajewole *et al.*, 2020; Okoro *et al.*, 2021; Roshidat *et al.*, 2020; Amajama *et al.*, 2023; Amajama, 2016; Ale *et al.* 2024; Ituebhor *et al.*, 2025).

However, when distance and station effects are controlled using multivariate regression (Table 5), neither temperature nor relative humidity remains statistically significant ($p > 0.05$). This suggests that the apparent correlations observed in the bivariate analysis likely reflect indirect coupling with distance and diurnal timing and are not independent causal effects on RSSI. Rather than acting in isolation, temperature and humidity in humid tropical environments jointly influence atmospheric refractivity. Variations in moisture content and thermal gradients can modify refractive indices near the surface, potentially affecting propagation conditions over short temporal scales, which governs the bending and ducting of VHF radio waves. Although refractivity was not explicitly derived in this study, the observed patterns are consistent with this physical framework and highlight the value of a refractivity-based study in future work.

The lack of statistical significance in the regression model does not imply that atmospheric effects are absent, but rather that their influence may manifest as short-term modulation around a dominant distance-controlled trend, particularly over the relatively short propagation paths examined. A more detailed refractivity or refractive gradient analysis would require higher-resolution meteorological data and multi-day observations, which are beyond the scope of this one-day pilot study. Consequently, the atmospheric interpretation is intentionally cautious and framed in terms of association rather than causation.

Station-to-Station Variability

Differences in RSSI levels among the four stations were observed throughout the measurement campaign (Table 3). Stations operating at higher transmitter power generally exhibited stronger received signals, consistent with theoretical expectations. However, station-specific differences in RSSI measured values may also reflect unreported parameters such as antenna height, radiation pattern, feeder losses, and effective radiated power. The regression model accounts for station identity through categorical terms (Table 5), revealing statistically significant negative offsets for Current FM and DBS Warri relative to the reference station. These offsets highlight the importance of transmitter-specific characteristics beyond frequency and nominal power and underscore the need for more complete technical metadata in future studies.

Implications and Limitations

The principal limitation of this work lies in its temporal scope. Measurements were conducted during a single day, limiting statistical power and precluding robust causal inference. Additionally, the absence of refractivity calculations, detailed urban morphology classification, and continuous atmospheric profiling constrains the physical interpretation of observed variability. Nonetheless, as a pilot field investigation, the study provides empirical baseline data for the Niger Delta region and establishes a methodological framework for extended multi-day campaigns incorporating refractivity analysis, terrain characterization, and advanced propagation modelling.

CONCLUSION

This study presents a short-term empirical assessment of diurnal variations in FM radio signal strength within a humid tropical coastal urban environment. Measurements obtained from four FM broadcast stations over distances of 1–10 km indicate that received signal strength is predominantly influenced by distance-dependent attenuation and station-specific transmission characteristics, with additional variability observed across different times of the day. Signal levels were generally higher during the afternoon than in the morning and evening, although this pattern was not consistent across all stations. Correlation analysis suggested moderate associations between RSSI and relative humidity, while temperature exhibited weaker and less consistent relationships. However, when distance and station-effects were accounted for through multivariate regression, atmospheric variables did not emerge as statistically significant predictors of mean signal strength over the short propagation paths considered. Regression analysis confirmed distance as a statistically significant predictor of signal strength, while time-of-day effects contributed additional, though comparatively smaller, explanatory influence. These findings indicate that, within the scope of this one-day study, spatial attenuation, station effects and diurnal variability jointly shape FM signal reception quality, with meteorological conditions contributing secondary modulation rather than primary control. The results should be interpreted within the context of short-duration observational analysis.

Furthermore, observed deviations from smooth distance-dependent decay highlight the influence of local urban propagation conditions, such as partial obstructions and reflections, which are characteristic of dense tropical cities. While these effects are physically plausible, their specific contributions could not be quantitatively resolved within the present dataset and are therefore interpreted cautiously.

Overall, the findings demonstrate the importance of controlling for distance and station effects when examining environmental influences on FM signal strength and caution against attributing short-term RSSI variability solely to atmospheric parameters based on correlation alone. The study provides a baseline empirical reference for FM propagation behaviour in the humid tropical coastal environments of the Niger Delta region and motivates future work incorporating longer observation periods, integrating simultaneous meteorological measurements, refined transmitter metadata, urban morphology characterization, and refractivity-based atmospheric analysis to better isolate physical propagation mechanisms. The findings are relevant for broadcast engineers, regulators, and network planners involved in coverage assessment, quality-of-service evaluation, and system planning.

REFERENCES

Abayomi-Shonuga, A., Oladipo, O., & Adekunle, T. (2022). Empirical propagation studies for FM broadcasting in tropical cities: Implications for quality of service. *Telecommunication Systems, 79*(2), 285–299.

Adeyemi, O., Akinwumi, O., & Samuel, I. (2023). Experimental investigation of FM signal degradation in humid tropical environments. *International Journal of Antennas and Propagation, 2023*, 1–12.

Ajewole, M. O., Akinbolati, T. A., & Ojo, J. S. (2020). Influence of atmospheric humidity on FM broadcast signal strength in Southwest Nigeria. *Radio Science, 55*(8), e2020RS007194.

Ale, F., Ayegba, A., Agboola, O. & Olatunji, P. J. (2024) Effects of some weather variables on signal strength of Malony FM radio, Nasarawa State, Nigeria. *Heliyon*. https://doi.org/10.1016/J.heliyon.2024.e25978.

Amajama, J. (2016) Force of atmospheric humiditiy on UHF radio signal. *International Journal of Scientific Research Engineering and Technology (IJSRET)*, *5*(2).

Amajama, J., Asagha, E. N. Ogir, J. U., Iwey, P. C., Akwagiobe, J. U., Fina, O. F., Ikeuba, A. I. & Bassey, D. E. (2023) Radio refractivity impact on signal strength of mobile communication. *Journal of Electrical and Computer Engineering*. https://doi.org/10.1155/2023/3052241.

Chibuzor, E. (2023) Analysis of some weather variables' impacts on UHF and VHF receivers in Yenagoa, southern Nigeria. *World Journal of Advanced Research and Reviews*, *19*(02), 675 – 681. https://doi.org/10.30574/wjarr.2023.19.2.1552.

Hassan, F., Karrar, A. K. & Zaid, N. K. (2017) Study and performance analysis of received signal strength indicator (RSSI) in wireless communication systems. *International Journal of Engineering Technology*, *6*(4), 195 – 200. www.sciencepubco.com/indu.php/JET.

ITU. (2021). Trends in broadcast media and digital transformation in Africa. *International Telecommunication Union*.

Ituebhor, OP., Olukanni, S. E., & Ikedu, R. (2025) Impact of atmospheric variables, radio resource control and call drop on radio frequency signal attenuation in wireless communication networks. *Journal of Sciences, Computing and Applied Engineering Research (JSCAER)*, 1(1), 28-33. https://jcaes.net.

Khan, R., Musa, A., & Lim, Y. (2020). Environmental impacts on radio frequency propagation: A review. *Wireless Personal Communications*, *111*(4), 2259–2276.

Matthew, O. V., Idiake, S. U., Noma-Osaghae, E. & Nwukor, F. (2018) Comparative analysis of the effect of distance on signal strength using selected communication media. *International Journal of Advances in Scientific Research and Engineering (IJASRE)*, *4*(8). https://doi.org/10.31695/IJASRE.2018.32833.

NEXUS-IBA (2025) Bridging the digital divide. The role of NEXUS-IBA Radio Broadcasting to remote regions. https://www.nexus.org/beyond-the-digital-divide-world-radios.

Nigerian Meteorological Agency (NiMet) (2023) Weather of Warri, Delta State Nigeria.

Ohworho, A. E. & Ossai, C. (2003): Pathloss measurements for wireless communication in South West Nigeria. *FUW Trends in Science and Technology Journal*, *8*(2), 337 – 340.

Ojebode, A., Adedoyin, A., & Salawu, A. (2022). Community radio and democratic participation in Nigeria: Potentials and constraints. *Journal of African Media Studies, 14*(2), 123–140.

Okoro, E., Nwankwo, C., & Bello, A. (2021). Atmospheric refractivity effects on terrestrial VHF signal propagation in coastal Nigeria. *Nigerian Journal of Technology*, *40*(3), 511–520.

Roshidat, M. Sabri, N. H., Roslan, U., Sabri, A., Sharifa, N. A. S. Z., Azman O. & Mustafa, W. A. (2020) Effect of humidity on tropospheric received signal strength (RSS) in Ultra-High Frequency (UHF) Band. *Journal of Physics*, Conference Series.

Samson, D. Y., Mayowa G. & Abdulmumin, Z. L. (2022) Assessment of radio waves propagation pattern from three radio stations in Lokoja, Kogi State, Nigeria. *International Journal of Electronics and Communication Engineering*, *9*(9). https://doi.org/10.14445/23488549/IJECE-V9I9P101.

Timtere, P., Oniku, S. A., & David. Y. M. (2020) Analysis of the effects of distance on signal strength, signal attenuation and refractivity of two radio stations in Yola, Nigeria. *American Journal of Engineering Research*, *9*(8), 169-175. https://www.ajer.org/papers/Vol-9-issue-8/S0908169175.pdf.

Ukhuerebor, K. E., Uttah, S., Olayinka A. S., Aigbe, U. O., Emegha, J. O. & Azi, S. O. (2020) Mean annual weather cycles of some weather variables over Warri, Delta State, Nigeria during 2009 to 2018. *Covenant Journal of Physical and Life Sciences (CJPL)*, *8*(1).

Usama, B. S., Ilsa, I. & Syeda S. B. (2024) Impact of FM radio on political awareness and engagement among university students: A socio-political study. *Global Mass Communication Review*, *9*(3). https://doi.org.10.31703/gmcr.2024(IX.III).

Yabwa, D., Kanu, O. M., & Dawaki, M. K. (2023) Determination of the effect of radio signal strength and attenuation as a function of linear distance and some atmospheric conditions on TSBS, Jalingo, Taraba State. *FUDMA Journal of Sciences (FJS)*, *7*(3), 207-214. https://doi.org/10.33003/fjs-2023.0703-1861.