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ANALYSIS OF RADIO WAVES PROPAGATION FOR FM BROADCASTING STATION (A CASE STUDY OF OSUN STATE BROADCASTING CORPORATION OSOGBO)

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Abstract
FM broadcast coverage in developing urban environments is frequently affected by terrain, building density, obstruction and multipath, yet station-level propagation data remain limited. This study investigated radio-wave signal-strength variation and propagation characteristics of the Osun State Broadcasting Corporation (OSBC) FM signal in Osogbo, Osun State, Nigeria, operating at 104.5 MHz, with a transmitting power of 100 W and a mast height of 340 m. An experimental quantitative design was adopted, with the coverage area divided into four routes: OSBC–Air Force Base–Ibokun Road (rural), OSBC–Ilesa Garage–Osun River (riverine/urban), OSBC–Stadium–Ring Road (densely built-up), and OSBC–Oja Oba–Isale Aro–Ola Iya (mixed urban/semi-urban). Measurements were taken at 1-km intervals from 1 to 6 km during daytime and evening periods over three weeks using an Agilent N9342C spectrum analyser and a Diamond RH799 omnidirectional antenna at 1.5 m. Signal strength declined across all routes, with net reductions of 76%, 70%, 62% and 90% for Routes 1–4, respectively. Route 4 exhibited the greatest attenuation variability (SD = 21.54; range = 64.35), whereas Route 2 recorded the highest mean signal strength (39.31) and lowest variability (SD = 15.57; variance = 242.57). Predicted eHata path loss increased with distance, ranging from 61.10 to 85.72. Elevation showed no consistent relationship with signal strength, indicating the influence of local propagation conditions. Signal strength fell below the reported minimum acceptable level of 40 within 2–3 km on all routes. The findings highlight the need for optimized antenna siting, appropriate power planning and mitigation of multipath and shadowing effects.

Keywords
FM propagation, Signal strength, Path loss, eHata model, Spectrum analyser, Osogbo

1. INTRODUCTION

Radio communication is a cornerstone of information dissemination and public engagement in both urban and rural environments. A radio signal consists of coupled electric and magnetic field components; the electric field component is expressed as the change of potential over a given distance, in volts per metre, and this quantity, the electric field strength is the standard measure of the intensity of an electromagnetic wave at a point, and hence of the coverage area of a transmitter [1]. In Nigeria, FM broadcasting remains the preferred mass medium because of its accessibility, affordability and relatively high sound fidelity. Operating within the Very High Frequency band of 88–108 MHz [1], FM radio delivers clear audio but is subject to significant propagation challenges arising from the essentially line-of-sight nature of its waves, which makes reception sensitive to buildings, trees, hills, and weather phenomena such as rain and humidity.

The relationship between signal strength and propagation is also influenced by climatic conditions. Rainfall, humidity and temperature inversions have been observed to cause signal degradation or enhancement depending on the region and time of year [2]. Free-space spreading is a further constraint: because the field strength created by a wave is inversely proportional to the square of the distance from the transmitting antenna, the received level weakens steadily with range even in the absence of obstruction [3]. More generally, radio signals are affected by the electrical parameters of the ground, the curvature of the earth's surface, the height of the antenna above the earth's surface, and the weather conditions in the troposphere [4].

The electric field strength of radio signals at VHF and higher bands varies in the troposphere as ground constants and the refractivity conditions of the air change with temperature, pressure and water-vapour pressure. Surface refractivity correlates positively with radio field strength, so knowledge of its temporal and

spatial variability is essential to predicting terrestrial network performance at VHF [5]. Local refractivity profiles are therefore required as reference data, a requirement recognised in the ITU-R recommendations on refractivity and refractivity gradients [6]. Over Nigeria, surface refractivity exhibits strong seasonal behaviour, with rainy-season values exceeding dry-season values across the North-Central zone , and field strength has been shown to follow the same seasonal pattern [7]. For broadcast planning, the propagation curve — the variation of field strength with distance for a given transmitter is therefore the primary design and coverage parameter [3].

Empirical coverage studies of Nigerian broadcast transmitters are relatively few. [8] measured FM signal strength across 14 locations in Uyo and reported correlations of −0.84 and −0.67 between line-of-sight distance and signal strength for two stations, and +0.71 and +0.55 between elevation and signal strength, concluding that raising transmitter height and power improves reception [8]. [9] compared Okumura-model attenuation with field measurements at 91.1 MHz and 101.5 MHz in Adamawa State, obtaining attenuation–distance correlations of 0.85 and 0.80 and finding that the documented 250 km coverage radius was not realised in the field. [10] developed an empirical path-loss model for an FM station in South-West Nigeria and reported high correlation with established prediction models, while a companion study determined propagation loss and a contour map for the same station using an irregular-terrain model [11]. [12] analysed field-strength distribution for a UHF television transmitter in Ekiti State, providing a coverage and elevation database for the state. On a larger scale, Faruk et al. conducted a multi-transmitter VHF/UHF measurement campaign across 145.5 km of Nigerian urban environment and examined the feasibility of Kriging-based path-loss prediction [13]. [14] measured received signal strength for digital terrestrial television base stations in Lagos, Kaduna and Katsina over three years, reporting path loss–distance correlations of 0.76, 0.75 and 0.74 and finding that the Okumura–Hata model underestimated path loss over their study locations. [15] related weather variability to surface refractivity and UHF signal strength in Abeokuta, finding lower signal strength in the rainy season and higher values in the dry season. [16] have published received-signal-strength and terrain-profile datasets along the Lagos–Badagry highway, establishing the value of open propagation data for model development. Collectively these studies establish three recurring findings relevant to the present work: strong inverse correlation between distance and received level, a measurable positive influence of elevation, and a systematic mismatch between nominal model predictions and Nigerian field measurements.

Okumura's graphical data were reduced to a computational form by Hata as $PL = A + B \log_{10}R$, valid for 100–1500 MHz, distances of 1–20 km, base-station antenna heights of 30–200 m and vehicular antenna heights of 1–10 m [17]. The model performs reasonably in built-up areas but can produce significant errors in rural environments, and least-squares adaptation has been used to reduce that error [18]. Least-squares optimisation of the Egli and Hata models has similarly been used to reconcile predictions with local measurements [19]. Popoola et al. showed that ignoring altitude, land use and clutter height leads to large deviations between Okumura–Hata predictions and measurements, and that improved accuracy follows from incorporating morphological and building data [20]. Model calibration is widely practised for exactly this reason: tuning nominal parameters to local measurements reduces error [21], and [22] reported that calibration of the Standard Propagation Model reduced mean absolute error, RMSE and standard deviation of error from 18.32, 21.55 and 11.34 dB to 5.40, 6.90 and 4.29 dB respectively. [23] note that typical best-case propagation-model accuracy is on the order of 12–15 dB RMSE, reducible to 8–9 dB with adjustable or data-fitted models, and recommend well-established models such as Okumura–Hata where reproducible comparison is the priority.

Alongside these classical approaches, neural-network and machine-learning methods have been applied to path-loss and received-signal-strength prediction to capture environmental complexity that empirical models handle only crudely [24][[25], with reported RMSE improvements over standard slope-intercept and 3GPP models [26] and with geospatial inputs drawn from open mapping platforms [27]. Ray-tracing-seeded machine-learning models have also been benchmarked against COST-231 Hata, Longley–Rice and close-in models in suburban bands [28], and artificial neural networks have been trained on multi-route rural measurement campaigns [29] Antenna height has itself been shown to materially alter the fitted propagation model, reinforcing the need to document the receive configuration [30]. Where refractivity is the dominant driver, data-driven formulations that model it directly have also been proposed [30][24].

Beyond the Okumura–Hata family, ITU-R P.1546 provides point-to-area field-strength prediction for the 30 MHz–3 GHz range and has been applied specifically to analogue FM broadcasting. Su compared P.1546 predictions with measured field strength over a 360° azimuth range from 2 km to 120 km, confirmed the method's validity, and recommended finer terrain databases, explicit urban/suburban/rural classification and locally measured refractivity gradients to improve accuracy [31]. Suh et al. derived field-strength prediction for digital television receivers from P.1546 and reported divergence from the Okumura–Hata model of about 6.8–11.5 % under dense-urban conditions [32][33]. The recommendation has also been implemented with supplementary transmitter parameters in simulator form [34] and applied to analogue-to-digital conversion planning [35].

GIS has been used to embed terrain and clutter data into field-strength and path-loss prediction for broadcast planning [36], including systems that couple GIS directly to the ITU-R P.526 diffraction model [37] and web-based three-dimensional coverage simulation for terrestrial broadcasting networks [38]. The accuracy of such methods depends on the terrain representation: triangulated irregular networks can capture sudden surface changes that regular grid models miss, yielding more accurate path profiles and path-loss estimates [39]. Wagen and Rizk show that building databases and terrain data are central to urban planning accuracy, and that roughly 1 m coordinate accuracy at building corners is acceptable for coverage prediction [40].

Field-strength determination from a spectrum analyser requires the antenna factor, which converts the voltage at the analyser input to the field strength in the antenna's polarisation plane [41]; its correct use presupposes knowledge of the calibrating field, the cable loss and any preamplifier gain [42][43]. [44] formalises the relationship between antenna gain and antenna factor for EMC applications. Antenna-factor uncertainty dominates the uncertainty budget of emission measurements [45], and while broadband antennas in the 30 MHz–1 GHz range were once calibrated to about ±2 dB, sub-±0.5 dB calibration is now attainable [46], with standard-antenna methods on an open-area test site achieving a standard uncertainty of 0.4 dB [47]. Uncertainty budgets for antenna factor have been established for both log-periodic and monopole antennas[48], and antenna-factor selection has itself been used to reduce measurement instrument uncertainty below CISPR limits [49]. These considerations set the traceability requirements against which the measurement chain of the present study is assessed.

Nigerian spectrum governance involves the Ministry of Information and Communications, the National Frequency Management Council, the Nigerian Communications Commission and the National Broadcasting Commission, and frequency assignment relies on propagation planning to avoid impairment and interference [50]. Regulation across Africa is characterised by nationally distinct frameworks overseen by national regulatory authorities [51]; in Nigeria specifically, monitoring, licensing, sanctioning and arbitration are the principal regulatory instruments [52][53]. Spectrum-management reform is an active area across West Africa, with dynamic sharing frameworks proposed to improve efficiency of use [54]. Coverage assessment against a minimum field strength therefore sits directly within a broadcaster's regulatory obligations.

The tropospheric refractivity regime over Osogbo has itself been characterised, and its influence on field strength and radio-horizon distance quantified for the location [55]. However, the field-strength and propagation behaviour of the broadcasting stations that operate within that regime has not, to the authors' knowledge, been characterised. Existing Nigerian studies address Uyo, Adamawa, Akure, Ekiti, Lagos/Badagry, Abeokuta and Niger State, and are either multi-station city surveys or single-station model derivations; limited attention has been given to FM propagation from a specific state broadcasting station in Osogbo, and even less to the application of an Extended Hata–Okumura formulation at this frequency and location. Practical field measurement is, moreover, essential if the applicability of established prediction models to a specific environment such as Osogbo is to be tested rather than assumed. This is the gap the present study addresses.

OSBC Radio transmits at 104.5 MHz from Oke Baale, Osogbo, with a 100 W transmitter and a 340 m mast serving a state capital whose terrain combines an elevated urban core, a river corridor and peripheral rural roads. The combination of a known transmitter configuration, a compact and varied service area, and an established regulatory field-strength criterion makes the station well suited to a site-specific empirical study. A single radial profile cannot, however, separate distance dependence from environmental dependence. The present study therefore sampled four routes selected to represent distinct environments; a relatively open rural road, an open corridor along the Osun River, a densely built-up commercial route, and a mixed urban/semi-urban route that route-to-route variability can be observed directly rather than inferred.

This study accordingly provides a site-specific empirical characterisation of the 104.5 MHz OSBC FM signal in Osogbo using measurements along four geographically and environmentally distinct road routes, evaluates the distance-dependent attenuation and route-to-route variability, and examines the applicability of an Extended Hata–Okumura formulation to the measured propagation environment. It additionally provides a route-specific assessment of the measured signal level against the applicable NBC field-strength criterion. The specific objectives are to: (i) measure the received level along four routes at 1 km intervals; (ii) quantify distance-dependent attenuation and route-level statistics; (iii) predict path loss with the Extended Hata–Okumura model and compare prediction with measurement; and (iv) evaluate the measured levels against the NBC minimum field strength for VHF-FM urban service.

2. MATERIALS AND METHOD

2.1 Study Design

The study adopted an experimental, quantitative design to evaluate the variation in signal strength and the propagation characteristics of the FM signal radiated by the Osun State Broadcasting Corporation station in Osogbo, Osun State, Nigeria. The eHata model, an extension of the Hata-Okumura model that widens applicability to 30–3000 MHz by incorporating corrections for terrain and environmental conditions such as hills, ridges and mixed land–sea paths were selected for its suitability to the FM broadcast band, for urban,

suburban and rural scenarios, and for its ease of empirical verification using MATLAB. The design combined field measurement of received signal strength along four routes with point-to-point coverage prediction, after which the measured data were validated against model-predicted path loss. Transmitter input data (geographic coordinates, conductivity, relative ground permittivity) and receiver input data (antenna height above ground, receiver sensitivity) were used to perform the model analysis.

2.2 Study Area

The study area spans part of south-western Nigeria, selected because of its diverse terrain features, thereby capturing the influence of the environment on radio wave propagation. Osun State lies between Longitude 7.30°N, Latitude 4.30°E and Longitude 7.50°N, Latitude 4.50°E, bounded in the north by Kwara State, in the east partly by Ekiti and Ondo States, in the south by Ogun State and in the west by Oyo State as shown in Figure 1. Over thirty radio stations broadcast in the VHF band in the state; the OSBC station at a centre frequency of 104.5 MHz was chosen because of the high strength of its transmitter signal, its coverage of the state with extension into neighbouring states, and its central location in the state capital.

The transmitter's coverage area was divided into four quadrants, with the transmitter at the convergence of the four. Each quadrant is treated as a direction/route from the transmitter, with one test site per quadrant at distances of 1 km to 6 km from the transmitter. Owing to road network accessibility, exact NE, NW, SW and SE alignment was not always achievable, particularly within the first kilometre of the transmitting station, so the same directions were used for the first kilometres on some routes. Table 1 summarises the station and receiver characteristics.

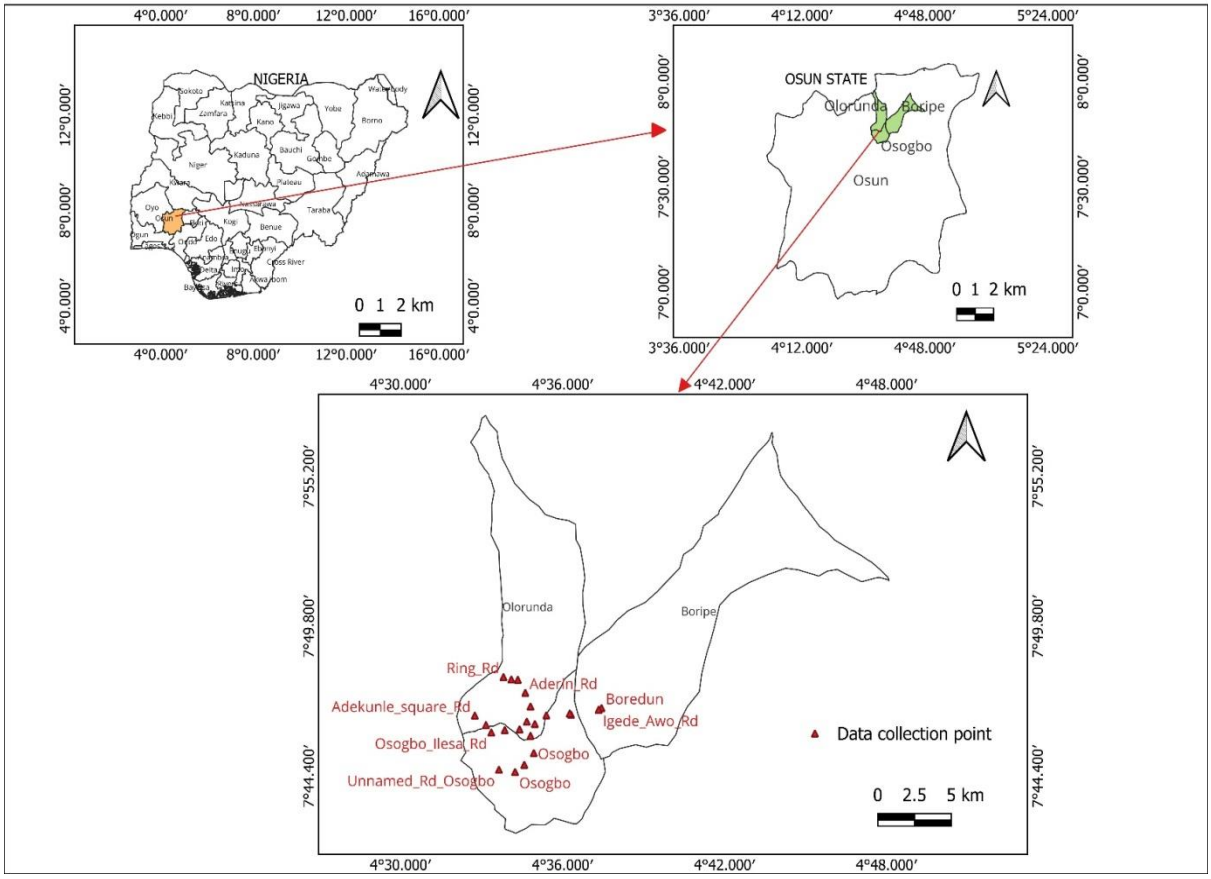


Figure 1: Map showing the data collection area

The parameters of the transmitting station used in this study is shown in Table 1.

Table 1: Parameters of the transmitting station

Parameter	Specification
Base station's geographical coordinate	Latitude N 7° 46'35 Longitude E 4°35''23
Base station frequency	104.5 MHz
Base station transmitting power	100 W
Height of the transmitting mast	340 m
Height of receiving antenna	1.51m

Receiving antenna gain	2.51 dB

2.3 Data Collection

Data collection occurred during both daytime and evening periods to evaluate diurnal variations in signal strength over three weeks. The primary tool was a portable hand-held Spectrum Analyzer with an in-built GPS unit, used to collect electric field strength and geographical coordinates at regular distance intervals along each route. The receiving antenna was connected to the analyzer and the setup installed on a vehicle that stopped at every marked 1 km location for a few minutes to allow the analyzer to scan and log the station's parameters effectively. Measurement data received signals at specific distances, terrain elevation and geo-location details were downloaded via a USB storage card into a computer in spreadsheet format for further processing.

The routes were chosen for ease of access and to reflect human habitation. The full description of the routes is presented in Table 2. Measurements focused on the FM band (87.5–108 MHz), with 104.5 MHz as the centre frequency.

Table 2: Routes direction for the field work

Route	Direction	Description
Route 1	OSBC-Ibokun road	Rural areas with lower population density. Less obstructed environment.
Route 2	OSBC-Osun River	Open spaces with river along the path
Route 3	OSBC-Stadium ring road	This route traverses through a densely built-up area, including commercial zones.
Route 4	OSBC-Oja Oba-Olaiya	This route covers a mix of urban and semi-urban areas with various buildings that may cause signal diffraction and attenuation.

2.4 Measurement Equipment and Configuration

The equipment comprised a Spectrum Analyzer N9342C Agilent (100 Hz–7 GHz) with in-built GPS, a laptop running signal analysis software, and a Diamond RH799 receiving antenna. Table 3 gives the analyzer configuration and antenna properties.

Table 3: Spectrum analyzer configuration and receiving antenna properties

Parameter	Value
Displayed Average Noise Level	−164 dBm/Hz
Preamplifier	ON
Resolution Bandwidth	10 kHz
Impedance	50 Ω
Attenuation	0.00 dB
Span	1.0 MHz
Sweep	3.407 ms
Antenna frequency range	70 MHz–1 GHz
Antenna form	Omnidirectional
Antenna height	1.5 m
Antenna gain	2.5 dB

2.5 Path Loss Modelling

Path loss was estimated using the extended Hata-Okumura (eHata) model, which incorporates additional correction factors to improve prediction accuracy across different terrains and operating conditions. In the form used for the computations:

Path loss was estimated using the extended Hata-Okumura (eHata) model, which incorporates additional correction factors to improve prediction accuracy across different terrains and operating conditions.
In the form used for the computations:

$$PL = 69.55 + 26.16\log_{10}(f) - 13.82\log_{10}(h_b) - a(h_r) + [44.9 - 6.55\log_{10}(h_b)]\log_{10}(d)$$

where:

- PL= median path loss (dB)
- f= frequency (MHz)
- h_b= effective transmitter/base-station antenna height (m)
- h_r= receiving/mobile antenna height (m)
- $a(h_r)$= receiver antenna-height correction factor (dB)
- d= transmitter-to-receiver distance (km)

The general eHata path loss form and the mobile antenna correction factor applied were:

$$PL_{50} = 46.3 + 33.9\log_{10}(f) - 13.82\log_{10}(h_b)\& - a(h_m) + [44.9 - 6.55\log_{10}(h_b)]\log_{10}(d) + C$$

The mobile/receiving antenna height correction factor is:

$$a(h_m) = [1.1\log_{10}(f) - 0.7]h_m - [1.56\log_{10}(f) - 0.8]$$

Where

PL_{50} = median path loss (dB),
f = frequency (MHz),
h_b = effective transmitter antenna height (m),
h_m = receiving/mobile antenna height (m),
d = transmitter-to-receiver distance (km),
$a(h_m)$ = mobile antenna height correction factor (dB),
C = environmental correction factor (dB).

Parameter values were f = 104.5 MHz, h_b = 340 m, h_m = 1.5 m, d = 1–6 km, and C = 3 dB for the urban environment.

3. RESULTS AND DISCUSSION

3.1 Results

In broadcasting systems, one of the primary tasks is to estimate the coverage area and evaluate the path loss resulting from the interaction of radio waves with the surrounding environment. Determining the propagation curve or profile is one of the approaches used to achieve this. Prediction of path loss is an important element of system design in any communication systems especially in radio and television broadcast. (Armoogun V., et al, 2010) Thus this work is apt at this point due to the novel results it presented, which would be useful for coverage areas prediction and path loss determination of radio waves of an FM broadcasting station in the study areas. Table 4 present the Electric Field Strength and other data samples recorded at multiple point along each of the route 1 to 4.

Table 4: Measured elevation and electric field strength across the four measurements.

S/No	Distance (km)	Elevation (m)				Electric Field Strength (dBµV/m)			
		Route 1	Route 2	Route 3	Route 4	Route 1	Route 2	Route 3	Route 4
1	0.00	361	345	345	345	70.36	73.87	75.13	71.81
2	1.00	354	340	329	340	49.33	43.52	47.25	51.21
3	2.00	348	341	338	310	34.63	33.13	19.34	26.25
4	3.00	346	328	340	361	25.99	27.06	25.75	8.79
5	4.00	344	334	320	327	18.67	39.49	22.87	44.91
6	5.00	346	329	330	317	18.95	35.55	15.48	31.83
7	6.00	344	321	321	320	16.72	22.48	28.37	7.46

On Route 1, as shown in Figure 2, electric field strength dropped from 70.36 dBµV/m at the base station to 49.33 dBµV/m at the next point yielding a decrease of 30% and continued downward to 16.72 dBµV/m at the final point. Elevation varied only between 361 m and 344 m, indicating relatively flat terrain unlikely to significantly affect propagation. The route exhibited the smoothest attenuation pattern overall, with a 76% reduction in signal strength, indicating relatively fewer propagation obstacles.

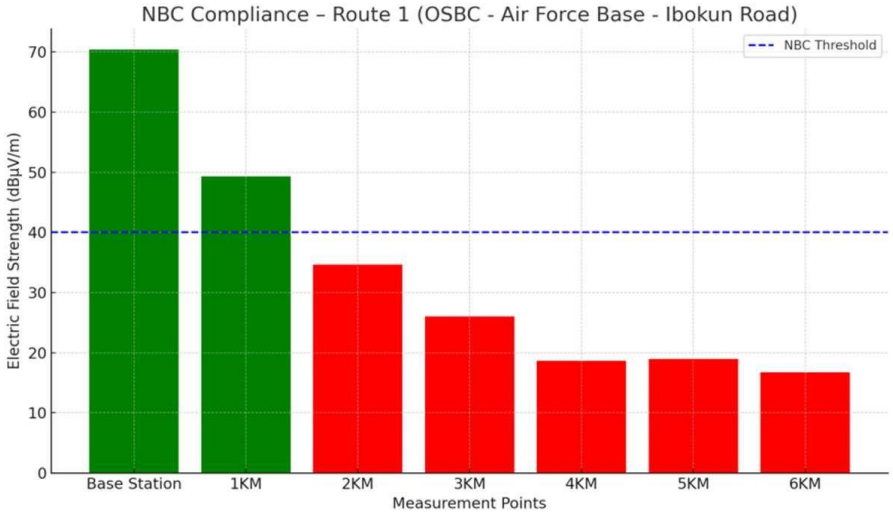


Figure 2: NBC Compliance – Route 1 (OSBC – Air Force – Ibokun Road)

Route 2 (Ilesa Garage–Osun River) as presented in Figure 3 showed an initial decline from 73.87 dBm (345 m elevation) to 43.52 dBµV/m (340 m), a significant drop of 41%, followed by notable fluctuations, an increase at the fifth point (39.59 dBµV/m at 334 m) before dropping at the sixth (35.53 dBµV/m at 329 m) and stabilising to 22.48 dBm at the final point. Altitude declined consistently from 345 m to 321 m, a total drop of 27 m (8%), yet the signal did not follow a simple altitude relationship. The sharp initial drop indicates high near-field attenuation from urban obstacles or vegetation, while the recovery at the fifth kilometre is attributable to reflections or signal reinforcement from nearby surfaces or terrain characteristic of multipath propagation, in which signals take different paths to the receiver, producing constructive or destructive interference. The route's more complex propagation characteristics are likely influenced by the proximity of the Osun River, which may cause reflections and diffraction, and by urban structures or vegetation density along the Ilesa Garage stretch. Route 2 experienced a 70% reduction overall but displayed moderate fluctuations attributed to reflections from nearby urban structures and the Osun River.

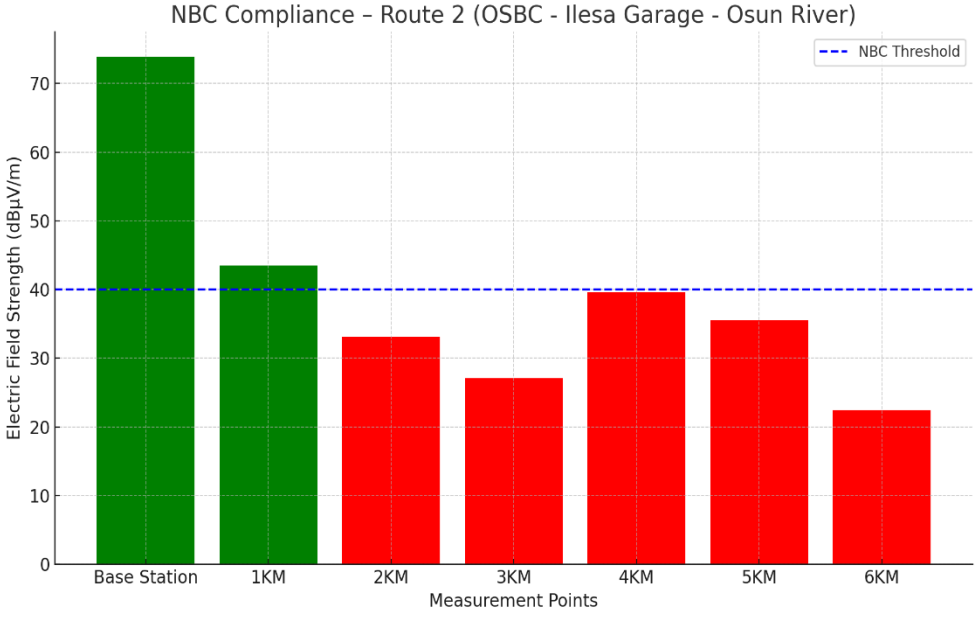
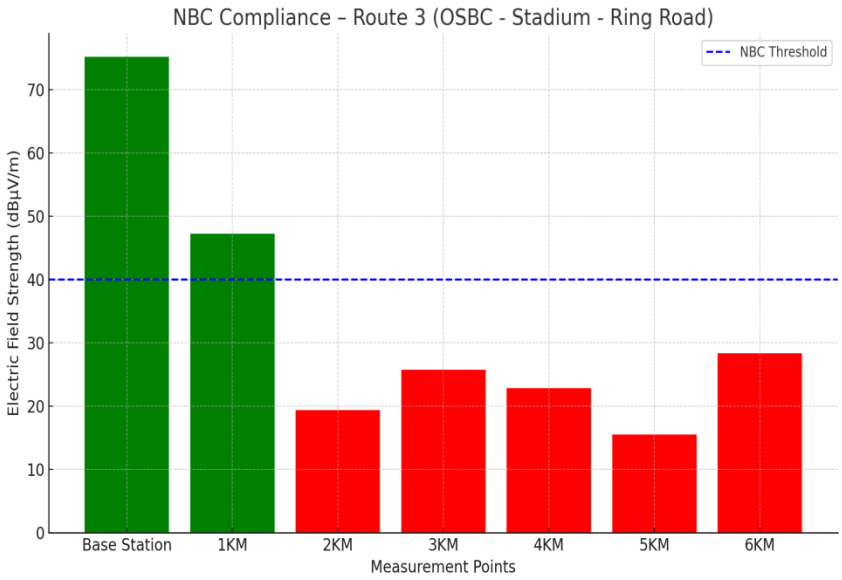


Figure 3: NBC Compliance – Route 2 (OSBC – Ilesa Garage – Osun River)

Route 3 (OSBC–Stadium–Ring Road) as shown in Figure 4 began with an initial steep decline from 75.13 dBµV/m (345 m) to 47.25 dBµV/m (329 m), a decrease of 37%, characteristic of free-space loss combined with near-field obstructions such as buildings or vegetation. Significant fluctuations followed: a sharp drop between the second (47.25 dBµV/m) and third points (19.34 dBµV/m), partial recovery at the fourth (25.75



dBµV/m), a further low of 15.48 dBm at the sixth point, and a slight increase to 28.37 dBµV/m at the final point. The recovery at the final point occurred at a relatively low altitude of 321 m, while the drop from 47.25 dBµV/m to 19.34 dBµV/m between the second and third points occurred despite an increase in altitude from 329 m to 338 m, indicating weak altitude–signal correlation and the dominance of localised factors such as reduced obstructions, open terrain, or reflective surfaces enhancing propagation. The route recorded a 62% reduction overall with pronounced fluctuations characteristic of multipath propagation.

Figure 8: NBC Compliance – Route 3 (OSBC – Stadium – Ring Road)

Route 4 (OSBC–Oja Oba–Isale Aro–Ola Iya) as presented in Figure 5 recorded an initial 29% reduction from 71.81 dBµV/m (345 m) to 51.21 dBµV/m (340 m), consistent with free-space path loss and near-field obstructions, followed by an extreme drop of 49% from 51.21 dBµV/m to 26.25 dBµV/m (310 m), compounded by a substantial 33 m altitude reduction suggestive of increased attenuation through diffraction or terrain blockage. Signal strength then fell sharply to its lowest value of 8.79 dBµV/m at the fourth point despite an increase in altitude from 310 m to 361 m attributed to shadowing effects from terrain or buildings and high levels of interference or absorption by obstacles along the route. This route showed the most severe attenuation, with a 90% reduction driven by terrain obstructions, shadowing, diffraction and interference. Route 4 shows the most severe attenuation (90%) and highest variability, indicating challenging propagation conditions, while the Air Force Base–Ibokun road has the smoothest attenuation curve, suggesting fewer obstructions. The Ilesa Garage–Osun River and Stadium–Ring Road routes show notable fluctuations reflecting the impact of urban structures, water bodies and multipath propagation, and changes in altitude do not strongly correlate with electric field strength across all routes

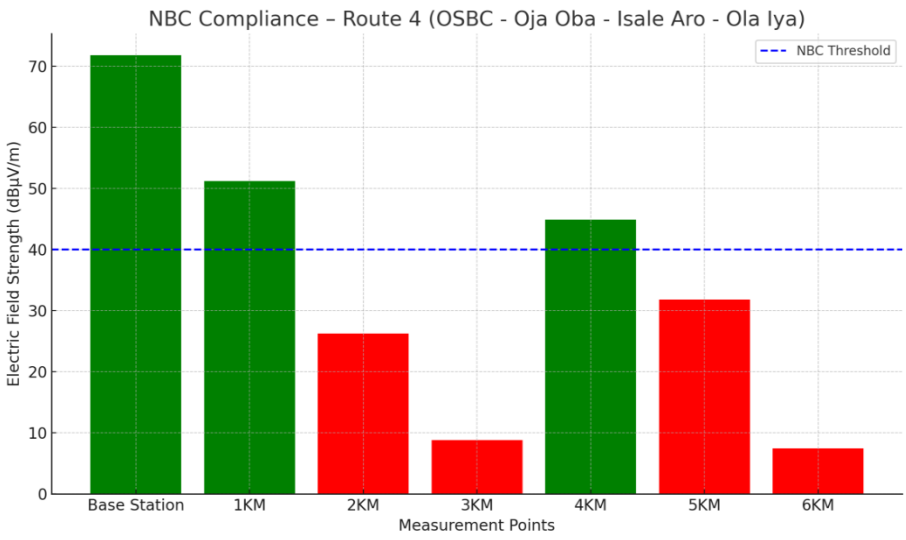


Figure 5: NBC Compliance – Route 4 (OSBC – Oja Oba – Isale Aro – Ola Iya)

The Nigerian Broadcasting Corporation regulates minimum and maximum field strength levels for proper radio and TV signal transmission. Typical standards specify a minimum of 50 dBμV/m and an optimal 70–80 dBμV/m for urban areas, and a 40–50 dBμV/m minimum for clear reception in suburban and rural areas.
Route 1 started strong at 70.36 dBμV/m but dropped to 16.72 dBμV/m at 6 km, falling below 40 dBμV/m after 3 km, which is non-compliant. Route 2 started at 73.87 dBμV/m and dropped to 22.48 dBμV/m at 6 km. Route 3 started at 75.13 dBμV/m, fluctuated, and ended at 28.37 dBμV/m, dropping too low after 2 km and violating urban/suburban broadcast standards; Route 4 started at 71.81 dBμV/m but dropped to 7.46 dBμV/m at 6 km, showing the worst performance with severe signal degradation.
Across all routes, signal strength failed to comply with NBC standards beyond 2–3 km. Where the NBC standard is implemented, minimum field strength should not drop below 40 dBμV/m, but in all cases it fell far below that threshold after a few kilometres, suggesting either signal attenuation, interference, or inadequate transmission power. Table 5 summarises the first-to-last signal change across all routes.

Table 5: Summary of collected data across the four routes

Route	Initial EFS (dBμV/m)	Final EFS (dBμV/m)	Net change	Key observations
1	70.36	16.72	76% reduction	Smooth signal attenuation with minor fluctuations, suggesting limited obstacles
2	73.87	22.48	70% reduction	Fluctuations due to environmental factors (e.g., river proximity, urban effects)
3	75.13	28.37	62% reduction	Pronounced fluctuations indicating significant multipath propagation effects
4	71.81	7.46	90% reduction	Severe attenuation with sharp drops and recovery, reflecting complex obstructions

Table 6 presents the descriptive analysis of signal strength across routes. Route 2 recorded the highest mean signal strength (39.31 dBμV/m), indicating relatively better signal reception along this path, while the other routes had comparable mean values with slight variations. Route 4 (OSBC–Oja Oba–Isale Aro–Ola Iya) had the highest standard deviation (21.54 dBμV/m), indicating greater variability, whereas Route 2 had the most consistent signal strength with the lowest standard deviation (15.57 dBμV/m). Route 4 also exhibited the largest range (64.35 dBμV/m) and highest variance (463.84 dBμV/m), supporting the observation of wide fluctuations, while Route 2 had the smallest range (51.39 dBμV/m) and smallest variance (242.57 dBμV/m), reaffirming its stability.

Table 6: Descriptive analysis of signal strength by route

Route	Mean (dBμV/m)	Std. deviation (dBμV/m)	Range (dBμV/m)	Variance (dBμV/m)
1	33.52	18.44	53.64	340.02
2	39.31	15.57	51.39	242.57
3	33.46	19.44	59.65	378.10
4	34.61	21.54	64.35	463.84

Path loss was calculated using the eHata model, which is commonly used for urban and suburban environments and incorporates additional correction factors to improve prediction accuracy over different terrains and operating conditions. The model was used to predict the expected path loss at different measurement locations and presented in Table 7. These predicted values were converted into predicted received signal strength and plotted against distance to produce the predicted propagation curve.
The model estimates signal loss based on distance from the transmitter and environmental factors such as terrain. Path loss increased with distance on all four routes, with predicted values ranging from 61.10 dBm to 85.72 dBm. Table 7 presents the computed path loss values.

Table 7: eHata path loss model results for the four routes

Distance (km)	Path loss(dB)			
	Route 1	Route 2	Route 3	Route 4
1	61.10	68.42	71.29	73.51
2	74.82	74.00	75.57	75.26
3	76.10	76.89	79.28	79.01
4	80.36	78.20	80.42	80.82
5	80.94	78.91	80.60	85.49

6	81.32	82.36	82.71	85.72

The measured and the predicted curves are then compared. A close agreement between the two curves indicates that the model accurately represents the propagation characteristics of the study area. Significant differences indicate the influence of local terrain, vegetations, buildings or atmospheric conditions that are not fully accounted for by the model.

The propagation curves provided insight into attenuation characteristics of these radio signals as they propagate through different environments along the chosen four routes.

The path loss values were plotted against distance alongside with the propagation curves which were presented in Figures 6,7,8 and 9.

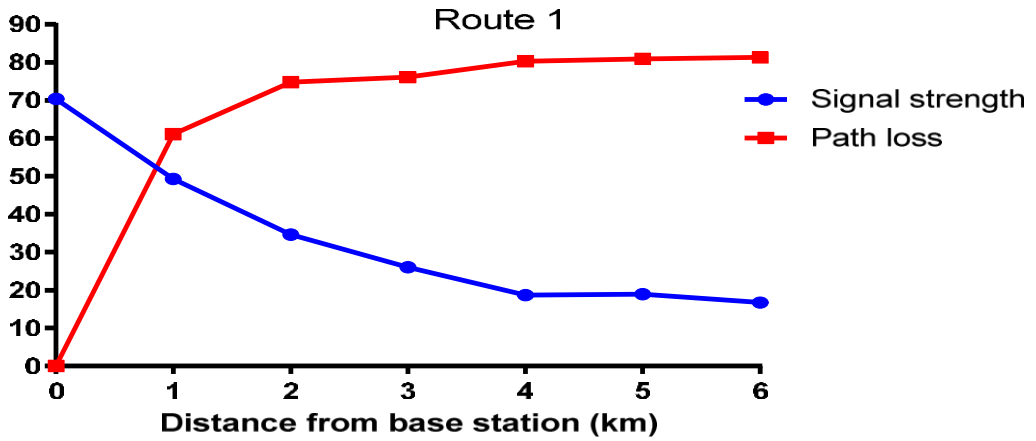


Figure 6: Propagation curve: Signal strength (dB) and path loss (dB) against distance (LoS) for route 1

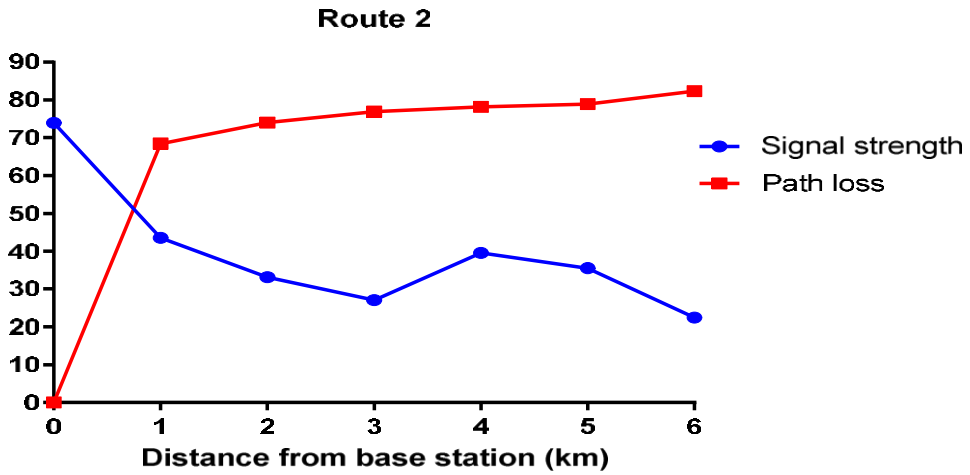


Figure 7: Propagation curve: Signal strength (dB) and path loss (dB) against distance (LoS) for route 2

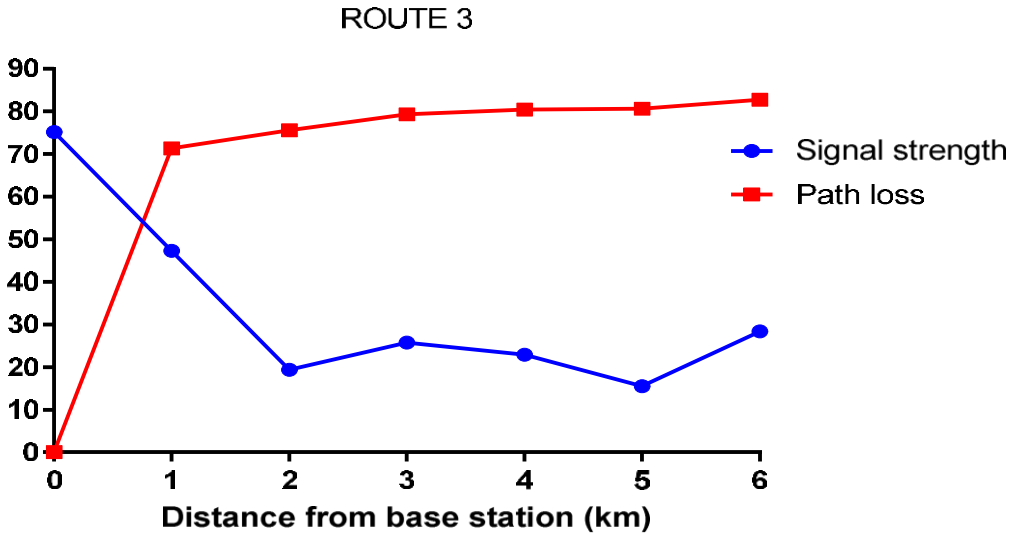


Figure 8: Propagation curve: Signal strength (dB) and path loss (dB) against distance (LoS) for route 3

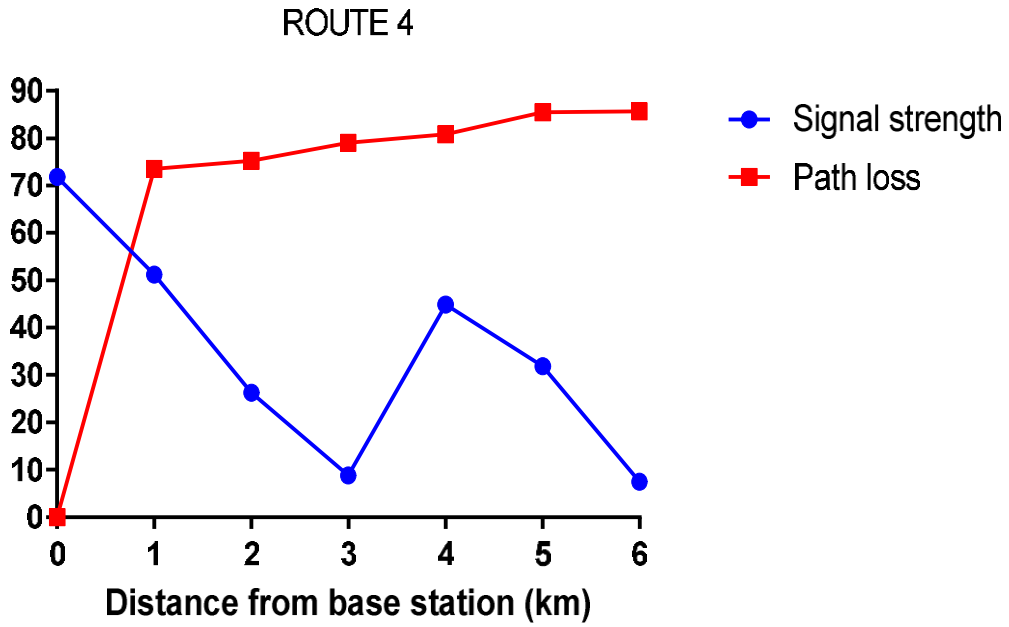


Figure 9: Propagation curve: Signal strength (dB) and path loss (dB) against distance (LoS) for route 4

3.2 Discussion of results

The results confirm that environmental factors play a crucial role in FM signal propagation in Osogbo. Urban areas experienced higher signal attenuation as a result of interference from buildings, multipath propagation and diffraction effects, causing significant signal degradation particularly at distances greater than 2–3 km from the transmitter, while semi-urban areas exhibited moderate signal strength variation, where minor obstacles such as low-rise buildings and vegetation caused moderate attenuation. The path loss calculations based on the eHata model validated the field measurements and provided a theoretical framework for understanding FM signal behaviour.

The route-level patterns align with recognised propagation mechanisms. The smoothest attenuation curve on the Air Force Base–Ibokun route reflects a comparatively unobstructed rural path, whereas the pronounced fluctuations along the Stadium–Ring Road and Ilesa Garage–Osun River routes are signatures of multipath propagation and reflective water bodies. The most severe attenuation on the Oja Oba–Isale Aro–Ola Iya route points to the dominant role of terrain obstruction, shadowing and interference, reinforced by the collapse of signal strength to 8.79 dBm at a point of higher elevation, evidence that shadowing and absorption, rather than elevation alone, govern reception in that corridor. The weak, non-monotonic altitude–signal relationship across routes supports this reading: distance, obstruction and interference dominate over altitude in determining received strength.

The descriptive statistics add a distinct dimension. Route 4's variance of 463.84 dBm and range of 64.35 dBm mark it as the most unstable propagation environment, whereas Route 2's combination of the highest mean signal strength (39.31 dBm), lowest standard deviation (15.57 dBm) and smallest variance (242.57 dBm) identifies it as the most stable, despite its 70% net reduction. This distinction is practically significant a route can suffer substantial total attenuation yet remain relatively predictable, while another can retain a comparable mean while behaving erratically and location-sensitively, which is far harder to plan around.

Structural differences between routes also explain divergence from the smooth expectations of free-space behaviour. Urban corridors produced substantial signal degradation through building density, multipath interference and the urban canyon effect, while mid-route recoveries the 39.59 dBm reading at the fifth kilometre on Route 2 and the 28.37 dBm reading at the final point on Route 3 reflect constructive interference or reduced obstruction rather than genuine coverage improvement. The eHata model's increasing predicted path loss tracked the measured decline but did not reproduce these localised fluctuations, underscoring the value of empirical field validation alongside model-based prediction in complex terrain.

The compliance analysis carries the clearest regulatory implication. Although signal levels at the transmitting station complied with recommended limits, all routes failed to maintain the minimum acceptable level, with signal strength falling below the required 40 dBm threshold within 2 to 3 km of the transmitter in every case Given a transmitter operating at 100 W with a 340 m mast, the early and steep attenuation is not fully explained by distance alone; the contributions of near-field obstruction, multipath and interference indicate that the current broadcasting infrastructure does not meet national standards, likely because of inadequate transmission power and significant environmental interference. These findings underscore the necessity for

optimised network planning, improved signal propagation strategies and potential infrastructure upgrades to ensure reliable FM radio service throughout the region.

4. CONCLUSION

The findings of this research confirm that environmental factors play a crucial role in determining FM signal propagation. The measured routes exhibited different attenuation and variability characteristics. The route classified as mixed urban/semi-urban exhibited the largest observed signal-level range and standard deviation, whereas the route through more open surroundings exhibited lower variability. These differences are consistent with possible contributions from local obstruction, diffraction, multipath and terrain, although the present measurements do not permit these factors to be isolated independently.

Rural areas experience minimal signal loss due to fewer obstructions and relatively open terrain, leading to more stable signal propagation over larger distances. The path loss calculations based on the Extended Hata-Okumura model validated the field measurements and provided a theoretical framework for understanding FM signal behaviour. The study highlighted the importance of transmitter placement, power, and antenna height for improving coverage, particularly in urban settings.

REFERENCES

[1] Morris S and William O (1973), Essentials of Communication Electronics, pp. 2-4 McGrawHill

[2] Bean B R and Dutton E J (1968), Radio Meteorology, pp. 1-22, Dover Publications Inc., New York.

[3] Bothias,L. Radio Wave Propagation,McGraw-Hill Inc.New York St. LouisSanFrancisca Montreal Toronto. Pp. (1987)

[4] Hall, M. P. M. and Barclay, L. W. (1991): Radio Wave Propagation, Peter Peregrinus Ltd, London, United Kingdom, pp. 23-60.

[5] Eichie, J. O., Oyedum, O. D., Ajewole, M. O., Adediji, A. T., Igwe, K. C., & Moses, A. S. (2015). Spatial Variability of VHF FM Radio Signals with Surface Refractivity Values in Niger State, Nigeria. *Journals & Books Hosting (International Knowledge Sharing Platform)*, *44*, 99–106. http://iiste.org/Journals/index.php/APTA/article/view/23037

[6] Ladan, M. B., David, O. O., Yabagi, J. A., Babakacha, N., Kimpa, M. I., Doko, M. B., Saba, A., Umar, S., & Cummings, F. (2021). Study of Seasonal Surface Refractivity over North-Central Nigeria. *Physics Access*, *1*(2), 5–13. https://doi.org/10.47514/phyaccess.2020.1.2.002

[7] Ibrahim, U. M., Musa, B., & Lawal, M. (2024). Estimating the Variability of Tropospheric Radio Refractivity and Field Strength over Enugu, South-East Nigeria. *International Journal of Science for Global Sustainability*, *10*(2), 251–257. https://doi.org/10.57233/ijsgs.v10i2.678

[8] Ekah, U., Adeniran, A., & Shogo, O. (2022). Spatial distribution of frequency modulated signals in Uyo, Nigeria. *World Journal of Advanced Engineering Technology and Sciences*, *5*(1), 39–46. https://doi.org/10.30574/wjaets.2022.5.1.0027

[9] Yusuf, S. D., & Musa, Y. D. (2026). Empirical and Measured Analysis of FM Signal Attenuation at 91.1 MHz and 101.5 MHz in Adamawa State, Nigeria. *Physical Science International Journal*, *30*(2), 44–54. https://doi.org/10.9734/psij/2026/v30i2933

[10] Olasoji, Y. O., & Oyetunji, S. a. (2020). Propagation Path Loss Model for FM radio Stations in South West, Nigeria. 14(1), 8-16. http://futajeet.com/index.php/jeet/article/view/228

[11] Oyetunji, O. S. A. (2013). Determination of Propagation Path Loss and Contour Map for FUTA FM Radio Federal University of Technology, Akure Nigeria. *IOSR Journal of Electronics and Communication Engineering*, *6*(3), 4–9. https://doi.org/10.9790/2834-0630409

[12] Fagbohun, O. O. (2014). Studies on Electric field strength distribution of uhf television signal propagation in Ekiti State. Nigeria. *IOSR Journal of Electronics and Communication Engineering*, *9*(2), 111–121. https://doi.org/10.9790/2834-0925111121

[13] Faruk, N., Abdulrasheed, I. Y., Surajudeen-Bakinde, N. T., Adetiba, E., Oloyede, A. A., Abdulkarim, A., Sowande, O. A., Ifijeh, A. H., & Atayero, A. A. (2021). Large-scale radio propagation path loss measurements and predictions in the VHF and UHF bands. *Heliyon*, *7*(6). https://doi.org/10.1016/j.heliyon.2021.e07298

[14] Akinbolati, A., & Ajewole, M. O. (2020). Investigation of path loss and modeling for digital terrestrial television over Nigeria. *Heliyon*, *6*(6). https://doi.org/10.1016/j.heliyon.2020.e04101

[15] Ilori, A. O., Amusa, K. A., Erinosho, T. C., & Idowu, O. A. (2025). Investigation of the Effects of Weather Variability on Surface Radio Refractivity and Digital Terrestrial Television Signal Strength in the UHF Band. *JOURNAL OF HIGH-FREQUENCY COMMUNICATION TECHNOLOGIES*, *3*(3), 339–348. https://doi.org/10.58399/mvsd5314

[16] Popoola, S. I., Atayero, A. A., Faruk, N., Calafate, C. T., Adetiba, E., & Matthews, V. O. (2017). Calibrating the Standard Path Loss Model for Urban Environments using Field Measurements and Geospatial Data. *Covenant University Repository (Covenant University)*.

[17] Hata, M. (1980). Empirical formula for propagation loss in land mobile radio services. *IEEE Transactions on Vehicular Technology*, *29*(3), 317–325. https://doi.org/10.1109/t-vt.1980.23859

[18] Medeišis, A., & Kajackas, A. (2002). *On the use of the universal Okumura-Hata propagation prediction model in rural areas*. *3*, 1815–1818. https://doi.org/10.1109/vetecs.2000.851585

[19] Jawhly, T., & Tiwari, R. C. (2020). The special case of Egli and Hata model optimization using least-square approximation method. *SN Applied Sciences*, *2*(7). https://doi.org/10.1007/s42452-020-3061-0

[20] Popoola, S. I., Adetiba, E., Atayero, A. A., Faruk, N., & Calafate, C. T. (2018). Optimal model for path loss predictions using feed-forward neural networks. *Cogent Engineering*, *5*(1), 1444345. https://doi.org/10.1080/23311916.2018.1444345

[21] Zhang, J., Gentile, C., & Garey, W. (2019). On the Cross-Application of Calibrated Pathloss Models Using Area Features: Finding a way to determine similarity between areas. *IEEE Antennas and Propagation Magazine*, *62*(1), 40–50. https://doi.org/10.1109/map.2019.2943272

[22] Popoola, S. I., Atayero, A. A., & Faruk, N. (2017). Received signal strength and local terrain profile data for radio network planning and optimization at GSM frequency bands. *Data in Brief*, *16*, 972–981. https://doi.org/10.1016/j.dib.2017.12.036

[23] Alobaidy, H. A. H., Singh, M. S. J., Behjati, M., Nordin, R., & Abdullah, N. F. (2022). Wireless Transmissions, Propagation and Channel Modelling for IoT Technologies: Applications and Challenges. *IEEE Access*, *10*, 24095–24131. https://doi.org/10.1109/access.2022.3151967

[24] Javeed, S., Alimgeer, K. S., Javed, W., Atif, M., & Uddin, M. (2018). A modified artificial neural network based prediction technique for tropospheric radio refractivity. *PLoS ONE*, *13*(3). https://doi.org/10.1371/journal.pone.0192069

[25] Vasudevan, M., & Yüksel, M. (2024). Machine Learning for Radio Propagation Modeling: A Comprehensive Survey. *IEEE Open Journal of the Communications Society*, *5*, 5123–5153. https://doi.org/10.1109/ojcoms.2024.3446457

[26] Gupta, A., Du, J., Chizhik, D., Valenzuela, R. A., & Sellathurai, M. (2022). Machine Learning-Based Urban Canyon Path Loss Prediction Using 28 GHz Manhattan Measurements. *IEEE Transactions on Antennas and Propagation*, *70*(6), 4096–4111. https://doi.org/10.1109/tap.2022.3152776

[27] Rafie, I. F. M., Lim, S. Y., & Chung, M. J. H. (2022). Path Loss Prediction in Urban Areas: A Machine Learning Approach. *IEEE Antennas and Wireless Propagation Letters*, *22*(4), 809–813. https://doi.org/10.1109/lawp.2022.3225792

[28] Tarhouni, F., Al-Zu'bi, M. M., & Alouini, M.-S. (2025). Machine Learning-based Path Loss Prediction in Suburban Environment in the Sub-6 GHz Band. *IEEE Transactions on Vehicular Technology*, 1–11. https://doi.org/10.1109/tvt.2025.3633604

[29] Ostlin, E., Zepernick, H., & Suzuki, H. (2010). Macrocell Path-Loss Prediction Using Artificial Neural Networks. *IEEE Transactions on Vehicular Technology*, *59*(6), 2735–2747. https://doi.org/10.1109/tvt.2010.2050502

[30] Shutimarrungson, N., & Wuttidittachotti, P. (2019). Realistic propagation effects on wireless sensor networks for landslide management. *EURASIP Journal on Wireless Communications and Networking*, *2019*(1). https://doi.org/10.1186/s13638-019-1412-6

[31] Su, H. (2013). Analysis and local application research on propagation prediction method for analogue FM broadcasting. *Chinese Journal of Radio Science*. https://en.cnki.com.cn/Article_en/CJFDTOTAL-DBKX201302031.htm

[32] Suh, K., Jung, H., & Lee, J.-H. (2010). The Prediction of Field Strength for DTV Receiver in the VHF and UHF Bands. *Journal of Broadcast Engineering*, *15*(6), 731–741. https://doi.org/10.5909/jbe.2010.15.6.731

[33] Suh, K., Jung, H., Lee, J.-H., & Jang, J.-S. (2010). *The calculation of field strength for DTV receiver by Rec. ITU-R P.1546*. 1–4. https://doi.org/10.1109/apace.2010.5719757

[34] Lee, K.-R., Choi, S.-W., Cha, J., & Kim, S.-K. (2011). ITU-R Rec. P.1546-3 Propagation Prediction model Simulator using additional transmitting parameter. *The Journal of the Korea Institute of Electronic Communication Sciences*, *6*(2), 157–162. https://doi.org/10.13067/jkiecs.2011.6.2.157

[35] Suh, K. (2011). A Consideration for Field Strength Analysis Based on Rec. ITU-R P.1546 Applicable to ATV to DTV Conversion. *Journal of Broadcast Engineering*, *16*(5), 824–833. https://doi.org/10.5909/jeb.2011.16.5.824

[36] Rong-shuang, F. (2007). Application of GIS in the analysis of field strength of radiowave propagation. *Cehui Kexue*. https://en.cnki.com.cn/Article_en/CJFDTOTAL-CHKD200706038.htm

[37] Zhang, C., Xiao, H., & Zheng, S. (2015). Prediction system about path loss of radio propagation based on GIS. *Proceedings of SPIE, the International Society for Optical Engineering/Proceedings of SPIE*, *9808*. https://doi.org/10.1117/12.2220610

[38] Kulawiak, M., Falkowski-Gilski, P., & Kulawiak, M. (2018). *DAB+ Coverage Analysis: a New Look at Network Planning using GIS Tools*. 327–331. https://doi.org/10.23919/spa.2018.8563396

[39] Yang, H. Y. (1997). A GIS approach for mobile telephone signal path-loss prediction. In *UTAS Research Repository*. https://doi.org/10.25959/23241818

[40] Wagen, J., & Rizk, K. (2003). Radiowave Propagation, Building Databases, and GIS: Anything in Common? A Radio Engineer's Viewpoint. *Environment and Planning B Planning and Design*, *30*(5), 767–787. https://doi.org/10.1068/b2958

[41] Agarwal, N. K., & Venkataramani, K. (2002). *Measurement of antenna factor-a case study*. 253–258. https://doi.org/10.1109/icemic.1997.669809

[42] Camell, D. G. (1991). *NIST calibration procedure for vertically polarized monopole antennas, 30 kHz to 300 MHz*. https://doi.org/10.6028/nist.tn.1347

[43] Celaya-Echarri, M., Azpilicueta, L., Karpowicz, J., Ramos, V., López-Iturri, P., & Falcone, F. (2020). From 2G to 5G Spatial Modeling of Personal RF-EMF Exposure Within Urban Public Trams. *IEEE Access*, *8*, 100930–100947. https://doi.org/10.1109/access.2020.2997254

[44] Trainotti, V. (2017). Electromagnetic Compatibility (EMC) Antenna Gain and Factor. *IEEE Transactions on Electromagnetic Compatibility*, *59*(4), 1006–1015. https://doi.org/10.1109/temc.2016.2642833

[45] Türetken, B., San, S. E., Yazici, M., Araz, İ., Yurekli, A. I., & Hekim, M. (2003). Evaluation of uncertainty budget for antenna calibrations. *International Conference on Mathematical Methods in Electromagnetic Theory*, *2*, 455–457. https://doi.org/10.1109/mmet.2002.1106960

[46] Alexander, M., Salter, M. J., Gentle, D. G., & Holland, K. P. (1994). Advances in measurement methods and reduction of measurement uncertainties associated with antenna calibration. *IEE Proceedings - Science Measurement and Technology*, *141*(4), 283–286. https://doi.org/10.1049/ip-smt:19941284

[47] Camell, D. G. (1998). *Uncertainty assessment for standard antenna measurements on the open area test site*. https://doi.org/10.6028/nist.tn.1507

[48] Dai, M., Ban, H., Meng, D., & Hao, D. (2025). Uncertainty Analysis of Antenna Factor at 1m distance for LPDA Antenna. *Journal of Physics Conference Series*, *2967*(1), 12005. https://doi.org/10.1088/1742-6596/2967/1/012005

[49] Bittera, M., Hallon, J., Szolik, I., & Harťanský, R. (2023). Alternative Approach Leading to Reduction in Measurement Instrument Uncertainty of EMI Measurement. *Measurement Science Review*, *23*(2), 64–71. https://doi.org/10.2478/msr-2023-0008

[50] Okorogu, V. N., L, A. T., P.E., O., & Emenike, C. J. (2016). Technical Overview of Frequency Assignment For Radio Broadcasting In Nigeria. *IOSR Journal of Electrical and Electronics Engineering*, *11*(5), 1–5. https://doi.org/10.9790/1676-1105010105

[51] Ezeigweneme, C., Umoh, A. A., Ilojianya, V. I., & Adegbite, A. O. (2024). Review of Telecommunication Regulation and Policy: Comparative Analysis USA And Africa. *Computer Science & IT Research Journal*, *5*(1), 81–99. https://doi.org/10.51594/csitrj.v5i1.703

[52] Ngozi, O. B., & Nzan-Ayang, M. A. (2023a). Evaluation of Conventional and Digital Broadcast Regulation: Challenges and Prospects in Nigeria. *International Journal of Sustainable Applied Sciences*, *1*(5), 569–582. https://doi.org/10.59890/ijsas.v1i5.590

[53] Ngozi, O. B., & Nzan-Ayang, M. A. (2023b). The challenges and Prospects of Digital Broadcast Regulation In Nigeria. *International Journal of Applied and Scientific Research*, *1*(4). https://doi.org/10.59890/ijasr.v1i4.1068

[54] Barkire, D. I., Koné, B., & Kora, A. D. (2026). *From Technical Validation to Policy Implementation: A Dynamic Spectrum Sharing Framework for 6G Networks in West Africa*. 1–11. https://doi.org/10.23919/icact68090.2026.11431316