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PERFORMANCE ANALYSIS AND DEVELOPMENT OF PATH LOSS MODEL FOR TELEVISION SIGNALS IN IMO STATE, NIGERIA

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It is impossible to overstate the importance of propagation models in wireless network planning, frequency assignment, and television parameter evaluation. The fact that no two locations are identical in terms of climatic conditions, building patterns, terrain, etc. makes using path loss predicting models for any area extremely challenging. Therefore, it is impossible to develop a single path loss model that applies to all environmental settings. The main aim of this study is to develop a path loss model for NTA channel 12 Owerri and evaluate its performance based on received signal strength values along five selected routes in Imo State, Nigeria. A suitable path loss model was developed by critically analyzing the measured path loss values of each base station, which were retrieved from the signal strength data received. The values of the developed path loss model were compared to those of other empirical path loss models developed by other researchers as well as the measured path loss values. The results show that the proposed path loss model is well suited for predicting the path loss of NTA channel 12 Owerri signals in the study environment, while the other conventional empirical models taken into consideration in this study overestimated the path loss of NTA channel 12 Owerri signals with Root Mean Square Error and Mean Error of 63.65 and above. Additionally, the findings indicate that NTA Owerri performs poorly at a distance of 18 kilometers from the base transmitting station. The overall findings are helpful for designing prospective television network channels in the study location and other similar environments.

Keywords: Path loss; Television; Path loss model; Received signal strength; Wireless network

Introduction

In today's world, the importance of wireless communications, particularly television (TV), cannot be overstated. According to data, more people than expected already use mobile devices to watch television in several nations [1]. Customers want a strong signal and good signal coverage for better viewing in these locations so they may obtain better information and other benefits of television. These television systems are utilized everywhere, both indoors and outdoors [2]. When designing the channel capacity, it is critical to take into consideration the environment in which the service will be provided to provide superior television services. Radio frequency barriers, scattering, and undulating terrain factors all contribute to the inconsistency of terrestrial television propagation in spread spectrum situations. The radio channel has an impact on how well television communication systems perform, and the propagation path between the transmitter and receiver might be anything from a normal line-of-sight (LOS) to a direction that is substantially impeded by nearby structures and vegetation [3]. In an urban setting, where most television systems are used, there is no direct signal arriving at the receiver. Instead, an integrated signal is created by diffraction, reflection, and scattering off numerous obstacles, such as buildings and moving objects.

The development of a transmission pattern that would improve coverage and reduce latency and interference is the primary design tenet for every wireless television broadcasting system. Any television system designed to operate in a specific setting must function the way a radio propagation channel behaves in that environment in order to be effective and be implementable [4]. Signal attenuation, or path loss occurs at all operating frequencies and gets worse with distance. Different signals may enter the detector in a subtractive or additive manner. This will result in minor signal fluctuation or multipath fading. Multipath fading is caused by the signal being reflected, scattered, and diffracted by environmental physical objects [5]. Amongst the most critical components of the television transmission environment is propagation path loss. Path loss is the term used to describe the decline in radio signal power caused by multipath fading, shadowing, and signal fluctuation on any radio signal path [6]. Path loss in wireless communication

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reception can be caused by a number of factors, such as television units, diffraction, refraction, and reflection [7]. Path loss features and models are employed to compute wireless network coverage and received signal strength (RSS) of electromagnetic waves that are broadcast at various locations inside a specific transmission perimeter. These models are a useful substitute for real-field measurements, which can take a lot of time and resources. Deterministic, semi-deterministic, and empirical path loss models are the three most common types of path loss models. Because they are straightforward, user-friendly, and require less computing efficiency than deterministic models, empirical models are frequently employed for path loss predictions [8].

In order to effectively plan and optimize radio networks in various propagation settings, a variety of research-based path loss models have been created. In general, no single path loss prediction model is regarded as the best or universally accepted as the most accurate; rather, the precision of a prediction model depends on how well the parameters required in the model correspond to those present in the measured field data [9]. Field measured data and predicted path loss values are made openly accessible to the public in this research article. In this study, the measured data was used to create a path loss model for NTA Owerri in South-East Nigeria and to evaluate signal quality in terms of efficiency. Additionally, the datasets are fully defined to aid future work by professionals in the engineering area, radio network engineers, research institutions, and other researchers. The path loss exponent, whose value varies according to the transmission conditions and environment, can be used to represent path loss. The path loss exponent may be higher in some environments, such as structures, public parks, and other urban locations, than it is in a free-space environment or a relatively scattered environment [10]. These values rely on the transmission environment and system and are affected by geographical features, settlement types, the transceiver distance, as well as the position, height, and type of antennas. The path loss notation, or proponent, is one of the most important features in all propagation loss and Rayleigh fading models, and understanding it for a specific environment simplifies signal coverage and propagation analysis [11].

The development of social and human interactions in society today is greatly enhanced by television network technology. Due to a dearth of knowledge about how television operations function in large-scale, concentrated, and constrained environments, particularly in urban areas, recent applications are quite limited. In an ideal arrangement, the total signal power transmitted is what is intended to be received at the receiving head. However, this is not always the case due to some common transmission issues [12; 13]. A plethora of man-made and natural factors, including mountains, tall buildings, atmospheric pressure, temperature, and relative humidity of the specific transmission environment, contribute to some of the technical difficulties with terrestrial television broadcasting and reception, in addition to the technical shortcomings of the transmitting stations. Like all other television transmitting stations, the Nigeria Television Authority (NTA) Owerri is not exempt from these adverse difficulties [3]. There has been lots of research conducted in the past to estimate and address the problems of terrestrial television signal attenuation. Some of these studies involved the development of models or modifications of existing models to aid in the prediction of the quality of television signals at specific locations. However, none of these studies were conducted for NTA channel 12 Owerri to evaluate the television station's signal attenuation level. Additionally, no one has been able to develop a path loss model that could help to some extent in describing the signal intensity generated by NTA Owerri. As a result, NTA Owerri operators need to perform field measurements on a regular basis to obtain the necessary signal data, which lowers the frequency and level of maintenance on their broadcasting systems. This has also caused a decrease in the level of routine checks on the performance of the NTA Owerri signal strength by the television operators. This is the rationale for our research, which we conducted to develop a path loss model for NTA channel 12, Owerri and evaluate its performance in Imo State, Nigeria.

1 Methodology

1.1 Study location

Imo State is a state in the South-Eastern geopolitical region of Nigeria. It is bordered to the west by Abia State, to the south and east by Rivers State, and to the north by Anambra State. It gets its name from the Imo River, which runs along the state's eastern border. Imo State has Owerri as its capital and is known as the "Eastern Heartland" due to its location in the Eastern part of Nigeria and the fact that it is the most economically successful state in the area. Imo state is the fourteenth (14th) most populated state out of the 36 states in Nigeria, with an estimated population of more than 5.4 million as of 2016 [14]. The state has an area of around 5,100 sq km and is located between latitudes 4° 45' N and 7° 15' N, and longitudes 6° 50' E and 7° 25' E. The annual rainfall ranges from 1,500 mm to 2,200 mm, with a thickness of 60 to 80 inches, during the rainy season, which starts in April and lasts until October. Its average yearly temperature is over 20 °C, resulting in a relative humidity that is typically 75%, though it can get as high as 95% during the rainy season.

Imo state is the third smallest state in terms of area. Geographically, the state is divided between the drier Cross-Niger transition woods in the center and the swamp forests of the Niger Delta in the extreme east. The state's lakes and rivers, including the Oguta Lake in western Imo State and the Orashi, Otamiri, Imo, and Awbana Rivers, are additional significant geographical features. Tropical rain forest is the predominant kind of vegetation in Imo State [15].

1.2 Measurement campaign

The goal of this research is to examine the signal strength generated by NTA channel 12, Owerri, and to develop a suitable path-loss prediction model for forecasting the path loss of the NTA channel 12, Owerri, signals. To do this, the NTA channel 12 Owerri signal strength was monitored along five different routes, starting from the broadcasting base station, using a cable television (CATV) signal analyzer. The RSS levels were measured along the various signal strength measurement routes, starting from 2 km to 24 km, at intervals of 2 km. The average received signal at each measurement site was used to average out inconsistent signals.

Table 1 shows the routes description where signal strength measurements were taken, which was properly considered based on their accessibility and road network. When the field measurements were being taken, a number of variables that could affect the signal quality before it reaches the intended customers were taken into account. These variables include atmospheric pressure, temperature, relative humidity, complex multi-channel environments, radio frequency generating equipment, tall structures, etc. Signal strength measurements were made during different hours of the day and months, from October 2021 to May 2022. The average field strength measurement results for the research period were taken in order to determine how well the signal strength produced by the NTA channel 12 Owerri transmitters performed along the chosen routes. The given data was then analyzed using Mat lab and the Python programming language.

Table 1. Routes description

Routes	Route A	Route B	Route C	Route D	Route E
Description(s)	Owerri-Onitsha	Owerri-Aba	Owerri-Umuahia	Owerri-Orlu	Owerri-Okigwe

An S110/S110D 5-870 MHz handheld analog cable TV radio frequency (RF) signal level meter was employed in this study as the CATV meter. The signal strength produced by any terrestrial television transmitter can be measured using a cable or community television (CATV) signal strength analyzer. It is a typical receiver that can measure the signal intensity produced by a signal generator in decibel microvolts (dBuV), and it is mostly used in TV signal level construction, repair, maintenance, and measurement. This S110/S110D CATV signal strength meter offers robust, all-encompassing performance and is compatible with analog and digital television and radio channels. It measures frequencies between 5 and 870 MHz with a frequency accuracy of +50 x 10^{-6} and a temperature range of 20^0C + 14^0C. This S110/S110D CATV signal strength meter for measuring television signal quality because it has a measuring range of 5 to 120 dBuV with a measuring accuracy of +2 dB and a carrier-to-noise measurement range of 20 to 50 dB for a signal input range of greater than or equal to 85 dBuV with an accuracy of +3 dB at a temperature of 20^0C + 14^0C.

The type of receiving antenna used for this research is the Yagi antenna, which is a directional antenna used in telecommunication when the frequency is above 10 MHz. The frequency range of the receiving antenna is between 10–870 MHz for channels of 1– 69 UHF and VHF with a gain of 20 ± 3 dB, a noise coefficient factor of about 2 dB and an impedance of 75Ω.

The NTA channel 12 in Owerri, Imo State, Nigeria, which broadcasts at a frequency of 224.25 MHz, is the transmitting station of interest in this research. It is situated at Chief Achike Udenwa Avenue, Akanchawa, New Owerri Road, Owerri, Imo State, Nigeria. It is one of the most viewed television channels in Imo state, Nigeria because it is the sole federal government-owned TV channel there. The parameters of the NTA channel 12 Owerri transmitter are shown in Table 2.

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Table 2. Transmitting parameters of nta channel 12 owerri transmitting station

Serial No.	**Transmitting parameters**	**Description**
1	Base station frequency	189.25 MHz
2	Transmission Type	Rohde & Schwarz 5 KW
3	Base station transmitting power	2.6 KW
4	Signal power transmitted	57.1 dB$\boldsymbol{I?V}$
5	Base station channel	Channel 12
6	Height of transmitting antenna	230 m
7	Transmitting antenna gain	30.02 dB
8	Base station position	Long. 6.50° N Lat 7.15° E
9	Receiving antenna orientation	Omni-directional
10	Height of receiving antenna	5 → m

1.3 Empirical path loss model

The major emphasis of propagation models has typically been on predicting the strength of the received signal, with the distance (d) between the transmitter and receiver being the most important factor. Path loss is the decrease or attenuation in power density of a radio wave as it travels across space. In order to effectively plan and optimize radio networks in various propagation settings, a number of empirical path loss models have been developed. This session discusses some of the few existing empirical path loss models that were used in this investigation.

1.3.1 Free-space path loss model

The simplest and most common empirical path loss model, the free-space model, simply considers frequency (f) and distance (d). Given that there are no barriers or atmospheric influences during free-space transmission, the path loss is given by

$$P_r = P_t G_t G_r \left(\frac{\lambda}{4\pi d}\right)^2 \tag{1}$$

where P_r = receive power, P_t = transmit power, G_t = gain of transmitter, G_r = gain of receiver, and d is the transmitter and receiver distance. The free-space path loss model in Equation 1 can be expressed as follows [16]:

$$L_{FS} = 32.45 + 20log_{10}d(Km) + 20log_{10}f(MHz), \tag{2}$$

where f = frequency in MHz and distance in Km

1.3.2 Walfisch-Ikegami propagation model

A different name for it is the empirical COST-Walfisch-Ikegami propagation model. In this model, only the buildings on the vertical plane were considered. However, this model is thought to be quite accurate, particularly in urban settings. The Cost 231 Walfisch-Ikegami model consists of three essential components, which are shown below [17].

$$L = L_0 + L_{rts} + L_{msd} \tag{3}$$

L_0 is the free space path loss which is represented by $L_0 = 32.5 + 20logd + 20logf$
The roof-top-to-street (rts) diffraction and scatter loss term is given by:

$$L_{rts} = -16.9 - 10log10^{w} + 10log10^{f} + 20log10^{(H_{roof} - H_m)} + L_{cri}$$

and the component of multi-screen diffraction loss is given by:

$$L_{msd} = L_{bsh} + ka + kdlog10^{d} + kflog10^{f} + 9log10^{b}$$

When there is a line-of-sight path between the transmitter and the receiver in a specific region, that is, when the source transmitting appliance is below the roof, the following equation can be used [17]:

$$L_b = 42.6 + 25log10^{d} + 20log10^{f} \quad for\ d \geq 0.020\ Km \tag{4}$$

The path loss estimates for the Cost 231 Walfisch-Ikegami model were computed in this study using equation 4.

1.3.3 The Cost Hata model

The path loss model broadens the urban Hata model, which is based on the Okumura model, to a wide frequency range of roughly 2 GHz. For frequency ranges between 800 and 2000 MHz, this model utilizes experimental and descriptive techniques to calculate transmission loss in an urban environment. The path loss equation for the COST 231 Hata Model is as follows [18]:

$$L = 46.3 + 33.9logf - 13.82logh_B - a(h_r) + (44.5 - 6.55logh_b)slogd + C \tag{5}$$

According to the Hata Model for urban areas, C is equal to zero for medium cities and suburban areas and three for metropolitan areas. L is the median path loss in dB, f is the transmission frequency in MHz, h_B is the base station antenna height in meters, d is the link distance in kilometers, h_r is the receiver station antenna effective height in meters, and $a(h_r)$ is the receiver station antenna height correction factor. For sub-urban and rural areas, $a(h_r) = [1.1\log(f) - 0.7]h_r - 1.56\log(f) - 0.8$ and for urban areas, $a(h_r) = 3.20[log10(11.75h_r)]2 - 4.97$; for f > 400 MHz

1.3.4 Okumura's model

One of the most frequently applied signal prediction models in urban areas is Okumura's. This type is suitable for distances of 1 to 100 kilometers and frequencies of 150 to 1920 MHz (but it is typically modified up to 3000 MHz). It is appropriate for base station antenna heights between 30 and 1000 meters. Equation 5 shows how the model can be stated [19]:

$$L = L_{FSL} + A_{mu} - G_{hte} - G_{hre} - G_{area} \tag{6}$$

where G_{hte} is the base station antenna height gain factor, G_{hre} is the mobile antenna height gain factor, and G_{area} is the gain due to environmental type. L is Okumura's path loss in decibels (dB), L_{FSL} is propagation loss in free space (dB), and A_{mu} is the median attenuation in relation to free space.

1.3.5 Egli model

The Egli model is a geographic model for electromagnetic waves (EM) propagation. This model was developed using accurate data from television (TV) transmissions on the VHF and UHF bands in a plethora of different locations. The expression for the Egli path loss model is shown in equation 7 [20].

$$L = 117 + 40logd + 20logf - 20\log(H_T - H_R) \tag{7}$$

1.4 Model validation and verification

To assess how well the developed and theoretical propagation models fit with the observed path loss, four different statistical tools were used to evaluate and validate the models. The four statistical techniques employed in this study were mean error (ME), standard deviation (SD), root mean square error (RMSE), and standard deviation error (SDE). A better fit for urban and suburban environments, respectively, is indicated by RMSE values of 6 to 8 and less than 15 [21]. The more closely the values of ME, SDE, SD, and even

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RMSE converge to zero, the better the model fits the observed variables [22; 23]. The statistical tool's equations are as follows:

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(PL_m - PL_c)^2} \quad (8)$$

$$ME = \frac{1}{n}\sum_{i=1}^{n}(PL_m - PL_c) \quad (9)$$

$$\text{SDE or } I?_e = \frac{I?}{\sqrt{n}} \quad (10)$$

$$\text{and } \sigma = \sqrt{\frac{\sum(x_i - \mu)^2}{n}} \quad (11)$$

where $I?_e$ is the SDE, $I?$ is the standard deviation and n is the number of the given sample. PL_m is the measured path loss value at a transmitter – receiver's distance (da) and PL_c is the empirical prediction path loss model.

2. Results and discussion

2.1. Results

Figures 1 and 2 depict graphs of the signal strength and signal path loss (SPL), respectively, for the signals generated by NTA channel 12 Owerri along the five different routes examined in Imo State, Nigeria.

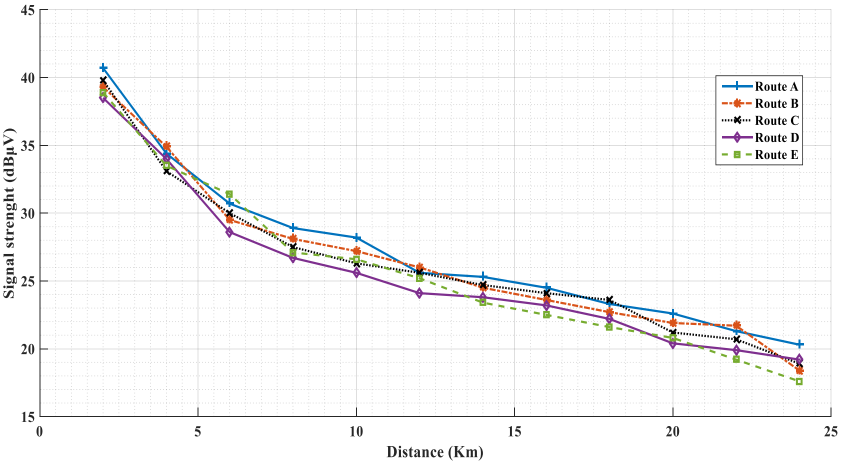

Fig. 1. NTA channel 12 Owerri signal strength along different routes in Imo State, Nigeria

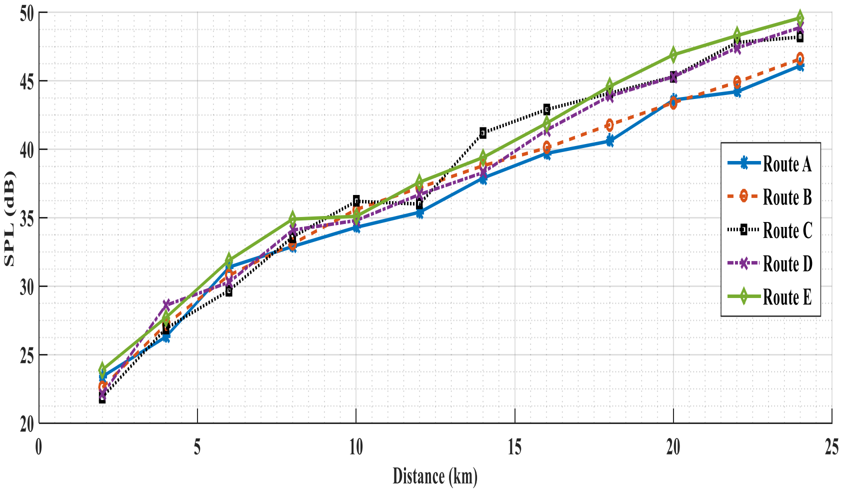

Fig. 2. NTA channel 12 Owerri path loss along different routes in Imo State, Nigeria

The path loss, which is defined as the difference between the total power transmitted and the total power received at a specific location, was calculated using the measured signal strength values while taking into account the measured power transmitted by the NTA channel 12 transmitter, which is 57.1 dB$I?V$.

In order to develop a mathematical path loss model that can accurately predict the path loss values of signals generated by NTA channel 12 Owerri, all the different path loss values for all the investigated routes were thoroughly analyzed, taking the path loss specified in figure 2 into consideration. Equation 14, which is the developed path loss model, was developed based on detailed analysis of the observed path loss values, keeping in mind the fundamental equation of path loss in equation 12 and also the basic equation of the straight-line graph shown in equation 13.

$$Path\ loss, Ls(dB) = Lp + 10nlog\frac{d_1}{d_0} \tag{12}$$

where, Ls = path loss, Lp = reference path loss, n = path loss exponent, d_1 = distance between the transmitter and the receiver.

$$y = mx + c \tag{13}$$

2.2 Path loss modeling

The path loss induced by NTA channel 12 in Owerri, Imo State, Nigeria, was predicted using a regression propagation model. The values of the path loss exponents were explicitly computed for each condition and used in the proposed model to characterize the television signal propagation as well as the distance breakpoint. Equation 14 shows the path loss model that was created, which is adequate for predicting the NTA signals' attenuation with distance in the Imo state of Nigeria.

$$PL = M_n + Aelogd_a + K \tag{14}$$

where $K = Aelogd_r + S$

M_n is the signal path loss value at a reference distance from the transmitter, which is considered to be 1 km from the transmitter of the base station, PL is the signal path loss value, A is the constant value of the logarithm's coefficient, which is 20, e is also known as the path loss proponent or exponent, d_r is the reference distance from the transmitter's antenna, which is assumed to be 1 km, d_a is the actual distance (in kilometers) between the transmitter and the receiver and S is the corrective factor that takes into account the loss brought on by obstructions, including scattering, interference, dispersion, and absorption etc.

The values of M_n and e varies depending on the base station's transmitter and the environment being investigated. The values for the path loss predicting model parameters for NTA channel 12 in Owerri, Imo State, Nigeria investigated are $M_n = 18$ and $e = 0.96$. The path loss exponent value e at the breakpoint for a particular site was obtained from the measured path loss by linear regression. The calculated path loss model in equation (14) was developed by using the appropriate values e, $M_{n,}$ and S for a giving *da*. An application software was developed for the predicting path loss model to correctly estimate the signal path loss in the different locations of signal strength measurements. Given the uncertainty of applying the path loss model, the application software had to be designed to quickly and easily determine the signal path loss values for NTA 12 Owerri, Nigeria. Figure 3 displays a snapshot of the graphic user interface for the software program that was developed.

The application software is run to provide an output in both tabular and graphical form if the required data is supplied into the model developed. The graph of the developed path loss against distance for the NTA channel 12 Owerri base station under investigation is shown in Figure 3.

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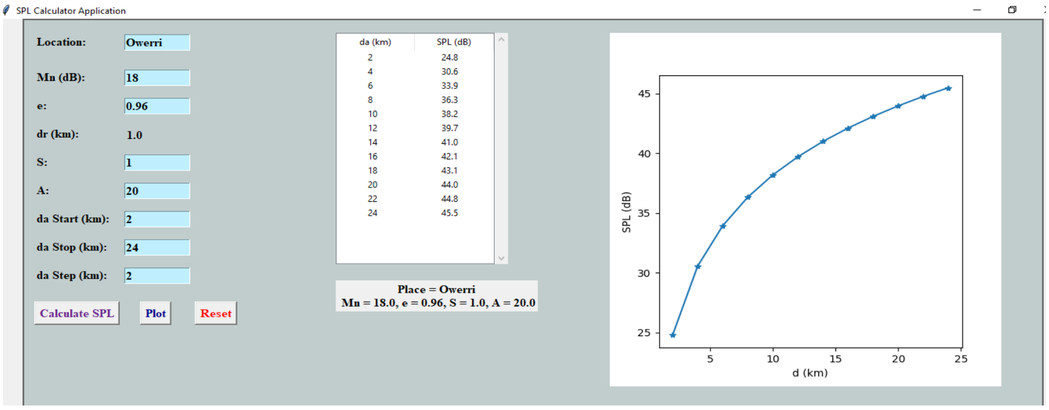

Location: Owerri

Mn (dB): 18

e: 0.96

dr (km): 1.0

S: 1

A: 20

da Start (km): 2

da Stop (km): 24

da Step (km): 2

da (km)	SPL (dB)
2	24.8
4	30.6
6	33.9
8	36.3
10	38.2
12	39.7
14	41.0
16	42.1
18	43.1
20	44.0
22	44.8
24	45.5

Place = Owerri
Mn = 18.0, e = 0.96, S = 1.0, A = 20.0

Fig. 3. Graphic user’s interface of the developed signal path loss model’s application software

2.3 Comparative analysis between measured path loss and developed model’s path loss

Path loss values from the developed model were compared to the path loss value of route A for the NTA channel 12 Owerri base stations, as shown in figure 4. The ME, Standard Deviation (SD), RMSE, and the standard deviation error (SDE) described in equation 9–11 are the statistical tools used to validate the developed path loss propagation model. Table 3 lists the results of each statistical tool that was used to validate and confirm the applicability of the developed path loss model in the investigated environments and to predict NTA channel 12 Owerri signals' path loss.

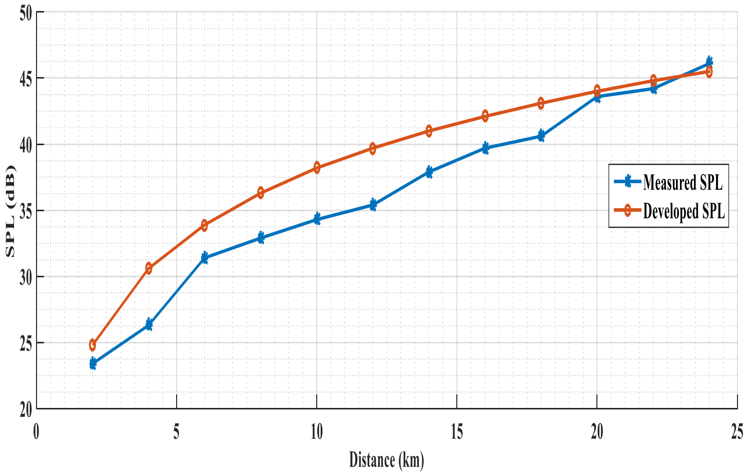

Fig. 4. Comparison of measured path loss values with the calculated path loss values for NTA Owerri in Imo State, South-Eastern, Nigeria.

Table 3. Statistical parameters of the developed path loss values for NTA channel 12 Owerri base station

S/N	RMSE	ME	SD	SDE
1	2.8056	2.3500	6.300	1.8187

All the statistical tools used in this study to validate the performance of this developed prediction model also show that the calculated path loss developed is accurate and very suitable for Distance (km) predicting path loss values of NTA channel 12 Owerri signal in the South-Eastern region of Nigeria.

2.4 Comparative analysis of different path loss models with measured values and developed path loss models’ values

This section compares the measured path loss values for the base station under investigation with the suggested model values, measured values, and five other conventional existing empirical path loss models stated in equations 1–7. The relationship between measured field values, proposed model values, and some existing empirical path loss models is depicted in Figure 5. The prediction errors of the different models under consideration as well as the measured field values were estimated based on the path loss comparisons in figure 5. Table 4 displays the outcomes of each statistical tool that was used to analyze the errors of the various prediction models using measured data.

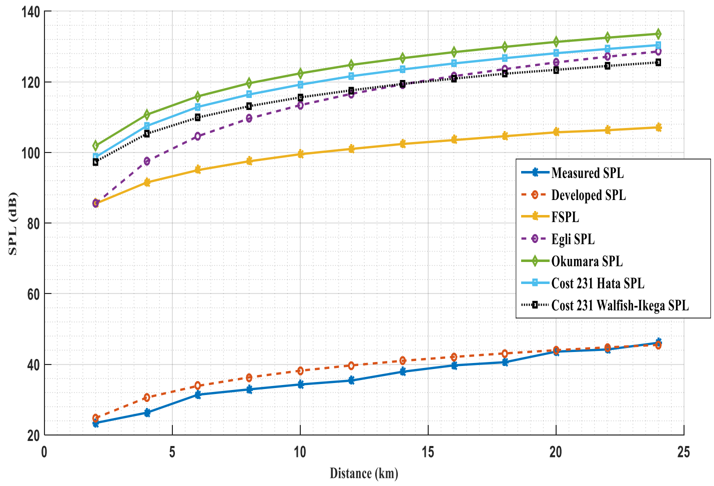

Fig 5. Comparison of some empirical path loss models with measured and developed models’ path loss values for NTA Owerri in Imo State, Nigeria.

Table 4: Error analysis of the different prediction models with measured values

Statistical tools	FSPL	Egli	Okumura	Cost-231 Hata	Cost W-L
RMSE	63.67	78.33	86.88	83.69	79.95
MSE	63.65	78.09	86.83	83.64	79.93

2.5 Performance of NTA signals Owerri in Imo State, Nigeria.

In this work, the performance of the NTA signals under study was also examined. The purpose is to evaluate the effectiveness of the NTA signals received at a specified location or distance. Equation 15 provides the expression to determine the performance or quality for the NTA signals under study at a particular distance [29].

$$P\ (\%) = \frac{TST\ (dB)}{TSR\ (dB)} \times 100\% \qquad (15)$$

When the overall performance of the signals is between 71 and 100%, the performance of the signals is considered excellent, and when the quality is between 51 and 70%, the performance of the signals is very good. The signal performance is deemed good and fair when the efficacy of the received signals is between 31 and 40%, and 41 and 50%, respectively. The performance of television signals ranging from 0 to 30% is regarded as being relatively low, making the audience who receives them feel very uneasy [24]. Table 5 shows the outcomes of the performance studies of NTA channel 12 Owerri signals evaluated at a particular distance. The findings show that NTA Owerri performs poorly at a distance of 18 km away from the base transmitting station.

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Table 5. Performance analysis of the different NTA signals

Distance (km)	2	4	6	8	10	12	14	16	18	20	22	24
Signal performance (%)	59.0	53.9	45.0	42.4	39.9	38.0	33.6	30.5	28.9	23.6	22.6	19.3

2.6 Discussion of results

The received signal intensity levels were measured along the different routes in Imo State, Nigeria, where signal strength measurements were taken at intervals of 2 km, ranging from 2 km to 24 km. Inconsistent and irregular signals were eliminated by taking the average received signal at each measurement point. Equation 16 was used to calculate the path loss in decibels from the measured receive signal strength values [25]. According to [26], path loss is the difference in decibels between the power that is transmitted and the power that is received. It also refers to the attenuation of signals due to the influence of topography, atmospheric characteristics, and other elements like absorption, interference, diffraction, scattering, etc.

$$SPL = TSPT - TSSR, \tag{16}$$

where SPL is the signal path loss, TSSR is the total signal strength received and TSPT is the total signal power transmitted.

Figure 2 show the variation of the measured path loss with distance for the NTA channel 12 Owerri base station under investigated. The figure show that the path loss measured for the NTA channel 12 Owerri signals propagation increases with distance along the different routes of signal strength measurements. Figure 2 shows that, for a 2 km distance, the path loss for paths A, B, C, D, and E is, respectively, 33.7, 34.5, 35.2, 35.0, and 33.2 decibels. Path loss values for the same routes at a distance of 4 km are 30.8, 29.9, 30.2, 28.5, and 29.4 km, while at a distance of 6 km, they are 25.7, 26.3, 27.4, 26.8, and 25.2 km, respectively, in Imo State. This illustrates how signal path loss increases with increasing base station transmitter and receiver distance. For all of the investigated routes, an increasing trend in signal path loss was observed. It therefore implies that the signal strength drops off as the distance increases along any path of signal propagation.

For the purpose of predicting the path loss induced by NTA channel 12 Owerri, Imo state in South East, Nigeria, a linear propagation model was developed. The developed path loss model's results were plotted in equation 4 and show comparable patterns to the measured values, suggesting that the path loss increases with the line-of-sight distance between the base station and the television reception station with fairly little dispersion. Attenuation and dispersion become more pronounced and erratic after the breakpoint distance, but the attenuation still fits the surroundings of transmitter base stations. To determine the effectiveness of the developed path loss model in predicting path loss for the NTA channel 12 Owerri station in the different research locations, the values from the developed path loss model were compared with those from the field measurement for route A as shown in figure 5. The figure demonstrates that the predicted path loss values are quite similar to the measured path loss values and that they both exhibit the same distance-dependent incremental trends. The computed path loss model developed is accurate and extremely suited for estimating path loss values of NTA channel 12 signals in the Imo State of Nigeria, as shown by RMSE and the other statistical tool utilized in this study to validate the performance of this prediction model. For the base station under investigation, the calculated path loss's RMSE value, which is less than 8 dB, demonstrates how well the model predicts route loss in the surroundings taken into account. The maximum RMSE values for urban and suburban areas are 8 and 15 respectively for any model to be assumed to be true for predictions.

Figure 5 shows the comparison of path loss values for measured values, produced model values, and other models' values for the NTA channel 12 Owerri base stations in Imo state, Nigeria. Other empirical models, compared to the proposed model, which, on the whole, predicted the path loss accurately, overestimated the measured path loss value by roughly 85.5 dB, demonstrating a lower degree of agreement with the measured route loss values. When compared to the observed and calculated path loss values across the whole research area, the free space path loss (FSPL) model came the closest of all the empirical path loss models. However, the Okumura and Cost-231 Hata models, which projected path loss of over 101.9 dB and 98.7 dB, respectively, in all the research locations, had the biggest prediction difference from the real path loss. Though they all overestimated the path losses, FSPL made a superior prediction overall when compared to the others. The prediction errors of the various models under consideration were calculated based on the path loss comparisons in Figure 6. For the base station taken into consideration, the mean error, the root-mean square error, the standard deviation, the standard deviation error, and the measured path loss values have been calculated as functions of distance. Table 5 displays the findings of each statistical tool that was used to analyze the errors of the different prediction models considering measured data. The difference between the measured and predicted losses for each of the models was used to compute the mean error. The results of the various statistical tools presented in table 5 affirm that the free space path loss (FSPL) model is closer to zero and therefore closer to the values of the proposed and observed path loss models. Nevertheless, in the analyzed context, the FSPL is still unsuitable to estimate route losses.

Conventional path loss models are incorrect and inappropriate for use with the NTA station under examination in this study area. For forecasting NTA channel 12 Owerri path loss, path loss models developed by other researchers for different regions and television stations were also ineffective. This led to the development of the model that you see here. The developed model performed flawlessly and was demonstrated to be quite effective for the research area and similar terrain when tested in this scenario. This generated model, in contrast to other empirical models developed by other researchers, can estimate path loss over a considerable distance exceeding 24 km. Path loss models are difficult for end users to employ because of their confusing nature due to their mathematical complexity. Thus, it has become absolutely essential to create an application software for the developed model that will allow users to quickly compute the path loss values of the developed model by inputting the pertinent variables into the application software. In summary, the model developed in this study is easy to use, efficient, reliable, appropriate, and scalable, especially in the study areas and on terrain that is similar to that of the terrain.

Conclusion

This study was conducted to develop a path loss model for NTA channel 12 Owerri and evaluate its performance in Imo State, Nigeria. Signal strength measurements were made during different hours of the day and months, from October 2021 to May 2022. In this study, the measured data was used to create a path loss model for NTA Owerri in South-East Nigeria and to evaluate signal quality in terms of efficiency.

The model developed in this study is easy to use, efficient, reliable, appropriate, and scalable, especially in the study areas and on terrain that is similar to that of the terrain. The findings show that NTA Owerri performs poorly at a distance of 18 km away from the base transmitting station. The results also show that the other conventional empirical models considered in this study overestimated the path loss of NTA channel 12 Owerri signals. Recommendations were made based on the results obtained from this study.

Recommendation

The proposed models are recommended for usage in the research areas and other places with comparable topographical features to ensure the best planning of the transmitted power efficiency and network design. Additionally, in order to ensure that their customers get signals well beyond 18 kilometers, it is also recommended that NTA Aba's management raise their power output to about 30 kW.

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