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OPTIMIZATION OF COST 231-HATA PROPAGATION MODEL FOR SELECTED FREQUENCY MODULATION STATIONS IN OSUN STATE, NIGERIA

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Abstract
The ability to predict the Frequency Modulation (FM) signals over a predetermined coverage area is of paramount importance for planning of wireless networks. Existing empirical propagation Path-Loss (PL) model such as Egli, Okumura-Hata, COST-231- Hata and Hata-Davidson have not been investigated for predicting the FM signals in Osun state, Nigeria, due to localization of the models. In this paper, applicability of the existing models is investigated on the FM frequency to select the most appropriate model for optimization. The investigation is carried out by measuring the received signal power to determine the PL values for two selected FM stations through a drive test. The drive test equipment consisting of Agilent spectrum analyzer, computer system and global positioning system were used to determine the applicability of the models to the FM stations. The COST 231-Hata model that give the closest values to the measured ones is then optimized using genetic algorithm. The performances of the selected PL models and optimized model were evaluated using PL, root mean square error and mean absolute error. The results obtained showed that the optimized COST 231-Hata model is the appropriate model for predicting the FM stations in the study area.

Keywords: Propagation models**,** COST 231-Hata**,** Path-loss and Genetic Algorithm Optimization

Introduction

Terrestrial broadcasting stations make use of electronic equipment such as transmitters and antenna to disseminate radio signals to general public. Radio signals are radiated from the antenna and propagated through the wireless medium known as the channel to the receiver, its signal strength decreases as it propagates through the channel resulting in signal loss along the path (Aremu *et al*., 2023; Akande *et al*., 2017; Bultitude, 1987). This signal encounters problems along the propagation path due to obstacles. This results to reduction in signal strength known as path-loss and multipath propagation. Multipath propagation occurs when the different copies of transmitted signal are being received at different time, through different angles of arrival (Huary *et al*., 2022; Akande *et al*., 2017; Graham *et al*., 2007). The prediction of signal strength is carried out by Path-Loss (PL) model. Path-loss models are the mathematical formulations for characterization of the radio waves between the receiver and transmitter to predict the behavior of different links with different characteristics and constraints. The models can be classified as stochastic, deterministic and empirical (Pathania and Shashi, 2014; Adeyemo *et al*., 2013; Rapaport, 2002).

Stochastic models give path-loss prediction in a random manner without considering the peculiarities of different environments, thus, have limited accuracies when applied at diverse terrains (Linus *et al*., 2021; Guatam, 2009; Hasult, 2008). Deterministic path-loss models are built on ray tracing optical theories which take into consideration various terrain parameters making them complex and highly demanding to compute although very accurate (Omoze and Edeko, 2020; Guatam, 2009; Wang and Zhang, 2005). Empirical models are developed based on measurement taken in an environment and modification of its parameters enables its suitability for a particular environment (Hasult, 2008; Rapaport, 2002). It has been shown that empirical path-loss models have varying degrees of accuracy in different environments due to differences in surrounding terrain contour (Alatishe *et al*., 2014; Nasir *et al*., 2013; Ogbeide and Edeko, 2013; Shoewu and Adedipe, 2010; Anderson *et al*., 1995).

Therefore, there is need to investigate the suitability of some selected empirical path-loss models such as Egli, Okumura-Hata, COST 231-Hata and Hata-Davidson and consequent applicability to Osun state for proper communication system planning. Though, the applicability range of COST 231-Hata is beyond the operating frequency range of the two FM stations considered but the paper investigates the adaptability of the model to lower frequency range. The investigation of selected propagation models is carried out by drive test along intercity roads using a spectrum analyzer to measure the radio signals of the two FM stations located in the state. The state is located between Longitude 7.3° N, Latitude 4.30°E and Longitude 7.8° N, Latitude 4.5° E. Path-loss values were measured along the intercity roads from the selected FM stations and were used as reference for the comparison with the existing empirical path-loss models values.

Related Works

In Abhayawardhana *et al*. (2015), the implementation and analysis of 30 different propagation models spanning 65 years of publication was done using Path-Loss (PL), Mean Error (ME), Root Mean Square Error (RMSE) and Spread Corrected Mean Square Error (SCRMSE) to gauge their performances. The models comprised variables such as position of transmitting and receiving antenna, carrier frequency, elevation and land cover classification for their predictions. The results indicated that no single model was able to consistently predict path-loss accurately under different conditions. The study was limited to implementation and comparison of the models, no optimization which would have improved prediction accuracy was carried out. In Nasir *et al*. (2013), some empirical path loss models were investigated for television signal prediction, the fitness function of seven empirical path-loss models were verified using PL, ME, RMSE and SCRMSE to measure their performances based on field strength measurements in Kwara State. The study provided error analysis of the path-loss model through a rigorous analysis of a propagation model via large data set through field measurements. However, the study was localized to Kwara state and the authors failed to carry optimization that can help in determine the best model that is suitable for the selected location.

In Ogeide and Edeko (2013), the suitability of Hata model for path-loss prediction in Edo State, Nigeria, was carried out through a quantitative measurement of the signal strength of Edo State Broadcasting Service television station through drive test. The Hata model was modified by the addition of the RMSE value, the modified Hata model has RMSE of 4.6 dB. The results obtained show that Hata propagation model do not accurately predict the path loss for television signal propagation in Edo State due to differences in the profile terrain between locations where the development of Hata model was carried out. However, the study was localized to Edo State and the author failed to carry optimization that can help in determine the best model that is suitable for the selected location.

In Adeyemo *et al*. (2016), the propagationloss of a frequency modulation radio station in Ankara, Turkey was investigated by conducting drive test to measure the received signal. The simulation of the received signal was done using COST 231-Hata, Okumura-Hata and Egli models, and were further modified using Artificial Neural Networks (ANN). The measured data were compared withthe PL values and the modified ANN model. However, there was a need for the rigorous training and re-training of the ANN, a more efficient optimization technique could be implemented.

Previous studies have investigated the suitability of several path-loss models, some of the studies were limited to comparison of path-losses predicted and measured without the use of performance metrics and optimization of the models. Some other studies made use of less effective optimization methods without the investigation of suitability of investigated path-loss models. Four path loss models are investigated in this paper to determine their suitability for path loss prediction in Very High Frequency (VHF) band where the FM is included. Metrics are also applied to evaluate their performances; the most accurate path-loss model is optimized using GA for better accurate path loss prediction.

Path-loss Models

The terrain contours, environment type, humidity, the distance between receiver and transmitter, the height and location of antenna affect the path loss. Propagation model is classified into deterministic models and empirical models. Empirical models described the field measurements of the received power that require less computational effort and less sensitive to geometry propagation of the environment. The models are very easy to implement. Deterministic models are based on physical basis which require enormous amount of environmental data. The models are more accurate but require more computational effort than the empirical models (Adeyemo *et al*., 2016; Nasir *et al*. 2013; Caleb *et al*., 2012).

The Egli, COST-231 Hata, Hata-Davidson and Okumura-Hata empirical models are selected due to the suitability of their station parameters such as antenna gain and antenna height to the environment of Osun state and the VHF band in which the radio stations are operating as evident from literature and previous studies.

Genetic Algorithm

Genetic Algorithm (GA) is an adaptive search method that simulates the natural evolutionary process. The algorithm realized the overall learning for the population which composed of individual through the strategy of population search and the exchange of information among the individuals in a population, in which individual represent the solution of a particular problem that is available in the search space. Also, it is generally reflected in a coded binary form known as chromosome (Jadhav and Kale-Sachin, 2014). In GA, the function of individual fitness is used as a guide that evolves the population from generation to generation to meet up with the termination condition and to reach the highest number of iterations through the random selection, mutation, crossover and other series of operations. The algorithm usually terminates when the highest iteration is reached and the value of final iteration is taken as a global solution to the problem. Therefore, the optimization in GA is implemented by simulating the evolution of species through the natural selection.

Methods

The data obtained from drive tests were used to investigate the path-loss models for prediction purposes. The applicability of the path-loss models selected for the routes under consideration which is along the major cities across the Osun state is investigated using the stations parameters. The performance of the models were evaluated by comparing with measured values using statistical tools; the best model in term of minimum path-loss was optimized using GA. The process is as shown in Figure 1, the measured signal strength was converted to the values of measured path-loss using the stations' parameters. The simulation values of the predicted path-loss for each of the models considered were done in order to compare with the values of the measured path-loss to determine the most accurate model using PL, MAE and RMSE values. The most accurate model was then optimized using GA to improve it.

Egli, Okumura-Hata, Hata-Davidson and COST 231-Hata models were used in this study. The choice of these models was due to their operating frequencies which are within the VHF band. The selected models also satisfy the environmental parameters and antenna heights requirement of the stations under study as indicated by previous studies. GA process does not easily break down when inputs are slightly altered or modified, even when there is a substantial level of noise, this makes it more robust than similar search algorithms such as firefly and flower pollination algorithm (Jadhav and Kale-Sachin, 2014). The use of GA also enables efficient search in large populations and quick convergence when many combinations are being sought, as required in this study.

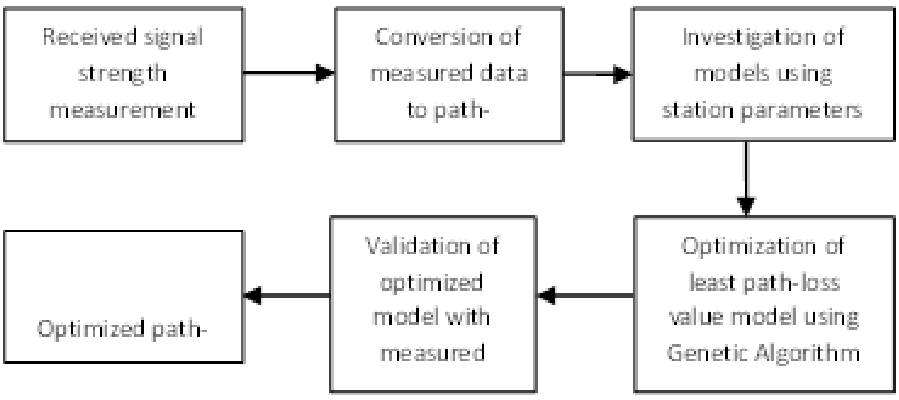

Figure 1. Block diagram of the path-loss optimization process.

Drive test routes for measuring the selected FM radio signals

The measurements of the strength of received signal were conducted at different distances from the two FM stations in the state. The state is a landlocked state in the South-Western of Nigeria that is hurdled by Kwara State in the North, by Ekiti and Ondo State in the East, while it is hurdled by Ogun State in the South and by Oyo State in the West. The state is located between Longitude 7.30° N, Latitude 4.30° E and Longitude 7.50° N, Latitude 4.50 °E. There are seven (7) radio stations in Osun State that are broadcasting in the VHF band. Parameters of the selected radio station were used to program the Spectrum Analyzer. The receiving antenna was connected to the Spectrum Analyzer and the set up installed inside a vehicle which was driven along the routes at manufacturers' specified speed of 40 km/hr to enable the Spectrum Analyzer effectively scans the stations' parameters.

The choice of the first selected FM radio station 'A' for this study was due to strength of its transmission signal which covers Osun State, extends to nearby states and its location in Osogbo, the state capital city. It has the transmitting power of 50 kW, antenna height and gain of 240 m and 3 dB, respectively. The second selected FM station 'B' located in Ilesa, was also chosen because of its situation in a suburban community with an averagely elevated terrain and its proximity to agrarian rural communities. This station has transmitting power of 10 kW, antenna height and gain of 198 m and 3 dB, respectively. The location and frequencies of transmission with the types of antenna are contained in Tables 1 and 2.

Table 1: Locations and frequency of radio stations selected for signal measurement

Parameters	Values
Displayed Average Noise Level	-164 dBm/Hz
Preamplifier	20 dB
Analyzer Frequency Range	100 Hz-7 GHz
Resolution Bandwidth (RBW)	10 kHz
Analyzer Receiver Antenna Height	1.5 m
Analyzer Receiver Antenna Form	Omni-directional
Analyzer Receiver Antenna Gain	2.5 dBi

Table 2: Locations and frequency of radio stations selected for signal measurement

FM station	Frequency	Coordinates	Antenna Type
A	104.5 MHz	7.38° N, 4.4° E	Omni-directional
B	95.5 MHz	7.42° N, 4.42° E.	Omni-directional

Investigation of Path-losses for the two selected FM radio stations

The path-loss (P_L) values for the station is obtained by subtracting the values of received signal (P_r) from the transmitted signal (P_t), the difference obtained accounts for the losses encountered by the signal. The path-loss for the radio station (A) (P_{LA}) is given in Equation 1 and calculated as follows when the transmitter is working at 40 % power output

$$P_t = 10 \times log_{10}(0.4 \times 50000)$$
$$P_t = 43.01dB$$
$$P_t(in\ dBm) = 43.01 + 30$$
$$P_t = 73.01dBm$$

Thus, the measured path-loss P_L for station (A) in dB is given as

$$P_{LA} = 73.01 - P_r \quad (1)$$

The measured path-loss P_L for station (B) is expressed in Equation 2 in (dB) with the transmitter working at 80 % power output is calculated as follows;

$$P_t = 10 \times log_{10}(0.8 \times 10000)$$
$$P_t = 39.03dB$$
$$P_t\,(in\ dBm) = 39.03 + 30$$
$$P_t = 69.03dBm$$
$$P_{LB} = 69.03 - P_r \qquad (2)$$

Applicability of Egli Model to the Two Selected FM Radio Stations

The Egli model is introduced in 1957 by John Egli. The frequency of operation for the model is between 40 MHz to 1 GHz with the link range of less than 60 km. The expression of Egli path-loss model (P_{EGLI}) is given in Equations 3 and 4 by Ozdemir *et al.* (2014) as:

$$P_{EGLIA} = 40 \times log_{10}d + 40.38 - 50.63 + 62.3 \qquad (3)$$
$$P_{EGLIB} = 40 \times log_{10}d + 52.05 \qquad (4)$$

where: P_{EGLI} is the path-loss in dB
h_b is the height of the transmitting antenna in meters
h_m is the height of the receiving antenna in meters
d is the distance from transmitting antenna in meters
f_c is the frequency of transmission in MHz

Inserting the parameters of the radio stations and spectrum analyzer into Equation 3 yield the Egli path-loss for each station as;

$$P_{EGLIA} = 40 \times log_{10}d + 52.05 \qquad (5)$$
$$P_{EGLIB} = 40 \times log_{10}d + 57.4 \qquad (6)$$

Applicability of Okumura-Hata Model to the Two Selected FM Radio Stations

The Okumura model is based on series of a large measurement made around Tokyo city of frequencies between 150 MHz and 1500 MHz. In this method, the prediction area were divided into series of cluster and various categories of terrain, namely: open, urban and sub-urban. Okumura-Hata path-loss model P_{Hata} is expressed using Hata's approximations for suburban areas by Adeyemo *et al.*, (2016) in Equations 7 to 10 as:

$$P_{Hata} = A + Blog_{10}d - C \qquad (7)$$

where: $A = 69.55 + 26.16log_{10}f - 13.82log_{10}h_b \qquad (8)$

$$B = 44.9 - 6.55log_{10}h_m \qquad (9)$$
$$C = 2\left(log_{10}\left(\frac{f}{28}\right)^2\right) - 5.4 \qquad (10)$$

All parameters have their usual meanings

Inserting the parameters of the radio stations and spectrum analyzer into Equation 7 gives Okumura-Hata path-loss for each station in Equations 11 and 12 as;

$$P_{HataA} = 114.03 + 28.3log_{10}d \qquad (11)$$
$$P_{HataB} = 113 + 30.32log_{10}d \qquad (12)$$

Applicability of COST 231-Hata Model to the Two Selected FM Radio Stations

The COST 231-Hata model (Cooperative European forum for Scientific Technique) is an extension of Okumura-Hata model for medium and small cities to cover the frequency band 500 - 2000 MHz; the model cover receiver antenna height of 1-10 m and the height of transmitting antenna of 30-200 m. COST 231-Hata path-loss (P_{COST}) is expressed by Sridhar and Khan (2014) in Equations 13 and 14 as;

$$L = F + Blog_{10}d + G \qquad (13)$$
$$F = 46.3 + 33.9log_{10}f - 13.82log_{10}h_b \qquad (14)$$

where: B has been defined in (9)
G is 0 dB for the suburban and small cities areas while G is 3 dB for the metropolitan areas.

Inserting the parameters of the radio stations and spectrum analyzer into Equation 13 gives COST 231-Hata path-loss for each station as presented in Equations 15 and 16;

$$P_{COSTA} = 81.2 + (44.9 - 6.55log_{10}d) \qquad (15)$$
$$P_{COSTB} = 84.17 + (44.9 - 6.55log_{10}d) \qquad (16)$$

Applicability of Hata-Davidson Model to the Selected FM Radio Stations

Hata-Davidson model is a modification of Okumura-Hata model which enables it to cover larger range of input parameters. The modification consists of correction factors which are added to Okumura-Hata model. Hata-Davidson path-loss model P_{David} is given by Adeyemo *et al.* (2016) in Equation 17 as:

$$P_{David} = P_{Hata} + T(h_b, d) - S_1(d) - S_2(h_b, d) - S_3(f) - S_4(f, d) \quad (17)$$

where: P_{Hata} is thepath-loss for Okumura-Hata model defined in (vii)

$$T(h_b, d) = \begin{cases} 0, d < 20 \\ 0.62137(d-20)\left[0.5 + 0.151\, log_{10}\left(\frac{h_b}{121.92}\right)\right] \end{cases} \quad (18)$$

$$S_1(d) = \begin{cases} 0, d < 64.38 \\ 0.174(d - 64.38) \end{cases} \quad (19)$$

$$S_2(h_b, d) = 0.00784 log_{10}\left|\frac{9.98}{d}\right|(h_b - 300) \quad (20)$$

$$S_3(f) = \frac{f}{250} log_{10}\left(\frac{1500}{f}\right) \quad (21)$$

$$S_4(f, d) = \left[0.1121\, log_{10}\left(\frac{1500}{f}\right)\right](d - 64.38), d < 6439km \quad (22)$$

The correction factors T and S_1 extend the link distance up to 300 km; S_2 extends the transmitter antenna up to 2500 m while S_3 and S_4 are the correction factors for extending the frequency to 1500 MHz.
Therefore, Hata-Davidson path-loss for each station is obtained in Equations 23 and 24 as;

$$P_{DAVIDA} = 113.6 + 28.3 log_{10} d + 1.51(d - 20) - 0.312\left(\frac{9.98}{d}\right) \quad (23)$$

$$P_{DAVIDB} = 112.81 + 30.32 log_{10} d + 1.42(d - 20) + 1.27\left(\frac{9.98}{d}\right) \quad (24)$$

Optimization of COST 231-Hata Model for the Two Selected FM Radio Using Genetic Algorithm

The path-loss model with the most accurate prediction compared with measured path-loss is optimized using GA. The procedure of optimization implemented as contained in Figure 2 is given in (Jadhav and Kale-Sachin, 2014). The objective function used for GA optimization is the COST 231-Hata model as expressed in Equation 13, the Path-loss value P_L was minimized with the distance d and antenna height h_b values set as constraints for the optimization. The initial population size of 100 was selected for the optimization in order to have adequate and optimal selection choices, the maximum number of iterations is set to 600; this was obtained from convergence obtained during preliminary iterations.

The Roulette wheel, random selection and tournament methods were utilized. The crossover percentage, mutation percentage and mutation rate values selected were 0.6, 0.3 and 0.1, respectively. The values chosen were found optimal after preliminary tests for the selection methods utilized. The best computed fitness at the final iteration, returned as global fitness for the problem, while the position of corresponding agent that specified the dimension happened to be the global solution for the problem.

Evaluation of the Investigated Path-loss Models

The four selected path-loss models and the optimized COST 231-Hata path-loss models were evaluated to determine their accuracies. The evaluation was done using three performance metrics; the average Path-loss value (PL), the Mean Absolute Error (MAE), and the Root Mean Square Error (RMSE). The lower the value of the metrics obtained, the better is the fitness of the Path-loss prediction model employed and this translates to a received signal of strong strength and a better quality of the radio broadcast.

The MAE is the absolute averaged prediction error taking into account all the n points use. It is given in Equation 25 by Mardeni and Kwan (2010); Eshelman *et al.* (1993) as:

$$MAE = \frac{1}{n}\sum_{i=1}^{n}|\varepsilon_i| \qquad (25)$$
$$\varepsilon_i = P_m - P_p$$

Ei is the prediction error;
P_m is the measured path-loss in (dB);
P_p is the predicted path-loss in (dB) and
n is the number of data points used

The RMSE describes the quantitative measure of how close the values of the predicted path-loss are to the values of the measured path-loss. To check the closeness of the value of logarithmic fit the value of RMSE is obtained and the one closer to zero describes the best fitness. The RMSE is given in Equation 26 by Sridhar and Mohammed (2015); Okumura (1968) as

$$RMSE = \left(\sum_{i=1}^{n}\frac{(P_{p_i} - P_{m_i})^2}{n}\right)^{\frac{1}{2}}$$

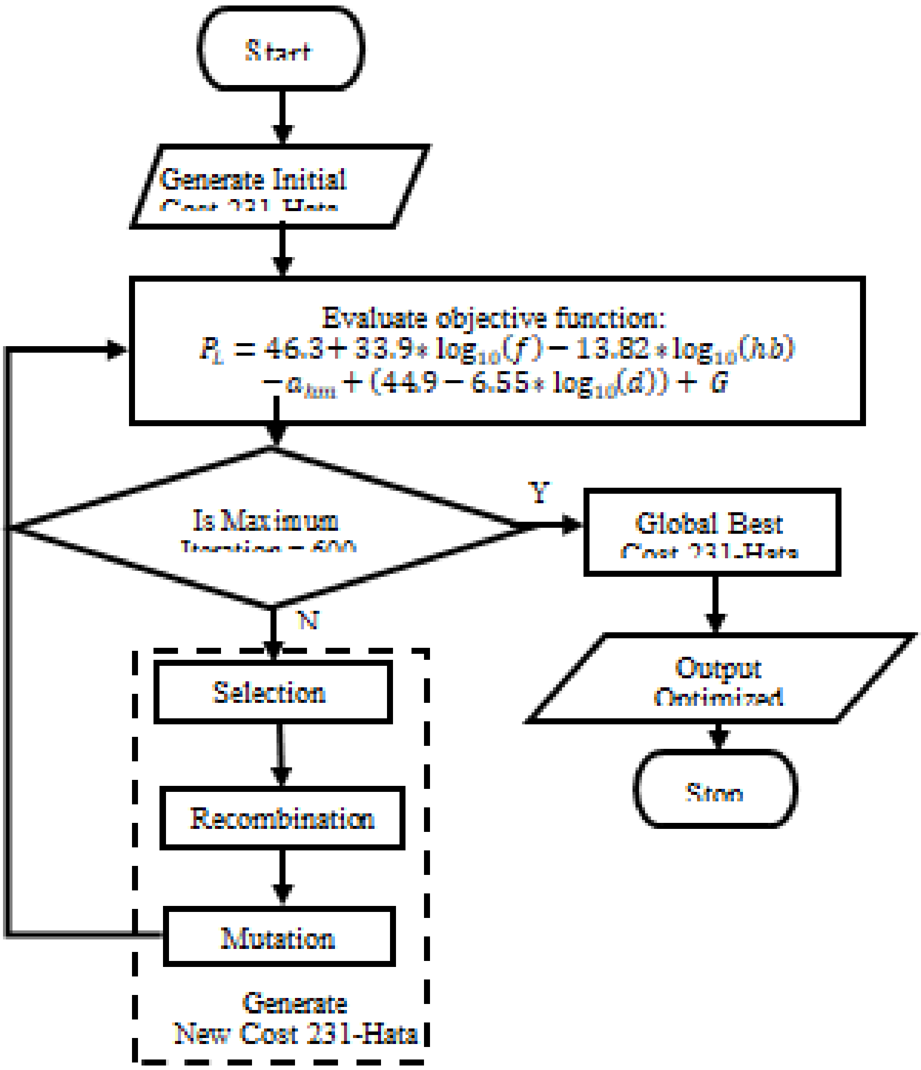

Figure 2: Flow chart of GA optimisation of Cost 231-Hata model for the two radio stations considered

Results and Discussion

Figure 3 shows the values of the measured PL against distance for the FM radio station (A) along the drive test route. The minimum path-loss value of 89.26 dB for radio station was measured at 0.26 km away from the transmitter while the maximum path-loss value of 154.53 dB was measured at 63.82 km away from the transmitter. The average measured path-loss value of 121.89 dB was obtained for the FM radio station (A) along the test drive route. It was observed that the measured path-loss values at the distance of about 17 km from the transmitter starts decreasing to 118.28 dB, compared with 121.23 dB measured at 15 km, the measured path-loss value was expected to increase with increased in distance between the receiver and transmitter. The decrease is attributed to a higher altitude of 338.1 m at 17 km compared with the altitude 332.7 m at 15 km; this gives the receiver a better line of sight connection leading to a reduction in path-losses

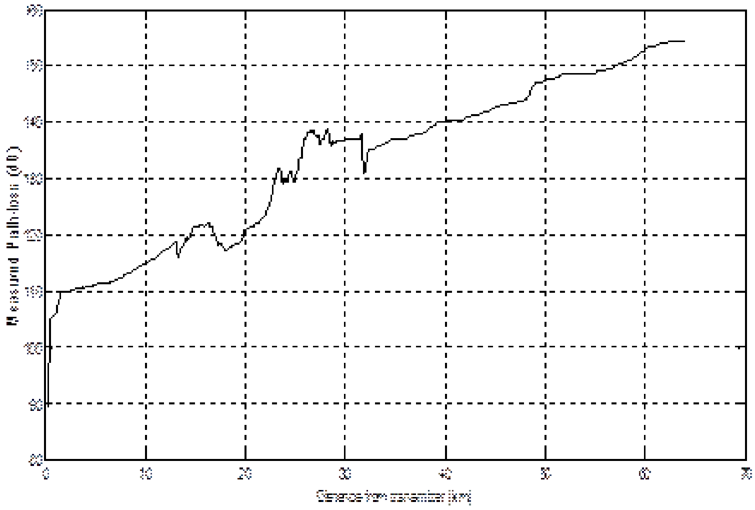

Figure 3: Measured PL values against distance for the FM radio station (A) along intercity roads

Figure 4 shows the measured path-loss values against distance for the radio station (B). The minimum PL value of 97.38 dB for the radio station (B) was obtained at 0.26 km away from the transmitter; the maximum PL value of 162.65 dB was obtained at 63.82 km away from the transmitter. The average measured path-loss value of 130.21 dB was obtained for the radio station (B) along the test drive route. At 28.62 km away from the transmitter, a sharp decrease in measured path-loss value of 143.88 dB was observed when compared with an average value of 145.63 dB obtained within a kilometer. The improved signal reception was due to the presence of a large lake within the vicinity of the measurement point. Figure 5 presents the results of existing models and measured PL values against distance for the radio station (A). At 0.26 km away from the radio transmitter (A), the path-loss values were 28.93 dB, 61.92 dB, 31.36 dB and 21.62 dB for Egli, COST 231-Hata, Okumura-Hata and Hata-Davidson models, respectively. While at 63.82 km away from the radio transmitter, the path-loss values were 124.28 dB, 129.03 dB, 262.80 dB and 282.45 dB for Egli, COST 231-Hata, Okumura-Hata and Hata-Davidson models, respectively, which give the average path-loss values of 76.12 dB, 95.68 dB, 147.08 dB and 152.04 dB, respectively.

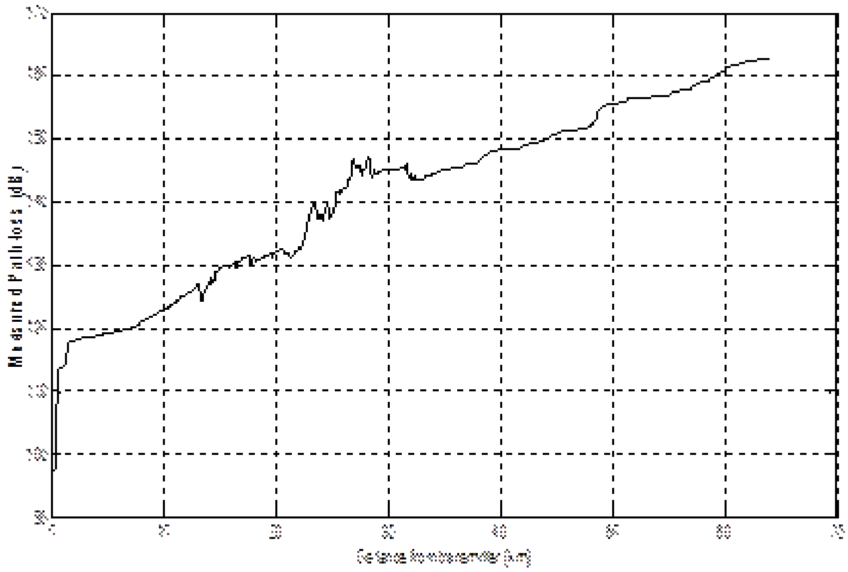

Figure 4: Measured PL values against distance for the FM radio station (B) along intercity roads

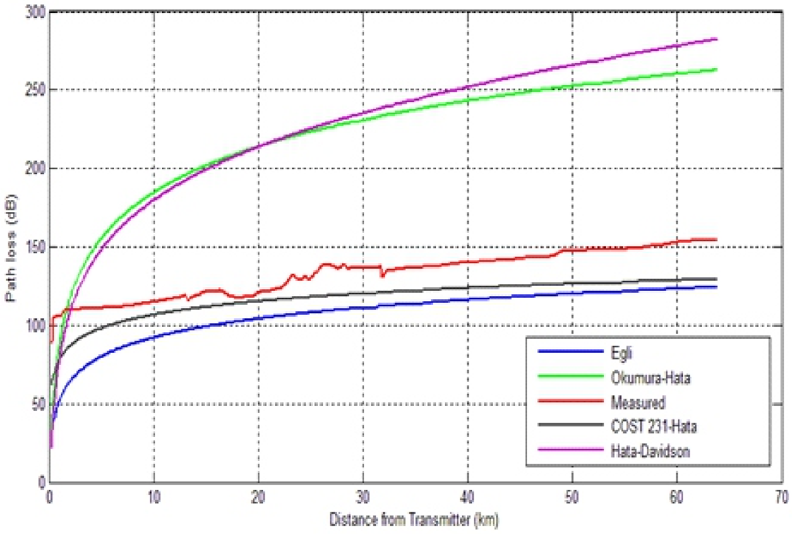

Figure 5: Path-loss values versus distance along the intercity roads for the FM radio station (A)

Figure 6 presents the results of existing models and measured path-losses against the distance for the FM radio station (B), at 0.26 km away from the radio transmitter, the path-loss values of 34.28 dB, 63.97 dB, 29.63 dB and 29.88 dB were obtained for Egli, COST 231-Hata, Okumura-Hata and Hata-Davidson models, respectively. When the distance increases to 63.82 km, the path-loss values were 129.64 dB, 131.48 dB, 261.06 dB and 280.72 dB for Egli, COST 231-Hata, Okumura-Hata and Hata-Davidson models, respectively, while the respective average PL values were 81.96 dB, 97.24 dB, 145.34 dB and 155.30 dB. The COST 231-Hata model gave the most accurate prediction out of the four existing models, and therefore, further optimized to get accurate results.

Figure 7 shows the PL value against distance for the measured, optimized and COST 231-Hata for the FM radio station (A). The average path-loss values obtained were 121.89 dB, 95.68 dB and 101.40 dB, for measured data, COST 231-Hata, and optimized COST 231-Hata models, respectively. Figure 8 shows the path-loss value against the distance for the measured, optimized and COST 231-Hata for the FM radio station (B). The average path-loss values of 113.01 dB, and 97.20 dB and 103.70 dB were obtained for measured data, COST 231-Hata, and optimized COST 231-Hata models, respectively. The improved accuracy observed in the path-loss values of optimized COST 231-Hata model when compared with COST 231-Hata model shows the minimization of the path-loss value in the objective function, and setting antenna height and distance as constraints was effective.

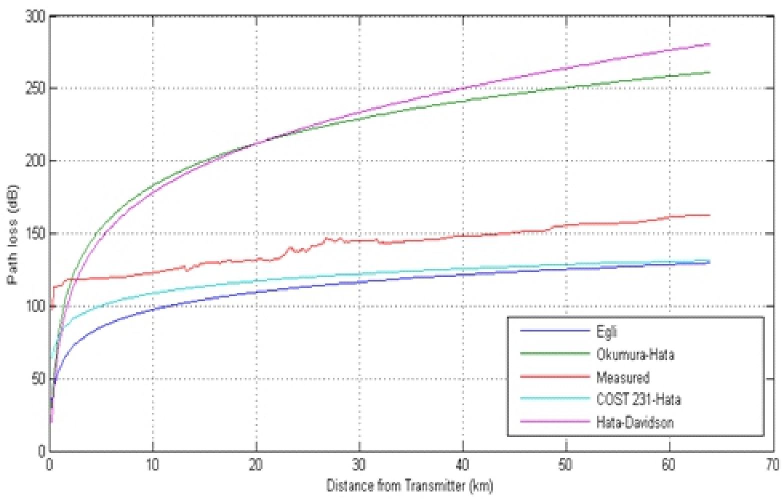

Figure 6: Path-loss values versus distance along the intercity roads for the FM radio station (B).

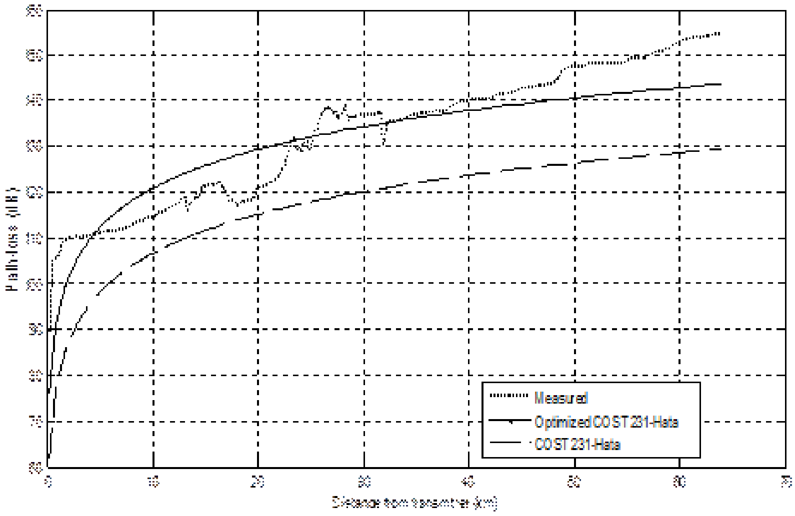

Figure 7: PL values against distance for measured data, COST 231-Hata and Optimized COST 231-Hata models along the intercity roads for the FM radio station (A).

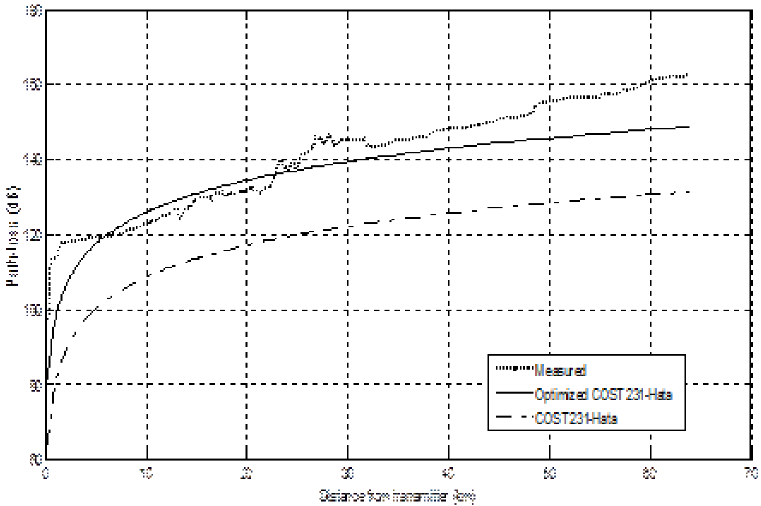

Figure 8: PL values against distance for measured data, COST 231-Hata and Optimized COST 231-Hata models along the intercity roads for the FM radio station (B)

Table 3 contains the MAE and RMSE values obtained for the existing and optimized models for the radio station (A). The optimized COST 231-Hata model has the lowest MAE value of 20.48 dB; this shows that, it is the most accurate model with minimum error when compared with measured value. The optimized COST 231-Hata model has the lowest RMSE value of 1.37 dB, indicating the best fit in path-loss prediction accuracy.

Table 3: MAE and RMSE values for the FM radio station (A) in Osun State

Path-loss model	Mean Absolute Error (*MAE*) in dB	Root Mean Square Error (*RMSE*) in dB
Egli	45.28	3.18
COST-231	26.21	1.75
Optimized COST-231	20.48	1.37
Okumura-Hata	83.08	5.80
Hata-Davidson	97.78	6.83

The MAE and RMSE values obtained for the existing and optimized models for the FM radio station (B) are contained in Table 4. The optimized COST 231-Hata model has the lowest MAE value of 26.3 dB indicating the most accurate model with minimum error while the lowest RMSE value of 1.76 dB was obtained for the optimized COST 231-Hata model showing the best fitness in predicting the path-loss for the area considered.

Table 4: MAE and RMSE values for the FM radio station (B) in Osun State

Path-loss model	Mean Absolute Error (*MAE*) in dB	Root Mean Square Error (*RMSE*) in dB
Egli	48.05	3.37
COST-231	32.29	2.16
Optimized COST-231	26.30	1.76
Okumura-Hata	84.32	6.15
Hata-Davidson	98.17	6.97

Conclusion

In this paper, investigation of the selected existing empirical models was carried out by drive test to measure the received signal strength of FM radio station (A)'s signal and FM radio station (B), situated in Osogbo and Ilesa, respectively in Osun State, South-Western Nigeria using a Spectrum Analyzer. The values of the measured PL were compared with predicted existing PL values to determine the closest model to optimized using Genetic Algorithm. The performance of the models was evaluated using the values of Root Mean Square and Mean Absolute Error. The results show that the optimized COST 231-Hata model has the lowest values of *MAE* and *RMSE* for FM radio station A and B. This implies that the optimized COST 231-Hata model is more accurate than the COST 231-Hata model and can be used for predicting path-losses in planning and improving the quality of service for FM radio stations in Osun State.

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