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A WAVELET GENETIC ALGORITHM BASED SIGNAL PATH LOSS MODEL FOR EVOLVED NODEB CELL SITES PLANNING AND EFFECTIVE COVERAGE OF WIRELESS COMMUNICATION SYSTEM

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ABSTRACT

In this study, a long term evolution (LTE) path loss prediction models were developed using wavelet transform and genetic algorithm (GA) approach, based on denoised signal data (designated as wavelet-GA model) and unprocessed signal data (designated as GA model). The reference signal received power (RSRP) and distance were extracted through drive-test method in four selected evolve NodeB (eNodeB) cell sites deployed in Port Harcourt at 2.6GHz. Also, the maximum cell radius and coverage area of transmitters deployed in Port Harcourt were estimated. The developed wavelet-GA path loss model was compared with GA model, existing standard models such as COST231-Hata and Okumura-Hata path loss models, based on root mean square error (RMSE), mean absolute error (MAE), and correlation coefficient (R). Standard COST231-Hata and Okumura-Hata models were compared with the measured data for path loss estimation and it showed that the path loss values estimated using Okumura-Hata model is more closer to the measured data path loss values as such the best standard model than COST231-Hata model. Result obtained showed the proposed wavelet-GA model as the most reliable and most suitable model to predict path loss within Port Harcourt, Nigeria. Wavelet-GA path loss model estimated the least RMSE and MAE of 2.90 dB, 3.87 dB, 4.66 dB, 7.33 dB and 2.20 dB, 2.71 dB, 3.39 dB, 6.09 dB respectively for all the sites as compared to GA model and COST231-Hata model. Also, the correlation coefficient when it was correlated with the measured data has the highest value of 90%, 63%, 79%, and 92% in all the sites. The COST231-Hata model evaluated the highest RMSE and MAE in all the sites. It showed that cell radius and coverage area evaluated to be suitable within Port Harcourt are 0.85 km and 1.39 km^2 respectively. The proposed wavelet-GA path loss model has proven to be the best for cell site planning within Port Harcourt and should be adopted for path loss evaluation during cell site planning.

Keywords: wavelet; genetic algorithm; signal path loss; eNodeB cell sites; effective coverage wireless system

INTRODUCTION

Several researches have been carried out to enhance cellular communication network in different environments, since the discovery of telecommunication which resulted to wireless communication network system that transmits data or voice information from a transmitter to a receiver through electromagnetic signal.

Since the introduction of commercial usage of long term evolution and GSM globally and specifically in Nigeria, subscribers demand for voice and data service has increased tremendously [9]. Despite the four major service providers operating in Nigeria, there has been several complains from the subscribers on the weak signal coverage. This is as a result of signal propagation path loss in electromagnetic signal as it transmits from the base station to the receiver. Base station has coverage area it is planned to cover for effective cellular communication network [3],[6]. Areas or spots where there is a weak signal result to constant drop calls, delay in downloading files, difficulty in connectivity, fluctuation of signal coverage. This basically means that the voice or data service is based on the signal propagation path loss of the electromagnetic wave as it transmits from the base station to the receiver. The gradual attenuation of the electromagnetic wave signal due to path loss as it transmits from the base station to the receiver is an issue for network providers [11]. To effectively predict the coverage area of a base station in an environment, an accurate estimation of the electromagnetic signal coverage is a priority. Signal path loss models are very significantly and required tools for finding out the properties of a terrain, as such the evaluation of path loss is a required for base station planning, coverage area, and location to site the base station. Path loss is cause by so many effects or factors such as the terrain of signal propagation distance between base station and receiver, base station and receiver height, base station location, cable loss, antenna loss, reflection, refraction, and diffraction [4]. The coverage areas of base stations are not fixed for all environments, but depend on the type of the terrain and the level of buildings in such area [5]. The purpose of this study is to develop a path loss model that is based on wavelet transform and genetic algorithm approach with high performance level for the prediction of path loss within part of Port Harcourt, Nigeria.

Literature Review

COST231-Hata path loss model

COST231-Hata path loss models was formulated and optimized from Okumura-Hata model in 1999 to account for higher transmission of frequency between 1.5GHz to 2GHz [8].

$$y_1(dB) = 46.3 + 33.9\log f - 13.82\log h_t - ah_r + [44.9 - 6.55\log h_t]\log d + F_C \tag{1}$$

Where

$ah_r = 3.2[\log(11.75h_r)]^2 - 4.97$, for urban terrain

$ah_r = (1.11\log f - 0.7)h_r - (1.56\log f - 0.7)$, for rural terrain

y_1 (dB) = path loss in decibel

f = transmitting frequency

h_t = transmitting height

h_r = receiver height

d = distance between transmitter and receiver

F_c = correction factor, 0dB for suburban and 3dB for urban environment respectively

Okumura-Hata model

This model was formulated to estimate signal path loss within the urban environment. It is suitable to operate in transmitting frequency range of 500MHz to 1.5GHz and can cover a peak distance of 100 km. The efficiency of these existing model cannot be guaranty in estimating path loss accurately in other environment, as such differs according to the environment of the signal propagation [13].

For urban terrain

$$y_1(dB) = \alpha - 4.78(\log f)^2 + 18.33\log f + 40.94 \tag{2}$$

For suburban terrain

$$y_1(dB) = \alpha - 2\left(\log\frac{f}{28}\right)^2 + 10.8 - C \tag{3}$$

For urban terrain

$$y_1(dB) = \alpha - C \tag{4}$$

Where

$\alpha = 69.55 + 26.16\log f - 13.82\log h_t + [44.9 - 6.55\log h_t]\log d$

$C = 3.2[\log(11.75h_r)]^2 - 4.97$

h_t = transmitter height

h_r = receiver height
d = distance between transmitter and receiver
f = transmitting frequency

MATERIALS AND METHOD

Port Harcourt is the capital city of Rivers State of Nigeria. It is highly populated with bungalows and upstairs between 2 to 20 storey buildings, as such considered as an urban city. The city is marked with residential, commercial building and industries. There are several service providers operating within the city such as Glo, MTN, airtel, and 9Mobile, but for the purpose of this study 4G LTE of MTN operating at 2600MHz was considered. Four eNodeB cell sites of LTE were selected for this study.
The instrumentation tools which were used for the measurement are; test mobile systems (TEMS) software, laptop, global positioning systems (GPS), and MTN SIM with data inserted in the modem. These devices are installed inside a car. The reference signal received power (RSRP) or received signal strength (RSS) are measured around the four eNodeB cell sites through drive-test method. As the car moves away from the stationary cell sites or base station, the TEMS software installed in the laptop is automatically recording the signal strength with respect to the distance from the base station and saved in the TEMS log file. The sketch of the drive test method during field measurement is as shown in figure 1 below.

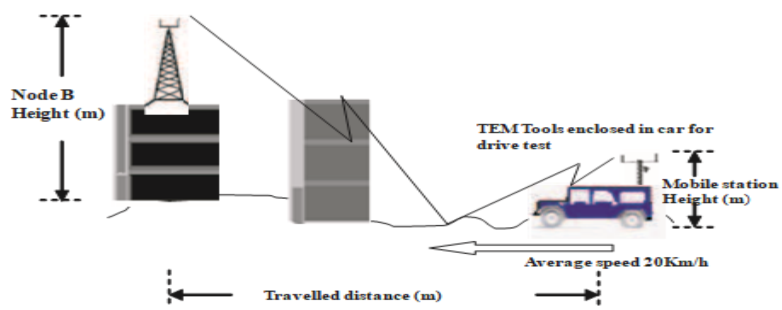

Fig. 1: Sketch of TEMS Drive Test Configuration

Calculation of Measured Path loss

The measured path losses were estimated using the expression as shown in equation (5) below [2]

$$y_{(m)} = P_t + G_t + G_r - L_A - L_F - RSRP \qquad (5)$$

Where
$y_{(m)}$ = measured path loss (dB)
Pt = transmitter power (dBm)
Gt = transmitting antenna gain (dBi)
Gr = receiving antenna gain (dBi)
L_A = antenna body loss (dB)
L_F = feeder cable loss (dB)
RSRP = measured signal strength (dBm)

Optimisation Algorithm Method

Optimization algorithm approach is basically a method established to achieve the best and optimal result by repeatedly comparing different solutions [1]. Genetic algorithm (GA) is a heuristic search whereby by fitness individual chromosomes are selected to produce off springs of the next generation, as such the produced off springs characterizes the parameters in the generic model and the steps to evaluate the off springs of the parameters in GA are; to select encoding type, to choose population size, to randomly choose initial population, to select parents' chromosomes, crossover and mutation, evaluation of offspring, and the iteration repeat step 4 again, if a criteria is not reached [14]. A path loss model is required for the optimization of the problem. For this purpose COST231-Hata model has been chosen for path loss optimization. The COST231-Hata model was deduced to generic model with parameters and these parameters are optimized by GA. The purpose of optimization process is to minimize the prediction of path loss. The standard COST231-Hata model was deduced to equation (6) below.

$Z_0 = 46.3 - 13.82\log(h_t) - a(h_r) + F_c$

$Z_1 = 33.9\log(f)$

$Z_2 = [44.9 - 6.55\log(h_t)]\log(d)$

Therefore,

$y_1 = Z_0 + Z_1 + Z_2$

Let

$Z_0 = P_1$

$Z_1 = P_2\log(f)$

$Z_2 = P_3\log(d)$

$$y_1(P_1, P_2, P_3) = P_1 + P_2\log(f) + P_3\log(d) \tag{6}$$

Table 1: Some the cell sites parameters used for this study [12].

Cell site type	ENodeB
Cellular network generation	4G LTE
Base station height	35 m
Receiver height	1.5 m
Base station power	43dBm
Transmitting frequency	2.6 GHz
Transmitter gain	17.5dBi
Transmitter power	43dBm
Antenna body loss	3dB
Feeder cable loss	2dB

Estimation of Cell Radius and Coverage Area

The cell radius expresses the maximum distance of the eNodeB that can transmit or communicate to a subscriber and still guarantee the required coverage signal quality [10]. Here, the cell radius and coverage area of each studied eNodeB site can be determined using the proposed wavelet-GA path loss model and other relevant antenna transmission parameters as follows:

$y_1 = P_1 + P_2\log(f) + P_3\log(d)$

$P_3\log(d) = y_1 - P_1 - P_2\log(f)$

$$d = \frac{y_1 - P_1 - P_2\log(f)}{P_3} \tag{7}$$

$$d_R = \frac{10^d}{1000} \tag{8}$$

$$d_A = \frac{9\sqrt{3}\times(d_R)^2}{8} \tag{9}$$

Where
y_1 = the maximum measured path loss value
P_1, P_2, P_3 = the parameters to be reproduced in genetic algorithm
f = 2600MHz
d = measurement distance
d_R = cell radius
d_A = cell coverage area

Performance of Distribution Function

RMSE, MAE, R are used for comparative analysis of the wavelet-GA model, GA model, COST231-Hata model with that of measured data. The lower the RMSE, MAE values, the better the performance level of the model and also the higher the R value, the higher the chances of the path loss model predicting the best result [7]. The equation 10-12 is an expression used for the comparison.

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(y_m - y_1)^2} \tag{10}$$

$$MAE = \frac{1}{n}\sum_{i=1}^{n}(y_m - y_1) \tag{11}$$

$$R = \frac{\sum_{i=1}^{n}\left(y_m - y_{m(mean)}\right)^2 - \sum_{i=1}^{n}(y_1 - y_m)^2}{\sum_{i=1}^{n}\left(y_m - y_{1(mean)}\right)^2} \tag{12}$$

RESULT AND DISCUSSION

Table 2: The mean developed Wavelet-GA and GA path loss models

eNodeB sites	Proposed Hybrid Wavelet-GA	GA Model
PH 1	-4.30+22,02log(d)+29.28log(f)	5.28+20.72log(d)+27.54log(f)
PH 2	9.28+14.85log(d)+28.67log(f)	-0.63+14.54log(d)+30.83log(f)
PH 3	-6.96+29.99log(d)+25.27log(f)	0.40+26.51log(d)+25.84 log(f)
PH 4	-7.50+29.98log(d)+24.07log(f)	-8.48+30.00log(d)+24.33log(f)
Mean	**-2.37+24.21log(d)+26.82log(f)**	**-0.86+22.94log(d)+27.14log(f)**

Table 3: Computed cell radius and coverage area for eNodeB site planning in Port Harcourt.

Location	eNodeB Cell Site Radius	eNodeB Cell Site Coverage Area
Port Harcourt	0.85km	1.39km^2

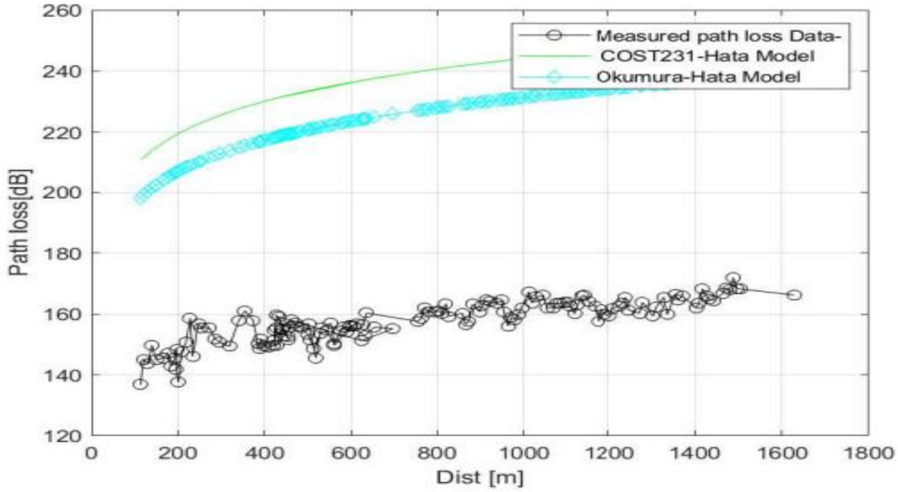

Figure 1: Measured Path loss compared with COST231-Hata and Okumura-Hata Models in eNodeB Site 1

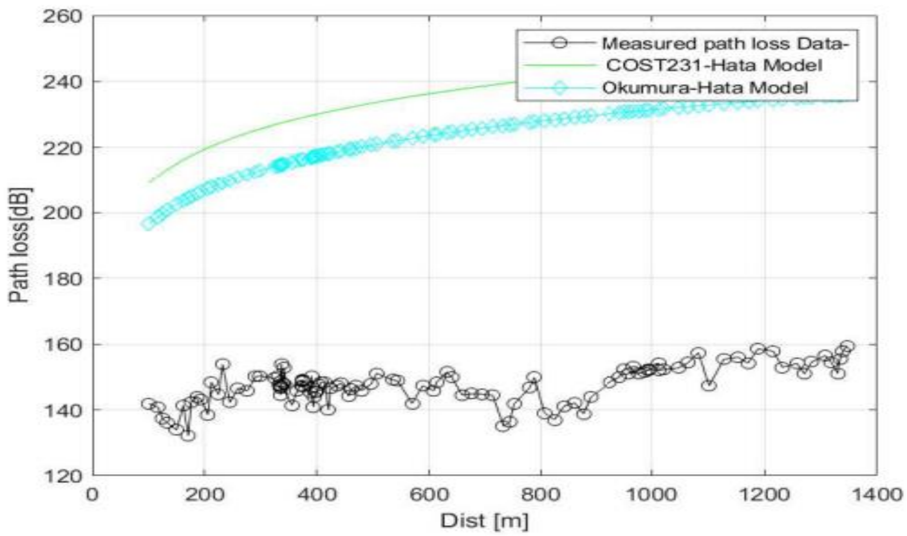

Figure 2: Measured Propagation loss compared with COST231-Hata and Okumura-Hata Models in eNodeB Site 2

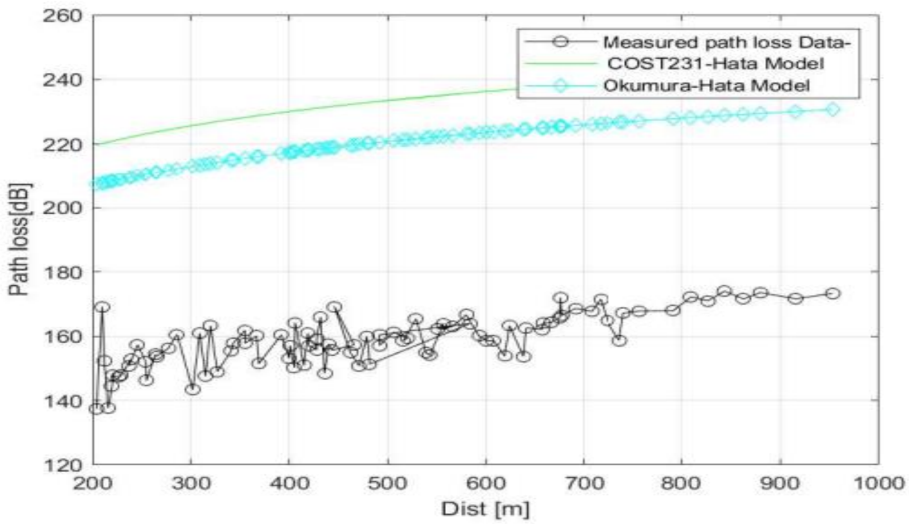

Figure 3: Measured Propagation loss compared with COST231-Hata and Okumura-Hata Models in eNodeB Site 3

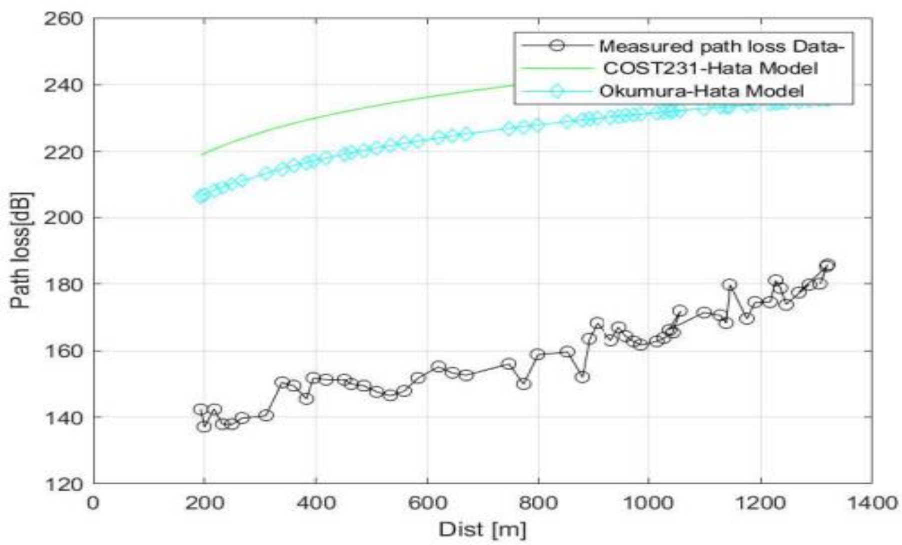

Figure 4: Measured Propagation loss compared with COST231-Hata and Okumura-Hata Models in eNodeB Site 4

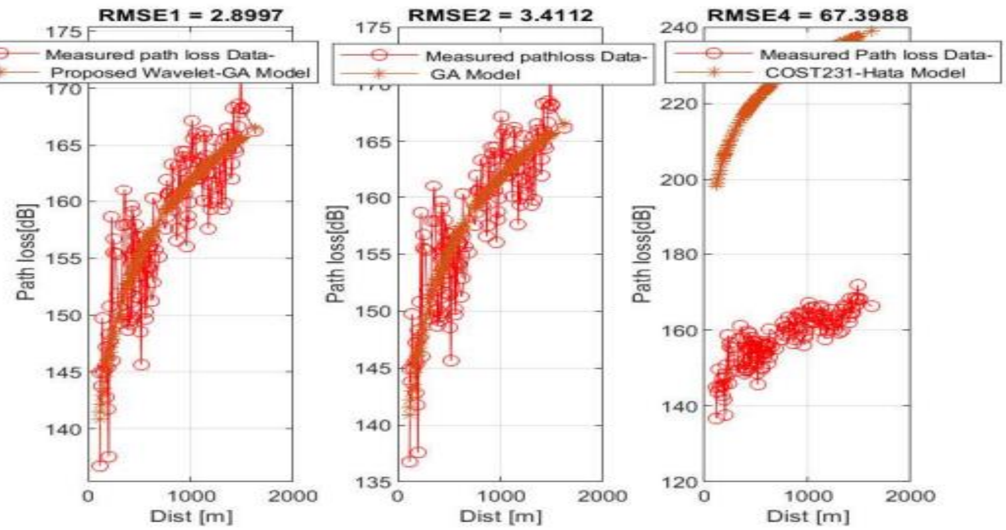

Figure 5: RMSE of Wavelet-GA model, GA Model, and COST231-Hata, in eNodeB Site 1

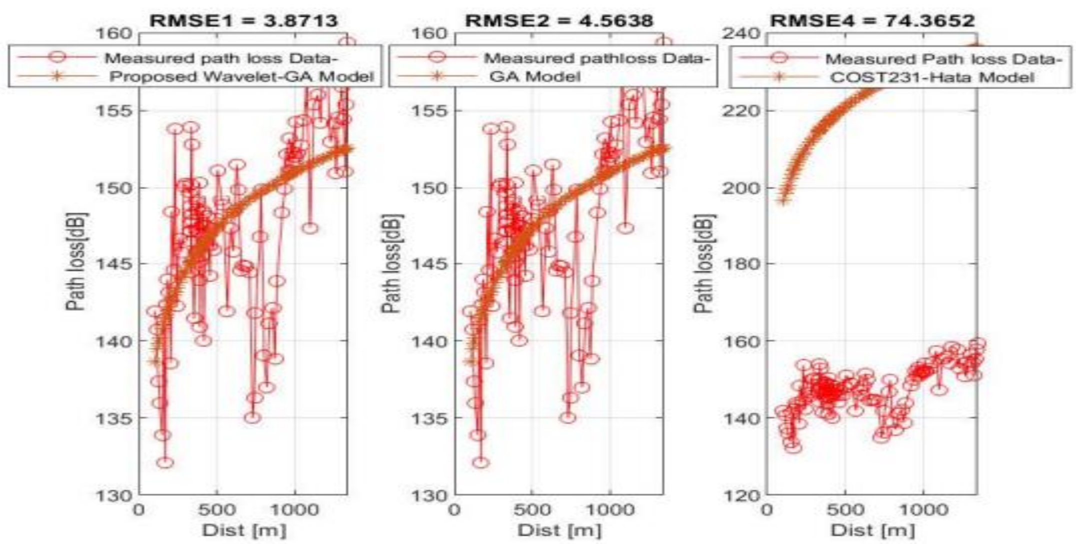

Figure 6: RMSE of Wavelet-GA model, GA Model, and COST231-Hata, in eNodeB Site 2

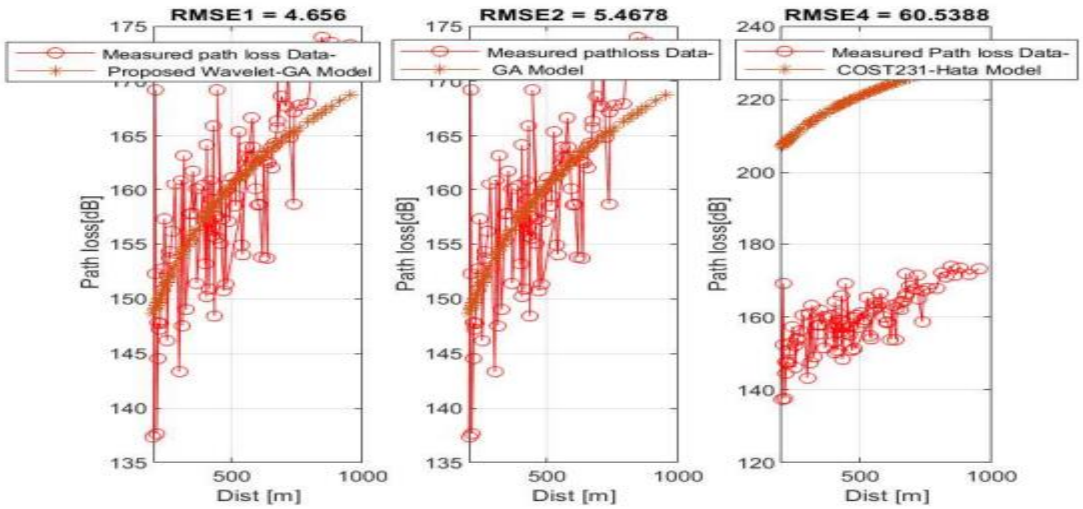

Figure 7: RMSE of Wavelet-GA model, GA Model, and COST231-Hata, in eNodeB Site 3

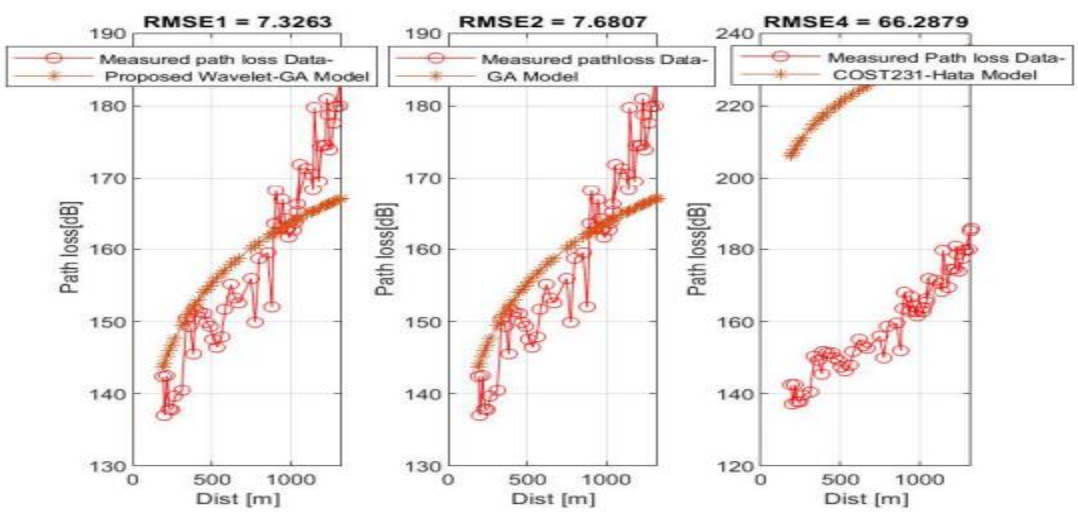

Figure 8: RMSE of Wavelet-GA model, GA Model, and COST231-Hata, in eNodeB Site 4

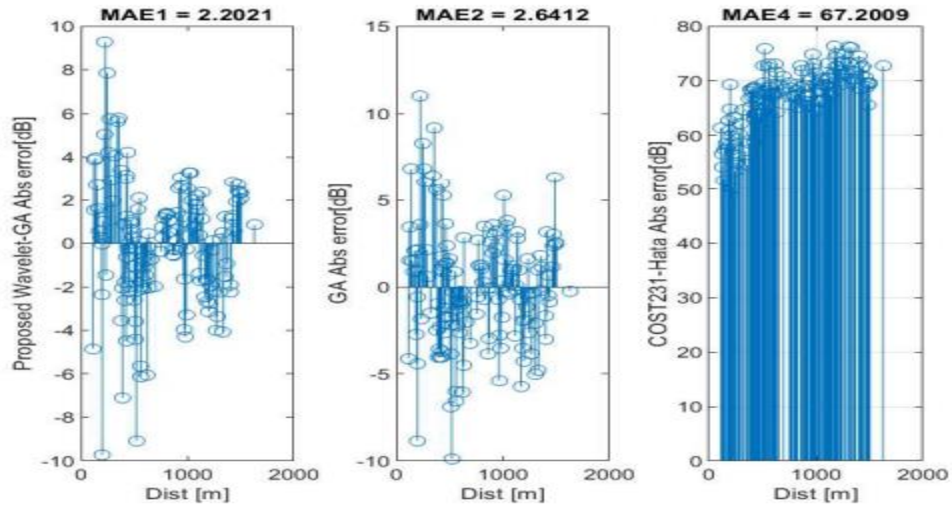

Figure 9: MAE of Wavelet-GA model, GA Model, and COST231-Hata in eNodeB Site 1

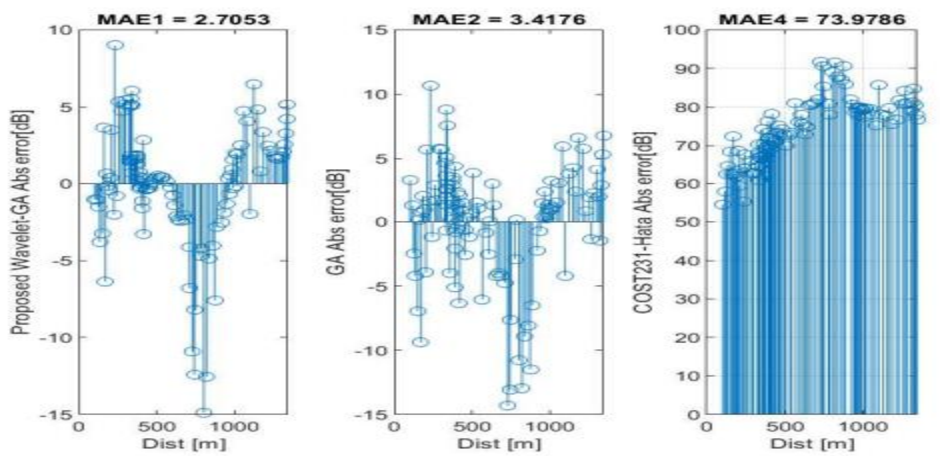

Figure 10: MAE of Wavelet-GA model, GA Model, and COST231-Hata in eNodeB Site 2

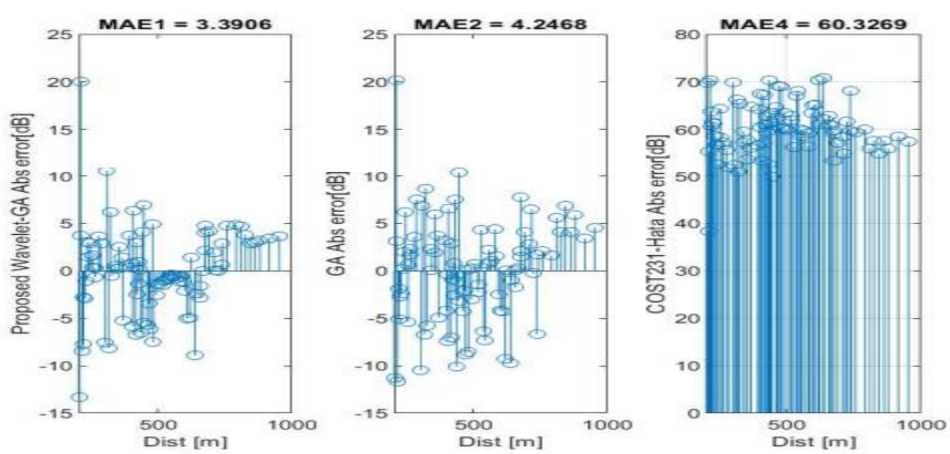

Figure 11: MAE of Wavelet-GA model, GA Model, and COST231-Hata in eNodeB Site 3

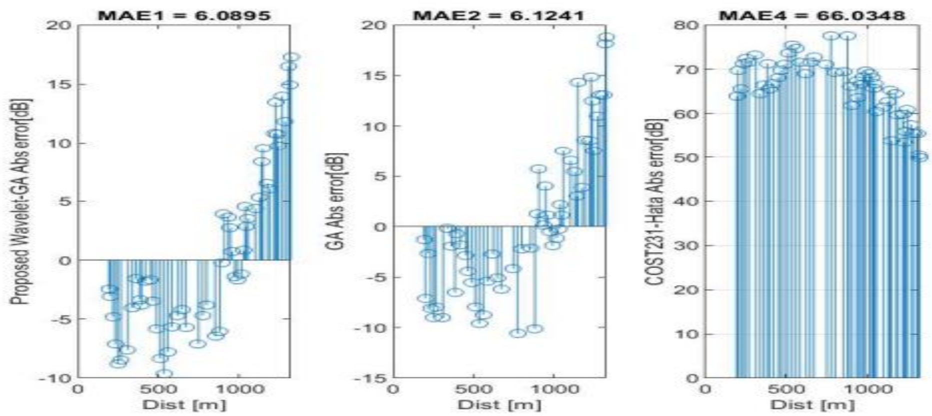

Figure 12: MAE of Wavelet-GA model, GA Model, and COST231-Hata in eNodeB Site 4

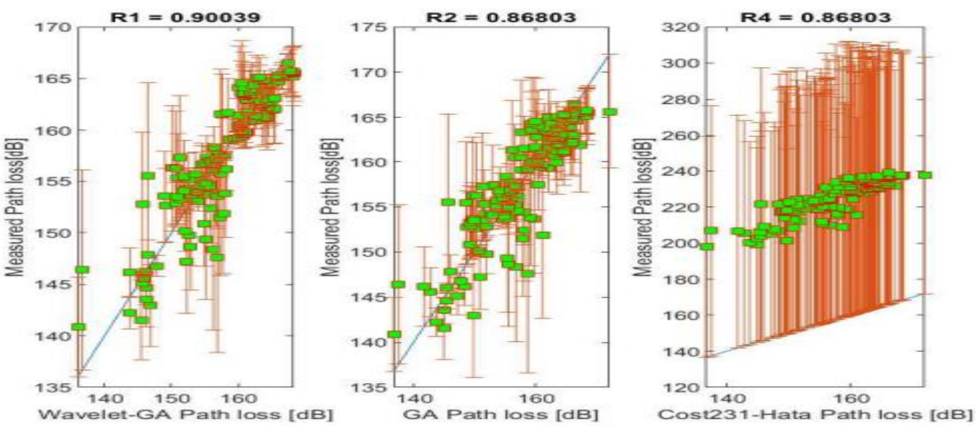

Figure 13: Correlation coefficient of wavelet-GA model, GA model, and COST231-Hata in eNodeB Site 1

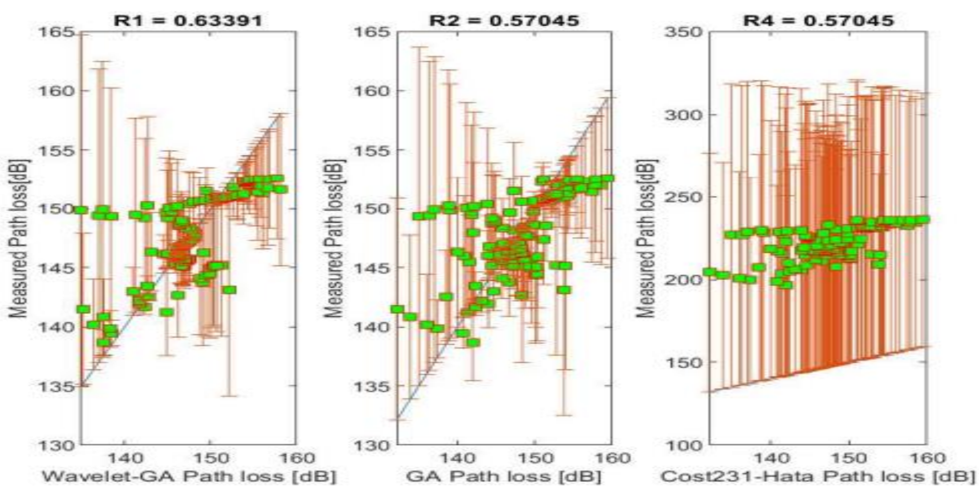

Figure 14: Correlation coefficient of wavelet-GA model, GA model, and COST231-Hata in eNodeB Site 2

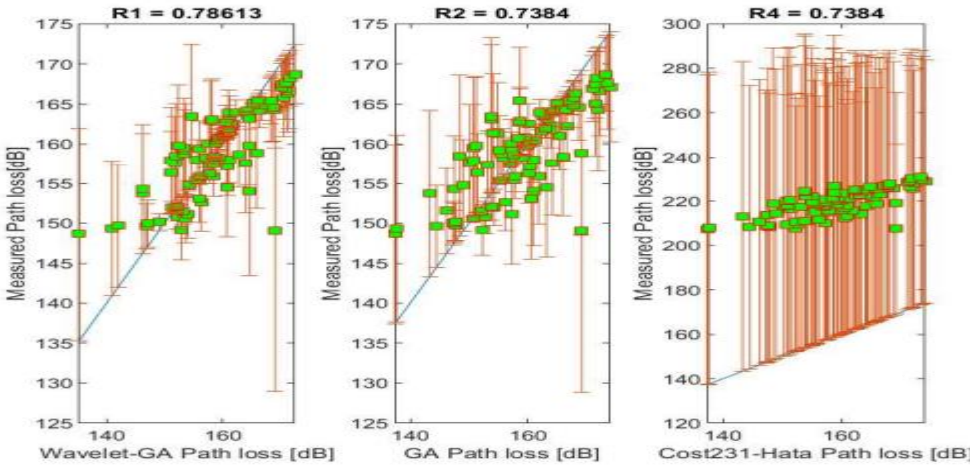

Figure 15: Correlation coefficient of wavelet-GA model, GA model, and COST231-Hata in eNodeB Site 3

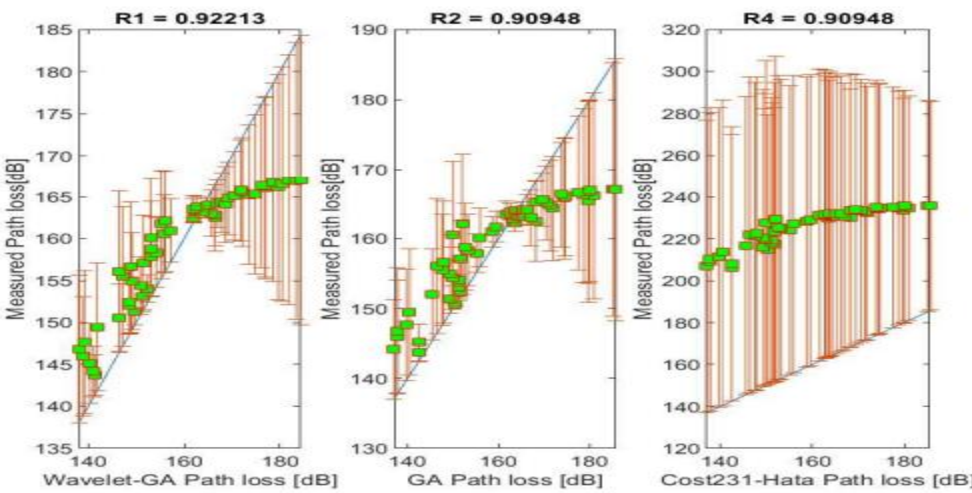

Figure 16: Correlation coefficient of wavelet-GA model, GA model, and COST231-Hata in eNodeB Site 4

CONCLUSION

The study showed that the proposed wavelet-GA model estimated the least RMSE, MAE and has the highest correlation coefficient in all the sites as compared to path loss estimation through GA model and COST231-Hata model. The RMSE and MAE values fall within the range of minimum standard value of 6 dB, as such suitable and should be adopted for path loss prediction during cell site planning. It also showed Okumura-Hata model as the best existing standard model that correlate with the measured data as compared to COST231-Hata model.

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