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Original Research

Clutter Height Variation Effects on Frequency Dependent Path Loss Models at UHF Bands in Build-Up Areas

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Abstract

In this work, the performance of eight prominent empirical path loss models and a localized model, in predicting path losses in build up areas is investigated. Multi-transmitter electromagnetic field strength measurements were conducted, using a dedicated Agilent spectrum analyzer, along five predefined routes in Osun State, Nigeria. The measured data were compared with the model predictions. Path profile and terrain undulations effects have been observed on the received signal. For all the routes and transmitters, Okumura, SUI models over predicted the path losses, while Ericsson model under predicted the losses. However, Hata, Davidson, Cost 231 and ILORIN models generally show promising results with varying performance. The average mean error values of 55.11 dB, -8.53 dB, 46.72 dB, -9.81 dB, -28.16 dB, -8.93 dB, -30.59 dB, -22.95 dB and -12.57 dB are respectively obtained for NTA OSOGBO transmitter for Okumra, Hata, SUI, Cost 231, CCIR, Davidson, Ericsson, EEC-33 and ILORIN models. In terms of RMSE, the average RMSE values of 9.24 dB, 9.08 dB and 9.18 dB were obtained for ILORIN, Hata and Davidson models respectively. This trend was found to be similar for other transmitters i.e. OSBC, NDTV and NTA Ile Ife with varying performances among the four contending models. We, further, examined the route performance for the two main contending models i.e. ILORIN and Hata models. Inconsistency in terms of the performance for each model were observed, however the localized model i.e. ILORIN was found to provide optimum path loss prediction with considerable accuracy, over the other models. With the aforementioned, we believe the results and observations presented would provide guide to radio system engineers in making informed choices on the applicability and predictability of such models in the terrain of Osun State and other similar build-up areas in Nigeria.

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INTRODUCTION

The presence of irregular terrain, on a radio signal path, degrades the quality of radio signal and this increases the signal path losses (Cox *et al*., 1994). Signal path losses can be simulated, through empirical path loss models, which are mathematical expressions, employed in the characterization of radio wave propagation and terrain features (Bernhardt, 1995). It is usually advisable to simulate the signals path losses before and after the official deployment of the radio network, because any shortcoming in the network planning process will lead to extra expenses as a corrective measure (Masahara, 1995). Therefore, simulated signal path losses are useful planning tools, required by the radio network designer to reach network optimal levels. However, the importance of understanding the terrain features, within the scope of the deploying network, cannot be overruled in the network planning process (Hviid *et al*., 1995). Majorly, terrain features constitute disturbances like reflection, refraction, diffraction and absorption. Other disturbances affecting the quality of radio signals are the free space losses, atmospheric losses etc. (Meeks, 1998). Hence, it is very important to investigate the applicability and predictability of empirical path loss models in different possible radio propagation terrains around the world.

As far back as 1980, great deals of research work on the empirical path loss models have been taking place, including, optimizing existing models to fit in to a certain environment and the studying of models applicability and predictability in different environments of interest etc (Ling and Moore, 1997). For instance, Okumura *et al*. (1968) presented the effect of radio signals field strength variability in VHF and UHF frequency bands was presented, graphically. In the work, it was concluded that field strength variability depends on frequency bands, distance and environment. Similarly, Hata, (1980), analyzed the graphical interpolation of path loss, median attenuation and the associated gain, set up by Okumura *et al*. (1968) to formulate Okumura – Hata empirical expression for propagation of path loss in land and mobile radio services.

Furthermore, the effectiveness of the Okumura – Hata model in a typical suburban area within the northern part of Nigeria was investigated by Shoewu and Adedipe (2010). Ayeni *et al*. (2012), investigated the variation of path loss prediction error for Kano State Nigeria, the research established the variations through practical measurement of data obtained from Kano province. Likewise, Obiyemi *et al*. (2012) investigated the suitability of propagation model for Ilorin, Kwara State, Nigeria. In the study, path loss measurements for two transmitters were captured and the results show that the empirical models neglected the actual terrain profile for television broadcast in Ilorin. Verification of the path loss predictability by nine widely used empirical path loss models was done by Faruk *et al*. (2013). In the work, performance criteria were based on statistical analysis and results show that no single model provides a good fit result consistently.

Chebil *et al*. (2013) presented a quantitative measurement for Nigeria Television Authority (NTA) in Edo State, Nigeria. The results show that the applicability and suitability of Hata propagation model are in doubt. The measurements and modeling of path loss propagation for three GSM operators were conducted in Mubi Kano, Nigeria (Ogbeide and Edeko, 2013). Danladi and Natalia (2014), presented an optimized path loss model for predicting TV coverage for secondary access. In the work, Hata – Davidson's model with least errors was optimized for better fit result. Generally, the related work reviewed; show that empirical path loss models applicability and predictability is necessary in Osun State, since no detailed bench mark research has been conducted with regard to the level of prediction performance of each of the models to be examined.

MATERIALS AND METHODS

The drive test was conducted at an average speed of 40 km/hr for the field strength measurement of four selected television transmitters. The measured path loss was mathematically computed from the received signal field strength, measured along the five selected measurements routes. The total measurement routes' distances are about 140 km with the longitude and latitude of measurements points captured. The spherical law of cosine was chosen as the conversion model for the estimation of field radial distance from the longitude and latitude of the measurements points. This is because the spherical law of cosine has a good precision level, which is well-conditioned to give results to the nearest meter. The measured path loss was statistically compared with the models predicted path losses. The measurement field set up and simulation parameters are presented in Figure 1 and Table 1 respectively.

Figure 1: Measurement Field Set Up

Table 1: Simulation Parameters

SPECTRUM ANALYZER AGILENT N9342C 100 HZ – 7 GHZ			
	Average noise level Displayed (ANLD)		-164 dBm/Hz
	Pre-amplifier		20 dB
	Bandwidth Resolution (BWR)		10 KHz
ANTENNA TYPE, DIAMOND RH799			
	Frequency range		100 MHz – 1 GHz
	Form		Omni directional
	Height		1.5 m
	Gain		2.51 dBi
TELEVISION TRANSMITTERS			
	NTA Osogbo	Center Frequency	695.25 MHz
		Antenna Height	136 m
	NTA Ile Ife	Center Frequency	615.25 MHz
		Antenna Height	136 m
	Osun State Broadcasting Corporation	Center Frequency	559.25 MHz
		Antenna Height	150 m
	New Dawn Television	Center Frequency	479.25 MHz
		Antenna Height	150 m

Okumura Path Loss Model

Set of curves relating signal median attenuation to free space signal propagation was formulated by Okumura *et al*., (1968). The mathematical expression is given by:

$$L_{50}(dB) = L_f + A_{mu}(f,d) - G(h_{te}) - G(h_{re}) - G_{Area} \quad (1)$$

$$L_f(dB) = 32.44 + 20*\log_{10}(f_C) + 20*\log(d)$$

$$G(h_{te}) = 20*\log_{10}(h_{te}/200) \qquad 30\,\text{m} < h_{te} < 100\,\text{m}$$

$$G(h_{re}) = \begin{cases} 10*\log_{10}(h_{re}/3); & 30\,\text{m} < h_{re} < 10\,\text{m} \\ 20*\log_{10}(h_{re}/3); & h_{re} \le 3\,\text{m} \end{cases}$$

where, d is the transmission link distance in km, L_{50} is the median path loss in dB, L_f is the free space path loss in dB, A_{mu} is the median attenuation in relation to free space path loss across all environments, $G(h_{te})$ and $G(h_{re})$ are the transmitter and receiver gain factors, f_c is the frequency in MHz, h_{te} is the transmitting antenna height in m, h_{re} is the receiver antenna height in m and G_{Area} is the terrain gain based on the type of environment.

Hata's Model

The Hata model is in closed form formula rather than curves, as presented by Hata, (1980). The mathematical expression is given by:

$$L_{50}(urban) = 69.55 + 26.16*\log_{10}(f_C) - 13.82*\log_{10}(h_{te}) - a(h_{re}) + (44.9 - 6.55*\log_{10} h_{te})*\log_{10}(d) \quad \text{........ (2)}$$

For a small or medium city $a(h_{re})$ is expressed

$$a(h_{re}) = (1.1*\log_{10}(f_C) - 0.7)h_{re} - (1.56*\log_{10}(f_C) - 0.8)$$

For large cities

$$a(h_{re}) = \begin{cases} 8.29*(\log(1.54*h_{re})^2) - 1.1; & f \le 200 \text{ MHz} \\ 3.2*(\log(11.75h_{re})^2) - 4.97; & f \ge 400 \text{ MHz} \end{cases}$$

Correction to the urban model is made for suburban and rural propagation, so that the models are given in equations 3 and 4 respectively:

$$L_{50}(Suburban) = L(urban) - 2*(\log_{10}(f_C/28))^2 - 5.4 \quad (3)$$

$$L_{50}(Rural) = L(urban) - 4.78*(\log_{10}(f_C))^2 + 8.33*\log_{10}(f_C) - K \quad (4)$$

where d is the transmission link distance in km, $a(h_{re})$ is the correction factor for the mobile antenna height based on the size of the coverage area, f_c is the center transmitting frequency in MHz, h_{re} is the receiver antenna height in m and K ranges from 35.94 (countryside) to 40.94 (desert).

Stanford University Interim Model

The empirical formulation for this model classified propagation terrain mainly into three types, namely A, B and C as shown in Table 2 (Abhayawardhana *et al*., 2005). The mathematical expression is given by:

$$PL(dB) = A + 10\gamma*\log_{10}(d/d_o) + X_f + X_h + S \quad \text{for } d > d_o \quad (5)$$

$$A = 20*\log_{10}(4\Pi d_o/\lambda)$$

$$\gamma = a - b*h_{te} + (c/h_{te})$$

The correction factor for the operating frequency and the receiver antenna height for the model are:

$$X_f = 6.0*\log_{10}(f/2000)$$

$$X_h = \begin{cases} -10.8*\log_{10}(h_{re}/2000); & \text{For Terrain A, B} \\ -20*\log_{10}(h_{re}/2000); & \text{For Terrain C} \end{cases}$$

$$S = 0.65*(\log f)^2 - 1.3*\log(f) + \alpha$$

where h_{te} is the transmitter antenna height above ground level in *m, a, b* and *c* are constants given in Table 2, γ is the path loss exponent, *f* is the frequency in MHz, h_{re} is the receiver antenna height above ground in *m, d* is the transmission link distance in km. *d* is 5.2 dB for rural and sub urban environments (terrain A and B) and 6.6 dB for urban environments (Terrain C) (Shabbir *et al*., 2011).

Table 2: SUI Terrain Parameters

Parameters	A	B	C
A	4.6	4.0	3.6
b (m^{-1})	0.0075	0.0065	0.005
c (m)	12.6	17.1	20

Cost 231-Hata-Model

The correction factors in Cost 231–Hata Model for urban, suburban and rural environments have improved the applicability of the Hata model for signal path loss prediction at VHF/UHF band up to 2 GHz (COST 1991). This model is design for European cities but it is widely used. The mathematical expression is given by:

$$L = 46.3 + 33.9\log f_c - 13.82\log h_t - a(h_r) + (44.9 - 6.55\log h_t)\log d + C_m \quad (6)$$

$$C_m = \begin{cases} 0\text{ dB}, & \text{For medium sized city and suburban areas} \\ 3\text{ dB}, & \text{For metropolitan} \end{cases}$$

where d is the transmission link distance in km, h_{re} is the receiver antenna height in m, h_{te} is the transmitter antenna height in m, f_c is center transmitting frequency in MHz, $a(h_{re})$ is the receiver antenna height correction factor which is the same as in the case of Hata model and C_m is the environment correction factor in dB.

Electronic Communication Committee Model

Electronic Communication Committee Model is also known and abbreviated as ECC-33 path loss model. The genesis of its formulation solely relies on extrapolation and modification of Okumura to suit fixed wireless systems. The model gives correction factor for urban and medium cities. The model is recommended for European cities and is defined in Abhayawardhana (2005). The mathematical expression is given by:

$$P_L(dB) = A_{fs} + A_{bm} - G_{re} - G_{te} \quad (7)$$

$$A_{fs} = 92.40 + 20*\log_{10}(d) + 20*\log_{10}(f)$$

$$A_{bm} = 20.41 + 9.83*\log_{10}(d) + 7.894*\log_{10}(f) + 9.56*\log_{10}(f)^2$$

$$G_{te} = \log(h_T/200)\{13.958 + 5.8[\log d]^2\}$$

For medium size city,

$$G_{re} = [42.7 + 13.7\log f_c][\log h_r - 0.585]$$

where A_{fs} is the free space attenuation path loss in dB, A_{bm} basic median path loss in dB, f is the operating frequency in GHz, h_m is the mobile receiver antenna height in m, h_b is the base station antenna height above terrain in m, d is the transmission link distance in km, G_{re} and G_{te} are the gain factor of the receiving and transmitting antenna.

Davidson's Model

Hata model has a transmission distance of 20 km; thereafter, prediction error becomes higher when used to predict path loss for distance greater than 20 km. The prediction error is obvious from the work of (Faruk *et al.*, 2013b).

Davidson provides six correction factors, which extend the range to 300 km. Path loss equation for Davidson model is defined in (Davidson, 1997) as follows,

$$PL_D = L_{HATA}(dB) + A(h_{te}, d_{km}) - S_1(d_{km}) - S_2(h_{te}, d_{km}) - S_3(f_{MH_Z}) - S_4(f_{MH_Z}, d_{km}) \quad (8)$$

$$A(h_{te}, d_{km}) = \begin{cases} 0; & d < 20km \\ 0.62317*(d-20)[0.5+0.15*\log(h_{te}/121.92)]; & 20km \le d < 64.38km \\ 0.62317*(d-20)[0.5+0.15*\log(h_{te}/121.92)]; & 20km \le d < 300km \end{cases}$$

$$S_1(d_{km}) = \begin{cases} 0; & d < 20km \\ 0; & 20km \le d < 64.38km \\ 0.174(d-64.38); & 64.38km \le d < 300km \end{cases}$$

$$S_2(h_{te}, d_{km}) = 0.0017484|\log(9.98/d)|(h_{te} - 300) \qquad h_T < 300\ m$$

$$S_3(f_{MH_Z}) = f \big/ 250*\log(1500/f)$$

$$S_4(f_{MH_Z}, d_{km}) = [0.112*\log(1500/f)](d - 64.38) \qquad d > 64.38\ km$$

where d is the transmission link distance in km, $a(h_{re})$ is the correction factor for the receiver antenna height defined in Hata model, h_{te} is the transmitter antenna height in m, h_{re} is the receiver antenna height in m, f is the transmitting frequency in MHz, $A(h_{te}, d_{km})$ is the transmitter antenna gain in dB as a function of transmission link distance in km, $S_1(d_{km})$ is the distance correction factor, $S_2(h_{te}, d_{km})$ is the transmitter antenna height correction factor as a function of transmission link distance km, $S_3(f_{MHz})$ is the frequency correction factor and $S_4(f_{MHz}, d_{km})$ is the frequency correction factor as a function of distance in km.

CCIR Model

The empirical formulation for the CCIR model relies on the combined effects of free space and terrain induced path loss (Lee and Miller, 1998) and CCIR (2015).

$$L_{CCIR} = 69.55 + 26.16*\log_{10}(f_C) - 13.82*\log_{10}(h_{te}) - a(h_{re}) + (44.9 - 6.55*\log(h_{te}))*\log d - B \quad (9)$$

$$B = 30 - 25*\log_{10}(\%\text{ of area covered by building})$$

where $a(h_{re})$ is the correction factor defined in Hata model, h_{te} is the transmitter antenna height in m, h_{re} is the receiver antenna height in m, f_c is the center transmitting frequency in MHz, d is the transmission link distance in km and B is a correction factor as regards the percentage of area covered by the building.

Ericsson 9999 Path Loss Model

Ericsson modified Hata- Okumura model which was originally created for frequency range 150 to1500 MHz. The mathematical expression of this model is given by (ECC 2012):

$$PL(dB) = a_o + a_1*\log_{10}(d) + a_2*\log_{0}(h_{te}) + a_3*\log_{0}(h_{te})*\log_{0}(d) - 3.2*(\log_{10}(11.75))^2 + g(f) \quad (10)$$

$$g(f) = 44.49*\log_{10}(f_C) - 4.78*(\log_{10}(f_C))^2$$

where $g(f)$ is the frequency correction factor, h_{te} is the height of the transmitting antenna in m, d is the transmission link distance in km and f_c is the transmitting frequency in MHz. The values of a_0, a_1, a_2 and a_3 are constant which changed according to the scenario. For example for urban the values are: 36.2, 30.2, -12.0 and 0.1 respectively. For other scenarios these values could be obtained from (ECC, 2012).

ILORIN Model

The ILORIN model is an optimized Davidson empirical model for the terrain of Ilorin Kwara State, Nigeria (Faruk *et al.*, 2013a). The model equation is given by:

$$PL_{ILORIN} = 73.56 + 26.16 * \log_{10}(f_C) - 13.82 * \log_{10}(h_{te}) - a(h_{re}) + 30.5\log_{10}(d) + A(h_{te}, d_{km}) - S_1(d_{km}) - S_2(h_{te}, d_{km}) - S_3(f_{MH_Z}) - S_4(f_{MH_Z}, d_{km}) \quad (11)$$

where all the correction factors $A(h_{te}, d_{km})$ $S_1(d_{km})$, $S_2(h_{te}, d_{km})$, $S_3(f_{MH_Z})$ and $S_4(f_{MH_Z}, d_{km})$ are as defined in Hata-Davidson model.

Table 3: Measurements Routes Descriptions

Routes	Description	(Km)
1	This Route spans from urban area to suburban area (i.e from Osogbo City Stadium Roundabout to Idominasi in Obokun Local Government Area). The route is an express road, busy with vehicular movement and it is characterized with an average building distance of 30 to 40 m apart mostly concentrated along the route.	30.00
2	The suburban area route spans from Ilesha, Isare Street, Sabo market to Ife Express Road. Majorly it is a single two-lane route with an average of one storey building about 100 m apart. The route is busy with vehicular and traders' movement.	25.00
3	The urban area route spans from NTA Ile-ife gate (Nokuro Road) to OAU Moro campus gate through Ooni palace, May fair round-about and OAU Campus gate. The route is majorly a two-lane with concentrated building along the road, busy with vehicles (mostly cars and motorcycles). The road width is about 8 m.	32.00
4	The route spans from Ede Road (in Ede South) to Abere Road, through Sekona, Idi-awe and Akoda Junction. The road is a two-lane with trees and green vegetation majorly concentrated along the road with a complex terrain: some areas are high whereas, some parts are very low.	25.00
5	The last route is an urban area with a mix of single and two-lane road that span from Osun State University gate Oke-Bale to Oja-Oba Market (in Osogbo). The road is a very busy road with buildings 10 to 20 m apart.	28.00

RESULTS AND DISCUSSION

Figure 2 shows the terrain path profile for each of the routes. The path profile is a measure of the terrain elevation from the ground level in meters and also the structural build up like buildings and vegetations.

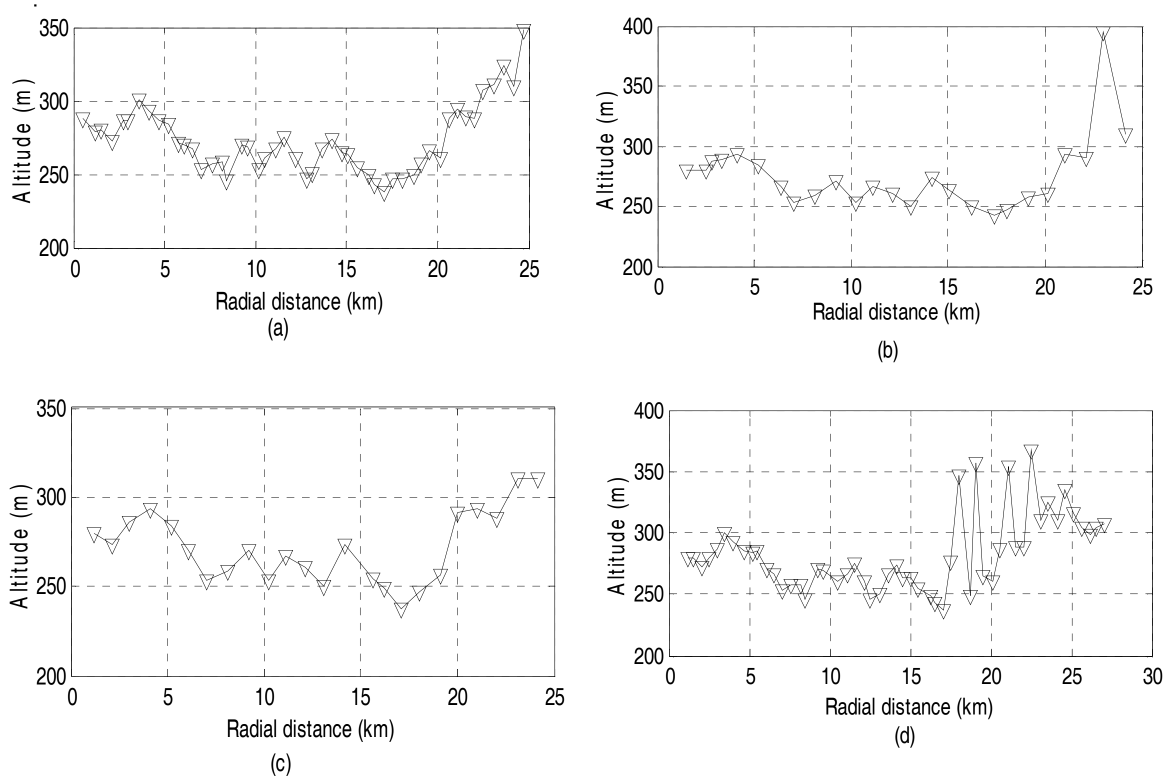

Figure 2: The terrain path profile along (a) Route 1 (b) Route 2 (c) Route 4 (d) Route 5.

Figure 2(a) is the path terrain along route 1 with varying altitude between the range of 240 m to 330 m approximately, Figure 2(b) shows the terrain profile along route 2, with altitude as high as 400 m and as low as 240 m. In all the figures 2(a)-(d) terrain undulations were observed. Figures 3-7 depict the comparison of the empirical path loss with the measured path loss values along routes 1-5.

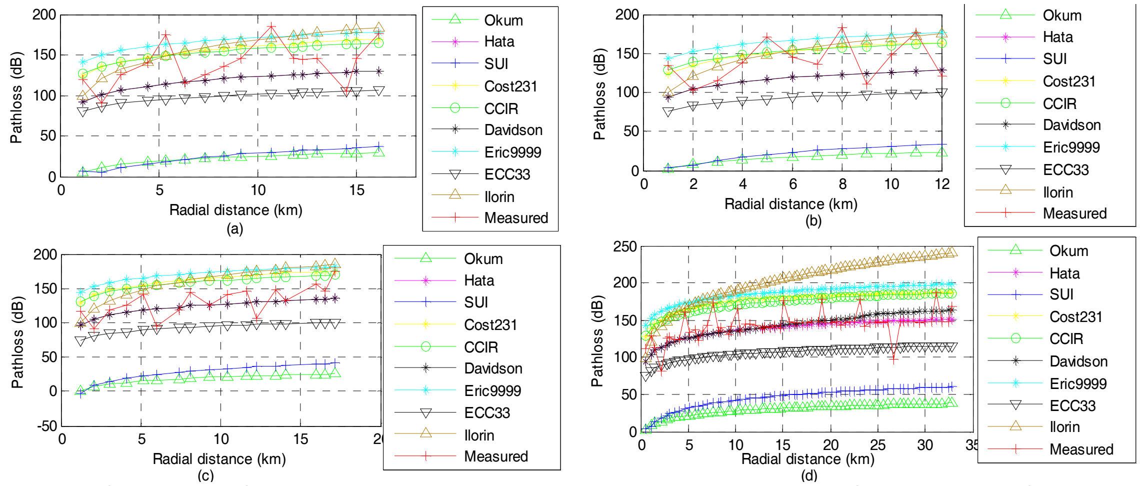

Figure 3: Comparison of Measured and Predicted path loss along route 1 (a) NDTV Obokun (b) NTA Osogbo (c) OSBC (d) NTA Ile Ife

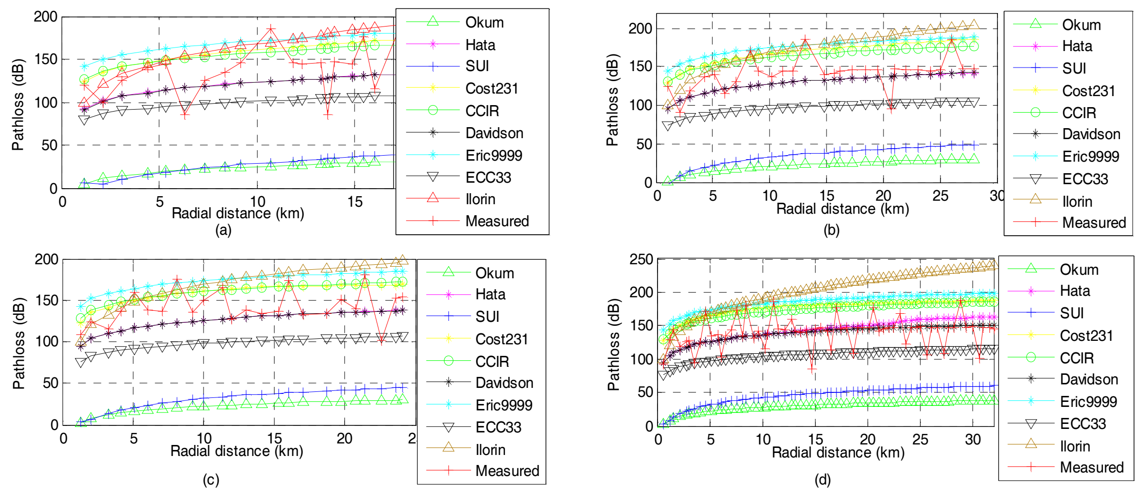

Figure 4: Comparison of Measured and Predicted path loss along route 2 (a) NDTV Obokun (b) NTA Osogbo (c) OSBC (d) NTA Ile Ife

It was observed in Figure 2(b) for path terrain for route 2 that within 20 km distance, the altitude height is around 240 m to 300 m and the path loss measured for each of the four transmitters considered are averagely around 150 dB, but at a further distance of 23 km, for instance, the altitude suddenly increases to around 400 m with an average measured path loss of 100 dB, these variations in altitude and measured path losses highlight the effect of variable altitude on signals strength as a result of mis-alignment in signal line of sight.

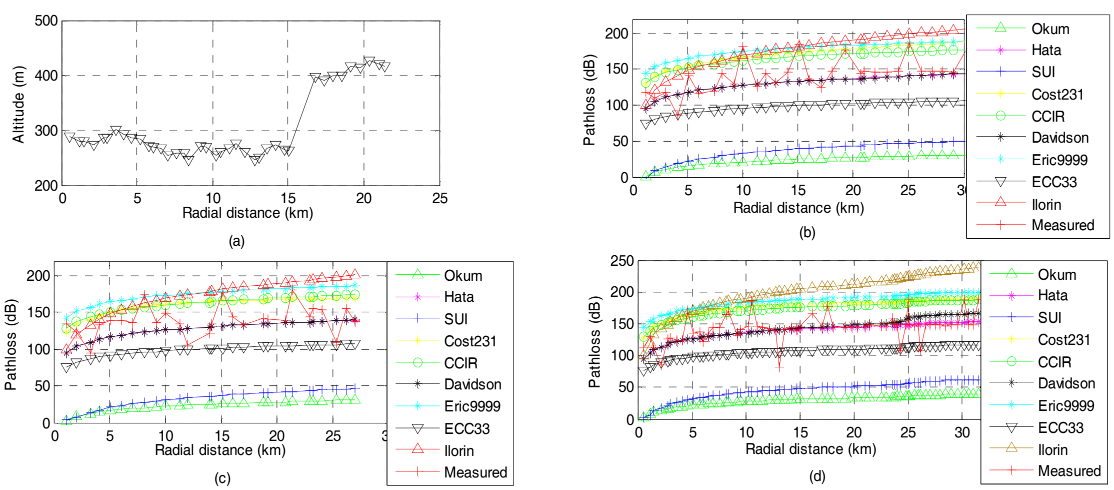

Figure 5: Path terrain with comparison of Measured and Predicted path loss route 3 (a) path terrain (b) NTA Osogbo (c) OSBC (d) NTA Ile Ife

Figure 5 depicts the terrain variation along route 3, the graph shows a rapid increase in the altitude values between 15 km and 17 km and the effects of this increase in the altitude values are easily noticeable, at exatly 17 km distance, with a drop in the path loss measured values of Figures 5(b), (c) and (d). The depiction of comparison of values obtained, using empirical path loss models with those measured, are shown in Figure 6 for route 4.

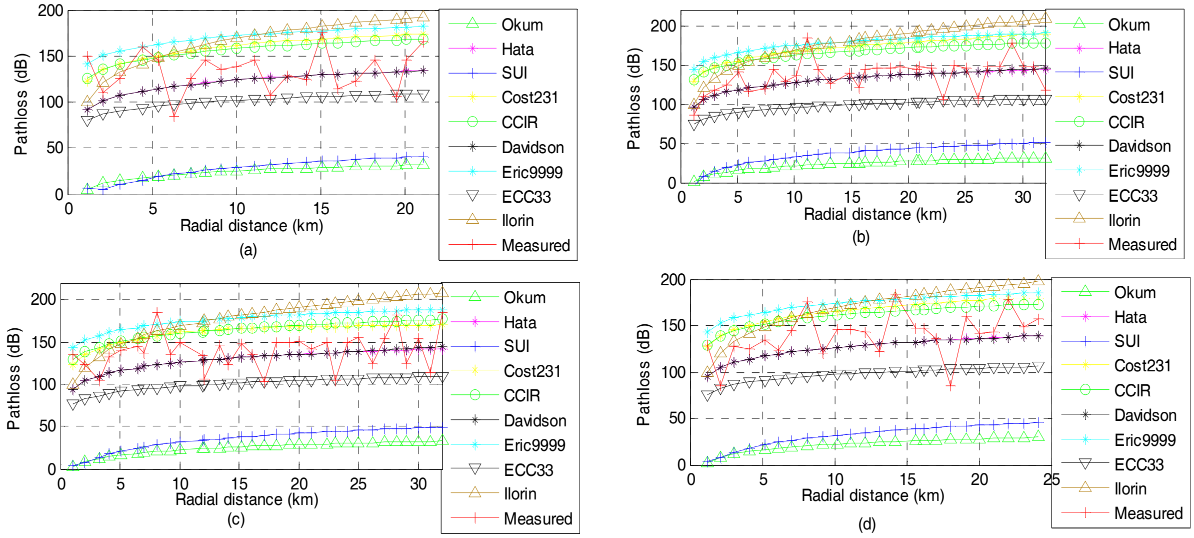

Figure 6: Comparison of Measured and Predicted path loss along route 4 (a) NDTV Obokun (b) NTA Osogbo (c) OSBC (d) NTA Ile Ife

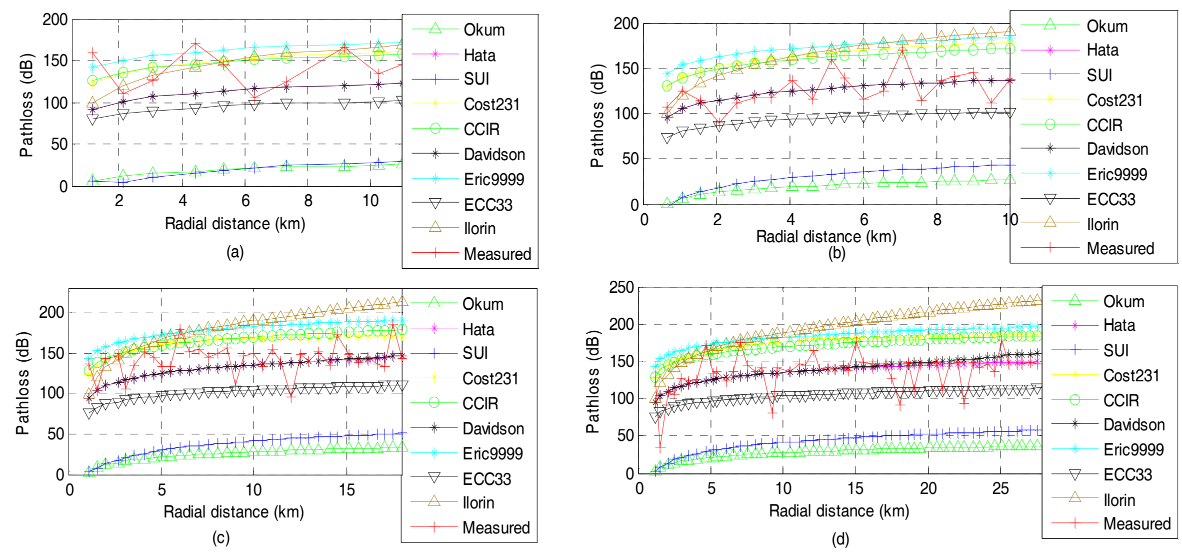

Figure 7: Comparison of Measured and Predicted path loss along route 5 (a) NDTV Obokun (b) NTA Osogbo (c) OSBC (d) NTA Ile Ife

The path profile effects can be visualized on the received signal from Figures 3-7, however, it would be very difficult to, accurately, bound the performance of these models, based on profiling. Therefore, the Mean Error (ME) and Root Mean Square Error (RMSE) for each of the models, across all the routes were statistically, computed and the results are shown in Figures 8 and 9. In Figure 8, the average mean error across all the routes for each transmitter is provided for all the models. For all the routes and transmitters, Okumura, SUI models predicted path losses are quite higher while the Ericsson model gave a predicted path loss that is significantly lower than the measured path losses that are being used in comparison. For NDTV, Cost, Hata and Davidson over predict while ILORIN under predicted the path loss.

In Figure 8, the average ME values of 55.11 dB, -8.53 dB, 46.72 dB, -9.81 dB, -28.16 dB, -8.93 dB, -30.59 dB, -22.95 dB and -12.57 dB are respectively obtained for NTA OSOGBO for Okumra, Hata, SUI, Cost 231, CCIR, Davidson, Ericsson, EEC-33 and ILORIN models. This trend was found to be similar for other transmitters i.e. OSBC, NDTV and NTA Ile Ife with varying performance among the four contending models. Average mean error may not be sufficient to gauge the model performance. We further examined the model performance, in terms of root mean square error (RMSE). Average RMSE for each route for all the transmitters was obtained. The results are shown in Figure 9.

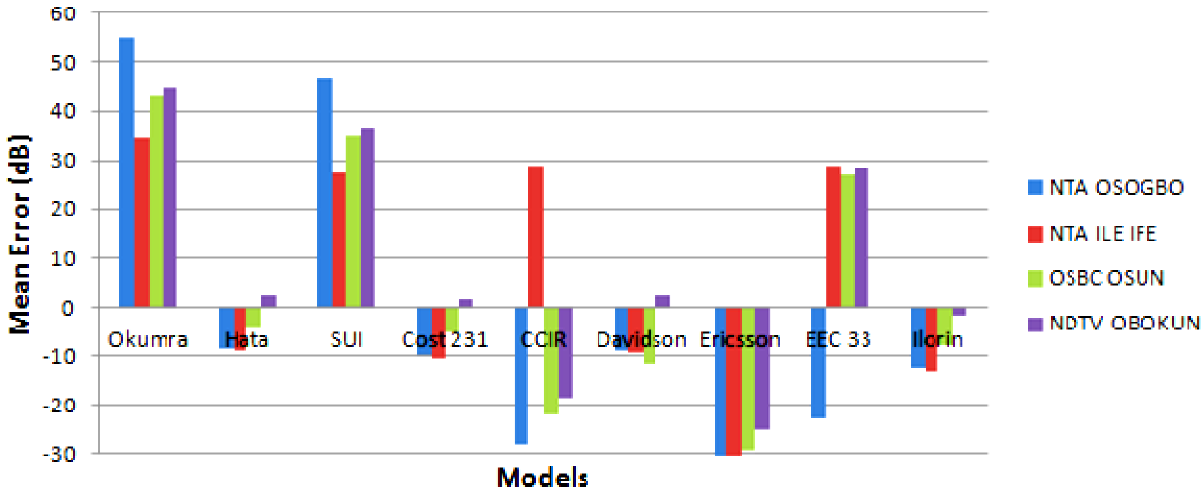

Figure 8: Average Mean Error

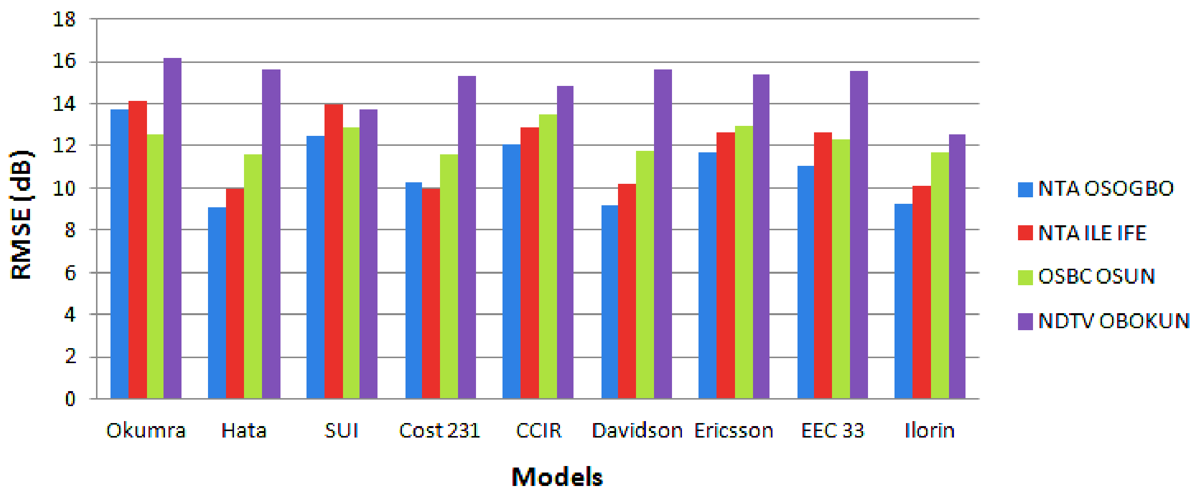

Figure 9: Average Root Mean Square Error

Acceptable RMSE of 6-10 dB in the urban area is assumed (Faruk *et al*., 2013; Faruk *et al*., 2014). Using a bench mark value of 10 dB it can be seen in Figure 9 that ILORIN, Hata and Davidson models are contending with average RMSE values of 9.24 dB, 9.08 dB and 9.18 dB respectively for NTA OSOGBO. Average RMSE values of 12.56 dB, 15.62 dB, 15.62 dB and 11.7 dB, 11.63 dB, 11.79 dB respectively for NDTV OBOKUN and OSBC OSUN transmitters. It is worth noting that for NTA Osogbo transmitter, all the models are within the acceptable value with Hata having the best. However, for NDTV and OSBC all the models are above 10 dB and ILORIN model provides better RMSE. Although for the OSBC, all the models were little above the cut-off value but could still be acceptable depending on the tradeoff. It is very important to note that the choice of using appropriate path loss model is necessary in achieving optimum coverage and signal quality. This has been demonstrated in (Faruk *et al*., 2014b; Alsamhi and Rajput., 2014; Alshami, *et al*., 2011; Abdallah *et al*., 2014 and Zhang and Andrews, 2015) where the impact of path loss models on spatial TV white space was investigated. It was found that few dBs error, in path loss, could affect the coverage. Similarly, Ayeni *et al*., 2015; Faruk *et al*., (2015) and Adediran *et al*., (2014) applied geo-spatial approach to quantify the amount of TV White Space in Nigeria in the UHF Bands, in the work GIS buffering operation was employed where an appropriate path loss model was used to estimate the buffer zone. Therefore, the choice of using any model in a given environment must depend on the accuracy of the model's prediction.

It is very difficult to gauge the performance of the models based on average RMSE, on this note we further examined the route performance for the two main contending models i.e. ILORIN and Hata models. We examined the performance of these models across all the routes for each of the transmitter and the results are presented in Figure 10. For each of the routes and transmitter, RMSE values were obtained for the two models. There is inconsistency in terms of the performance for each model but the figure provides a clear picture of each model performance across the routes and transmitters. When observed, we can clearly see that in the routes where Hata is better than ILORIN model, the difference is not very obvious and could be over-looked when compared with the routes where ILORIN model is better. Typical situation is NDTV routes 1 and 4, Hata performed woefully and the marginal differences between the two models along these routes are quite high and therefore, one could easily, justify the use of ILORIN over Hata along this terrain.

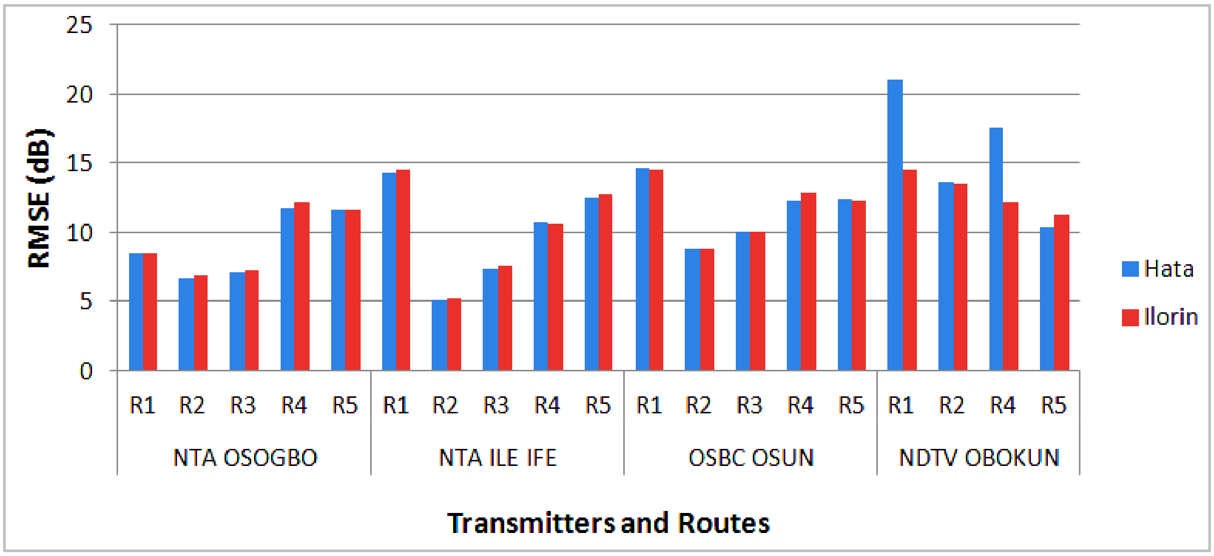

Figure 10: RMSE for each route for ILORIN and Hata Models

CONCLUSIONS

The performance of eight prominent empirical path loss models and one localized model in predicting path loss have been investigated. Models inconsistency performance were observed with Hata, Cost 231, ILORIN and Davidson models providing optimum path loss predictions. Further results and observations reveal some practicalities which seemed responsible for the declination in the performance of empirical models when applied to complex terrains, some of the convictions include:

The assumption for the formulation of correction's factors for most empirical path loss models rely on measurements and observations only over a terrain, these ingenuineness, do not represent all the necessary, required by a model to fully predict the path loss. This is due to the fact that, terrains in this day and age project nonlinear features and obstacles on the path of propagation, which degrade the quality and strength of radio signal. This is evident from the results presented in Okumura and SUI empirical path loss models. Their prediction values have the most deviations from the measured values. These deviations are due to the assumptions in the formulation of Okumura model, which is based on the development of a set of curves through measurements of base station to mobile signal attenuation, rather than providing correction's factors for the series of the irregularities on the path of propagation, which ought to compensate for losses of signal on the irregular terrain and in the SUI empirical path loss model, the classification of terrain for proper applicability of the model does not fully suit the terrain of Osun State, resulting to inappropriate application of the constants a, b and c in the model expression.

Distortion in signal line-of- sight (LOS) was established from the graphical depiction due to the field measurement experiment set up and nature of the terrain topology. These effects (i.e. variations in the altitude and nonlinearity of the routes measurement) altered and reduced signal quality and LOS received by the spectrum analyzer.

ILORIN model which is a localized model built, based on data collected from the neighboring state, provided optimum path loss prediction in Osun terrain. This conclusion is being made based on least error values obtained when compared to other models. However, more measurement campaigns are required in diverse build-up areas and routes across wide bands so as to bound the practical errors for these models and appropriate correction factors could be added to minimize the prediction error.

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Conflict of Interest

Conflict of Interest none declared.

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