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A Gis Based Uhf Radio Wave Propagation Model for Area Within 25km Radius From OSRC Transmitting Antenna

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***Abstract-** For effective network coverage across different terrain and landcover, accurate prediction model is required. Radio wave models are essential tools for predicting wave propagation characteristics in a particular environment. This paper investigates signal strength using Geospatial Technology which was applied to UHF radio wave propagation within 25km radius from Ondo State Radiovision Corporation Transmitting Antenna. Five major routes within the study area were considered and signal strength measurements were carried out at interval of 1km across different land cover type and terrain variations. Three empirical models (Okumura-Hata, COST-Hata and Egli model) were considered for the study due to their system parameter. The path loss of the empirical model was compared with measured path loss and the mean deviation errors of the models were computed. Consequently, Okumura-Hata's model is suitable for prediction along the five routes. A modified Okumura-Hata model was developed for path loss prediction in 25km radius away from the transmitting antenna which is applicable for network planning and design.*

***Keyword:** Geospatial, Ondo, Empirical models, path loss, Okumura-Hata, COST-Hata and Egli model*

1. INTRODUCTION

Radio waves are part of the broad electromagnetic spectrum that extends from the very low frequencies which are produced by electric power facilities up to the extremely high frequencies of cosmic rays which travel from a source into the surrounding space at the speed of light, approximately 3.0x108 m/s when in free space. The electromagnetic spectrum extends as low as sub-hertz frequencies to 30 000 GHz. They are divided into several bands by frequency in which FM and TV broadcast is a good example with a very high frequency band from 30 to 300MHz [1]. In radio broadcasting, the energy that is emitted from an antenna takes different paths before it reach the receiver and radio wave pathway depends on many factors, some of which include: frequency, antenna type and height, atmospheric conditions, land use variation and terrain [2].

The wireless communication has drawn attention as a result of drastic change in technology and the demand for the quality products and services over the years. From the transmitter, radio propagation takes different propagation path to the receiver and it depends on the interaction with interfering object along the path of propagation. In radio wave propagation, there are interactions between waves and environment attenuates the signal level which causes path loss and finally limits coverage area. This is simply because propagation characteristics of radio wave such as fading, path loss and attenuation do not only depend itself on frequency, path distance, and characteristics scatter distance, but also on scatter angle that depends on what is causing obstruction to the propagated wave. Propagation models are classified into three main groups: deterministic, statistical and empirical models [3]. Deterministic models make use of the physical laws which determine radio wave propagation mechanisms for a particular location. Stochastic (statistical) models, on the other hand, require the least information about the environment but provide the least accuracy. Empirical models are based on extensive measurements and mainly give prediction of path loss. They are more often used in practice than statistical and deterministic propagation models, because of low cost and model simplicity with acceptable accuracy". Examples of wireless models include the Okumura-Hata model, COST 231-Hata model, COST 231-Walfisch-Ikegami, Friis model, 2D and 3D ray tracing, SUI model, Cluster Factor model, Walfisch-Bertoni model, Eglic model, Erecg Model, COST 123 model etc. Each of these model are useful for specific environment and the accuracy of any of the model depends on the parameter required by the model and the environment. There is no universal model for all kind of propagation situation. All propagation models are based on the terrain parameters (rural, urban and suburban area) and system parameter like antenna height, frequency (Abhayawardhana, et al). All computations in radio communication are based on the use of radio propagation prediction models. It is also reported that, Geographical Information System (GIS) as a tool in partner with the field of remote sensing has become an important component for modeling radio wave prediction [4].

Until recently, empirical propagation prediction model seemed sufficient. However, more efficient prediction models are required in transmitting data (voice and non voice) from the antenna to the receiver. These propagation models are usually based on the computation of the physical interaction of radio waves and the environment. Thus, more detailed geo-databases of the environment are required, especially in urban environments where most users are located [5]. In broadcast frequency planning, GIS is relevant in base station programming, base station position selection, field strength prediction, coverage analysis, interference analysis, frequency distribute and so on. For accurate prediction of radio wave, interference analysis and coverage calculation demand detail location of spatial database of the predicted area. The evaluation of the wireless technology grows; the industry development trend uses geographic information system to strengthen TV broadcasting, coverage, network management and construction [6]. The inability of radio wave to penetrate or bend around geographic features which result in non line of sight can be easily modeled in geographical information system. GIS have ability to model the communication sheds (commshed) which is also known as the viewshed. Having the LOS properties of the wavelength, the viewshed shows the zone where there will be signal [7].

Ondo State Radio vision Corporation propagates in UHF band. The UHF band goes from 300 MHz to 3GHZ which is the ideal choice for ground to air communication. UHF has a wide band width which propagates principally on line of sight from the transmitter to the receiver. The effects of local area topography and conditions in the lower atmosphere mostly govern UHF propagation. For communication to take place the transmitting and receiving antennas must have a fairly unobstructed path between them, hence the term line-of-sight can be established [8]. Radio wave is a function of frequency of propagation, lower radio frequencies, such as AM/FM radio, have lower wavelengths which allow them to penetrate geographic features such as vegetation, building wall and others. As the wavelength decreases, the frequency increases which make more influence by geographic feature in the environment [9]. It is stated that the quality of signal strength is extensively blocked or degraded by nature and man to the relatively short wavelength propagation [4]. Geographic features hinder the propagation of wave which can be easily model Invisibility theory i.e. line of sight theory [10].

II. STUDY AREA AND CHARACTERSTIC

The study area covers 25km from Ondo State Radiovision Corporation Antenna which lies within latitudes 6° 30’ 00” and 8° 00’ 00” and longitudes 4° 30’ 00” and 5° 30′ 00" which cut cross three states; Ondo, Osun and Ekiti States. Within the three states, the study area covers ten Local Government across the state; Ondo State (Akure North, Akure South, Ondo East, Idanre, Ifedore, Okeigbo/Ile Oluji Local Government), Ekiti State (Ekiti South West, Ikere and Ise/Orun Local Government) and Oriade Local Government in Osun State. The study area was found to have minimum elevation value 204m above the mean sea level and maximum elevation value of 1065m above the mean sea level.

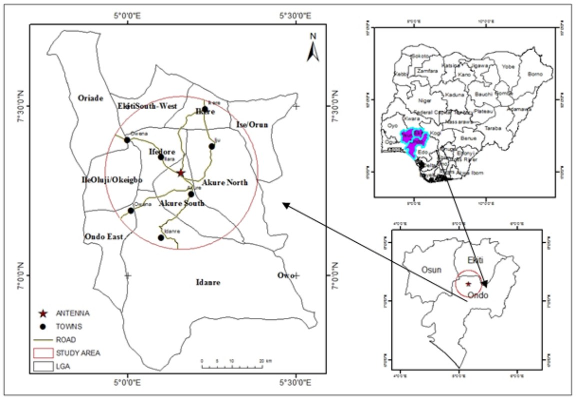

Figure 1: The map of the Study Area

III. RESEARCH METHODOLOGY

a. Data and their Sources

Table 1: Data and their sources

Data	*Year*	*Source*	*Relevance*
Google image	2007	Google earth	For route design and navigation
ASTER	2011	USGS	For digital elevation model and spot height
Field measurement	2014	Self	For signal strength measurement
Antenna description	2013	OSRC	For path loss calculation
Landsat	2014	USGS	For landuse/cover classification

b. Observation Instruments

1. Garmin 76c handheld GPS was used basically to determine the point of observation and the transmitting antenna.

Fig 2.1: Global Positioning System (GPS) used for direct observation

2. Professional TV signal field strength meter type UNAOHM model EP742A was used measure signal field strength which was carried out round the selected route.

Fig 2.2: Field strength Meter used for direct observation

3. A Yagi array receiving antenna covering both VHF and UHF frequency bands was used for measurements. This was mounted on support about eight metre (8m).

Fig 2.3: Yagi Antenna used for direct observation

IV. METHODS

The method employed for this research involves measuring signal strength which relies on GIS and remote sensing techniques for measurement and visualization. This research was based on three characteristic which are terrain, land cover type and distance from the transmitting antenna. The method adopted for this research is as follows:

Driving Route Test Design: The GPS coordinate of the transmitting antenna was obtained. This was plotted in ArcGIS environment and 25km ring buffering around the transmitting antenna was carried out at 1km interval. Points where the buffer crosses the route were recorded. This coordinates were traced to the ground for signal observation.

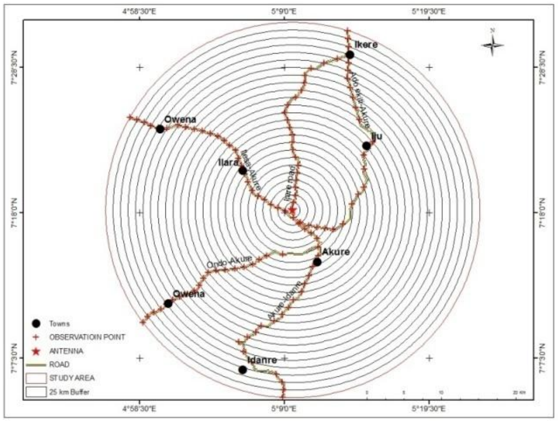

Figure 3.1: Driving route drive

Landcover Classification: The land use/cover of the study area was obtained from Lansat 8 imagery downloaded from USGS and subjected to unsupervised classification using ENVI 4.5 which gave a general idea of the land use/cover type of the area. Bands 543 were combined to obtain a colour composite that was used for the unsupervised classification. Research showed that the different land cover/use type affect signal strength [11], [12].

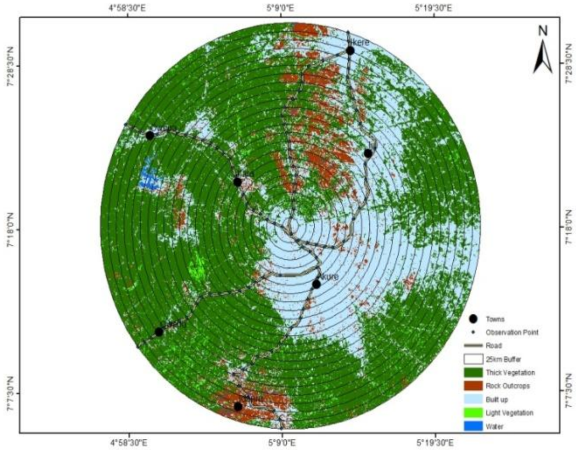

Figure 3.2: Land cover classification of the study area

Digital Elevation Model: For this study, ASTER DEM at 30m resolution was used for the study area which was further reclassified into low and high. Spot height across the study area was generated using TIN node tools in ArcGIS. Elevation value and the corresponding signal strength was noted at every 1km interval from the transmitter.

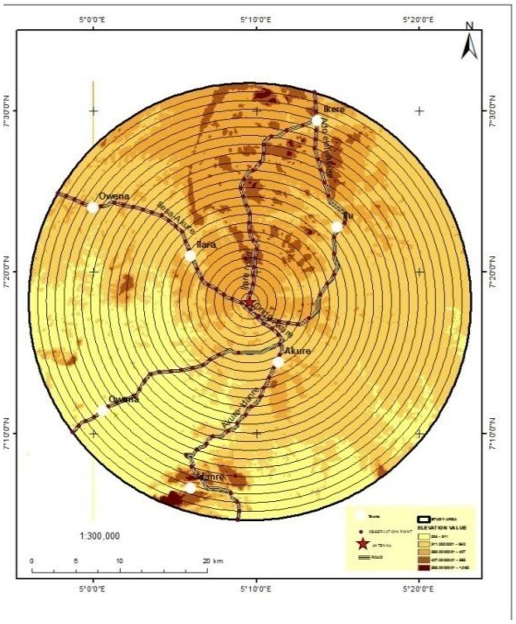

Figure 3.3: Digital Elevation Model of the study area

Signal Strength Measurement: The signal strength measurement was carried out at frequency 487.25MHz based on the coordinate obtained during driving route design. Coordinate information from ArcGIS software for every point of observation was used after carrying a ring buffer operation from the transmitting antenna at every 1km to 25km. Signal strength across terrain variation was measured and recorded at every route

Signal Strength Measurement with Expected Signal Strength Value: The signal strength measurement was carried out based on the above route design. Measurement was carried out in different defined route land use type and terrain classification in order to predict signal strength. Distance and line of sight (LOS) from the transmitter to the receiver were considered. Field signal strength data was acquired within ten days. It was carried out in late January with little or no atmospheric interference. The measured signal was compared to theoretical value. Equation 1 was used to calculate theoretical values as obtained.

$$E\left(\frac{V}{m}\right) = \frac{\sqrt{30P_tG_t}}{d\,(LOS)} \qquad (1)$$

where P_t is the transmitted power in (W), G_t is the gain of the transmitter, and d is the LOS distance in (m).

Signal Strength Measurement with Existing Models: The field measurement was carried out in the study area and compared with empirical models that are developed to predict signal strength. The empirical model used in this study are Okumura Hata, Egli and COST 123 model which was compared with field measurement in the study area in other to develop a based model for the study area. Equations 2, 3 and 4 were used to determine the corresponding path loss for each measurement taken.

$$E_h = \frac{88\sqrt{P}h_rh_td_h^{N-2}}{\lambda d^2} \qquad (2)$$

$$P_r = \frac{P_tG_tG_r}{PL} \qquad (3)$$

$$P_r = \frac{P_tG_tG_rh_t^2h_r^2}{d^4} \qquad (4)$$

Where P_r is in watts, h_r, h_t is in metre, d_h, d are in Km and f is the frequency in MHz, [13].

V. RESULT AND DISCUSSION

a. *Result of Television Signal Strength Measurement*

The following tables show the field strength measured across each of the route at 1km interval from the transmitter at frequency 487.25MHz. The location data (x,y) of the observation point was considered for signal measurement and there was direct line of sight observed for measurement in this study. Below is table and corresponding graph.

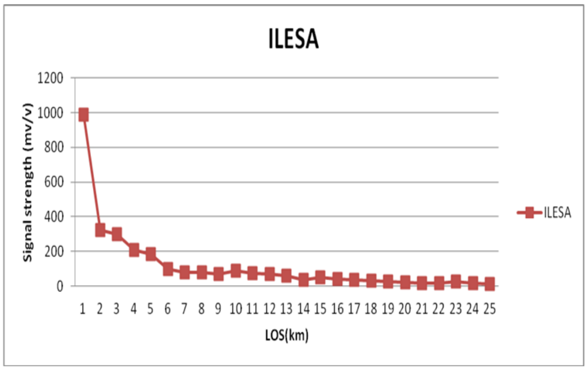

Figure 4.1a: Graph of field strength measurement in Ilesa

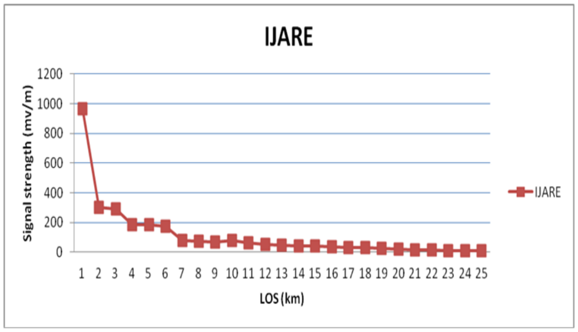

Figure 4.1b: Graphic of field strength measurement in Ijare route

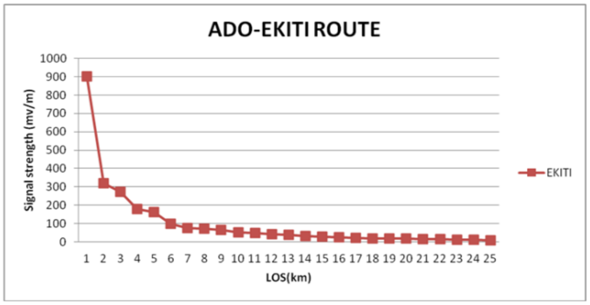

Figure 4.1c: Graphic of Signal strength measurement in Ado-Ekiti route

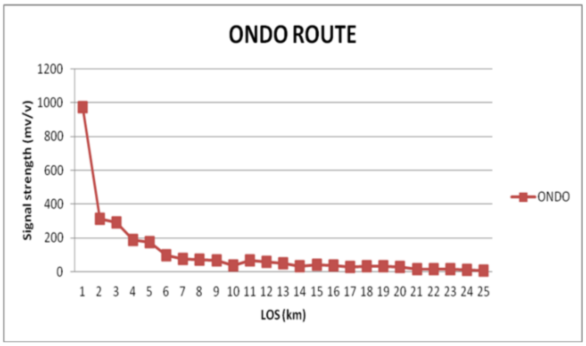

Figure 4.1d: Graphic of signal strength measurement of Ondo route

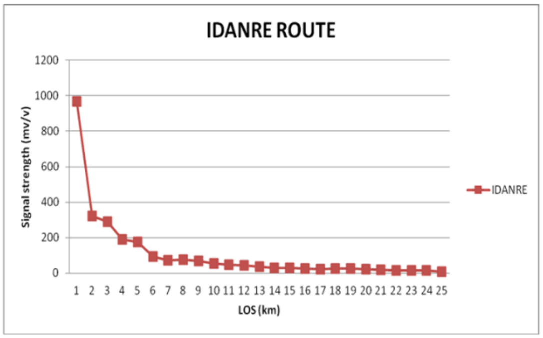

Figure 4.1e: Graphic of field strength measurement in Idanre

From the television signal strength measured across the five route, it was observed that their are direct line of sight between the transmitter and the receiver but the signal strength reduces as reciever is moved away from the transmitter. The reduction in signal strength is not uniform which is as a result of attenuation caused by different land cover/use, atmospheric refraction and other.

b. Result of Measured Value Compared with Theoretical Value

The following table shows the measured against the theoretical measurement

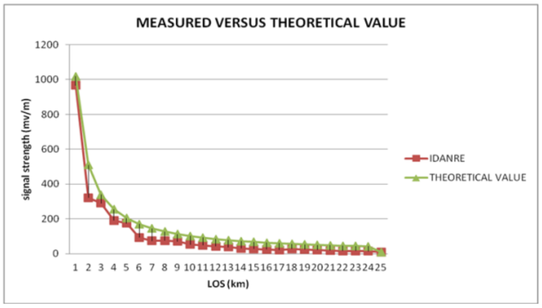

Figure 4.2a: Line graph showing the relationship between the theoretical measurement and field strength measurement in the Idanre route

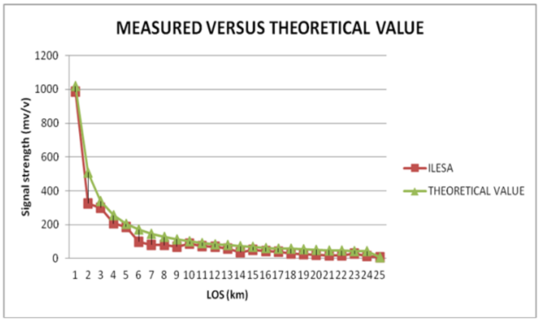

Figure 4.2b: Line graph showing the relationship between the theoretical measurement and field strength measurement in the Ilesa route

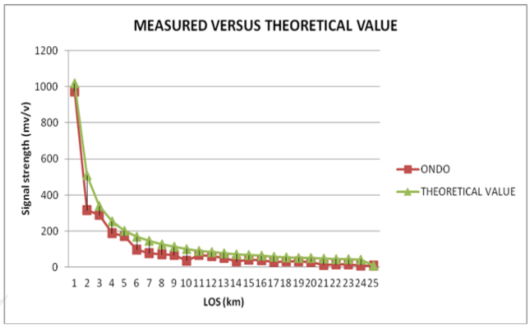

Figure 4.2c: Line graph showing the relationship between the theoretical measurement and field strength measurement in the Ondo route

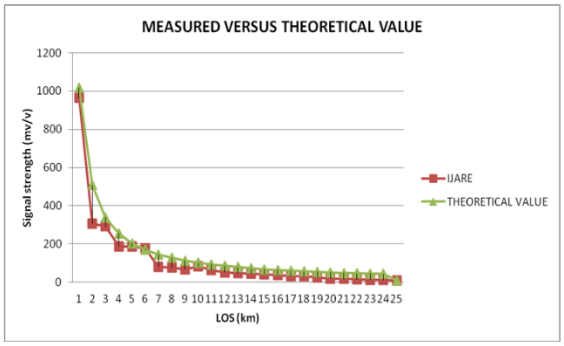

Figure 4.2d: Line graph showing the relationship between the theoretical measurement and field strength measurement in the Ijare route

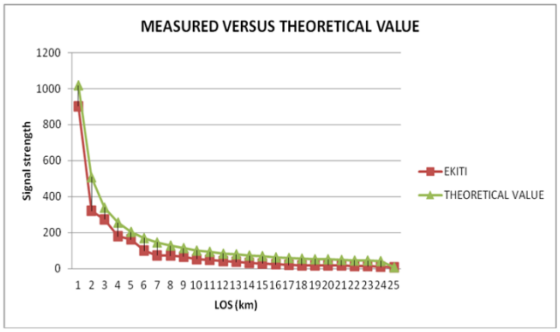

Fig 4.2e: Line graph showing the relationship between the theoretical measurement and field strength measurement in the Ado-Ekiti route

c. *Result of Comparism for Measured Signal and the Empirical Model*

Path Loss Calculation

Okumura-Hata model, COST-Hata model and Egli model were used to predict the path losses along the five routes and the results are as shown in Tables 3. Path loss was computed by using the reference station specification from the model used: Okumura, COST-Hata and Egli model was reduce to the equation 5, 6and 7 respectively

$$P_L = 119.892 + 26.44\log d \qquad (5)$$

$$P_L = 93.988 + 63.36\log d \qquad (6)$$

$$P_L = 68.01/d^2 \qquad (7)$$

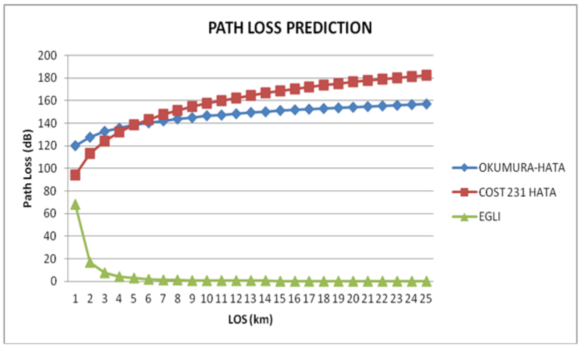

Figure 4.3a: Path loss predictions with existing model

From the above diagram, Path loss for each model was calculated at each LOS. The result shows that Egli model assumes that there is obstruction such as buildings and hilly area that is why the path loss is low which is not true while Okumura-Hata and COST 231 shows better prediction of signal strength. The overlap that occurs between the two models shows that Okumura Hata model was modified to develop COST 231 model.

d. *Result of Measurement obtained compared to Empirical Model for each route*

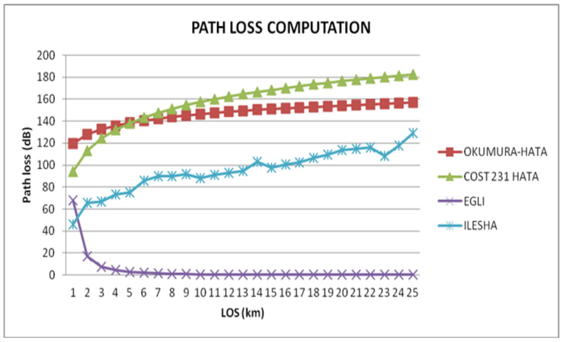

Figure 4.3b: Path losses in Ilesha route with existing model

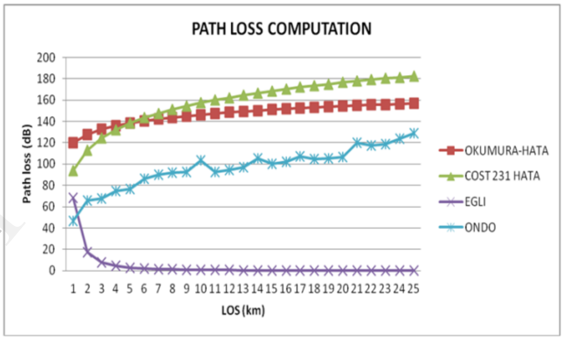

Figure 4.3c: Path loss in Ondo route with existing model

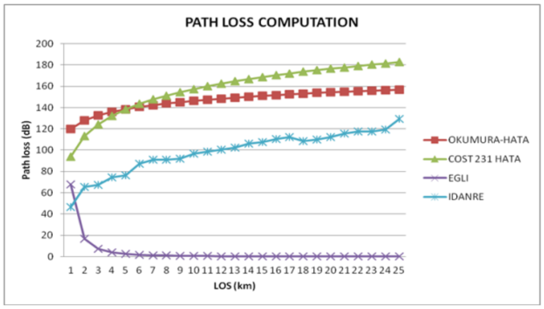

Figure 4.3d: Path loss in Idanre route with existing model

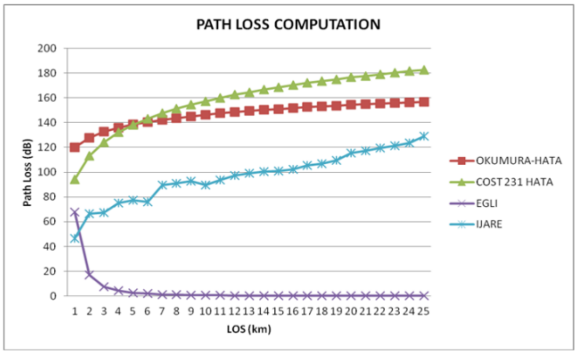

Figure 4.3e: Path loss in Ijare route with existing model

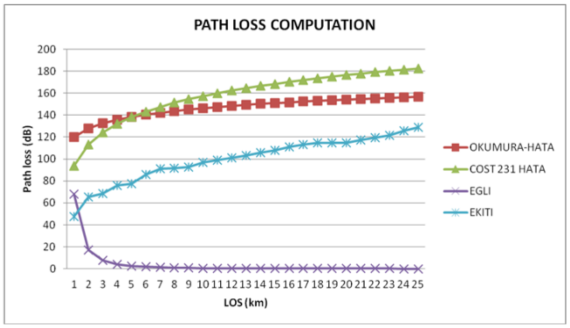

Figure 4.3f: Path Loss in Ado-Ekiti route with existing model

From the above path loss across the five route considered in this research, it was observed that Egli model was out rightly ineffective for the predicted area. The model shows obstruction along the path of observations. At each of the distance where measurement was observed, there is direct line of sight from the receiver to antenna. For each of the route, Okumura model is better than COST 231 model in this study area based on closeness of path loss to the measured value along each of the paths.

e. Comparism of Empirical Models with Measurements

The corresponding error statistics in terms of the mean prediction error are shown in the Tables 2, 3, 4, 5 and 6 were gotten from the above graphs for each of the route.

Table 2: Comparison of Path Loss of Empirical Models with Measurements for Ilesa Route.

Model	Okumura-Hata	COST-Hata	Egli
Path Loss Mean Error (dB)	52.08	63.37	90.08

Table 3: Comparison of Path Loss of Empirical Models with Measurements for Ondo Route.

Model	Okumura-Hata	COST-Hata	Egli
Path Loss Mean Error (dB)	50.01	61.31	93.87

Table 4: Comparison of Path Loss of Empirical Models with Measurements for Idanre Route.

Model	Okumura-Hata	COST-Hata	Egli
Path Loss Mean Error (dB)	48.61	59.91	95.27

Table 5: Comparison of Path Loss of Empirical Models with Measurements for Ijare Route.

Model	Okumura-Hata	COST-Hata	Egli
Path Loss Mean Error (dB)	50.05	61.34	93.83

Table 6: Comparison of Path Loss of Empirical Models with Measurements for Ekiti Route.

Model	Okumura-Hata	COST-Hata	Egli
Path Loss Mean Error (dB)	46.84	58.14	96.94

f. Discussion:

It was observed from the analysis that out of the three models considered, Okumura-Hata model has minimum error of 52.08dB along Ilesa route, 50.02dB along Ondo route, 48.62dB along Idanre route, 50.05dB along Ijare route and 46.85dB along Ekiti route. Also, the measurements taken were compared with the theoretical estimations for validation which shows the theoretical measurements as obtained from equation (1) with respect to the LOS distance and the measurements taken in the 25km radius for the five chosen routes around the antenna. With the disparity shown between these measured values along the five chosen routes, it could be deduced that the propagation here suffered attenuation caused by physical environment, atmospheric refraction; and the neutral atmosphere induce propagation delays. In the neutral atmosphere, delays are induced by refractivity of gases, hydrometeors, and other particulates, depending on their permittivity and concentration, and forward scattering from hydrometeors and other particulates. Changes in temperature, moisture, and pressure in the atmospheric column cause a change in atmospheric density, which in turn causes variations in the intensity of waves in both the vertical and horizontal. Reflection and diffraction caused by obstruction (buildings, mountains with different elevations among others) and the effect of tree density with foliages along the paths chosen. The presence of vegetation produces a constant loss, independent of distance between communication terminals that are spaced 1 km or more apart. Since the density of foliage and the heights of trees are not uniformly distributed in the area (forested environment) and corresponding error statistics in terms of the mean prediction error. It could be observed clearly that all the three empirical models under predicted the path loss with COST-Hata model and most especially Egli model grossly under predicted the path loss (i.e. Okumura-Hata model has minimum error in the prediction).

Consequently, Okumura-Hata's model is suitable for prediction along the five routes, while Okumura-Hata's model is suitable for path loss prediction along those paths taken.

VI. CONCLUSION

In this research work, three empirical propagation models: Okumura-Hata model, COST-Hata model, and Egli model were used for path loss computation along the selected five routes. Along the five routes chosen it was observed that COST231-Hata model and Egli model showed larger mean path loss error i.e. they grossly under predicted the path loss, while Okumura-Hata model showed closer agreement with the results measured with lower mean path loss error. Therefore, a modified Okumura-Hata model was developed for path loss prediction at 25km radius around the transmitting antenna which will assist engineers in network planning and design.

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