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UHF Radio Frequency Propagation Model for Akure Metropolis

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Abstract

During radio frequency propagation, an interaction between waves and environment attenuates the signal level. It causes path loss and finally limits coverage area. Empirical models are employed in network planning, most especially for conducting feasibility studies. This research work embraces two empirical models: Friis and Okumura-Hata and are used to predict broadcast signal strength for Akure, Ondo State, Nigeria. Measurement results of signal strength in UHF band taken in the three routes of Akure were compared with the predicted results using the empirical models. However, in this research paper, a modified Okumura-Hata model was developed and can be used for radio communication system design in Akure metropolis.

Keywords: Radio frequency propagation, empirical models, network planning and Akure.

Introduction

Increasing complexity of wireless network design, empirical models have become a necessity for wireless network engineers. Examples of wireless models include the Okumura-Hata model, COST 231-Hata model, COST 231-Walfisch-Ikegami, and Friis model as stated in Saunders[1]. Each of the models designed are site specific and therefore in using them for analysis, they must be used for the right sites for which they were designed. The Okumura model is one of the models which are used for prediction of wireless propagation parameters across different terrains namely the urban, sub-urban and rural environments. A path loss prediction system lies on the foundation of every wireless networks, which make signal-strength prediction an important research interest in the radiowave propagation. Efficient and accurate methods are needed for use in current wireless network design and future wireless network research. Olorunnibi[2] reported that radiowave propagation through a city is greatly affected depending on whether there is line-of-sight between transmitting and receiving antennae or not. This is because propagation characteristics of radiowave such as path loss, attenuation and fading do not only depend on path distance, characteristics scatter distance and frequency, but also on scatter angle that depends itself on what is causing obstruction to the propagated wave. Vijay Garg[3] also stated that non- line- of- sight (NLOS) link encounters obstacles such as buildings, trees and hills during radiowave propagation. The ground is one common source of reflection. In urban settings or cities, buildings, trees, road traffic, etc. often block the ground reflection path. For long range paths, ground reflection is significant. Signal loss due to trees depends on the specific type of tree (i.e. whether leaves are present or not) or the nature of the surface of the leaves (i.e. whether wet or dry). Isolated trees are not usually a major problem, but a dense forest is. Attenuation of radiowave is a function of distance the signal must penetrate through the forest, and it increases with frequency.

Serpil[4] evaluated the performance of very high microwave frequency transmission by making use of various models such as geometrical optics (GOPT) low altitude spherical earth (LAPSE), and low amplitude propagation which in combination formed up SEKE (Spherical Earth Knife Edge) with a subroutine in a program for wireless prediction over irregular terrains. Rappaport et al[5] reported that urban radio channels provide more predictable path loss due to diffraction waves and wave guiding effects along city streets. Transmission in hilly terrains arrives at a greater delay after a direct line of sight (LOS) is established. Rappaport et al[5] noted that for mountainous regions amplitudes within 100dB of a direct signal at excess delay of 20μ or more can be arrived at according to the author's study carried out. Ramakrishna[6] performed a path loss prediction in the areas where there is building and an assumption of the field to possess a flat terrain. The approach Ramakrishna used for validation was a three dimensional vector parabolic equation concept for calculating path loss in an urban environment and then compared to results produced by the uniform theory of diffraction (UTD). This model may not be an efficient prediction for transmission in an area without buildings especially for repeater stations located in isolated mountainous areas because they don't possess some field characteristics described. Neˇskoviˊc et al[7] used four empirical models: SUI model, COST 231-Hata model, Macro and Ericsson model, which are most suitable for path loss prediction for such a system to work on radio frequency propagation mechanisms and empirical models for fixed wireless access systems. By using these propagation models the receiving signal levels are predicted for different types of environment for WiMAX (Worldwide Interoperability for Microwave Access) system installed in the city of Osijek, Croatia. Measurement results of receiving WiMAX power at 3.5GHz were compared with the results predicted by using the propagation models. Ostlin et al[8] developed an approximate model of radiowave propagation for inter-vehicles communication simulation systems using Kaji model; a distance between vehicles, a building density and an angle between a road and a line-of-sight of two vehicles were used as the approximate parameters instead of detailed information of buildings. From experimental results, the model has 84% accuracy and 17 times computation speed-up in comparison with the original kanji model.

Wireless Propagation Models: A radio propagation model, also called radio frequency propagation model is an empirical mathematical formulation for the characterization of radiowave propagation as a function of frequency, distance and other conditions. Models are usually developed to predict the behaviour of propagation for all similar links under similar constraints[9]. The Hata model for urban areas, also known as the Okumura-Hata model for being a modified version of the Okumura model, is the most widely used radio frequency propagation model for predicting the behavior of cellular transmissions in built up areas. This model incorporates the graphical information from Okumura model and develops it further to realize the effects of diffraction, reflection and scattering in suburban areas and open areas, Hata model predicts the total path loss along a link of terrestrial microwave or other type of cellular communications.

This model is suited for both point-to-point and broadcast transmissions and it is based on extensive empirical measurements taken. The Okumura-Hata model for urban area as stated in Famoriji[9] is given below:

$$PL = 69.55 + 26.16\log f - 13.82\log h_B - a(h_m) + [44.9 - 6.55\log h_B]\log d \quad (1)$$

For large city with the wave frequency of transmission, $f \geq 400MHz$

$$a(h_M) = 3.2[\log(11.75h_M)]^2 - 4.97 \quad (2)$$

For specifications, Okumura-Hata has the following range: Carrier frequency: $150MHz \leq f \leq 1500MHz$, Base station height: $30m \leq h_B \leq 200m$, mobile station height: $1m \leq h_M \leq 10m$, distance between mobile station: $1Km \leq d \leq 20Km$ as stated in Famoriji[9].

Friis model is used by radio and antenna engineers to predict path loss between two isotropic antennas in free space. The simplified model as stated in Vijay Garg[3] is given by equation 3

$$PL = 20\log_{10}\left(\frac{4\pi d}{\lambda}\right) \quad (3)$$

Where PL is path loss, d is the line-of-sight distance λ is the wavelength which is a function of frequency.

Material and Methods

Block diagram (figure-1) shows the procedure followed in carrying out the research work.

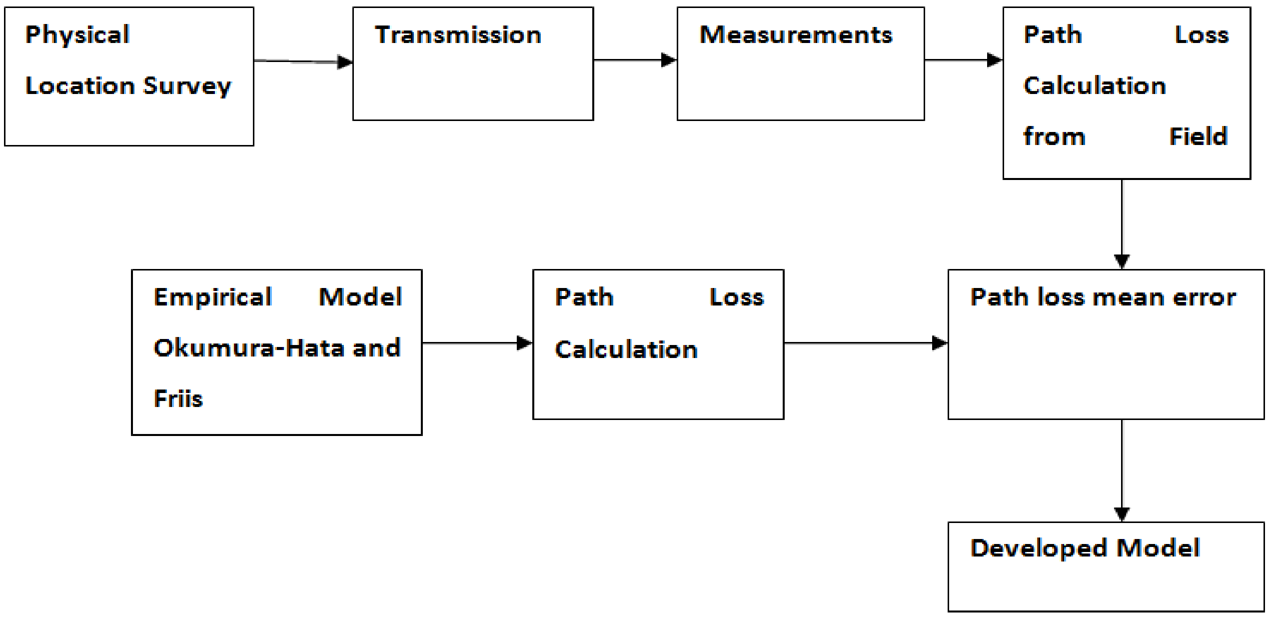

Figure-1
Block diagram showing the procedure used to carry out the research

Physical Location Survey: Physical location survey was the preliminary stage conducted to select sites. During the site survey, obstacles such as trees, hills and structures capable of causing obstruction of radio signal along the line of sight were taken note of. Investigation was carried out along three different routes (i.e. locations away from the transmitting station of Ondo State Radiovision Corporation OSRC). These include Route A, Route B and Route C representing OSRC/Ilara/Igbara Oke highway (Akure South), OSRC/Iju/Ado highway (Akure North) and OSRC/ Oyemekun/ Alagbaka highway respectively.

Measurement: Akure, in Ondo State of Nigeria, is used as the study area. It is situated in the tropics at Lat 7.25^{0}N, Long 5.2^{0}E, altitude 420m above sea level; an agricultural trade centre with light industries and is minimally influenced by industrial pollutants or aerosols as reported by Olasoji and Kolawole[10]. A series of readings of television broadcast signal strength were carried out in the UHF band (470 - 862 MHz) using Yagi array antenna coupled through a 50-ohm feeder to the UNAOHM model EP742A field strength meter in various distances between the transmitting antenna at OSRC and the receiving antenna in the respective location were mapped using the GPS (Global Position Satelite) receiver. The position of the transmitting antenna or base station was marked as a "home" waypoint on the mark position page of the GERMIN GPS Map 76 receiver and stored in the memory. A trip of 20km with the aid of a slowly moving vehicle away from the base station through Route A was taken at an incremental rate of approximately 1km line of sight. This procedure was also used to determine straight line distance between the receiving antenna in the other routes and the transmitting antenna that was permanently fixed at OSRC, Akure.

Results and Discussion

Path Loss Calculations: Friis model (see equation 3) and Okumura-Hata model (see equation 1) was used to predict the path losses along the three routes and the results are shown against the line of sight distance graphically in figures: 2, 3 and 4. The corresponding path loss for each signal field strength measured were calculated using equations 4, 5 and 6 as obtained from Rappapot[11]. The specification of Okumura-Hata model about transmitting antenna height is within antenna the range of 30m to 200m. However, the base station height used for the calculations is 325m. All other specifications of this model were met by the conditions of the experiment. Also, the measurements taken along the Northern, Southern and Central routes of Akure metropolis are assumed to be applied to other parts of the city.

$$P_r = \frac{P_t G_t G_r}{PL} \quad (4)$$

$$P_r = \frac{P_t G_t G_r h_t^2 h_r^2}{d^4} \quad (5)$$

$$E\left(\frac{V}{m}\right) = \frac{\sqrt{30 P_t G_t}}{d(LOS)} \quad (6)$$

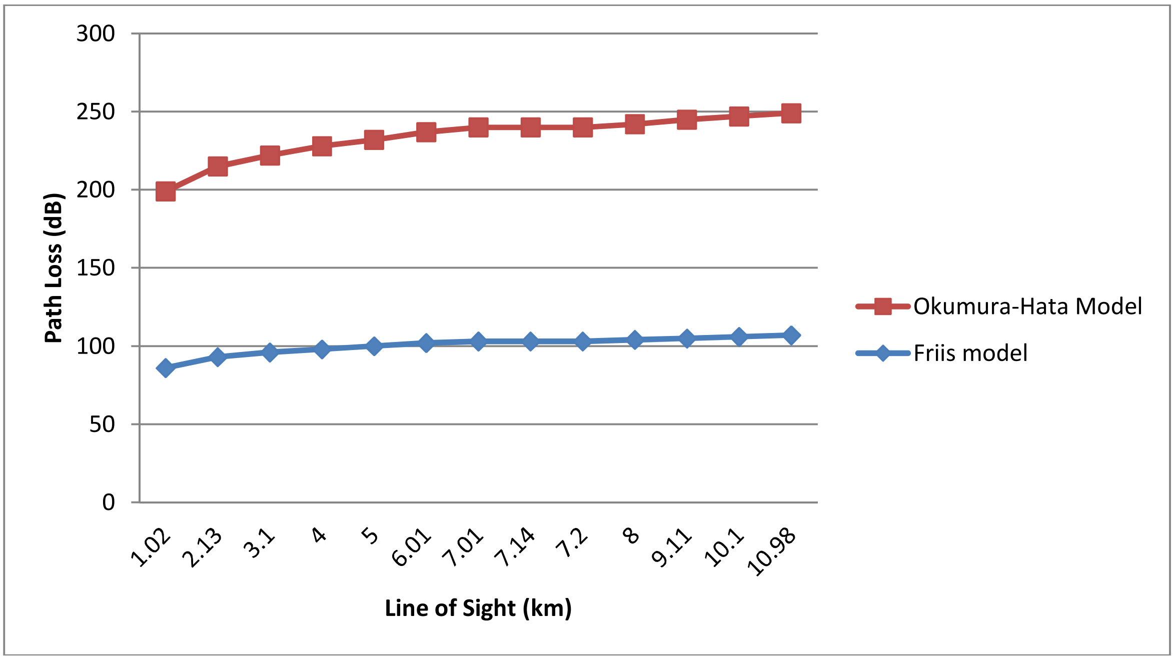

Figure-2
Path Loss Prediction along Route A

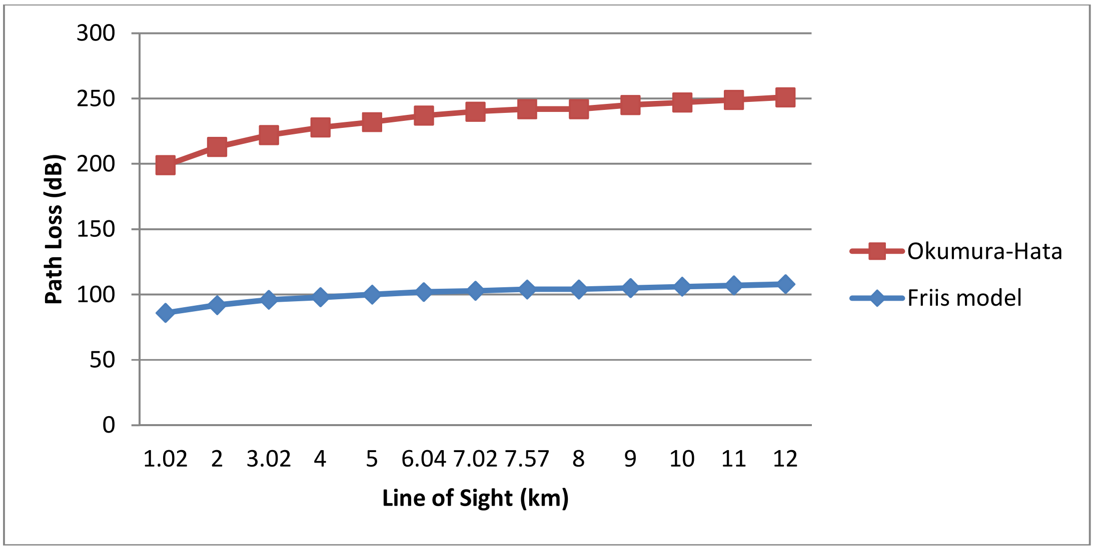

Figure-3
Path Loss Prediction along Route B

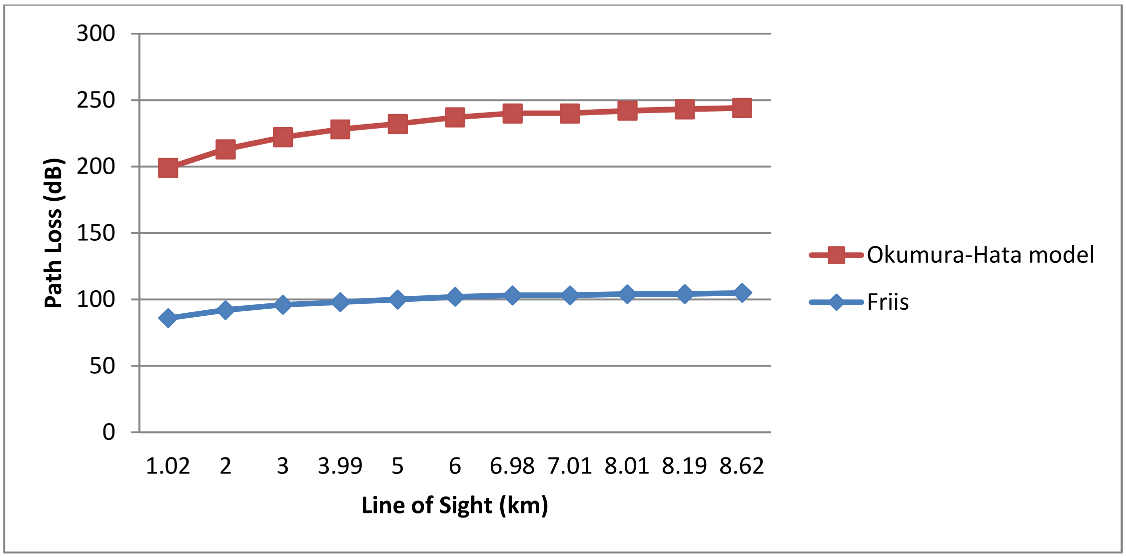

Figure-4
Path Loss Prediction along Route C

Comparison with Measurements: The corresponding error statistics in terms of the mean prediction error was determined for each model. The prediction errors were calculated as the difference between the measurement and prediction. Tables-1, 2 and 3 show path loss mean error for each model along routes: A, B and C respectively. It was discovered that Friis and Okumura-Hata model under predict the path loss with Friis model grossly under predict the path loss.

Table-1
Path Loss mean error of Empirical models along Route A

Empirical Model	Friis	Okumura-Hata
Path Loss mean error (dB)	54.83	21.33

Table-2
Path Loss mean error of Empirical models along Route B

Empirical Model	Friis	Okumura-Hata
Path Loss mean error (dB)	52.33	19.17

Table-3
Path Loss mean error of Empirical models along Route C

Empirical Model	Friis	Okumura-Hata
Path Loss Mean Error	59.00	25.40

The Developed Model: From tables: 1, 2 and 3, Okumura-Hata model gave a closer prediction to the measurement in all the routes and so suitable for path loss prediction along routes A, B and C respectively. The mean deviation errors were added to the Okumura-Hata model (equation 1) to generate a path loss model suitable for prediction along the routes under consideration in Akure metropolis. Therefore the modified Okumura-Hata model developed for the three routes are stated below:

$$PL_A = 69.55 + 26.16\log f - 13.82\log h_B - a(h_m) + [44.9 - 6.55\log h_B]\log d + 21.33dB \quad (7)$$

$$PL_B = 69.55 + 26.16\log f - 13.82\log h_B - a(h_m) + [44.9 - 6.55\log h_B]\log d + 19.17dB \quad (8)$$

$$PL_C = 69.55 + 26.16\log f - 13.82\log h_B - a(h_m) + [44.9 - 6.55\log h_B]\log d + 25.4dB \quad (9)$$

with PL_A, PL_B *and* PL_C representing the path loss prediction along routes A, B, and C respectively and all other terms remain as previously defined. The mean of equations: 7, 8 and 9 gives equation 10 can be generally used for prediction of path loss in Akure metropolis.

$$PL = 69.55 + 26.16\log f - 13.82\log h_B - a(h_m) + [44.9 - 6.55\log h_B]\log d + 21.97dB \quad (10)$$

Conclusion

Two empirical models: Friis and Okumura-Hata models were used to predict path loss along the three different routes in Akure metropolis. Consequently, Friis model showed high path loss mean error grossly under predicted the path loss while Okumura-Hata showed closer agreement with the path loss obtained from the measurement results with lower path loss mean error of 21.33, 19.17 and 25.40 along routes: A, B and C respectively. The performance of Okumura-Hata model shows its suitability for prediction in Akure metropolis. Modified Okumura-Hata model was developed for deployment in Akure metropolis.

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