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Modification of the Hata Empirical Propagation Model for Application in Vhf Band in Edo State, Nigeria

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ABSTRACT: *This research work is aimed at arriving at a suitable propagation model that can best explain or predict path loss variability in Edo state region of Nigeria by modifying the widely accepted Hata model. The work was carried out through a quantitative measurement of the signal strength of a VHF Television Broadcasting Stations in Edo State known as Nigeria Television Authority (NTA) monitored on 189.25MHz frequency. The results obtained using the root mean square error RMSE performance metrics shows that the Hata propagation model do not accurately predict the path loss for television signal propagation in Edo State as the value of the root mean square error (RMSE) obtained is found to be in excess of the 7dB allowed for radio prediction. Better results is obtained if the Hata model is modified. Modification based on results from measurements of the Hata model gave a lower and acceptable root mean square error. The modifield equation was verified using data obtained from measuremnets.*

Keywords: *Hata model, Pathloss, Propagation, rmse*

I. INTRODUCTION

With the increasing need to develop radio communication systems that are more reliable and efficient, there is need for proper radio coverage planning. These planning require the use of adequate propagation models. Broadcasting communication systems like other radio communication systems comprise of a transmitter, a propagation path and a receiver. The process of signal propagation from the transmitter en route to the receiver has been a subject of much research, the focus of more recent work has been on predicting the signal strength [1].

In order to achieve a reliable communication with a simple and small receiver, one require the knowledge of the spatial and temporal variability of field strength. This assume greater significance in broadcasting applications where the user expects a very high quality of signal. The performance of such a communication system depends on the models employed to calculate the coverage area and interference problems.The development and identification of models is a continuing and ongoing process and there is always scope for refinement [2].

1.1 EXISTING PROPAGATION MODELS

Path loss prediction is normally carry out using path loss models which are vital to any radio communication system. In this article , a basic theoretical propagation model- the free space and the Hata empirical model are analysed.

1.1.1 Free Space Path loss model

Free-space propagation model is used to predict received signal strength when the path between the transmitter and the receiver is a clear and unobstructed line-of-sight
[3]. The ideal propagation radiates in all directions from transmitting source and propagating to an infinite distance with no degradation. Attenuation occurs due to spreading of power over greater areas [4]. The resulting power density P_d is calculated using equation 1.

$$P_d = \frac{P_t}{4\pi d^2} \qquad (1)$$

where P_t is the transmitted power and P_d is power at distance d from antenna. As the signal propagates from the antenna, it experiences a reduction in intensity and the amount of power received depends on the effective capture area of the receiving antenna . The power received P_r for a given power density is calculated as

$$P_r = P_d \times A_e \qquad (2)$$

Where A_e is the effective antenna aperture and is given by equation 3

$$A_e = \frac{\lambda^2}{4\pi} \tag{3}$$

Where λ is the signal wavelength. The amount of power captured by the antenna at the required distance d, thus depends on power density and also on the effective capture aperture of the antenna. Combining equations (1) and (3) into (2), we have the power received to be as expressed as

$$P_r = P_t\left[\frac{\lambda}{4\pi d}\right]^2 \tag{4}$$

The free space path loss L_p is given as Pt / Pr. How ever we often are dealing with frequency rather than wavelength of signals, we can make the substitution □ □ = c/f to get the free space path loss as shown in equation 5

$$Lp = \left[\frac{4\pi}{c}\right]^2 d^2 f^2 \tag{5}$$

Where c and f are the speed of light and operating frequency respectively. The free space path loss equation is more usefully expressed logarithmically as in equation 6

Lp (dB) = 32.5 + 20 log10 (d) + 20 log10 (f) (f in MHz, d in km) (6)

1.1.2 Hata Model

The Hata model is a popular propagation tool for radio propagation planning. The model is based on an empirical relation derived from Okumura's report on signal strength variability measurements [5]. The simple modeling of path loss is still dominated by the Hata empirical model [6], where the propagation results are fitted to a simple analytical expression, which depends on antenna height, environment, frequency and other parameters . Hata's method is basically an extension of Okumura's method (which is somewhat cumbersome due to numerous correction factors) and employs propagation curves instead of parametric equations [7]. It is applicable to frequencies between 150MHz and 1500MHz, transmitter-receiver separation distance from 1Km to 20Km, transmitter antenna height between 30m and 200m and the height of receiver antenna from 1m to 10m. Hata's model for urban area is expressed as :

$$L_U = 69.55 + 26.16\log f - 13.82\log h_{te} - a(h_{re}) + (44.9 - 6.55\log h_{te})\log d \tag{7}$$

where L_U is the path loss in urban areas in dB, h_{te} is the height of the transmitter antenna in *m*, h_{re} is the height of the receiver antenna in *m*, *f* is the transmission frequency in *MHz*, *d* is the transmitter-receiver separation distance in *km* and $a(h_{re})$ is the receiver antenna correction factor expressed as,

$$a(h_{re}) = 8.29(\log(1.54\, h_{re}))^2 - 1.1 \quad \text{for } f \le 300\text{MHz} \tag{8}$$

Since the model only requires four parameters for the computation of path loss, the computation time is very short. This is the primary advantage of the model. However, the model neglects the terrain profile between transmitter and receiver, i.e. hills or other obstacles between the transmitter and the receiver are not considered.

II. METHODOLOGY

The measurement was taken radially along six routes starting at the transmission stations using handheld RF field strength spectrum analyzer (Sefram 7808) and a Germain 78CX GPS receiver. A drive test was employed for this measurement using a VHF broadcasting stations located in the Ikpoba hill axes of Edo state. In each measurement sessions, field strength meter is set to the desired frequency of the television station to be monitored and field strength measurements is carried out at intervals starting from the transmitting stations. The spatial information (Latitude and Logitude) are taken at each measurement location. The drive test was facilitated by a route map of Edo State obtained from the Ministry of Lands and survey.

III. RESULTS AND DISCUSSION

The field strength values measured are converted into a pathloss value called 'measured pathloss'. Pathloss values were computed using the Hata prediction model of equations 7 and 8 and compared to that of the measured pathloss. The comparison between the measured and predicted pathloss are as shown in Tables 1 to 2 and Figures 1 to 2 for two routes.

Table 1: Measured and Predicted path loss along route 1

Distance (km)	Measured Pathloss (dB)	Hata Model (dB)
1.26	138.33	102.68
3.48	146.13	116.31
5.37	146.47	122.14
6.34	144.80	124.38
7.43	147.93	126.50
8.32	148.53	128.02
9.31	150.33	129.53
10.18	149.60	130.73
13.03	151.83	134.04
15.02	150.83	135.95
16.87	152.30	137.51
17.88	152.67	138.29
18.89	151.90	139.03

Table 2: Measured and Predicted path loss along route 2

Distance (km)	Measured Pathloss (dB)	Hata Model (dB)
1.27	136.67	102.83
4.52	141.60	119.82
5.91	146.00	123.44
7.28	151.63	126.22
8.74	152.63	128.68
10.40	152.57	131.01
11.26	153.23	132.08
12.11	152.63	133.06
13.03	152.80	134.04
14.02	153.30	135.03
15.21	153.00	136.12
16.87	155.93	137.51
18.66	155.23	138.86

Using Microsoft Excel software, the data presented in Table 1 to 2 are graphically depicted as shown in the Figures 1 to 2 below:

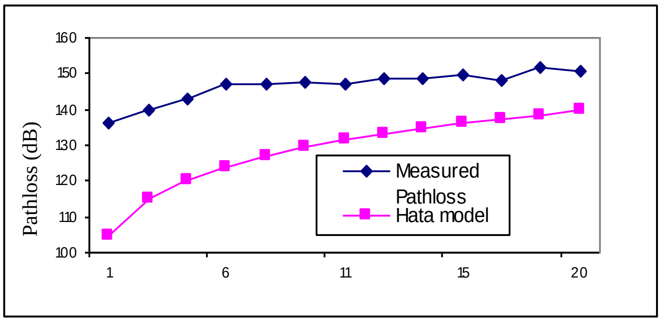

Figure 1: Measured and Predicted pathloss versus distance (route 1)

Distance (Km)

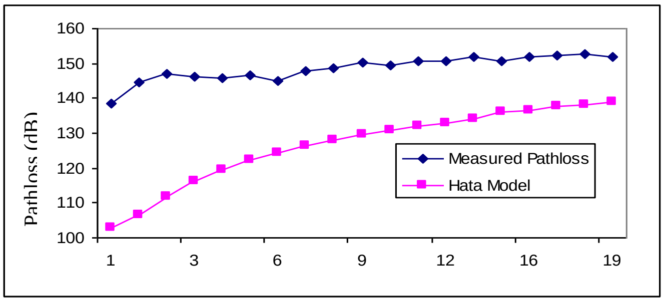

Figure 2: Measured and Predicted pathloss versus distance (route 2)

A study of the above graphical plots shows that the Predicted pathloss is lesser than the measured pathloss, this is due to the difference in the terrain in the two environments under consideration as the geographical terrain in Edo State is different from the geographical terrain in Japan where the Hata model was developed. Further evaluation is carried out to evaluate the suitability of Hata model for radio prediction in Edo State using statistical tool. A commonly used statistical tool for evaluating propagation models is the root mean square error as reported by [8]. The Root Mean Square Error RMSE is a frequently used measure of the difference between values predicted by a model and the values actually observed from the environment that is being modeled [9].

The RMSE of a model prediction with respect to the estimated variable X_{model} is defined as the square root of the mean squared error as given in equation 9

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(X_{obs,i} - X_{model,i})^2}{n}} \qquad (9)$$

where X_{obs} is observed values and X_{model} is modelled values at time/place i. and n is the number of measured data points.Using the equation 9 the RMSE is found to be 18.9dB and 21.1dB for route1 and route 2 respectively. However the acceptable RMSE value is up to 6-7dB for urban area [10]. When the average of the RMSE obtained above is added to the Hata equation for urban area, a resulting modified Hata equation which in more suited for path loss prediction is obtained as given in equation 10

$$L_{U(Modified)} = 89.55 + 26.16\log f - 13.82\log h_{te} - a(h_{re}) + (44.9 - 6.55\log h_{te})\log d \qquad (10)$$

The modified Hata model is further validated using measurement data obtained from route 3. Table 3 and Figure 3 shows the predicted path loss using equation 10 and the graphical plot of comparison between the measured path loss and that predicted by the modified Hata equation.

Table 3: Measured and Predicted path loss along route 3

Distance (km)	Measured Pathloss (dB)	Modified Hata model (dB)
1.27	136.67	125.827
4.52	141.60	142.8205
6.06	148.83	146.7728
8.74	152.63	151.6756
9.55	151.83	152.8702
10.40	152.57	154.0144
11.26	153.23	155.0771
12.11	152.63	156.058
14.02	153.30	158.0271
16.87	155.93	160.5076
18.66	155.23	161.8631
20.11	155.93	162.8678

Using Microsoft Excel software, the data presented in Table 3 is graphically depicted as shown in the Figure 3 below:

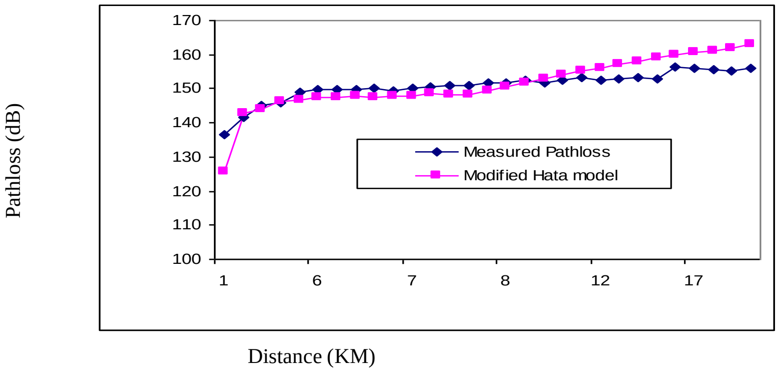

Figure 3: Measured and Predicted pathloss (modified Hata) versus distance (route 3)

IV. CONCLUSION

The research work has focused on determining the suitability of Hata model for path loss prediction in Edo State. It is observed that the Hata model for urban area do not correctly predict the path loss as the root mean square error obtained was outside the range accepted for radio prediction. This is due to differences in the terrain profile between where the Hata model was developed and where it is been applied. However when the hata model is modifiel, a new modified equation is obtained which is discovered to be suitable for path loss prediction in the VHF band in Edo State. The modified Hata model gave a RMSE of 4.6dB which is acceptable radio prediction.

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