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Statistical Modification of Hata Model for Pathloss Prediction in the Coastal City of Warri, Nigeria

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Abstract

The aim of this study is to test the performance of the Hata model for pathloss prediction in the coastal city of Warri, Delta state Nigeria. In this study, the applicability of the Hata model is tested by comparing the Hata predicted pathloss with the measured pathloss. Pathloss models are important tools as they are useful in estimating radio propagation coverage during radio system planning. The Hata model was used due to its simplicity and reliability. A quantitative signal strength measurement was carried out using the Delta Broadcasting Service (DBS) Station operating at the ultra high frequency band (UHF) at a frequency of 636MHz. The results showed that the Hata model in its original form did not predict the pathloss as depicted by the terrain of Warri. This was observed using the performance metric of the Root Mean square error (RMSE) value. The computed RMSE value was found to be 24.62dB which is outside the accepted range for pathloss prediction models. Statistically modifying the original Hata model yielded a modified Hata model which gave a lower and acceptable root mean square error of 3.96dB accepted for pathloss prediction. The modified equation was validated using data obtained from measurements in another location in the city of Warri.

Keywords: Path loss, Hata model, rmse, prediction

1.0 Introduction

Propagation pathloss models are propagation tools used for estimating pathloss during radio system planning. Predictions obtained from these models are used for planning and designing wireless communication systems like TV broadcasting, mobile communication networks as well as other wireless systems.

The performance of any wireless communication systems depends on the propagation characteristics of the channel. Channel characteristics have an impact on the design of the transmission strategy. Received signal prediction models play an important role in the RF coverage optimization and efficient use of the available resources. These models can differ in their properties with locations due to different terrain environment[1].

However, in spite of the development of numerous pathloss prediction models, the generalization of these models to any environment is still in question. They are suitable for either a particular area (urban, suburban, rural, etc.) or specific cell radius (Macrocell, Microcell, Picocell). To overcome this drawback, the model's parameters can be tuned according to the targeted environment to improve its prediction accuracy [2].

2.1 Path Loss

The reduction in power density of an electromagnetic wave is called Path loss (or path attenuation) as it propagates through space. Path loss is a major component in the analysis and design of the link budget of a telecommunication system. This term path loss is commonly used in wireless communications and signal propagation. Path loss may be due to many effects, such as free-space loss, refraction, diffraction, reflection, aperture-medium coupling loss, and absorption [3]. Path loss is also influenced by terrain contours, environment (urban or rural, vegetation and foliage), propagation medium (dry or moist air), the distance between the transmitter and the receiver, and the height and location of antennas [4]. Figure 1 shows the illustration of pathloss.

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2.2 The Hata Propagation Model

The Hata Model also known as the Okumura-Hata model is a widely used propagation model for predicting path loss in urban areas [5]. This model takes into account the effects of diffraction, reflection and scattering caused by city structures. The model also has formulations for predicting path loss in Suburban and Open Areas.
The Hata Model for Urban Areas has the following parameters:
Frequency Range: 150 MHz to 1500 MHz,
Transmitter Height: 30 m to 200 m
Link distance: 1 km to 20 km
Receiver height: 1 m to 10 m.

Hata model for urban areas is formulated as follows,

$$Lu = 69.55 + 26.16Log(f) - 13.82Log(hb) - Ch + \{44.9 - 6.55Log(hb)\}Log(d) \quad (1)$$

For small or medium sized cities (where receiver antenna height is not more than 10m)

$$Ch = 0.8 + \{1.1Log(f) - 0.7)hm - 1.56Log(f) \quad (2)$$

For large cities,

$$Ch = \begin{cases} 8.29\{Log(1.54hm)\}^2 - 1.1, & \text{for } 150\text{MHz} \leq f \leq 200\text{MHz} \\ 3.2\{Log(11.75hm)\}^2 - 4.97, & \text{for } 200\text{MHz} \leq f \leq 1500\text{MHz} \end{cases} \quad (3)$$

Where,
Lu= Path loss in Urban Areas
hb= Height of base station antenna in meters (m)
hm= Height of mobile station antenna in meters (m)
f= Frequency of Transmission in megahertz (MHz).
Ch= Antenna height correction factor
d= Distance between the base and mobile stations in kilometers (km).

The Hata Model for Suburban Areas is widely used for path loss prediction in city outskirts and other rural areas where man-made structures are available but not as high and dense as in the cities. The model is based on the Hata Model for Urban Areas and uses the median path loss from urban areas. The Hata Model equation for Suburban Areas is formulated as

$$L_{su} = L_u - 2(\text{Log}\frac{f}{28})^2 - 5.4, \quad (4)$$

Where,
L_{su} *= Path loss in suburban areas in decibels (dB)*
L_u *= Average Path loss in urban areas in decibels (dB)*
f = Frequency of Transmission in megahertz (MHz).

The Hata Model for open areas predicts path loss in open areas where no obstructions block the transmission link. This model is suited for both point-to-point and broadcast transmissions. Hata model for open areas is formulated as,

$$L_o = L_u - 4.78(logf)^2 + 18.33logf - 40.94 \quad (5)$$

Where,
L_o *= Path loss in open area. Unit: (dB)*
L_u *= Path loss in urban area. Unit: decibel (dB)*
f = Frequency of transmission. Unit: (MHz).

2.3 Received Signal Strength

Received signal strength is a strength used to measure the power of the received radio signals [6]. Theoretically, the RSS can be calculated using equation 6 [7].

$$Pr = Pt + G_t + G_r - P_L - A \quad (6)$$

Where,
Pr is received signal strength in dBm
Pt is transmitted power in dBm.
Gt is transmitted antenna gain in dBm
Gr is received antenna gain in dBm
PL is total path loss in dBm
A is connector and cable loss in dBm .

3.0 Field Strength Measurements

The measurement of the UHF signal strength was taken along various routes starting at the transmission base station. A drive test was taken round Warri/Effurun area of Delta state Nigeria. Devices used where a GPS device, a vehicle for movement and a field strength analyzer capable of measuring field strength of frequencies reaching 2GHz. In each test, the field strength analyzer was set to the frequency of the television station to be monitored (Delta Broadcasting Service) and the field strength is then measured at intervals. Each measurements location are also geo-referenced. Figure 2 shows the map of the City of Warri where the measurements was carried out.
The Measurement parameters are as given:

Frequency-636MHz
Height of Base antenna- 195m
Power transmitted from basestation-2kw
Height of receiver-1.5m
Transmitter gain – 13dB

3.1 Results and Discussion

The results obtained from the measurements and the prediction obtained from the Hata model in route 1 are shown in the table 1 and Figure 3 shows the graphical plot of the measured pathloss and the pathloss obtained from the Hata model.

Figure 3 shows the graph of the predicted pathloss and the measured pathloss. The difference between the predicted pathloss and the measured pathloss can be attributed to the difference in the geographical terrain Japan where the Hata model was developed and that of Warri, Delta state, Nigeria. The Root mean square error (RMSE) Statistical tool is used to evaluate the suitability of the Hata model for the City of Warri. The RMSE value is computed using the equation 7 [8].

$$RMSE = \sqrt{\frac{\sum(pm-pr)^2}{N}} \quad (7)$$

Where p_m is measured path loss (dB), p_r is predicted path loss (dB) and N is number of measured data points
The RMSE was calculated to be 24.6dB. This is outside the acceptable range of between 6-8dB required for in deploying a given pathloss model for prediction in a given environment [8].Therefore the value of the RMSE was added to the original Hata equation to obtained the modified Hata model L_m

$$Lm = 94.15 + 26.16Log\,(f) - 13.82Log(hb) - Ch + \{44.9 - 6.55Log\,(hb)\}Log(d) \quad (8)$$

The modified Hata model is validated with data obtained from measurements in other part of the City of Warri. Table 2 shows the measured pathloss for route 2 and the predicted pathloss using the modified Hata model.

Figure 3 shows the pathloss obtained from measurements and the pathloss predictions obtained from the modified Hata model. The modified Hata model on evaluation gave a RMSE value of 3.96dB which is within the acceptable range for pathloss prediction models hence the modified Hata model can be used for planning other new TV stations in the coastal city of Warri, Nigeria.

4.0 Conclusion

The study focused on pathloss prediction in the coastal City of Warri, Delta State of Nigeria. Since most existing predictions models differ in their applicability over different terrain and environmental conditions, there was need to have a more specific model for radio planning purpose. This is achieved in this study by statistically modifying the widely accepted Hata pathloss model. The modified Hata model was validated using measurement data and the RMSE value was found to be 3.96dB which is within the acceptable range for pathloss predication.

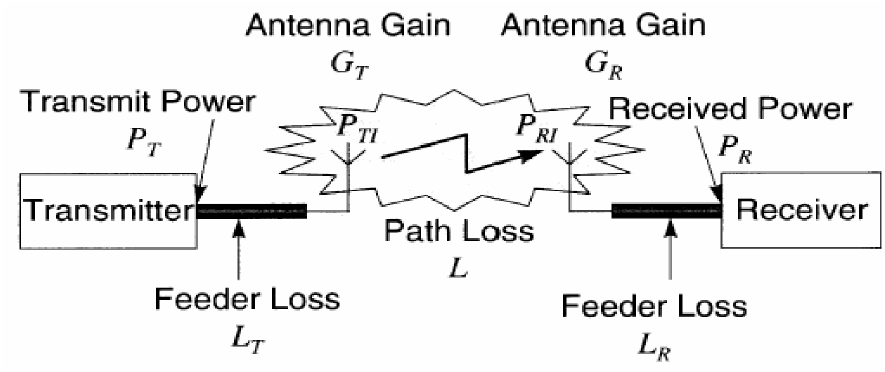

Figure 1:Concept of pathloss [8]

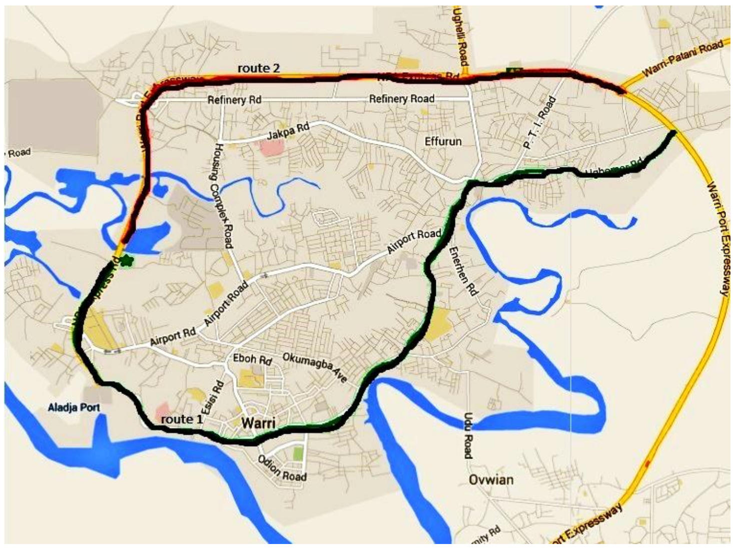

Figure 2: Map of Warri showing the measurement routes.

Table 1 showing measured and hata predicted pathloss for route 1

Distance (Km)	Measured pathloss(dB)	Hata pathloss (dB)
1.24	141.01	114.05
1.68	146.01	118.02
2.28	144.01	121.95
2.85	143.01	124.85
3.17	152.01	126.67
3.83	154.01	128.68
4.33	157.01	130.28
4.74	160.01	131.47
4.92	160.01	131.94
5.24	162.01	132.77
5.62	161.01	133.67
6.28	161.01	135.11
6.72	162.01	135.99
7.18	153.01	136.86
7.64	158.01	137.66
8.16	160.01	138.49
8.52	156.01	139.08

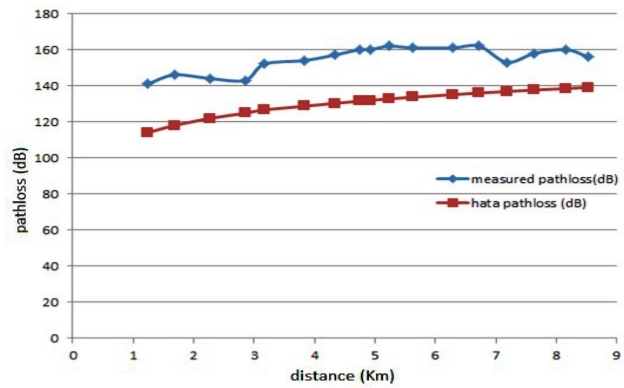

Figure 3: Pathloss versus distance (route 1)

Table 2:Measured and predicted pathloss for route 2

Distance (Km)	Measured pathloss(dB)	Modified hata pathloss (dB)
1.24	141.01	138.67
1.68	146.01	142.64
2.28	144.01	146.57
2.85	143.01	149.47
3.17	152.01	151.29
3.83	154.01	153.3
4.33	157.01	154.9
4.74	160.01	156.09
4.92	160.01	156.56
5.24	162.01	157.39
5.62	161.01	158.29
6.28	161.01	159.73
6.72	162.01	160.61
7.18	153.01	161.48
7.64	158.01	162.28
8.16	160.01	163.11
8.52	156.01	163.7

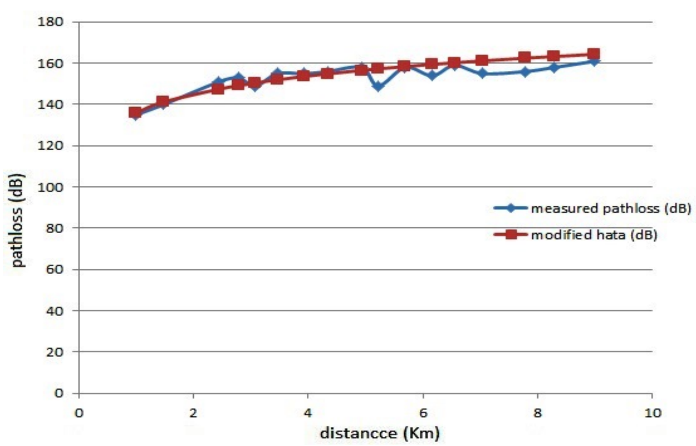

Figure 3:Pathloss versus distance (route 2)

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