International Journal of
Advances in Scientific Research and Engineering (ijasre)

E-ISSN : 2454-8006

DOI: http://doi.org/10.31695/IJASRE.2018.32992

Volume 4, Issue 12
December - 2018

# Radio Wave Detection Using Cost 231-Hata Model for Wireless Network Planning; A Case Study of Senate Building Environs of Unilag, Nigeria

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## ABSTRACT

*Radio waves are a type of electromagnetic radiation with wavelengths in the electromagnetic spectrum longer than infrared light. Accurate characterization of radio channel through key parameters and a mathematical model is important for predicting signal coverage, achievable data rates, bit error rate (BER), path loss and antenna gain especially within residential areas. An investigation on how suitable the COST 231-Hata model on radio wave detection within the engineering and senate building environs of the University of Lagos is presented here. Electric field strength data from the MTN base station located in the faculty of science is compared against field predictions made by the COST 231-Hata model. Analysis of results shows that the COST 231-Hata model is suitable for the terrain with a RMSE of 4.095 dB which is within the suitable 6 dB range. Further tuning of this model predicted the measured path loss with a RMSE of 1.371 dB which is a better result for signal prediction and assessment.*

***Keywords:*** *Radio wave, Cost 231-HATA Model, Electric field.*

## 1.0 INTRODUCTION

Radio waves are generated by transmitters and received by radio receivers using antennas. Different frequencies of radio waves have different propagation characteristics in the Earth's atmosphere. The determination of radio propagation characteristics for a given terrain is a key consideration in wireless network planning and radio wave detection. For this purpose, radio propagation models are quite useful. Some of the most widely used models are the experimental Propagation Models, part of which is the COST 231-Hata model [1],[2],[3]. The suitability of any propagation model is site specific and depends on terrain clutter, frequency of operation, velocity of mobile terminal, interface sources and other constraints. Radio propagation is essential for emerging technologies with appropriate design, deployment and management strategies for any wireless network. Large scale path loss modeling plays a fundamental role in designing both fixed and mobile radio systems. Predicting the radio coverage area of a system is not done in a standard manner. Wireless systems are expensive systems. Therefore, before setting up a system one has to choose a proper method depending on the channel's BTS antenna height gain.

Propagation models are essential tools for wireless network planning, interference analysis, frequency assignment and cell parameters evaluation. These models are designed to predict the path loss of the received signal strength measured with a mobile receiver at a specified distance from the transmitter [4]. Some of these models require analytical description of the measured data from an environment of interest for efficient performance. However, it is often difficult to generalize these models for a particular environment. In order to overcome this difficulty, the parameters of certain empirical models can be modified with reference to the targeted environment. Thus, this report presents propagation measurements and modeling at 900 MHz

Radio waves are type of electromagnetic radiation with wavelengths in the electromagnetic spectrum longer than infra red light. They have frequencies as high as 300 giga hertz to as low as 30 hertz. Like all other electromagnetic waves, radio waves travel at speed of light and generated by electric chares undergoing acceleration such as time varying electric currents. They are first predicted by mathematical work done in 1867 by Scottish mathematical physicist James Maxwell. He noticed wavelike properties of light and similarities in electrical and, magnetic observations. The wavelength is the distance from one peak of the wave's electric field to the next crest and is inversely proportional to the frequency of the wave. The study of radio propagation, how radio waves move in free space and over the surface of the earth, is vitally important in the design of practical radio systems.

### 1.1 AIM AND OBJECTIVES

The aim of this study is to detect radio wave signals and compare with COST 231-HATA model to ascertain the most suitable while the specific objectives are:

- To measure electric fields at various distances in a specified area
- To use COST 231-HATA model to measure and determine parameters such as path loss, radiated power.
- To use MATLAB for the simulation, obtain the results and discuss

## 2.0 METHODOLOGY

### 2.1 Area of Investigation

Data is obtained within the senate building and engineering areas of the University of Lagos. The area is densely packed with buildings and car parks. For the purpose of this study, it was considered as an urban area.

### 2.2 Data Collection

Electric field strength data is collected using the G-net and a GPS software is used to measure the distance between the transmitter and the receiver. We considered the mobile network service provider base station (MTN) situated at the Indomie bridge area close to faculty of science as the transmitter with a height of 36m above ground level. Propagation measurements were taken at 900MHz. Ten (10) points were considered within the terrain, each with ten (10) electric field measurements starting from 0.34km away from the transmitter, at an interval of 2s and 0.1km apart for a period of five (5) days and the average for each day are taken. The average measurements for each day at their respective distances are also summed up and the average is computed. The receiver height is taken as 1.5m. The results of these measurements are further discussed below. The tuning method used is the Root Mean Square Error Method (RMSE).

### 2.3 COST 231-HATA MODEL

This model is widely used for predicting path loss in mobile wireless system. Given the limitation of the Hata [5] model to 1.5 GHz and below, as well as the interest in personal communications systems operating near 1.9 GHz, this model was devised as an extension to the Hata-Okumura model [6], [7] to be used in the frequency band from 500 to 2000 MHz It contains corrections for urban, suburban and rural (flat) environments with the following parameters;

- Frequency Range: 500 MHz to 2000 MHz
- Transmitter Height: 30 m to 100 m
- Link distance: up to 20 km
- Mobile Station (MS) height: 1 m to 10 m

The model is very simple and easy to use for path loss prediction and the basic equation for the path loss predicted by this model is [2] , [8];

$$L = 46.3 + 33.9logf - 13.82logh_B - a(h_R) + (44.9 - 6.55h_B)logd + c \quad (1)$$

Where,

- c=0 for medium cities and suburban areas
- c=3 for metropolitan areas
- L = Median path loss in Decibels (dB)
- f = Frequency of Transmission in Megahertz (MHz)
- $h_B$ = Base Station Antenna effective height in Meters (m)



DOI: 10.31695/IJASRE.2018.32992

- d = Link distance in Kilometers (km)
- $h_R$ = Mobile Station Antenna effective height in Meters (m)
- $a(h_R)$ = Mobile station Antenna height correction factor as described in the Hata Model for Urban Areas.

For urban areas, $a(h_R)$= $3.20(log10(11.75hr))^2$−4.97, for f > 400 MHz (2)

For sub-urban and rural areas, $a(h_R)$ = (1.1log (f) - 0.7)$h_R$ - 1.56log (f) -0.8 (3)

## 3. RESULTS AND DISCUSSION

Results of mean power received in dBm from the ten (10) points studied are discussed in Table1.1. A graph is plotted with the mean power against respective distances as shown in fig 1.1 using MATLAB. Also, Predicted path loss (PL predicted) is calculated using Equation (1) where;

- c=3 for metropolitan areas
- L = Median path loss in Decibels (dB)
- f = 900MHz
- $h_B$ = 36m
- d = Link distance in Kilometers (km)
- $h_R$ = 1.5m
- $a(h_R)$ = Mobile station Antenna height correction factor as described in the Hata Model for Urban Areas.
  $a(h_R)$= $3.20(log10(11.75hr))^2$−4.97 (4)

PL measured is then calculated as; EIRP-MEAN PR

Where EIRP is the effective isotropic radiated power in dBm and is measured as;

EIRP = $P_{BTS}$ + $G_{BTS}$ + $G_{MS}$ - $L_{FC}$ -$L_{AB}$ – $L_{FC}$ (5)

$P_{BTS}$ = Transmitter power (dBm)

$G_{BTS}$ = Transmitter Antenna Gain (dBi)

$G_{MS}$ = Receiver Antenna Gain (dBi)

$L_{FC}$ = Feeder Cable and Connector Loss (dB)

$L_{AB}$= Antenna Body Loss (dB)

$L_{FC}$ = Combiner and Filter Loss (dB)

Total transmit loss in BTS between TRX and antenna feeder includes losses in the connecting waveguides, combiners, filters and duplexers. Feeder Loss from cabinet to top of mast is dependent mainly on length and dimension of feeder. This loss is also frequency dependent and is assumed to include "normal" jumper cables between actual antenna feeder and BTS cabinet and antenna respectively by Wikipedia. A Combiner is a device that combines feeds from several TRXs so that they could be sent out through a single antenna. Antenna combiners are implemented to use the same antenna for several TRXs (carriers) and the more TRXs are combined the greater the combiner loss will be. Substituting these values into Equation (2) gives;

EIRP = 46 + 18.15 – 3- 3 – 4.7

EIRP = 53.5dBm.

∴ PL measured = 53.5+MEAN PR (6)

Consider equation (1), It can be decomposed into;

PL predicted =A + B log D + C (7)

Where;



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A= 46.3 +33.9 log (f) - 13.82 log($h_b$) – a($h_m$)

B = 44.9 - 6.55 log($h_b$)

C = 3dBm

PL predicted = 127.942+34.71 log D

To get the RMSE before tuning = $\sqrt{\frac{\sum(PL\ measured - PL\ predicted)^2}{n}}$ (8)

Where n= number of measured data points =10

From the table2 below,

$$\sum(PL\ predicted) = 1232.50$$

$$\sum(PL\ measured) = 1204.24$$

RMSE = $\sqrt{\frac{(1204.24 - 1232.50)^2}{10}} = 8.936 \cong 8.94dBm$

The new tuned path loss (PL tuned) = equation (4) - 8.936

This shows that COST 231-Hata model is suitable for the terrain as it is still within the acceptable 6dBm range.

∴ PL tuned = 123.847+34.71 logd (9)

The values for equation (3), (4), (5) are shown in table 2.

The tuned path loss obtained is also compared with the measured path loss using the RMSE.

RMSE after tuning = $\sqrt{\frac{\sum(PL\ measured - PL\ tuned)^2}{n}}$ (10)

RMSE after tuning =1.371dBm

The results obtained after tuning shows that the tuned path loss gives an error closer to 0, showing that the tuned path loss is better.

A graph of the predicted, measured and the tuned path loss obtained against the distance between the transmitter and receiver was plotted using Matlab as shown in figure 2.

**Table 3.1: Daily received power at various distance/data points**

| S/N | DISTANCE (KM) | DAY1 | DAY2 | DAY3 | DAY4 | DAY5 | MEAN PR |
|---|---|---|---|---|---|---|---|
| **1** | 0.34 | -55.2 | -65.2 | -62 | -67 | -69 | -63.68 |
| **2** | 0.44 | -57 | -55 | -59 | -61 | -63 | -59 |
| **3** | 0.54 | -63 | -65 | -67 | -71 | -73 | -67.8 |
| **4** | 0.64 | -67 | -68 | -65.4 | -69.5 | -71.5 | -68.28 |
| **5** | 0.74 | -73 | -69 | -67 | -64 | -71 | -68.8 |
| **6** | 0.84 | -71 | -75 | -69 | -70.5 | -73 | -59.1 |
| **7** | 0.94 | -67.5 | -65.5 | -69 | -71 | -72.5 | -69.1 |
| **8** | 1.04 | -73 | -69.5 | -71.5 | -75 | -69.1 | -71.62 |
| **9** | 1.14 | -71 | -73 | -69 | -65 | -69.5 | -69.5 |



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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **10** | 1.24 | -75 | -71 | -69.3 | -71.5 | -65 | -70.36 |

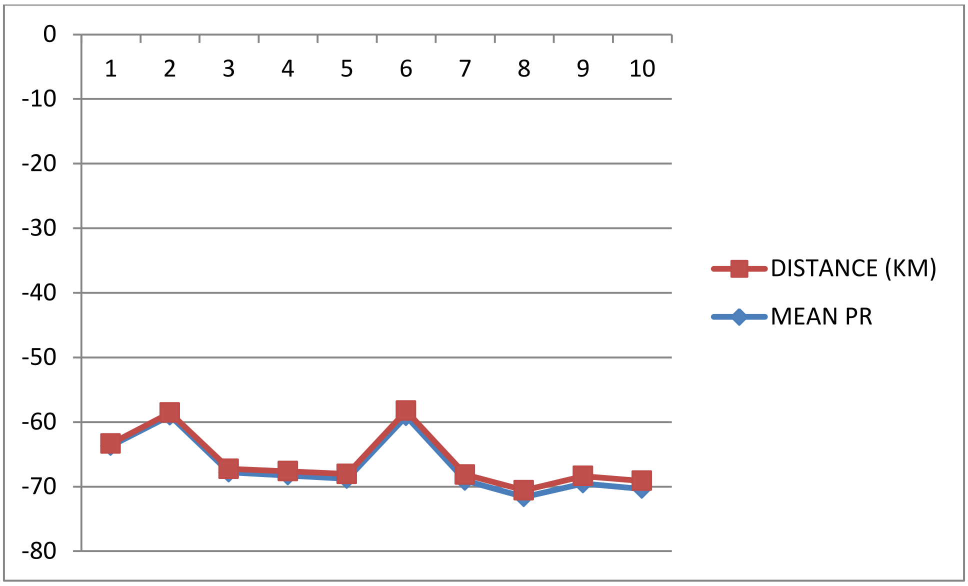


**Fig 3.1: Comparison of Mean power against respective distances**

**Table 3.2: Comparison of path loss for predicted, measured and tuned model.**

| DISTANCE (KM) | PL PREDICTED | MEAN PR | PL MEASURED | PL TUNED |
|---|---|---|---|---|
| **0.34** | 111.68 | -65.68 | 119.18 | 102.73 |
| **0.44** | 115.57 | -59 | 112.5 | 106.63 |
| **0.54** | 118.65 | -67.8 | 121.3 | 109.71 |
| **0.64** | 121.21 | -68.28 | 121.78 | 112.27 |
| **0.74** | 123.4 | -68.8 | 122.3 | 114.46 |
| **0.84** | 125.31 | -59.1 | 112.6 | 116.37 |
| **0.94** | 127.01 | -69.1 | 122.6 | 118.06 |
| **1.04** | 128.53 | -71.62 | 125.12 | 119.59 |
| **1.14** | 129.92 | -69.5 | 123 | 120.98 |
| **1.24** | 131.18 | -70.36 | 123.86 | 122.24 |
| -- | 1232.5 | -- | 1204.24 | 1143.04 |



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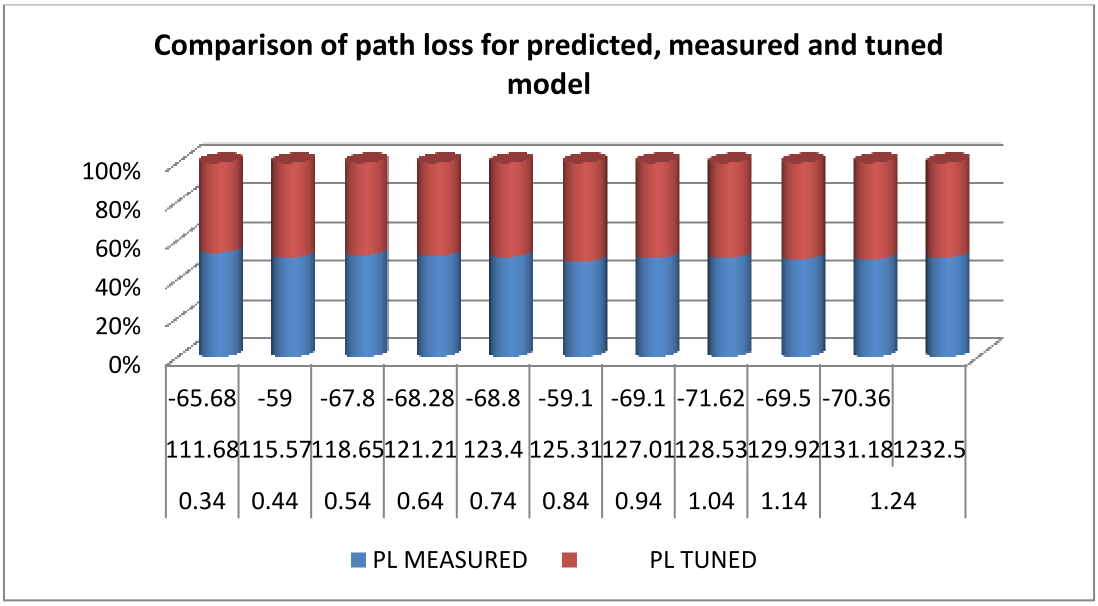


**Fig3. 2: Comparison of path loss for COST 231 model tuning using Matlab**

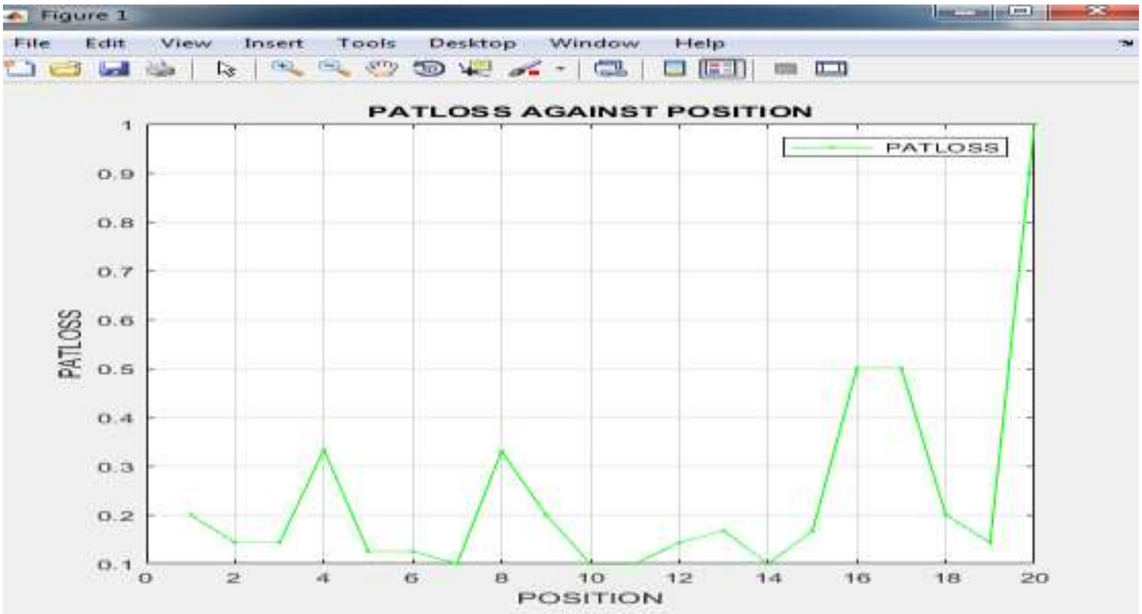


**Fig3. 3: Comparison of path loss for COST 231 for different positions**

**3.1Matlab Script for Figure 1**

```
clc
%%%%%%%% MEAN POWER AROUND ENGINEERING AND SENATE BUILDING
MEANPOWER=[-65.68,-59,-67.8,-68.28,-68.8,-59.1,-69.1,-71.62,-69.5,-70.36];
d=[0.34,0.44,0.54,0.64,0.74,0.84,0.94,1.04,1.14,1.24];
plot(d,MEANPOWER,'g.-');
grid on;
xlabel('DISTANCE (KM)'),ylabel('MEAN POWER RECEIVED (dBm)');
title('MEAN POWER RECEIVED (dBm)  AGAINST  DISTANCE (KM)')
legend('MEAN POWER')
grid on
```



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### 3.2. Matlab Script for Figure 2

```
clc
%%%% COMPARISON OF PREDICTED, MEASURED, TUNED PATH LOSS AGAINST DISTANCE
%%%%%%%%%%%%%
PLpredicted=[111.68,115.57,118.65,121.21,123.40,125.31,127.01,128.53,129.92,131.18];
PLmeasured=[119.18,112.50,121.30,121.78,122.30,112.60,122.60,125.12,123.00,123.86];
PLtuned=[107.59,111.48,114.56,117.12,119.31,121.22,122.92,124.44,125,127.09];
d=[0.34,0.44,0.54,0.64,0.74,0.84,0.94,1.04,1.14,1.24];
plot(d,PLpredicted,'g.-',d,PLmeasured,'r.-',d,PLtuned,'b.-');
xlabel('DISTANCE (KM)'),ylabel('PATHLOSS (dB)');
title('PATHLOSS (dB) AGAINST DISTANCE (KM) IN SENATE AND ARCHITECTURE AREAS')
legend('PLpredicted','PLmeasured','PLtuned')
grid on
```

## 4.0 CONCLUSION

The predicted COST 231-Hata model gives a RMSE of 8.936 dBm which shows that it is suitable for this terrain as it falls within the acceptable range of 6dBm from international telecommunication union (ITU). Also, where there are mountains, ills, and where the line of site is not visible, this method can be applicable. Upon further tuning of the model, it gives a RMSE of 1.4dBm which is even better value for path loss and signal strength predictions. The tuned cost 231-Hata model is thereby recommended for better signal strength and path loss prediction for the senate building and architecture areas of the University of Lagos. It is however recommended that other researchers could also adopt other models like HATA-231 and so on.

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DOI: 10.31695/IJASRE.2018.32992