American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-4, Issue-11, pp-109-115
www.ajer.org
Research Paper Open Access

Comparative Study of Path Loss Models for Wireless Communication in Urban and Sub-urban Environment for Port Harcourt, Nigeria.

Akujobi Ekeocha[1], Nosiri Onyebuchi[2] and Achumba Ifenyinwa[2]
[1.] *Department of Computer Science, University of Port Harcourt, Nigeria*
[2.] *Department of Electrical and Electronic Engineering Futo, Owerri, Nigeria*

ABSTRACT: *The study was based on the comparative analysis of radio propagation models for Global System for Mobile Communications at 900MHz. Drive test analyses were carried out from two selected terrains in Rivers State namely GRA Phase II and Aggrey Road classified as urban and suburban areas respectively, to evaluate the best propagation model for the study area. The data obtained were used to compare the various prediction models namely; Cost 231, Okumura-Hata and ECC-33. Mean path loss values of 115.16dB for Okumura-Hata and 117.79dB for COST 231 and 280.88dB for ECC-33 respectively were predicted in the urban environment. Mean path loss values of 115.16dB, 114.76dB and 314.84dB were predicted by Okumura-Hata, Cost 231and ECC-33 models respectively in the suburban environment. ECC-33 over estimated path loss and gave the highest prediction in both environments. Okumura-Hata model showed better performance in urban while COST 231 performed better in the suburban environment. Okumura-hata and COST 231 models are recommended for deployment in urban and suburban environments respectively.*

Keywords -*Path Loss, Propagation Model, Received Signal Strength, Empirical models, wireless communication*

I. INTRODUCTION

Planning has been identified as a key factor before the implementation of designs, and also setting up of wireless communication systems. One basic requirement for an effective and reliable signal transmission is the knowledge of the received signal strength and its variability at different distances within the surrounding base station [**1**]. The propagation of wireless signals is subject to various propagation mechanisms and heavily influenced by the environment which results to a reduction in the signal strength. Path loss is described as a reduction in the transmitted power of an electromagnetic wave as it propagates through space. It is a major component in the analysis and design of link budget of a communication system. It depends on frequency, antenna height, receive terminal location relative to obstacles and reflectors, and link distance, among many other factors [**2**]. Propagation path loss model prediction plays an important role in the design of cellular systems to specify key system parameters such as transmission power, frequency and antenna heights [**2**].

A number of propagation prediction models for mobile radio communication systems have been developed. However, the selection of the most suitable model for any given geographical region is not a simple task, but depends on descriptions of terrain and effect of vegetation which vary widely from one place to another [**3**]. Propagation models are divided into three groups; the empirical models, semi-deterministic models and deterministic models [4]. Empirical models which are based on measurement data, statistical properties and few parameters. Examples of this model category are Okumura model and Hata model. Semi-deterministic models are based on empirical models and deterministic aspects, examples are the Cost-231 and Walfish-Ikegami. Deterministic models, these are site-specific, they require enormous number of geometry information about the city, computational report and more accurate model [4].

This study was aimed at carrying out field measurements to evaluate the received signal strength and path loss, compare the measured path loss with predicted models for GRA Phase II and Aggrey Road in Port Harcourt, River State, Nigeria.

II. LITERATURE REVIEW

Over the years, different propagation path loss models have been developed for performance assessment of wireless communication systems. To achieve high quality of service delivery, various researchers have undergone research studies on the behaviour of radio wave within different environments under diverse environmental and geographical conditions. The models derived are specific for the respective environment.

In [**5**], a study conducted in India, they opined that path loss propagation models may give different results if used in different environments other than one which they were designed. Different path loss models were compared with measured field data. The field measurement data were obtained in urban, suburban and rural environments at 900 MHz and 1800 MHz frequency bands with the help of spectrum analyser. The analysis showed that ECC–33 and SUI models results performed better in urban areas. In suburban areas, ECC–33, Standard University Interim (SUI) and COST 231–Hata models showed good performance. Okumura – Hata and Log – distance models showed better performance in rural areas.

According to [**1**], they compared empirical models for cellular transmission in River State. In their study, downlink data was collected at various distances on live Globacom WCDMA network at 2100 MHz frequency. Result of predictions from three path loss models and the measured path loss were compared and simulated using MATLAB software. The COST 231 Hata showed better result from the comparison and thus recommended that an adjustment be made to the Cost 231 Hata model for cellular communication in the area.

According to [**6**], they developed a statistical path loss model that could be applied in the South South region of Nigeria. In their work, data was collected from 10 existing microcells operating at 876 MHz in Port Harcourt. The environment was categorized into urban (Category A) and suburban (Category B).The results showed that the Path loss increases by 35.5dB and 25.7 dB per decade in the urban (Category A) and suburban (Category B) areas respectively. Variations in path loss between the measured and predicted values from the Okumura-Hata model were calculated by finding the Mean Square Errors (MSE) to be 10.7dB and 13.4dB for urban and suburban terrains respectively. They opined that the comparison between the modified Hata models and measured values for the two categories showed a better result and thus was effective for use in the study area.

III. PROPAGATION MODELS

3.1Free Space Path Loss Model

Path loss in free space defines how much strength of signal is lost during propagation from transmitter to receiver. This model is applied in an environment that is characterized by less or no obstructions to wireless signal. Free space path loss depends on frequency and distance.

The following equation represents the free space path loss as in [3]:

$$P_L = 32.45 + 20\log_{10}(d) + 20\log_{10}(f) \quad (1)$$

Where,

f: Frequency (MHz)

d: T-R separation (m)

3.2Okumura-Hata Model

Hata model is expressed as a mathematical formulation to mitigate the best fit of the graphical data provided by the classical Okumura model. Hata model is used for the frequency range of 150 MHz to 1500 MHz to predict the median path loss for the distance d from transmitter to receiver antenna in 20 km range and height of transmitting antenna is considered 30 m to 200 m and receiver antenna height is 1 m to 10 m. The model is represented in equation 2 as given by [4]:

$$P_L = A + B\log_{10} d - C \quad (2)$$

Where,

$$A = 69.55 + 26.16\log_{10}(f_c) - 13.82\log_{10}(h_b) - a(h_m)$$

$$B = [44.9 - 6.55\log(h_b)]\log_{10}(d)$$

$$C = 5.4 + 2\left[\log_{10}\left(f_c/28\right)\right]^2$$

$$a(h_m) = 3.2\left(log_{10}(11.75h_m)\right)^2 - 4.79, f > 400MHz$$

f_c = carrier frequency

h_m = transmitter antenna height in meter

h_b = receiver height in meter
d = transmitter-receiver distance in km
a(h_m) = mobile station antenna height correction factor

3.3COST 231 Hata Model

The COST 231 Hata model was developed as an extension to Hata-Okumura model. This model operates in the frequency range from 500MHz to 2GHz, applied in the prediction of path loss for three different environments like urban, suburban and rural. It consists of a correction factor for these three environments. The path loss equation for this model can be expressed as [6]:

$$P_L = 46.3 + 33.9\log_{10} h_t - a(h_r) + [44.9 - 6.55\log_{10} h_t]\log_{10} d + C \quad (3)$$

C= 0 or 3dB, for suburban areas and metropolitan cities
h_t= Transmitting Antenna height in meter
$a(h_r) = (1.11\log_{10} f_c - 0.7)h_r - (1.5\log_{10} f_c - 0.8)$,
for suburban environment
$a(h_r)$= mobile station antenna height correction factor
f_c = Carrier frequency in MHz
d = Transmitter-receiver separation distance in km
h_r = Receiver antenna height in meter

3.4ECC-33 Model

The ECC-33 model formulation is based on original measurements from Okumura model. The model is most widely used in large and medium size cities, areas having crowded and tall buildings. The operation range of this model is up to 3000MHz and distance range from 1 to 100 km. The model is expressed as [9]:

$$P_L = A_{fs} + A_{bm} - G_b - G_r \quad (4)$$

Where,

A_{fs} [dB]= free space attenuation
A_{bm} [dB] =basic median path loss
G_b =Transmitter antenna height gain factor
G_r =Receiver antenna height gain factor

Further expressed as,

$$A_{fs} = 92.4 + 20log_{10}(d) + 20log_{10}(f_c)$$

$$A_{bm} = 20.41 + 9.83log_{10}(d) + 7.894\log_{10}(f_c) + 9.56[\log_{10}(f_c)]^2$$

$$G_b = \log_{10}\left(\frac{h_b}{200}\right)\{13.958 + 5.8[\log_{10}(d)]^2\}$$

$$G_r = [42.57 + 13.7\log_{10}(f_c)][\log_{10}(d_r) - 0.585]$$

IV. MATERIALS AND METHOD

4.1 Description of the Propagation Terrain

The study area is located in the River State, with coordinates (04°48′54″ N, 06° 59′ .52″E) and (04° 45′ .06″N, 07° 02′ .24″E). The area under study was categorized as suburban and urban environment with narrow streets, trees and moderately high buildings.

4.2 Data Collection Process

A drive test was conducted within the study area; GRA phase II and Aggrey road, Nigeria with a vehicle driven along predefined routes. The drive test survey routes follow the design from a cell reference. The cell reference is a telecommunication road map which shows drive test routes to cover antenna sectors. Transmission Evaluation and Monitoring System (TEMS) Investigation software was used on a laptop with a Global Positioning System (BU353) and a TEMS Mobile Station (Sony Ericsson w995) connected through Universal Serial Board (USB) ports. The personal computer serves as the communication hub for all equipment in the system. The Global Positioning Satellites (GPS) provides the location tracking for the system during data collection. This enables the system to determine the position of the Mobile Station (MS) on a global map which is already installed on the laptop. The MS was used to initiate calls during data collection process. While driving was going on, the handset was configured to automatically make calls to a fixed destination number. Each call lasted for 1minute hold time and the call was dropped. The phone remained idle for some period of time then another call was made. The collected data was saved in Log file format for further processing,Actix Analyser was used for the post processing.

4.3 Drive Test Survey Route

The drive test survey route was carefully planned with the aid of a cell reference (cell ref) such that the measurement collection process involved base stations sited within an area marked for investigation. The survey route was also indicated on the map to aid accessibility of the drive test vehicle to the active sector of the base station in consideration. The distance covered was ensured to be long enough to allow the noise level of the receiver to be reached. The routes covered in this study were GRA phase II and Aggrey road. These routes were chosen based on their uniqueness in order to represent the features of these cities. Fig 1.0 Showed the TEMS view of the drive test routes.

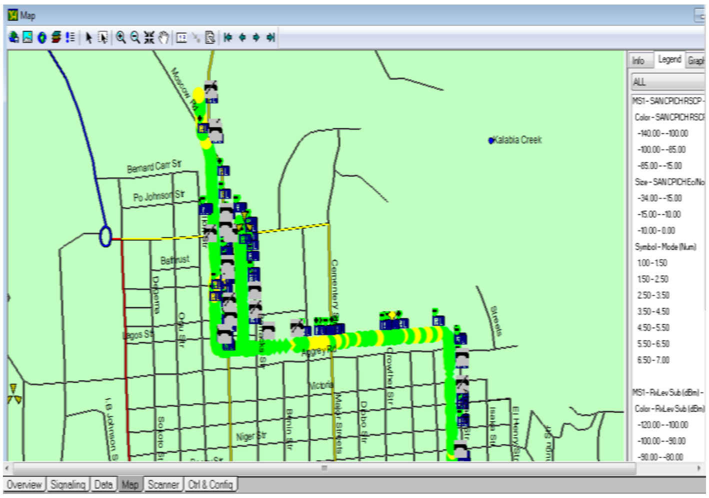

Figure 1: View of drive test routes

V. RESULTS AND DISCUSSION

The path loss values from the three existing models are presented using equation (2), (3), (4) and were compared with the field measured values and their results displayed in figs 2 and 3.

Table 1: Network Parameters for Urban and Sub-urban

Par:ameters	**Values**
Frequency	900MHz
Transmitting Antenna Height	40m
Receiving Antenna Height	1.5m

Table 2: Empirical and Measured Path loss values for Urban Environment

Distance (km)	**ECC-33(dB)**	**COST-231 (dB)**	**OKUMURA-HATA (dB)**	**MEASURED (dB)**
0.1	262.65	93.00	90.27	100
0.2	269.55	103.30	100.63	106
0.3	273.93	109.30	106.67	104
0.4	277.19	113.61	110.97	120
0.5	279.81	116.90	114.31	158
0.6	282.00	119.67	117.03	158
0.7	283.90	121.97	119.34	158
0.8	285.57	123.96	121.33	113
0.9	287.07	125.72	123.09	112
1.0	288.42	127.30	124.67	128
1.1	289.66	128.72	126.08	135
1.2	290.81	130.02	127.39	136

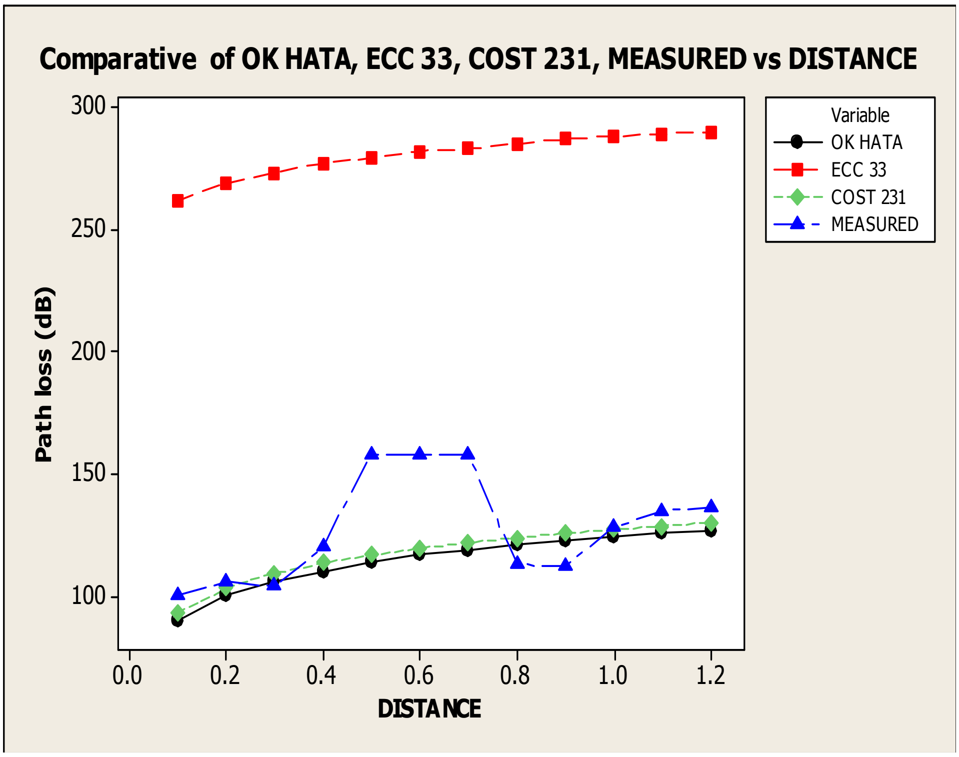

Figure 2: Comparison between predicted and measured Path loss in an urban environment

The prediction results of empirical propagation models employed in this study are represented graphically. The values of the predicted Path loss and the field measured data were plotted against the distance of separation between the Base Station (BS) antenna and the Mobile Station (MS) antenna. Fig 2.0 showed the result of Path loss prediction from Okumura-Hata, COST 231, ECC-33 and the measured Path loss from the urban propagation environment. The result of the drive test carried out within the coverage area of the cell reported a mean RSS of -83dBm. Mean measured Path loss values of 115.16dB, 117.79dB and 280.88dB were predicted by Okumura-Hata, COST 231-Hata and ECC-33 Models respectively. COST 231 and Okumura-Hata models showed some level of similarity with slight difference. The ECC-33 model predictions were high compared to Okumura-Hata and Cost 231. The high Path loss prediction recorded from ECC-33 clearly showed that the environment of study needs to be considered in the siting of GSM base stations. The measured Path loss showed some level of fluctuations resulting from obstructions of physical structures within the environment or topology. The COST 231 Hata model was chosen for the optimization of this environment.

Table 3: Empirical and Measured Path loss values for Suburban Environment

Distance (km)	ECC 33(dB)	COST 231 (dB)	OKUMURA HATA (dB)	MEASURED (dB)
0.1	296.60	89.88	90.27	111
0.2	303.51	100.25	100.63	113
0.3	307.89	106.31	106.69	114
0.4	311.15	110.61	110.99	131
0.5	313.77	113.95	114.32	116
0.6	315.96	116.67	117.04	158
0.7	317.86	118.97	119.35	140
0.8	319.53	120.97	121.34	158
0.9	321.02	122.73	123.10	152
1.0	322.38	124.30	124.68	128
1.1	323.62	125.71	126.10	141
1.2	324.77	127.03	127.40	124

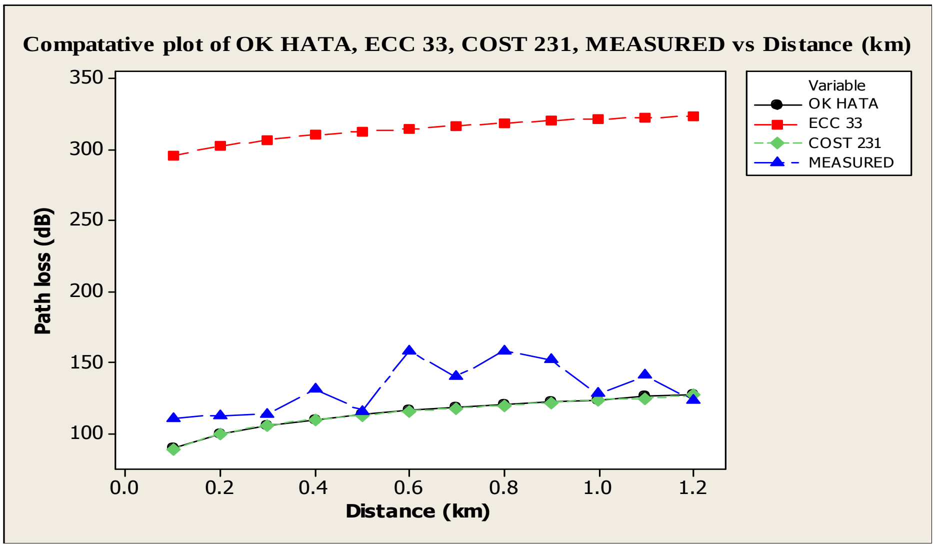

Figure 3.0: Comparison of Predicted and Measured Path loss in suburban environment

Fig 3.0 showed a plot of the predicted propagation models and measured radio propagation characteristics of the transmitted signal within the suburban environment. Okumura-Hata, COST 231, and ECC-33 Models predicted mean Path loss values of 115.16dB, 114.76dB and 314.84dB respectively. The ECC-33 model over predicted path loss compared to Okumura-Hata and COST 231. The deviations between Okumura-Hata model and COST 231 models can be considered as negligible. The mean Received Signal Strength (RSS) obtained from the propagation environment within the radio coverage of the cell was -79.39 dBm.

Table 4: Measured Received Signal Strength for Urban Environment

S/N	Measured RSS (Urban)	Measured RSS(Suburban)
1	-67	-65
2	-73	-66
3	-71	-64
4	-83	-67
5	-77	-67
6	-91	-66
7	-81	-66
8	-80	-69
9	-79	-74
10	-95	-76
11	-102	-77
12	-103	-78

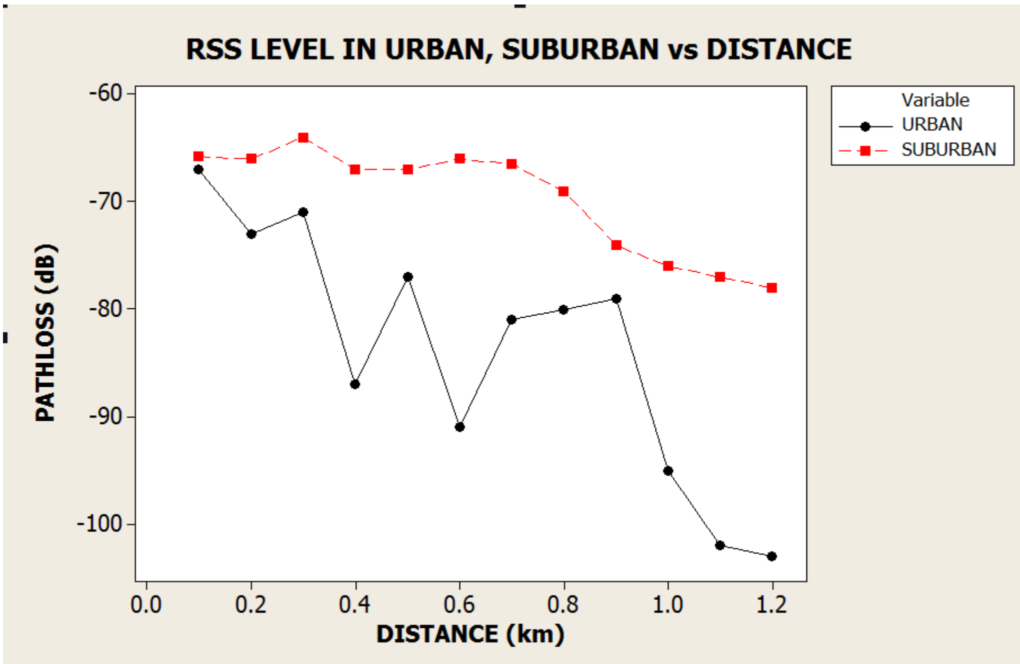

Figure 4.0: RSS plots in urban and suburban environment

Fig 4.0 represented a plot of the (RSS) in the suburban environment. There is a gradual degradation of the signal strength as compared to the urban environment. In the urban plot, the existence of signal fluctuations indicates obstructions encountered along the signal path. These obstructions are high rise buildings in close proximity, as well as trees sandwiched between houses within the environment. These obstructions account for call drops, cross talk, and loss of signal experienced in the study area.

VI. CONCLUSION

In this research, the received signal strength and path loss of a mobile communication system was measured in an urban and suburban environment respectively. The predicted Path loss was compared with measured data using a graphical representation, the performance of all models were analysed and it was shown that Cost 231 and Okumura-Hata models showed considerable performance and could be adjusted for better performance. It can be said that the performance of radio propagation models are environment dependent. Thus, the influence of environmental factors must be emphasised and properly accounted for when considering base station sites. Therefore, one of the best possible ways of obtaining a better radio channel characteristics is to optimize the existing path loss models based on measured data collected from a specific area.

REFERENCES

[1] Akinwole B.O.H, and Biebuma J.J, “Comparative Analysis of Empirical Path Loss Model for Cellular Transmission in Rivers State”, *American Journal of Engineering Research (AJER). ISSN 2320-0936, Volume 02, Issue- 08, PP 24 – 31, 2013.*

[2] Nwalozie Gerald .C, Ufoaroh S.U, Ezeagwu C.O, Ejiofor A.C, “Path Loss Prediction for Gsm Mobile Networks for Urban Region of Aba, South-East Nigeria”.*International Journal of Computer Science and Mobile Computing, Vol.3 Issue.2, PP. 267-281, 2014.*

[3] PranjaliRaturi, Vishal Gupta, SamreenEram , “Proposed Propagation Model for Dehradun Region” *International Journal of Soft Computing and Engineering (IJSCE), ISSN: 2231-2307 Volume 3, Issue 6*, 2014.

[4] Mardeni, R and Kwan K.F, “Optimization of Hata Propagation model of Sub-Urban Area in Malaysia”, *Progress in Electromagnetic Research C, Vol 13, 91 – 106, 2010.*

[5] SharmaP.K and R.K. Singh, “Comparative Analysis of Propagation Path Loss Models with Field Measured Data”.*International Journal of Engineering Science and Technology, Vol. 2*(6), 2014.

[6] Ubom, E.A, Idigo V.E, Azubogu A.C, Ohaneme C.O. and Alumona T.L (2011). “Path loss Characterization of Wireless Propagation for South - South Region ofNigeria”. *International Journal of Computer Theory and Engineering, Vol.3, No3. PP 360-364.*

[7] Ujjawalbahuguna, Bhagirathi Pradhan (2014), “A Review on Path Loss Models for Suburban Regions Using Fuzzy Logic” *International Journal of Computer Engineering & Science(IJCES).ISSN: 2231–6590, 2014*

[8] Ogbulezie J.C, M.U. Onuu, J.O. Ushie, B.E. Usibe,“Propagation Models for GSM 900 and GSM 1800MHz for Port Harcourt and Enugu, Nigeria”, *Network and Communication Technologies; vol. 2, No. 2*, 2013.PP 1–10.

[9] KumariManju, YadavTilotma and PoojaYadav, “Comparative Study of Path loss Models in different Environments”. *International Journal of Engineering Science and Technology (IJEST), Vol. 3 No. 4 April 2011.*