

DETERMINATION OF A PATHLOSS MODEL FOR LONG TERM EVOLUTION (LTE) IN FESTAC TOWN LAGOS

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ABSTRACT

The analysis of propagation model in urban terrains is necessary owing to the fact that the environment is composed of different physical obstructions. These models are useful planning tools that allow the network planner of wireless communication networks to achieve optimal levels for the base station deployment and meeting the expected service level requirements. In this work, five empirical propagation models- FSPL, EGLI, ECC, COST 231 and ERICSSON Model are considered for pathloss performance analysis in the urban area of Lagos metropolis (FESTAC). A drive test was conducted to obtain the actual field data on the LTE with a frequency of 700MHz network deployed in the area under study. All prediction calculations were carried out in the TEMS Investigation and Discovery network planning tool. Ericsson model best predict the environment with a minimum deviation of 10.13dB being closest to measured pathloss with 2.02dB compared to the other models

Key words: pathloss, LTE, Base Station, Model, propagation

1. INTRODUCTION

Call drops; slow data rate is gradually becoming an issue in broadband transmission. This could be as a result of poor capacity, low average, and attenuation when waves are propagated from one point to another.[1]

Radio propagation planning is highly important in wireless network development in any region. Wireless network can be propagated via different mechanism scattering, diffraction and reflection.

Pathloss is the power reduction of EM waves as it propagates through space[2].

Pathloss is simply the difference between the power transmitted and power received[3]. In planning 4G network, pathloss is a key component. It is the attenuation of EM waves as it propagate from one point to the other through space.

A whole lot of factors can influence the pathloss, environment (Urban, sub-urban, rural), distance between the transmitter and the receiver, the location and the height of the antenna.

As signal passes through multi-path propagation, it tends to reduce due to density of electromagnetic waves and reduction of power. This poses a high

challenge in the use of mobile radio communications and its effect can be felt in highly populated cities such as FESTAC Lagos.

Due to the various differences in city structures, local terrain profiles, weather etc., predicting the pathloss with reference to the existing empirical path loss models such as the SUI, Ericsson model, Hata's model etc., may differ from the actual one.

Therefore determination of pathloss for a particular terrain becomes highly necessary for network planning and optimization engineers.

2. LITERATURE REVIEW

4G Review

LTE is a standard of 4G that uses MIMO and OFDM technology. LTE was developed by 3GPP to improve UMTS wireless standard. LTE has huge merit ranging from better spectrum efficiency, high peak data rate, and low latency. LTE technology uses multiple-input-multiple output (MIMO). This could either be spatial multiplexing and space-time coding [4].

[5] in their paper did a pathloss study of 3 regions: urban, sub-urban and rural terrain using a VHF Omni directional ratio (VOR). Their analysis were carried out using monte carlos simulation technique. They deduced that increase in cell radii resulted to an increase in pathloss which in turn reduced the signal strength. They concluded that before an effective signal coverage can be achieved in cellular network, the cell radius should be relatively small to reduce path for effective signal strength.

[6] carried out their measurement based pathloss and on pathloss models. Their test measurement were carried out in sub-urban, urban and rural areas under terrains with non line of sight. They carried out drive test with the use of spectrum analyzer tool and they were able to measure the pathloss values of various terrain. In their experiment , they considered a frequency of 940Mhz GSM frequency. they obtained 85 dB in urban region, 102 dB in rural region and 89 dB in sub-urban region and this was less compared to free space pathloss value. Hata pathloss model had a high value with respect to 158 dB in urban area, 139 dB in rural region and 142 dB in sub-urban region. As displayed in their result, it caused higher probability of RF signal errors. On the basis of observation and with the help of clutter, they presented a pathloss model which can be used to predict the model within the discussed regions

[7] carried out an empirical test to predict the most suitable pathloss model in mobile communication. The frequency of operation considered was 900Mhz GSM. The site location where test was carried out was in Tanzania. They considered SUI, COST, ECC, Ericson amd Hava-Okumura model. From their findings, the ECC model showed the best prediction while other model underestimated the pathloss when being considered for urban area. (Akpado et al, 2013) compared for Hata okumura, Cost 231, ECC 33 with MATLAB for a GSM 900Mhz.

Results obtained showed clearly that as distance increases, the pathloss for the various model also increased.

They also observed that Hata Okumura and cost model were lesser than the threshold value and should be preferred for maximum coverage to reduce handoff.

[8] in their paper considered pathloss model using Geographic information systems. They compared their result with a previous test in southern Nigeria. The high value of pathloss in Ughelli amd Afiesere was a result of heavy forest which include palm and vegetation. They also deduced that high attenuation factors between Diobu Creek and Nun River are as a result of forest and mangrove depicted from their display. They predicted low receiving signal if measures are not taking to improve signal quality within this terrain.

EMPIRICAL METHOD OF PATHLOSS ANALYSIS

Models have been postulated considering different factors including geographical terrain, frequency of operation over a given distance. They could be applicable to other environment other than the one that was predicted but most ties, they become less accurate.

COST 231 HATA MODEL

COST 231 HATA model is used for predicting path loss in mobile wireless system is the COST-231 Hata model. It is a revised version and an extension to the Hata-Okumura model. The designated frequency of operation is between the range of 500 MHz to 2000 MHz. there are also provisions for antenna factor corrections for flat environment. Due to its provision for correction factor and simplicity, it is often used to predict pathloss. The basic equation for path loss in dB

$$PL = 46.3 + 33.9 \log(f) - 13.82 \log(h_b) - ah_m + (44.9 - 6.55 \log(h_b)) \log d + C_n \quad (1)$$

where, f is the frequency in MHz, d is the distance between AP and CPE antennas in km, and hb is the AP antenna height above ground level in metres. C_n is 0dB for suburban and 3dB for urban region. ah_m can be defined for urban region as

$$ah_m = 3.20(\log(11.75h_r))^2 - 4.97, \text{ for } f > 400\text{MHz} \quad (2)$$

And for sub-urban and rural environments,

$$ah_m = (1.1 \log f - 0.7)h_r - (1.56 \log f - 0.8) \quad (3)$$

EGLI MODEL

This model is good in predicting point to point links. It is most preferred where the one antenna is mobile and the other fixed. It is not applicable in terrains where there is vegetation obstructing line of sight. Egli model is given by

$$PL(dB) = G_b G_m \left(\frac{h_b h_m}{d^2}\right)^2 \left(\frac{40}{f}\right)^2 \quad (4)$$

Where

G_b is the BTS antenna gain

G_m is the mobile station antenna gain

h_b is the base station height

h_m is the mobile station height

d is the distance in meters

f is the frequency in Hz

STANFORD UNIVERSITY INTERM (SUI) MODEL

The Stanford University Interm (SUI) model development took place under the institute of Electrical and Electronic Engineers (IEEE) 802.16 broad band wireless access working group. This model takes into consideration correction factors for the Hata model with frequencies above 1900MHz. This model consist of three terrains; A, B and C. Type A is for hilly terrains, type C is for areas with reduced pathloss and densities. Type B is with flat terrains with light tree densities [9]. SUI equation model is given by

$$PL(dB) = A + 10\gamma \log_{10} \left(\frac{d}{d_0}\right) + X_f + X_h + X_s \quad \text{for } d > d_0 \quad (5)$$

where, d is the distance between the BTS and the mobile device in m, $d_0 = 100$ m and s takes the effect of shadowing into consideration and is a log normally distributed factor and other and has a value between 8.2 dB and 10.6dB .Other parameters are defined as

$$A = 20 \log_{10} \left(\frac{4\pi d_0}{\lambda}\right) \quad (6)$$

$$\gamma = a - b h_b - c / h_b \quad (7)$$

where, the h_b is the base station height in metres. The constants a , b and c are defined in the table 2.1 below. The parameter γ in is equivalent to the exponent of the pathloss.

Table 1 SUI Constants

model parameters	Terrain A	Terrain B	Terrain C
a	4.6	4	3.6
b	0.0075	0.0065	0.005
c	12.6	17.1	20

The antenna correction factors for the frequency and for the mobile equipment antenna height for the SUI model are

$$X_f = 6.0 \log_{10} \left(\frac{f}{2000}\right) \quad (8)$$

$$X_h = -10.8 \log_{10} \left(\frac{h_r}{2000}\right) \quad \text{for Terrain A and B} \quad (9)$$

$$= 6.0 \log_{10} \left(\frac{f}{2000}\right) \quad \text{for Terrain C} \quad (10)$$

ERICSSON MODEL

The modification of the Okumura hata Model according to a propagation environment gave room for change in parameters which eventually lead to Ericsson model. Network engineers used a software to actually develop this model.

According to this model, the pathloss is given by

$$Pl = a_0 + a_1 \log_{10} d + a_2 \log_{10} h_b + a_3 \log_{10} h_b \log_{10} d - 3.2(\log_{10}(11.75 h_r))^2 + g(f) \quad (11)$$

$$\text{Where } g(f) = 44.49 \log_{10} f - 4.78(\log_{10} f)^2 \quad (12)$$

Where f is the frequency in Mhz

hb is the distance in m

hr is the receiver antenna height in m

The default values of these parameters (a_0 , a_1 , a_2 and a_3) for different terrain are given in Table below

Table 2 Ericsson Constants

environment	a_0	a_1	a_2	a_3
urban	36.2	30.2	12.0	0.1
sub-urban	43.2	68.93	12.0	0.1
rural	45.95	100.6	12.0	0.1

The value of parameter a_0 and a_1 in suburban and rural area are based on the Least Square (LS) method [10]

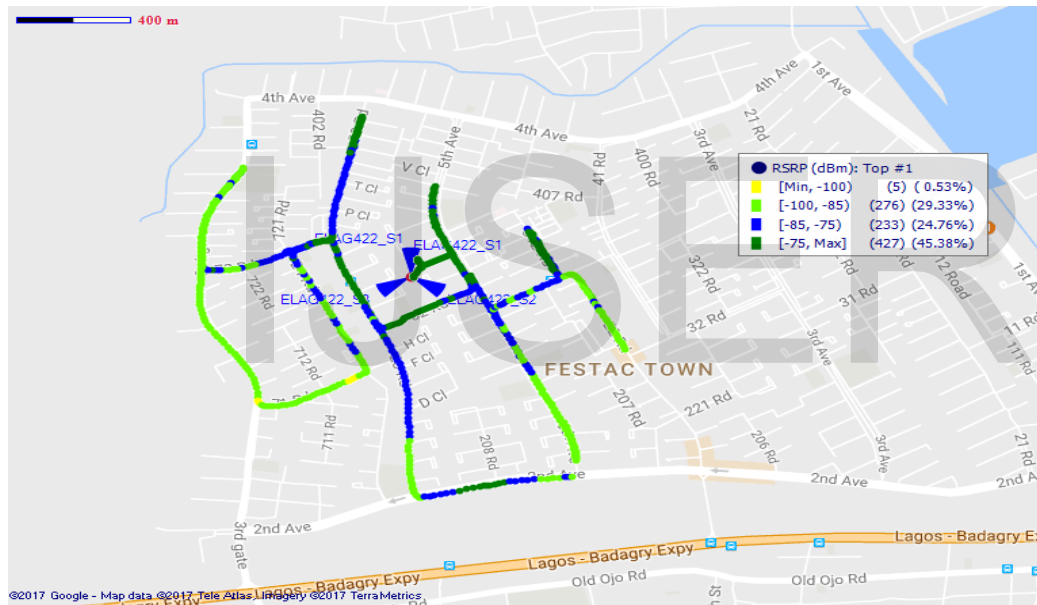
3. DESIGN METHODOLOGY

DRIVE TEST

A drive test was conducted with the aid of a laptop with TEMS investigation 15.3.3. the mobile device is a Samsung S5 galaxy pre installed with TEMS pocket and GLO LTE enabled sim. An inverter provided power supply for the laptop and a GPS was used to record coordinate of site. The BTS antenna was located at 26m height while the mobile station height is 1m. the car was driven at a speed not more than 40km/hr while the TEMS recorded the received power(RSRP). Measurements were taken twice in a

day for a period of six month and mean average values of received signal strength obtained for this work.

FIG 1 DRIVE TEST FOR LAG_422 ON TEMS SOFTWARE



PATHLOSS EQUATION ANALYSIS

Path loss can be defined as the ratio of the transmitted to received power, usually expressed in decibels. The equation for the Least Square (LS) regression analysis shows the path loss at distance d in the form

$$10 \log P_r(mw) = P_r(dBm) \quad (13)$$

Where P_r is the receive power

$$PL(d_i)(dB) = PL(d_0) + 10n \log \left(\frac{d}{d_0} \right) \quad (14)$$

Where

$PL(d_i)$ is the measured pathloss with respect to distance

$PL(d_0)$ is the predicted pathloss with respect to reference distance $d_0 = 0.1km$

LOG NORMAL SHADOWING MODEL

During transmission, obstructions are caused by objects such as buildings and trees thus causing some part of the signal being lost via diffraction, scattering, absorption and reflection. This effect is referred to as shadowing.

Based on this equation above can be modeled into

$$PL(d_i) = PL(d_0) + 10n \log\left(\frac{d}{d_0}\right) + \chi_\sigma \quad (15)$$

Where χ_σ is a Gaussian distributed random variable with standard deviation σ

$PL(d_0)$ is the pathloss at reference distance

$PL(d_i)$ is the measured pathloss at various distances

n is the pathloss exponent

$$n = \frac{PL(d_i) - PL(d_0)}{10 \log\left(\frac{d}{d_0}\right)} \quad (16)$$

In the above equation, we can analyse it with linear regression where pathloss exponent n can be evaluated by obtaining the mean square error and minimizing it.

$$n = \frac{\sum_{i=1}^k PL(d_i) - PL(d_0)}{\sum_{i=1}^k 10 \log\left(\frac{d_i}{d_0}\right)} \quad (17)$$

The standard deviation σ can be obtained via the formula below

$$\sigma = \sqrt{\frac{\sum_{i=1}^k PL(d_i) - PL(d_0)^2}{N}} \quad (18)$$

Where N is the number of set points

TABLE 3 SITE PARAMETERS

SITE NAME	ELAG_422(FESTAC)
BTS power	45dB
BTS antenna height	26m
LTE Operating frequency	700Mhz
Mobile station height	1m

TABLE 4 Reference Power Received Signal(RSRP)

Distance (Km)	ELAG_422(FESTAC-Urban) Measured RSRP(dBm)
0.1	-75.8
0.2	-78.1
0.3	-81.3
0.4	-83.7
0.5	-85.9
0.6	-87.7
0.7	-89.3
0.8	-91.2
0.9	-94.2
1	-96.1

From table 4, we can calculate the average power received P_r at various distances

$$P_r(dBm) = 10 \log P_r(mW) \quad (19)$$

$$PL(d_0) = 10 \log\left(\frac{P_t}{P_r}\right) \quad (20)$$

where

P_t is the BTS transmit power at 45dBm

P_r is the RSRP in dBm

$PL(d_0)$ is the measured pathloss value in dB

TABLE 5 MEASURED PATHLOSS AND THE RECEIVED POWER FOR THE VARIOUS DISTANCES

Distance	ELAG_422(FESTAC-Urban)	PLm
(Km)	Measured RSRP(dBm)	dB
0.1	-75.8	120.8
0.2	-78.1	123.1
0.3	-81.3	126.2
0.4	-83.7	128.9
0.5	-85.9	130.9
0.6	-87.7	132.7
0.7	-89.3	134.7
0.8	-91.2	136.3
0.9	-94.2	139.2
1	-96.1	141.1

Based on table 5, it can be deduced that the pathloss measurement increases as distance increases. The rate at which the pathloss increases exponentially (n) with respect to distance can be computed taken into consideration the effect of log normal shadowing

$$Pl(d_i) = Pl(d_0) + 10n \log\left(\frac{d_i}{d_0}\right) \quad (21)$$

Where $Pl(d_0)$ is 120.8 and d_0 is the reference distance 0.1Km.

TABLE 6 PREDICTED PATHLOSS

Distance	ELAG_422	Measured PLm	Predicted PL
(Km)	Measured RSRP(dBm)	dB	
0.1	-75.8	120.8	120.8
0.2	-78.1	123.1	120.8+3.01n
0.3	-81.3	126.2	120.8+4.77n
0.4	-83.7	128.9	120.8+6.02n
0.5	-85.9	130.9	120.8+6.99n
0.6	-87.7	132.7	120.8+7.78n
0.7	-89.3	134.7	120.8+8.45n
0.8	-91.2	136.3	120.8+9.03n
0.9	-94.2	139.2	120.8+9.54n
1	-96.1	141.1	120.8+10.00n

Applying least square method of regression analysis , we can obtain the mean square error by applying the formula below

$$MSE = e(n) = \sum_{i=1}^k [Pl(d_i) - Pl(d_0)]^2 \quad (22)$$

$$= 521.40n^2 - 1761.16n + 1527.79$$

Since the MSE is a function of n, we can obtain n by minimizing the equation above and equating it to zero.

$$\frac{\partial e(n)}{\partial n} = 2[521.40] - 1761.16 = 0$$

$$1042.8n = 1761.16$$

$$n = 1.68$$

Substituting n in the equation below

$$PL(d_i) = PL(d_0) + 10n \log\left(\frac{d}{d_0}\right) + \chi_\sigma \quad (23)$$

$$Pl(d_i) = 120.8 + 16.8 \log\left(\frac{d}{d_i}\right) + \chi_\sigma$$

To obtain the standard deviation σ we use the formula

$$\sigma = \sqrt{\frac{1}{N} \sum_{i=1}^k (Pl(d_i) - Pl(d_0))^2} \quad (24)$$

$$\sigma = \sqrt{\frac{1}{10} ((521.40n^2 - 1761.16n + 1527.79))}$$

$$\sigma = 2.02dB$$

The resultant model will be

$$Pl(d_i) = 120.8 + 10(1.68) \log\left(\frac{d_i}{d_0}\right) + 2.02$$

$$Pl(d_i) = 122.82 + 16.8 \log(D) \quad (25)$$

$$\text{where } D = \frac{d_i}{d_0}$$

Where d_i is the distance at any point

d_0 is the reference distance point

The pathloss model of FESTAC town Lagos can be predicted by equation (25)

To give room for comparison, we need to compare the measured pathloss model against empirical pathloss models.

TABLE 7 MEASURED AND CALCULATED EMPIRICAL PATHLOSS VALUES

d(km)	Measured(dB)	free space(dB)	egli model(dB)	cost231(dB)	ecc33(dB)	Ericsson(dB)
0.1	120.8	69.34	76.56	89.52	96.74	101.95
0.2	123.1	75.36	88.60	100.24	103.09	111.08
0.3	126.2	78.88	95.65	106.52	107.24	116.43
0.4	128.9	81.38	100.64	110.97	110.37	120.22
0.5	130.9	83.32	104.52	114.42	112.92	123.16
0.6	132.7	84.90	107.69	117.24	115.07	125.56
0.7	134.7	86.24	110.37	119.63	116.93	127.59
0.8	136.3	87.40	112.68	121.70	118.59	129.35

0.9	139.2	88.43	114.73	123.52	120.08	130.90
1	141.1	89.34	116.56	125.15	121.43	132.29

TABLE 8 MSE EVALUATIONS FOR VARIOUS EMPIRICAL METHOD

	$(PL_m - PL_{FSPL})^2$	$(PL_m - PL_{EGLI})^2$	$(PL_m - PL_{COST231})^2$	$(PL_m - PL_{ECC})^2$	$(PL_m - PL_{ERICSSON})^2$
D(Km)	FSPL	EGLI	COST231	ECC	ERICSSON
0.1	2648.13	1957.06	978.66	578.93	355.32
0.2	2279.11	1190.08	522.45	400.40	144.48
0.3	2239.18	933.54	387.41	359.60	95.45
0.4	2258.15	798.42	321.52	343.25	75.34
0.5	2263.86	695.90	271.52	323.42	59.91
0.6	2284.84	625.63	238.90	310.99	50.98
0.7	2348.37	592.18	227.14	315.70	50.55
0.8	2391.21	557.67	213.30	313.75	48.30
0.9	2577.59	598.73	245.92	365.77	68.89
1.0	2679.10	602.15	254.45	386.91	77.62
	$\Sigma = 23969.54$	$\Sigma = 8551.37$	$\Sigma = 3661.26$	$\Sigma = 3698.72$	$\Sigma = 1026.85$

To obtain the standard deviation

$$\sigma = \sqrt{\frac{1}{N} \sum (Pl_m - Pl_{empirical})^2} \tag{26}$$

TABLE 9 CALCULATED STANDARD DEVIATION OF PATHLOSS MODELS

$\sigma_{measured}$	$\sigma_{ericsson}$	$\sigma_{COST231}$	σ_{ECC}	σ_{EGLI}	σ_{FSPL}
2.02dB	10.13dB	19.13dB	19.23dB	29.34dB	48.96dB

4 RESULTS AND DISCUSSIONS

MATLAB was used to plot the graphs of both empirical and measured pathloss against distance

FIG3 PLOT OF RECEIVED POWER AGAINST DISTANCE

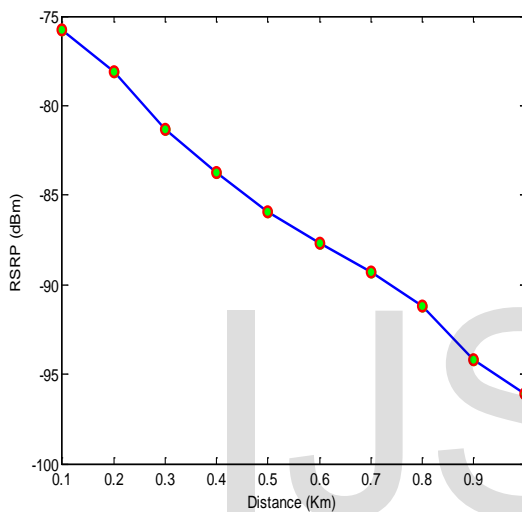
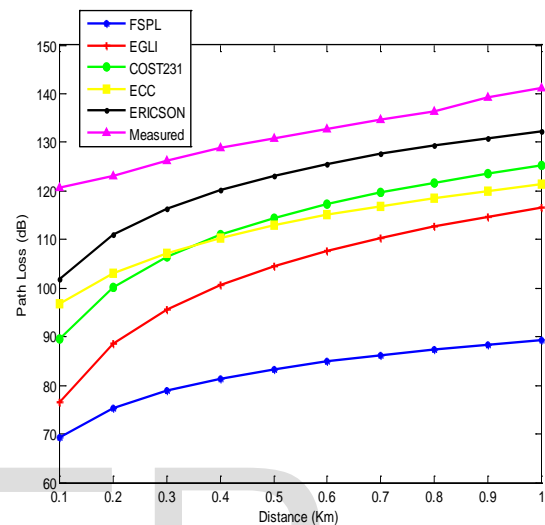


FIG 3 PLOTS OF MEASURED AND EMPIRICAL PATHLOSS AGAINST DISTANCE



From fig3 which shows a combined plot of measured pathloss and empirical pathloss model against distance, it is observed that the free space pathloss(FSPL) under-predicts the urban environment. This could be deduced from the fact the FSPL does not take into consideration, correction factors for base station height h_b and receiver station height h_r . Also we notice the FSPL has the highest standard deviation of value 48.96dB.

The EGLI model shows a standard deviation of 29.24dB. Based on its deviation, it truly shows it is more conservative when compared to FSPL.

COST 231 and ECC shows a standard deviation of 19.13dB and 19.23dB respectively. Both values were

close and it could also be observed from the plot in fig above as both curves lie side by side.

Ericsson show the best prediction of the environment compared to the measured pathloss model when compared from the plot. Also, the standard deviation shows minimum deviation with a value of 10.13dB as compared to the measured pathloss with 2.02dB.

In predicting the value of n for the measured pathloss, we adopted the log normal shadowing effect which can be analyzed using least square method(LS). Ericsson model constant a_0 and a_1 were also obtained using LS method thus best predicting the measured pathloss for the environment as seen from the plots and the deviation compared to other models.

FUTURE WORKS

The deployment of 4G has begun to extend to sub-urban areas in Nigeria. Test measurement may also be carried out in this environment and compared with empirical methods.

REFERENCE

- [1] Akpado K.A, Oguejifor O.S, Abeadwale, Ejiofor A.C (2013) "Pathloss Prediction for a typical mobile communication system in Nigeria using empirical models". International Journal of Computer Networks and wireless Communications Vol. 3, No. 2, pp 1215-1226.
- [2] Nwalozie Gerald .C. Ufoaroh S.U. Ezeagwu C.O Ejiofor A.C (2013) "Pathloss 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, February 2014, pg. 267-281.
- [3] Obot, O. Simeon and J. Afolayan (2011), "Comprehensive analysis of pathloss prediction models for urban macro cellular environments." Nigerian Journal of Technology, Vol. 30.
- [4] Shakti Raj, Navjot Kaur, Himashu Monga (2016), "Space time coding in MIMO". India Journal of Science and Technology. Vol.9.
- [5] Biebuma J.J, Omijeh B.O, Nathaniel M.M (2014), " Signal Coverage Estimation Model for Microcellular Network Propagation" IOSR Journal of Electronics and Communication Engineering Vol. 9, Issue 6, pp 45-53.
- [6] Rakesh N. and S.K. Srivatsa (2013) A study on pathloss analysis for GSM Mobile Networks for Urban, Rural and Sub-Urban Regions of Karnataka State, International Journal of Distributed and parallel systems (IJDPS) vol. 4
- [7] Michael S. Mollé, Michael Kisagiri (2014) "Comparism of Emperical Propagation Pathloss Models for mobile Communication" Computer engineering & Invelligent system vol. 5 No. 9, 2014.
- [8] Biebuma, J.J, Omijeh, B.O (2013), "Pathloss Model Using Geaographic Information System, International Journal of Engineering and Technology. Vol.3 No.3.
- [9] Sami A. Mawjoud(2013) Path Loss Propagation Model Prediction for GSM Network Planning, International Journal of Computer Applications (0975 – 8887) Volume 84 – No 7, December 2013

[10] Gupreet Singh Bola and Gurpreet Singh
Saini(2013) Path Loss Measurement and Estimation
Using Different Empirical Models For WiMax In
Urban Area, Area International Journal of Scientific
and Engineering Research, Volume 4, Issue 5, May
2013

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