Path Loss Propagation Model Prediction for GSM Network Planning

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ABSTRACT
This paper deals with the outdoor path loss behavior. The study has been conducted in Mosul city Iraq to fit a suitable propagation model to measured data at 900 MHz and 1800 MHz in urban and suburban environment. The empirical models dealt which are Hata, Cost-231 Hata, international Telecommunication Union (ITU-R), Ericsson and Stanford University Interm (SUI). Path loss accuracy of the fitting of the empirical models to the measured data is estimated using Root Mean Square (RMS) error.

Keywords
Path Loss Models, Propagation Measurement, GSM Network Planning, 900 MHz, 1800MHz

1. INTRODUCTION
It is of vital importance in network planning is the predication of path loss and hence the coverage area, frequency assignment and interference which are the main concern in mobile network planning. The available empirical formulae cannot be generalized to different environment (urban, suburban, ..etc), in general the suitability of these models differ for different environments. The data collected from measurements are compared with four empirical propagation models at 900 MHz and 1800 MHz in urban and suburban areas in Mosul city. The accuracy of path loss model is estimated by calculating the Root Mean Square (RMS) error between the measured and estimated path loss of the applicable empirical models.

2. PATH LOSS MODELS
Radio transmission in mobile communication system often takes place over irregular terrain. A number of propagation models are available to predict path loss over different types of terrain [1][2]. The models dealt with are applicable for GSM bands (900 MHz, 1800 MHz).

2.1 Hata Model
Hata Model [3][4] is an empirical formulation of graphical path loss data provided by Okumura model. The Hata model gives prediction of the median path loss. The standard formula for urban area is

$$P_{L(urban)}\,(dB) = 69.55+26.16 \log_{10}(f_c) - 13.82 \log_{10}(h_b) - a(h_m) + (44.9-6.55 \log_{10}(h_b)) \log_{10}(d) \quad \ldots (1)$$

Where fc is MHz and for frequency range of 150MHz to 1500 MHz, h_b is the BTS effective transmitter antenna height in meter ranging from 30m to 200m, h_m is the effective mobile receiver antenna height in meter ranging from 1m to 10m.

d is the distance between Base Station (Bs) and the Mobile Station (Ms) in Kilometers.
$a(h_m)$ is the correction factor for effective Ms antenna height which is a function of the size of the coverage area .

For a small to medium size city, the mobile antenna correction factor is given by :

$$a(h_m) = (1.1 \log_{10}(f_c) - 0.7)\, h_m - (1.56 \log_{10}(f_c) - 0.8) \quad \ldots (2)$$

To obtain the path loss in suburban area, equation (1) is modified to

$$P_{L(Suburban)}(dB) = PL_{(urban)} - 2 (\log_{10}(fc/28))^2 - 5.4 \quad \ldots (3)$$

The predication of Hata model compares very closely with the original Okumura model as long as d exceeds 1km. This model is suitable for large cell system, but not personal communication systems (PCS) which have cells of the 1km radius [2].

2.2 Cost-231 Hata Model
The European Cooperative for Scientific and Technical research (EURO-COST) formed the COST-231 working committee to develop an extended version of the Hata model. Cost-231 proposed path loss model is [5][6].

$$P_{L(urban)}\,(dB) = 46.3+33.9 \log_{10}(f_c) - 13.82 \log_{10}(h_b) - a(h_m) + (44.9-6.55 \log_{10}(h_b)) \log_{10}(d) + C_m \quad \ldots (4)$$

Where $a(h_m)$ is defined as.

$$a(h_m) = (1.1 \log_{10}(f_c) - 0.7)\, h_m - (1.56 \log_{10}(f_c) - 0.8)\ dB \quad \ldots (5)$$

$$\left.\begin{aligned} C_m &= 0 \text{ for median sized cities and suburban areas.} \\ &= 3dB \text{ for metropolitan areas} \end{aligned}\right\} \ldots 6)$$

The Cost-231 extension of the Hata model is restricted to the following range of parameters, f_c is 1500 MHz to 2000 MHz, h_b is 30m to 200m, h_m is 1m to 10m and d is 1km to 20km.

2.3 ITU-R Model
The ITU-R model is to be used for the outdoor to indoor and pedestrian (microcell) in urban and suburban environment [7][8]. The path loss is given as:

$$P_L(dB) = 40 \log d + 30 \log f_c + 49 \quad \ldots (7)$$

Where: d is the distance between the base station and the mobile unit in km, f_c is the frequency to 2000 MHz, L in no circumstances to be less than free space loss. The model is for Non-Line of Sight (NLOS) case only and describes worst condition deviation of 10dB for outdoor users.

2.4 ERICSSON Model

Model 9999 [9][10] is the Ericsson's implementation of Hata model. In this model parameter is possible according to propagation environment. The path loss P_L is given as:

$P_L(dB)= a_o+ a_1 \log (d)+ a_2 \log (h_b)+ a_3 \log(h_b) \log(d)- 3.2 (\log(11.75 h_m))^2 + g(f)$ …..(8)

Where g(f) is defined by :
$g(f)= 44.49 \log(f)- 4.78 (\log(f))^2$ …..(9)

The parameters a_o, a_1, a_2 and a_3 are constants, and can be change for better fitting specific propagation conditions. Default values are a_o = 36.2, a_1=30.2, a_2=-12, and a_3=0.4.

2.5 Stanford University Interm (SUI) Model

The Stanford University Interm (SUI) model [11][12] in developed under the institute of Electrical and Electronic Engineers (IEEE) 802.16 broad band wireless access working group. The model is an extension of the Hata model with correction parameters for frequencies above 1900 MHz. The SUI model can be used for base station antenna height of 10 meters to 80 meters, the mobile station antenna height between 2 meters to 8 km. The SUI model is divided into three types of terrain (environments) namely A, B and C. Type A is associated with maximum path loss and is appropriate for hilly terrain with moderate to heavy foliage densities, type C is associated with minimum path loss and densities. Type B is characterized with characterized with either mostly flat terrain with moderate to heavy tree densities or hilly terrain with light tree densities. The basic path loss equation is given by:

$$P_L (dB) = A+ 10\Upsilon \log_{10} (d/d_o) + X_f + X_h + S \quad …(10)$$

Where: d is the distance between the base station and the receiving antenna, d=100m, S is the lognormal distributed factor that is used to account for the shadow fading due to trees and other clutter and has a value between 8.2 dB and 10.6 dB. The remaining parameters are defined as:

$$A= 20\log_{10} (4\pi d_o/\lambda) \quad …(11)$$

$$\Upsilon = a- bh_b + c/h_b \quad ...(12)$$

Where the parameter h_b is the base station height above ground in meters and between 10m-80m. The constant used for a, b and c are given in table 1. The parameters Υ in equation (13) is the path loss exponent. For a given terrain type the path loss exponent is determined by h_b.

Table (1) SUI model numerical values for different terrain categories

Mode Parameters	Terrain A (hilly/moderate to heavy tree density)	Terrain B (hilly/light tree density of flat / moderate to heavy tree density)	Terrain C (flat/light tree density)
a	4.6	4.0	3.6
$b(m^{-1})$	0.0076	0.0065	0.005
c	12.6	17.1	20

The correction factor for the operation frequency for the receiver antenna height for the model is:

$$X_f = 6 \log_{10} (f/2000) \quad ….(13)$$

$$X_h = -10.8 \log_{10} (h_r/2000) \quad \text{for terrain type A and B} \quad ….(14)$$

$$X_h = -20.0 \log_{10} (h_r/2000) \quad \text{for terrain type C} \quad ….(15)$$

f is the frequency in MHz and h_r is the receiver antenna height above ground in m. The SUI model is used to predict the path loss in all three environments namely urban, suburban and rural. In the present paper SUI model B is chosen compling to the areas under study in Mosul city.

3. EXPERIMENTAL RESULTS

The measurements has been carried out in Mosul city areas at 900 MHz, different terrains are considered, Faysalya (Urban) and Wana (Suburban). Similarity at 1800 MHz, Industrial zone (Urban) and Sinjar (suburban). The base station transmitting sites specifications are shown in table 2.

Table (2) Specifications of Base Stations Sites

Site Name	Faysalya	Wana	Industrial zone	Sinjar
Antenna Gain	17 dB	17 dB	18 dB	18 dB
Antenna Height	22 m	58 m	35m	26 m
Antenna Downtilt	5.5^o	5.5^o	5.5^o	5.5^o
Frequency Band	900MHz	900 MHz	1800 MHz	1800MHz
Max Tx Power	47 dBm	47 dBm	45 dBm	45 dBm

3.1 Method of Measurements

Measurements of the received power have been executed using a special Sony Ericsson handset. The handset contains a software, memory and a Global Position System (GPS) chipset. When the received power measurement is required, the handset is activated and held by the user either pedestrian or in a car depending on the measurement required. The handset record the received power by time intervals defined by the user e.g five seconds. At each received power measurement, the distance separation from base station transmitter is also received by the GPS chipset in the handset. The information of the received power, distance, frequency and time of measurement is stored in the memory of the handset. After completing the measurement, the handset is then connected to a personal computer (PC) through a Universal Serial Bus (USB) port and the data stored in the memory of the handset is transfer to software in the PC. The Test Mobile System Measurement Unit (TEMS) is special software used for processing and analyzing the collected measurement and can display the measurements on maps stored inside it or download from Internet. To obtain the path loss, the received power is subtracted from the transmitted power of the base station which is known to the cellular operator.

3.2 Method of Simulation

In this paper the software used for the simulation of the received power is MATLAB v7.8, the program is written as mfile formed. The complete information of the areas under consideration are entered to the program and stored in the file, information such as transmitter antenna (base station) height, receiver antenna (mobile unit) height, terrain information, operating frequency, etc. When the simulation is run, the mobile starts to move on the same direction of the actual mobile measurements path. According to the path loss model used, the path loss of each location is calculated and stored in the program. Four path loss models are used in this study for the 900MHz frequency and the 1800MHz frequency, they are Hata model, Cost-231 Hata model, ITU-R model, Ericsson model and SUI model. For each model, the simulation is run for the two frequencies bands 900 MHz and 1800 MHz, and for each frequency, two types of terrain, urban and suburban are considered.

3.3 Root Mean Square Error (RMS Error)

An efficient method for estimating the accuracy of path loss model is the RMS error, which is the difference in dB between the measured path loss and estimated path loss [13][14][15].

$$\text{RMS Error (dB)}=\sqrt{\frac{1}{N}\sum_{i=1}^{N}(L_{mi}-L_{ei})^2} \quad \ldots(16)$$

Where:

L_{mi} is the measured path loss in dB, L_{ei} is the estimated path loss from the model in dB, and Nis the number of total data.

4. Results and Discussion

Figures 1 and 2 show the results of path loss estimation using the path loss models of Hata, ITU-R, Ericsson and SUI-TypeB for two different areas in Mosul city which are Faysalya (urban area) and Wana (suburban area) both measured results are estimated at 900 MHz frequency. Figures 3 and 4 show the at 1800 MHz, the areas are Industrial zone (urban) and Singar (suburban) using Cost-231 Hata model, ITU-R, Ericsson and SUI-TypeB. The mean square error of the four graphics is calculated using equation (16) and the results are in figures 3 and table 4.

Table (3) RMS Error for propagation models

Frequency (MHz)	Area	Models RMS Erorr (dB)			
		Hata	ITU-R	Ericsson	SUI
900 MHz	Faysalya (urban)	9.8	17.3	12.6	28
	Wana (suburban)	8.1	31	7.4	37.1

Table (4) RMS Error for propagation models

Frequency (MHz)	Area	Models RMS Erorr (dB)			
		Cost-Hata	ITU-R	Ericsson	SUI
1800 MHz	Industrial zone(urban)	12.1	21.1	15.4	27.1
	Sinjar (suburban)	17.9	17.9	19.3	25.1

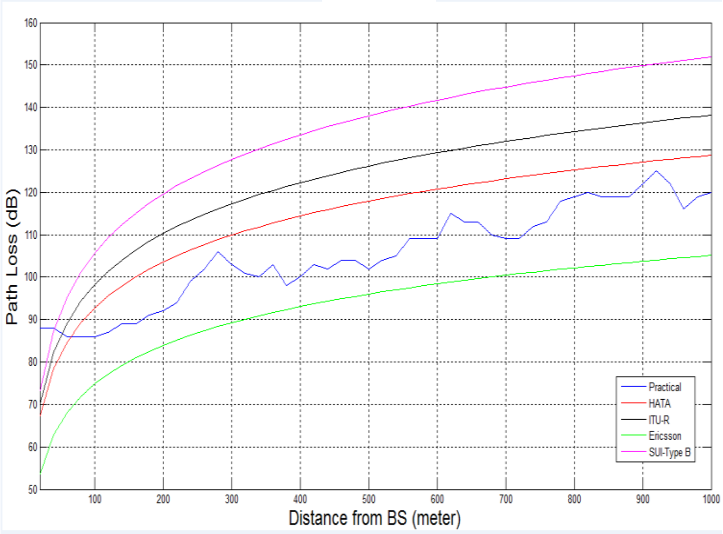
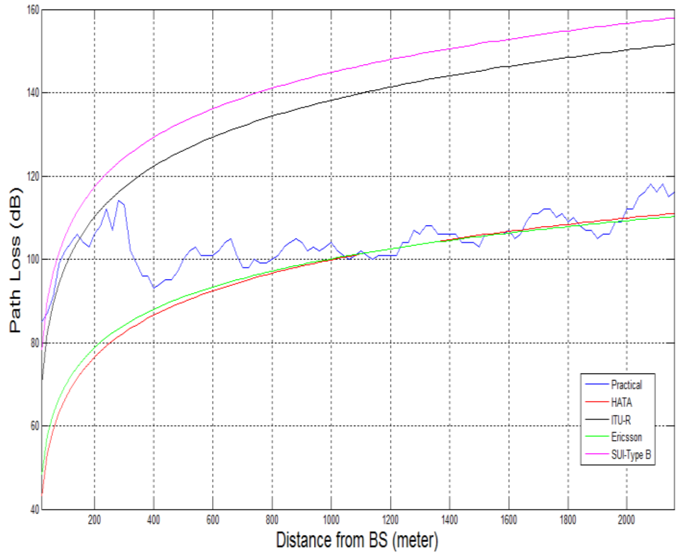
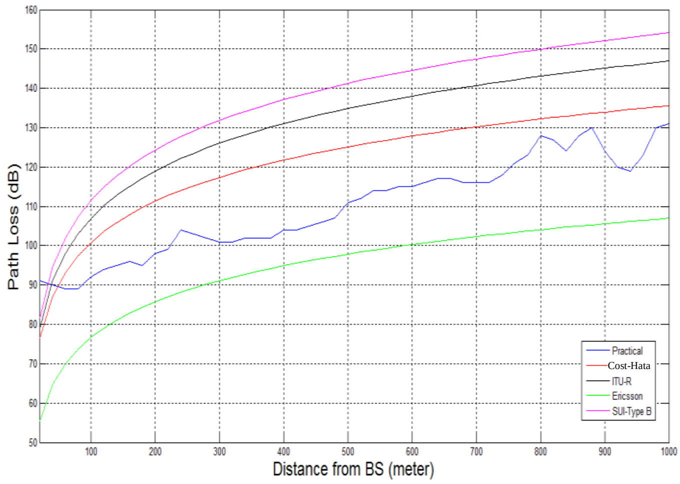


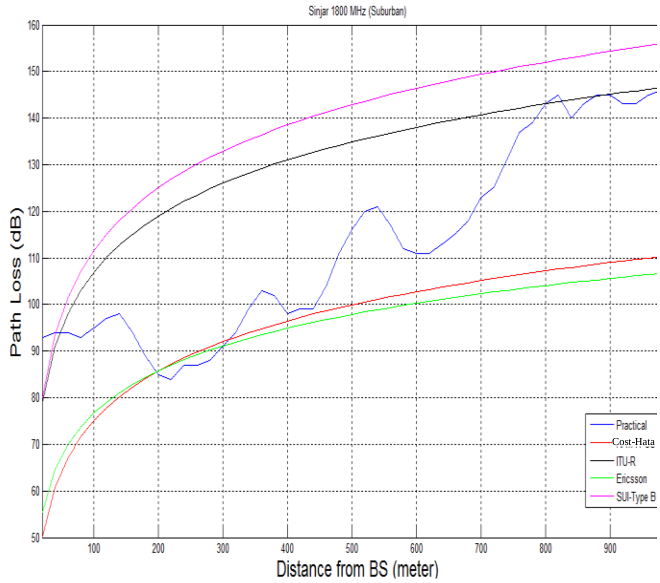
Figure (1): Faysala (urban) at 900MHz



Figure(2): Wana (Suburban) at 900 MHz



Figure(3): Industrial Zone (urban) at 1800MHz



Figure(4): Sinjar (Suburban) at 1800MHz

5. CONCLUSIONS

In this paper the applicable path loss models are compared with measured path loss for urban and suburban areas in Mosul city for two frequency bands of 900 MHz and 1800 MHz. At 900MHz frequency the best fit models for Faysalya (Urban) and Wana (Suburban) is first Hata model and the second is the Ericsson model. For 1800MHz frequency, the best fit for Industrial zone (Urban) and Sinjar (Suburban) area is the Cost-Hata model.

6. REFERENCES

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