Simulation and Performance Evaluation of Different Propagation model under Urban, Suburban and Rural Environments for mobile communication

[1]Vishal D. Nimavat, [2]Dr. G. R. Kulkarni

[1] Research Scholar, Singhania University, Rajasthan, India And Asst. Prof., V.V.P. Engg. College, Rajkot, Gujarat- India

[2] Principal, R.W.M.T's Dnyanshree Institute Of Engineering And Technology, (Vit Pune's Satara Campus), A/P : Sonawadi-Gajawadi, Sajjangad Road, Tal & Dist : Satara, 415013 (Maharashtra)

Abstract

Nowadays the Global System for Mobile Communication (originally from Groupe Special Mobile) –GSM technology becomes popular. GSM has potential success in its line-of-sight (LOS) and non line-of-sight (NLOS) conditions which operating in the 900 MHz or 1800/1900 MHz bands. There are going to be a surge all over the world for the deployment of GSM networks. Estimation of path loss is very important in initial deployment of wireless network and cell planning. Numerous path loss (PL) models (e.g. Okumura Model, Hata Model) are available to predict the propagation loss. If Path loss increases, then signal power decrease and also bit error rate increase. This paper compares and analyzes three path loss models namely COST 231 Hata model, Ericsson model and COST 231 Walfish-Ikegami model. AWGN channel is used for all simulations. These models are simulated with different frequencies, distance between transmitter and receiver, transmitter antenna and receiver antenna heights in urban, suburban and rural environments in Non Line of site (NLOS) condition. Our main concentration in this paper is to find out a suitable model for different environments to provide guidelines for cell planning of GSM Network.

Keywords: Okumura Model, Cost 231 Model, Cost 231 W-I Model, Ericsson Model, NLOS

1. Introduction

Nowadays people are enjoying wireless network access for telephony, radio and television services when they are in fixed, mobile or nomadic conditions. For user mobility: users communicate 'anytime, anywhere, with anyone', device portability: devices can be connected anytime, anywhere to the network and insure quality of service.

During the initial phase of network planning, propagation models are extensively used for conducting feasibility studies. There are numerous propagation models available to predict the path loss e.g. Okumura Model, Hata Model.

2. Considered PATH LOSS

In this paper we compare and analyze three path loss models (e.g. COST 231 Hata model, Ericsson model and COST 231 Walfish-Ikegami (W-I) model) which have been proposed in urban and suburban and rural environments for different frequencies distances, transmitter and receiver antenna heights.

By combining analytical and empirical methods the propagation models is derived. Propagation models are used for calculation of electromagnetic field strength for the purpose of wireless network planning during preliminary deployment. It describes the signal attenuation from transmitter to receiver antenna as a function of distance, carrier frequency, antenna heights and other significant parameters like terrain profile (e.g. urban, suburban and rural)

In all models, f is the carrier frequency in MHz , d is the distance between the transmitter GSM Cell BS and the receiver MS user in km, transmitter and receiver antenna height in m. Most of the models provide two different conditions i.e. LOS and NLOS. In our entire paper we concentrate on NLOS condition except in rural area, we consider LOS condition for COST 231 W-I model, because COST 231 W-I model did not provide any specific parameters for rural area.

Free Space Path Loss Model (FSPL)

Path loss in FSPL defines how much strength of the signal is lost during propagation from transmitter to receiver. FSPL is diverse on frequency and distance. The calculation is done by using the following equation [9]. The free space propagation model assumes the ideal propagation condition that there is only one clear line-of-sight path between the transmitter and receiver. H. T. Friis presented the following equation to calculate the received signal power in free space at distance d from the transmitter [1].

$$PLfs = 32.45 + 20 \log_{10}(d) + 20 \log_{10}(f) \text{ [dB]} \quad (1)$$

Where, d is in km and, f is in MHz

Okumura Model

Okumura's model is used to predict the path loss in suburban and rural environments.

$$PL = PLfs + Amn(f, d) – G(hb) – G(hm) – Garea \quad (2)$$

Where, PLfs is free space path loss, Amn(f,d) is the median attenuation relative to free space, Garea is the gain due to the type of environment, extracted as in [2][3].

$$G(hb) = 20 \log_{10}(hb/200) \quad \text{for } 10m < hb < \text{ Km} \quad (3)$$
$$G(hm) = 20 \log_{10}(hm/3) \quad \text{for } hb < 3Km \quad (4)$$
$$G(hm) = 10 \log_{10}(hm/3) \quad \text{for } 10m < hb < 1000m \quad (5)$$

Okumura carried out extensive drive test measurements with range of clutter type, frequency, and transmitter height, and transmitter power. It states that, the signal strength decreases at much greater rate with distance than that predicted by free space loss [4] [5] [6].

COST-231 Model

This model is derived by modifying the Hata model [4], and is used in urban, suburban and rural environments.

Scenario 1: Urban Cost-231 Path loss

$$PL = 46.3 + 33.9 \log_{10}(f) – 13.82 \log_{10}(hb) – 3.20 (\log_{10}(11.75\, hm))^2 – 4.79 + (44.9 – 6.55 \log_{10}(hb)) \log_{10}(d) + Cm \quad (6)$$

Scenario 2: Suburban & Rural Cost-231 Path loss

$$PL = 46.3 + 33.9 \log_{10}(f)\,(1.11 \log_{10}(f) - 0.7)\, hm – (1.5 \log_{10}(f) – 0.8) + (44.9 – 6.55 \log_{10}(hb)) \log10(d) + Cm \quad (7)$$

Where,

d: Distance between transmitter and receiver antenna in Km,
f : Frequency in MHz ,
hb : Transmitter antenna height in m,
hm: Receiver antenna height in m

The parameter cm has different values for different environments like 0 dB for suburban and 3 dB for urban areas.

Stanford University Interim (SUI) Model

IEEE 802.16 Broadband Wireless Access working group proposed the standards for the frequency band below 11 GHz containing the channel model developed by Stanford University, namely the SUI models [7].

The basic path loss expression of The SUI model with correction factors is presented as [7]:

$$PL = A + 10\,\gamma \log_{10}(d/do) + Xf + Xh + S \quad \text{for } d > do \quad (8)$$

The random variables are taken through a statistical procedure as the path loss exponent γ and the weak fading standard deviation S is defined. The log normally distributed factor S, for shadow fading because of trees and other clutter on a propagations path and its value is between 8.2 dB and 10.6 dB [7].
The parameter A is defined as:

$$A = 20 \log_{10}(4pido/\lambda) \quad (9)$$

and the path loss exponent

$$\gamma = a – b*hb + (c/hb) \quad (10)$$

Where, d0 is reference distant, 100m, the parameter hb is the base station height in meters. This is between 10 m and 80 m. The constants a, b, and c depend upon the types of terrain, that are given in Table I. The value of parameter $\gamma = 2$ for free space propagation in an urban area, $3 < \gamma < 5$ for urban NLOS environment, and $\gamma > 5$ for indoor propagation [8].

TABLE 1. THE PARAMETER VALUES OF DIFFERENT TERRAIN FOR SUI MODEL

Model	Terrain A	Terrain B	Terrain C
a	4.6	4.0	3.6
b(1/m)	0.0075	0.0065	0.005
c(m)	12.6	17.1	20

The frequency correction factor Xf and the correction for receiver antenna height Xh for the models are expressed in [3].

Xf = 6 log10 (f/2000) (11)

Xh = -10*8log10 (hr/2000) for terrain type A and B (12)

Xh = -20log10 (hr/2000) for terrain type C (13)

Where, f is the operating frequency in MHz, and hm is the receiver antenna height in meter. For the above correction factors this model is extensively used for the path loss prediction of all three types of terrain in rural, urban and suburban environments.

COST 231 Walfish-Ikegami (W-I) Model

This model is a combination of J. Walfish and F. Ikegami model. The COST 231 project further developed this model. Now it is known as a COST 231 Walfish-Ikegami (W-I) model. This model is most suitable for flat suburban and urban areas that have uniform building height .The equation of the proposed model are expressed in [9].

for LOS (line of sight) condition

$PLlos = 42.6 + 26 \log_{10}(d) + 20 \log_{10}(f)$ (14)

for NLOS (non- line of sight) condition

PLnlos=Lfsl+ Lrts + Lmsd for urban and suburban (15)

PLnlos= Lfs if Lrts + Lmsd > 0 (16)

Where,
Lfsl = Free space loss,
Lrts = Roof top to street diffraction,
Lmsd = Multi –screen diffraction free space loss [9];

Lfsl = 32.45 + 20log(d) +20log(f) (17)

Roof top to street diffraction [9];

for hroof > h mobile

$Lrts = -16.9 - 10 \log_{10}(w) + 10 \log_{10}(f) + 20 \log_{10} * (hmobile) + Lori$ (18)

Lrts =0 (19)

Where,

Lori = $10 + 0.354\varphi$ for $0 <= \varphi < 35$ (20)
= $2.5 + 0.075(\varphi-35)$ for $35 <= \varphi < = 55$ (21)
= $4-0.114(\varphi -55)\ \varphi$ for $55 <= \varphi <= 90$ (22)

Ericsson Model

To predict the path loss, the network planning engineers are used a software provided by Ericsson company is called Ericsson model. This model also stands on the modified Okumura-Hata model to allow room for changing in parameters according to the propagation environment. Path loss according to this model is given by [8].

$PL = ao + a1 * \log_{10}(d) + a2 * \log_{10}(hb) + a3 * \log_{10}(hb) \log_{10}(d) - 3.2(\log_{10}(11.75*hr)\ 2) + g(f)$ (23)

$G(f) = 44.49 \log_{10}(f) - 4.78(\log_{10}(f))$ (24)

The value of parameter a0, a1, a2 and a3 are given in Table II.

TABLE 2. VALUES OF PARAMETERS FOR ERICSSON MODEL

Environment	a0	a1	a2	a3
Urban	36.2	30.2	12.0	0.1
Suburban	43.20*	68.93*	12.0	0.1
Rural	45.95*	100.6*	12.0	0.1

*The value of parameter a0 and a1 in suburban and rural area are based on the Least Square (LS) method.

3. Simulation of Models

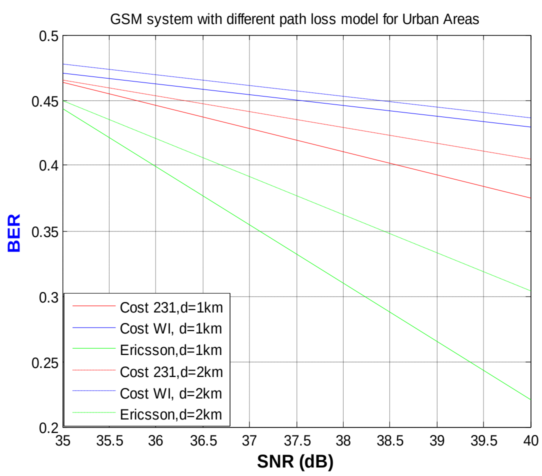
Detailed comparisons of the proposed models were obtained for four cases where in each case three parameters are fixed and one particular parameter has two values.

In our computation, we are operating frequencies at 1500, 1800 and 1900MHz, distance between transmitter antenna and receiver antenna is 1 km, transmitter antenna height is 30 m and transmitter antenna height is 5m in urban, suburban area and rural area. We considered 2 different distances between transmitter antenna and receiver antenna 1km and 2km, 2 different frequency 1500MHz and 1900MHz, 2 transmitter antenna height 30m and 40m, 2 receiver antenna height 2m and 9m for path loss with AWGN. We fixed 15 m average building height and building to building distance is 50 m and street width is 25 m. Most of the models provide two different conditions i.e. LOS and NLOS. In our entire thesis we concentrate on NLOS condition except in rural area, we consider LOS condition for COST 231 W-I model, because COST 231 W-I model did not provide any specific parameters for rural area. The following presents the parameters we applied in our simulation. Base station transmitter power 43 dBm, Mobile transmitter power 30 dBm, building to building height 50m, average building distance 15m , street width 25m, street orientation angle 30º in urban and 40º in suburban.

Path loss for the Cost 231 Hata, COST 231 Walfish-Ikegami (W-I) and Ericsson models were plotted for two different distances, frequencies, transmitter and receiver antenna heights. Model is simulated using changing SNR values and at the same time path loss is kept fixed. While changing the SNR it is observed that BER also changed. This indicates changing height of transmitting antenna.

(A) PATH LOSS (SNR) VS BER IN URBAN AREA

In our calculation, we set frequency 1900MHz, transmitter antenna height is 40m, receiver antenna height is 5m and plotted for different distances are 1km and 2km in propagation model with AWGN channel.



Figureure.1 SNR VS BER in urban environment at 1km and 2km distance.

In our calculation, we set distance is 1km, transmitter antenna height is 40m, receiver antenna height is 5m and plotted for different frequencies are 1500MHz and 1900MHz in propagation model with AWGN channel.

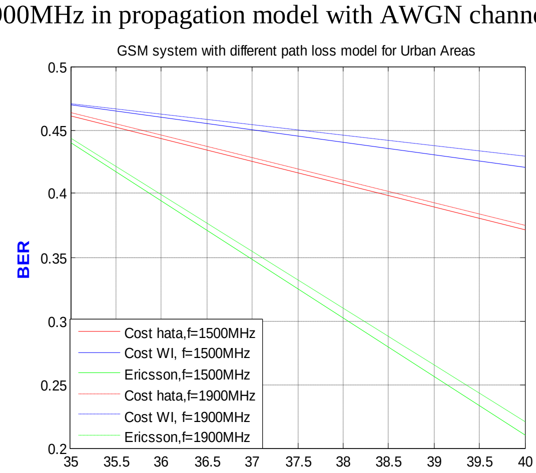


Figure.2 SNR VS BER in urban environment at 1500MHz and 1900MHz frequency.

In our calculation, we set frequencies 1800MHz , distance is 1km, receiver antenna height is 5m and plotted for different , transmitter antenna height are 30m and 50m in propagation model with AWGN channel.

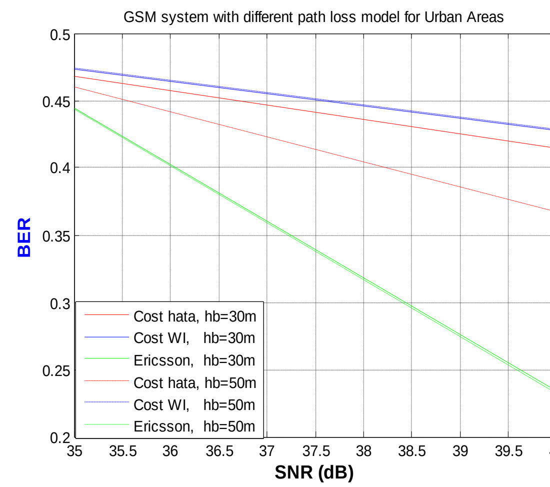


Figure.3 SNR VS BER in urban environment at 30m and 50m Transmitter antenna height

In our calculation, we set frequencies 1800 MHz , distance is 1km, transmitter antenna height is 30m and plotted for different receiver antenna height is 2m and 9m in propagation model with AWGN channel.

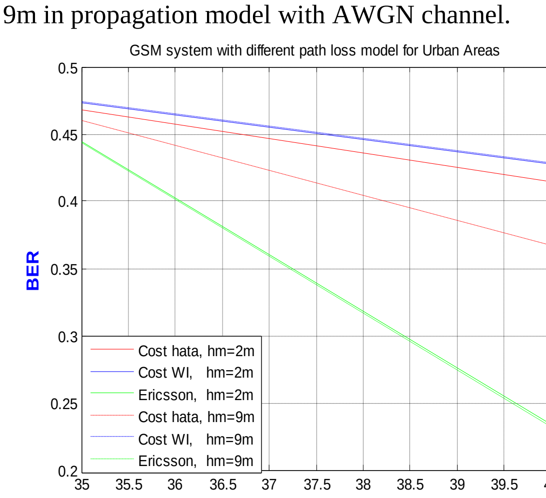


Figure.4 SNR VS BER in urban environment at 2m and 9m Receiver antenna height.

(B) PATH LOSS (SNR) VS BER IN URBAN AREA SUBURBAN AREA

In our calculation, we set frequency 1900MHz, transmitter antenna height is 40m, receiver antenna height is 5m and plotted for different distances are 1km and 2km in propagation model with AWGN channel.

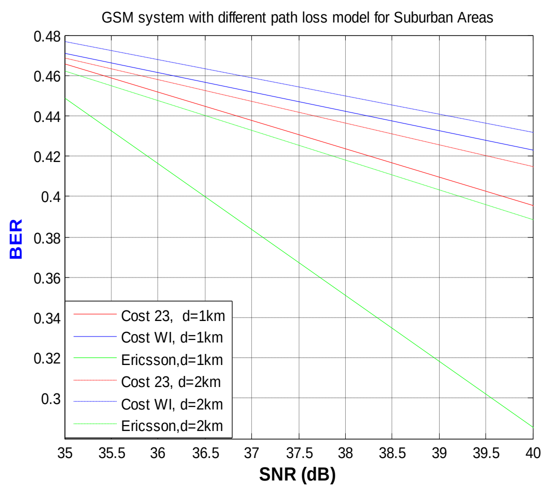


Figure.5 SNR VS BER in suburban environment at 1km and 2km distance.

In our calculation, we set distance 1km, transmitter antenna height is 40m, receiver antenna height is 5m and plotted for different frequencies are 1500MHz and 1900MHz in propagation model with AWGN channel.

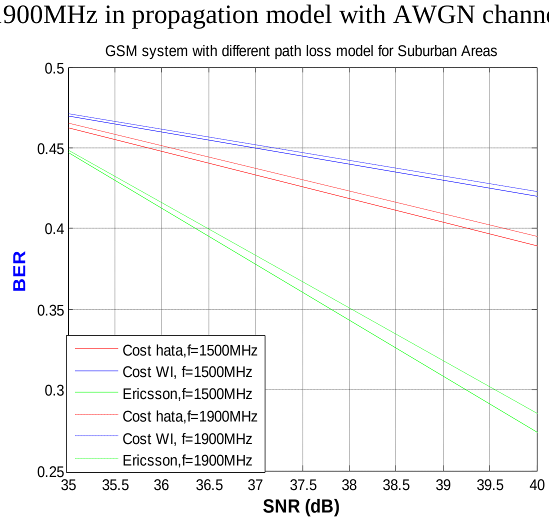


Figure.6 SNR VS BER in suburban environment at 1500MHz and 1900MHz frequency.

In our calculation, we set frequencies 1800MHz , distance is 1km, receiver antenna height is 5m and plotted for different , transmitter antenna height are 30m and 50m in propagation model with AWGN channel.

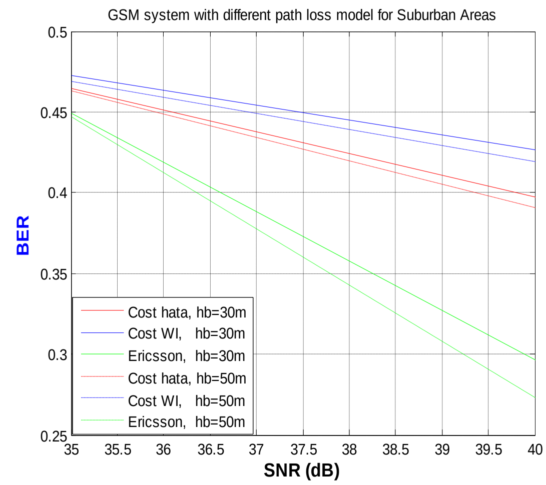


Figure.7 SNR VS BER in suburban environment at 30m and 50m Transmitter antenna height

In our calculation, we set frequencies 1800MHz, distance is 1km, transmitter antenna height is 30m and plotted for different receiver antenna height is 2m and 9m in propagation model with AWGN channel.

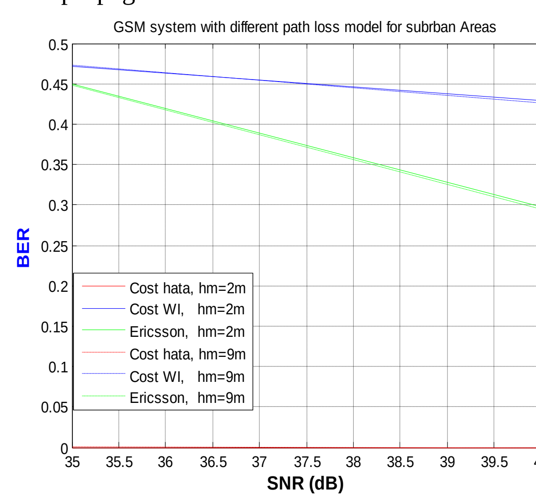


Figure. 8 SNR VS BER in suburban environment at 2m and 9m Receiver antenna height.

(C) PATH LOSS (SNR) VS BER IN URBAN AREA IN RURAL AREA

In our calculation, we set frequency is 1900MHz, transmitter antenna height is 40m, receiver antenna height is 5m and plotted for different distances are 1km and 2km in propagation model with AWGN channel.

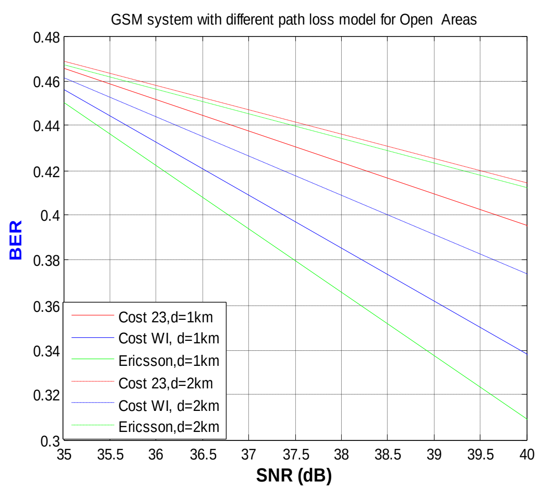


Figure. 9 SNR VS BER in suburban environment at 1km and 2km distance.

In our calculation, we set distance is 1km, transmitter antenna height is 40m, receiver antenna height is 5m and plotted for different frequencies are 1500MHz and 1900MHz in propagation model with AWGN channel.

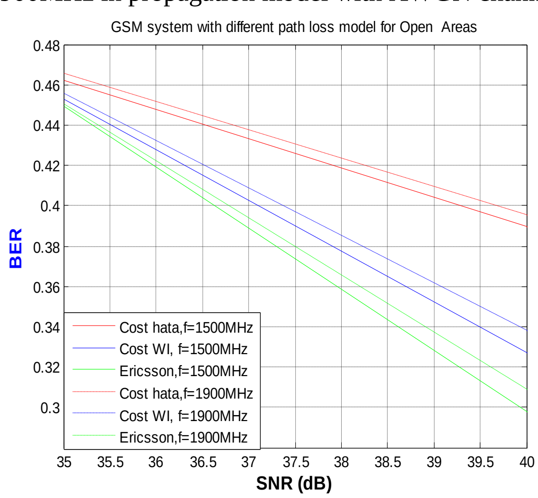


Figure.10 SNR VS BER in rural environment at 1500MHz and 1900MHz frequency.

In our calculation, we set frequencies 1800MHz, distance is 1km, receiver antenna height is 5m and plotted for different transmitter antenna height are 30m and 50m in propagation model with AWGN channel.

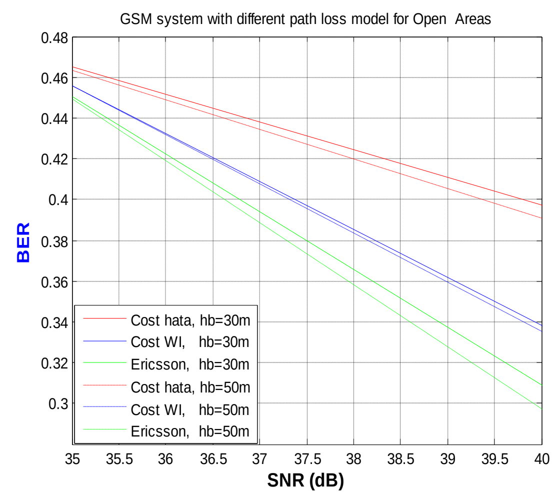


Figure.11 SNR VS BER in rural environment at 30m and 50m Transmitter antenna height

In our calculation, we set frequencies 1800MHz , distance is 1km, transmitter antenna height is 30m and plotted for different receiver antenna height is 2m and 9m in propagation model with AWGN channel.

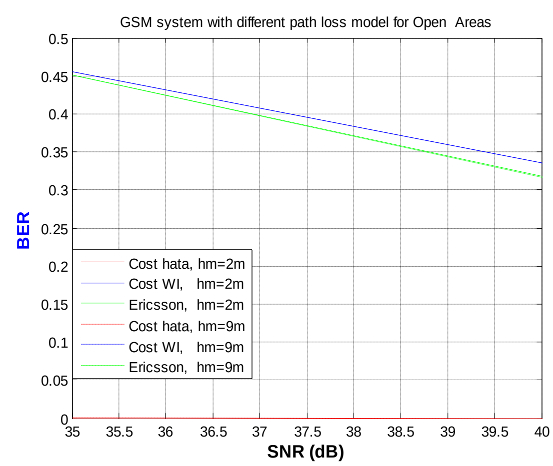


Figure.12 SNR VS BER in rural environment at 2m and 9m Receiver antenna height

4. Conclusions

It is observed that BER is sensitive to changing values of SNR. When earlier mentioned parameters' values changed the SNR is changed which directly reflected to changing values of BER.

In all Environments, if distance and frequency are increases then Path loss increases, then signal power decrease and also bit error rate increase and if transmitter and receiver antenna heights are increases then Path loss decreases, then signal power increase and also bit error rate decrease.

Our comparative analysis indicate that due to multipath and NLOS environment in urban area, all models experiences higher path losses compare to suburban and rural areas. Moreover, we did not find any single model that can be recommended for all environments.

5. References

[1] Ibrahim Khider Eltahir "The Impact of Different Radio Propagation Models for Mobile Ad hoc Networks (MANET) in Urban Area Environment" The 2nd International Conference on Wireless Broadband and Ultra Wideband Communications (Aus Wireless 2007).

[2] Y.Okumura, "Field strength variability in VHF and UHF land mobile services," Rev. Elec. Comm. Lab. Vol. 16, pp. 825-873, Sept-Oct 1968.

[3]T.S Rappaport, Wireless Communications: Principles and Practice, 2nd edition, New Delhi, Prentice Hall, pp. 151-152, 2005.

[4] S. R. Saundrs M. Hata, "Empirical Formula for Propagation Loss in Land Mobile Radio Services", IEEE Transactions on Vehicular Technolog Conference Proceedings, Vol. VT 29,August 1980.

[5] A. Medeisis and A. Kajackas, " On the useof the Use of the Universal Okumura-Hata Propagation Predication Model in Rural Areas" Vehicular Technolog Conference Proceedings, VTC Tokyo, Vol.3, pp.1815-1818, May 2000.

[6] R. D. Wilson and R. A. Scholtz, Comparison of CDMA and Modulation Schemes for UWB Radio in a Multipath Environment, Proceedings of IEEE Global Telecommunications Conference, Vol. 2, pp. 754-758, Dec 2003 .

[7] V.S. Abhayawardhana, I.J. Wassel, D. Crosby, M.P. Sellers, M.G. Brown, "Comparison of empirical propagation path loss models for fixed wireless access systems*," 61th IEEE Technology Conference,* Stockholm, pp. 73-77, 2005.

[8]Josip Milanovic, Rimac-Drlje S, Bejuk K, "Comparison of propagation model accuracy for WiMAX on 3.5GHz," 14th IEEE International conference on electronic circuits and systems, Morocco, pp. 111-114. 2007.

[9] V. Erceg, K.V. S. Hari, M.S. Smith, D.S. Baum, K.P. Sheikh, C. Tappenden, J. M. Costa, C. Bushue, A. Sarajedini R. Schwartz, D. Branlund, T. Kaitz, D. Trinkwon, "Channel Models for Fixed Wireless Applications," IEEE 802.16 Broadband Wireless Access Working Group, 2001.