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Received Signal Strength (RSS) Calculation for GSM Cellular System at BSNL Pondicherry using Modified HATA Model

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***Abstract*— Radio propagation profoundly site specific and varies considerably based on speed of mobile terminal, frequency of operation and the parameters like Antenna height, Antenna gain, Transmitted power, Path loss, other losses and Receiver sensitivity. The received signal strength depends on the path loss and the parameters of the transmitter and receiver. Quality of call establishment is based on received signal strength. Signal strength varies based on the environment and the intermediate losses. In this paper a modified HATA propagation model suggested for path loss calculation for different environment. The real time received signal strength at BSNL Pondicherry is compared with the received signal strength calculated using HATA and modified HATA model for different environment.**

***Index Terms*— Global system for Mobile Communication (GSM), path loss, link budget, coverage area, Base Transceiver Station (BTS), Mobile Station (MS).**

I. Introduction

The implementation of a wireless communication telephony system needs a proper planning and designing of a system. Such designing needs a link budget calculation for proper call establishment. There are two well known mobile technologies namely Global System for Mobile Communication (GSM) and Code Division Multiple Access (CDMA). Here link budget calculation for GSM system with different key parameters is discussed. The key parameters are Antenna height, Antenna Gain, Transmitted power, losses and Receiver sensitivity. Link budget is calculated with various key parameters for the proper call establishment. A communication system is said to be a successful system when a call is established properly and effectively.

Global System for Mobile Communications, originally *Groupe Spécial Mobile*, is a standard set developed by the European Telecommunications Standards Institute (ETSI) to describe protocols for second generation (2G) digital cellular networks used by mobile phones.

The GSM standard was developed as a replacement for first generation (1G) analog cellular networks, and originally described a digital, circuit switched network optimized for full duplex voice telephony. This was expanded over time to include data communications, first by circuit switched transport, then packet data transport via General Packet Radio Services (GPRS) and Enhanced Data rates for GSM Evolution (EDGE) or EGPRS.

Further improvements were made when the 3GPP developed third generation (3G) UMTS standards followed by fourth generation (4G) LTE Advanced standards.

The GSM architecture consists of Mobile Station (MS), Base Transceiver System (BTS), Base Switching Centre (BSC), Mobile Switching Centre (MSC), Gateway Mobile Switching Centre (GMSC) and Public Switched Telecommunication Network (PSTN). When a signal is initiated or transmitted from a mobile station, it is received by the BTS and sent to the BSC. The combination of BTS and BSC is called as Base Sub System (BSS). BSC sends it to the MSC. MSC makes switching between two BTS. GMSC is for making a call from the MS to the landline phones.

The MSC block consists of Home Locator Register (HLR) contains the permanent database of the users. VLR Visitor Locator Register (VLR) contains the temporary information and also the permanent user's database that are all using the network.

During the transmission of the signal, propagation loss occurs. Propagation models are used to find the path loss and the received signal strength. Propagation is also very much useful in predicting the signal coverage area.

Chapter II deals with propagation models HATA and modified HATA for cellular mobile communication. Chapter III contains the link budget calculation for GSM cellular communication system. Chapter IV deals with the calculation of the path loss for uplink and downlink. Chapter V discusses the performance analysis of cellular GSM system at BSNL Pondicherry for different environments using HATA and modified HATA models. Chapter VI concludes the paper.

II. Propagation Models

Coverage area is an area of extent to which the radiated signal is covered. A cellular network is a radio network distributed over land areas called cells, each served by at least one fixed-location transceiver known as a cell site or base station. These cells joined together provide radio coverage over a large geographic area. This radio networks makes large number of portable transceivers like mobile phones to communicate with each other [9, 10].

The cell coverage depends on the environment and it differs according to the environment. The environments are Urban, Sub-urban and Rural. The three main mechanisms

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which are the causes for the reduction in the cell coverage are reflection, diffraction and scattering [1].

Reflection: It occurs when the electromagnetic wave strikes against a smooth surface, whose dimensions are large compared with the signal wavelength.

Diffraction: It occurs when the electromagnetic wave strikes a surface whose dimensions are larger than the signal wavelength, new secondary waves are generated.

Scattering: It happens when a radio wave strikes against a rough surface whose dimensions are equal to or smaller than the signal wavelength.

There are two ways in which radio planners can use propagation models. They can use their own model or they can use the existing standard models. The empirical models uses Existing equations obtained from results of several measurement efforts. Some of the path loss models are as follows. HATA Model Cost 231 model, HATA Okumura Model, ECC 33 Model and Walfisch-Bertoni Model [3-7].

The above path loss models are used to find the coverage distance. Each path loss model has empirical formula for each environment. In this paper, we have discussed HATA and Cost 231 models.

A. HATA model

The path loss is the unwanted reduction in the signal strength during the propagation of the transmitted signal from the transmitter to the receiver. It is the loss present in the signal during the propagation from the base station to the mobile station and from the mobile station to the base station. The strength of the signal reduces due to the various parameters like antenna height, antenna gain, transmitted power, received signal strength and losses.

HATA model is the most widely used radio frequency propagation model for predicting the behaviour of cellular transmission. HATA Model predicts the total path loss along a link of terrestrial microwave or other type of cellular communications. This model has three different path loss models for different environments namely urban, sub-urban and rural. This model is suited for both point-to-point and broadcast transmissions and it is based on extensive empirical measurements taken.

The path loss formula for urban environment is given as follows.

$$\mathrm{PL(U)} = 69.55 + 26.16\log(\mathrm{f}) - 13.82\log\mathrm{h(t)} - \mathrm{a}(\mathrm{h(r)}) + \left(44.9 - 6.55\log\mathrm{h(t)}\right)\log(\mathrm{d})$$

Where,

PL is the path loss,
f is the frequency of operation,
h (t) is the height of the transmitter,
a (h(r)) is the HATA correction factor,
d is the coverage distance

The path loss formula for Sub-urban environment is

$$\mathrm{PL(SU)} = \mathrm{PL(U)} - 2[\log_{10}(\frac{\mathrm{f}}{28})]^2 - 5.4$$

The path loss formula for rural environment is

$$\mathrm{PL(R)} = \mathrm{PL(U)} - 4.78[\log_{10}(\mathrm{f})]^2 + 18.33\log_{10}(\mathrm{f}) - \mathrm{K}$$

where K ranges from 35.94 (countryside) to 40.94 (desert).

The correction factor a(h(r)) is given for small to medium cities and for large cities. Correction factor for small to medium cities is given by

$$\mathrm{a}(\mathrm{h(r)}) = (1.1\log_{10}(\mathrm{f}) - 0.7)\mathrm{h(r)} - (1.56\log_{10}(\mathrm{f}) - 0.8)$$

Correction factor for larger cities is given by

$$\mathrm{a}(\mathrm{h(r)}) = 3.2(\log_{10}(11.75.\mathrm{h(r)}))^2 - 4.97$$

B. Modified HATA model

The actual HATA path loss model is not suitable for the present environment. So the HATA model is modified as follows for each environment.

For urban environment,

$$\mathrm{PL(U)} = 69.55 + 26.16\log(\mathrm{f}) - 13.82\log\mathrm{h(t)} - \mathrm{ahr} + 44.9 - 6.55\log\mathrm{ht}\log(\mathrm{d}) + \mathrm{Cm(U)}$$

For sub-urban environment,

$$\mathrm{PL(SU)} = \mathrm{PL(U)} - 2[\log_{10}(\mathrm{f}/28)]^2 - 5.4$$

For rural environment,

$$\mathrm{PL(R)} = \mathrm{PL(U)} - 4.78[\log_{10}(\mathrm{f})]^2 + 18.33\log_{10}(\mathrm{f}) - \mathrm{Cm(R)}$$

where Cm (U) is the correction factor for urban environment and taken as 12. Cm (R) is the correction factor for rural environment and taken as 29.

III. LINK BUDGET CALCULATION

Link budget is the analysis or reporting of all losses and gains from the transmitter through the medium to the receiver. It is necessary to calculate link budget in the complete design of mobile communication system for proper call establishment. The link budget includes the following key parameters such as Antenna height, Antenna gains, Path loss, Transmitted power and Receiver sensitivity [8].

In order to formulate a link budget equation, it is required to look into all the areas where gains and losses may occur between the transmitter and the receiver. The calculation of the basic link budget is very easy.

Received power (dBm) = Transmitted power (dBm) + gains (dbm) - losses (dBm)

In basic calculation of link budget equation it is assumed that the power spreads out equally in all directions from the transmitter source. The indirect meaning is that the antenna used is an isotropic source, radiating equally in all directions. This is good for theoretical calculations, But not for practical calculations. A typical link budget equation for a radio communications system may look like the following:

$$\mathrm{Prx} = \mathrm{Ptx} - \mathrm{Gtx} + \mathrm{Grx} - \mathrm{Ltx} - \mathrm{Lfs} - \mathrm{Lfm} - \mathrm{Lrx}$$

Where

Prx= received power (dBm)
Ptx= transmitter output power (dBm)
Gtx = transmitter antenna gain (dBi)
Grx= receiver antenna gain (dBi)
Ltx = transmitter feeder and connector losses (dB)
LFS = free space loss or path loss (dB)
LFM = many-sided signal propagation losses (dB)
LRX = receiver feeder connector losses (dB)

The objective of power budget calculation is to balance the uplink and down link. The receiver sensitivity may be different because the mobile station and the base station transceiver have different Radio frequency architecture.

If downlink is greater than the uplink it results in range of BTS is greater than the range of MS. Coverage area is smaller than the predicted area. This condition is most frequent. If Uplink is greater than the downlink it results in range of MS is greater than the range of BTS. No coverage problem from MS to BTS.

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IV. Path Loss Calculation

Link budget calculation involves both uplink and downlink calculation. In uplink, the signal transmission is from MS to the BTS. Here MS acts as a transmitter and the BTS acts as receiver. In downlink, the signal transmission is from the BTS to the MS. Here BTS acts as a transmitter and the MS acts as a receiver. The allowable path loss calculated for uplink is 150.6 dB and downlink is 157.6 dB as per Table 3and 4 respectively. The coverage area calculated for different environment using HATA and modified HATA model.

C. Uplink Budget

EIRP (Effective Isotropic Radiated Power) is the actually radiated power which is obtained by adding the antenna gain and subtracting the losses from the transmitted power. At the transmitter system EIRP is a function of transmit power, the feeder loss and transmit antenna gain.

$$P_{EIRP} = f\,(P_{TX}, a_{Feeder}, G_{TX})$$

Table.1. Uplink Transmitter Parameters

Transmitter (MS)	Value
Transmitter Power of MS (PTx)	33dBm
Antenna Gain (G(ms))	0dB
Connector loss or Feeder Loss (L(f))	0dB
Body Loss	3dB
MS Antenna Height	1.5m

$$\mathrm{EIRP} = \mathrm{Ptx} + \mathrm{G(ms)} - \mathrm{BL} = 30\mathrm{dBm}$$

Table.2. Uplink Receiver Parameter

Receiver (BTS)	Value
Receiver Sensitivity (Rs)	-114dBm
BTS Antenna Gain (G(bts))	17dBi
Cable Loss	0.4dB
Connector Loss	3dB
Interference Margin	2dB
Fading Margin	5dB

$$\mathrm{PL} = \mathrm{EIRP} + \mathrm{Rs} - \mathrm{Im} - \mathrm{Fm} - \mathrm{L(f)} + \mathrm{G(bts)} = 150.6\ \mathrm{dB}$$

D. Downlink Budget

Table.3. Downlink Transmitter Parameter

Transmitter (BTS)	Value
BTS Antenna Gain (G(bts))	17dBi
Output Power of BTS (Pt)	43dBm
Combiner Loss (Lc)	3dB
Cable Loss	0.4dB
Connector Loss (L(f))	3dB

Table.4. Downlink Receiver Parameter

Receiver (MS)	Value
MS Sensitivity (Rs)	-103dBm
Body Loss (BL)	3dB
MS Antenna Gain (G(ms))	0dBi
Interference Margin (Im)	2dB
Fast Fade Margin (Fm)	5dB
Connector Loss (Lc)	0dB

$$\mathrm{EIRP} = \mathrm{Pt} - \mathrm{L\,(f)} - \mathrm{Lc} + \mathrm{G\,(bts)} = 53.6\ \mathrm{dbm}$$

$$\mathrm{PL} = \mathrm{EIRP} + \mathrm{Rs} - \mathrm{BL} - \mathrm{Im} - \mathrm{Fm} - \mathrm{Lc} + \mathrm{G\,(ms)} = 157.6\ \mathrm{dB}$$

V. Performance Analysis

The Table.5 shows the specification of the BTS in each environment such as urban environment (J.N Street), sub-urban environment (Villiyanoor) and rural environment (Bahoor) in Pondicherry BSNL service.

Table.5. Downlink Receiver Parameter

Parameter	Urban	Sub-Urban	Rural
Antenna height	20m	35m	40m
Antenna gain	17dBi	17dBi	17dBi
Transmitted power	43dBm	43dBm	43dBm
Body loss	3dB	3dB	3dB
Interference margin	2dB	2dB	2dB
Fading margin	5dB	5dB	5dB
Connector loss	3dB	3dB	3dB
Cable loss	0.4dB	0.7dB	0.8dB
Combiner loss	3dB	3dB	3dB
Receiver sensitivity	-114dBm	-114dBm	-114dBm

E. Urban environment

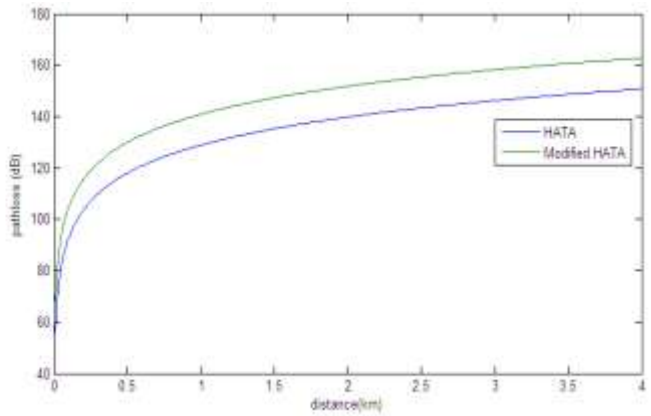

Fig.1. Path Loss at J.N.Street (Urban).

Fig.1.shows the Path loss for the urban environment which is calculated from the Table.5 parameters by the HATA and modified HATA path loss models.

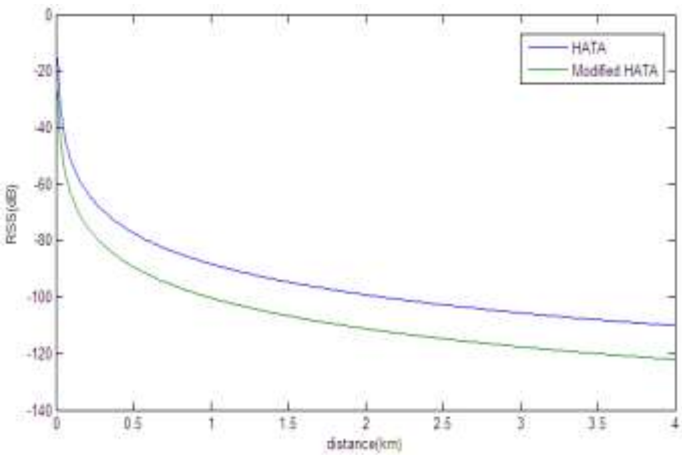

Fig.2. RSS at J.N.Street (Urban)

Fig.2.shows the received signal strength for the urban environment which is calculated from the Table.5 parameters by the HATA and modified HATA path loss models.

Table.6. Downlink Receiver Parameter

Distance	Towards	RSS	HATA	Modified HATA
50m	Hotel Atithi	-58	-40.92	-52.92
75m	Hotel Atithi	-65	-48.35	-59.33
100m	Hotel Atithi	-68	-51.87	-63.87
150m	Hotel Atithi	-74	-58.28	-70.28
50m	Beach	-55	-40.92	-52.92
100m	Beach	-64	-51.87	-63.87
150m	Beach	-69	-58.28	-70.28
200m	Beach	-74	-62.83	-74.83
50m	Railway Station	-55	-40.92	-52.92
100m	Railway Station	-63	-51.87	-63.87
150m	Railway Station	-70	-58.28	-70.28
200m	Railway Station	-72	-62.83	-74.83
50m	JOY Alukkas	-52	-40.92	-52.92
75m	JOY Alukkas	-55	-48.35	-59.33
100m	JOY Alukkas	-60	-51.87	-63.87
125m	JOY Alukkas	-65	-56.02	-67.4

The Table.6 shows the comparison between the real time RSS values and the predicted RSS values by HATA and modified HATA models in urban environment which is taken at J.N.Street in Pondicherry.

F. Sub-urban environment

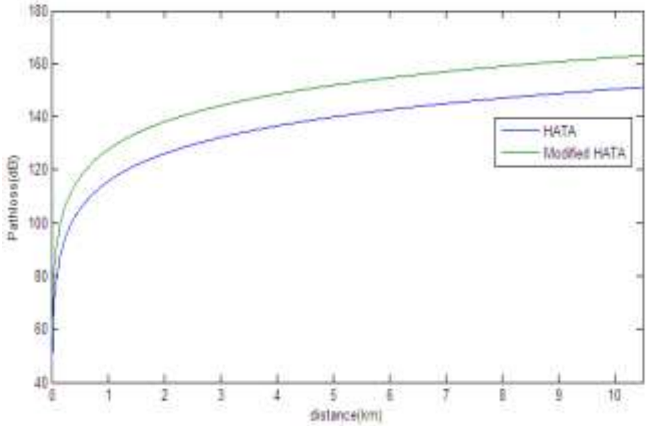

Fig.3 Path Loss at Villiyanoor (Sub-Urban)

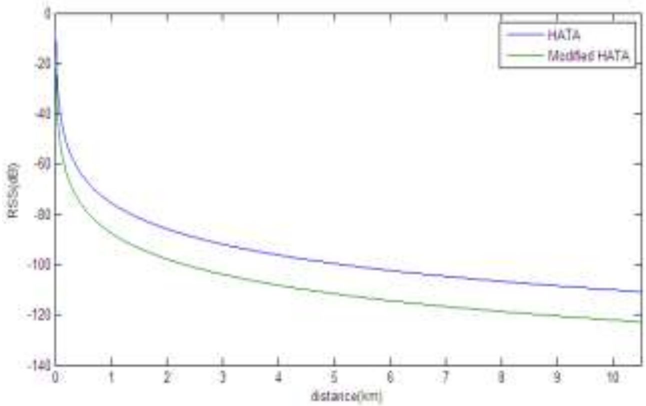

Fig.4 RSS at villiyanoor (Sub-Urban)

Fig.3.and Fig.4 shows the Path loss and received signal strength for the sub-urban environment which is calculated from the Table.5 parameters by the HATA and modified HATA path loss models.

Table.7. Downlink Receiver Parameter

Distance	Towards	RSS	HATA	Modified HATA
100m	Pondicherry	-52	-45.87	-52.47
300m	Pondicherry	-61	-62.46	-69.06
400m	Pondicherry	-72	-66.81	-73.41
600m	Pondicherry	-79	-72.93	-79.53
50m	Kombakkam	-50	-35.39	-41.99
150m	Kombakkam	-58	-51.99	-58.59
300m	Kombakkam	-64	-62.46	-69.06
400m	Kombakkam	-73	-66.81	-73.41
100m	Uruvaivar	-55	-45.87	-52.47
200m	Uruvaivar	-68	-56.34	-62.94
300m	Uruvaivar	-76	-62.46	-69.46
500m	Uruvaivar	-80	-70.18	-76.78
150m	Kandamangalam	-56	-51.99	-58.59
300m	Kandamangalam	-65	-62.46	-69.06
400m	Kandamangalam	-70	-66.81	-73.41
500m	Kandamangalam	-74	-70.81	-76.78

The Table.7 shows the comparison between the real time RSS values and the predicted RSS values by HATA and modified HATA models in sub-urban environment which is taken at villiyanoor in Pondicherry.

G. Rural environment

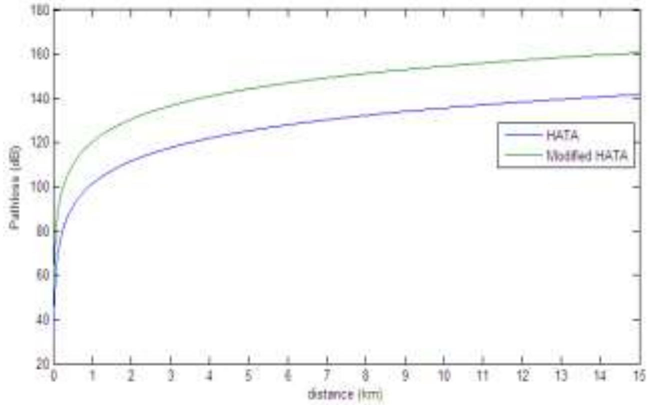

Fig.5 Path loss at Bahoor (Rural)

Fig.5 and Fig.6 shows the Path loss and received signal strength for the rural environment which is calculated from the Table.5 parameters by the HATA and modified HATA path loss models.

The Table.8 shows the comparison between the real time RSS values and the predicted RSS values by HATA and modified HATA models in rural environment which is taken at Bahoor in Pondicherry.

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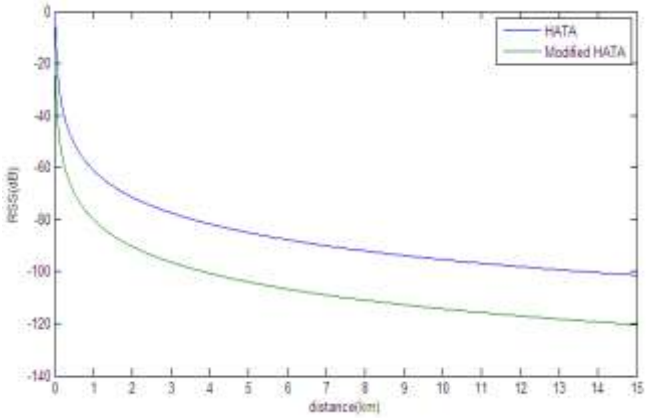

Fig.6 RSS at Bahoor (Rural)

Table.8. Downlink Receiver Parameter

Distance	Towards	RSS	HATA	Modified HATA
100m	Karikalampakkam	-55	-26.58	-45.52
400m	Karikalampakkam	-67	-47.3	-66.23
750m	Karikalampakkam	-72	-56.69	-75.63
1000m	Karikalampakkam	-78	-60.99	-79.93
200m	Pondicherry	-57	-36.94	-55.88
350m	Pondicherry	-64	-45.3	-64.24
500m	Pondicherry	-71	-50.63	-69.57
750m	Pondicherry	-76	-56.69	-75.63
100m	Cuddalore	-55	-26.58	-45.52
400m	Cuddalore	-68	-47.3	-66.23
600m	Cuddalore	-70	-53.35	-72.29
850m	Cuddalore	-76	-58.56	-77.5
150m	Kuruvinatham	-52	-32.64	-51.58
300m	Kuruvinatham	-59	-43	-61.94
500m	Kuruvinatham	-66	-50.63	-69.57
700m	Kuruvinatham	-71	-55.66	-74.6

VI. CONCLUSION

In this paper a modified HATA propagation model is proposed for path loss calculation has taken on the GSM cellular system at BSNL Pondicherry. There are three different environments such as urban, sub-urban and rural area in Pondicherry were chosen and the path losses are calculated through the BTS specification of each environment using two propagation models such as HATA and modified HATA. The real time received signal strength value is compared with the received signal strength value calculated using HATA and modified HATA models. The comparison Table 6, 7 and 8 shows the RSS value calculated by the proposed modified HATA propagation model is more appropriate to calculate the path loss for different environments in GSM cellular communication at BSNL Pondicherry.

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