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ELECTRICAL AND COMPUTER ENGINEERING DEPARTMENT

Development of Large Scale Path Loss Model for 3rd Generation Networks: The Case of Eastern Addis Ababa

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A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Masters of Science in Electrical Engineering

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By: Ephrem Berhane

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Declaration

I, the undersigned, declare that this MSc thesis is my original work, has not been presented for fulfillment of a degree in this or any other university, and all sources and materials used for the thesis have been acknowledged.

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This thesis work has been submitted for examination with my approval as a university advisor.

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Abstract

The design of efficient cellular system requires a detail understanding of propagation characteristics of mobile channel. A signal propagation through a channel undergo two kind of variations; large scale and small scale path loss. This thesis focuses on large scale propagation model for Eastern Addis Ababa of Ethio telecom. The results are evaluated based on different parameters such as coverage radius, antenna height, and E_b/N_o. And network planning, operation, maintenance and upgrade depend on radio channel environment and property. Radio propagation parameters that affect the receive signal level on radio links are analyze the best path loss model for prediction of the receive signal level is determine. This thesis work on the most commonly used path loss models among others, for 3G based cellular systems in Eastern Addis Ababa. It collected two types of data, static and dynamic data. From the static data it get eNodeB and mobile station height in meter and operating frequency in mega Hertz that is 2100 Mhz. And using this data it modeled Hata and COST 231 empirical model. And from drive test it collected dynamics data, distance from transmitter to receiver and receive signal strength in dBm. And from this data it get path loss exponent, reference path loss, standard deviation and MSE for the four eNodeB and its average that are located in Eastern Addis Ababa. Several electronic equipment are used for the measurement for RSS such as Samsung S5 mobile that are installed Nemo software , Global positioning System((BU353 GPS) and Laptop that are installed Actix software and data export to Excel program. The selected sites are Bole Homes, Bole Intentional Stadium, Summit Beverage and Summit Savory. The path loss exponent for the above four Eastern Addis Ababa place are **2.87, 5.38, 4.55** and **2.58** respectively .And standard deviation was evaluated as **6.24**dB, **4.78**dB, **6.11**dB and **7.58**dB respectively. And path loss model was developed as 'P_L **=114.5 + 45.5 log (d/d_o)**' for Summit Beverage. For Bole International Stadium the path loss model are 'P_L**=95.9+53.8log (d/d_o)**'. For Bole Homes modeling and Summit Savory 'P_L**=116.5+28.7 log (d/d_o)**' and 'P_L**=109.17+25.8 log (d/d_o)**'respectively. And MATLAB R2015a was used for simulation.

Keywords: Path Loss Model, Receive Signal Strength, Path Loss Exponent, Standard Deviation, Hata Model, COST -231 Models, Drive Test.

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Contents

Abbreviations

3G	Third generation
BICC	Bearer Independent Call Control
BMC	Broadcast and Multicast
BS	Base Station
CGW	Charging Gateway
CN	Core Network
CRNC	Controlling RNC
DRNC	Drifting RNC
FPLMTS	Future Public Land Mobile Telecommunication System
GGSN	Gateway GPRS SUPPORT Node
GMSP	Gateway MSC
GSM	Global System for mobile
ISUP	ISDN User Part
ITU	International Telecommunication Union
MGCP	Median Gateway Control Protocol
MGW	Median Gateway
MMS	Multimedia Messaging Service
MS	Mobile Station
MSC	Mobile Switching Center
NBAP	Node B Application Part
O & M	Operation and Maintenance
PDCP	Packet Data Control Protocol
PDN	Packet Data Network
PSTN	Public Switching Telephone Network
RAB	Radio Access Bearers
RANAP	RAN Application Part
RANAP	Radio Access Network Application Part
RNC	Radio Network Controller
RNS	Radio Network Subsystem
RRM	Radio Resource Management
RRS	Radio Resource Control
SGSN	GPRS Support Node
SRNC	Serving RNC
UE	User Equipment
UMTS	Universal Mobile Telecommunication system
URA	UTRAN Registration Area
UTRAN	UMTS terrestrial access Network

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CHAPTER ONE

1.1 Introduction

The mobile radio channel places fundamental limitations on the performance of wireless communication systems. The transmission path between the transmitter and the receiver can vary from simple line-of-sight to one that is severely obstructed by buildings, mountains, and foliage. Unlike wired channels that are stationary and predictable, radio channels extremely random and do not offer easy analysis. Even the speed of motion impacts how rapidly the signal level fades as a mobile terminal moves in space. Modeling the radio channel has historically been one of the most difficult parts of mobile radio system design, and is typically done in a statistical fashion, based on measurements made specifically for an intended communication system or spectrum allocation [1].

Exponential growth of mobile communications has increased interest in many topics in radio propagation. Much effort is now devoted to refine radio propagation path-loss models for urban, suburban, and other environments together with substantiation by field data. Radio propagation in urban areas is quite complex because it often consists of reflected and diffracted waves produced by multipath propagation. Radio propagation in open areas free from obstacles is the simplest to treat, but, in general, propagation over the earth and the water invokes at least one reflected wave [1].

It is no-longer novel that environmental factors such as buildings, trees, rain, snow, dust, fog and vapors has significant influence on the integrity of wireless transmitted signals. It is also worth noting that these signal-limiting factors which are found in the communication channels between the transmitting and receiving antennas, degrade the radiated signals through reflecting back some of the radiated signals into the initial medium, diffracting some of the signals, scattering some and also causing the medium to absorb some signals [2]. Hence, the efficiency of any wireless communication system is said to be essentially dependent on the propagation features of the system channel which has a great influence on the design of the propagation structure. Radio propagation models are a set mathematical formulations developed for the characterization of radio waves in a propagation environment as a function of frequency of transmission, distance and other conditions that influence the behavior of the radio channel [3]. The models constitute a basic part in the design for wireless communication systems. The propagation models predict the received signal strength at a given distance from the transmitter, including the variability strength of the signal within a specific location. It is useful in predicting the signal coverage of a transmitter for any transmitter-receiver distance of separation. Also, it is valuable in predicting signal attenuation or path loss whose knowledge serves as a controlling factor for system analysis and performance and aids in system optimization of the signal coverage.

Signal propagation models are used extensively in network planning, particularly for conducting feasibility studies and performing initial system development [1]. The planning of cellular networks requires an understanding of basic concepts concerning the use of Radio signals. The path traveled by the signal from one point to another through or along a medium is called propagation [2]. In cellular networks, a signal is propagated to and from a base station. When a signal is transmitted through space, it gets weaker with the distance traveled, resulting in the received power being significantly less than the original transmitted power. This phenomenon is referred to as propagation loss. The propagation path between the transmitter and the receiver may vary from simple line-of-sight (LOS) to very complex one due to diffraction, reflecting and scattering, [3]. To estimate the performance of wireless channels, propagation models [4] are often used. The radio wave propagation or path loss models, the properties of the base station and the properties of the mobile station are required to calculate the radio coverage for a chosen base station. Path loss models represent a set of mathematical equations and algorithms which are applied for radio signal propagation prediction in certain environments. Path loss models describe the signal attenuation between a transmitting and a receiving antenna as a function of the propagation distance and other parameters which provide details of the terrain profile required to estimate the attenuating signal. This thesis appraises a collection of path loss models through a comparative survey and simulates for each classification a generic case in Eastern Addis Ababa city [3].

1.2 Statement of the problem

Most empirical propagation models used to predict the propagation of radio signal in a place does not always correctly predict the radio signal fading. The traditional empirical models for predicting path-loss in a place are rigidly compare to some measure data, and the one with least error (deviations) preferred. It is possible to reduce the error margin by training some model to adapt to the measure data of a place over different network standards. This thesis aims to train large scale path loss model that can adapt to the traffic changes of an urban/rural city and path-losses due to the environment into already existing empirical path-loss propagation models. It is a common knowledge that the UMTS (3G) network has been well deploy in Addis Ababa. Due to the availability of several path loss models, it is therefore necessary to ascertain which of the most commonly use ones could be programmed for 3G networks. The problem statement for this thesis can therefore be expresses as follows [12]:

(i) Which of the path loss models is best for 3G Networks Eastern Addis Ababa?

(ii) What limitations exist in these models?

(iii) How can these models be generically adapted?

(iv) How these models develop from existing data using path loss exponent, reference path loss and standard deviation[12]?

1.3 Motivation

The existence of poor signal strength and path loss – due to the reduction of power density of an electromagnetic wave as it passes through multi-path propagation environment, has been a major challenge over the years in the use of radio mobile communications and this effect is greatly seen in cities with high population density such as Addis Ababa City [5]. This path loss may be due to many effects, such as free space loss, diffraction, reflection, aperture-medium coupling loss and absorption. Other times congestion of buildings also does obstruct greatly signal strength across board and this has hindered effective communication in the affected areas over the years. Due to the differences in city structures, local terrain profiles, weather etc., the path loss prediction with reference to the existing empirical path loss models such as the Okumura's model, Hata's model etc., may differ from the actual one. Furthermore, network planning and optimization has become complicated and difficult as high numbers of base stations are involved in a network with significant co channel interference.

The network operators may face huge losses resulting from complaints from the network users due to improper link budget calculations and path loss predictions. Thus, Base Station transmitters should be sited with through considerations on the effect of the location of other Base Stations on the signal strength, precise path loss calculations and using appropriate propagation models [5].

1.4 Objective of the Study

This thesis aims to achieve the following general and specific objectives.

1.4.1 General Objective

The general objective of the thesis that aims at studying wireless communication signal propagation path-loss prediction models using large scale path loss modeling will be present.

1.4.2 Specific Objectives

- To evaluate the signal environment using Drive test.
- To determine the path loss and standard deviation for the proposed model.
- To study different propagation models and their parameters.
- Assess the important of model for good planning and optimization.
- To predict antenna radius of coverage.
- To compare the empirical model such as Hata and COST 231 model with measure and proposed model.

1.5 Literature Review

So far many researches have been conducted on large scale path loss modeling and 3^{rd} generation network. Short literature surveys of some selected papers are reviewed here.

In December 2012, Singh Yuvraj: proposed "Comparison of Okumura, Hata and Cost-231 Models on the Basis of Path Loss and Signal Strength", in order to choose the accurate radio propagation model which is essential for emerging technologies with appropriate design, deployment and management strategies for any wireless network; and he focuses on large-scale path loss model. He compares the above mentioned models based on path loss and signal strength by applying empirical result. After that, he concludes Okumura model has the least path loss and high signal strength in contrast to the other. Besides, relatively Cost-231 model has largest path loss and weak signal strength [11].

In January 2010, Moses Effiong Ekpenyong : "On Propagation Path Loss Models For 3-G Based Wireless Networks: A Comparative Analysis" explain that This paper studies comparatively, the most commonly used path loss models among others, for UMTS based cellular systems, with the goal of reporting through computer simulation, the most reliable one, suitable for efficient coverage planning. We experiment these path loss models using empirical data for macro-cellular (urban) environments. We observe that the Lee path loss model has an improved coverage performance compared to the COST-231 and ECC-33 path loss models respectively. The simulator could generically be adapted for other propagation environments [12].

In December 2016,Nwaokoro A.A.: proposed "Signal Strength Evaluation of a 3G Network in Owerri Metropolis Using Path Loss Propagation Model at 2.1GHz" the study focused on investigative analysis of the effects of propagation environment on the wireless communication signals within some geographical domains in Port Harcourt, River State, Nigeria. Field measurements were carried out in some selected areas namely GRA phase II and Aggrey Road categorized as urban and sub-urban areas respectively using Sony Ericsson (W995) Test Phone and GPS receiver (BU353). The analyses were based on linear regression (mean square error) approach. The results obtained were used to compare the performance of the various existing path loss prediction models such as Okumura-Hata, Cost 231 and ECC-33. From their observations, Okumura-Hata model showed better performance in urban environment while Cost 231 performed better in rural environment. Hence they recommended the deployment of optimized Okumura-Hata model in urban, while Cost 231for sub-urban areas [14].

1.6 Methodologies

The methodologies include the following things:

- ✓ **Literature review**: includes reading books, journal, articles, simulation tools and other resources related to the topic.
- ✓ **System modeling**: Involves the existing system Cost-231 and HATA model for a better path loss prediction result of 3G network.
- ✓ **Simulation:** Simulating the proposed (measured), Cost-231 and HATA model using MATLAB R2015a.
- ✓ **Analysis and Interpretation of the results**: Finally, the results obtained from the simulation results analyzed and compared based on performance analysis criteria's.

Computation of COST 231 extension of HATA Model for Eastern Addis Ababa urban: Computation of Path loss from existing models:

- ➢ Computation of path loss exponent for Addis Ababa using linear regression method.
- ➢ The path loss exponent for urban region is given in Computation of the Reference Path Loss for Addis Ababa urban.
- ➢ Computation of the Standard Deviation for Easter Addis Ababa urban.
- ➢ Standard deviation of the distribution will evaluate using the mean square error method. The sum of the mean square error is as represent in equation.

1.7 Scope

This thesis is a case study and its aim to develop a large-scale path loss model for Eastern Addis Ababa. The performance analyses in this thesis work will be based on simulation of the propose solutions using MATLAB and developing different type of modeling, calculating path loss exponent and standard deviation for this specify area.

1.8 Contribution

The contribution of this study can be drawn as follows:

- ➢ Several thesis done under this title in nationally and internationally but this study helps to ascertain the actual antenna height, link distance that will ensure optimum signal propagation. Hence the waste of device and cost is minimizing.
- ➢ The thesis use as document for each base station for maintains and upgrades the system.

1.9 Thesis Layout

The work of this thesis is organized in to seven Chapters. Chapter one presents the introduction, methods and objectives of this thesis work. In Chapter two, we are going to see some theoretical parts of radio wave propagation, small-scale path loss and large-scale path loss models have been described in Chapter three. Then in the fourth Chapter we will see the principle of 3^{rd} generation mobile network. Chapter five contains modeling, analysis of different parameters, Simulation results and discussions in chapter six. Finally, the last Chapter contains conclusions and recommendations for future works. At the appendix it written MATLAB simulation code.

CHAPTER TWO

2. Fading Channel Model

2.1 Introduction

Radio-wave propagation through wireless channels is a complicated phenomenon characterized by various effects, such as multipath and shadowing. A precise mathematical description of this phenomenon is either unknown or too complex for tractable communications systems analyses. However, considerable efforts have been devoted to the statistical modeling and characterization of these different effects. The result is a range of relatively simple and accurate statistical models for fading channels which depend on the particular propagation environment and the underlying communication scenario [1][2].

The wireless radio channel poses a severe challenge as a medium for reliable high-speed communication. It is not only susceptible to noise, interference, and other channel impediments, but these impediments change over time in unpredictable ways due to user movement [3].In this thesis part it presents different fading channel concept. In section 2.2 it include Wireless channel such as path loss, multipath and shadowing. Fading channel model such as Doppler effect, flat, frequency selectivity, fast and slow fading discussed in section 2.3. At the last Gaussian, Rayleigh and Rician channel discusses.

2.2 wireless channels

The term channel refers to the medium between the transmitting antenna and the receiving antenna as shown in Figure 2.1.The characteristics of wireless signal changes as it travels from the transmitter antenna to the receiver antenna. These characteristics depend upon the distance between the two antennas, the path taken by the signal, and the environment (buildings and other objects) around the path. The profile of received signal can be obtained from that of the transmitted signal if we have a model of the medium between the two. This model of the medium is called channel model [4].

In general, the power profile of the received signal can be obtained by convolving the power profile of the transmitted signal with the impulse response of the channel. Convolution in time domain is equivalent to multiplication in the frequency domain [4].

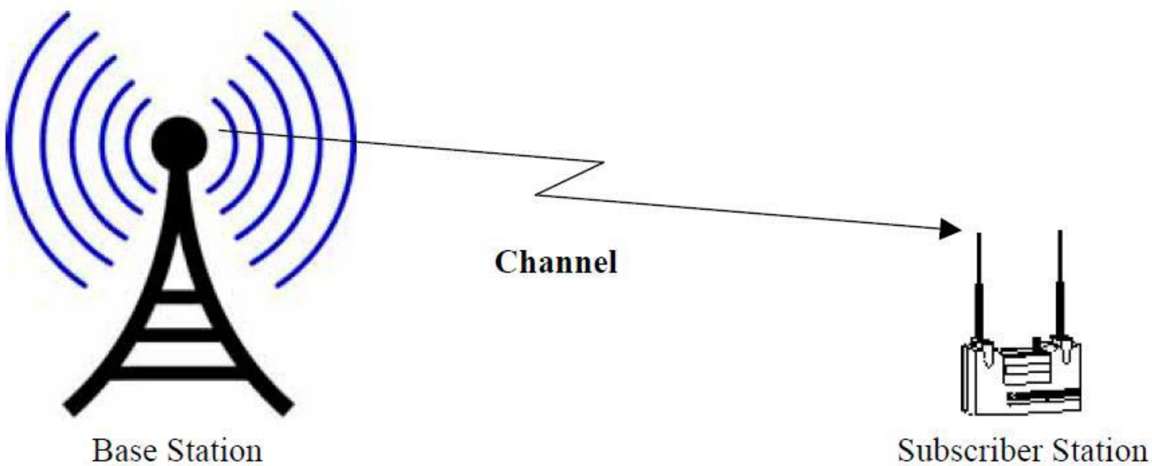


Figure 2.1: wireless Channel [4]

2.2.1 Path Loss

When there are no obstacles around or between the base station (BS) and mobile station (MS), the propagation path characteristics are subject to free space propagation. In this case, the path loss is given by

$$L_{pf}(\text{dB}) = 32.44 + 20\log f_c + 20\log d \qquad (2.1)$$

f_c = carrier frequency (megahertz);

d = distance between BS and MS (kilometers);

L_{pf} = path loss in decibels.

On the other hand, when there are many obstacles around or between the BS and MS, path loss is determined by many factors, such as irregular configuration of the natural terrain and irregularly arranged artificial structures [5]. Since mobile station far from base station the signal attenuate because of noise and interference, this situation is path loss.

Environment	Path Loss Exponent , n
Free Space	2
Urban area cellular radio	2.7 to 3.5
Shadowed urban cellular radio	3 to 5
In building line-of-sight	1.6 to 1.8
Obstructed in building	4 to 6
Obstructed in factories	2 to 3

Table 2.1: Path Loss Exponents for Different Environments [1].

2.2.2 Multipath

As the receiver moves, the received signal is not only the signal that was transmitted by the transmitter, but a combination of signals received at that point from different paths through reflecting and diffraction. The effect of the differential time delays of these will be to introduce relative phase shift between component waves, and superposition of these waves can lead to either constructive or destructive [5]. This situation may create Inter Symbol Interference (ISI) so it needs some mitigation technique to correct the distorted signal, such as channel equalizer.

2.2.3 Shadowing

Shadowing refers to variations in received signal strength due to specific geometries of the paths between the transmitter and receiver and is effected by such objects as trees, hills. If there are any objects (such buildings or trees) along the path of the signal, some part of the transmitted signal is lost through absorption, reflection, scattering, and diffraction. This effect is called shadowing. As shown in Figure 2.2, if the base antenna were a light source, the middle building would cast a shadow on the subscriber antenna. Hence, the name shadowing [5].

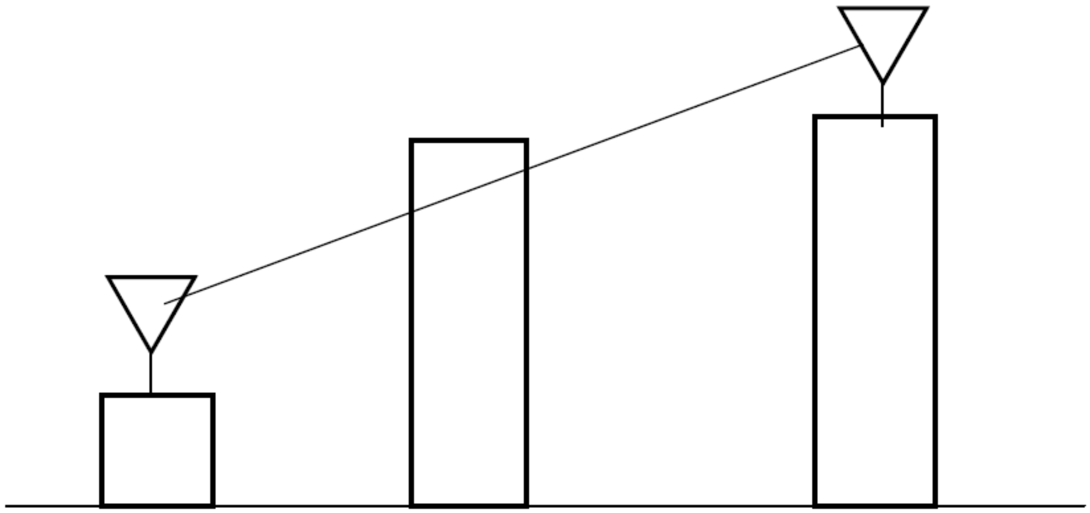


Figure 2.2: Shadowing [4]

2.3 Fading Channel Models

In principle the following are the main multipath effect:

1. Rapid change in signal strength over a small travel distance or time interval.
2. Random frequency modulation due to varying Doppler shifts on different multipath signal.
3. Time dispersion or echoes caused by multipath propagation delays.
4. Channel and signal bandwidth.

2.3.1 Multipath Propagation

The presence of reflecting objects and scattering in the channel creates a constantly changing environment that dissipates the signal energy in amplitude, phase, and time. These effects result in multiple versions of the transmitted signal that arrive at the receiving antenna, displaced with respect to one another in time and spatial orientation. The random phase and amplitudes of the different multipath components cause fluctuations in signal strength, thereby inducing small-scale fading, signal distortion, or both. Multipath propagation on lengthens the time required for the baseband portion of the signal to reach the receiver which can cause signal smearing due to inter symbol interference [1].

Multipath fading is due to the constructive and destructive combination of randomly delayed, reflected, scattered, and diffracted signal components. This type of fading is relatively fast and is therefore responsible for the short-term signal variations. Depending on the nature of the radio propagation environment, there are different models describing the statistical behavior of the multipath fading envelope [2].

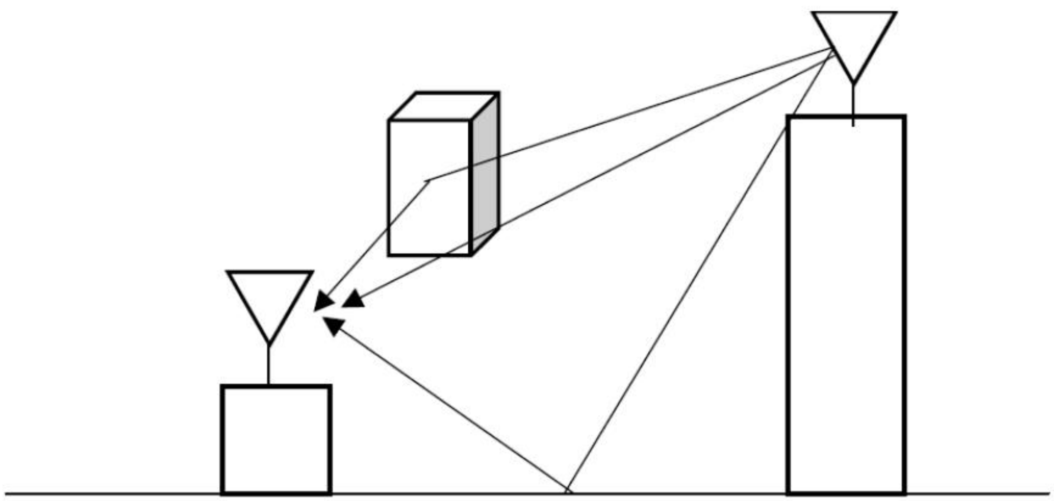


Figure 2.3: Multipath [4]

2.3.2 Doppler Shift

The relative motion between the base station and the mobile results in random frequency modulation due to different Doppler shifts on each of the multipath components. Doppler shift will be positive or negative depending on whether the mobile receiver is moving toward or away from the base station [1].Receive frequency not always equal to the carrier frequency. If mobile station move toward base station the receive frequency is equal to the carrier frequency plus Doppler frequency. And when mobile station move away to base station the receive frequency is carrier frequency minus Doppler frequency and the receive frequency depend on the direction of mobile station and the direction of signal.

$$\Delta\Phi = \frac{2\pi\Delta l}{\lambda} = \frac{2\pi v \Delta t}{\lambda}\cos\theta \tag{2.2}$$

$$f_d = \frac{1}{2\pi} \cdot \frac{\Delta\Phi}{\Delta t} = \frac{v}{\lambda}\cos\theta \tag{2.3}$$

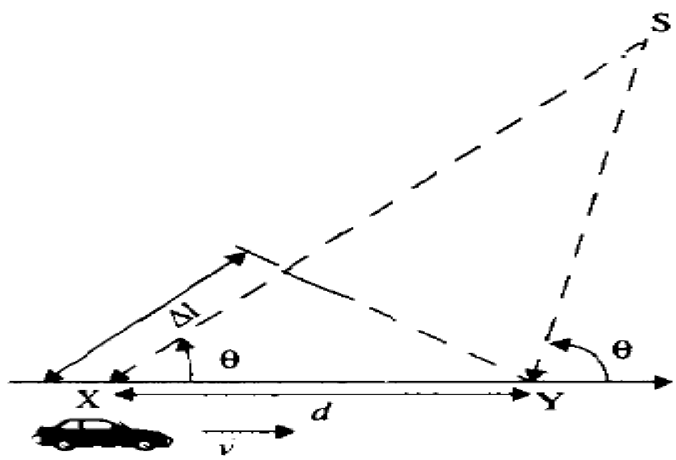


Figure 2.4: Illustration of Doppler effects [1]

2.3.3 Fading Effect Due To Multipath Time Delay Spread

2.3.3.1 Flat Fading

Such type of fading occurs when the bandwidth of the transmitted signal is less than the coherence bandwidth of the channel. Equivalently if the symbol period of the signal is more than the rms delay spread of channel, then the fading is flat fading.

So we can say that fading occurs when

$$B_S << B_C \quad (2.4)$$

Where B_S is the signal bandwidth and B_C is the coherence bandwidth. Also

$$T_S >> \sigma_\tau \quad (2.5)$$

Where T_S the symbol period and σ_τ is the rms delay spread. And in such case mobile channel has a constant gain and linear phase response over its bandwidth [1][4][15].

2.3.3.2 Frequency Selective Fading

Frequency selective fading occurs when the signal bandwidth is more than the coherence bandwidth of mobile radio channel or equivalently the symbols duration of the signal is less than rms delay spread

$$B_S >> B_C \quad (2.6)$$

And

$$T_S << \sigma_\tau \quad (2.7)$$

At the receiver, we obtain multiple copies of the transmitted signal, all attenuated and delayed in time.[1][4][15].

2.3.4 Fading Effects due to Doppler Spread

2.3.4.1 Fast Fading

In a fast fading channel, the channel impulse response change rapidly within the symbol duration of the signal. Due to Doppler spreading signal under goes frequency dispersion leading to distortion. Therefore a signal under goes fast fading if

$$T_S >> T_C \quad (2.8)$$

Where T_C is the coherence time and

$$B_S << B_D \quad (2.9)$$

Where B_D is the Doppler spread .Transmission involving very low data rates suffers from fast fading [1][4][15].

2.3.4.2 Slow Fading

In such channel the rate of the change of the channel impulse response is much less than the transmitted signal. It can consider a slow fading channel in which channel is almost constant over at least one symbol duration. Hence

$$T_S << T_C \tag{2.10}$$

And

$$B_S >> B_D \tag{2.11}$$

It observe that the velocity of the user play an important role in deciding whether the signal experience fast or slow fading [1][4][15].

2.3.5 Statistical Models for Fading Channel

In general, the term fading describes the variations with time of the received signal strength. Fading, due to the combined effects of multipath propagation and of relative motion between transmitter and receiver, generates time-varying attenuations and delays that may significantly degrade the performance of a communication system. With multipath and motion, the signal components arriving from the various paths with different delays combine to produce a distorted version of the transmitted signal. Because of the multiplicity of factors involved in propagation in a cellular mobile environment, it is convenient to apply statistical techniques to describe signal variations. In a narrowband system, the transmitted signals usually occupy a bandwidth smaller than the channel's coherence bandwidth, which is defined as the frequency range over which the channel fading process is correlated. That is, all spectral components of the transmitted signal are subject to the same fading attenuation. This type of fading is referred to as frequency nonselective or frequency flat. On the other hand, if the transmitted signal bandwidth is greater than the channel coherence bandwidth, the spectral components of the transmitted signal with a frequency separation larger than the coherence bandwidth are faded independently. The received signal spectrum becomes distorted, since the relationships between various spectral components are not the same as in the transmitted signal. This phenomenon is known as frequency selective fading. In wideband systems, the transmitted signals usually undergo frequency selective fading [1][3][4].

2.4 Classification of Fading Channel

We consider three types of channels to place bounds on radio system performance.
These are:

- Gaussian channel
- Rayleigh channel
- Rician channel

2.4.1 The Gaussian Channel

The Gaussian channel can be considered the ideal channel, and it is only impaired by "additive white Gaussian noise" (AWGN) developed internally by the receiver. We hope to achieve a BER typical of a Gaussian channel when we have done everything we can to mitigate fading and its results. These measures we take could be diversity, equalization, FEC coding with interleaving, and so forth. The ideal Gaussian channel is very difficult to achieve in the mobile radio environment [14].

2.4.2 The Rayleigh Channel

The Rayleigh channel is at the other end of the line, often referred to as a worst-case channel. We treated fading on LOS microwave as Rayleigh fading and gave us the very worst case fading scenario. Figure 2.5 shows a channel where the signal approaches Rayleigh fading characteristics. Of course, we are dealing with multipath here [4][10][14].

We showed that in the mobile radio scenario, multipath reception commonly had many components. Thus if each multipath component is independent, the PDF (probability density function) of its envelope is Rayleigh [4][10][14].

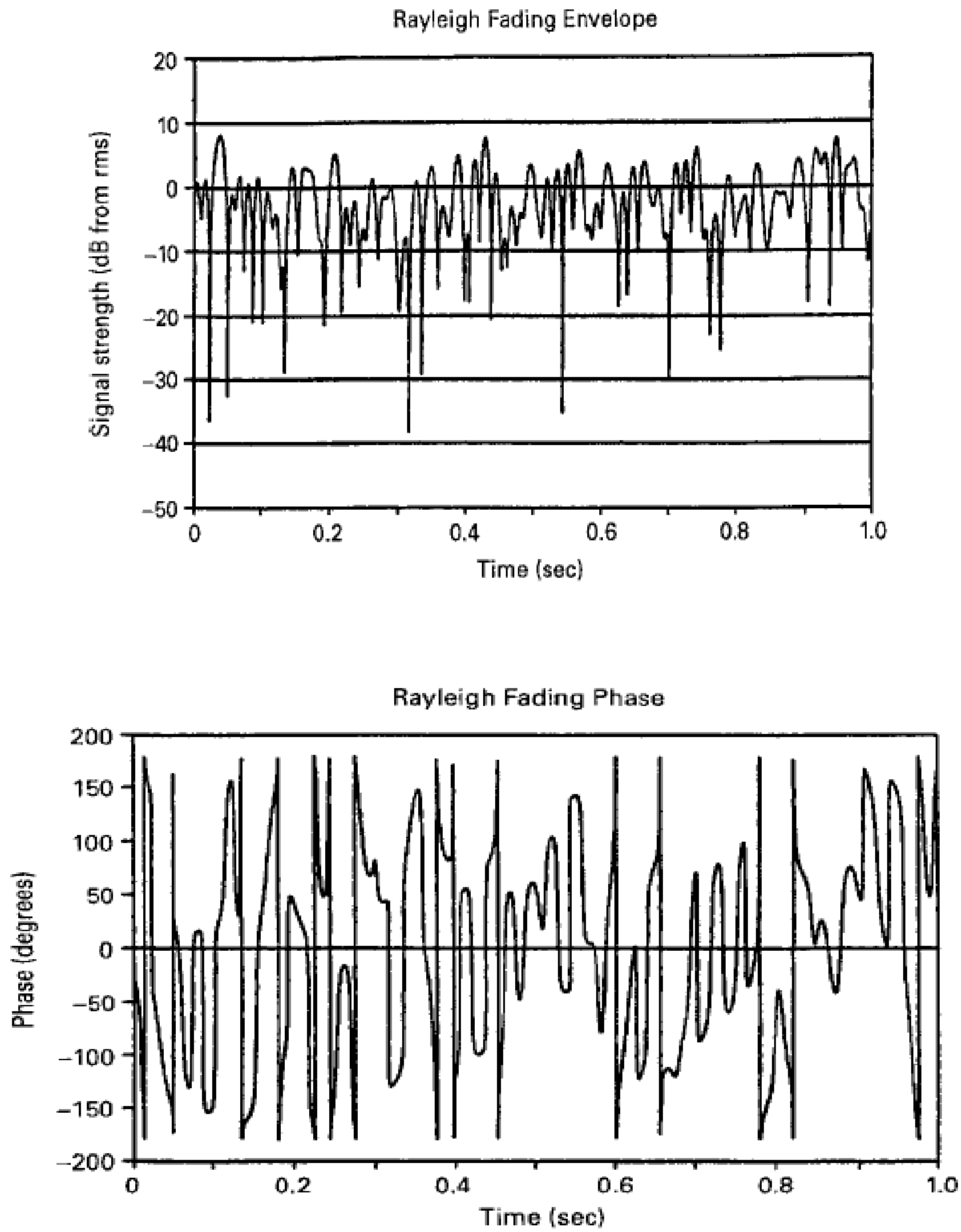


Figure 2.5: Typical Rayleigh fading envelope and phase in a mobile scenario [14]

2.4.3 The Rician Channel

The characteristics of a Rician channel are in between those of a Gaussian channel and those of a Rayleigh channel. As cells get smaller, the LOS component becomes more and more dominant. There are many cases; in fact, in nearly all cases where there is no full shadowing, there is an LOS component and scattered components. This is a typical multipath scenario [14].

CHAPTER THREE

3 Large Scale Path Loss Model

3.1 Introduction

The mobile radio channel places fundamental limitations on the performance of wireless communication systems. The transmission path between the transmitter and the receiver can vary from simple line-of-sight to one that is severely obstructed by buildings, mountains, and foliage. Unlike wired channels that are stationary and predictable, radio channels are extremely random and do not offer easy analysis. Even the speed of motion impacts how rapidly the signal level fades as a mobile terminal moves in space. Modeling the radio channel has historically been one of the most difficult parts of mobile radio system design, and is typically done in a statistical fashion, based on measurements made specifically for an intended communication system or spectrum allocation [1]. Radio-wave propagation through wireless channels is a complicated phenomenon characterized by various effects, such as multipath and shadowing [2]. The wireless radio channel poses a severe challenge as a medium for reliable high-speed communication. It is not only susceptible to noise, interference, and other channel impediments, but these impediments change over time in unpredictable ways due to user movement. In this section we will characterize the variation in received signal power over distance due to path loss and shadowing. Path loss is caused by dissipation of the power radiated by the transmitter as well as effects of the propagation channel [3].

3.2 Free Space Propagation

The free space propagation model is used to predict received signal strength when the transmitter and receiver have a clear, unobstructed line-of-sight path between them. As with most large-scale radio wave propagation models, the free space model predicts that received power decays as a function of the T-Reparation distance raised to some power (i.e. a power law function). The free space power received by a receiver antenna which is separated from a radiating transmitter antenna by a distance d, is given by the Friis free space equation [1],

$$p_r(\mathrm{d}) = \frac{p_t G_t}{(4\pi)^2} \frac{G_r \lambda^2}{d^2 L} \qquad (3.1)$$

Where $P_r(d)$ is the received power, P_t is the transmitted power, G_t is the transmitter antenna gain, G_r is the receiver antenna gain, *d* is the T-R separation distance in meters, L is the system loss factor not related to propagation ($\boldsymbol{L \geq 1}$), and λ is the wavelength in meters. The gain of an antenna is related to its effective aperture, A_e by [1].

$$G = \frac{4\pi A_e}{\lambda^2} \qquad (3.2)$$

The effective aperture A_e is related to the physical size of the antenna, and λ is related to the carrier frequency by

$$\lambda = \frac{C}{f} = \frac{2\pi C}{\omega_c} \qquad (3.3)$$

The power is spread over an ever-expanding sphere if radiating elements generates a fixed power. As the sphere expands the energy will be spread more thinly [1, 4].

3.3 Propagation Mechanism

Reflection, diffraction, and scattering are the three basic propagation mechanisms which impact propagation in a mobile communication system.

3.3.1 Reflection

When a radio wave propagating in one medium impinges upon another medium having different electrical properties, the wave is partially reflected and partially transmitted. If the plane wave is incident on a perfect dielectric, part of the energy is transmitted into the second medium and part of the energy is reflected back into the first medium, and there is no loss of energy in absorption.

If the second medium is a perfect conductor, then all incident energy is reflected back into the first medium without loss of energy [1].

3.3.2 Ground Reflection (2-ray) Model

In a mobile radio channel, a single direct path between the base station and a mobile is seldom the only physical means for propagation, and hence the free space propagation model of equation (3.1) is in most cases inaccurate when used alone. The 2-ray ground reflection model shown in Figure 3.1 is a useful propagation model that is based on geometric optics, and considers both the direct path and a ground reflected propagation path between transmitter and receiver. This model has been found to be reasonably accurate for predicting the large-scale signal strength over distances of several kilometers for mobile radio systems that use tall towers (heights which exceed 50 m), as well as for line-of-sight microcell channels in urban environments [1]

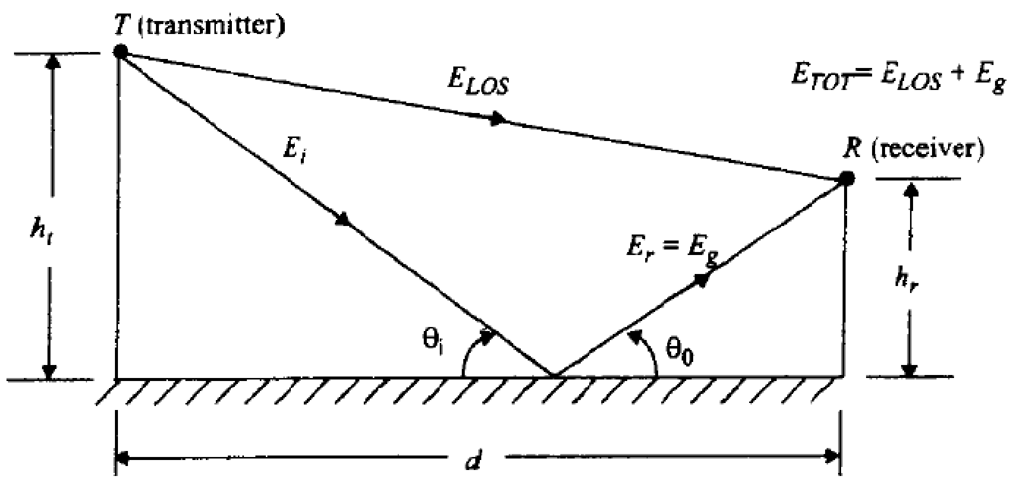


Figure 3.1: Two-ray ground reflection [2]

In most mobile communication systems, the maximum **T-R** separation distance is at most only a few tens of kilometers, and the earth may be assumed to be flat. The two-ray model is used when a single ground reflection dominates the multipath effect [1, 3].

3.3.3 Diffraction

Diffraction allows radio signals to propagate around the curved surface of the earth, beyond the horizon, and to propagate behind obstructions. Although the received field strength decreases rapidly as a receiver moves deeper into the obstructed (shadowed) region, the diffraction field still exists and often has sufficient strength to produce a useful signal [1].

The propagation model for the LOS and reflected paths was outlined in the previous section. Diffraction occurs when the transmitted signal "bends around" an object in its path to the receiver, as shown in Figure 3.2 [3][9].

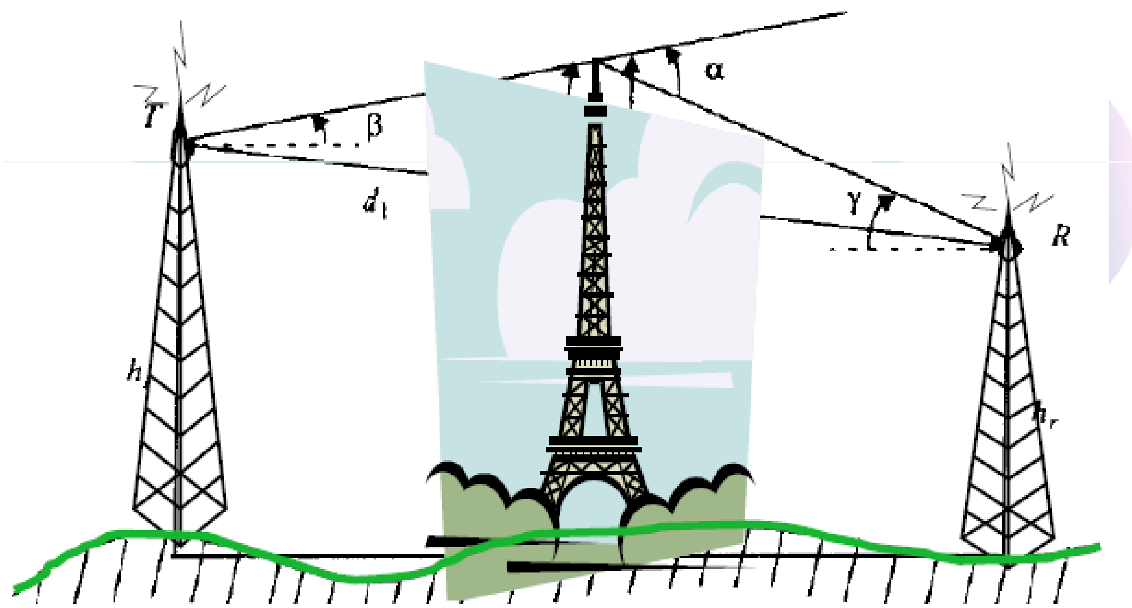


Figure 3.2: Diffraction [1]

3.3.4 Scattering

The actual received signal in a mobile radio environment is often stronger than what is predicted by reflection and diffraction models alone. This is because when a radio wave impinges on a rough surface, the reflected energy is spread out (diffused) in all directions due to scattering. Objects such as lamp posts and trees tend to scatter energy in all directions, thereby providing additional radio energy at a receiver [1][5][9].

3.4 Empirical Path Loss Models

Most mobile communication systems operate in complex propagation environments that cannot be accurately modeled by free-space path loss or ray tracing. A number of path loss models have been developed over the years to predict path loss in typical wireless environments such as large urban macro cells, urban microcells, and, more recently, inside buildings. These models are mainly based on empirical measurements over a given distance in a given frequency range and a particular geographical area or building [3].Propagation models can be classified mainly into two extremes, i.e. fully empirical models and Deterministic models. There are some models which have the characteristics of both types. Those are known as Semi-empirical models. Empirical models are based on practically measured data. Since few parameters are used, these models are simple but not very accurate. The models which are categorized as empirical models for macro cellular environment. These include Hata model, Okumura model, and COST-231 Hata model. On the other hand, deterministic models are very accurate. Some of the examples include Ray Tracing and Ikegami model. As mentioned earlier, semi-empirical models are based on both empirical data and deterministic aspects. Cost-231 Walfisch-Ikegami model is categorized as a semi empirical model [3][11].

3.4.1 The Okumura Model

This is the most popular model that being used widely The Okumura model for Urban Areas is a Radio propagation model that was built using the data collected in the city of Tokyo, Japan. The model is ideal for using in cities with many urban structures but not many tall blocking structures. The model served as a base for Hata models. Okumura model was built into three modes which are urban, suburban and open areas. The model for urban areas was built first and used as the base for others. Clutter and terrain categories for open areas are there are no tall trees or buildings in path, plot of land cleared for 200-400m [1][3][11].

$$L_m(\text{dB}) = L_F(\text{d}) + A_{mu}(\text{f, d}) - \text{G}\,(h_r) - \text{G}(h_t) - G_{AREA} \quad (3.4)$$

Where:

L_m= (i.e., median) of path loss

L_F(d) = free space propagation path loss.

A_{mu}(f,d) = median attenuation relative to free space

G (h_m) = mobile antenna height gain factor

$$G(h_b) = 20\log(h_b/200),\ 1000m > h_b > 30m \tag{3.5}$$

$$G(h_m) = 10\log(h_m/3) \quad ,\ h_m <= 3m \tag{3.6}$$

$$G(h_m) = 20\log(h_m/3) \quad ,\ 10m > h_m > 3m \tag{3.7}$$

Okumura's model is wholly based on measured data and does not provide any analytical explanation. For many situations, extrapolations of the derived curves can be made to obtain values outside the measurement range, although the validity of such extrapolations depends on the circumstances and the smoothness of the curve in question [1] [3].

3.4.2 Hata Model

The Hata model is an empirical formulation of the graphical path loss data provided by Okumura, and is valid from 150 MHz to 1500 MHz's. Hata presented the urban area propagation loss as a standard formula and supplied correction equations for application to other situations. The standard formula for median path loss in urban areas is given by[1][11][12][13][19]

$$L_m(dB) = 69.55+26.16\log f_c - 13.82\log h_{te} - a(h_{re}) + (44.9 - 6.55\log h_{te})\log(d) \tag{3.8}$$

Where f_c is the frequency (in MHz) from 150MHz to 1500MHz , h_{te} is the effective transmitter (base station) antenna height (in meters) ranging from 30 m to 200m , h_{re} is the effective receiver (mobile) antenna height (in meters) ranging from 1m to 10m, d is the T-R separation distance (in km), and a(h_{re}) is the correction factor for effective mobile antenna height which is a function of the size of the coverage area. For a small to medium sized city, the mobile antenna correction factor is given by

$$a(h_{re}) = (1.1\log f_c - 0.7)h_{re} - (1.56\log f_c - 0.8) \tag{3.9}$$

And for a large city, it is given by

$$a(h_{re}) = 8.29(\log 1.54 h_{re})^2 - 1.1\ dB \quad \text{for } f_c \le 300MHz \tag{3.10}$$

a(h_{re})= 3.2(log11.75h_{re})^2-4.97 dB for $f_c \geq$ 300MHz (3.11)

3.4.3 COST- 231 Hata model

The European Co-operative for Scientific and-Technical research IEUROCOST) formed the COST-231 working committee to develop an extended version of the Hata model. COST-231 proposed the following formula to extend Hata's model to 2 GHz. The proposed model for path loss is [1][3][11][12][13].

L_m(dB) = 46.3 + 33.9logf_c – 13.82logh_{te} – a (h_{re}) + (44.9 – 6.55logh_{re}) logd +C_m (3.12)

Where a (h_{re}) is defined in the above equations

0 dB for medium sized city and suburban areas

$C_{m=}$ (3.13)

3 dB for metropolitan centers

The COST-231 extension of the Hata model is restricted to the following range of parameters:

f**:** 1500 MHz to 2000 MHz

h_{te}: 30 m to 200 m

h_{re}: 1 m to 10 m

d : l k m to 20 k m

3.4.4 The Lee Model

The lee model has been widely used in the prediction of path loss in macro cell applications, particularly for systems operating near 900MHz and for ranges greater than 1.6km [12]. The Lee model specifies distinct parameters for varying region types. Lee model should not be expected to be accurate outside a relatively narrow range of frequencies near 900MHz [19].

The Lee model [12] is formally expressed mathematically as

P_L = L_o+ δ log d – 10 log F_A (3.14)

$P_{L=}$ the median path loss with units in decimal (dB)

$L_{o\,=}$ the reference path loss along 1km; unit in dB

δ =the slope of the path loss curve; unit in dB *d* = the distance on which the path loss is to be calculated; unit in meter (m)

F_A = The adjustment factor.

In a given location, the L_o and δ parameters should be determined empirically through a set of measurements [12][13].

3.4.5 ECC – 33 Path Loss Model

The original Okumura experimental data were gathered in the suburban of Tokyo [11]. The refers to urban areas as subdivided into large city and medium city categories. Correction factors for suburban and open areas were also given. Since the characteristics of a highly built-up area such as Tokyo are quite different to those found in typical European suburban areas, use of the medium city model is recommended for European cities [12].

The medium city model is more appropriate for European cities whereas the large city environment should only be used for cities with tall buildings [12]. The path loss equation for ECC-33 model [12] is defined as

$$P_L = A_{fs} + A_{bm} - G_b - G_r \quad (3.15)$$

Where $A_{fs,}$ A_{fs} ,G_b and G_r are free space attenuation the basics median path loss, base station height gain factor and the terminal (CPE) height gain factor. They are individual defined as

$$A_{fs,} = 92.4 + 20\log10\,(d) + 20\log10\,(f)$$

$$A_{bm} = 20.41 + 98.3\log10\,(d) + 7.894 + 95.6[\log10\,(f)]^2$$

$$G_b = \log10\,(h_b/200)\,\{13.958 + 58[\log\,(d)]^2\}$$

And for medium city environments

$$Gr = [42.57 + 13.7\log10\,(f)]\,[\log10\,(hr) - 0.585]$$

Where *f* is the frequency in GHz

d is the distance between AP and CPE in km

h_b is the BS antenna height in meters

h_r is the CPE antenna height in meters

3.4.6 SUI Model

This stands for Stanford university Interim model. It is developed by Stanford University for frequency band of 2.5GHZ. In this model, the height of the base station antenna can be any value between 10m to 80m while that of the receiver can be between 2m to 20m based on[13].

The SUI model listed out three classes of terrain namely: terrain A, B, and C. According to [13] and [14], terrain A is suitable for dense urban locality, terrain B for hilly regions, while terrain C is appropriate for rural community with considerable vegetation. The equation of the Stanford university interim model is thus:

$$P_L = A + 10n \log_{10}(d/d_o) + X_f + X_h + S \quad \text{for } d > d_o \qquad (3.16)$$

Where

d is the distance between Base Station and Receiving antenna (m)

d_o is 100 meters

X_f is the correction for frequency

X_h is the correction for receiving antenna height in meters

S is the correction for shadowing in dB

n Is the path loss exponent

[14] further stated that random variables can be taken as the path loss exponent n while the weak fading standard should be derived. Hence, the parameter A, which is the Attenuation, is presented as,

$$A = 20\log_{10}\left(4\pi do/\lambda\right) \qquad (3.17)$$

The path loss exponent n , is expressed as

$$n = a - bh_b + \left(C/h_b\right) \qquad (3.18)$$

Where;

H_b is base station antenna height which is between 10m to 80m.

a, b, and c are constant and depend on the terrain type.

The value of n is 2 for free space,3<n<5 for urban Non-Line of Sight (NLOS) environment, and n> 5 for indoor propagation.

Also;

The correction for frequency, Xf is expressed as:

$X_f = 6.2 \log_{10}(f/2000)$ (3.19)

3.4.7 Regression Models:

Regression models are used to predict one variable from one or more other variables [12]. These models are very powerful tools that help scientists forecast about past, present or future activities through the use of information from past or present happenings. According to these [13], a regression model can be represented as shown in the equation below,

$\gamma = b_o + b_1$ (3.20)

$b_1 = \frac{\sum(x_i - \bar{x})(\Upsilon_i - \Upsilon)}{\sum(X_i - \bar{x})^2}$ (3.21)

$b_0 = \frac{1}{n}(\sum \gamma - b_1 \sum x_l)$

$= \bar{\gamma} - b_1\bar{x}$ (3.22)

Where :

γ is the dependent variable which is the attenuation represented as A

X is the independent variable

b_0 Is the intercept

$b_1$is the slope calculated from equation (3.21)

In other words, equation (3.20) can be re-written as

$A = b_0 + b_1 D_d$ (3.23)

Where;

D_d Is the independent variable

Hence, equation (3.23) is used to calculate the empirical formula while equation (3.22) and (3.21) are used to determine the values of b0 and b1 in that order.

CHAPTER FOUR

4. 3rd Generation Mobile Principles

4.1 3G mobile systems

Third-generation (3G) wireless communications is the evolution of second-generation (2G) mobile systems towards increased data rates as well as a wide range of advanced services (from the traditional voice and paging services to interactive multimedia including high-quality teleconferencing and high speed Internet access [10]. The International Telecommunication Union (ITU) began its activities dealing with future mobile communication systems in 1985 under the name Future Public Land Mobile Telecommunication System (FPLMTS). ITU-R Task Group 8/1 was in charge of identifying FPLMTS needs. Subsequently, ITU-R changed the name of FPLMTS to International Mobile Telecommunications after the year 2000 (IMT- 2000), whose air interface standardization studies began in 1997.

Some requirements for 3G technologies are [11]:

- ✓ More efficient use of the available spectrum,
- ✓ Support for a wide variety of mobile equipment,
- ✓ Flexible introduction of new services and technologies,
- ✓ Voice quality comparable to that of the Public Switched Telephone Network (PSTN),
- ✓ A data rate of 144 Kbit/s for users moving fast over large areas,
- ✓ A data rate of 384 Kbit/s for pedestrians or slow moving users over small areas,
- ✓ Support for 2.048 Mbit/s operation for office use,
- ✓ Support for both packet-switched and circuit-switched data services
- ✓ An adaptive radio interface suited to the highly asymmetric nature of most Internet communications,
- ✓ A much greater bandwidth for downlink than for uplink.

4.2 UMTS Radio Access Network Architecture

To cope with the advancement in the future mobile telecommunication systems, the UMTS is gradually evolving to fully support multi-radio access networks. This evolution process has formed the UMTS terrestrial access network (UTRAN) [16] as the main radio access network technology for the UMTS. Typically the UTRAN is located in between the Uu and Iu UMTS interfaces, and it is used to provide a bearer service over these interfaces [26]. In the UMTS, Radio Access Bearers (RAB) is created by the UTRAN which empowers CN entities to facilitate communication paths among UEs. RABs form logical connections between the UE and RNC, and carry user data. Figure 4.1 shows the high-level system design of the UMTS network, including the UE and CN[26].

The UTRAN offers various differences in operations and functionalities in comparison to the GSM radio access network, such as:

- The UTRAN introduces several new interfaces in the UMTS radio access network (RAN), such as Uu, Iu, Iub and Iur as well as some new interfaces in the CN like Iu-PS and Iu-CS [16]. All these interfaces provide flexibility of operation while internetworking with other network entities.

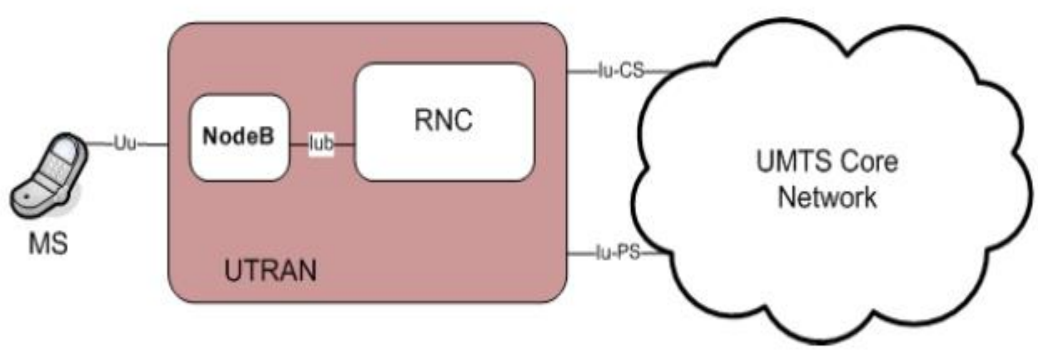


Figure 4.1: UMTS high level system architecture [18]

- Unlike GSM, WCDMA is used as radio access technique in the UTRAN. The use of WCDMA provides macro diversity which does not exist in TDMA-based radio access systems.
- The UTRAN uses Asynchronous Transfer Mode (ATM) [17] for transporting information with variable bit rates.
- In the UTRAN, mobility management is handled at the cell and UTRAN Registration Area (URA) without involving the CN [27]. This significantly decreases the exchange of signaling between the UE and CN and provides efficient radio resource management.

4.2.1 UTRAN Architecture

Figure 4.2 illustrates the UTRAN architecture, which basically consists of one or more Radio Network Subsystem (RNS). In the UTRAN, the RNS controls the allocation and release of radio resources while establishing a communication path between the UE and UTRAN. Usually the RNS consists of a Radio Network Controller (RNC) and one or many NodeBs, where both the RNC and Node B are connected through the Iub interface in the RNS. In the presence of many RNCs in the UTRAN, the Iur interface is used to connect all of them [28].

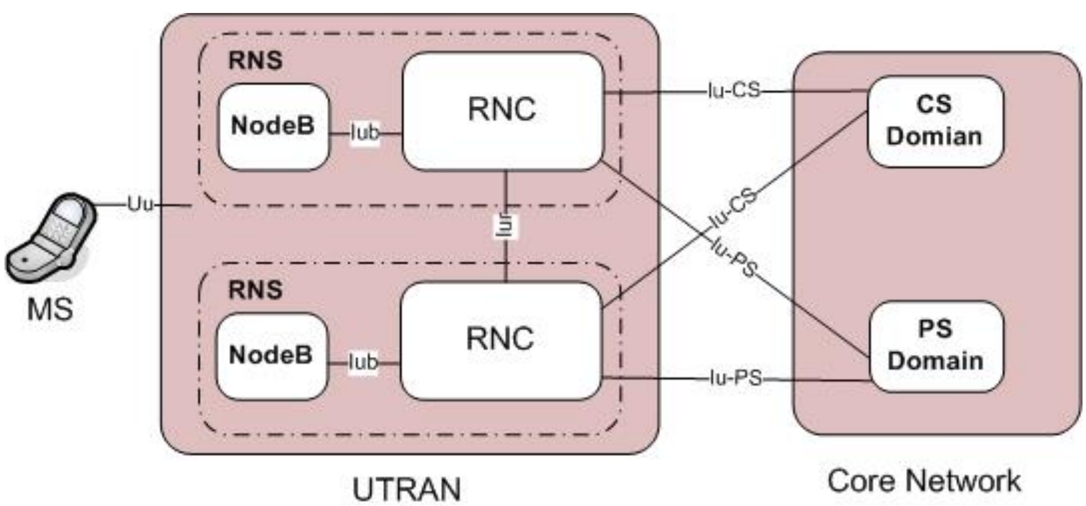


Figure 4.2: UTRAN architecture [20]

4.2.2 UTRAN Interfaces

In the UTRAN, several new interfaces have been introduced which are used to connect the logical network elements in the UTRAN system. All these interfaces also describe the mode of operation of the UTRAN network entities. These are as follows:

- Cu Interface is an electrical interface which operates between the Universal Subscriber Identity Module (USIM) and the UE.
- Uu Interface is used by the UE to access the UTRAN. This is a typical UMTS open WCDMA radio interface through which mobile stations (MSs) are used to send and receive communication requests.
- Iu Interface is used to connect the RNC to the CN. This interface comes with two variants, Iu-CS and Iu-PS [16] to facilitate a user's initiated requests for circuit and packet domains respectively.
- Iur Interface is an over-the-air UMTS interface and it links different RNCs. This interface facilitates soft handovers in the presence of RNCs manufactured by different venders.
- Iub Interface is an open UMTS interface which links an RNC to a Node B[16].

4.2.3 Node B

With the evolution of mobile communication systems, in the UTRAN the term base station has also evolved into Node B [16]. Node B is a physical network entity and is situated at the edge of the UTRAN. The main functions of Node B are to transmit and receive radio signals, perform modulation and demodulation of signals, and signal filtering. Node B performs all its operations between the Uu and Iub interfaces.

In the UMTS, the logical structure of Node B is vender dependent, meaning that besides performing its traditional operations, Node B can also have power control and Operation and Maintenance (O&M) functionalities. With O&M [28] enabled functionalities, a Node B can also be used by the operators to perform network management functions. It is also important to note that in release 5, a packet scheduling function is embedded in Node B [29]. Hence with the evolution of the UTRAN, Node B is introduced with those control functions that have a central role in the UTRAN.

4.2.4 Radio Network Controller (RNC)

In the UTRAN, switching and control of communication links are handled through the RNC. The RNC in the UTRAN architecture connects with the Iub and Iu interfaces and in the presence of more RNSs, inter RNC communication is facilitated through the Iur interface. Moreover, the RNC also handles the switching between the RAB and Iu bearers. The RNC can perform several logical roles while operating in the UTRAN such as the Controlling RNC (CRNC), Serving RNC (SRNC) and Drifting RNC (DRNC) [29]. When the RNC is used to control a single Node B then it is termed as the CRNC. The CRNC controls congestion in its cell and when new radio links are establish, it grants them admission and code allocation. In the SRNC logical role, the RNC is responsible for holding the Iu bearer and RAN Application Part (RANAP) signaling between the UE and CN [26, 30]. The last logical role an RNC can perform is known as a DRNC. In drifting mode the RNC controls cells and allocated UE context through itself. It is also capable of routing data between the Iub and Iur interfaces [30].

In order to understand the RNC operations in the UTRAN, its functionality can be divided into radio resource management (RRM) and controlling functions. When we talk about RRM in the UTRAN, we come to know that it is a set of different algorithms which are used by the RNC to establish a steady radio path. In the UTRAN these algorithms are used for handover, power control, code management, admission control and packet scheduling. The protocol which is used by RRM is called the Radio Resource Control (RRC) protocol. RRM is also responsible for providing QoS to all radio links in terms of efficient resource sharing and management. RNCs use control functions to create, terminate and maintain RABs [28].

CHAPTER FIVE

5 Modeling and Analysis

5.1Material

This thesis was carried out in Easter Addis Ababa metropolis during dry season. The key materials used for this investigative research are: Samsung S5 mobile station that are installed Nemo software, a global positioning system (BU353 GPS), and a laptop with Actix software installed in it, power supply unit and a vehicle.

The Laptop computer is connected to an external power source, while the Samsung S5 mobile phone and GPS are all connected to the Laptop through its USB ports. The 3G network, operating at the frequency of 2.1GHz, was under investigation in this thesis within the Eastern metropolis in Addis Ababa city. Drive test is a technique that is deployed in assessing the state of radio frequency signal of the operator.

5.2 METHOD

Before the drive test commenced, all the needed configurations on the Transmission Evaluation and Monitoring System (TEMS 11) equipment were carried out. The drive test readings at each case begin whenever “record” is clicked on the start command.

The Samsung S5 handset was set in such a way that it initiated calls that lasted for 10 seconds each before the calls got terminated and then the calls commenced again. This call process continued all through the routes under the study. The investigations were carried out into two (2) phases which covered the major routes under consideration. The areas covered were categorized into two which are: urban area and Sub-urban area.

The urban area comprises:

I. Part 1 Bole homes in Eastern Addis Ababa.
II. Part 2 Bole International Stadiums Eastern Addis Ababa.

While the Sub-urban area is comprised of:

I. Part 3 Summit Savory

II. Part 4 Summit Beverage

Table 5.1 is the transmission parameters for the Network. This is a 3G based network, and it is used for the drive test.

- Nemo Outdoor tools, Laptop, mobile (Samsung S5) and GPS.
- Site Selection:- Tele network ,site Id ,PSC ,scrambling code Lock channel and then Test.
- Test Data:-the data recorded using ACTIX tools and export data to excel software.

Table 5.1: Transmission parameter for the network

No	Transmission parameter	Value
1	Transmitter total Power	43 dBm
2	Transmitter height	26.375 m
3	Mobile station height	1.5 m
4	Gain of transmitter	17 dB
5	Frequency of operation	2.1GHz

These measurements were carried out in a car with the speed limit kept as constant as possible in order to ensure accuracy of signal recordings. In the course of the drive test, the received signal level (RSL) that existed between the mobile station (MS) and Base transceiver station (BTS) were recorded in a log file of the laptop with Actix investigation software. The Global positioning system (BU 353 GPS) indicated the distance and location with regard to the base station which was also recorded on the laptop. Figs. 5.1 to 5.4 below represent the log of the field work along various routes. The curves stand for the routes followed during the drive test in the areas while the color variations indicate the strength of the received signals as shown below.

Figure 5.1: 111162(Summit Savory)

Figure 5.2: 111164(Bole Homes)

Figure 5.3: 111421 (Bole International Stadium)

Figure 5.4: 111583 (Summit Beverage)

Interference: Co-Channel or Adjacent interference **Ranges (Legend):**

Ranges	Color	Grade
0 > 9	Red	Very bad
9 > 15	Yellow	Accepted
15 > 30	Green	Good

Interference >>>> bad C/I >>>> Bad Rx qual>>>> Bad SQI

Ranges			Color	Grade
0	>	2		Excellent
2	>	4		Good
4	>	6		Bad
6	>	7		Very bad

FER (Frame Erasure Rate): Percentage of frames being dropped **BER actual:** (Number of bit errors / Number of bit transmitted) **SQI**: Speech Quality Index **Ranges (Legend):**

Ranges			Color	Grade
-20	>	0		Very bad
0	>	9		Bad
9	>	18		Good
18	>	30		Excellent

MS Power control level: Power control (0 > 8) depend on network design. **DTX**: Discontinuous Transmission.

TA: Timing advance (0 > 63) Enable MS to advance its transmission to compensate the propagation delay **0**: 500m **1**: 1K, and so on.

5.3 Calculation of Path Loss From The Existing Models

Two (2) existing models were considered for modeling the Eastern Addis Ababa Metropolis 3G network: Hata model, and COST 231 model, with distance in Km, frequency in MHz, the antenna height in meters.

5.3.1 Calculation of Hata Path Loss model for Eastern Addis Ababa

Using the transmission parameters given in Table 5.1 and equation (3.8), the Hata model is computed as shown below:

L_m(Hata) = 69.55+26.16logf_c-13.82logh_{te}- a(h_{re}))+ (44.9 -6.55logh_{te})log(d)+ C_m

(5.1)

The correction factor for the receiving antenna height is calculated using equation (5.2)

a (h_{re}) =(1.1logf_c-0.7)h_{re}-(1.56logf_c-0.8) (5.2)

The C_m for the environment is given as 0dB. Therefore, by substituting equation (5.2), into equation (5.1), the path loss for this environment is calculated as,

Where

F_c= 2100 MHz

h_{te}= 26.375 m

h_{re}=1.5 m

And a (h_{re}) for frequency above 300 MHz is

a(h_{re})= 3.2(log(11.75h_{re}))^2-4.97 dB for $f_c \geq$ 300MHz (5.3)

a(h_{re})= 3.2(log(11.75 x 1.5))^2-4.97 dB (5.4)

a(h_{re})= -0.000919 dB (5.5)

so by substitute a(h_{re}) in the equation (5.1) we get

L_{Hata}(dB) = 69.55 +26.16 log(2100)- 13.82 log(26.375)- (-0.000919)+(44.9 -6.55 log(26.375))log(d) (5.6)

L_{Hata}(dB) = 136.8 +35.59 log(d) (5.7)

The above equation (5.2) is Hata model.

5.3.2Computation of COST 231 extension Hata model for selected Eastern Addis Ababa area

Also using the transmission parameter in Table 1 and equation (3.12) or equation (5.3)

Cost 231 model

L_{Cost}(dB) = 46.3 + 33.9logf_c – 13.82logh_{te} – a (h_{re}) + (44.9 – 6.55logh_{re}) log (d) +C_m (5.8)

Where a(h_{re}) is the same with the above Hata model

So a(h_{re}) = -0.919 dB

And C_m for metropolitan city is 3 dB

L_{Cost}(dB)=46.3 +33.9 log(2100) – 13.82 log(26.375) –(-9.19)+(44.9-6.55 log(26.375)) log(d)+3 (5.9)

L_{Cost}(dB)= 142.28 + 35.59 log(d) (5.10)

The above equation (5.4) is Cost 231 model for Eastern Addis Ababa.

5.4 LOG Normal Shadowing Model

Shadowing refers to the gradual variation of Receive Signal Strength around an average value. This model describes the random Shadowing effect which occurs over large number of measurement locations.

$$L_p(d_i) = L_p(d_o) + 10n\log(\frac{d_i}{d_o}) + X\sigma \quad (5.11)$$

Where Xσ , describes a Zero-Mean Gaussian distributed random variable (in dB) with standard deviation σ in (dB). Using linear regression analysis, the path loss exponent n, can be determined by minimizing (in a mean square error sense) the difference between measured and predicted values of (5.5) to yield n is path loss exponent and given in (5.12) as below:

$$\mathbf{n} = \frac{\mathbf{N}\,(\sum_{i=1}^{n}(\mathbf{Xi\ Yi}))-(\sum_{i=1}^{n}\mathbf{Xi})(\sum_{i=1}^{n}\mathbf{Yi})}{\mathbf{N}\,(\sum_{i=1}^{n}\mathbf{Xi}^2)-(\sum_{i=1}^{n}\mathbf{Xi})^{\wedge}2} \quad \mathbf{(5.12)}$$

Where $L_p\ (d_i)$ represents measured path loss and $L_p\ (d_o)$ predicted path loss at any reference distance. N is the number of measured data or sample points. The standard deviation is minimized as:

$$\sigma = \sqrt{\frac{\sum(L_p(d_i)-L_p(d_o))^{\wedge}2}{N}} \quad (5.13)$$

The sum of the mean squared error , e(n) is shown as:

$$e(n) = \sum_{i=1}^{N}\left(L_p(d_i) - L_p(d_o)\right)^{\wedge}2 \quad (5.14)$$

The reference Path loss calculated using the formula below as:

$$L_p(d_o) = \frac{\sum_{i=1}^{n} Yi - n\sum_{i=1}^{n} Xi}{N} \quad (5.15)$$

And x_i is calculated as:

$$X_i = 10\log(d/d_o) \quad (5.16)$$

Whereas d is distance from transmitter and d_o reference distance that is 0.05km.

5.5 Analysis from Measured Data

During the drive test, it was closely observed that the urban section of the area under study had a fair signal received level whereas the sub-urban area had poor signal received level. Therefore, this work resolved to generate separate path loss models that will describe the signal path loss at Addis Ababa urban and sub-urban regions, so as to assist the network operators that are operating within the area or that may wish to site their network within the area ascertain the challenges in the study area, and then plan for the way to tackle them.

To develop the proposed models the following parameters were obtained accordingly;

I. the path loss exponent,
II. reference path loss,
III. predicted path losses, and
IV. standard deviation

Base station location, height

The base station location is finding from GPS in the form of longitudinal and latitude. Its height is from recorded data as follow :

Table5.2:Base station location

Base Station and Place	PCI	Longitude	Latitude	Height
111583 (Summit Beverage)	133	E38.84887	N9.00272	27.5
111421 (International Stadium)	165	E38.79004	N9.00554	25
111164 (Bole Homes)	211	E38.79966	N8.98847	30
111162 (Summit Savory)	13	E38.8519	N9.00882	23

Receive signal strength

In order to determine the Path Loss within Eastern Addis Ababa metropolis, the data obtained from the field experiment on the path loss was collected and has its validity tested in order to derive an appropriate model that best predict the signal path loss within Eastern Addis Ababa metropolis. Tables 5.3 and 5.4 below indicate the median values of the measured Received Signal Levels (RSL) and corresponding values of measured Path Losses for specified distances, 0.05km≤ di ≤0.5km of the routes as generated from the analysis of Actix software. The values did not ultimately follow a decreasing order with distance which could possibly be as a result of interferences from other transceiver stations other than the reference transmitting station at the start of the drive test.

Table 5.3: measured signal strength (dBm) for each base station

No	Distance (Km)	111583-133	111421-165	111164-211	111162-137	Average RSS
1	0.05	-70.20	-42.60	-68.00	-63.60	-61.10
2	0.10	-62.60	-54.30	-71.40	-59.20	-61.88
3	0.15	-71.13	-64.10	-64.80	-51.45	-62.87
4	0.20	-84.90	-74.50	-77.20	-57.85	-73.61
5	0.25	-90.70	-87.85	-76.60	-64.33	-79.87
6	0.30	-100.90	-87.78	-78.45	-71.45	-84.64
7	0.35	-99.90	-93.10	-85.10	-81.20	-89.83
8	0.40	-99.45	-84.30	-83.60	-84.30	-87.91
9	0.45	-104.30	-86.50	-89.70	-80.03	-90.13
10	0.50	-105.27	-96.20	-103.20	-78.68	-95.84

Calculated path loss from receive signal strength

Path loss for free space is 10n log (p_t/ p_r) but for real world it is necessary to include several loss. The RSS value recorded at each of the receiving point is converted to measured path loss (P_L) in dB by using the formula:

$$P_L\,(dB) = (PBTS + GBTS + GMS - LFC - LAB - LCF) - RSS \quad (5.17)$$

Where

P_L(dB) is the measured path loss for each measurement location at a distance d (km) from the base station.

PBTS = Base transceiver station power (dBm),

GBTS = Base transceiver station antenna gain (dBi),

GMS = Mobile station antenna gain (dBi),

Feeder cable and connector loss =3dB

LAB = Antenna body loss =3dB

LCF = Combiner and filter loss =4.7dB

Transmitter power (PBTS) = 43dBm

Transmitter Antenna Gain = 17dB

Receiver Antenna Gain = 0

$$P_L = 43 + 17 - 3 - 3 - 4.7 - RSS = 49.3 - RSS \quad (5.18)$$

For instance for RSS = -70.2 the path loss at this point

$$P_L = 49.3 - RSS = 49.3 - (-70.2) = 49.3 + 70.2 = 119.5$$

In the same way for -62.6,-71.13,-84.9,-90.7 are 111.9, 120.43, 134.2, and 140 respectively.

Table 5.4: calculated path loss

No	Distance (Km)	111583-133	111421-165	111164-211	111162-137	Average RSS
1	0.05	119.50	91.90	117.30	112.90	110.40
2	0.10	111.90	103.60	120.70	108.50	111.17
3	0.15	120.43	113.40	114.10	100.75	112.17

4	0.20	134.20	123.80	126.50	107.15	122.91
5	0.25	140.00	137.15	125.90	113.63	129.17
6	0.30	150.20	137.00	127.70	120.75	133.95
7	0.35	149.20	142.40	134.40	130.50	139.15
8	0.40	148.75	133.60	132.90	133.60	137.21
9	0.45	153.60	135.80	139.00	129.33	139.43
10	0.50	154.57	145.50	152.50	127.98	145.13

Calculation of Path Loss Exponent, Reference Path Loss, Standard Deviation, MSE And Modeling For Each Base Station

The basic aim of this thesis is to model the different base station and the average NodeB. In order to model and to represent in formula or equation for one cell, several parameter are needed among those parameter path loss exponent, standard deviation and reference path loss are the basics once. Those equation are given in equation (5.12),(5.13),(5.14),(5.15) and form Table5.4 those result were calculated in the tables below:

Data Analysis for summit Beverage (111583-2-133)

In this sub section path loss exponent is calculated from measured RSS for each Base Station .

Table5.6: base station 111583-2-133 (Summit Beverage)

No	Distance (Km)	RSS (dBm)	X_i=10log(d/do)	Y_i=PL(dB)	X_i^2	X_iY_i

1	0.05	-70.20	0.0000	119.50	0.0000	0.0000
2	0.10	-62.60	3.0103	111.90	9.0619	336.8526
3	0.15	-71.13	4.7712	120.43	22.7643	574.5956
4	0.20	-84.90	6.0206	134.20	36.2476	807.9645
5	0.25	-90.70	6.9897	140.00	48.8559	978.5580
6	0.30	-100.90	7.7815	150.20	60.5517	1168.7813
7	0.35	-99.90	8.4510	149.20	71.4194	1260.8892
8	0.40	-99.45	9.0309	148.75	81.5572	1343.3464
9	0.45	-104.30	9.5424	153.60	91.0574	1465.7126
10	0.50	-105.27	10.0000	154.57	100.0000	1545.7000
SUM			**65.5976**	**1382.35**	**521.5155**	**9482.4002**

Where, d_o is the close in distance =0.05 km, Y_i is the measured path loss.

The path loss exponent for selected area of Eastern Addis Ababa is given in equation (5.12)

$$\mathbf{n} = \frac{N\left(\sum_{i=1}^{n}(Xi\ Yi)\right) - \left(\sum_{i=1}^{n} Xi\right)\left(\sum_{i=1}^{n} Yi\right)}{N\left(\sum_{i=1}^{n} Xi^2\right) - \left(\sum_{i=1}^{n} Xi\right)^{\wedge}2} \qquad [14]$$

Where N is the total number of data points.

$$n = \frac{(10*9482.4)-(65.5976*1382.35)}{(10*521.5159)-(65.5976)^{\wedge}2}$$

$$= \frac{4145.158}{912.114}$$

n=4.55 (5.19)

Based on Table 5.5 the Path loss exponent of Base station 111583-2-133 is 4.55 and group under shadow urban cellular radio since path loss exponent of shadow urban cellular radio is from 3 to 5.

Computation of the Reference Path Loss

The reference path loss is computed using equation (5.15) and Table 5.6.

$$L_p(d_o) = \frac{\sum_{i=1}^{n} Yi - n\sum_{i=1}^{n} Xi}{N} \qquad [14]$$

$$= \frac{1382.38 - (4.55 \ *65.5976)}{10}$$

$L_p(d_o)$ = 108.39 dB (5.20)

Computation of the Standard Deviation mean square error for Summit Beverage Standard deviation of the distribution was evaluated using the mean square error method the sum of the mean square error is as represented in equation (5.14)

$$e(n) = \sum_{i=1}^{k} [lm(d) - Lp(d)]\verb|^|2 \qquad [14]$$

Where L_m is the measured path loss and L_p is predicted path loss. The value of the measured path loss and predicted path losses shown in Table5.7. Where substituted in equation (5.14) in order to get the sum of the Mean Squared Error (MSE) of the system.

$L_p(d)_{dBm}$= 108.39 + 45.5*log (d/d_o)

Table 5.7: Mean Squared Error calculated table for Summit Beverage

Distance (Km)	Measured Path loss Lm(d)dB	Predicted Path loss LP(d) dB	[Lm(d) - Lp(d)]2
0.05	119.50	108.39	123.43
0.10	111.90	122.09	103.84

0.15	120.43	130.10	93.51
0.20	134.20	135.78	2.50
0.25	140.00	140.19	0.04
0.30	150.20	143.80	40.96
0.35	149.20	146.84	5.57
0.40	148.75	149.48	0.53
0.45	153.60	151.80	3.24
0.50	154.57	153.89	0.46

e(n) = 374.08

The Standard deviation δ was calculated using equation (5.13)

$$\boldsymbol{\delta = \sqrt{\frac{\sum[Lm-Lp]^\wedge 2}{N}}} \quad [14]$$

Where N is the total number of data point which is 10 in this case

$$\delta = \sqrt{\frac{374.08}{10}}$$

δ = 6.11 dB **(5.21)**

By substitute the value obtained to equation (5.14) the predict path loss is obtain as

$\mathbf{P_L = L_p (d_o) + 10*n *log (d/d_o) + \delta}$ [14]

$P_L = 108.39 + 10* 4.55 *\log (d/d_o) + 6.11$ **(5.22)**

$P_L = 114.5 + 45.5\log (d/d_o)$ **(5.23)**

The mean square error (e) of the distribution is obtained using equation (5.14)

$$\mathbf{e = \frac{\delta}{N}}$$

$$e = \frac{6.11}{10}$$

e=0.611 (5.24)

Data Analysis for Bole International Stadium (111421-1-165)

Table 5.8: Base station 111421-1-165(Bole International Stadium)

No	Distance (Km)	Receive Signal strength (dBm)	Xi=10log(d/do)	Yi=PL(dB)	Xi^2	XiYi
1	0.05	-42.6	0.0000	91.9	0.0000	0
2	0.10	-54.3	3.0103	103.6	9.0619	311.86708
3	0.15	-64.1	4.7712	113.4	22.7643	541.05408
4	0.20	-74.5	6.0206	123.8	36.2476	745.35028
5	0.25	-87.85	6.9897	137.15	48.8559	958.637355
6	0.30	-87.78	7.7815	137.08	60.5517	1066.68802
7	0.35	-93.1	8.4510	142.4	71.4194	1203.4224
8	0.40	-84.3	9.0309	133.6	81.5572	1206.52824
9	0.45	-86.5	9.5424	135.8	91.0574	1295.85792
10	0.50	-96.2	10.0000	145.5	100.0000	1455
Sum			**65.5976**	**1264.15**	**521.5155**	**8784.4054**

Where, d_o is the close in distance =0.05 km, Y_i is the measured path loss.

The path loss exponent for selected area of Eastern Addis Ababa is given in equation (5.12)

$$\mathbf{n=} \frac{\mathbf{N\,(\sum_{i=1}^{n}(Xi\,Yi\,))-(\,\sum_{i=1}^{n}\,Xi\,)(\,\sum_{i=1}^{n}Yi)}}{\mathbf{N\,(\,\sum_{i=1}^{n}Xi^{2})-(\,\sum_{i=1}^{n}Xi\,)^{\wedge}2}} \qquad \mathbf{[14]}$$

Where N is the total number of data points.

$$n= \frac{(10*8783.33)-(65.5976*1264.15)}{(10*521.5159)-(65.5976)^{\wedge}2}$$

$$=\frac{4908.1}{912.114}$$

n=5.38 **(5.25)**

Based on Table 5.5 the Path loss exponent of Base station 111421-1-165 is 5.38 and group under obstructed in building since path loss exponent of obstructed in building is from 4 to 6.

Computation of the Reference Path Loss

The reference path loss is computed using equation (5.15) and Table 5.8

$$\mathbf{L_p\,(d_o) =} \frac{\boldsymbol{\sum_{i=1}^{n}Yi-n\sum_{i=1}^{n}Xi}}{\boldsymbol{N}} \qquad \mathbf{[14]}$$

$$=\frac{\mathbf{1264{,}15-(5.38\ *65.5976)}}{\mathbf{10}}$$

$L_p(d_o)$ = 91.12 dB **(5.26)**

Computation of the Standard Deviation for Bole International Stadium

Standard deviation of the distribution was evaluated using the mean square error method the sum of the mean square error is as represented in equation (5.14)

$$\mathbf{e\,(n)} = \sum_{i=1}^{k}[\boldsymbol{lm(d)-Lp(d)}]^{\wedge}\mathbf{2} \qquad \mathbf{[14]}$$

Where L_m is the measured path loss and L_p is predicted path loss. The value of the measured path loss and predicted path losses shown in Table 5.9. Where substituted in equation (5.14) in order to get the sum of the Mean Squared Error (MSE) of the system.

$$L_p(d)_{dBm} = 91.12 + 53.8 * \log(d/d_o) \quad \textbf{(5.27)}$$

Table 5.9: Mean Squared Error calculated table for Bole International Stadium

Distance (Km)	Measured Path loss Lm(d)dB	Predicted Path loss LP(d) dB	[Lm(d) - Lp(d)]2
0.05	91.90	91.12	0.61
0.10	103.60	107.31	13.76
0.15	113.40	116.79	11.49
0.20	123.80	123.51	0.08
0.25	137.15	128.72	71.06
0.30	137.00	132.98	16.16
0.35	142.40	136.59	33.76
0.40	133.60	139.7	37.21
0.45	135.80	142.46	44.36
0.50	145.5	144.92	0.34
Sum			**228.83**

$$\mathbf{e(n) = 228.83} \quad \textbf{(5.28)}$$

The Standard deviation δ was calculated using equation (5.13)

$$\delta = \sqrt{\frac{\sum[Lm-Lp]^2}{N}}$$ [14]

Where N is the total number of data point which is 10 in this case

$$\delta = \sqrt{\frac{228.57}{10}}$$

δ = 4.78 dB **(5.29)**

By substitute the value obtained to equation (5.14) the predict path los is obtain as

$P_L = L_p(d_o) + 10*n*\log(d/d_o) + \delta$ [14]

$P_L = 91.12 + 10*5.38*\log(d/d_o) + 4.78$

$P_L = 95.9 + 53.8\log(d/d_o)$ **(5.30)**

The mean square error (e) of the distribution is obtained using equation (5.14)

$$e = \frac{\delta}{N}$$

$$e = \frac{4.78}{10}$$

e=0.478 **(5.31)**

Data Analysis Bole Home (111164-3-211)

Table 5.10: Base station 111164-3-211

Table 5.10: Base station 111164-3-211

No	Distance (Km)	Receive Signal strength (dBm)	Xi=10log(d/do)	Yi=PL(dB)	Xi^2	XiYi
1	0.05	-68.00	0.0000	117.30	0.0000	0.0000
2	0.10	-71.40	3.0103	120.70	9.0619	363.34321
3	0.15	-64.80	4.7712	114.10	22.7643	544.39392
4	0.20	-77.20	6.0206	126.50	36.2476	761.6059
5	0.25	-76.60	6.9897	125.90	48.8559	880.00323

6	0.30	-78.45	7.7815	127.75	60.5517	994.086625
7	0.35	-85.10	8.4510	134.40	71.4194	1135.8144
8	0.40	-83.60	9.0309	132.90	81.5572	1200.20661
9	0.45	-89.70	9.5424	139.00	91.0574	1326.3936
10	0.50	-103.20	10.0000	152.50	100.0000	1525
sum			**65.5976**	**1291.05**	**521.5155**	**8730.8475**

Where, d_o is the close in distance =0.05 km, Yi is the measured path loss.

The path loss exponent for Bole Home (111164-3-211) area is given by equation (5.12)

$$\mathbf{n=\frac{N\,(\sum_{i=1}^{n}(Xi\;Yi\,))-(\,\sum_{i=1}^{n}\;Xi\,)(\,\sum_{i=1}^{n}Yi)}{N\,(\,\sum_{i=1}^{n}Xi^{2})-(\,\sum_{i=1}^{n}Xi\,)^{\wedge}2}}\qquad \textbf{[14]}$$

where N is the total number of data points.

$$n=\frac{(10*8730.63)-(65.5976*1291)}{(10*521.5159)-(65.5976)^{\wedge}2} \qquad \textbf{(5.32)}$$

$$=\frac{2619.79}{912.114}$$

$$\mathbf{n=2.87} \qquad \textbf{(5.33)}$$

Based on Table 5.5 the Path loss exponent of Base station 111164-3-211 is 2.87 and this Node B group under urban area cellular radio. Since path loss exponent of urban area cellular radio is given from 2.7 to 3.5.

Computation of the Reference Path Loss

The reference path loss is computed using equation (5.15) and Table 5.10.

$$L_p(d_o) = \frac{\sum_{i=1}^{n} Yi - n\sum_{i=1}^{n} Xi}{N} \qquad [14]$$

$$= \frac{1291.00-(2.87 \ *65.5976)}{10}$$

$$L_p(d_o) = 110.27 \text{ dB} \qquad (5.34)$$

Computation of the Standard Deviation for Bole Home(111164-3-211)

Standard devastation of the distribution was evaluated using the mean square error method the sum of the mean square error is as represented in equation (5.14)

$$e(n) = \sum_{i=1}^{k}[lm(d) - Lp(d)]^2 \qquad [14]$$

Where L_m is the measured path loss and L_p is predicted path loss. The value of the measured path loss and predicted path losses shown in Table 5.11. Where substituted in equation (5.14) in order to get the sum of the Mean Squared Error (MSE) of the system.

$$L_p(d)_{dB} = 110.27 + 28.7 * \log(d/d_o) \qquad (5.35)$$

Table 5.11: Mean Squared Error calculated table for Bole Home

Distance (Km)	Measured Path loss Lm(d)dB	Predicted Path loss LP(d) dB	[Lm(d) - Lp(d)]2
0.05	117.30	110.27	49.42
0.10	120.70	118.91	3.20
0.15	114.10	123.96	97.22
0.20	126.50	127.55	1.10
0.25	125.90	130.33	19.62
0.30	127.75	132.6	23.52
0.35	134.40	134.52	0.01

0.40	132.90	136.19	10.82
0.45	139.00	137.6	1.96
0.50	152.5	138.97	183.06
Sum			390.42

e(n) = 390.42 **(5.36)**

The Standard deviation δ was calculated using equation (5.13)

$$\boldsymbol{\delta = \sqrt{\frac{\sum[Lm - Lp]^2}{N}}} \quad [14]$$

Where N is the total number of data point which is 10 in this case

$$\delta = \sqrt{\frac{390.42}{10}}$$

δ = 6.24 dB **(5.37)**

By substitute the value obtained to equation (5.14) the predict path los is obtain as

$$\mathbf{P_L = L_p (d_o) + 10*n *\log (d/d_o) + \delta} \quad [14]$$

$P_L = 110.27 + 10* 2.87 *\log (d/d_o) + 6.24$ **(5.38)**

$P_L = 116.51 + 28.7\log (d/d_o)$ **(5.39)**

The mean square error (e) of the distribution is obtained using equation (5.14)

$$\mathbf{e = \frac{\delta}{N}}$$

$$e = \frac{6.24}{10}$$

e=0.624 **(5.40)**

5.3.4 Summit Savory (111162-2-137)

Table 5.12: Base station 111162-2-137

No	Distance	Receive Signal	Xi=10log(d/do)	Yi=PL(dB)	Xi^2	XiYi

	(Km)	strength (dBm)				
1	0.05	-63.60	0.0000	112.90	0.0000	0.0000
2	0.10	-59.20	3.0103	108.50	9.0619	326.6176
3	0.15	-51.45	4.7712	100.75	22.7643	480.6984
4	0.20	-57.85	6.0206	107.15	36.2476	645.1073
5	0.25	-64.33	6.9897	113.63	48.8559	794.2396
6	0.30	-71.45	7.7815	120.75	60.5517	939.6161
7	0.35	-81.20	8.4510	130.50	71.4194	1102.8555
8	0.40	-84.30	9.0309	133.60	81.5572	1206.5282
9	0.45	-80.03	9.5424	129.33	91.0574	1234.1186
10	0.50	**-78.68**	10.0000	127.98	100.0000	1279.8000
Sum			**65.5976**	**1185.09**	**521.5155**	**8009.5813**

Where, d_o is the close in distance =0.05 km, Y_i is the measured path loss.

The path loss exponent for Summit Savory (111162-2-137) is get by substitute in equation (5.10)

$$n= \frac{N\left(\sum_{i=1}^{n}(Xi\,Yi)\right)-\left(\sum_{i=1}^{n}Xi\right)\left(\sum_{i=1}^{n}Yi\right)}{N\left(\sum_{i=1}^{n}Xi^2\right)-\left(\sum_{i=1}^{n}Xi\right)^2} \qquad [14]$$

where N is the total number of data points.

$$n = \frac{(10*8009.58)-(65.5976*1185.09)}{(10*521.5159)-(65.5976)^2}$$

$$= \frac{2356.74}{912.114}$$

n=2.58 **(5.41)**

Based on Table 5.5 the Path loss exponent of Base station 111162-2-137 is 2.58 and this Node B environment group under obstructed in factories since path loss exponent of obstructed in factories is from 2 to 3.

Computation of the Reference Path Loss

The reference path loss is computed using equation (5.15) and Table 5.12.

$$L_p(d_o) = \frac{\sum_{i=1}^{n} Yi - n\sum_{i=1}^{n} Xi}{N} \qquad [14]$$

$$= \frac{1185.09-(2.58*65.5976)}{10}$$

$L_p(d_o)$ = 101.59 dB **(5.42)**

Computation of the Standard Deviation for Summit Savory

Standard deviation of the distribution was evaluated using the mean square error method the sum of the mean square error is as represented in equation (5.12)

$$e(n) = \sum_{i=1}^{k}[lm(d) - Lp(d)]^2 \qquad [14]$$

Where L_m is the measured path loss and L_p is predicted path loss. The value of the measured path loss and predicted path losses shown in Table 5.13. Where substituted in equation (5.15) in order to get the sum of the Mean Squared Error (MSE) of the system.

$L_p(d)_{dBm}$= 101.59 + 25.8 *log (d/d_o) **(5.43)**

Table 5.13: Mean Squared Error calculated table for Summit Savory (111162-2-137)

Distance (Km)	Measured Path loss Lm(d)dB	Predicted Path loss LP(d) dB	[Lm(d) - Lp(d)]2

0.05	112.90	101.59	127.92
0.10	108.50	109.36	0.74
0.15	100.75	113.9	172.92
0.20	107.15	117.12	99.40
0.25	113.63	119.62	35.88
0.30	120.75	121.67	0.85
0.35	130.50	123.39	50.55
0.40	133.60	124.89	75.86
0.45	129.33	126.21	9.73
0.50	127.98	127.39	0.35
Sum			**574.19**

e(n) = 574.19 **(5.44)**

The Standard deviation δ was calculated using equation (5.13)

$$\boldsymbol{\delta} = \sqrt{\frac{\sum[\boldsymbol{Lm}-\boldsymbol{Lp}]^\wedge 2}{\boldsymbol{N}}} \qquad [14]$$

Where N is the total number of data point which is 10 in this case

$$\delta = \sqrt{\frac{574.19}{10}}$$

δ = 7.58 dB **(5.45)**

By substitute the value obtained to equation (5.15) the predict path loss is obtain as

$$\mathbf{P_L = L_p (d_o) + 10 * n * \log (d/d_o) + \delta} \quad [14]$$

P_L= 101.59 + 10* 2.58 *log (d/d_o) +7.58 **(5.46)**

P_L = 109.17 + 25.8 log (d/d_o) **(5.47)**

The mean square error (e) of the distribution is obtained using equation (5.14)

$$\mathbf{e = \frac{\delta}{N}}$$

$$e = \frac{7.58}{10}$$

e=0.758 **(5.48)**

Table 5.14: measured signal strength (dBm) for each base station

No	Distance (Km)	111583-133	111421-165	111164-211	111162-137	Average RSS
1	0.05	-70.20	-42.60	-68.00	-63.60	-61.10
2	0.10	-62.60	-54.30	-71.40	-59.20	-61.88
3	0.15	-71.13	-64.10	-64.80	-51.45	-62.87
4	0.20	-84.90	-74.50	-77.20	-57.85	-73.61
5	0.25	-90.70	-87.85	-76.60	-64.33	-79.87
6	0.30	-100.90	-87.78	-78.45	-71.45	-84.64
7	0.35	-99.90	-93.10	-85.10	-81.20	-89.83
8	0.40	-99.45	-84.30	-83.60	-84.30	-87.91
9	0.45	-104.30	-86.50	-89.70	-80.03	-90.13

10	0.50	-105.27	-96.20	-103.20	-78.68	-95.84

Table 5.15: calculated path loss

No	Distance (Km)	111583-133	111421-165	111164-211	111162-137	Average RSS
1	0.05	119.50	91.90	117.30	112.90	110.40
2	0.10	111.90	103.60	120.70	108.50	111.17
3	0.15	120.43	113.40	114.10	100.75	112.17
4	0.20	134.20	123.80	126.50	107.15	122.91
5	0.25	140.00	137.15	125.90	113.63	129.17
6	0.30	150.20	137.00	127.70	120.75	133.95
7	0.35	149.20	142.40	134.40	130.50	139.15
8	0.40	148.75	133.60	132.90	133.60	137.21
9	0.45	153.60	135.80	139.00	129.33	139.43
10	0.50	154.57	145.50	152.50	127.98	145.13

The above table show path loss of for four each base station and its average.

Analysis for average Node B data

Table 5.16: Computation of path loss exponent for average Node B using linear regression method

No	Distance (Km)	Receive Signal strength (dBm)	Xi=10log(d/do)	Yi=PL(dB)	Xi^2	XiYi
1	0.05	-61.10	0.0000	110.40	0.0000	0
2	0.10	-61.88	3.0103	111.17	9.0619	334.6551
3	0.15	-62.87	4.7712	112.17	22.7643	535.1855
4	0.20	-73.61	6.0206	122.91	36.2476	739.9919
5	0.25	-79.87	6.9897	129.17	48.8559	902.8595
6	0.30	-84.64	7.7815	133.95	60.5517	1042.3319
7	0.35	-89.83	8.4510	139.15	71.4194	1175.9567
8	0.40	-87.91	9.0309	137.21	81.5572	1239.1298
9	0.45	-90.13	9.5424	139.43	91.0574	1330.4968
10	0.50	-95.84	10.0000	145.13	100.0000	1451.3000
Sum			**65.5976**	**1280.69**	**521.5155**	**8751.9072**

Where, d_o is the close in distance =0.05 km, Yi is the measured path loss.

The path loss exponent for the average Node B of Eastern Addis Ababa is given in equation (5.12)

$$\mathbf{n=}\ \frac{\mathbf{N\ (\sum_{i=1}^{n}(Xi\ Yi\ ))-(\sum_{i=1}^{n}\ Xi\ )(\sum_{i=1}^{n}Yi)}}{\mathbf{N\ (\sum_{i=1}^{n}Xi^2)-(\sum_{i=1}^{n}Xi\ )\hat{}2}} \qquad \mathbf{[14]}$$

where N is the total number of data points.

$$n= \frac{(10*8752.01)-(65.5976*1280.7)}{(10*521.5159)-(65.5976)\hat{}2}$$

$=\frac{3509.154}{912.114}$

n= 3.85 **(5.49)**

Computation of the Reference Path Loss

The reference path loss is computed using equation (5.15) and Table 5.16.

$$L_p(d_o) = \frac{\sum_{i=1}^{n} Yi - n\sum_{i=1}^{n} Xi}{N} \quad [14]$$

$$= \frac{1280.7-(3.85 \ * 65.5976)}{10}$$

$L_p(d_o)$ = 102.81 dB **(5.50)**

Computation of the Standard Deviation for average Node B

Standard deviation of the distribution was evaluated using the mean square error method the sum of the mean square error is as represented in equation (5.14)

$$e(n) = \sum_{i=1}^{k}[lm(d) - Lp(d)]^2 \quad [14]$$

Where L_m is the measured path loss and L_p is predicted path loss. The value of the measured path loss and predicted path losses shown in Table 5.17. Where substituted in equation (5.14) in order to get the sum of the Mean Squared Error (MSE) of the system.

$L_p(d)_{dBm}$= 102.81 + 38.5 *log (d/d_o) **(5.51)**

Table 5.17: Mean Squared Error calculated table for average total Node B

Distance (Km)	Measured Path loss Lm(d)dB	Predicted Path loss LP(d) dB	[Lm(d) - Lp(d)]2
0.05	110.40	102.81	57.61
0.10	111.17	114.40	10.43
0.15	112.17	121.18	81.18
0.20	122.91	126.00	9.55

0.25	129.17	129.72	0.30
0.30	133.95	132.77	1.39
0.35	139.15	135.35	14.44
0.40	137.21	137.50	0.08
0.45	139.43	139.50	0.00
0.50	145.13	141.31	14.59
Sum			**193.59**

e(n) = 193.592 **(5.52)**

The Standard deviation δ was calculated using equation (5.13)

$$\boldsymbol{\delta} = \sqrt{\frac{\sum[Lm-Lp]^2}{N}} \quad [14]$$

Where N is the total number of data point which is 10 in this case

$$\delta = \sqrt{\frac{193.592}{10}}$$

δ = 4.4 dB **(5.53)**

By substitute the value obtained to equation (5.14) the predict path loss is obtain as

$$\mathbf{P_L = L_p (d_o) + 10 * n * \log (d/d_o) + \delta} \quad [14]$$

P_L= 102.81 + 10* 3.85 *log (d/d_o) +4.4 **(5.54)**

P_L = 107.25 + 38.5log (d/d_o) **(5.55)**

The mean square error (e) of the distribution is obtained using equation (5.11)

$$\mathbf{e} = \frac{\delta}{N} (5.11)$$

e= $\frac{4.4}{10}$

e=0.44 **(5.56)**

Table 5.18: summary path loss exponent and environment

No	Base station	Path loss exponent	Environment	Factor
1	111583-2-133	4.55	shadow urban cellular radio	3 to5
2	111421-1-165	5.38	obstructed in building	4 to 6
3	111164-3-211	2.87	urban area cellular radio	2.7 to 3.5
4	111162-2-137	2.58	obstructed in factories	2 to 3
5	Average	3.85	shadow urban cellular radio	3 to 5

Table 5.19: summary path loss exponent and environment

No	Base station	Site Place	Path loss exponent	Environment	Factor
1	111583-2-133	Summit Beverage	4.55	shadow urban cellular radio	3 to5
2	111421-1-165	Bole International Stadium	5.38	obstructed in building	4 to 6
3	111164-3-211	Bole Home	2.87	urban area cellular radio	2.7 to 3.5
4	111162-2-137	Summit Savory	2.58	obstructed in factories	2 to 3
5	Average	Average	3.85	shadow urban cellular radio	3 to 5

Table 5.20: Summary Different Parameter for Four and Average Base Station

No	Network I.D	Site Place	Path loss exponent	Reference Path loss(dB)	Standard Deviations(dB)	MSE	Antenna Coverage(m)
1	111583-2-133	Summit Beverage	4.55	108.39	6.11	0.611	290.93
2	111421-1-165	Bole International Stadium	5.38	91.12	4.78	0.478	491.51
3	111165-3-211	Bole Home	2.87	110.27	6.24	0.624	694.19
4	111162-2-137	Summit Savory	2.58	101.59	7.58	0.758	1796
5	Average	Average	3.85	102.81	4.4	0.44	619.75

And from Table5.10 and equation (5.11) the modeling are formulated as below:

$$L_p(d_i) = L_p(d_o) + 10n\log\left(\frac{d_i}{d_o}\right) + X\sigma \quad \textbf{(5.57)}$$

Table 5.21: Modeling for each NodeB

No	Network I.D	Site Place	PL =Lp (do) +10*n *log (d/do) + δ
1	111583-2-133	Summit Beverage	PL = 114.5 + 45.5 log(d/do)
2	111421-1-165	Bole International Stadium	PL = 95.9 + 53.8 log(d/do)
3	111165-3-211	Bole Home	PL = 116.51 + 28.7 log(d/do)
4	111162-2-137	Summit Savory	PL = 109.17 + 25.8 log(d/do)
5	Average	Average	PL = 107.21 + 38.5 log(d/do)

Simulations were carried out on the measured values obtained during the drive test conducted on the major streets/roads of the Eastern Addis Ababa metropolis. These major routes include: Bole Home to Bole International Stadium and surrounding road. And Summit Square to summit beverage and Summit Savory. The path loss and the received signal level along these mentioned routes were simulated and plotted as shown in Figs. 5.5 to 5.10 using the MATLAB codes shown in the Appendices A to H. The proposed models for the Eastern Addis Ababa urban are shown in figures 5. and 5.12 respectively using the MATLAB codes in Appendices I and J.

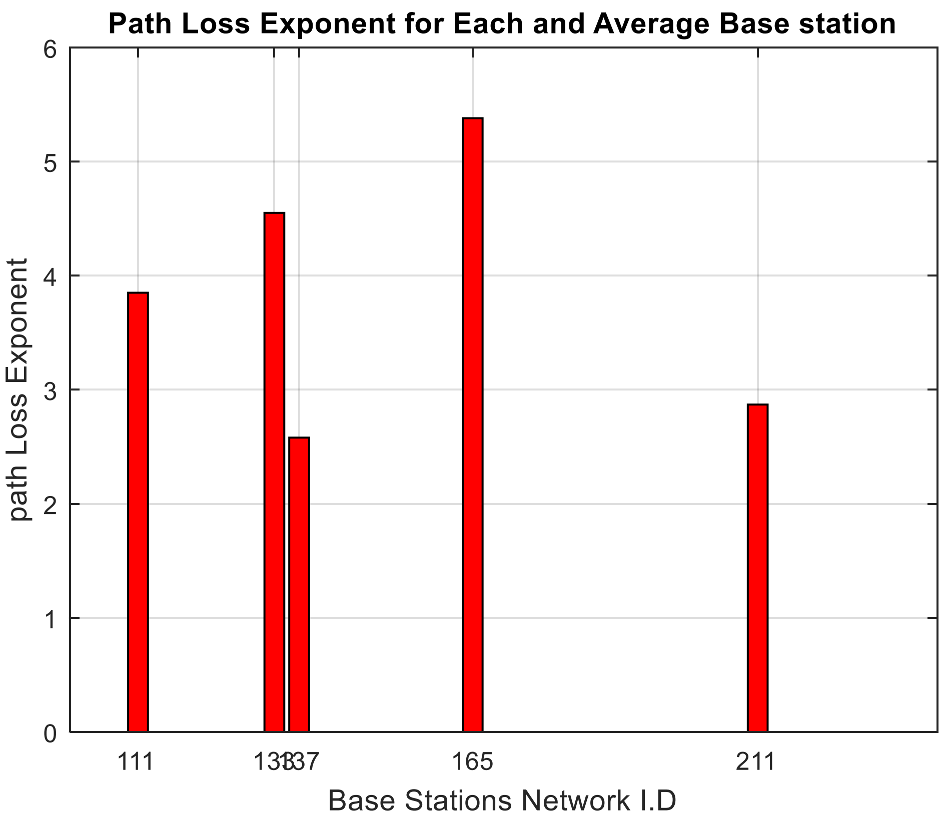


Figure5.5: simulation for path loss exponent

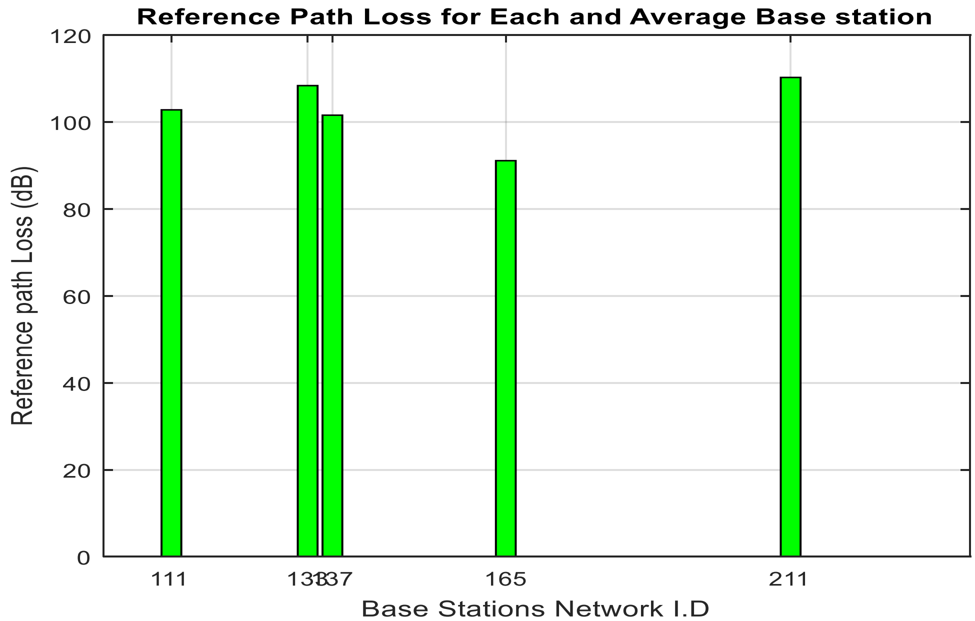
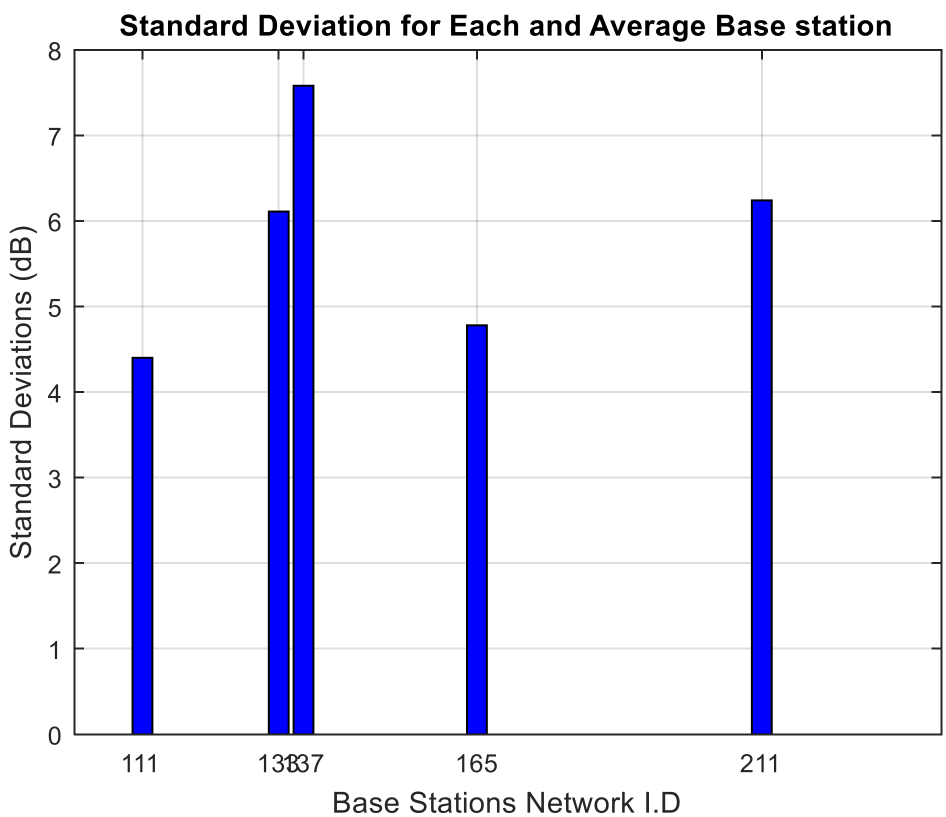


Figure5.6:simulation for reference path loss



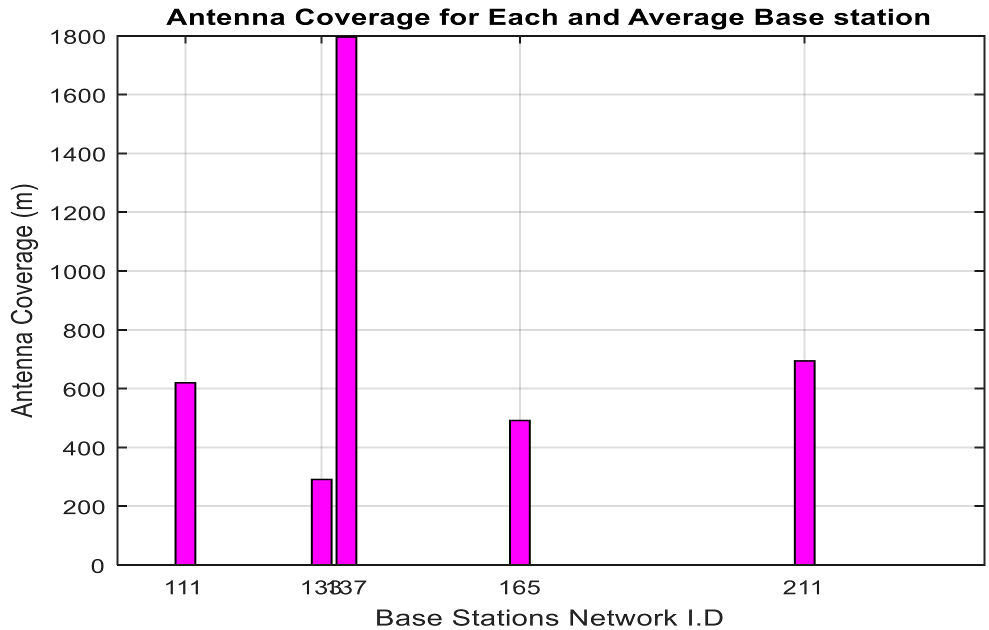


Figure 5.6 and 5.7: simulation for Standard Deviation and Antenna coverage

CHAPTER SIX

6.1 Results and Discussion

Simulations were carried out on the measured values obtained during the drive test conducted on the major streets/roads of the Eastern Addis Ababa. These major routes include: Bole Homes, Bole International Stadium, Summit Beverage and Summit Savory. The path loss and the received signal level along these mentioned routes were simulated and plotted as shown in Figs. 6.1 to 6.18 using the MATLAB codes shown in the Appendices A to R. The proposed models for the Eastern Addis Ababa are shown in figures 6.11 and 6.12 respectively using the MATLAB codes in Appendices A to R.

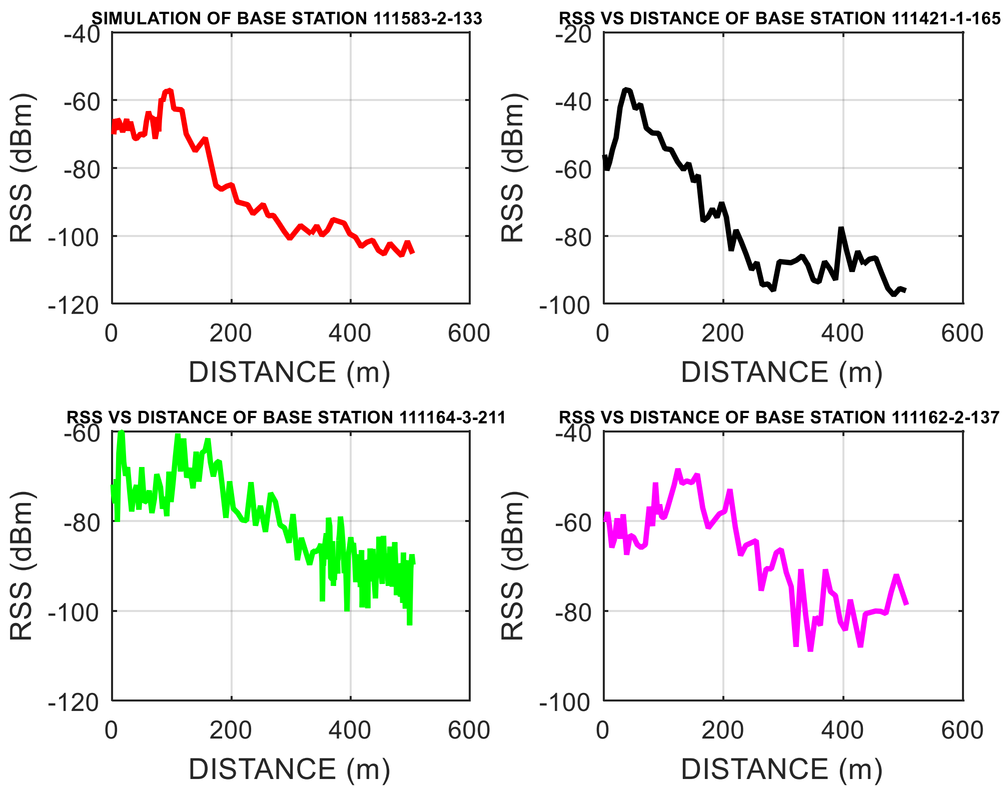


Figure 6.1 Receive signal strength vs. distance for the four site

Fig.6.1 represents the plot of the measured signal strength of the four eNodeB. The MATLAB program for this plot is shown in Appendix A.

As we are learned in wireless communication the above four graph show the effect of small scale fading. The receive signal fluctuated with small distance travel in meter and within small time interval in second. The reasons of Small scale fading are multipath, Doppler effect, bandwidth and movement of surrounding body.

The above graphs show Receives signals strength in dBm with distance in meter .As the graph indicated the signal is high at the starting point because of the apparatus near to the base station and there is line of sight and ground reflection. As indicated in base stations 133,165,and 137 the signal strength -60 dBm and after travel some distance the signal strength higher between -60 dBm to -40dBm the reason is at the beginning there is shadow, after some distance travel the shadow clear and it is line of sight between transmitter and receiver. As the result show the two base station 133 and 165 that means Summit Beverage and Bole International Stadium the signal fade linearly this may create negative effect in mobile communication. If the correcting measure is not done the mobile communication is in worst case ,it may be call block ,call drop and miss call happen frequently.

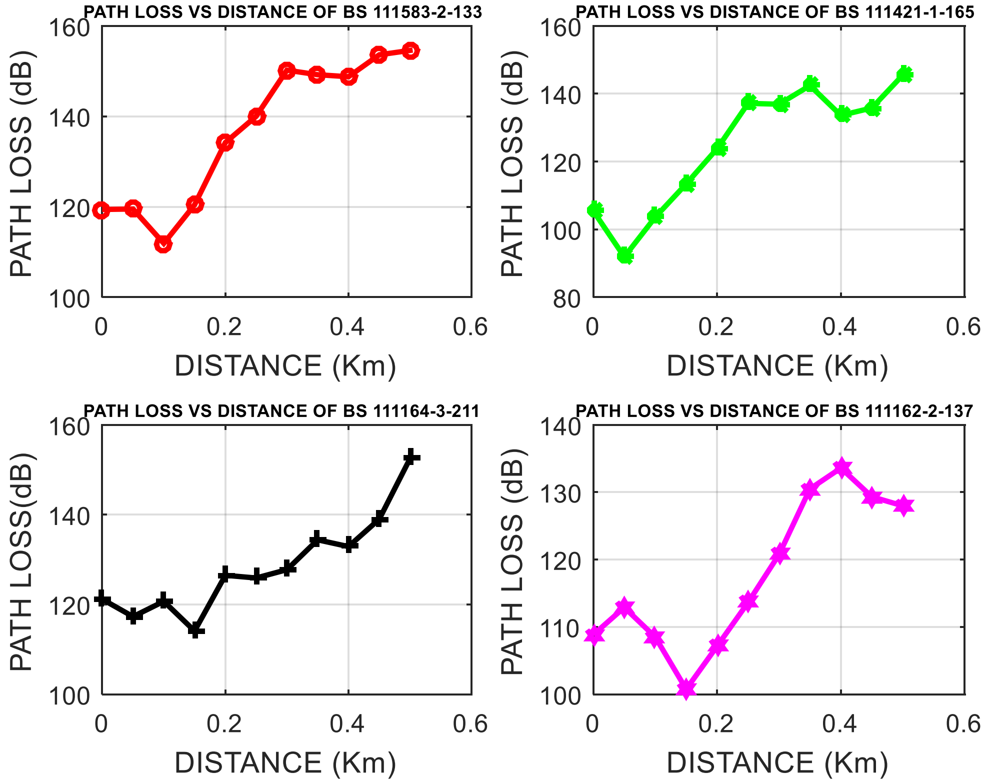


Figure 6.2 path loss vs. Distance in km

Fig.6.2 represents the plot of the measured signal path loss of the four eNodeB. The MATLAB program for this plot is shown in Appendix B.

The above graphs shows path loss vs. distance travel in km for the proposed four base stations. As the graph show the path loss increase with distance and the signal attenuated because of several reasons. The signal reach to receiver by traveling several distance and it follow different way. So the signal may reach to receiver in some case by line of sight and in other case from reflection from ground. And mostly in urban and in city mobile communication done through reflection, diffraction and scattering. As the distance between transmitter and receiver increase the signal loss its power strength through noise in environment. For those base station RSS measure by traveling mobile station away from transmitter so Doppler effect shows clearly. The receive frequency is the carrier frequency minus the Doppler frequency. So the data rate and band width decreased when mobile station far from base station.

Table 6.1: Different Parameter for Summit Beverage

Network I.D	Path loss exponent	Reference Path loss(dB)	Standard Deviations(dB)	MSE	Antenna Coverage(m)
111583-2-133	4.55	108.39	6.11	0.611	290.93

Table 6.2:Signal Status for 111583-2-133

Distance (km)	Calculated path loss (dB)	Signal status
0.05	114.50	Good
0.10	128.20	Good
0.15	136.20	Fair
0.20	141.60	Fair
0.25	146.30	Fair
0.30	149.90	Fair
0.35	152.90	Poor
0.40	155.60	Poor
0.45	157.90	Poor
0.50	160.00	No Signal

Fig.6.1 represents the plot of the measured signal strength of the Base Station located at Summit Beverage. At the beginning the receive signal strength -70dBm and up to 100m the signal increase gradually and it reach to -57dBm, this show line of sight up to100m. Then the signal decrease irregularly between 100m and 300m.Between 300m to 400m and between 400m to 500m it is constants

Fig.6.2 represents the plot of the measured signal path loss for Base Station located in Summit Beverage. From 0 to50m the path loss is constant and it is 120dB.And from 50m up till100m decrease linearly .From 100m to 300m increase irregularly and at0.3 km it is 150dB. And from0.3kmto 0.5 is slightly constant.

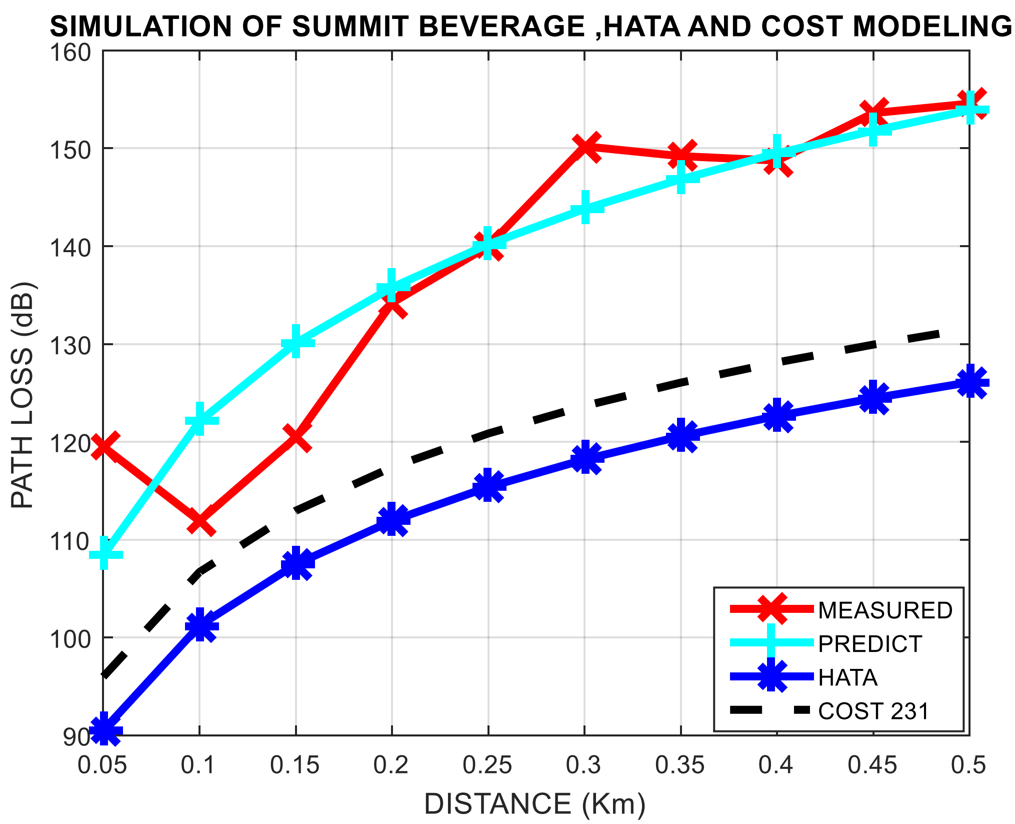


Figure 6.3: comparison of predict and measure model with Hata and COST 231 of Summit Beverage (111583-2-133)

Fig.6.3 represents the plot of the measured signal path loss for Base Station located in Summit Beverage, Hata and COST 231 model. The MATLAB program for this plot is shown in Appendix E.

Figure 6.5: show comparison of predict and measured model with Hata and Cost 231 model of base station that is located in Summit Beverage with network code 111583-2-133. As in section 5.3.1.1 to5.3.1.3 shown the predict Path loss model has 6.11 dB deviation with model path loss model and it has 0.611 mean squared error(MSE). As in the table 5.4 and 5.5 shown the path loss exponent and reference path loss are 4.55 and 108.39 dB respectively. As shown in figure 6.5: the predict and measured path loss model nearly match with Cost 231 than Hata model so this base station(111583-2-133) modeled with Cost 231.

- Hata Model as in equation (5.2)

  $PL_{Hata}(dB)=136.7+35.59\log(d)$
- Cost 231 model as shown in equation(5.4)

  $PL_{Cost}\ (dB) = 142.28 + 35.59\log\ (d/d_o)$

- The model of 111583-2-133(Summit Beverage) is

  $PL\ (dB) = 114.5 + 45.5\ \log\ (d/d_o)$

Table 6.3: Different Parameter for Bole International Stadium

Network I.D	Path loss exponent	Reference Path loss(dB)	Standard Deviations(dB)	MSE	Antenna Coverage(m)
111421-1-165	5.38	91.12	4.78	0.478	491.51

Table 6.4: signal status for Bole International Stadium (111421-1-165)

Distance (km)	Calculated path loss (dB)	Signal status

0.05	**95.90**	**Good**
0.10	**112.10**	**Good**
0.15	**121.50**	**Good**
0.20	**128.20**	**Good**
0.25	**133.50**	**Good**
0.30	**137.70**	**Fair**
0.35	**141.30**	**Fair**
0.40	**144.49**	**Fair**
0.45	**147.24**	**Fair**
0.50	**149.70**	**Poor**

Fig.6.1 represents the plot of the measured signal strength of the Base Station located at Bole International Stadium. At starting point RSS is -60dBm and up to50m it show increase linearly .This show the elevation of the road increase with same angle and the mobile station expose to line of sight with the base station. From 0.05km to0.26 km decrease irregularly. And from0.3km to 0.5km show up and down fluctuation.

Fig.6.2 is the plot of the path loss experienced along Bole International Stadium.As shown in the graph there is linearly decrease in path loss from the beginning up to 0.05km this show the signal strength is high and good quality up to this range. From 0.05km to 0.25km the path loss increase in great amount this indicate the signal attenuate highly this is because of distance. But from 0.25km to 0.5km the path loss increase and decreases irregularly

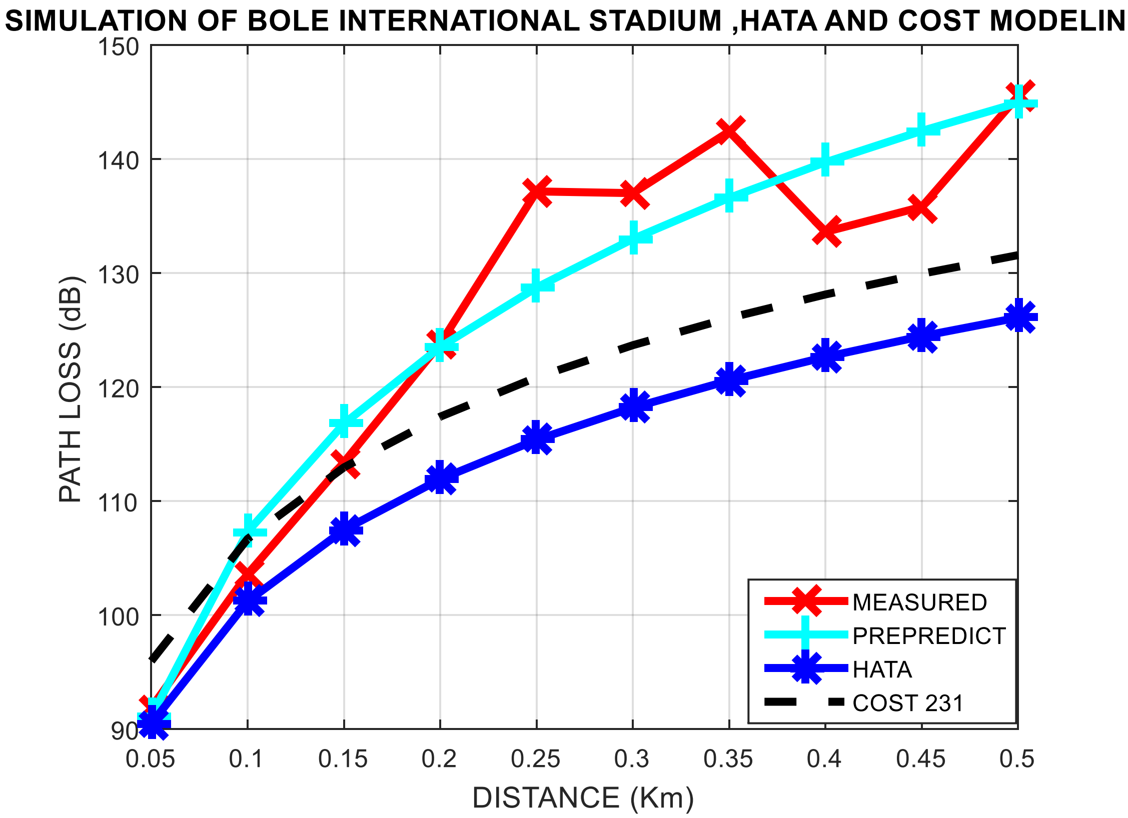


Figure 6.4: comparison of predict and measure model with Hata and COST 231 of Bole International Stadium(111421-1-165)

As shown in Figure 6.4 predict and measured path loss model compare with Hata and Cost 231 model. This base station located in Bole International Stadium, with network code 111421-1-165. As in Table5.6 shown the predict Path loss model has 4.78 dB deviation with model path loss model and it has 0.478 mean squared error(MSE). And the path loss exponent and reference predict path loss are 5.38 and 91.12 dB respectively. As shown in figure 6.8 the predict and measured path loss model nearly match with Cost 231 than Hata model so this base station (111421-1-165) modeled with Cost 231.

- The model of111421-1-165(Bole International Stadium) is
  P_L (dB) =95.9+ 5.38*log (d/d_o)

Table 6.5: Different Parameter for Bole Home

Network I.D	Path loss exponent	Reference Path loss(dB)	Standard Deviations(dB)	MSE	Antenna Coverage(m)
111165-3-211	2.87	110.27	6.24	0.624	694.19

Table 6.6: signal status for Bole Home (111164-3-211)

Distance (km)	Calculated path loss (dB)	Signal status
0.05	116.50	Good
0.10	125.20	Good
0.15	130.20	Good
0.20	133.80	Good
0.25	136.60	Fair
0.30	138.80	Fair
0.35	140.80	Fair
0.40	142.40	Fair
0.45	143.90	Fair
0.50	145.20	Fair

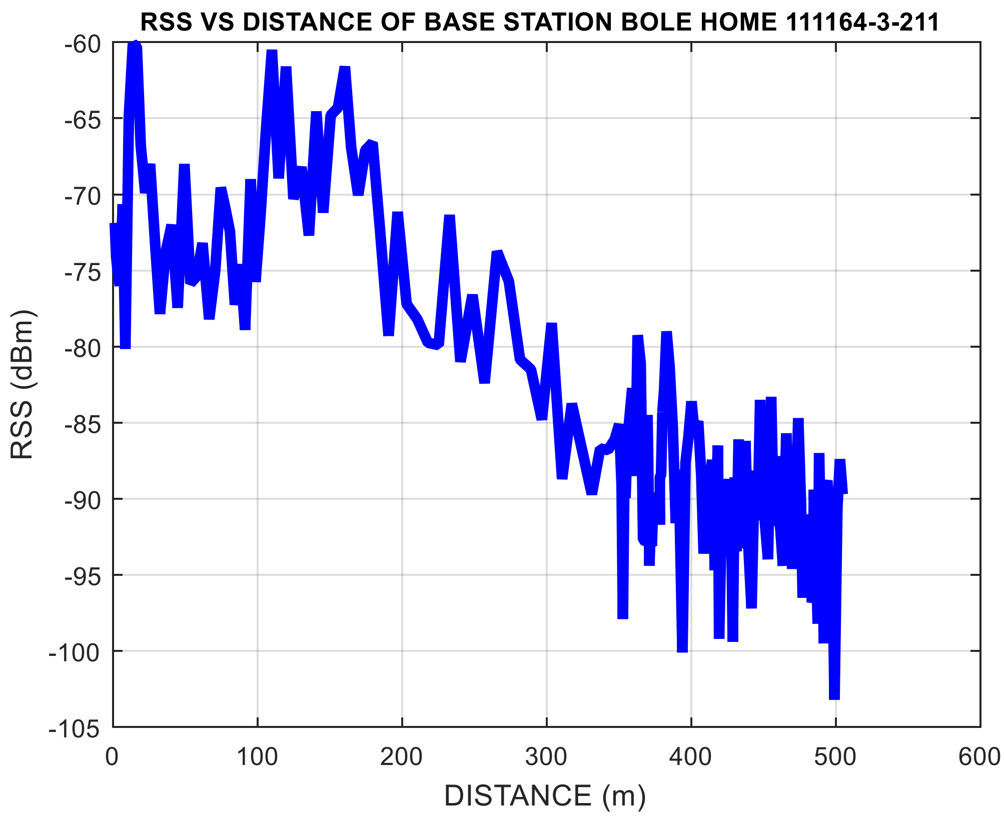


Figure 6.5: Receive Signal Strength for Bole Home.

Fig.6.5 represents the plot of the measured signal strength of the Base Station located at Bole Home. The MATLAB program for this plot is shown in Appendix I.

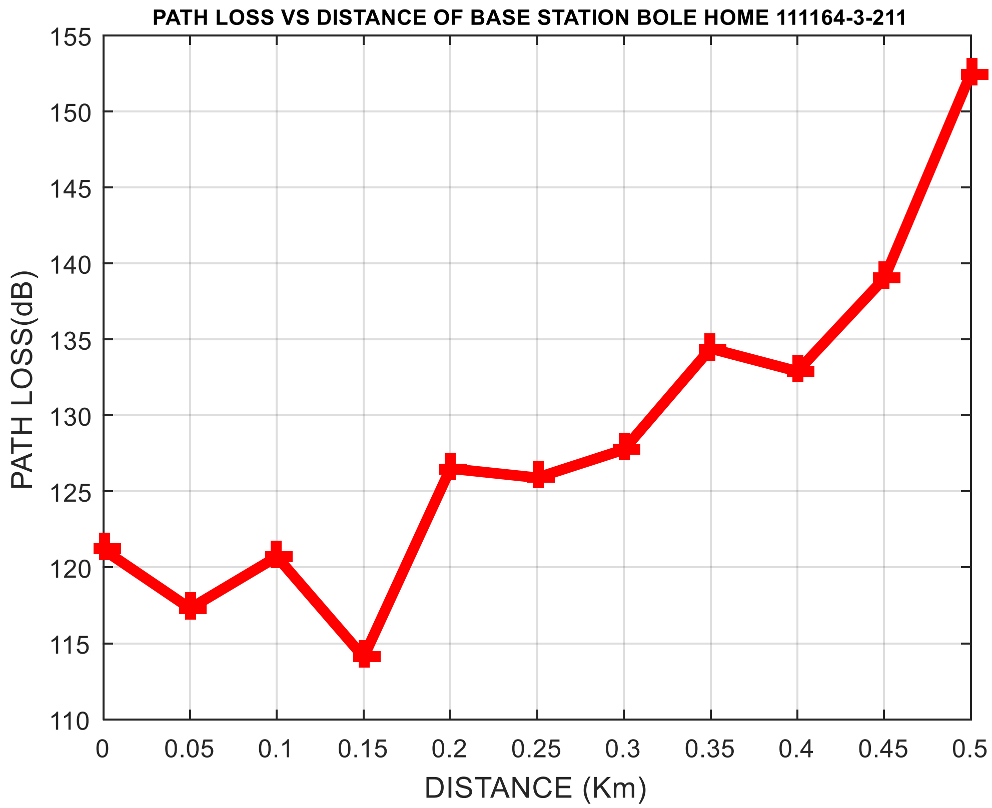


Figure 6.6: Path loss plot for Bole Home.

Fig.6.6 is the plot of the path loss experienced along Bole Home. The MATLAB program for this plot is shown in Appendix J

There was gradual but irregular change of signal loss with distance up till distance of about0.4km before the rise in the path loss again and at 0.35 the path loss is 135 dB. And from 0.4km to0.5 km the path loss increase linearly. This irregular behavior could be attributed to interference of intervening transceiver with and lack of proper signal handover.

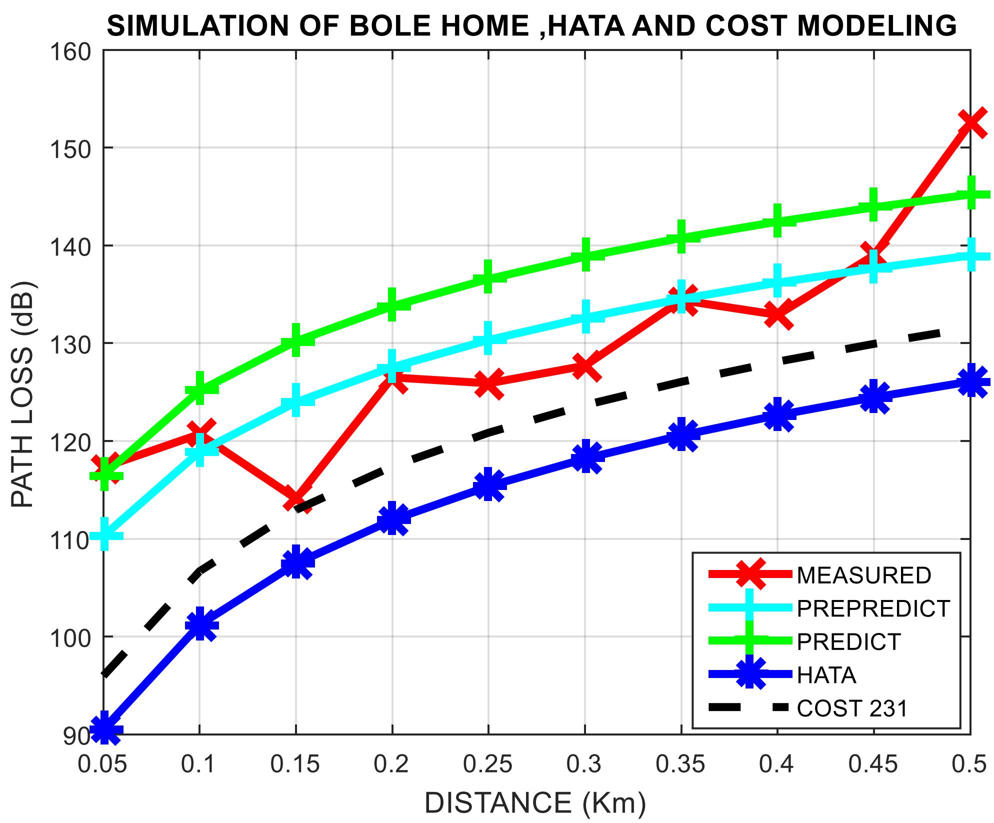


Figure 6.7: comparison of predict and measure model with Hata and COST 231 of Bole Homes (111164-3-211)

Figure 6.7 show a comparison of predict and measured path loss model with Hata and Cost 231 model. This base station is located at Bole Homes and its network code is 111164-3-211. As in section Table5.7 shown the predict Path loss model has 6.24 dB deviation with model path loss model and it has 0.624 mean squared error (MSE). As in the table5.10 and 5.11 shown the path loss exponent and reference predict are 2.87 and 110.27 dB respectively. And at 0.05 km the measured path loss is 117.3 dB and predict path loss is 110.27 dB and Hata model at this distance 99.69dB and Cost 231 Model at 0,05km has 105.166 dB.In the same way path loss at 0.5km were 152.5 dB ,145 dB,135.28 dB and Cost 231 model has140.7 dB so it is near to predicted model . As shown in figure 5.9 the predict and measured path loss model nearly match with Cost 231 than Hata model so this base station(111164-3-211) modeled with cost 231.

- The model of111421-1-165(Bole Homes) is

PL (dB) =116.51+ 28.7log(d/d_o)

Table 6.7: Different Parameter for Summit Savory

Network I.D	Path loss exponent	Reference Path loss(dB)	Standard Deviations(dB)	MSE	Antenna Coverage(m)
111162-2-137	2.58	101.59	7.58	0.758	1796

Table 6.8: signal status for Summit Savory (111162-2-137)

Distance (km)	Calculated path loss (dB)	Signal status
0.05	109.20	Good
0.10	116.40	Good
0.15	121.50	Good
0.20	124.70	Good
0.25	127.20	Good
0.30	129.30	Good
0.35	131.00	Good
0.40	132.50	Good
0.45	133.80	Good
0.50	135.00	Good

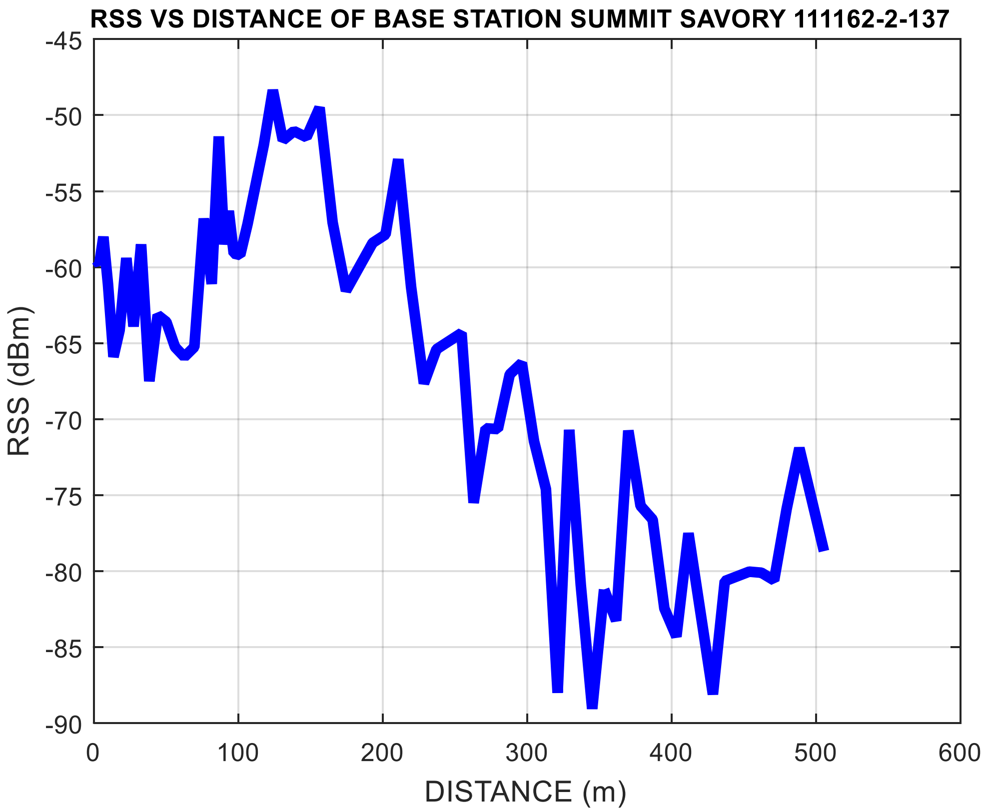


Figure 6.8: Figure 6.9: Receive Signal Strength for Summit Savory.

Fig.6.8 represents the plot of the measured signal strength of the Base Station located at Summit Savory. The MATLAB program for this plot is shown in Appendix L.

The received signal level along this rout indicates rapid increase of signal level with a little change in the distance. The sharp fall in the received level at a point may be as a result of improper hand over among the cells.

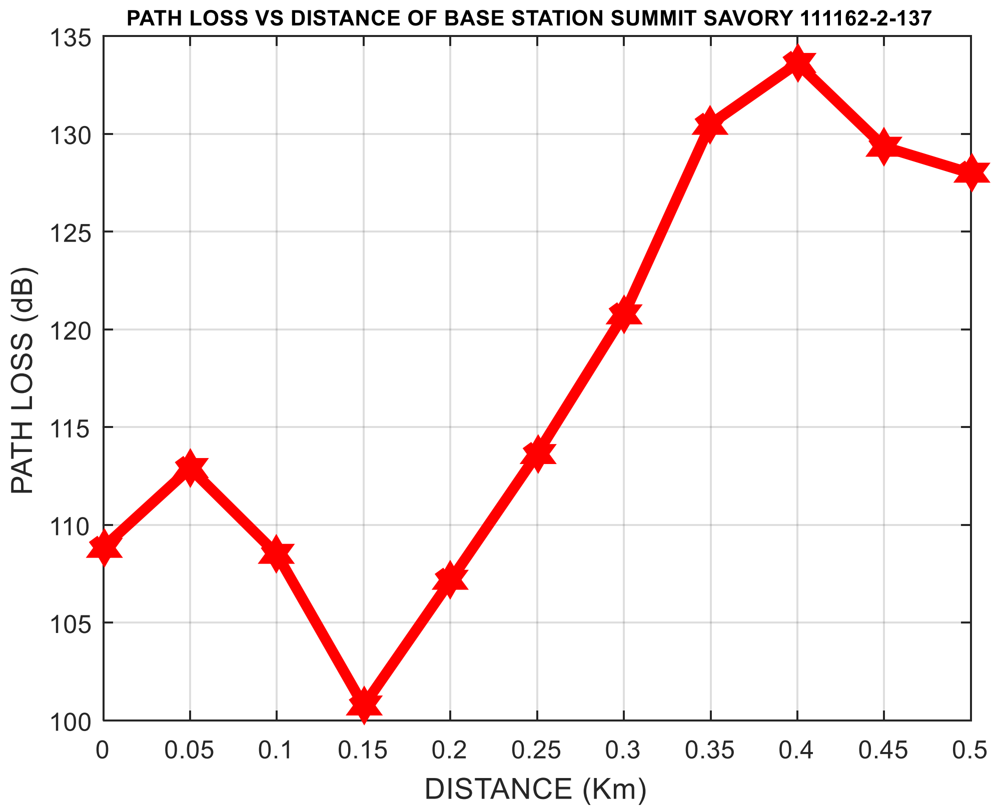


Figure 6.9: Path loss plot for Summit Savory.

Fig.6.9 is the plot of the path loss experienced along Summit Savory. The MATLAB program for this plot is shown in Appendix M.

From starting point to 0.05 the path loss increase linearly and from0.05km to 0.15km the signal improve ,the path loss decrease from 113dB to100dB.As shown from the plot from 0.15km to 0.4km the path loss increase from100dB to133dB.

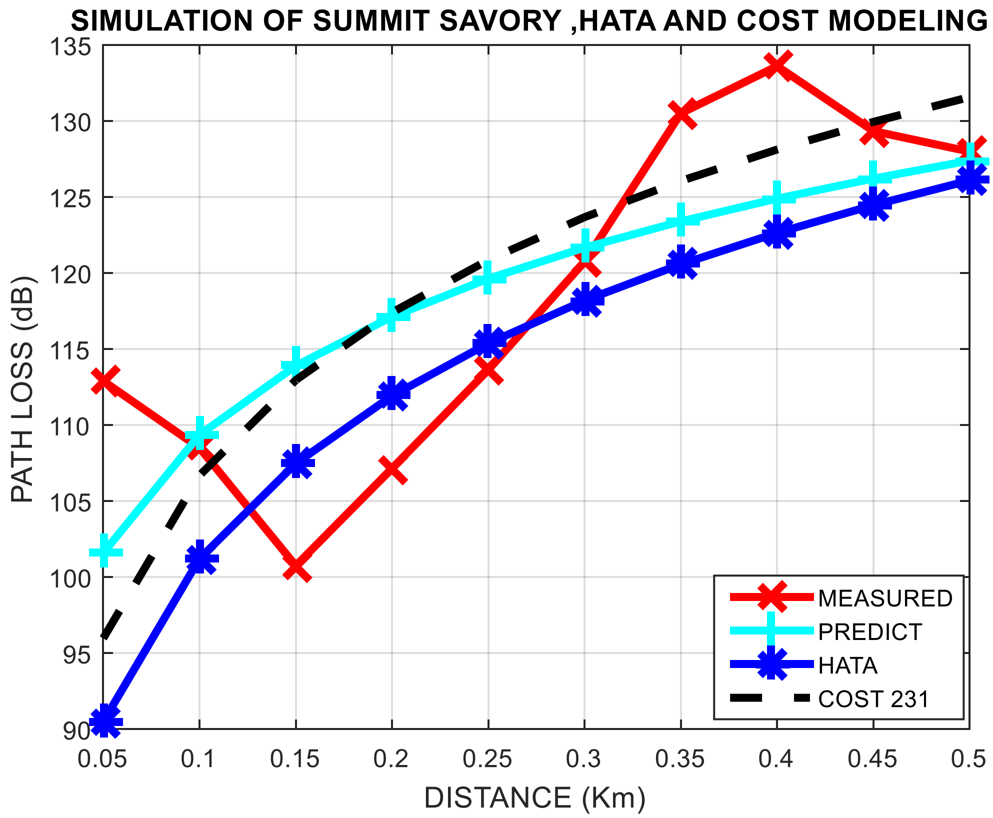


Figure 6.10: comparison of predict and measure model with Hata and COST 231 of Summit Savory (111162-2-137)

Figure 6.10 show comparison of predict and measured path loss model with Hata and Cost 231 model. The MATLAB program for this plot is as shown in Appendix N.

This base station is located of Summit Savory with network code 111162-2-137.As shown in above figure the measured path loss high at the beginning (112.9dB for0.05km) and 108.5dB for 0.10km and100dB for0.15km this effect show there is shadow at the starting of drive test and there was line of sights communication from 100m to200m. As in section Table 5.8 shown the predict Path loss model has 7.58 dB deviation with model path loss model and it has 0.758 mean squared error (MSE). As in the table 5.4 and 5.9 shown the path loss exponent and reference predict path loss are 2.58 and 101.59 dB respectively. And at 0.05 km the measured path loss is 112.9 dB and predict path loss is 109.17 dB and Hata model at this distance 99.69dB and Cost 231 Model at 0,05km has 105.166 dB.In the same way path loss at 0.5km were 127.98 dB ,134.97 dB,135.28 dB and Cost 231 model has140.7 dB so it is near to predict model . As shown in figure 5 the predict and measured path loss model nearly match with Cost 231 than Hata model so this base station(111164-3-211) modeled with cost 231.

- The model of111421-1-165(Summit Savory) is pL (dB) =109.17+25.8log(d/d_o)

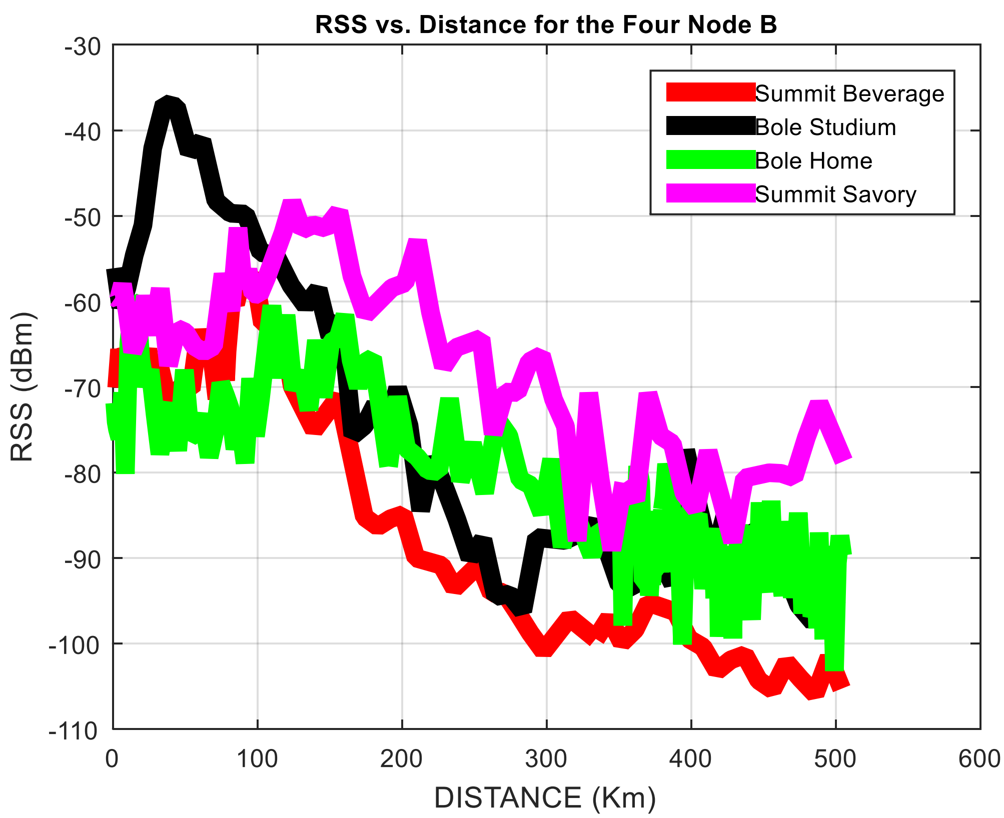


Figure 6.11: the receive signal strength for four base station

Fig.6.11 shows the RSS for four eNodeB. The MATLAB code shown in Appendix O.

The RSS of Bole Stadium show high level between 0.01km to0.1km.But Summit Savory have good signal form0.1km to 0.5km.and Summit Beverage show poor and the worst case throughout the route.

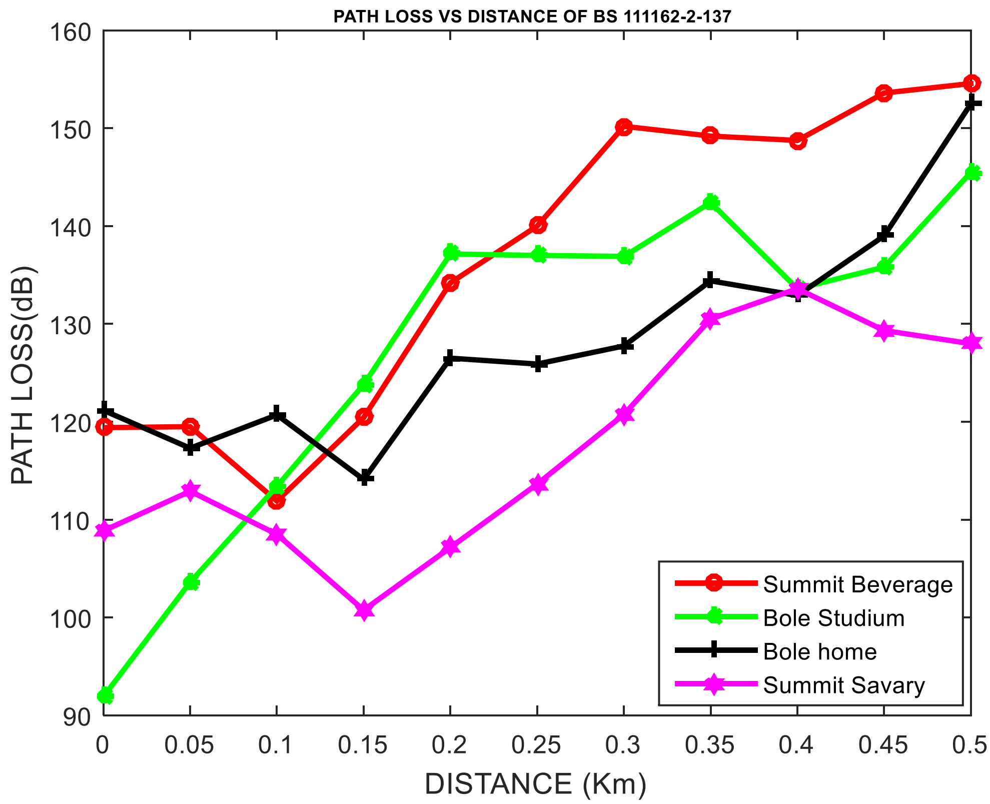


Figure 6.12: the path loss for the four Base stations

Fig.6.12 show the path loss for the four base station. The MATLAB code for this graph shown in Appendix P.

Unlike the figure 6.15 this plot show the reverse of the RSS the summit Beverage have large path loss amount and summit savory show small amount of path loss this indicate Summit Savory have good signal quality and good antenna coverage

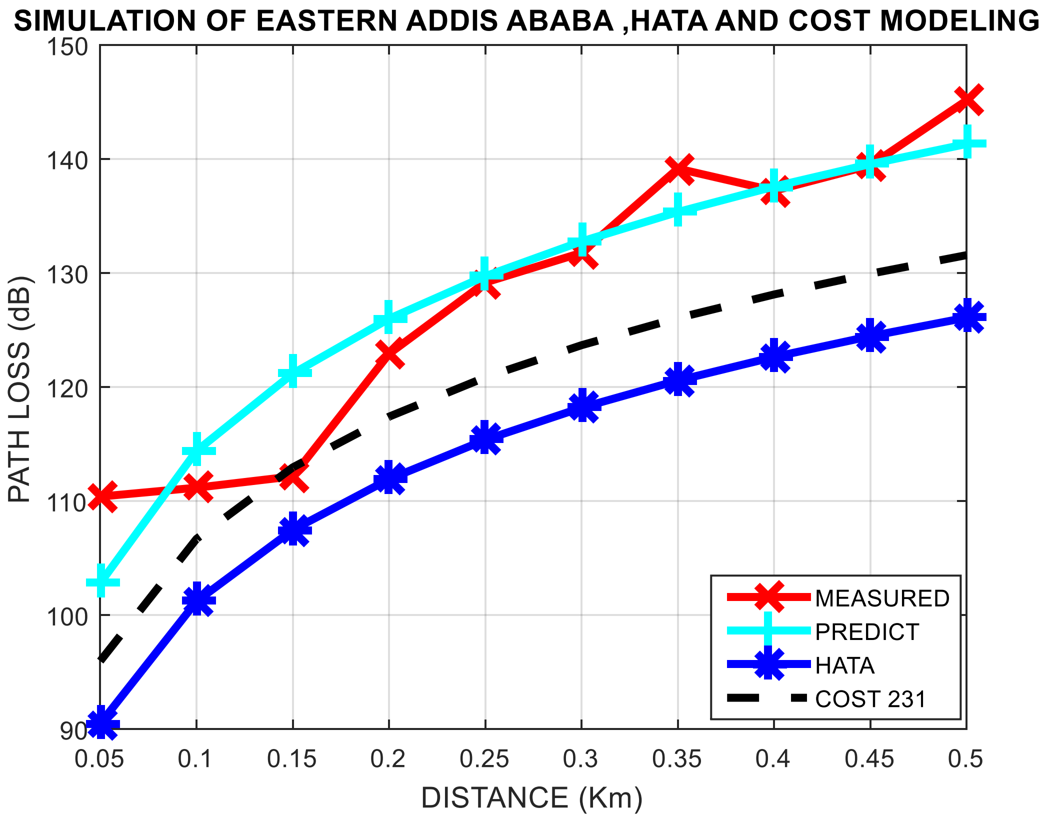


Figure 6.13: Comparison of Eastern Addis Ababa average model with Hata and COST 231

Figure 6.13 show comparison of predict and measured model path loss with Hata and Cost 231 model .The MATLAB program for this plot is shown in Appendix Q.

This model is average for the four base stations. As in section Table 5.9 shown the predict Path loss model has 4.4 dB deviation with model path loss model and it has 0.44 mean squared error(MSE). As in the table5.4 and 5.9 shown the path loss exponent and reference predict path loss are 3.85 and 102.81 dB respectively. And at 0.05 km the measured path loss is 110.4 dB and predict path loss is 107.21 dB and Hata model at this distance 99.69dB and Cost 231 Model at 0.05km has 105.166 dB In the same way path loss at 0.5km were 145.13 dB ,145.71 dB,135.28 dB and Cost 231 model has140.7 dB so it is near to predict model . As shown in figure 5.11 the predict and measured path loss model nearly match with Cost 231 than Hata model so this average base station modeled as Cost 231.

Based on this thesis it cover modeling, analysis and simulation of Eastern Addis Ababa area by using measured data that are collected from different base station. Using linear regression method and MATLAB software analysis and simulation done. And the modeling of this area matches with Cost 231 modeling. The environment of Eastern Addis Ababa group under shadowed urban cellular radio.

CHAPTER SEVEN

7.1 Conclusion

In this thesis cover main theory of large scale path loss principle. It is case study and focus in Eastern Addis Ababa selected site (base stations). Drive Test done as main methodology of the thesis. In this drive test collected receive signal strength from 4 different sites. Based on this path loss exponent, reference path loss, standard deviation and MSE were found for four base station found in Bole Home, Bole International Stadium, Summit Savory and Summit Beverage.

The two base stations (Bole Home and Summit Savory) are good signal strength and environment for mobile communication. Two base stations are found in Bole International Stadium and Summit Beverage are signal loss and obstructed by building.

In this work the path loss of the measured and predicted models are discussed. The selected sites are Bole Homes, Bole Intentional Stadium, Summit Beverage and Summit Savory. The path loss exponent for the above four eastern Addis Ababa place are **2.87, 5.38, 4.55** and **2.58** respectively. And standard deviation was evaluated as **6.24**dB, **4.78**dB, **6.11**dB and **7.58**dB respectively. Based on the data collected and analysis done a path loss model that was developed as '$\mathbf{P_L = 114.5 + 45.5 \log (d/d_o)}$' for Summit Beverage. For Bole International Stadium the path loss model are '$\mathbf{P_L=95.9+53.8\log (d/d_o)}$'. For Bole Homes modeling and Summit Savory '$\mathbf{P_L=116.5+28.7 \log (d/d_o)}$' and '$\mathbf{P_L=109.17+25.8 \log (d/d_o)}$'respectively. And MATLAB 2015 was used for simulation. Thereafter, the proposed models were compared with Hata model and COST 231 model. From all indications, these classical models did overestimate the path losses within the Eastern Addis Ababa environments. Thus, the proposed models are best deployed in the environment under study for 2.1GHz Communication networks, followed by COST 231 model.

7.2 Recommendations

Based on the observation made on this research work, this study therefore recommends that:

1. Based on the result Summit Beverage and Bole International Stadium have weak signal. In Summit Beverage the path loss exponent was 4.55 and the signal was poor from 350m to 450 m and there is no communication above 500m (path loss was160 dB). And its antenna coverage radius was 290.93m. In the same way in Bole International Stadium antenna radius of coverage was 491.51m and it has fair signal between 300m and 450 and communication block above 500m. So it needs to upgrade the base stations.
2. For each Base Station based on their antenna radius of coverage software program should be prepare and planned in such a way that they intersect one another in order to facilitate call hand offs between adjacent cell.
3. 3G Network operators at the stated frequency should mount Bi-sector high gain antenna that will ensure wide and all round signal coverage especially for Summit Beverage and Bole International Stadium to improve poor signal quality because of shadow happening with tall building.
4. The network under study should also resolve the issue of antenna azimuth encountered along Engineering complex back gate by adjusting the antenna properly.

7.3 Contributions to Knowledge

1. The research realized path loss exponents for the Eastern Addis Ababa at frequency of 2.1GHz. This enables the 3G network operators to understand the rate at which the signal loss varies with distance.
2. The research developed a measurement-based path loss models for Eastern Addis Ababa as '$\mathbf{P_L}$ **=114.5 + 45.5 log (d/$\mathbf{d_o}$)**' for Summit Beverage. For Bole International Stadium the path loss model are '$\mathbf{P_L}$**=95.9+53.8log (d/$\mathbf{d_o}$)**'. For Bole Homes modeling and Summit Savory '$\mathbf{P_L}$**=116.5+28.7 log (d/$\mathbf{d_o}$)**' and '$\mathbf{P_L}$**=109.17+25.8 log (d/$\mathbf{d_o}$)**'respectively. This models will assist the 3G Network operators using frequency of 2.1GHz in Eastern Addis Ababa metropolis understand that the path loss experienced in the environment, at a close-in distance of 0.05 km is about **114.5dB** , **95.9 dB**, **116.5** ,and **109.17** for Summit Beverage, Bole International Stadium, Bole Homes modeling and Summit Savory respectively , while subsequent signals received at intervals of this distance is dependent on the factors " **45.5 log (d/$\mathbf{d_o}$)"** and "**53.8log (d/$\mathbf{d_o}$)**" ," **28.7 log (d/$\mathbf{d_o}$)**" and" **25.8 log (d/$\mathbf{d_o}$)**" respectively.
3. It also generated the standard deviations between the measured path losses and the predicted path losses. This helps to envisage the extent the predicted path losses deviated from the measured path loss values.

   The above information can be used as a platform and benchmark to aid in the 3G system optimization process for improved performance for service providers in Eastern Addis Ababa metropolis.

7.4 Recommendation for Further Work

This work was carried out during the dry season. Since external factors such as rain, wind, etc are found to influence path loss, further study and verification should be done on the empirical modeling of the path loss during the rainy seasons to improve the reliability of the model.

Reference

[1] T.S.Rappaport, wireless communication :principle and practice , singapor : pearson education, 2002.

[2] Peter Stavroulakis, "The Wireless Channel Characteristics and coding," British Library Cataloguing, 2003,pp. 47-82.

[3] A. Gold smith, wireless communications , cambridge university press, 2005.

[4] Ali Award, "Propagation Path Loss Model in Cell Phone system," M.S thesis, Dept. Information and Computer Eng., Syrian Private University, 2015.

[5] J.D. Parsons, The Mobile Radio Propagation Channel, New York, John Wiley & Sons, 2000.

[6] Marvin K. Simon, Digital Communication over Fading Channels, USA, John Wiley & Sons, ,2000.

[7] Alessandro Andrade's, Giovanni Giambene, "Protocols for high- efficiency wireless networks ", New York, Kluwer Academic Publishers, 2003.

[8] Wolfgang Granzow,"3rd Generation Mobile Communications Systems", Ericsson Euro lab Deutschland, pp 89-94,2000.

[9] Prabhakar Chitrapu, "Wideband TDD", IOSR Journal of Applied Physics(IOSR-JAP), VOLUME 3,Issue 4,pp08-18, 2013.

[10] Shinsuke Hara, Ramjee Prasad, "Multicarrier Techniques for 4G Mobile Communications" Artech House, USA, 2013.

[11] Yuvraj Singh, "Comparison of Okumura, Hata and COST-231 Models", International Journal of Advanced Research in Communication Engineering"Vol 3 ,Issue 1 pp 5004-5008, December 2014.

[12] Joseph Isabona," On Propagation Path Loss Models For 3-G Based Wireless Networks Comparative Analysis, " M.S. Thesis, University of Uyo, Nigeria, January 2010

[13] M. A. Alim, M. M. Rahman," Analysis of Large-Scale Propagation Models for Mobile Communications in Urban Area", Bangladesh, Khulna University, *Vol. 7, No. 1, 2010*

[14] Nkwachukwu Chukwuchekwa, "Signal Strength Evaluation of a 3G Network in Owerri Metropolis Using Path Loss Propagation Model at 2.1GHz," M.S. thesis,Owerri,Nigeria ,2016.

[15] Lokesh Kumar Ary, "wireless Communication",Jaipur,2016.

[16] M.R. Karim and M. Sarraf," W-CDMA and cdma2000 for 3G Mobile Networks" ,McGraw-Hill,USA,2009.

[17] Peter Stavroulakis, "Interference Analysis and Reduction for Wireless Systems", Artech House, British, 2010.

[18] J.D. Parsons," The mobile Radio Propagation Channel", John Wiley & Sons Inc, USA, 2011

[19] N.T. Surajudeen Bakinde, N. Faruk, "Comparison of Propagation Models for GSM 1800 and WCDMA Systems in Selected Urban Areas of Nigeria", Huawei Technologies & Co. Ltd, Kano, Nigeria ,2012.

[20] X. Wang, "OFDM and its application to 4G, Wireless and Optical Communications", IEEE 2005. Mag., Vol. 23, No. 6, pp. 19-27, December 2005.

[21] 3GPP, "Technical specifications Group Radio Access Network; High Speed Packet Access (HSPA) evolution Frequency Division Duplex (FDD); Release6 and Release 7, TR 25.999; http://www.3gpp.org/

[22] 3GPP, "Technical specifications Group Radio Access Network; Scope of High Speed Packet Access (HSPA) Evolution for 1.2 Mcps TDD"; Release 8, TR 25.824; http://www.3gpp.org/

[23] Internet World Statistics. [Online] http://www.lteforum2010.com/

[24] 3GPP, "Technical specifications Group Radio Access Network; Requirements for further advancements for Evolved Universal Terrestrial Radio Access (EUTRA) (LTE-Advanced)"; Release 8, 36.913; http://www.3gpp.org/

[25] 3GPP, "Technical Speciation Group Radio Access Network; Feasibility study for Further Advancements for E-UTRA (LTE-Advanced); Release 9, TR 36.912; http://www.3gpp.org/

[26] 3GPP, "Technical Specification Group Radio Access Network; UTRAN Iu Interface:

General aspects and principles; Release 4, Release 5 and Release 7, TS 25.410; http://www.3gpp.org/

[27] M. Bauer, P. Schefczik and M. Soellner; Evolution of the UTRAN architecture, 3G Mobile Communication Technologies, IEEE 2004, pp. 244 - 248, November 2004.

[28] 3GPP, "Technical specifications Group Radio Access Network; UTRAN Implementation Specific O&M Transport; Release 4, Release 5 and Release 7, TS 25.442; http://www.3gpp.org/ , 14 September 2014.

[29] E. Dahlman, S. Parkvall, J. Sk□old and P. Beming; "3G EVOLUTION: HSPA and LTE for Mobile Broadband", Second Edition, Academic Press 2008.

[30] 3GPP, "Technical Specification Group Radio Access Network; UTRAN Iu interface RANAP signaling; Release 4, Release 5 and Release 7, TS 25.413; http://www.3gpp/, 18April 2013.

Appendix

Appendix A

% for receive signal strength for four Base Station

```
a1=[2.61828,4.619789,6.621297,8.956391,11.441811,17.463,20.71,24.19...
27.30,30.67,37.48,40.81,47.48,50.93,54.16,57.38,60.75,63.77,66.80...
69.69,71.96,73.90,75.54,77.94,78.98,82.16,84.92,88.81,92.99,98.04...
103.43,116.85,124.00,139.14,156.20,173.95,183.20,192.01,200.81,209.61...
227.33,236.14,253.30,261.66,270.57,279.37,288.62,297.85,315.91,333.95...
343.18,351.97,361.20,370.31,389.21,398.44,408.11,417.78,427.34,437.01...
446.68, 456.24,465.91,475.58,485.69,495.25,504.04];



length(a1);
b1=[-70.1,-65.6,-68.8,-65.6,-66.27,-69.4,-67.7,-65.6,-69,-66.4,-71.2...
    -71.37,-69.93,-70.2,-70.3,-66.23,-63.4,-65.2,-64.9,-68.1,-71.4...
-69.65,-65,-69.25,-65.83,-59.6,-60.3,-57.5,-57.45,-57.03,-62.6,-62.87...
-69.95,-75.03,-71.13,-85.2,-86.33,-85.4,-84.9,-90,-90.85,-93.53,-90.7...
-94.1,-94,-96.25,-98.75,-100.9,-96.97,-99.45,-97,-99.9,-98.37,-95.2...
-96.3,-99.45,-100.4,-103.2,-101.9,-101.3,-104.3,-105.4,-102.2,-104.1...
-105.9,-101.6,-105.27];
length (b1);


subplot(2, 2, 1)
plot(a1,b1,'-r','linewidth',2,'markersize',5)
xlabel('DISTANCE (m)')
ylabel('RSS (dBm)')
grid
title('SIMULATION OF BASE STATION 111583-2-133','FontSize',7)

 c1= [1.66,5.43,9.77,14.77,20.78,27.53,35.47,43.96,52.76,61.55,71.22...
81.23,91.67,102.23,112.67,123.21,133.21,142.00,150.01,157.92,165.94...
173.85,181.43,189.34,196.92,204.83,212.87,220.88,229.42,237.93,246.90...
255.93,264.68,274.17,283.46,293.02,312.46,321.82,331.44,340.97,350.08...
359.34,368.74,377.71,387.12,396.18,405.44,414.60,424.08,433.70,443.57...
453.95,463.96,474.30,484.27,494.24,504.47];

length(c1);


d1= [ -56.1,-60.7,-58.4,-54.6,-51.1,-42.1,-36.9,-37.25,-42.6,-41.2...
    -48.25,-49.7,-49.8,-54.3,-54.6,-58.15,-60.5,-58.6,-64.1,-62.1,-75.65...
-74.55,-72.05,-74.6,-70.15,-74.5,-84.45,-78.3,-81.7,-85.5,-90.0,-87.85...
-94.5,-94.2,-96.2,-87.6,-87.95,-87.2,-85.9,-88.65,-93.1,-93.65,-87.6...
-89.8,-93.0,-77.4,-84.3,-90.5,-84.55,-88.4,-86.9,-86.5,-91.05,-95.5,-97.5...
-95.55,-96.2];
length(d1);
```

```
subplot(2,2,2)
plot (c1, d1,'-k','linewidth', 2,'markersize', 5)

xlabel('DISTANCE (m)')
ylabel ('RSS (dBm)')
grid
title ('RSS VS DISTANCE OF BASE STATION 111421-1-165','FontSize', 7.1)




e1= [ 1.30,2.28,3.17,4.82,6.81,8.61,11.03,13.84,16.55,19.27,22.37,25.71...
29.18,32.54,36.42,40.62,44.82,49.44,53.63,57.80,61.98,66.59,70.78,74.65...
77.96,80.96,84.39,88.13,91.43,95.27,98.62,102.07,105.81,109.99,114.63...
119.74,124.89,130.39,135.58,140.73,145.45,150.63,155.69,160.47,164.78...
169.65,174.56,179.59,184.71,190.67,196.93,203.15,210.54,217.88,225.31...
232.85,240.38,248.68,257.09,265.66,273.84,281.58,289.13,296.71,303.44...
310.69,317.41,331.25,336.99,342.39,347.11,350.15,351.85,352.74,353.62...
354.07,354.53,355.74,357.08,359.17,361.26,362.93,365.03,366.69,368.46...
369.67,370.11,371.02,371.79,372.70,373.91,374.41,375.85,376.63,377.94...
378.27,378.27,379.16,380.07,381.28,382.93,385.02,387.22,389.31,391.39...
393.92,396.01,398.10,400.18,402.27,404.81,406.91,408.57,410.67,412.77...
414.45,415.78,416.28,417.08,417.57,418.45,419.29,420.64,422.33,424.01...
426.14,427.50,427.957825,428.73,429.62,430.07,431.36,432.75,435.33...
437.45,439.56,441.72,443.83,445.97,447.65,449.35,453.06,455.28...
457.10,458.58,459.13,460.15,461.54,463.41,465.73,468.00,469.87,472.10...
474.02,475.89,477.06,477.95,478.94,479.83,480.81,481.80,482.44,483.43...
484.37,484.82,486.11,487.49,488.47,489.83,490.72,491.76,492.65,494.12...
495.56,497.15,499.08,501.07,502.87,504.74];

length(e1);

f1= [-71.87,-74.1,-74.95,-76,-70.65,-80.15,-64.9,-60.1,-60.3,-66.8,-69.9...
-68,-73.2,-77.85,-73.83,-72,-77.45,-68,-75.85,-75.4,-73.2,-78.2,-75.0...
-69.55,-71,-72.45,-77.25,-74.6,-78.9,-69,-75.75,-71.4,-65.9,-60.5,-68.95...
-61.6,-70.3,-68.2,-72.7,-64.55,-71.2,-64.8,-64.3,-61.6,-66.9,-70.05...
-67.1,-66.6,-72.3,-79.3,-71.15,-77.2,-78.2,-79.75,-79.9,-71.35,-81,-76.6...
-82.4,-73.75,-75.7,-80.85,-81.5,-84.8,-78.45,-88.7,-83.75,-89.7,-86.7...
-86.8,-86.1,-85.1,-89.15,-97.9,-89.7,-89.4,-89.95,-86.55,-84.9,-82.73...
-88.5,-79.25,-81.1,-92.7,-92.8,-84.5,-86.6,-94.4,-92.4,-93.1,-89.8,-91.4...
-91.05,-91.5,-89.6,-91.7,-88.6,-88.4,-84.3,-82.8,-79,-81.3,-85.3,-91.6...
-88.1,-100.1,-87.65,-85.9,-83.6,-85.7,-84.9,-88.45,-93.6,-90.15,-88.7...
-87.45,-92.3,-94.7,-89.3,-88.8,-86.5,-99.2,-93.15,-89.7,-92.65,-88.7...
-92.95,-93.85,-99.4,-92.05,-88.6,-93.45,-86.1,-93.25,-86.2,-93.2,-97.2...
-88.15,-91.4,-83.5,-89.7,-93.97,-83.3,-91.55,-88.3,-87.2,-91.4,-91.85...
-94.4,-85.7,-91.1,-94.6,-91,-84.7,-90.3,-96.5,-93.4,-91.8,-94.05,-91.8...
-91.05,-93.95,-96.8,-96.45,-89.4,-93.2,-98.2,-87,-94,-94.45,-99.5,-89.4...
-88.8,-91.15,-90.9,-103.2,-90.55,-87.4,-89.7];

length(f1);
```

```
subplot(2,2,3)
plot (e1, f1,'-g','linewidth', 2,'markersize', 5)
xlabel('DISTANCE (m)')
ylabel ('RSS (dBm)')
grid
title ('RSS VS DISTANCE OF BASE STATION 111164-3-211','FontSize', 7)



g1= [1.73,3.84,6.62,9.85,13.63,17.86,22.53,27.54,32.76,38.44,44.23,50.24...
  56.24,62.71,69.60,76.16,81.63,86.52,90.33,93.44,96.89,101.36,106.49...
 117.72,123.96,130.87,138.58,147.27,156.32,165.33,174.60,193.07,201.98...
210.77,219.67,228.56,237.25,254.60,262.96,271.30,279.75,287.99,296.33...
304.79,313.02,321.13,329.15,337.15,345.05,353.29,361.63,370.09,378.55...
386.89,395.02,403.36,411.71,428.62,436.85,453.76,462.22,471.01,479.68...
488.48,505.51];

h1= [-59.55,-59.8,-58,-61.15,-65.9,-64.15,-59.4,-63.9,-58.5,-67.5,-63.15...
-63.6,-65.25,-65.9,-65.25,-56.8,-61.1,-51.4,-58.5,-56.3,-59.1,-59.2...
-57.15,-51.95,-48.35,-51.65,-51.05,-51.45,-49.5,-57.05,-61.55,-58.4...
-57.85,-52.9,-61.3,-67.65,-65.4,-64.33,-75.5,-70.6,-70.65,-67.05,-66.3...
-71.45,-74.6,-88,-70.7,-80.9,-89.05,-81.2,-83.25,-70.75,-75.7,-76.6...
-82.45,-84.3,-77.5,-88.1,-80.65,-80.03,-80.1,-80.6,-75.9,-71.9,-78.68];



subplot(2,2,4)

plot (g1, h1,'-m','linewidth',2,'markersize',5)
xlabel ('DISTANCE (m)')
ylabel ('RSS (dBm)')
grid
title ('RSS VS DISTANCE OF BASE STATION 111162-2-137','FontSize',7)
```

Appendix B

```
% path loss MATLAB code for the four base station

a1=[0:0.05:0.5];
b1=[119.4,119.5,111.9,120.43,134.2,140,150.2,149.2,148.75,153.6,154.57];
subplot(2,2,1)
```

```
 plot (a1, b1,'-or','linewidth',2,'markersize',5)
xlabel ('DISTANCE (Km)')
ylabel ('PATH LOSS (dB)')
grid
title ('PATH LOSS VS DISTANCE OF BASE STATION SUMMIT BEVERAGE 111583-2-
133','FontSize',7)



c1= [0:0.05:0.5];
d1=[105.4,91.9,103.6,113.4,123.8,137.15,136.9,142.4,133.6,135.8,145.5];

subplot(2,2,2)
 plot (c1, d1,'-*g','linewidth',2,'markersize',5)
xlabel ('DISTANCE (Km)')
ylabel ('PATH LOSS (dB)')
grid
title ('PATH LOSS VS DISTANCE OF BASE STATION BOLE INTERNATIONAL STADIUM
111421-1-165','FontSize',7)



e1= [0:0.05:0.5];
f1=[121.17,117.3,120.7,114.1,126.5,125.9,127.75,134.4,132.9,139,152.5];

subplot(2,2,3)
 plot (e1, f1,'-+k','linewidth', 2,'markersize',5)
xlabel ('DISTANCE (Km)')
ylabel ('PATH LOSS(dB)')
grid
title ('PATH LOSS VS DISTANCE OF BASE STATION BOLE HOME 111164-3-
211','FontSize', 7)


g1= [0:0.05:0.5];
h1=[108.85,112.9,108.5,100.75,107.15,113.63,120.75,130.5,133.6,129.33,127.98]
;
subplot(2,2,4)
plot (g1, h1,'-hm','linewidth', 2,'markersize',5)
xlabel ('DISTANCE (Km)')
ylabel ('PATH LOSS (dB)')
grid
title('PATH LOSS VS DISTANCE OF BASE STATION SUMMIT SAVORY 111162-2-
137','FontSize',5)
```

Appendix C

```
% RSS MatLab code for Summit Beverage

a1=[2.61828,4.619789,6.621297,8.956391,11.441811,17.463,20.71,24.19...
    27.30,30.67,37.48,40.81,47.48,50.93,54.16,57.38,60.75,63.77,66.80...
```

```
69.69,71.96,73.90,75.54,77.94,78.98,82.16,84.92,88.81,92.99,98.04...
103.43,116.85,124.00,139.14,156.20,173.95,183.20,192.01,200.81,209.61...
227.33,236.14,253.30,261.66,270.57,279.37,288.62,297.85,315.91,333.95...
343.18,351.97,361.20,370.31,389.21,398.44,408.11,417.78,427.34,437.01...
446.68, 456.24,465.91,475.58,485.69,495.25,504.04];


length(a1);
b1=[-70.1,-65.6,-68.8,-65.6,-66.27,-69.4,-67.7,-65.6,-69,-66.4,-71.2...
    -71.37,-69.93,-70.2,-70.3,-66.23,-63.4,-65.2,-64.9,-68.1,-71.4...
-69.65,-65,-69.25,-65.83,-59.6,-60.3,-57.5,-57.45,-57.03,-62.6,-62.87...
-69.95,-75.03,-71.13,-85.2,-86.33,-85.4,-84.9,-90,-90.85,-93.53,-90.7...
-94.1,-94,-96.25,-98.75,-100.9,-96.97,-99.45,-97,-99.9,-98.37,-95.2...
-96.3,-99.45,-100.4,-103.2,-101.9,-101.3,-104.3,-105.4,-102.2,-104.1...
-105.9,-101.6,-105.27];
length (b1);

plot(a1,b1,'-b','linewidth',4,'markersize',7)
xlabel('DISTANCE (m)')
ylabel('RSS (dBm)')
grid
title('SIMULATION OF BASE STATION SUMMIT BEVERAGE 111583-2-
133','FontSize',10)
```

Appendix D

% path loss MatLab code for Summit Beverage

```
a1=[0:0.05:0.5];
b1=[119.4,119.5,111.9,120.43,134.2,140,150.2,149.2,148.75,153.6,154.57];
 plot (a1, b1,'-or','linewidth',4,'markersize',7)
xlabel ('DISTANCE (Km)')
ylabel ('PATH LOSS (dB)')
grid
title ('PATH LOSS VS DISTANCE OF BASE STATION SUMMIT BEVERAGE 111583-2-
133','FontSize',8)
```

Appendix E

```
%MATLAB code to create graph for SUMMIT BEVERAGE ,Hata and cost 231 model
 d1=0.05:0.05:0.50;
pr1=108.39+45.5*log10(d1/0.05);


m1=[119.5,111.9,120.43,134.2,140,150.2,149.2,148.75,153.6,154.57];
p1=114.5+45.5*log10(d1/0.05);
h1=136.8 +35.59*log10 (d1); %code for HATA model


c1=142.28 +35.59*log10(d1); %code for cost 231
```

```
 plot (d1, m1,'-xr','linewidth', 3,'markersize', 10)

xlabel('DISTANCE (Km)')

ylabel ('PATH LOSS (dB)')

grid

title ('SIMULATION OF SUMMIT BEVERAGE ,HATA AND COST MODELING')

hold on
plot(d1, pr1,'-+c','linewidth', 3,'markersize',10)


plot(d1, p1,'-+g','linewidth', 3,'markersize',10)

plot(d1, h1,'-*b','linewidth', 3,'markersize',10)

plot(d1, c1,'--k','linewidth', 3,'markersize',10)

hold off

legend('MEASURED','PREPREDICT','PREDICT','HATA','COST 231',4)
```

Appendix F

%RSS MatLab code for Bole International Stadium

```
c1= [1.66,5.43,9.77,14.77,20.78,27.53,35.47,43.96,52.76,61.55,71.22...
81.23,91.67,102.23,112.67,123.21,133.21,142.00,150.01,157.92,165.94...
173.85,181.43,189.34,196.92,204.83,212.87,220.88,229.42,237.93,246.90...
255.93,264.68,274.17,283.46,293.02,312.46,321.82,331.44,340.97,350.08...
359.34,368.74,377.71,387.12,396.18,405.44,414.60,424.08,433.70,443.57...
453.95,463.96,474.30,484.27,494.24,504.47];

length(c1);


d1= [ -56.1,-60.7,-58.4,-54.6,-51.1,-42.1,-36.9,-37.25,-42.6,-41.2...
    -48.25,-49.7,-49.8,-54.3,-54.6,-58.15,-60.5,-58.6,-64.1,-62.1,-75.65...
-74.55,-72.05,-74.6,-70.15,-74.5,-84.45,-78.3,-81.7,-85.5,-90.0,-87.85...
-94.5,-94.2,-96.2,-87.6,-87.95,-87.2,-85.9,-88.65,-93.1,-93.65,-87.6...
-89.8,-93.0,-77.4,-84.3,-90.5,-84.55,-88.4,-86.9,-86.5,-91.05,-95.5,-97.5...
```

```
-95.55,-96.2];
length(d1);


plot (c1, d1,'-b','linewidth', 4,'markersize', 7)

xlabel('DISTANCE (m)')
ylabel ('RSS (dBm)')
grid
title ('RSS VS DISTANCE OF BASE STATION BOLE INTERNATIONAL STADIUM  111421-1-165','FontSize', 10)
```

Appendix G

%Path loss MatLabe code for Bole International Stadium

```
c1= [0:0.05:0.5];
d1=[105.4,91.9,103.6,113.4,123.8,137.15,136.9,142.4,133.6,135.8,145.5];

 plot (c1, d1,'-*r','linewidth',4,'markersize',7)
xlabel ('DISTANCE (Km)')
ylabel ('PATH LOSS (dB)')
grid
title ('PATH LOSS VS DISTANCE OF BASE STATION BOLE INTERNATIONAL STADIUM 111421-1-165','FontSize',8)
```

Appendix H

```
%MATLAB code to create graph for BOLE INTERNATIONAL Stadium ,Hata and cost 231 model
 d1=0.05:0.05:0.50;
pr1=91.12+53.8*log10(d1/0.05);


m1=[91.9,103.6,113.4,123.8,137.15,137,142.4,133.6,135.8,145.5];
p1=95.9+53.8*log10(d1/0.05);
h1=136.8 +35.59*log10 (d1); %code for HATA model


c1=142.28 +35.59*log10(d1); %code for cost 231

 plot (d1, m1,'-xr','linewidth', 3,'markersize', 10)

xlabel('DISTANCE (Km)')

ylabel ('PATH LOSS (dB)')
```

```
grid

title ('SIMULATION OF BOLE INTERNATIONAL STADIUM ,HATA AND COST MODELING')

hold on
plot(d1, pr1,'-+c','linewidth', 3,'markersize',10)


plot(d1, p1,'-+g','linewidth', 3,'markersize',10)

plot(d1, h1,'-*b','linewidth', 3,'markersize',10)

plot(d1, c1,'--k','linewidth', 3,'markersize',10)

hold off

legend('MEASURED','PREPREDICT','PREDICT','HATA','COST 231',4)
```

Appendix I

%RSS MatLab code for Bole Home

```
e1= [ 1.30,2.28,3.17,4.82,6.81,8.61,11.03,13.84,16.55,19.27,22.37,25.71...
29.18,32.54,36.42,40.62,44.82,49.44,53.63,57.80,61.98,66.59,70.78,74.65...
77.96,80.96,84.39,88.13,91.43,95.27,98.62,102.07,105.81,109.99,114.63...
119.74,124.89,130.39,135.58,140.73,145.45,150.63,155.69,160.47,164.78...
169.65,174.56,179.59,184.71,190.67,196.93,203.15,210.54,217.88,225.31...
232.85,240.38,248.68,257.09,265.66,273.84,281.58,289.13,296.71,303.44...
310.69,317.41,331.25,336.99,342.39,347.11,350.15,351.85,352.74,353.62...
354.07,354.53,355.74,357.08,359.17,361.26,362.93,365.03,366.69,368.46...
369.67,370.11,371.02,371.79,372.70,373.91,374.41,375.85,376.63,377.94...
378.27,378.27,379.16,380.07,381.28,382.93,385.02,387.22,389.31,391.39...
393.92,396.01,398.10,400.18,402.27,404.81,406.91,408.57,410.67,412.77...
414.45,415.78,416.28,417.08,417.57,418.45,419.29,420.64,422.33,424.01...
426.14,427.50,427.957825,428.73,429.62,430.07,431.36,432.75,435.33...
437.45,439.56,441.72,443.83,445.97,447.65,449.35,453.06,455.28...
457.10,458.58,459.13,460.15,461.54,463.41,465.73,468.00,469.87,472.10...
474.02,475.89,477.06,477.95,478.94,479.83,480.81,481.80,482.44,483.43...
484.37,484.82,486.11,487.49,488.47,489.83,490.72,491.76,492.65,494.12...
495.56,497.15,499.08,501.07,502.87,504.74];

length(e1);

f1= [-71.87,-74.1,-74.95,-76,-70.65,-80.15,-64.9,-60.1,-60.3,-66.8,-69.9...
-68,-73.2,-77.85,-73.83,-72,-77.45,-68,-75.85,-75.4,-73.2,-78.2,-75.0...
-69.55,-71,-72.45,-77.25,-74.6,-78.9,-69,-75.75,-71.4,-65.9,-60.5,-68.95...
-61.6,-70.3,-68.2,-72.7,-64.55,-71.2,-64.8,-64.3,-61.6,-66.9,-70.05...
-67.1,-66.6,-72.3,-79.3,-71.15,-77.2,-78.2,-79.75,-79.9,-71.35,-81,-76.6...
-82.4,-73.75,-75.7,-80.85,-81.5,-84.8,-78.45,-88.7,-83.75,-89.7,-86.7...
```

```
-86.8,-86.1,-85.1,-89.15,-97.9,-89.7,-89.4,-89.95,-86.55,-84.9,-82.73...
-88.5,-79.25,-81.1,-92.7,-92.8,-84.5,-86.6,-94.4,-92.4,-93.1,-89.8,-91.4...
-91.05,-91.5,-89.6,-91.7,-88.6,-88.4,-84.3,-82.8,-79,-81.3,-85.3,-91.6...
-88.1,-100.1,-87.65,-85.9,-83.6,-85.7,-84.9,-88.45,-93.6,-90.15,-88.7...
-87.45,-92.3,-94.7,-89.3,-88.8,-86.5,-99.2,-93.15,-89.7,-92.65,-88.7...
-92.95,-93.85,-99.4,-92.05,-88.6,-93.45,-86.1,-93.25,-86.2,-93.2,-97.2...
-88.15,-91.4,-83.5,-89.7,-93.97,-83.3,-91.55,-88.3,-87.2,-91.4,-91.85...
-94.4,-85.7,-91.1,-94.6,-91,-84.7,-90.3,-96.5,-93.4,-91.8,-94.05,-91.8...
-91.05,-93.95,-96.8,-96.45,-89.4,-93.2,-98.2,-87,-94,-94.45,-99.5,-89.4...
-88.8,-91.15,-90.9,-103.2,-90.55,-87.4,-89.7];

length(f1);



plot (e1, f1,'-b','linewidth', 4,'markersize', 7)
xlabel('DISTANCE (m)')
ylabel ('RSS (dBm)')
grid
title ('RSS VS DISTANCE OF BASE STATION BOLE HOME 111164-3-211','FontSize',
10)
```

Appendix J

%Path loss Mat Lab code Bole Home

```
e1= [0:0.05:0.5];
f1=[121.17,117.3,120.7,114.1,126.5,125.9,127.75,134.4,132.9,139,152.5];
 plot (e1, f1,'-+r','linewidth', 4,'markersize',7)
xlabel ('DISTANCE (Km)')
ylabel ('PATH LOSS(dB)')
grid
title ('PATH LOSS VS DISTANCE OF BASE STATION BOLE HOME 111164-3-
211','FontSize', 8)
```

Appendix K

```
%MATLAB code to create graph for BOLE HOME ,Hata and cost 231 model
 d1=0.05:0.05:0.50;
pr1=110.27+28.7*log10(d1/0.05);

m1=[117.3,120.7,114.1,126.5,125.9,127.7,134.4,132.9,139.0,152.5];
p1=116.51+28.7*log10(d1/0.05);
h1=136.8 +35.59*log10 (d1); %code for HATA model

c1=142.28 +35.59*log10(d1); %code for cost 231

 plot (d1, m1,'-xr','linewidth', 3,'markersize', 10)

xlabel('DISTANCE (Km)')
```

```
ylabel ('PATH LOSS (dB)')

grid

title ('SIMULATION OF BOLE HOME ,HATA AND COST MODELING')

hold on
plot(d1, pr1,'-+c','linewidth', 3,'markersize',10)


plot(d1, p1,'-+g','linewidth', 3,'markersize',10)

plot(d1, h1,'-*b','linewidth', 3,'markersize',10)

plot(d1, c1,'--k','linewidth', 3,'markersize',10)

hold off

legend('MEASURED','PREPREDICT','PREDICT','HATA','COST 231',4)
```

Appendix L

%RSS MatLab code summit Savory

```
g1= [1.73,3.84,6.62,9.85,13.63,17.86,22.53,27.54,32.76,38.44,44.23,50.24...
  56.24,62.71,69.60,76.16,81.63,86.52,90.33,93.44,96.89,101.36,106.49...
 117.72,123.96,130.87,138.58,147.27,156.32,165.33,174.60,193.07,201.98...
210.77,219.67,228.56,237.25,254.60,262.96,271.30,279.75,287.99,296.33...
304.79,313.02,321.13,329.15,337.15,345.05,353.29,361.63,370.09,378.55...
386.89,395.02,403.36,411.71,428.62,436.85,453.76,462.22,471.01,479.68...
488.48,505.51];

h1= [-59.55,-59.8,-58,-61.15,-65.9,-64.15,-59.4,-63.9,-58.5,-67.5,-63.15...
-63.6,-65.25,-65.9,-65.25,-56.8,-61.1,-51.4,-58.5,-56.3,-59.1,-59.2...
-57.15,-51.95,-48.35,-51.65,-51.05,-51.45,-49.5,-57.05,-61.55,-58.4...
-57.85,-52.9,-61.3,-67.65,-65.4,-64.33,-75.5,-70.6,-70.65,-67.05,-66.3...
-71.45,-74.6,-88,-70.7,-80.9,-89.05,-81.2,-83.25,-70.75,-75.7,-76.6...
-82.45,-84.3,-77.5,-88.1,-80.65,-80.03,-80.1,-80.6,-75.9,-71.9,-78.68];



plot (g1, h1,'-b','linewidth',4,'markersize',7)
xlabel ('DISTANCE (m)')
ylabel ('RSS (dBm)')
grid
title ('RSS VS DISTANCE OF BASE STATION SUMMIT SAVORY 111162-2-
137','FontSize',10)
```

Appendix M

%Path loss MatLab code for Summit Savory

```
g1= [0:0.05:0.5];
h1=[108.85,112.9,108.5,100.75,107.15,113.63,120.75,130.5,133.6,129.33,127.98]
;
plot (g1, h1,'-hr','linewidth', 4,'markersize',7)
xlabel ('DISTANCE (Km)')
ylabel ('PATH LOSS (dB)')
grid
title('PATH LOSS VS DISTANCE OF BASE STATION SUMMIT SAVORY 111162-2-
137','FontSize',8)
```

Appendix N

```
%MATLAB code to create graph for SUMMIT SAVORY ,Hata and cost 231 model
 d1=0.05:0.05:0.50;
pr1=101.59+25.8*log10(d1/0.05);

m1=[112.9,108.5,100.75,107.15,113.63,120.75,130.5,133.6,129.33,127.98];
p1=109.17+25.8*log10(d1/0.05);
h1=136.8 +35.59*log10 (d1); %code for HATA model

c1=142.28 +35.59*log10(d1); %code for cost 231

 plot (d1, m1,'-xr','linewidth', 3,'markersize', 10)

xlabel('DISTANCE (Km)')

ylabel ('PATH LOSS (dB)')

grid

title ('SIMULATION OF SUMMIT SAVORY ,HATA AND COST MODELING')

hold on
plot(d1, pr1,'-+c','linewidth', 3,'markersize',10)


plot(d1, p1,'-+g','linewidth', 3,'markersize',10)

plot(d1, h1,'-*b','linewidth', 3,'markersize',10)

plot(d1, c1,'--k','linewidth', 3,'markersize',10)

hold off

legend('MEASURED','PREPREDICT','PREDICT','HATA','COST 231',4)
```

Appendix O

```
%MATLAB code to create graph for proposed ,Hata and cost 231 model
 d1=0.05:0.05:0.50;
pr1=102.81+38.5*log10(d1/0.05);

m1=[110.4,111.175,112.17,122.91,129.17,131.77,139.15,137.21,139.43,145.13];
p1=107.21+38.5*log10(d1/0.05);
h1=136.8 +35.59*log10 (d1); %code for HATA model

c1=142.28 +35.59*log10(d1); %code for cost 231

 plot (d1, m1,'-xr','linewidth', 3,'markersize', 10)

xlabel('DISTANCE (Km)')

ylabel ('PATH LOSS (dB)')

grid

title ('SIMULATION OF EASTERN ADDIS ABABA ,HATA AND COST MODELING')

hold on
plot(d1, pr1,'-+c','linewidth', 3,'markersize',10)

plot(d1, p1,'-+g','linewidth', 3,'markersize',10)

plot(d1, h1,'-*b','linewidth', 3,'markersize',10)

plot(d1, c1,'--k','linewidth', 3,'markersize',10)

hold off

legend('MEASURED','PREPREDICT','PREDICT','HATA','COST 231',4)
```

Appendix p

```
a1=[2.61828,4.619789,6.621297,8.956391,11.441811,17.463,20.71,24.19...
    27.30,30.67,37.48,40.81,47.48,50.93,54.16,57.38,60.75,63.77,66.80...
69.69,71.96,73.90,75.54,77.94,78.98,82.16,84.92,88.81,92.99,98.04...
103.43,116.85,124.00,139.14,156.20,173.95,183.20,192.01,200.81,209.61...
227.33,236.14,253.30,261.66,270.57,279.37,288.62,297.85,315.91,333.95...
343.18,351.97,361.20,370.31,389.21,398.44,408.11,417.78,427.34,437.01...
```

```
446.68,456.24,465.91,475.58,485.69,495.25,504.04];



b1=[-70.1,-65.6,-68.8,-65.6,-66.27,-69.4,-67.7,-65.6,-69,-66.4,-71.2...
    -71.37,-69.93,-70.2,-70.3,-66.23,-63.4,-65.2,-64.9,-68.1,-71.4...
-69.65,-65,-69.25,-65.83,-59.6,-60.3,-57.5,-57.45,-57.03,-62.6,-62.87...
-69.95,-75.03,-71.13,-85.2,-86.33,-85.4,-84.9,-90,-90.85,-93.53,-90.7...
-94.1,-94,-96.25,-98.75,-100.9,-96.97,-99.45,-97,-99.9,-98.37,-95.2...
-96.3,-99.45,-100.4,-103.2,-101.9,-101.3,-104.3,-105.4,-102.2,-104.1...
-105.9,-101.6,-105.27];



plot(a1,b1,'-r','linewidth',7,'markersize',15)
xlabel('DISTANCE (Km)')
ylabel('RSS (dBm)')
grid
title('RSS vs. Distance for the Four Node B','FontSize',10)
hold on

 c1= [1.66,5.43,9.77,14.77,20.78,27.53,35.47,43.96,52.76,61.55,71.22...
81.23,91.67,102.23,112.67,123.21,133.21,142.00,150.01,157.92,165.94...
173.85,181.43,189.34,196.92,204.83,212.87,220.88,229.42,237.93,246.90...
255.93,264.68,274.17,283.46,293.02,312.46,321.82,331.44,340.97,350.08...
359.34,368.74,377.71,387.12,396.18,405.44,414.60,424.08,433.70,443.57...
453.95,463.96,474.30,484.27,494.24,504.47];



d1= [ -56.1,-60.7,-58.4,-54.6,-51.1,-42.1,-36.9,-37.25,-42.6,-41.2...
    -48.25,-49.7,-49.8,-54.3,-54.6,-58.15,-60.5,-58.6,-64.1,-62.1,-75.65...
-74.55,-72.05,-74.6,-70.15,-74.5,-84.45,-78.3,-81.7,-85.5,-90.0,-87.85...
-94.5,-94.2,-96.2,-87.6,-87.95,-87.2,-85.9,-88.65,-93.1,-93.65,-87.6...
-89.8,-93.0,-77.4,-84.3,-90.5,-84.55,-88.4,-86.9,-86.5,-91.05,-95.5,-97.5...
-95.55,-96.2];



plot (c1, d1,'-k','linewidth', 7,'markersize', 15)



e1= [ 1.30,2.28,3.17,4.82,6.81,8.61,11.03,13.84,16.55,19.27,22.37,25.71...
29.18,32.54,36.42,40.62,44.82,49.44,53.63,57.80,61.98,66.59,70.78,74.65...
77.96,80.96,84.39,88.13,91.43,95.27,98.62,102.07,105.81,109.99,114.63...
119.74,124.89,130.39,135.58,140.73,145.45,150.63,155.69,160.47,164.78...
```

```
169.65,174.56,179.59,184.71,190.67,196.93,203.15,210.54,217.88,225.31...
232.85,240.38,248.68,257.09,265.66,273.84,281.58,289.13,296.71,303.44...
310.69,317.41,331.25,336.99,342.39,347.11,350.15,351.85,352.74,353.62...
354.07,354.53,355.74,357.08,359.17,361.26,362.93,365.03,366.69,368.46...
369.67,370.11,371.02,371.79,372.70,373.91,374.41,375.85,376.63,377.94...
378.27,378.27,379.16,380.07,381.28,382.93,385.02,387.22,389.31,391.39...
393.92,396.01,398.10,400.18,402.27,404.81,406.91,408.57,410.67,412.77...
414.45,415.78,416.28,417.08,417.57,418.45,419.29,420.64,422.33,424.01...
426.14,427.50,427.957825,428.73,429.62,430.07,431.36,432.75,435.33...
437.45,439.56,441.72,443.83,445.97,447.65,449.35,453.06,455.28...
457.10,458.58,459.13,460.15,461.54,463.41,465.73,468.00,469.87,472.10...
474.02,475.89,477.06,477.95,478.94,479.83,480.81,481.80,482.44,483.43...
484.37,484.82,486.11,487.49,488.47,489.83,490.72,491.76,492.65,494.12...
495.56,497.15,499.08,501.07,502.87,504.74];



f1= [-71.87,-74.1,-74.95,-76,-70.65,-80.15,-64.9,-60.1,-60.3,-66.8,-69.9...
-68,-73.2,-77.85,-73.83,-72,-77.45,-68,-75.85,-75.4,-73.2,-78.2,-75.0...
-69.55,-71,-72.45,-77.25,-74.6,-78.9,-69,-75.75,-71.4,-65.9,-60.5,-68.95...
-61.6,-70.3,-68.2,-72.7,-64.55,-71.2,-64.8,-64.3,-61.6,-66.9,-70.05...
-67.1,-66.6,-72.3,-79.3,-71.15,-77.2,-78.2,-79.75,-79.9,-71.35,-81,-76.6...
-82.4,-73.75,-75.7,-80.85,-81.5,-84.8,-78.45,-88.7,-83.75,-89.7,-86.7...
-86.8,-86.1,-85.1,-89.15,-97.9,-89.7,-89.4,-89.95,-86.55,-84.9,-82.73...
-88.5,-79.25,-81.1,-92.7,-92.8,-84.5,-86.6,-94.4,-92.4,-93.1,-89.8,-91.4...
-91.05,-91.5,-89.6,-91.7,-88.6,-88.4,-84.3,-82.8,-79,-81.3,-85.3,-91.6...
-88.1,-100.1,-87.65,-85.9,-83.6,-85.7,-84.9,-88.45,-93.6,-90.15,-88.7...
-87.45,-92.3,-94.7,-89.3,-88.8,-86.5,-99.2,-93.15,-89.7,-92.65,-88.7...
-92.95,-93.85,-99.4,-92.05,-88.6,-93.45,-86.1,-93.25,-86.2,-93.2,-97.2...
-88.15,-91.4,-83.5,-89.7,-93.97,-83.3,-91.55,-88.3,-87.2,-91.4,-91.85...
-94.4,-85.7,-91.1,-94.6,-91,-84.7,-90.3,-96.5,-93.4,-91.8,-94.05,-91.8...
-91.05,-93.95,-96.8,-96.45,-89.4,-93.2,-98.2,-87,-94,-94.45,-99.5,-89.4...
-88.8,-91.15,-90.9,-103.2,-90.55,-87.4,-89.7];


plot (e1, f1,'-g','linewidth', 7,'markersize', 15)

g1= [1.73,3.84,6.62,9.85,13.63,17.86,22.53,27.54,32.76,38.44,44.23,50.24...
  56.24,62.71,69.60,76.16,81.63,86.52,90.33,93.44,96.89,101.36,106.49...
 117.72,123.96,130.87,138.58,147.27,156.32,165.33,174.60,193.07,201.98...
210.77,219.67,228.56,237.25,254.60,262.96,271.30,279.75,287.99,296.33...
304.79,313.02,321.13,329.15,337.15,345.05,353.29,361.63,370.09,378.55...
386.89,395.02,403.36,411.71,428.62,436.85,453.76,462.22,471.01,479.68...
488.48,505.51];

h1= [-59.55,-59.8,-58,-61.15,-65.9,-64.15,-59.4,-63.9,-58.5,-67.5,-63.15...
-63.6,-65.25,-65.9,-65.25,-56.8,-61.1,-51.4,-58.5,-56.3,-59.1,-59.2...
-57.15,-51.95,-48.35,-51.65,-51.05,-51.45,-49.5,-57.05,-61.55,-58.4...
-57.85,-52.9,-61.3,-67.65,-65.4,-64.33,-75.5,-70.6,-70.65,-67.05,-66.3...
-71.45,-74.6,-88,-70.7,-80.9,-89.05,-81.2,-83.25,-70.75,-75.7,-76.6...
-82.45,-84.3,-77.5,-88.1,-80.65,-80.03,-80.1,-80.6,-75.9,-71.9,-78.68];
```

```
plot (g1, h1,'-m','linewidth',7,'markersize',15)

hold off

legend('Summit Beverage','Bole Studium','Bole Home','Summit Savory')
```

Appendix P

% Path loss MatLab code for all Base Station

```
d1=0.05:0.05:0.50;
 prsb=108.39+45.5*log10(d1/0.05);

msb =[119.5,111.9,120.43,134.2,140,150.2,149.2,148.75,153.6,154.57];
psb=114.5+45.5*log10(d1/0.05);
h1=136.8 +35.59*log10 (d1); %code for HATA model

c1=142.28 +35.59*log10(d1); %code for cost 231

prbs=91.12+53.8*log10(d1/0.05);

mbs=[91.9,103.6,113.4,123.8,137.15,137,142.4,133.6,135.8,145.5];
pbs=95.9+53.8*log10(d1/0.05);

prbh=110.27+28.7*log10(d1/0.05);

mbh=[117.3,120.7,114.1,126.5,125.9,127.7,134.4,132.9,139.0,152.5];
pbh=116.51+28.7*log10(d1/0.05);

prss=101.59+25.8*log10(d1/0.05);

mss=[112.9,108.5,100.75,107.15,113.63,120.75,130.5,133.6,129.33,127.98];
pss=109.17+25.8*log10(d1/0.05);



 plot (d1, msb,'-xr','linewidth', 3,'markersize', 10)


xlabel('DISTANCE (Km)')

ylabel ('PATH LOSS (dB)')
grid
title(' Modeling of the Four Node B in one graph','FontSize',10)

hold on
```

```
plot(d1, prsb,'-+c','linewidth', 3,'markersize',10)


plot(d1, psb,'-+g','linewidth', 3,'markersize',10)

plot(d1, h1,'-*b','linewidth', 3,'markersize',10)

plot(d1, c1,'--k','linewidth', 3,'markersize',10)

 plot(d1, msb,'-xr','linewidth', 3,'markersize', 10)

 %MATLAB code to create graph for BOLE INTERNATIONAL ,Hata and cost 231 model



 plot(d1, prbs,'-+c','linewidth', 3,'markersize',10)


plot(d1, pbs,'-+g','linewidth', 3,'markersize',10)
plot (d1, mbs,'-xr','linewidth', 3,'markersize', 10)

%MATLAB code to create graph for BOLE HOME ,Hata and cost 231 model



plot (d1, mbh,'-xr','linewidth', 3,'markersize', 10)
plot(d1, prbh,'-+c','linewidth', 3,'markersize',10)


plot(d1, pbh,'-+g','linewidth', 3,'markersize',10)



%MATLAB code to create graph for SUMMIT SAVORY ,Hata and cost 231 model


 plot (d1, mss,'-xr','linewidth', 3,'markersize', 10)
 plot(d1, prss,'-+c','linewidth', 3,'markersize',10)


plot(d1, pss,'-+g','linewidth', 3,'markersize',10)

hold off


legend('MEASURED','PREPREDICT','PREDICT','HATA','COST 231',4)
```

Appendix Q

```
%MATLAB code to create graph for proposed ,Hata and cost 231 model
 d1=0.05:0.05:0.50;
pr1=102.81+38.5*log10(d1/0.05);

m1=[110.4,111.175,112.17,122.91,129.17,131.77,139.15,137.21,139.43,145.13];
p1=107.21+38.5*log10(d1/0.05);
h1=136.8 +35.59*log10 (d1); %code for HATA model

c1=142.28 +35.59*log10(d1); %code for cost 231

 plot (d1, m1,'-xr','linewidth', 3,'markersize', 10)

xlabel('DISTANCE (Km)')

ylabel ('PATH LOSS (dB)')

grid

title ('SIMULATION OF EASTERN ADDIS ABABA ,HATA AND COST MODELING')

hold on
plot(d1, pr1,'-+c','linewidth', 3,'markersize',10)

plot(d1, p1,'-+g','linewidth', 3,'markersize',10)

plot(d1, h1,'-*b','linewidth', 3,'markersize',10)

plot(d1, c1,'--k','linewidth', 3,'markersize',10)

hold off

legend('MEASURED','PREPREDICT','PREDICT','HATA','COST 231',4)
```

Appendix R

MatLab code all graph in in one window

```
d1=0.05:0.05:0.50;
 prsb=108.39+45.5*log10(d1/0.05);

msb =[119.5,111.9,120.43,134.2,140,150.2,149.2,148.75,153.6,154.57];
```

```
psb=114.5+45.5*log10(d1/0.05);
h1=136.8 +35.59*log10 (d1); %code for HATA model

c1=142.28 +35.59*log10(d1); %code for cost 231

prbs=91.12+53.8*log10(d1/0.05);

mbs=[91.9,103.6,113.4,123.8,137.15,137,142.4,133.6,135.8,145.5];
pbs=95.9+53.8*log10(d1/0.05);

prbh=110.27+28.7*log10(d1/0.05);

mbh=[117.3,120.7,114.1,126.5,125.9,127.7,134.4,132.9,139.0,152.5];
pbh=116.51+28.7*log10(d1/0.05);

prss=101.59+25.8*log10(d1/0.05);

mss=[112.9,108.5,100.75,107.15,113.63,120.75,130.5,133.6,129.33,127.98];
pss=109.17+25.8*log10(d1/0.05);



 plot (d1, msb,'-xr','linewidth', 3,'markersize', 10)


xlabel('DISTANCE (Km)')

ylabel ('PATH LOSS (dB)')
grid
title(' Modeling of the Four Node B in one graph','FontSize',10)

hold on
plot(d1, prsb,'-+c','linewidth', 3,'markersize',10)


plot(d1, psb,'-+g','linewidth', 3,'markersize',10)

plot(d1, h1,'-*b','linewidth', 3,'markersize',10)

plot(d1, c1,'--k','linewidth', 3,'markersize',10)

 plot(d1, msb,'-xr','linewidth', 3,'markersize', 10)

 %MATLAB code to create graph for BOLE INTERNATIONAL ,Hata and cost 231 model



 plot(d1, prbs,'-+c','linewidth', 3,'markersize',10)
```

```
plot(d1, pbs,'-+g','linewidth', 3,'markersize',10)
plot (d1, mbs,'-xr','linewidth', 3,'markersize', 10)

%MATLAB code to create graph for BOLE HOME ,Hata and cost 231 model



plot (d1, mbh,'-xr','linewidth', 3,'markersize', 10)
plot(d1, prbh,'-+c','linewidth', 3,'markersize',10)


plot(d1, pbh,'-+g','linewidth', 3,'markersize',10)



%MATLAB code to create graph for SUMMIT SAVORY ,Hata and cost 231 model


 plot (d1, mss,'-xr','linewidth', 3,'markersize', 10)
 plot(d1, prss,'-+c','linewidth', 3,'markersize',10)


plot(d1, pss,'-+g','linewidth', 3,'markersize',10)

hold off


legend('MEASURED','PREPREDICT','PREDICT','HATA','COST 231',4)
```