Syrian Private University
Faculty of Informatics & Computer Engineering

Propagation Path Loss Model in Cell Phone system

A Senior Project (Phase II)

Presented to the Faculty of Computer and Informatics Engineering

In Partial Fulfillment of the Requirements for the Degree

Of Bachelor of Engineering in Communications and Networks

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Year: 2014/2015

Acknowledgments

We would like to thank our University (Syrian Private University) College of Computer and Informatics Engineering, and also our Academic staff.

We present our Project as a Recognition of the effort which everyone did.

Greeting to all four college flags and thanks to gave help

Dr. Ali Skaf

Dr. Samaoaal Hakeem

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Dedication

أهدي هذا العمل إلى :

ملاك السماء على الأرض . زهرة التضحية وزنبقة الحنان

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الابتسامات الجميلة وكبرياء الأنوثة وروعة الحنان

أخواتي

ربيعُ خريفي وشتاءُ صيفي . أنوثتها الخجولة وكبرياء ذاتها

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رجال الكرامة

نورس نسيب زيتونه

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لـ **رجال الله في الأرض** حماة الديار الجيش العربي السوري

لـ **شهداء الوطن** وقدسية أرواحهم الطاهرة

لـ **أمي** التي تزرع الورود في دمي وتبعثني من جديد

لـ **أبي** رجلي الأول، لعينيه التي أغفو فيها كوطن

لـ **إخوتي** الذين تنبض قلوبهم في عروقي

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لـ أصحاب القلب الواحد والوجه الواحد والموقف الواحد

بشرى عبد الحميد فرحات

أهدي هذا العمل إلى :

لبلدي الصامد أبداً

لرجال الجيش العربي السوري وأرواح شهدائه الطاهرة

إلى أمي التي لطالما كانت دافعي للنجاح

إلى أبي الذي كان معلمي ومثلي وقدوتي وقوتي

إلى أخوتي باحترامهم وحنانهم

للأساتذتي ومن علمني

أصدقائي الدائمين الأوفياء وزملائي على مقاعد الدراسة

إلى من تعطر درب نجاحي بإبتسامتها الرائعة وتملئ قلبي بشغف الحب والتفاؤل

أغيد السوسي

Abstract

This project concerns about the radio propagation models used for the upcoming 4th Generation (4G) of cellular networks known as Long Term Evolution (LTE). The radio wave propagation model or path loss model plays a very significant role in planning of any wireless communication systems. In this paper, a comparison is made between different proposed radio propagation models that would be used for LTE, Okumura-Hata model, Hata COST 231 model, COST Walfisch-Ikegami & IMT-2000 model. The comparison is made using different terrains e.g. urban, suburban and rural area. The model shows the lowest path lost in all the terrains while COST 231 Hata model illustrates highest path loss in urban area and COST Walfisch-Ikegami model has highest path loss for suburban and rural environments.

Fading channel concept considered before study a propagation model which examined the applicability of Okumura-Hata model, Hata COST 231 model, COST Walfisch-Ikegami & IMT-2000 model in GSM frequency band. And accomplish the investigation in variation in path loss between Urban, Suburban, and Ural area. Through MATLAB graph was plotted between path loss verses distance.

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List of Abbreviations

Abbreviations	Full name
LTE	Long Term Evolution
ITU	International Telecommunication Union
RF	Radio Frequency
STF	Short Term Fading
LOS	Line of Sight
IR	Impulse response
FSL	Free space Loss
GUI	Graphical User Interface
GSM	Global system of mobile communication
MS	Mobile Station
ME	Mobile Equipment
SIM	Subscriber Identity Module
BSS	Base Station Subsystem
BTS	Base Transceiver Station
BSC	Base Station Controller
MSC	Mobile Switching Center
HLR	Home Location Register
VLR	Visitor Location Register
AUC	Authentication Center

Chapter 1
Introduction

Since the mid 1990's the cellular communications industry has witnessed rapid growth. Wireless mobile communication networks have become much more pervasive than anyone ever imagined when cellular concept was first developed. High quality and high capacity network are in need today, estimating coverage accurately has become exceedingly important. Therefore for more accurate design coverage of modern cellular networks, measurement of signal strength must be taken into consideration, thus to provide efficient and reliable coverage area. In this clause the comparisons between the theoretical and experimental propagation models are shown. The more commonly used propagation data for mobile communications is Okumura's measurements and this is recognized by the International Telecommunication Union (ITU).

In the mid of 1940's, researchers and engineers have pondered this problem and have developed myriad schemes that purport to predict the value or distribution of signal attenuation (path loss) in many different environments and at different frequencies. This chapter will attempt to give a complete review of the work to date, updating and extending a series of excellent-but-dated surveys from the last 15 years.

The cellular concept came into picture which made huge difference in solving the problem of spectral congestion and user's capacity. With no change in technological concept, it offered high capacity with a limited spectrum allocation. The cellular concept is a system level idea in which a single, high power transmitter is replaced with many low power transmitters. The area serviced by a transmitter is called a cell. Thus each cell has one transmitter. This transmitter is also called base station which provides coverage to only a small portion of the service area. Transmission between the base station and the mobile station do have some power loss this loss is known as path loss and depends particularly on the carrier frequency, antenna height and distance. The range for a given path loss is minimized at higher frequencies. So more cells are required to cover a given area. Neighbor base stations close are assigned different group of channels which reduces interference between the base stations. If the demand increases for the service, the number of base stations may be increased, thus providing additional capacity with no increase in radio spectrum. The advantage of cellular system is that it can serve as many number of subscribers with only limited number of channel by efficient channel reuse.

The discussion here is exhaustive, including more than 50 proposed models from the last 60 years, 30 of which are described in detail. The models are described at a high level with a brief focus on identifying their chief differences from other models. Figure 1.1 provides a family tree of the majority of path loss models discussed in the following subsections and may prove useful for understanding the lineage of various proposals as well as their functional relationship to one another.

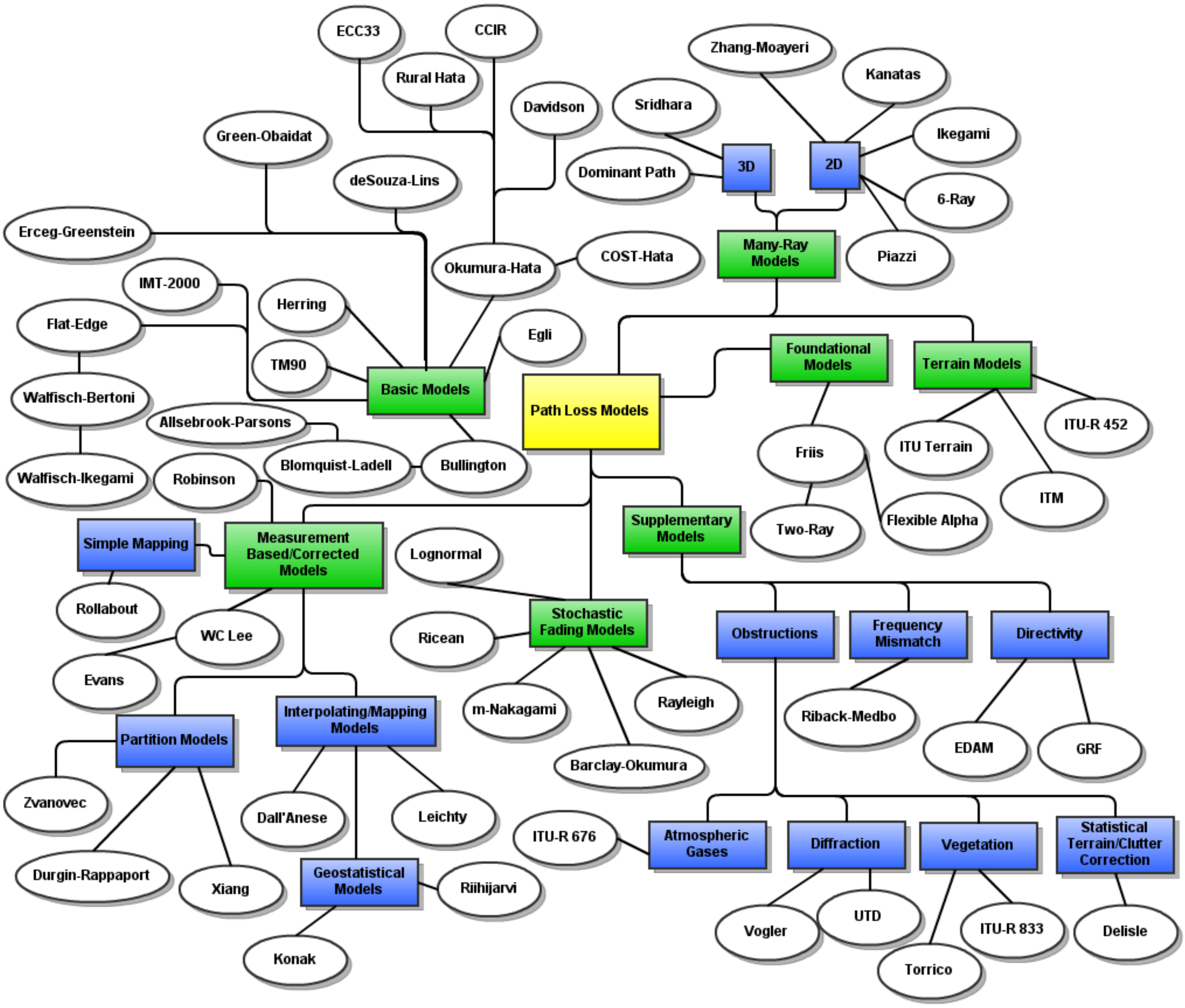

Figure 1.1: Path loss model family tree.

Individual models are shown as circles and categories as are shown as rectangles. Major categories are green. Minor categories are blue.

The remainder of the report is organized as follows:

Chapter 2 discusses basic of RF Fading Channel Models and Statistical Models for Fading Channels.

Chapter 3 focuses on Propagation models consist Path loss propagation models and Empirical propagation models.

Chapter 4 consider the global system of mobile communication and Radio Network Planning and Optimization.

Chapter 5 includes simulation of propagation model (Okumura-Hata - COST-231 IMT-2000) using MATLAB software.

Chapter 6 consist the conclusion of the project and some future enhancement.

Chapter 2
Fading channel model

2-1 Introduction

The wireless communications channel constitutes the basic physical link between the transmitter and the receiver antennas. Its modeling has been and continues to be a tantalizing issue, while being one of the most fundamental components based on which transmitters and receivers are designed and optimized. The ultimate performance limits of any communication system are determined by the channel it operates in [1]. Realistic channel models are thus of utmost importance for system design and testing.

In addition to exponential power path-loss, wireless channels suffer from stochastic short term fading (STF) due to multipath, and stochastic long term fading (LTF) due to shadowing depending on the geographical area. STF corresponds to severe signal envelope fluctuations, and occurs in densely built-up areas filled with lots of objects like buildings, vehicles, etc. On the other hand, LTF corresponds to less severe mean signal envelope fluctuations, and occurs in sparsely populated or suburban areas [2-4]. In general, LTF and STF are considered as superimposed and may be treated separately [4].

Ossanna [5] was the pioneer to characterize the statistical properties of the signal received by a mobile user, in terms of interference of incident and reflected waves. His model was better suited for describing fading occurring mainly in suburban areas (LTF environments).

It is described by the average power loss due to distance and power loss due to reflection of signals from surfaces, which when measured in dB’s give rise to normal distributions, and this implies that the channel attenuation coefficient is log-normally distributed [4].

Furthermore, in mobile communications, the LTF channel models are also characterized by their special correlation characteristics which have been reported in [6-8].

However, these models assume that the channel state is completely observable, which in reality is not the case due to additive noise, and requires long observation intervals.

Mobile-to-mobile (or ad hoc) wireless networks comprise nodes that freely and dynamically self-organize into arbitrary and/or temporary network topology without any fixed infrastructure support [19]. They require direct communication between a mobile transmitter and a mobile receiver over a wireless medium. Such mobile-to-mobile communication systems differ from the conventional cellular systems, where one terminal, the base station, is stationary, and only the mobile station is moving. As a consequence, the statistical properties of mobile-to-mobile links are different from cellular ones.

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

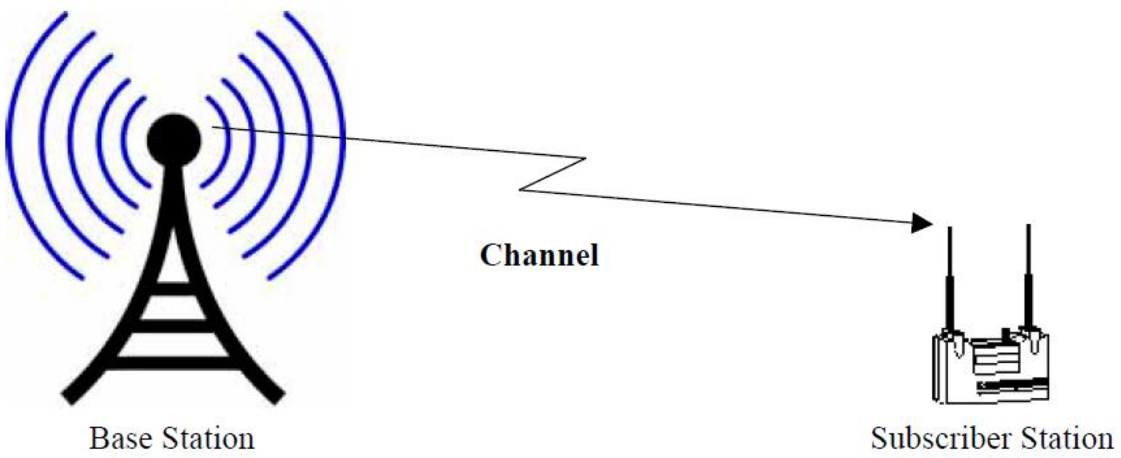

Figure 2.1: Channel

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(s) 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.

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.

2-2-1 Path Loss

The simplest channel is the free space line of sight channel with no objects between the receiver and the transmitter or around the path between them. In this simple case, the transmitted signal attenuates since the energy is spread spherically around the transmitting antenna. For this line of sight (LOS) channel, the received power is given by:

$$P_r = P_t \left[\frac{\sqrt{G_l \lambda}}{4\pi d}\right]^2 \tag{2.1}$$

Here, P_t is the transmitted power, G_l is the product of the transmit and receive antenna field radiation patterns, λ is the wavelength, and d is the distance. Theoretically, the power falls off in proportion to the square of the distance. In practice, the power falls off more quickly, typically 3rd or 4th power of distance.

2-2-2 Shadowing

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.

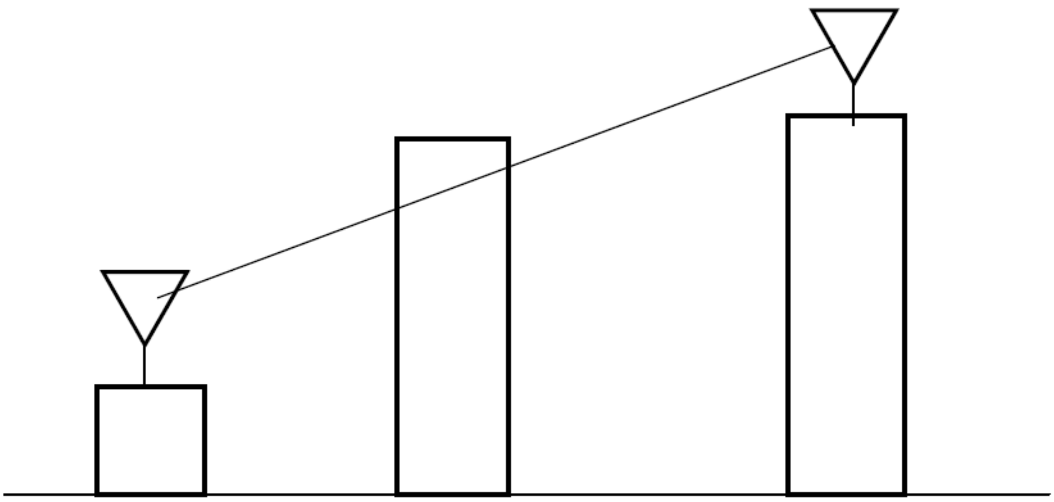

Figure 2.2: Shadowing

2-2-3 Multi Path

The objects located around the path of the wireless signal reflect the signal. Some of these reflected waves are also received at the receiver. Each of these reflected signals takes a different path, it has a different amplitude and phase.

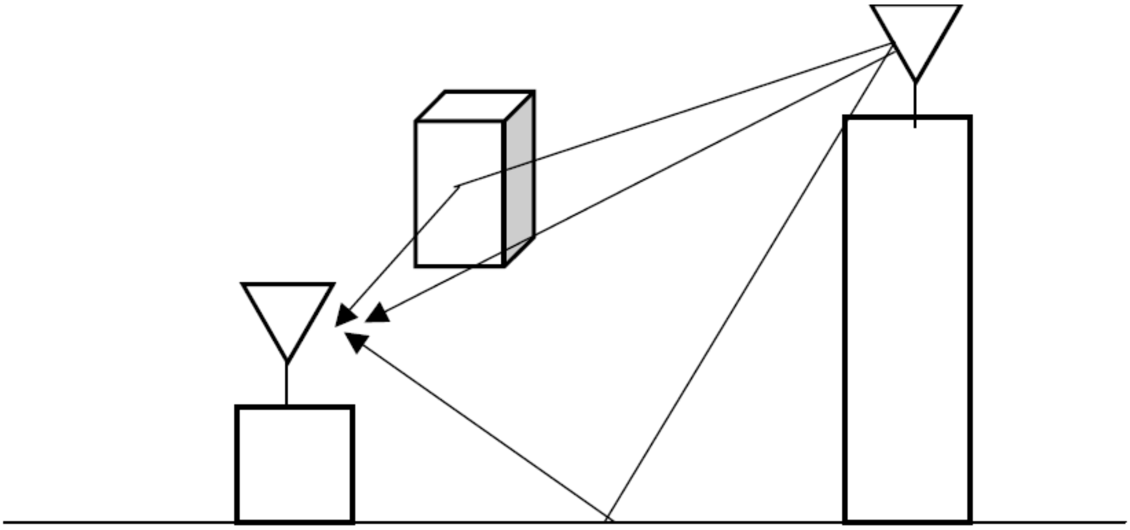

Figure 2.3: Multipath

Depending upon the phase, these multiple signals may result in increased or decreased received power at the receiver. Even a slight change in position may result in a significant difference in phases of the signals and so in the total received power. The three components of the channel response are shown clearly in Figure 2.3. The thick dashed line represents the path loss. The lognormal shadowing changes the total loss to that shown by the thin dashed line. The multipath finally results in variations shown by the solid thick line. Note that signal strength variations due to multipath change at distances in the range of the signal wavelength.

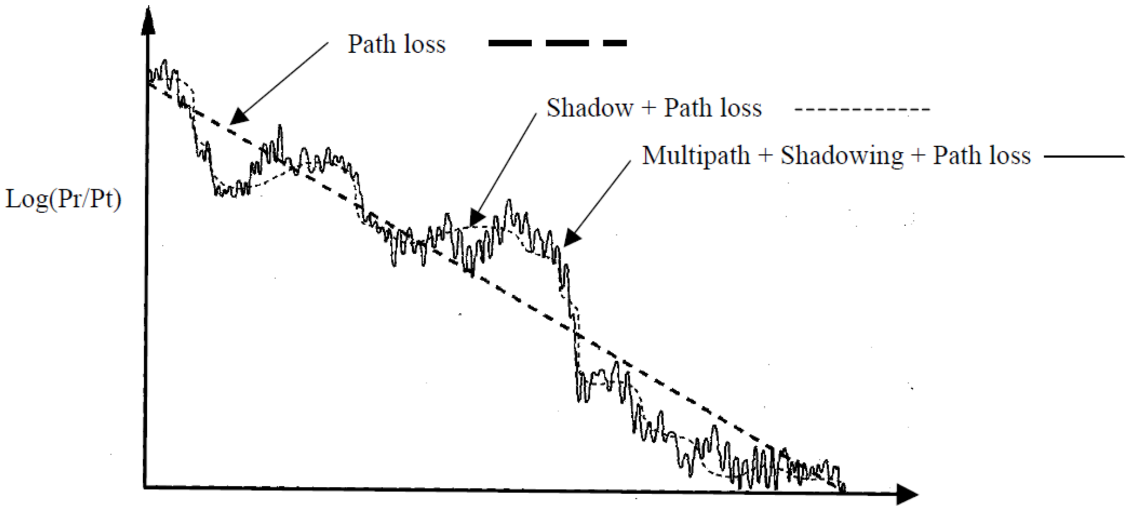

Figure 2.4: Path loss, shadowing, and Multipath

Since different paths are of different lengths, a single impulse sent from the transmitter will result in multiple copies being received at different times as shown in Figure 2.5

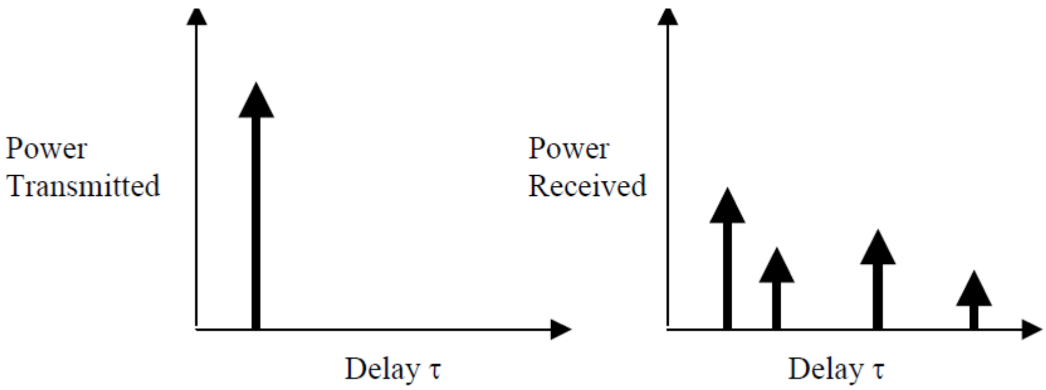

Figure 2.5: Multipath Power Delay Profile

2-3 Fading Channel Models

The impulse response (IR) of a wireless channel is typically characterized by time variations and time spreading [2]. Time variations are due to the relative motion between the transmitter and the receiver and temporal variations of the propagation environment. Time spreading is due to the fact that the emitted electromagnetic wave arrives at the receiver having undergone reflections, diffraction and scattering from various objects along the way, at different delay times. At the receiver, a random number of signal components, copies of a single emitted signal, arrive via different paths thus having undergone different attenuation, phase shifts and time delays, all of which are random and time-varying. This random number of signal components add vectorially giving rise to signal fluctuations, called multipath fading, which are responsible for the degradation of communication system performance.

2-3-1 Multipath Propagation

The received power in a radio channel is affected by attenuations that are conveniently characterized as a combination of three effects, as follows:

A- The path loss is the signal attenuation due to the fact that the power received by an antenna at distance D from the transmitter decreases as D increases.

Empirically, the power attenuation is proportional to Da, with a an exponent whose typical values range from 2 to 4. In a mobile environment, D varies with time, and consequently so does the path loss. This variation is the slowest among the three attenuation effects we are examining here.

B- The shadowing loss is due to the absorption of the radiated signal by scattering structures. It is typically modeled by a random variable with log-normal distribution.

C- The fading loss occurs as a combination of two phenomena, whose combination generates random fluctuations of the received power. These phenomena are rnultipath propagation and Doppler frequency shift. In the following we shall focus our attention on these two phenomena, and on mathematical models of the fading they generate.

In a cellular mobile radio environment, the surrounding objects, such as houses, building or trees, act as reflectors of radio waves. These obstacles produce reflected waves with attenuated amplitudes and phases. If a modulated signal is transmitted, multiple reflected waves of the transmitted signal will arrive at the receiving antenna from different directions with different propagation delays. These reflected waves are called multipath waves.

Due to the different arrival angles and times, the multipath waves at the receiver site have different phases. When they are collected by the receiver antenna at any point in space, they may combine either in a constructive or a destructive way, depending on the random phases.

The sum of these multipath components forms a spatially varying standing wave field. The mobile unit moving through the multipath field will receive a signal which can vary widely in amplitude and phase. When the mobile unit is stationary, the amplitude variations in the received signal are due to the movement of surrounding objects in the radio channel.

The amplitude fluctuation of the received signal is called signal fading. It is caused by the time-variant multipath characteristics of the channel.

2-3-2 Doppler Shift

Due to the relative motion between the transmitter and the receiver, each multipath wave is subject to a shift in frequency. The frequency shift of the received signal caused by the relative motion is called the Doppler shift. It is proportional to the speed of the mobile unit.

Consider a situation when only a single tone of frequency f_c is transmitted and a received signal consists of only one wave coming at an incident angle θ with respect to the direction of the vehicle motion. The Doppler shift of the received signal, denoted by f_d, is given by

$$f_d = \frac{vf_c}{c}\cos(\theta) \tag{2.2}$$

Where v is the vehicle speed and c is the speed of light. The Doppler shift in a multipath propagation environment spreads the bandwidth of the multipath waves within the range of $f_c \pm f_{dmax}$, where $fdmax$ is the maximum Doppler shift, given by:

$$f_{dmax} = \frac{vf_c}{c} \tag{2.3}$$

The maximum Doppler shift is also referred as the maximum fade rate. As a result, a single tone transmitted gives rise to a received signal with a spectrum of nonzero width. This phenomenon is called frequency dispersion of the channel.

2-3-3 Statistical Models for Fading Channels

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. A simple example will illustrate this fact.

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.

In this section we introduce Rayleigh and Rician fading models to describe signal variations in a narrowband multipath environment.

2-3-3-1 Rayleigh Fading

We consider the transmission of a single tone with a constant amplitude. In a typical land mobile radio channel, we may assume that the direct wave is obstructed and the mobile unit receives only reflected waves. When the number of reflected waves is large, according to the central limit theorem, two quadrature components of the received signal are uncorrelated Gaussian random processes with a zero mean and variance σ_s^2 . As a result, the envelope of the received signal at any time instant undergoes a Rayleigh probability distribution and its phase obeys a uniform distribution between $-\pi$ and π. The probability density function (pdf) of the Rayleigh distribution is given by

$$P(\alpha) = \begin{cases} \frac{\alpha}{\sigma_s^2}\, e^{-\frac{\alpha^2}{2\sigma_s^2}} & , \ \alpha \geq 0 \\ 0 & , \ \alpha < 0 \end{cases} \qquad (2.4)$$

The mean value, denoted by ma, and the variance, denoted by σ_a^2 , of the Rayleigh distributed random variable are given by

$$m_a = \sqrt{\frac{\pi}{2}}\, \sigma_s = 1.2533\, \sigma_s \qquad (2.5)$$

$$\sigma_a^2 = \left(2 - \frac{\pi}{2}\right) \sigma_s^2 = 0.4292\, \sigma_s^2 \tag{2.6}$$

If the probability density function is normalized so that the average signal power $E[a^2]$ is unity, then the normalized Rayleigh distribution becomes

$$P(\alpha) = \begin{cases} 2\, a^{-a^2} & , \ \alpha \geq 0 \\ 0 & , \ \alpha < 0 \end{cases} \tag{2.7}$$

The mean value and the variance are

$$m_a = 0.8862 \tag{2.8}$$

$$\sigma_a^2 = 0.2146 \tag{2.9}$$

The pdf for a normalized Rayleigh distribution is shown in **Fig**. 2.6.

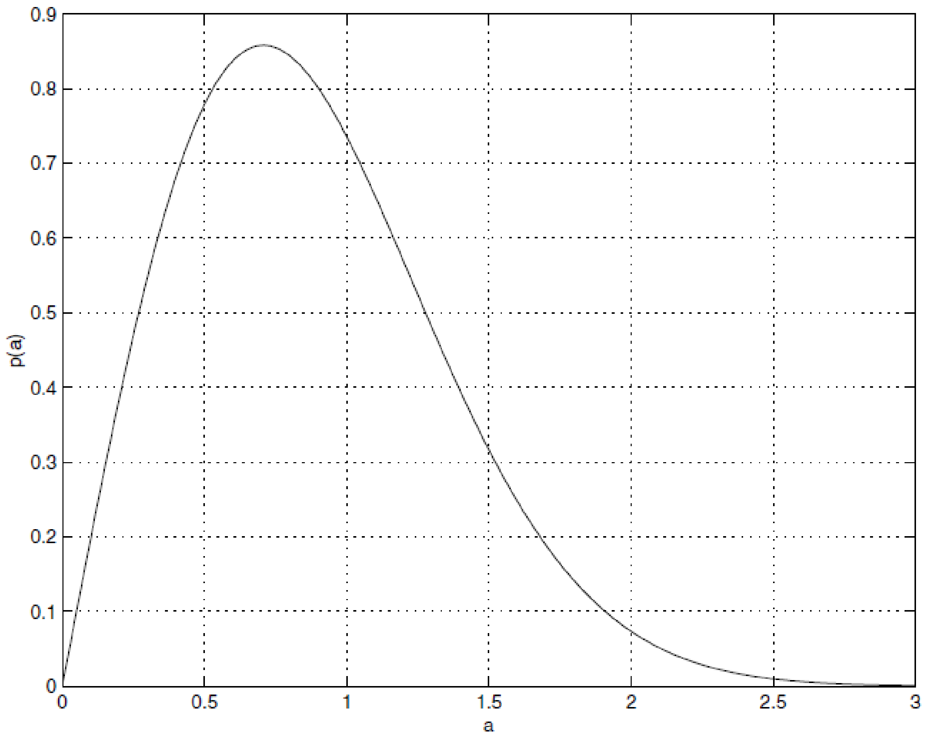

Figure 2.6 The pdf of Rayleigh distribution

In fading channels with a maximum Doppler shift, the received signal experiences a form of frequency spreading and is band-limited between $f_c \pm f_{dmax}$. Assuming an omnidirectional antenna with waves arriving in the horizontal plane, a large number of reflected waves and a uniform received power over incident angles, the power spectral density of the faded amplitude, denoted by $|P(f\ )|$, is given by:

$$|P(f)| = \begin{cases} \dfrac{1}{2\pi\sqrt{{f_{dmax}}^2 - f^2}} & , \quad if \ |f| \ \leq \ |f_{dmax}| \\ 0 & , \ Otherwise \end{cases} \qquad (2.10)$$

Where f is the frequency and $fdmax$ is the maximum fade rate. The value of $f_{dmax} T_s$ is the maximum fade rate normalized by the symbol rate. It serves as a measure of the channel memory. For correlated fading channels this parameter is in the range $0 < f_{dmax} T_s < 1$, indicating a finite channel memory. The autocorrelation function of the fading process is given by

$$R(\tau) = J_0(2\pi f_{dmax} \tau) \qquad (2.11)$$

Where J_0 is the zero-order Bessel function of the first kind.

2-3-3-2 Rician Fading

In some propagation scenarios, such as satellite or microcellular mobile radio channels, there are essentially no obstacles on the line-of-sight path. The received signal consists of a direct wave and a number of reflected waves. The direct wave is a stationary nonfading signal with a constant amplitude. The reflected waves are independent random signals. Their sum is called the scattered component of the received signal.

When the number of reflected waves is large, the quadrature components of the scattered signal can be characterized as a Gaussian random process with a zero mean and variance σ_s^2. The envelope of the scattered component has a Rayleigh probability distribution.

The sum of a constant amplitude direct signal and a Rayleigh distributed scattered signal results in a signal with a Rician envelope distribution. The pdf of the Rician distribution is given by

$$P(\alpha) = \begin{cases} \dfrac{\alpha}{\sigma_s^2} \, e^{-\frac{\alpha^2 + D^2}{2\sigma_s^2}} \, I_0\left(\dfrac{D\,\alpha}{\sigma_s^2}\right) & , \ \alpha \geq 0 \\ 0 & , \ \alpha < 0 \end{cases} \qquad (2.12)$$

Where D^2 the direct signal is power and I_0 is the modified Bessel function of the first kind and zero-order.

Assuming that the total average signal power is normalized to unity, the pdf in becomes

$$P(\alpha) = \begin{cases} 2a(1+K)\, e^{-K-(1+K)a^2}\, I_0\left(2a\sqrt{K(K+1)}\right) & , \ \alpha \geq 0 \\ 0 & , \ \alpha < 0 \end{cases} \qquad (2.13)$$

Where K is the Rician factor, denoting the power ratio of the direct and the scattered signal components. The Rician factor is given by

$K = \frac{D^2}{2\sigma_s^2}$The mean and the variance of the Rician distributed random variable are given by

$$ma = \sqrt{\frac{\pi}{1+K}}\, e^{-\frac{K}{2}\left[(1+K)I_0\left(\frac{K}{2}\right)+KI_1\left(\frac{K}{2}\right)\right]} \qquad (2.14)$$

$$\sigma_a^2 = 1 - m_a^2 \qquad (2.15)$$

Where $I_1(\cdot)$ is the first order modified Bessel function of the first kind. Small values of K indicate a severely faded channel. For K = 0, there is no direct signal component and the Rician pdf becomes a Rayleigh pdf. On the other hand, large values of K indicate a slightly faded channel. For K approaching infinity, there is no fading at all resulting in an AWGN channel. The Rician distributions with various K are shown in **Fig**. 2.7.

These two models can be applied to describe the received signal amplitude variations when the signal bandwidth is much smaller than the coherence bandwidth.

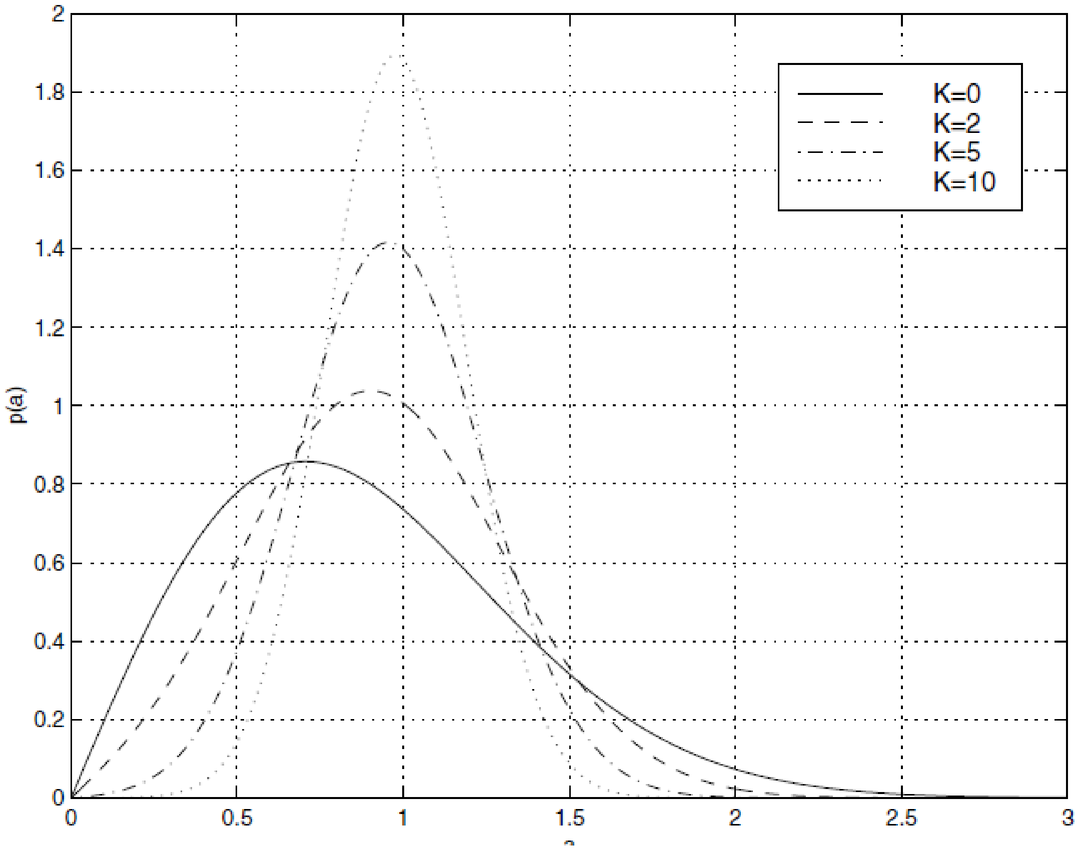

Figure 2.7 The pdf of Rician distributions with various K

Chapter 3
Propagation models

3-1 Path loss propagation models

The path loss propagation models have been an active area of research in recent years Path loss arises when an electromagnetic wave propagates through space from transmitter to receiver. The power of signal is reduced due to path distance, reflection, diffraction, scattering, free-space loss and absorption by the objects of environment. It is also influenced by the different environment (i.e. urban, suburban and rural). Variations of transmitter and receiver antenna heights also produce losses. The losses present in a signal during propagation from base station to receiver may be classical and already exiting. General classification includes three forms of modeling to analyze these losses [5]:

1. Empirical
2. Statistical
3. Deterministic

In the above models Deterministic models are better to find the propagation path losses, The Statistical models Uses Probability analysis by finding the probability density function. The empirical models uses with Field Measured Data obtained from results of several measurement efforts .this model also gives very accurate results but the main problem with this type of model is computational complexity. The field measurement data was taken in the urban, sub urban and rural environments.

The mechanisms behind electromagnetic wave propagation are large it can generally be attributed to scattering, diffraction and reflection. Because of multiple reflection from various objects, they travel along different paths of varying lengths. Most cellular radio systems operate in urban areas where there is no direct line-of-sight path between the transmitter and receiver and where presence of high rise buildings causes severe diffraction loss.

Basically propagation models are of two types:

3-1-1 Free space propagation:

The wave is not reflected or absorbed in free space propagation model. The ideal propagation radiates in all directions from transmitting source and propagating to an infinite distance with no degradation. Attenuation occurs due to spreading of power over greater areas. Power flux is calculated by,

$$Pd = Pt / 4\pi d^{2} \tag{3.1}$$

Where Pt is transmitted power

Pd is power at distance d from antenna.

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.

The power received can be calculated from the antenna if a receiver antenna is placed in power flux density at a point of a given distance from the radiation.

To calculate the effective antenna aperture and received power the formulas are shown in equation. The amount of power captured by the antenna at the required distance d, depends on the effective aperture of the antenna and the power flux density at the receiving element. There are mainly three factors by which the actual power received depends upon by the antenna: **(a)** the aperture of receiving antenna **(b)** the power flux density **(c)** and the wavelength of received signal.

Then substituting (λ (in km) = 0.3 / f (in MHz)) and rationalizing the equation produces the generic free space path loss formula,

$$Lp\ (dB) = 32.5 + 20\ log10\ (d) + 20\ log10\ (f) \tag{3.2}$$

3-1-2 Plane earth propagation model:

The effects of propagation model on ground is not considered for the free space propagation model. Some of the power will be reflected due to the presence of ground and then received by the receiver when a radio wave propagates over ground. The free space propagation model is modified and referred to as the ‘Plain-Earth’ propagation model by determining the effect of the reflected power. Thus this model suits better for the true characteristics of radio wave propagation over ground. This model computes the received signal to be the sum of a direct signal which reflected from a smooth, flat earth. The relevant input parameters include, the length of the path, the antenna heights, the operating frequency and the reflection coefficient of the earth. The coefficient will vary according to the type of terrain either water, wet ground, desert etc.

For this the path loss equation is given by,

$$Lpe = 40log10\,(d) - 20log10\,(h1) - 20log10\,(h2\,) \qquad (3.3)$$

Here „ d" is the path length in meter h1 and h2 are the antenna heights at the base station and the mobile, respectively. The plane earth model in not appropriate for mobile GSM systems as it does not consider the reflections from buildings, multiple propagation or diffraction effects. Furthermore, if the mobile height changes (as it will in practice) then the predicted path loss will also be changed.

3-2 Empirical propagation models

The two basic propagation models are free space loss and plane earth loss would be requiring detailed knowledge of the location and constitutive parameters of building, terrain feature, every tree and terrain feature in the area to be covered. It is too complex to be practical and would be providing an unnecessary amount of detail therefore appropriate way of accounting for these complex effects is by an empirical model. There are many empirical prediction models like, Cost 231 – Hata model, Okumura – Hata model, Sakagami- Kuboi model, Cost 231 Walfisch – Ikegami model.

3-2-1 Okumura Propagation Model

In this section Okumura and Hata propagation models are discussed. The two models or their modified version are frequently used throughout commercially available RF engineering tools.

Okumura's model is one of the most frequently used macroscopic propagation models. It was developed during the mid 1960's as the result of large-scale studies conducted in and around Tokyo. The model was designed for use in the frequency range 200 up to 1920 MHz and mostly in an urban propagation environment.

Okumura's model assumes that the path loss between the TX and RX in the terrestrial propagation environment can be expressed as:

$$L_{50} = L_{FS} + A_{mu} + H_{tu} + H_{ru} \tag{3.4}$$

Where:

L_{50} Median path loss between the TX and RX expressed in dB

L_{FS} - Path loss of the free space in dB

A_{mu} - "Basic median attenuation" – additional losses due to propagation in urban environment in dB

H_{tu} - TX height gain correction factor in dB

H_{ru} - RX height gain correction factor in dB

The free space loss term can be calculated analytically using:

$$L_{FS} = 32.45 + 20\log\left(\frac{d}{1\ Km}\right) + 20\log\left(\frac{f}{1\ MHz}\right) - 10\log(G_t) - 10\log(G_r) \tag{3.5}$$

Where:

d - Distance between the TX and RX in km

f - Operating frequency in MHz

G_t , G_r- TX and RX antenna gains (linear)

3-2-1-1 Basic Median Attenuation (A_{mu})

This term models additional propagation losses due to the signal propagation in a terrestrial environment. The curves for determining the basic median attenuation are provided in Figure 1. On the horizontal axis of the graph in Figure 1, we find operating frequency expressed in MHz. On the vertical axis we find the additional path loss attenuation expressed in dB. The parameter of the family of the curves is the distance between the transmitter and receiver. The curves in Figure 3.1 were derived for TX height reference of 200m and RX height of 3m. If the actual heights of the TX and RX differ from those referenced, the appropriate correction needs to be added. For example, at 850MHz frequency and the transmitter-receiver distance of 5km, the attenuation is close to 26dB. This value is read from the leftmost scale in Figure 3.1 at the point where constant vertical line at 850MHz intersects with the parametric 5km distance curve. The projection of this intersection on the basic median attenuation scale gives the resulting attenuation of approximately 26dB.

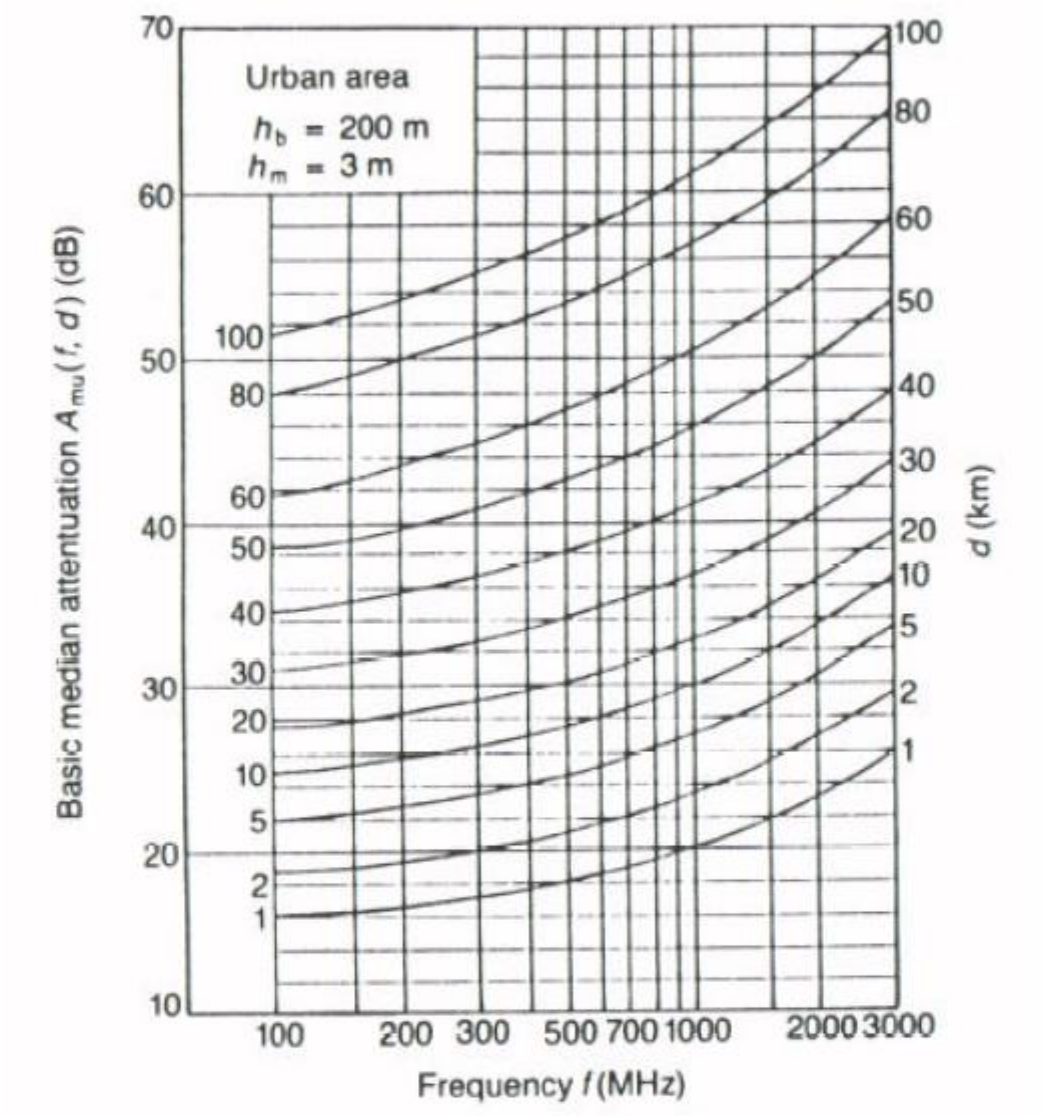

Figure 3.1. Basic median attenuation as a function of frequency and path distance. After Okumura [6].

3-2-1-2 Base station height gain (H_{tu}) and mobile height gain factor (H_{ru})

The curves used for correction of nonstandard transmitter and receiver heights are presented in Figure 3.2 and Figure 3.3. Figure 3.2 shows the correction factor if the base station antenna is not 200m high. At the effective height of 200m, all curves meet and no correction gain is required (H_{tu} =0dB). Base station antennas above 200m introduce positive gain in the Okumura model given by equation 1 and antennas lower than 200m have negative gain factor. The parameter is again the distance between the transmitter and the receiver, similar to Figure 1. For example, for 100m antennas and 1km distance, the base station antenna gain H_{tu} is approximately –4dB.

Figure 3.3 is interpreted similarly for the mobile antenna height correction. All curves meet at the referent 3m horizontal coordinate. Higher antennas introduce gain and lower cause loss of referent signal level. The parameter for this family of curves is not the distance between the base and mobile station as in Figure 2, but frequency. For example, a 5m high antenna operating at 800MHz will have approximately H_{ru} =2dB gain relative to the referent 3m antenna in the large city. Mobile height gain factor is also separated according to the size of the city in two clusters in Figure 2.3: medium and large city. If the same mobile antenna (5m, 800MHz) is deployed in a medium city, the height gain factor is increased from 2dB to 6dB.

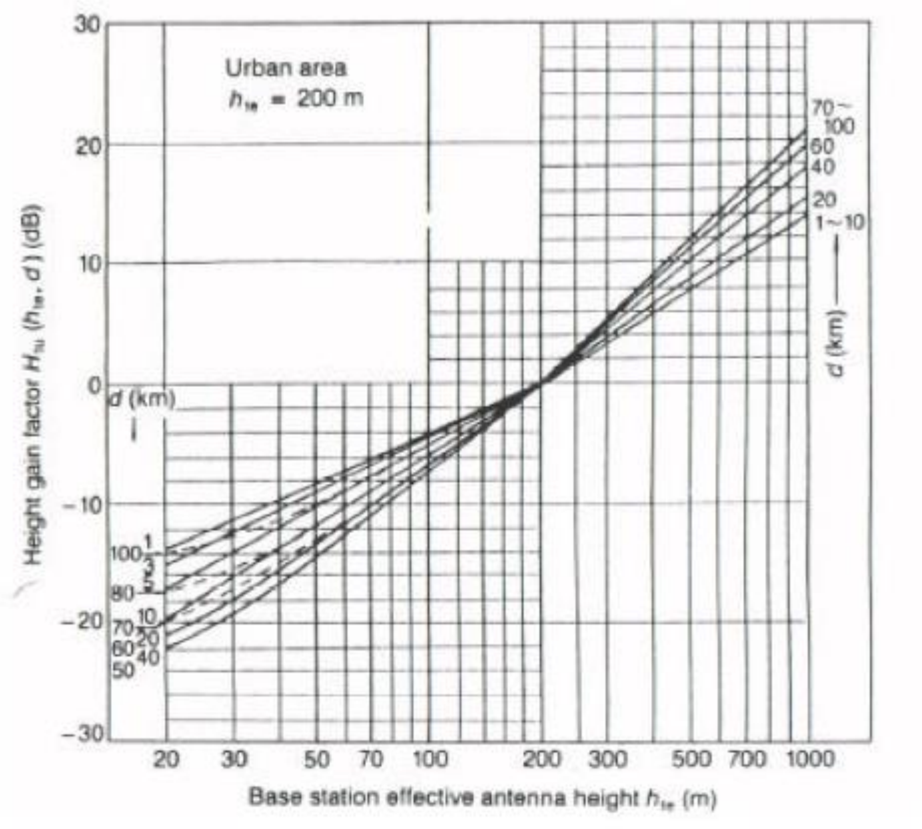

Figure 3.2 Base station height correction gain – after Okumura [4]

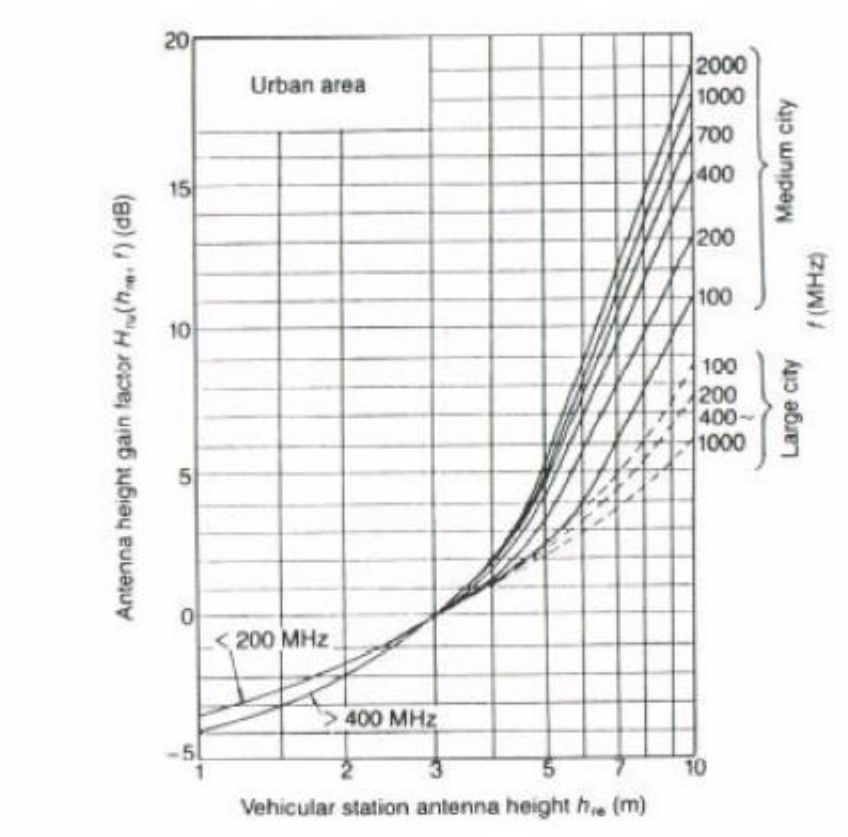

Figure 3.3 Mobile station height correction gain – after Okumura [4]

One should notice that the base station correction factor is provided as a function of the effective height of the transmitter antenna. The effective antenna height is calculated as the height of the antenna's radiation above the average terrain. The terrain is averaged along the direction of radio path over the distances between three and fifteen kilometers.

The procedure is easily be explained with the aid of Figure 3.4. First, a terrain profile is determined from the TX and in the direction of the receiver. The terrain values along the profile that fall between 3 km and 15 km are averaged to determine the height of the average terrain. Finally the effective antenna height is determined as the difference between the height of the BTS antenna and the height of the average terrain.

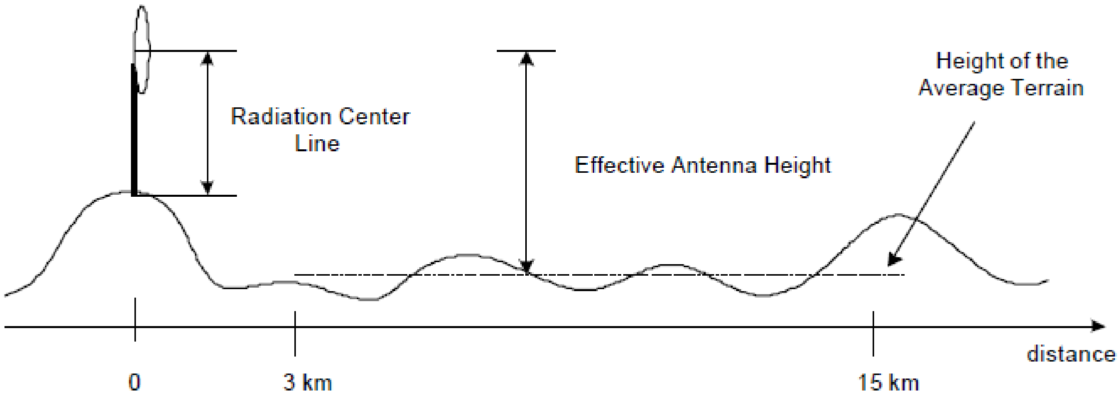

Figure 3.4 Calculation of the effective antenna height for the Okumura model

In his model Okumura provides some additional corrections in graphical form. For example, corrections for street orientation, general slope of the terrain, mixture of land and sea can be used to enhance the model's accuracy. However, in practice these corrections are seldom used.

3-2-2 Hata-Okumura propagation model

In an attempt to make the Okumura's model easier for computer implementation Hata has fit Okumura's curves with analytical expressions. This makes the computer implementation of the model straightforward. Hata's formulation is limited to some values of input parameters.

Hata's model for RSL prediction and the range of parameters for its applicability is given as:

$$RSL_P = P_t + G_t - 69.55 - 26.16\log(f) + 31.82\log\left(\frac{h_{be}}{h_o}\right) + \alpha(h_m) \\ - \left(44.9 - 6.55\log\left(\frac{h_{be}}{h_o}\right)\right)\log\left(\frac{R}{R_o}\right)A_\alpha + DL + A_\alpha + DL \qquad (3.6)$$

Where:

RSL_P Received Signal Level in dBm

P_t Transmitted power in dBm

G_t Transmit antenna gain in the direction of the receiver in dB

f Operating frequency MHz

h_{be} Effective base station antenna height in m

h_o Reference base station antenna height, selected as 1m.

$\alpha(h_m)$ Mobile antenna height correction in dB

R Distance between the bin and the transmitter in km

R_o Reference distance. In Hata model it is always set to 0.62 miles (1km)

DL Diffraction losses in dB

A_α Area adjustment factor in dB

<u>The mobile antenna height correction factor is computed as:</u>

A. For a small city and medium size city:

$$\alpha(h_m) = (1.1\log(f) \; - 0.7)h_m - \; (1.56\log(f) \; - 0.8) \tag{3.7}$$

B. For a large city

$$\alpha(h_m) = 8.29(\log(1.54h_m)\,)^2 - 1.1 \qquad f \leq 200\ Mhz \tag{3.8}$$

$$\alpha(h_m) = 3.2(\log(11.75h_m)\,)^2 - 4.97 \qquad f \geq 400\ Mhz \tag{3.9}$$

<u>The area correction factor can be computed as:</u>

A. For suburban areas:

$$A_\alpha = 5.4 + 2\left[\log\left(\frac{f}{29}\right)\right]^2 dB \tag{3.10}$$

B. For open areas:

$$A_\alpha = 4.78\log(f)^{\,2} - 18.33\;\log(f)\; + 40.94\;\; dB$$

The Hata model was derived for the following values of the system parameters:

$$\begin{gathered} 150\ MHz \;\leq\; fc \;\leq\; 1500\ MHz \\ 30\ ft \;\leq\; h_{be} \;\leq\; 200\ ft \\ 1m \;\leq h_m \;\leq\; 10m \\ 1km \;\leq\; R \;\leq\; 20\ km \end{gathered}$$

Hata implementation of the Okumura's model can be found in almost every RF propagation tool in use today. However, there are some aspects of its application that a user has to be aware of:

1. The Hata model was derived as a numerical fit to the propagation curves published by Okumura. As such, the model is somewhat specific to Japan's propagation environment. In addition, terms like "small city", "large city", "suburban area" are not clearly defined and can be interpreted differently by people with different backgrounds. Therefore, in practice, the area adjustment factor should be obtained from the measurement data in the process of propagation model optimization.
2. In the Okumura's original model, the effective antenna height of the transmitter is calculated as the height of the TX antenna above the average terrain. Measurements have shown several disadvantages to that approach for effective antenna calculation.
   In particular, Hata's model tends to average over extreme variations of the signal level due to sudden changes in terrain elevation. To circumvent the problem, some prediction tools examine alternative methods for calculation of the effective antenna height.

3-2-3 Cost 231(Walfisch and Ikegami) Model:

3-2-3-1 Walfisch and Bertoni model:

A model developed by Walfisch and Bertoni [13] considers the impact of rooftops and building heights by using diffraction to predict average signal strength at street level. It is a semi deterministic model. The model considers the path loss, S, to be the product of three factors:

$$S = P_0 \,.\, Q^2 \,.\, P_1 \qquad (3.11)$$

Where P_0 is the free space path loss between isotropic antennas given by:

$$P_0 = (\lambda/4\pi R)^2 \qquad (3.12)$$

The factor Q^2 reflects the signal power reduction due to buildings that block the receiver at street level. The P1 term is based on diffraction and determines the signal loss from the rooftop to the street. The model has been adopted for the IMT- 2000 standard.

3-2-3-2 Walfisch and Ikegami Model:

This empirical model is a combination of the models from J. Walfisch and F. Ikegami. It was developed by the COST 231 project. It is now called Empirical COST-Walfisch-Ikegami Model. The frequency ranges from 800MHz to 2000 MHz. This model is used primarily in Europe for the GSM1900 system [14] [15]

Path Loss,

$$L_{50} = L_f + L_{rts} + L_{msd} \tag{3.13}$$

Where:

L_f Free-space loss

L_{rts} Rooftop-to-street diffraction and scatter loss

$$L_{rts} = -16.9 - 10\log\left(\frac{w}{m}\right) + 10\log\left(\frac{F}{MHz}\right) + 20\log\left(\frac{\Delta h_{mobile}}{m}\right) + L_{Ori} \tag{3.14}$$

L_{msd} Multi-screen loss

$$L_{msd} = L_{bsh} + K_a + K_d \log d + K_f \log f_c - 9\log b \tag{3.15}$$

This model is restricted to the following range of parameter: frequency range of this model is 800 to 2000 MHz and the base station height is 4 to 50 m and mobile station height is 1 to 3 m, and distance between base station and mobile station d is 0.02 to 5km.

3-2-4 IMT-2000 Pedestrian Environment:

International Mobile Telecommunications (IMT)-2000 (formerly known as Future Public Land Mobile Telecommunication Systems), also known as third-generation wireless, is intended to provide future public telecommunications capable of broadband and multimedia applications [1{8]. Even though the terrestrial component of IMT-2000 will be implemented on a national basis, seamless global roaming and a high degree of commonality of design and compatibility of services are considered essential attributes of IMT- 2000 systems. The Universal Mobile Telecommunications System (UMTS) is the proposed European member of the IMT-2000 family [9,10]. As a concept, it will move mobile communications forward from second-generation systems into the information society and deliver voice, data, pictures, graphics, and other wideband information directly to the user

Three path loss models for IMT-2000/3G are provided in [6], one for the indoor office environment, one for the outdoor to indoor and pedestrian environment, and one for the vehicular environment.

It is the pedestrian model which we describe here, which is simply next equation with

$$P_{rx} = P_{tx} - (40\log(d) + 30\log(f) + k_1 + k_2 + 21) \tag{3.16}$$

Where:

$\alpha = 4$, a constant (optional) offset.

k_1 Building penetration loss

$$k_1 = \begin{Bmatrix} 18 & indoors \\ 0 & outdoos \end{Bmatrix} \tag{3.17}$$

k_2 Log normally distributed offset to account for shadowing loss.

$$k_2 = LN(0,10) = e^{0+10N(0,1)} \tag{3.18}$$

$LN(0,10)$ is a log normally distributed random variable with zero mean and a standard deviation of 10.

Chapter 4
GSM technology and Radio Network Planning

4-1 GSM Technology

GSM is a global system for mobile communication GSM is an international digital cellular telecommunication. The GSM standard was released by ETSI (European Standard Telecommunication Standard) back in 1989. The first commercial services were launched in 1991 and after its early introduction in Europe; the standard went global in 1992. Since then, GSM has become the most widely adopted and fastest-growing digital cellular standard, and it is positioned to become the world's dominant cellular standard. Then the second-generation GSM networks deliver high quality and secure mobile voice and data services (such as SMS/ Text Messaging) with full roaming capabilities across the world.

GSM platform is a hugely successful technology and as unprecedented story of global achievement. In less than ten years since the first GSM network was commercially launched, it become, the world's leading and fastest growing mobile standard, spanning over 173 countries. Today, GSM technology is in use by more than one in ten of the world's population and growth continues to sour with the number of subscriber worldwide expected to surpass one billion by through end of 2003.

Today's GSM platform is living, growing and evolving and already offers an expanded and feature-rich 'family' of voice and enabling services.

The performance of GSM network is mainly based on radio network planning and optimization. Due to increasing subscribers, the changing environments, rapid network expansion exceeding initial projections, capacity limitations due to lack of frequency resources and subscribers mobility profile changing, we need a continuous radio network planning (RNP) and Optimization process that is required as the network evolves. The RNP procedure involves among others coverage and interference analysis, traffic calculations, frequency planning, and cell parameter definitions.

Network optimization is a tradeoff between quality, traffic/revenues and investments. Without fine-tuned network the customer complaints and work load are increased and marketing becomes inefficient. The planning and optimization tools will assist the planner.

However, all GSM operators find problems which are solved through KPI and drive test analysis. This paper addresses few problems and provides the solutions of these problems. The following parameters such as coverage, capacity, quality and cost for planning are considered during planning and optimization process.

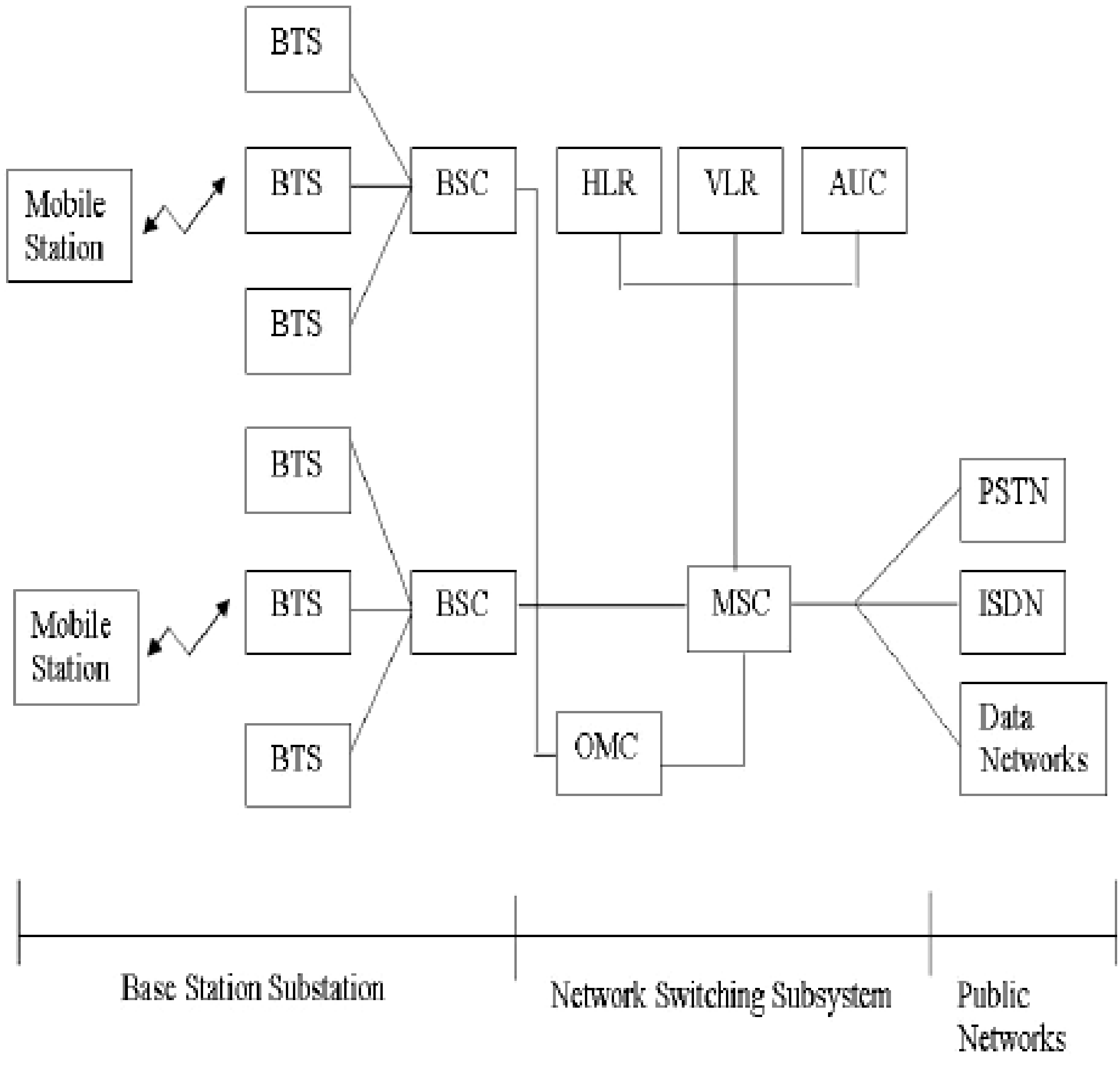

Figure 4.1 GSM Architecture

4-1-1 Basic Specification in GSM

S.N.	Parameter	Specifications
1	Reverse Channel frequency	890-915MHz
2	Forward Channel frequency	935-960 MHz
3	Tx/Rx Frequency Spacing	45 MHz
4	Tx/Rx Time Slot Spacing	3 Time slots
5	Modulation Data Rate	270.833333kbps
6	Frame Period	4.615ms
7	Users per Frame	8
8	Time Slot Period	576.9microsec
9	Bit Period	3.692 microsecond
10	Modulation	0.3 GMSK
11	ARFCN Number	0 to 124 & 975 to 1023
12	ARFCN Channel Spacing	200 kHz
13	Interleaving	40 ms
14	Voice Coder Bit Rate	13.4kbps

Table: 4.1 GSM Air Interface Specifications.

4-1-2 GSM Services

GSM services follow ISDN guidelines and classified as either tele services or data services. Tele services may be divided into three major categories:

- Telephone services, include emergency calling and facsimile. GSM also supports Videotext and Teletext, though they are not integral parts of the GSM standard.
- Bearer services or Data services, which are limited to layers 1, 2 and 3 of the OSI reference model. Data may be transmitted using either a transparent mode or nontransparent mode.
- Supplementary services, are digital in nature, and include call diversion, closed user group, and caller identification. Supplementary services also include the short message service (SMS).

4-2 Radio Network Planning and Optimization

The radio network planning and optimization is usually comparative process and requires an initial baseline of KPI’s and objectives. These can be derived from operator’s individual design guidelines, service requirements, customer expectation, market benchmarks and others. Networks must be dimensioned to support user demands. RNP and optimization process play a very significant and vital role in optimizing an operational network to meet the ever-increasing demands from the customers.

Coverage is the most important quality determining parameter in a radio network. A system with good coverage will always be superior to a system with less good coverage. An area is referred to as being covered if the signal strength received by an MS in that area is higher than a certain minimum value. A typical value in this case is around -95dBm. However, coverage in a two-way radio communication system is determined by the weakest link.

A link budget must be compiled before start of the dimensioning of the radio network. In the link budget, different design criteria for coverage (e.g. outdoor, indoor, in-car) is determined. In addition to this, factors such as receiver sensitivity and different margins are considered. Power budget implies that the coverage of the downlink is equal to the coverage of the uplink. The power budget shows whether the uplink or the downlink is the weak link. When the downlink is stronger, the EIRP used in the prediction should be based on the balanced BTS output power.

When the uplink is stronger, the maximum BTS output power is used instead. Practice indicates that in cases where the downlink is the stronger it is advantageous to have a somewhat (2-3 dB) higher base EIRP than the one strictly calculated from power balance considerations [5], [6].

Defining the radio network parameters is the final step in the design of a radio network. There are a number of parameters that has to be specified for each cell. The parameters could be divided into four different categories, which are:

1- Common cell data

Example: Cell Identity, Power setting, Channel numbers

2- Neighboring cell relation data

Example: Neighboring Cell relation, Hysteresis, Offset

3- Locating and idle mode behavior

Example: Paging properties, Signal strength criteria, Quality thresholds

4- Feature control parameters

Example: Settings to control the behavior of e.g. Frequency Hopping and Dynamic Power Control [7].

Under normal circumstances, careful planning of wireless networks is vital if operators wish to make full use of existing investments. The optimization process has to produce alternative designs that fit according to the operator's planning goals depending on parameter settings. The traffic projection figures are vital for planners as it is used to denote the volume and nature of traffic processed by network nodes as shown in figure 4.2. The volume of traffic received determines the number of nodes used and capacity provisioned between nodes, whilst the nature of traffic has a bearing on the type of nodes deployed as well as allowing the planner to forecast traffic trends.

To determine projected growth in traffic, several factors are involved such as population types, incomes, distribution of wealth, taxation and spending habits. There is also a need for statistics depicting the existing penetration of mobile voice services and average Internet usage in the market.

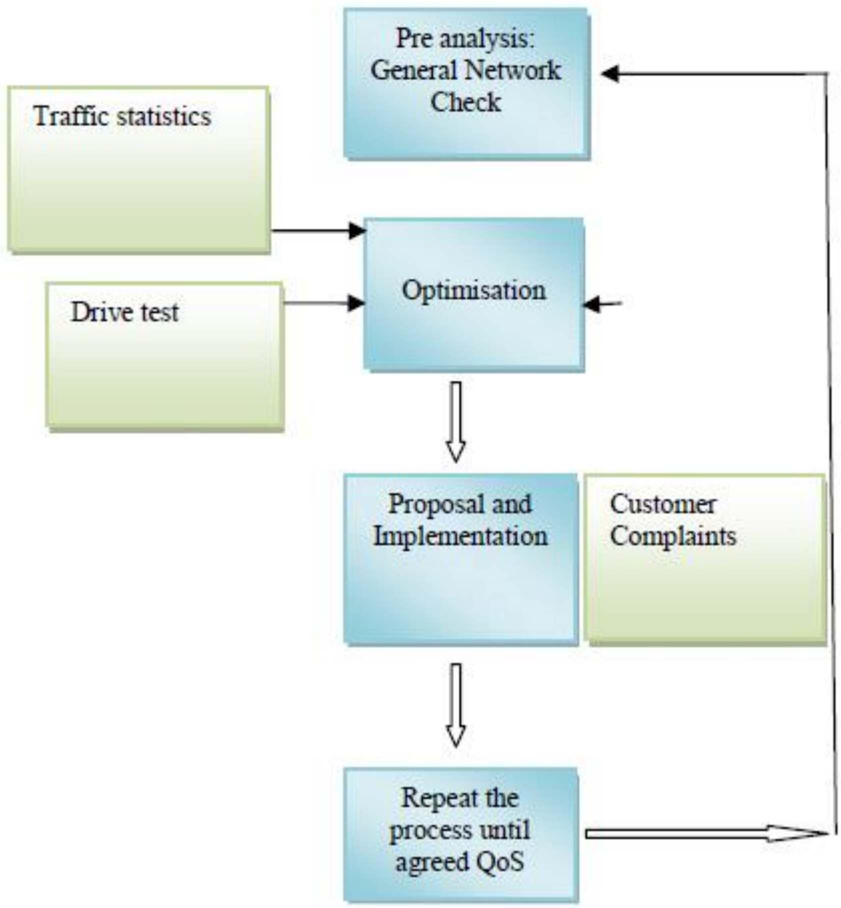

Figure 4.2 Radio Network Optimization Process

4-3 Frequency Reuse

In mobile communication systems a slot of a carrier frequency / code in a carrier frequency is a radio resource unit. This radio resource unit is assigned to a user in order to support a call/ session. The number of available such radio resources at a base station thus determines the number of users who can be supported in the call. Since in wireless channels a signal is "broadcast" i.e. received by all entities therefore one a resource is allocated to a user's it cannot be reassigned until the user finished the call/ session. Thus the number of users who can be supported in a wireless system is highly limited. In order to support a large no. of users within a limited spectrum in a region the concept of frequency re-use is used.

The signal radiated from the transmitter antenna gets attenuated with increasing distance. At a certain distance the signal strength falls below noise threshold and is no longer identifiable.

In this region when the signal attenuates below noise oor the same radio resource may be used by another transmission to send different information. In term of cellular systems, the same radio resource (frequency) can used by two base stations which a sufficient spaced apart. In this way the same frequency gets reused in a layer- geographic area by two or more different base station different users simultaneously.

The cellular concept is the major solution of the problem of spectral congestion and user capacity. Cellular radio rely on an intelligent allocation and channel reuse throughout a large geographical coverage region.

4-3-1 Cellular Frequency Reuse

Each cellular base station is allocated a group of radio channels to be used within a small geographic area called a cell. Base stations in adjacent cells are assigned channel groups which contain completely different channels than neighboring cells. Base station antennas are designed to achieve the desired coverage within a particular cell. By limiting the coverage area within the boundaries of a cell, the same group of channels may be used to cover different cells that are separated from one another by geographic distances large enough to keep interference levels within tolerable limits. The design process in figure 4.3 of selecting and allocating channel groups for all cellular base stations within a system is called frequency reuse or frequency planning.

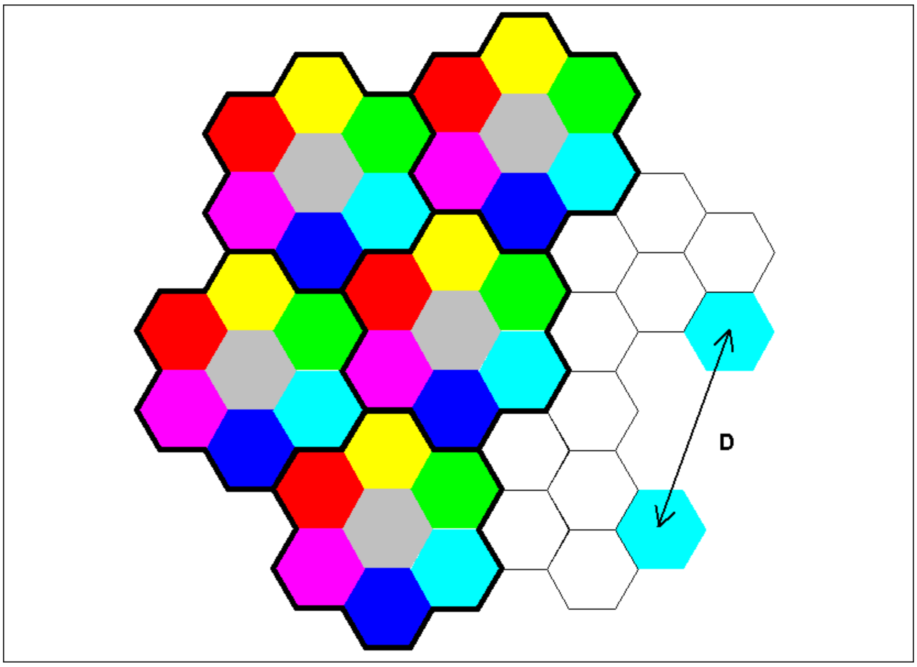

Figure 4.3 Cellular Frequency Reuse

4-3-2 Hexagonal Cell Structure

In figure 4.4, cells labeled with the same letter use the same group of channels. The hexagonal cell shape is conceptual and is the simplistic model of the radio coverage for each base station. It has been universally adopted since the hexagon permits easy and manageable analysis of a cellular system. The actual radio coverage of a system is known as the footprint and is determined from old measurements and propagation prediction models. Although the real footprint is amorphous in nature, a regular cell shape is needed for systematic system design and adaptation for future growth.

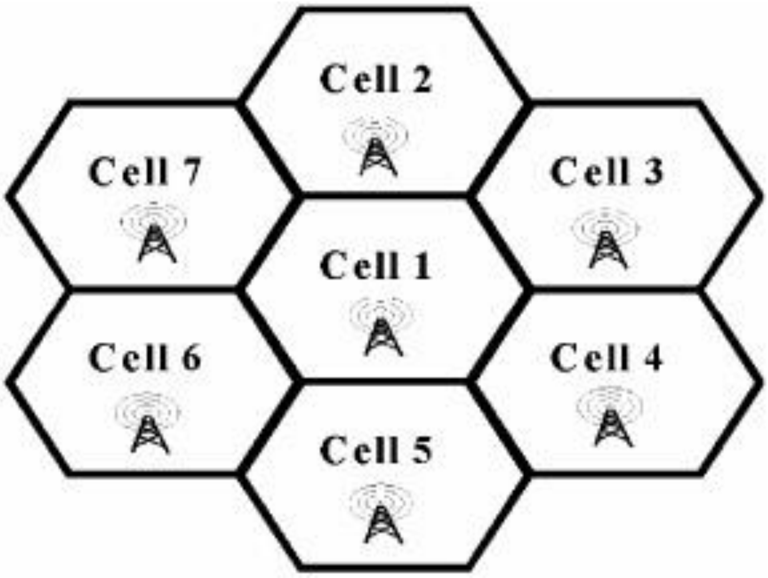

Figure 4.4 Hexagonal Cell Structure

If a circle is chosen to represent the coverage area of a base station, adjacent circles overlaid upon a map leave gaps or overlapping regions. A square, an equilateral triangle and a hexagon can cover the entire area without overlap and with equal area. A cell must serve the weakest mobiles typically located at the edge of the cell within the foot print. For a given distance between the center of a polygon and its farthest perimeter points, the hexagon has the largest area of the three. Thus, with hexagon, the fewest number of cell scan cover a geographic region and close approximation of a circular radiation pattern that occurs for an omni-directional base antenna and free space propagation is possible.

Base station transmitters are situated either at the center of the cell (center-excited cells) or at three of the six cell vertices (edge-excited cells). Normally, omnidirectional antennas are used in center-exited cells and sectored directional antennas are used in edge-exited cells.

Practical system design considerations permit a base station to be positioned up to one-fourth the cell radius away from the ideal location.

4-3-3 Cell Cluster

Considering a cellular system as figure 4.5 that has a total of S duplex radio channels. If each cell is allocated a group of k channels $(k < S)$and if the S channels are divided among N cells into unique and disjoint channel groups of same number of channels, then,

$$S = kN \qquad (4-1)$$

The N cells that collectively use the complete set of available frequencies is called a cluster. If a cluster is replicated M times within the system, the total number of duplex channels or capacity,

$$C = MkN = MS\,kN \qquad (4-2)$$

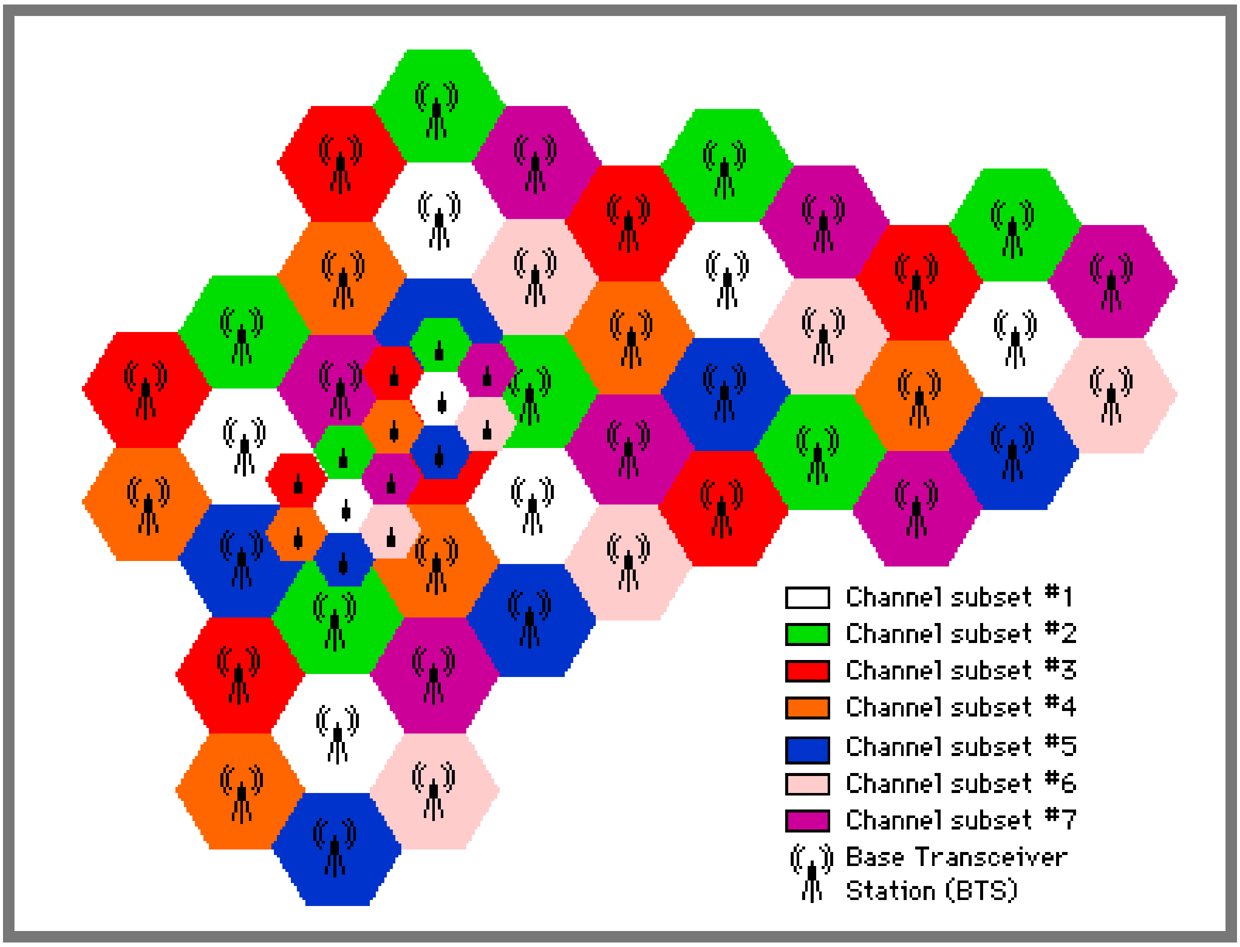

Figure 4.5 Cell Cluster

Chapter 5
Practical Implementation

5-1 Introduction

Theoretical study always lead to practical implementation in order to check the results of these studies. The project was implemented using MATLAB© Software, which it is a high-level language and interactive environment for numerical computation, visualization, and programming. The project was divided into 3 sections, Okumura-Hata Model, COST-231 Model and IMT-2000 Model.

5-2 Okumura-Hata Model

Okumura-Hata Model is the most widely used radio frequency propagation model for predicting the behavior of cellular transmissions in built up areas. This model incorporates the graphical information from Okumura model and develops it further to realize the effects of diffraction, reflection and scattering caused by city structures. This model has three varieties for transmission, Urban Areas, Suburban Areas and Rural.

<u>This model coverages the following parameters:</u>

- Frequency: 150–1500 MHz
- Mobile Station Antenna Height: 1–10 m
- Base station Antenna Height: 30–200 m
- Link distance: 1–10 km.

Okumura-Hata model was implemented as shown in the figure (5.1) below. The figure shows the selected propagation model, in response to this selection the propagation parameters panel was appeared. After that, the parameters were inserted according to the model coverage parameters, then the button was pressed to calculate the transmission loss curves in the different areas. The legend in the axes panel shows the corresponding curves and its mapping. All function codes listed in Appendix A.

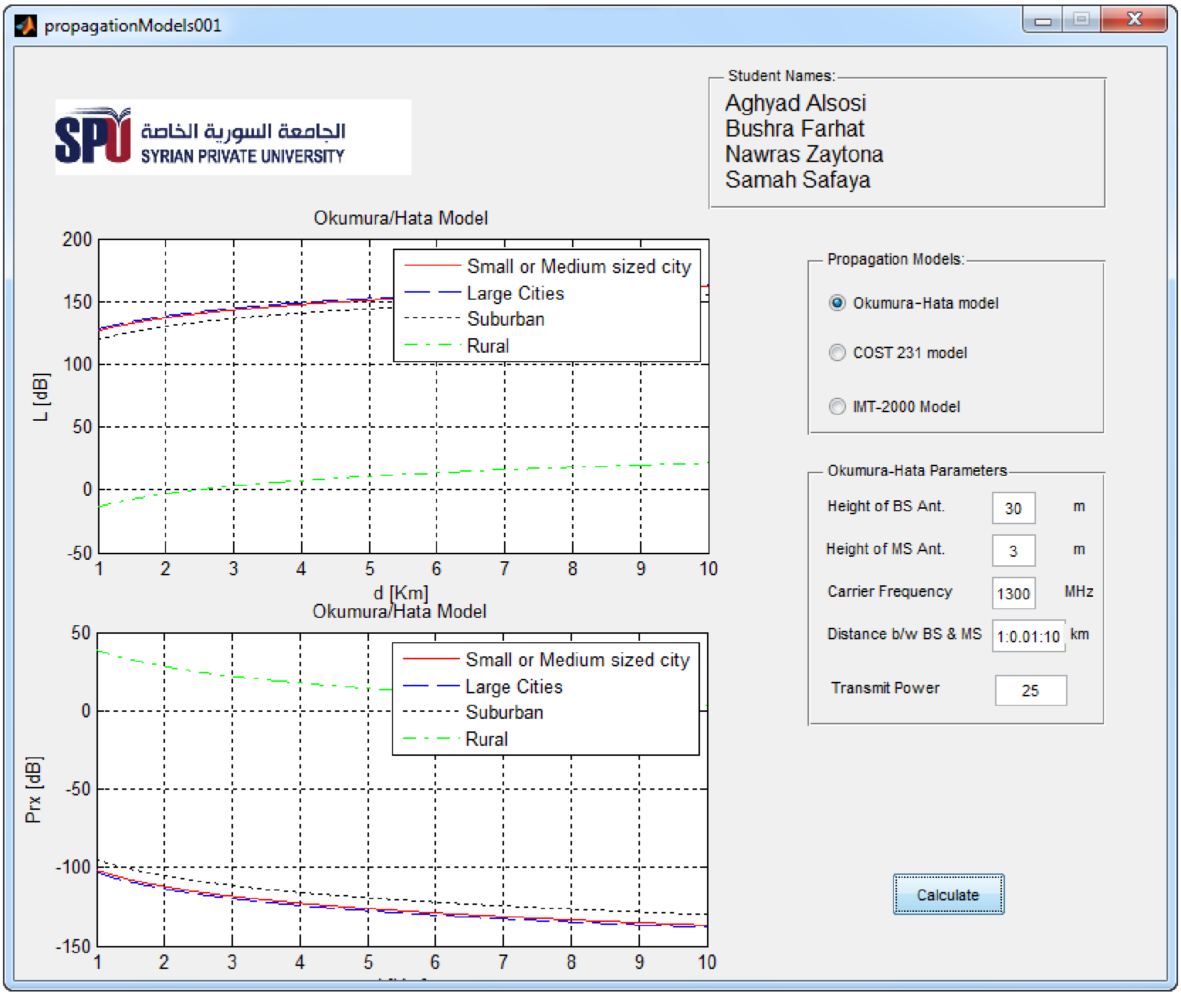

Figure 5.1 Implementing of Okumura-Hata model

The figure shows a comparison between the different Okumura/Hata Model Types. The loss axes shows that the rural model is the lowest one of loss.

Compression with another study, at operating frequencies 1900 MHz are used. The average building height is fixed to 15 m while the building to building distance is 50 m and street width is 25 m [18]. Then on that basis a comparison was done between theoretical and experimental values by MATLAB as show in figure 5.2 for Rural, Urban, and sub-urban area. In practical case the losses are close to project simulation results.

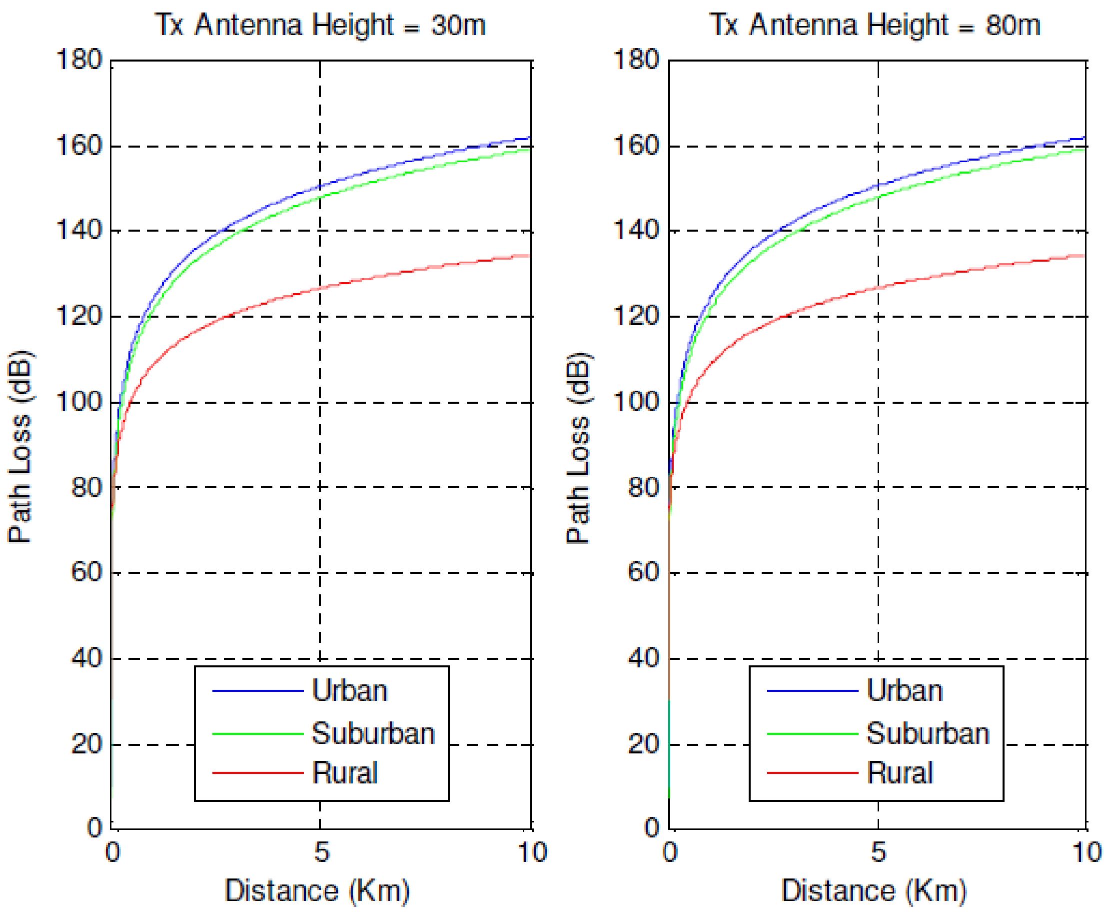

Figure 5.2 Another simulation of Okumura-Hata model

5-3 COST-231 Model

COST-231 Model also called (COST Hata model) is a radio propagation model that extends the urban Hata model (which in turn is based on the Okumura model) to cover a more elaborated range of frequencies. This model is applicable to urban areas. To further evaluate Path Loss in Suburban or Rural Quasi-open/Open Areas, this path loss has to be substituted into Urban to Rural/Urban to Suburban Conversions.

<u>This model coverages the following parameters:</u>

- Frequency: 1500–2000 MHz
- Mobile station antenna height: 1–10 m
- Base station Antenna height: 30–200 m
- Link distance: 1–20 km

COST-231 model was implemented as shown in the figure (5.3) below. After the selection of COST 231 Model in Propagation Models Panel, the COST 231 Parameters Panel appear. The parameters were inserted according to the coverage parameters of the model. All function codes listed in Appendix A.

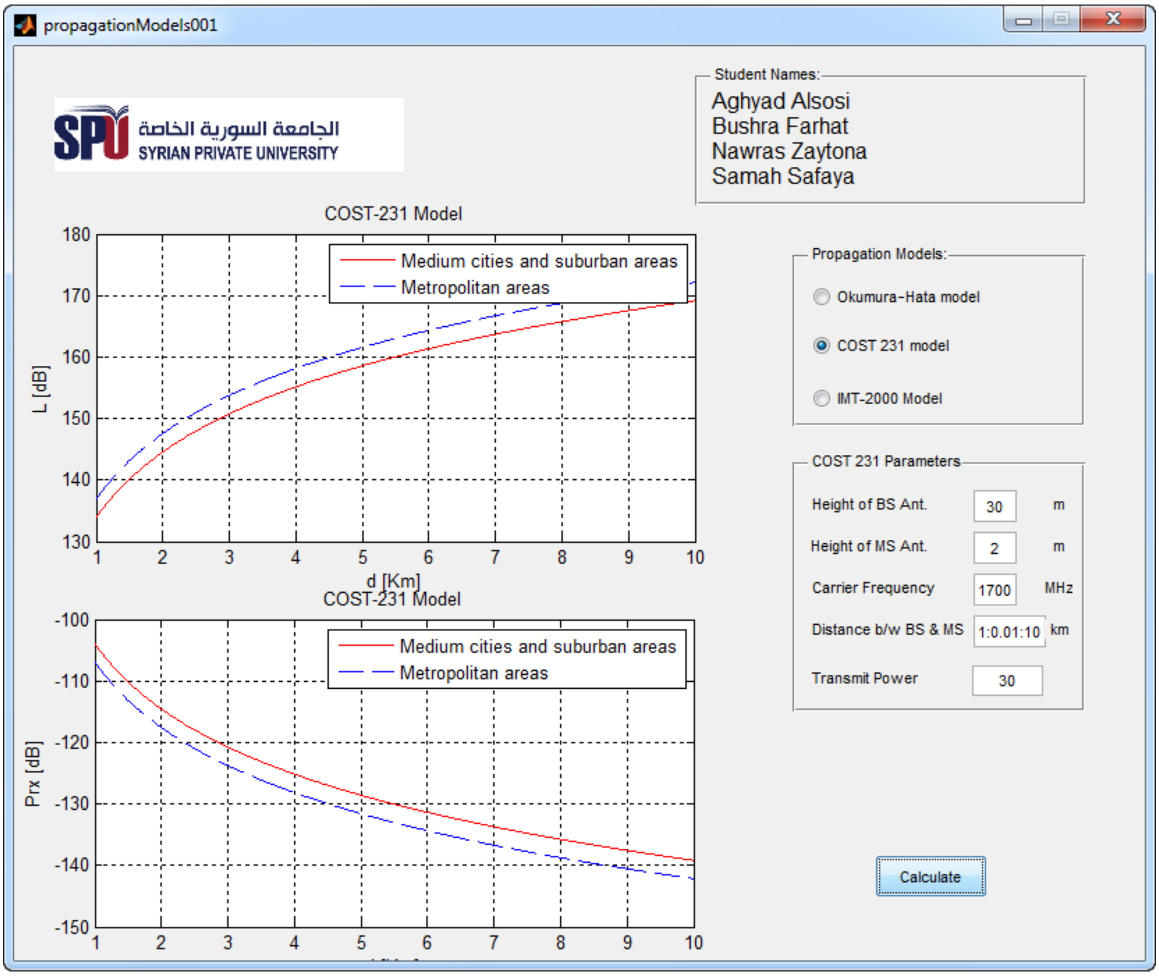

Figure 5.3 Implementing of Cost-231 model

Compression with another study the empirical formulas of path loss calculation as described in the earlier section are used and the path loss is plotted against the distance for different frequencies & different BS heights [18]. Figure 5.5, path loss for COST Walfisch-Ikegami Model. In practical case the losses are close to project simulation results.

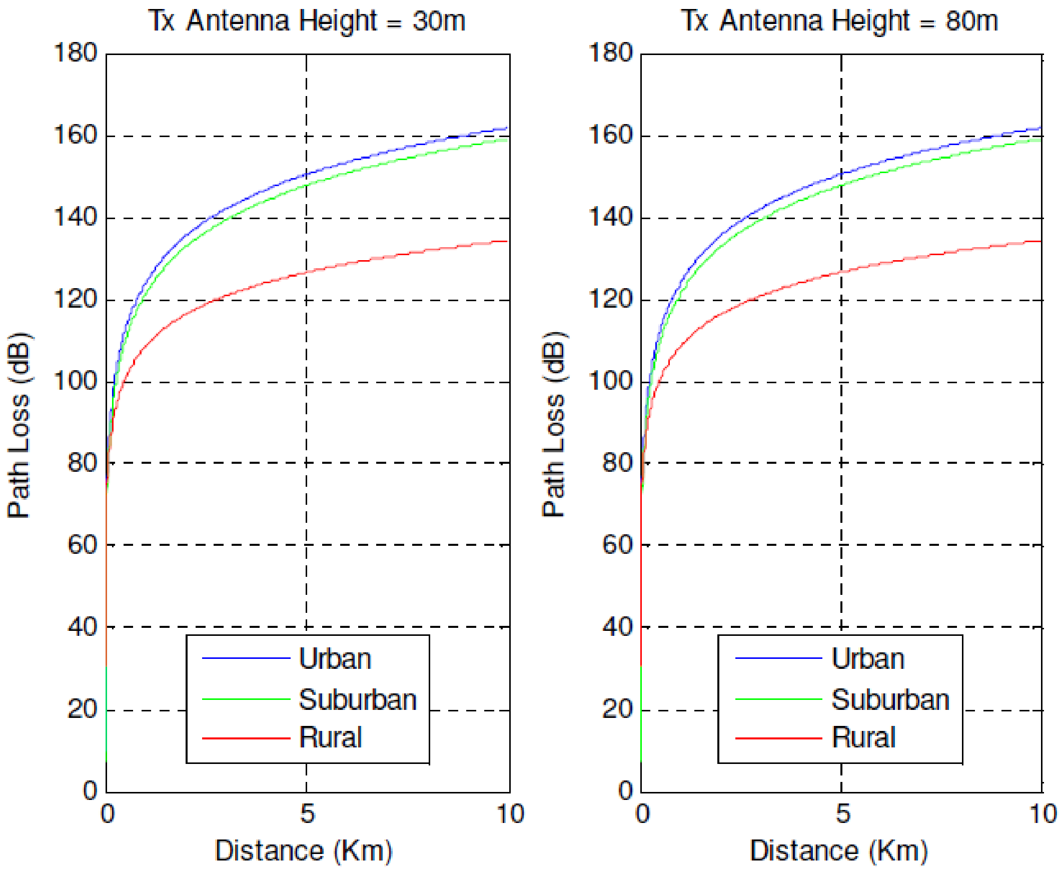

Figure 5.4 Another simulation of COST Walfisch-Ikegami Model

5-4 IMT-2000 Model

International Mobile Telecommunications-2000 (IMT-2000) are third generation mobile systems which are scheduled to start service around the year 2000 subject to market considerations. They will provide access, by means of one or more radio links, to a wide range of telecommunication services supported by the fixed telecommunication networks (e.g. PSTN/ISDN), and to other services which are specific to mobile users.

Key features of IMT-2000 are:

- High degree of commonality of design worldwide.
- Compatibility of services within IMT-2000 and with the fixed networks.
- High quality.
- Use of a small pocket terminal with worldwide roaming capability.

5-4-1 Path loss model for indoor office test environment

The indoor path loss model (dB) is in the following simplified form, which is derived from the COST 231 indoor model. This low increase of path loss versus distance is a worst-case from the interference point of view:

$$L = 37 + 30\log_{10} R + 18.3n^{\left(\frac{n+2}{n+1}-0.46\right)} \tag{5.1}$$

Where:

R: transmitter-receiver separation (m)

n: number of floors in the path.

IMT-2000 indoor model was presented in figure (5.5) below. Function code listed in Appendix A.

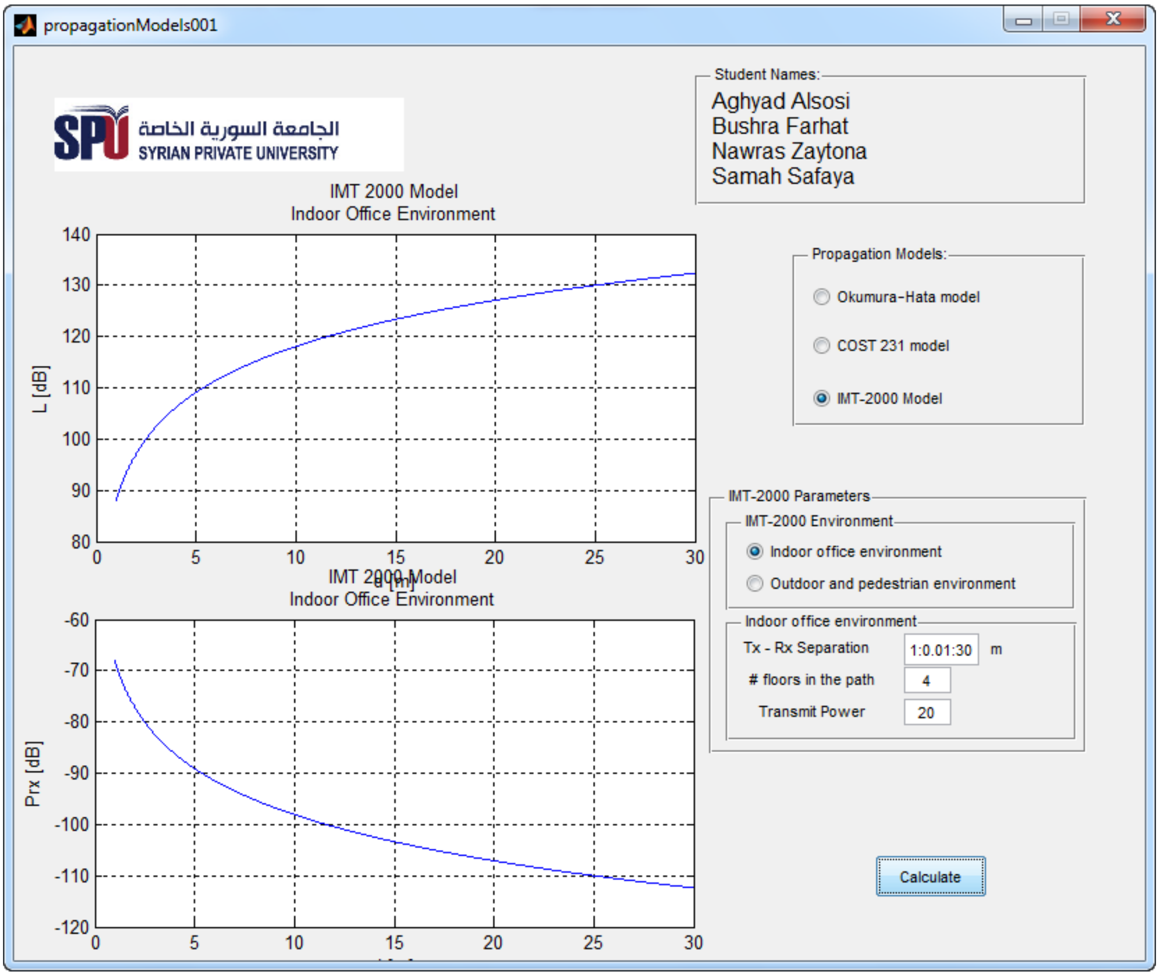

Figure 5.5 Implementing of IMT-2000 model for indoor office test environment

5-4-2 Path loss model for outdoor to indoor and pedestrian test environment

The following model should be used for the outdoor to indoor and pedestrian test environment:

$$L = 40\log_{10} R + 30\log_{10} f + 49 \qquad (5.2)$$

Where:

R: base station – mobile station separation (km)

f: carrier frequency of 2 000 MHz for IMT-2000 band application.

IMT-2000 outdoor model was presented in figure (5.6) below. Function code listed in Appendix A.

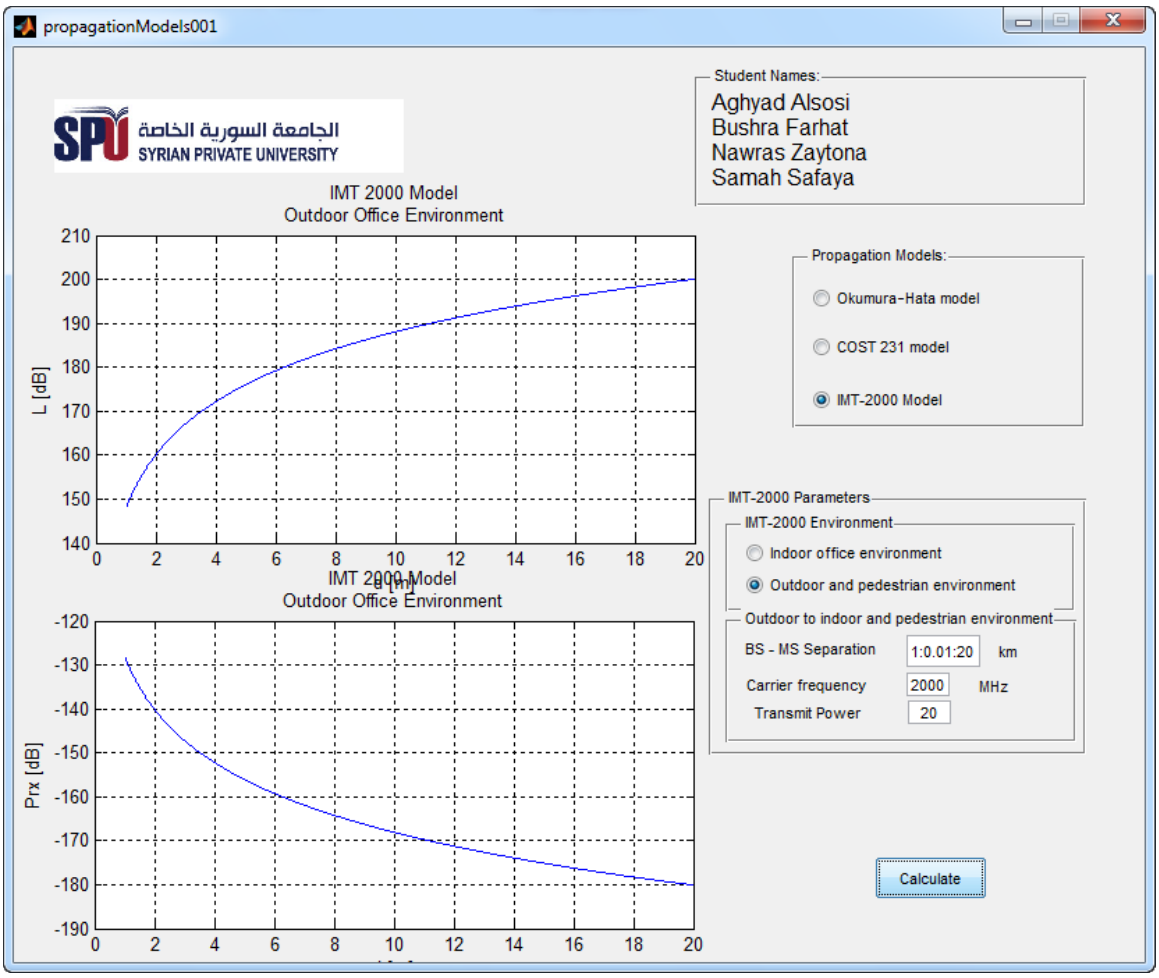

Figure 5.6 Implementing of IMT-2000 model for outdoor to indoor and pedestrian test environment

Chapter 6
Conclusion and future work

6-1 Conclusion

In order to estimate the signal parameters accurately for mobile systems, it is necessary to estimate a system's propagation characteristics through a medium. Propagation analysis provides a good initial estimate of the signal characteristics. The ability to accurately predict radio-propagation behavior for wireless personal communication systems, such as cellular mobile radio is becoming crucial to system design. Since site measurements are costly, propagation models have been developed as a suitable, low-cost, and convenient alternative. Channel modeling is required to predict path loss and to characterize the impulse response of the propagating channel. The path loss is associated with the design of base stations, as this tells us how much a transmitter needs to radiate to service a given region. Channel characterization, on the other hand, deals with the fidelity of the received signals, and has to do with the nature of the waveform received at a receiver. This report introduce a review of the information available on the various propagation models for both indoor and outdoor environments. We have reported the important aspects of empirical models that they attempt to predict the field strength at a precise point in space by considering the specific propagation environment circumstances involved.

In spite of their limitations, empirical models such as the Okumura-Hata, COST-231, and IMT-2000 models are still widely used because they are simple and allow rapid computer calculation. When the propagation environment is fairly homogeneous and similar to the environment where the model measurements were taken, an empirical model can achieve reasonably good prediction results.

6-2 Future Work

The project was developed in a very good process. Since we study the theoretical study after that we study the equation and design the Graphical User Interface that we had been showed earlier. We can develop the GUI to take into consideration another types of propagation models, or compute the loss versus frequency instead of distance.

However, most propagation models aim to predict the median path loss. Today‟s predictions models differ in their applicability over different environmental and terrain conditions. There are many predictions methods based on deterministic processes through the availability of improved data values, but still the Okumura-Hata model is most commonly used empirical propagation model.

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Appendix A

A.1 Okumura-Hata Model

```
function [l1, l2, l3, l4, p1, p2, p3, p4] = hata(d, frequency, hbs,
hms, pin)


hataLoss1 = hata_medium_to_small(d, frequency, hbs, hms);

hataLoss2 = hata_large(d, frequency, hbs, hms);

hataLoss3 = hata_suburban_areas(d, frequency, hbs, hms);

hataLoss4 = hata_open_areas(d, frequency, hbs, hms);

l1 = hataLoss1;
l2 = hataLoss2;
l3 = hataLoss3;
l4 = hataLoss4;

prx1 = pin - hataLoss1;
prx2 = pin - hataLoss2;
prx3 = pin - hataLoss3;
prx4 = pin - hataLoss4;

p1 = prx1;
p2 = prx2;
p3 = prx3;
p4 = prx4;
```

```
function lossDB = hata_large(distance, frequency, hbs, hms)

A = 69.55 + 26.16*log10(frequency) - 13.82*log10(hbs);
B = 44.9 - 6.55*log10(hbs);
if frequency >= 300
    E = 3.2*(log10(11.7554*hms)*log10(11.7554*hms)) - 4.97;
elseif frequency < 300
    E = 8.29*(log10(1.54*hms)*log10(1.54*hms)) - 1.1;
end
lossDB = zeros(length(distance),1);
for k = 1 : length(distance),
   lossDB(k) = A + B*log10(distance(k)) - E;
end
```

```
function lossDB = hata_medium_to_small(distance, frequency, hbs,
hms)
```

```
A = 69.55 + 26.16*log10(frequency) - 13.82*log10(hbs);
B = 44.9 - 6.55*log10(hbs);
E = (1.1*log10(frequency) - 0.7)*hms - (1.56*log10(frequency) -
0.8);
lossDB = zeros(length(distance),1);
for k = 1 : length(distance),
   lossDB(k) = A + B*log10(distance(k)) - E;
end
```

```
function lossDB = hata_open_areas(distance, frequency, hbs, hms)

A = 69.55 + 26.16*log10(frequency) - 13.82*log10(hbs);
B = 44.9 - 6.55*log10(hbs);
D = 4.78*(log10(frequency)*log10(frequency)) +
18.33*log10(frequency) + 40.94;
lossDB = zeros(length(distance),1);
for k = 1 : length(distance),
   lossDB(k) = A + B*log10(distance(k)) - D;
end
```

```
function lossDB = hata_suburban_areas(distance, frequency, hbs, hms)

A = 69.55 + 26.16*log10(frequency) - 13.82*log10(hbs);
B = 44.9 - 6.55*log10(hbs);
C = 2*(log10(frequency/28)*log10(frequency/28)) + 5.4;
lossDB = zeros(length(distance),1);
for k = 1 : length(distance),
   lossDB(k) = A + B*log10(distance(k)) - C;
end
```

A.2 COST-231 Model

```
function [l1, l2, p1, p2] = hatacost231(distance, frequency, hbs,
hms, pin)

cost231suburban = hatacost231suburban(distance,frequency,hbs,hms);
cost231metropolitan =
hatacost231metropolitan(distance,frequency,hbs,hms);

l1 = cost231suburban;
l2 = cost231metropolitan;

prx1 = pin - cost231suburban;
prx2 = pin - cost231metropolitan;

p1 = prx1;
```

```
p2 = prx2;
```

```
function metropolitanLoss = hatacost231metropolitan(distance, 
frequency, hbs, hms)

for k = 1 : length(distance),
    loss = 46.30 + 33.90*log10(frequency) - 13.82*log10(hbs) + (44.9 
- 6.55*log10(hbs))*log10(distance(k));
    loss = loss -(1.1*log10(frequency)-0.7)*hms + 
(1.56*log10(frequency)-0.8);
    loss = loss + 3;
    metropolitanLoss(k) = loss;
end
```

```
function suburbanLoss = hatacost231suburban(distance, frequency, 
hbs, hms)

for k = 1 : length(distance),
    loss = 46.30 + 33.90*log10(frequency) - 13.82*log10(hbs) + (44.9 
- 6.55*log10(hbs))*log10(distance(k));
    loss = loss -(1.1*log10(frequency)-0.7)*hms + 
(1.56*log10(frequency)-0.8);
    suburbanLoss(k) = loss;
end
```

A.3 IMT-2000 Model

```
function indoorofficeenivron(d,n)

y = ((n+2)/(n+1)-0.46);
for k = 1:length(d)
    L50(k) = 37 + 30*log10(d(k)) + 18.3*n^y;
end

plot(d , L50);
grid on;
xlabel('d [m]');
ylabel('L [dB]');
title({'IMT 2000 Model';'Indoor Office Environment'});
```

```
function outdoortoindoor(fc,d)

for k = 1:length(d)
    L50(k) = 40*log10(d(k)) + 30*log10(fc) + 49;
end

plot(d , L50);
grid on;
```

```
xlabel('d [m]');
ylabel('L [dB]');
title({'IMT 2000 Model';'Outdoor Office Environment'});
```