EFFECT OF TERRAIN FEATURES ON WAVE PROPAGATION

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Date : 10 June 2013

This project and research work is dedicated to my beloved parents for their devoted caring throughout my life, my loving sister, also my friends for their encouragement and support.

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ABSTRACT

Path-loss prediction algorithms for advanced wireless communication system planning have long considered the effect of electromagnetic propagation over buildings between the base station and subscriber. It briefly discusses the theory of reflection, diffraction and scattering over urban, suburban and rural area. This research is to present the implementation of different models for predicting the path loss between a base station antenna and mobile station antennas. The prediction of path loss is a very important step in planning a mobile radio system and accurate prediction methods are needed to determine the parameters of a radio system which will provide efficient and reliable coverage of a specified service area. The significant of this research is to determined the best emperical method for predicting the path loss between base station antenna and mobile station. This research describes three chosen path loss models which is Hatta-Okumura model, Stanford University Interim (SUI) model and Ericson model. In this research, the analyzing model above in different distance range, height of base station and height of mobile station in urban, suburban and rural environment. As a conclusion, in order to build an effective communication link the precise path loss prediction is very important. For each type of terrains (urban, suburban and rural) Hatta-Okumura model are the best path loss prediction model.

ABSTRAK

Path loss prediction adalah penting dalam perancangan sistem komunikasi yang maju. Ia adalah kesan daripada penyebaran electromagnetik diantara bangunan daripada stesen pemancar kepada stesen penerima. Secara ringkasnya, kajian ini membincangkan kesan aktiviti pantulan, pembiasan dan penyebaran di kawasan Bandar, pinggir Bandar dan luar Bandar. Kajian ini membincangkan kepelbagaian model *path loss prediction* untuk meramalkan *path loss* yang terjadi apabila isyarat di hantar daripada stesen pemancar kepada stesen penerima. Ini adalah satu langkah yang amat penting dalam perancangan system komunikasi yang berkesan di setiap kawasan. Kajian ini menerangkan tiga kaedah erbaik untuk path loss prediction yang mana ia nya adalah kaedah *Hatta-Okumura*, kaedah *Stanford university Interim (SUI)* dan kaedah *Ericson*. Saya juga menganalisis kaedah tersebut dalam jarak kawasan liputan yang berbeza, ketinggian stesen pemancar yang berbeza dan ketinggian stesen penerima yang berbeza di kawasan Bandar, pinggir Bandar dan luar Bandar. Kesimpulannya, untuk membina satu sistem komunikasi yang baik, *path loss* perlu diramal secara tepat. Melalui kajian ini dapat saya nyatakan untuk setiap jenis kawasan (Bandar, pinggir Bandar dan luar Bandar) model *Hatta-Okumura* adalah yang terbaik untu meramalkan *path loss*.

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CHAPTER 1

INTRODUCTION

According to the technological advancements which permit wider deployment nowadays, wireless communication has been grow rapidly in mobile communications field [1,2]. The requirement for high quality and high capacity networks, estimating coverage accurately has become extremely important. Therefore, for more accurate design coverage of modern networks, signal strength measurements must be taken into account in order to provide an efficient and reliable coverage area [3].

This research is to discuss the impact of terrains future on wave propagation. The common type of terrains future on wave propagation field is urban environment, rural place, forest environment and suburban area. Furthermore, the effect of hills, vegetation effects, high land, high buildings, vehicles and other obstacles will contribute to the great path losses in mobile communication.

Any of the ways in which wave are travel are called wave propagation. Radio wave propagation is propagation of radio frequency electromagnetic waves in the atmosphere, in outer space and underground. The path traveled by radio waves between a base station (transmitter) and mobile station (receiver). The way in which radio waves propagate depends on certain factors such as the wavelength and how far the waves are transmitted. Not like the wired channels that are stationary and predictable, radio channels are extremely random and do not easily analyze.

Over the years, a lot of study had been done about how the types of terrain give an effect on wave propagation. Cities are frequently built on rolling hills or on undulating terrain so that, radio propagation may be simultaneously affected by both buildings and terrain [4]. That has long been recognized that communication by means of radio waves in forest environments is affected by transmission losses which are substantially higher than those occurring in the absence of vegetation [5]. All this studies are briefly explain the effect of terrains features on wave propagation [6-18].

The objectives of this research are to estimates the effect of natural terrain features on the wave propagation. Natural terrain is referring to the location of the base station (transmitter). Either in urban area or suburban area or rural places, all this location will contribute to interferences of wave propagation. Based on the study from previous paper, the main effect from each area could determine such as reflection, diffraction and scattering. The explanation about each effect will discuss in next chapter.

Besides that, this research is to implement the chosen models for predicting the path loss between the base station (transmitter) and mobile station (receiver). From the study, the path loss prediction on wave propagation could be determined by so many technique such as the slab model of the forest [5], 3D Parabolic equation [18] and others techniques. The model of predicting the path loss will discuss detailed in next chapter.

The main issue of this research is investigation the factor of natural terrains on wave propagation. When wave are propagate in urban area, there will have tall tower, huge building, vehicles, diffraction over roof top and other obstructions. While, on suburban area there has vegetation effect and buildings reflection. Then, for rural place maybe there has high land, hills and foliage effect that has to be considered in field to predict the path loss. All this three types of terrains has their correction environment factor that determine in each path loss prediction model. Moreover, the height of base station antenna and mobile station antenna also give effect on wave propagation loss [19].

This research is limited on certain range of distance, height base station and height mobile station. The challenge in this project is how to predict the path loss at the cellular frequency of 2.4 GHz. There are several empirical propagation models which can precisely calculate up to 2 GHz. In recent study, has determined the path loss prediction for WiMAX application [20-22].

This research deals with how the natural terrains give effect on wave propagation. First of all, the basic mechanism of wave propagation had been discussed in detail. Next, the three chosen model for path loss prediction which is Hatta-Okumura model, SUI model and Ericson model had been described briefly with varies base station antenna height and mobile station antenna height which have been proposed for frequency at 2.4GHz in urban and suburban and rural environments. Otherwise, this research also provides the development of MATLAB coding and run that simulation program for predicting path loss.

In short, this research starts with the phenomenon of the natural terrains on wave propagation. Then, understand the theory of wave propagation mechanism in term of path loss prediction. Next, familiar with MATLAB program and build the coding. In chapter 2, it discusses the theoretical background study of this research and in chapter3, discusses the path loss model prediction. Chapter 4 is about MATLAB coding and simulation. Lastly, Chapter 5 is conclusion of this research.

CHAPTER 2

LITERITURE REVIEW

Over the years, a lot of study had been done about how the types of terrain give an effect on wave propagation. Cities are frequently built on rolling hills or on undulating terrain so that, radio propagation may be simultaneously affected by both buildings and terrain [4]. That has long been recognized that communication by means of radio waves in forest environments is affected by transmission losses which are substantially higher than those occurring in the absence of vegetation [5]. All this studies are briefly explain the effect of terrains features on wave propagation [6-18].

2.1 Basic Mechanism of Wave Propagation

Wireless communication term refers to transfer of information via electromagnetic waves over atmospheric space rather than along a wierd cable. The apparent wrinkle between such a scheme and conventional wired systems is the presence of the wireless channel as the medium over which the communication must take place. Unfortunately, this medium is hostile in regards to delaying, attenuating, and even completely interfere the transmitted signal. Thus when considering a basic digital wireless communication system, the design of each building block will be dependent on the channel between transmitter and receiver.

Propagation channel is a linear system defining a transformation between an input and an output signal, for best understanding the channel and overcome its imperfections. In fact, signal contempt many distortions such as delays and spreading. These distortions are due to various reflections that signal faces up during the Emission- Reception path. Consequently, other additive signals will be perceived by the receiver besides the main transmitted signal which must be captured in ideal situations. These additional signals have followed various and different paths. That's what is usually callaed as Multipath. With higher rates used in digital communications the delay spreading scale and a superposition between them will be observed. Parameters like antennas heights, interference, frequency band, polarization etc, and have an influence upon channel behavior. Direction and distance between reflectors (buildings, mountains, walls, cars) influence followed channel and channel awkward [22].

The wireless medium presents the difficulties for communication system by its natural phenomenon. The atmospheric medium most relevant to terrestrial radio propagation may be specified as figure below. The troposphere is the first layer above the earth surface, it contains almost half of earth's atmosphere and which weather takes place. The troposphere is the region up to a height of 8 up to 10 km from earth's surface. The percentage of gas vapor remains constant with increase of height, but the water vapor component reduced significantly with height. In troposphere or space wave propagation the EM waves transmitted by transmitting antenna reach the receiving antenna either directly or after reflecting from the earth surface in the troposphere region within 16 km above the earth surface. The space wave at the receiver is constituted of direct ray from the transmitter and reflected ray from earth. Both wave reach the receiver at same time but may have same phase or out of phase as they travel different path.

Next is the ionosphere, where ions and electrons exist in sufficient quantities to refract and/or reflect the electromagnetic radio waves. Ionosphere is the upper part of the atmosphere where the ionization is appreciable. The upper part of atmosphere absorbs larger quantity of radiant energy from the sun. This not only heats the atmosphere but also produces ionization. The ions can be easily affected by electric forces collision occurs between ion, electron and recombination takes place.

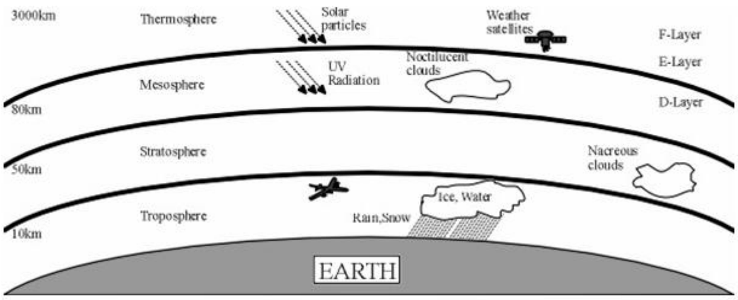

Figure 2.1: Earth layer

The propagation of a radio wave through some physical environment is effected by various mechanisms which affect the fidelity of the received signal. Accurate prediction of these effects is important in the design and development of a communications system. These effects can include shadowing and diffraction caused by obstacles along the propagation path, such as hills or mountains in a rural area, or buildings in a more urban environment. Reflections off obstacles or the ground cause multipath effects and the radio signal can be significantly attenuated by various environmental factors such as ionospheric effects, propagation through vegetation such as in a forest environment, or reflection from an impedance transition such as a river or land/sea interface. When line-of-sight (LOS) propagation is not present these environmental mechanisms have the dominate effect on the fidelity of the received signal through dispersive effects, fading, and signal attenuation.

The mechanism of electromagnetic waves propagation generally be attributed to reflection, diffraction and scattering. Most of wave propagation radio system operates with non line of sight path between the transmitter and the receiver and which the presence of high buildings causes severe diffraction loss. Besides that, due to multiple reflections from various objects, the electromagnetic waves travel along different paths of various lengths. The interaction between these waves causes multipath fading at a specific location and decreases the strengths of the waves as the increasing distance between transmitter and receiver.

Reflection, diffraction and scattering are the three basic propagation mechanism that effect on the wave propagation. It depends on the wavelength compare to object sizes, inject angel of wave and atmospheric temperature.

2.2 Reflection and Refraction

Reflection occurs when wave propagation hits upon an object which has very large dimension when compared to the wavelength of the propagating wave. Reflections occur from the earth surfaces and from buildings, vehicles and walls. When radio wave propagate from one medium hits another medium, its have different electrical properties. Some of the wave has been reflected and a part of it was transmitted. If the plane wave is incident on a perfect dielectric, a part of the energy is transmitted into the second medium and the other is reflected back into the first medium.

Then, there is no loss of energy in absorption. If the second medium was a perfect conductor, there has no loss of energy due to all the incident energy is reflected beck to the first medium. The reflection coefficient is a function of the material properties, and generally depends on the angle of incidence, wave polarization and the frequency of the wave propagation.

When electromagnetic wave propagates, it experiences a reflection due to object of the environment is large enough compared to its wavelength. Reflection created from many sources like the ground surfaces, the walls and from equipments. The co-efficient of reflection and refraction depends on angel of incident, the operating frequency and the wave polarization.

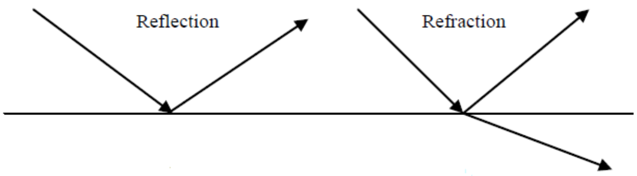

Figure 2.2: Reflection and refraction

Angle of Incidence is the angle between the direction of propagation and a line perpendicular to the boundary, on the same side of the surface. Angle of Reflection is the angle between the direction of propagation of the reflected wave and a line perpendicular to the boundary, also on the same side of the surface. Due to the change of air temperature the density of atmosphere is changed, if a wave is impacted upon this kind of medium, the wave changed its direction from the original wave's path and refraction occurred. Then the rule for reflection is simply stated as:

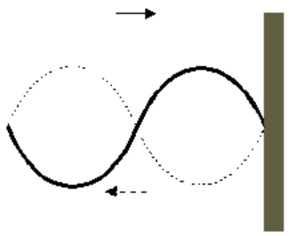

Figure 2.3: The angle of reflection = the angle of incidence

If the incident medium has a lower index of refraction then the reflected wave has 180^0 phase shift upon reflection. Conversely, if the incident medium has a larger index of refraction the reflected wave has no phase shift.

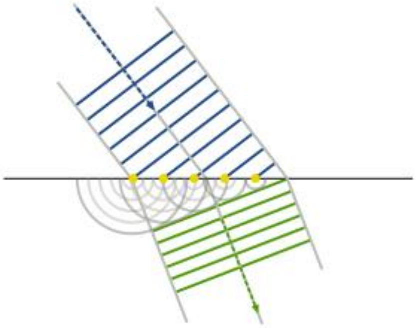

Figure 2.4: Wave refraction

2.3 Diffraction

Diffraction occurs when the wave path between the transmitter and receiver is obstructed by a surface that has sharp edges. Diffraction is the bending of a wave around objects or the spreading after passing through a gap. The secondary wave resulting from the obstructing surface is present throughout the space. Even behind the obstacle has giving rises to bending of waves around the obstacle whereas between transmitter and receiver, a line of sight path does not exist.

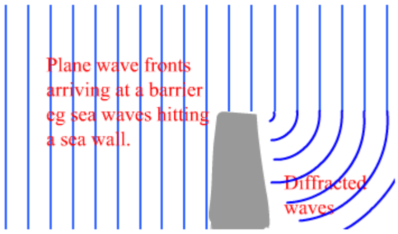

Figure 2.5: Diffraction Illustration

Same as reflection, in the high frequency diffraction depends on the geometric of the object such as phase, amplitude and polarization of the incident wave at the point of diffractions. Recall that the idealized plane wave is actually infinite in extent. If this wave passes through an opening, called an aperture, it will diffract, or spread out, from the opening. The degree to which the cropped wave will spread out depends on the size of the aperture relative to the wavelength. In the extreme case where the aperture is very large compared to the wavelength, the wave will see no effect and will not diffract at all. At the other extreme, if the opening is very small, the wave will behave as if it were at its origin and spread out uniformly in all directions from the aperture. In between, there will be some degree of diffraction.

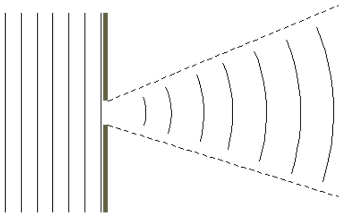

Figure 2.6: Diffraction

First consider a circular aperture. If a wave with wavelength, λ encounters an opening with diameter D, the amount of diffraction as measured by the angle, Θ ,at which the new wave diverges from the opening, measured from edge to edge, will be approximated by :

$$\Theta = \lambda / D$$

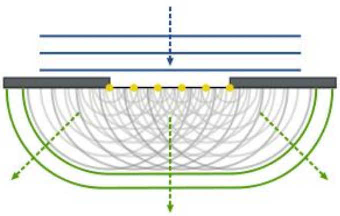

Figure 2.7: The Diffraction Phenomenon

When the link distance is greater than the LOS distance, or when a natural or man-made obstacle blocks the direct path, there still may be a useful amount of signal power in the shadow zone at the receiver by the phenomenon of diffraction.

Huygen’s principle states that any wavefront can be decomposed into a collection of point sources. New wavefronts can be constructed from the combined “spherical wavelets” from the point sources of the old wavefront. According to Huygens' principle, a plane light wave propagates though free space at the speed of light, c. The light rays associated with this wave front propagate in straight-lines, as shown in figure below. It is also fairly straight forward to account for the laws of reflection and refraction using Huygens Principle.

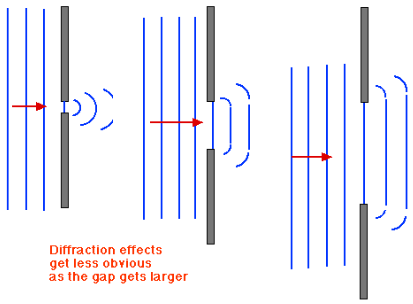

Figure 2.8: Different diffraction effects

A commonly used technique in predicting path loss from terrain obstacles is knife-edge or Kirchhoff diffraction. Based on Huygen's principle, the obstacle is represented by a blocking screen and the field distribution across the resulting aperture (from the top of the screen, vertically to infinity) integrated to produce the diffracted fields. The technique is a 2-D method (does not account for oblique incidence) and assumes that both the source and observation are very distant from the obstacle. It is a scalar method (does not account for polarization effects) and cannot account for surface effects such as reflected fields or creeping waves. Also it does not account for the impedance of the surface.

2.4 Scattering

Scattering occurs when the medium through which the wave travels consists of objects with dimensions that are small compared to the wavelength and where the number of obstacles per unit volume is large. Scattered wave are produced by rough surfaces, small objects or by other irregularities in the channel. In real phenomenon, foliage, street signs and lamp posts induce scattering in wave propagation. The actual received signal in wave propagation is often stronger than what is predicted by reflection and diffraction. This is due to when wave are struck on a rough surface, the reflected energy is spread out in all directions due to scattering. An object around such as lamp posts and tree tends to scatter energy in all direction so it will provide additional wave energy at the receiver. Reflective surface are form when the flat surfaces have much larger dimension than a wavelength. However, the roughness of such surfaces often induces propagation effect different from the specula reflection.

The requirement that there be many scattered present means that Rayleigh fading can be a useful model in heavily built-up city where there is non-line of sight between the transmitter and receiver and many buildings and other objects attenuate, reflect, refract, and diffract the signal.

The scattering of plane waves from a flat boundary between two media is a typical canonical problem, where analytical solutions are straightforward and well-known. It is an idealized case: all real surfaces are rough. The scattering problem will then depend on the 'roughness' of the surface, and exact analytical solutions will not be generally available.

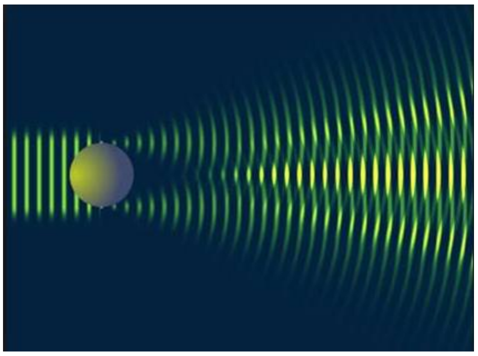

Figure 2.9: Scattering effect

2.5 Effects of Base Station Antenna Height

Propagation characteristics of smart antenna systems can be described by vector channels. In order to accurately characterize and model vector channels, extensive measurements in realistic wireless environments are needed. Variation of vector channels in non-stationary propagation environments which are caused by deploying the base station antenna at different heights and keeping the mobile terminal stationary and fixing the base station antenna height and moving the mobile terminal. Measurements of vector channel parameters in a non-line-of-sight (NLOS) environment are with a uniform circular array at the base station.

Smart antenna systems that use multiple antennas (antenna arrays) at the base station (BS) along with advanced space-time signal processing techniques have been