UNIVERSITI PUTRA MALAYSIA

PATH LOSS PREDICTION MODEL FOR MOBILE RADIO WAVE PROPAGATION INTO A MULTI-FLOORED BUILDING

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By

ZAINAL HAFIZ BIN RAMLY

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

December 2007

To:

My dear beloved family…

Thanks for the encouragement, love and support in fulfilling my endeavour…

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chairman : Zulkifly Abbas, PhD

Faculty : Science

This thesis presents the development of a new path loss prediction model for mobile communication field due to wave propagation into multifloored building. Field strength measurements from four different base transceivers (BTS) located at Universiti Putra Malaysia (UPM) campus and Taman Desa Serdang were conducted at two buildings using an Advantest U3641 spectrum analyzer and AHS519-4 log-periodic antenna. A computer program has been developed to retrieve the measured field strength data from the spectrum analyzer and convert the values gained to path loss using Agilent VEE software. Line-of-sight propagation (for open area) and non-line-of-sight propagation (for building wall obstruction) have been investigated. The measured path loss data have been compared with the results obtained using various path loss prediction models such as COST231 line-of-sight (CLOS), COST231 non-line-of-sight (CNLOS), Gahleitner-Stochastic (GS), Paulsen-Microcell (PMI) and Paulsen-Macrocell

(PMA). The results demonstrate poor agreement between the predicted and the true measured path loss. For line-of-sight case; CLOS, GS, PMI and PMA models have overestimated the path loss as high as 16.1%, 78%, 8.61% and 35.8% respectively. For non-line-of-sight case; CNLOS, GS, PMI and PMA models have overestimated the path loss as high as 14%, 91%, 5.56% and 56.17% respectively in all measurement frequencies. An improved version of the PMI model has been developed and tested where the mean error values are found to be approximately 2.5% for all the measurement frequencies. In addition, integrated software UPMIPL for path loss prediction of wave propagation in both line-of-sight and non-line-of-sight cases has been developed and implemented using Agilent VEE. The UPMIPL program provides the utility for calculating the signal characteristics of radio propagation paths and is realized in the run time version.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

JANGKAAN KEHILANGAN LALUAN UNTUK PERAMBATAN GELOMBANG RADIO PERHUBUNGAN BERGERAK DI DALAM BANGUNAN PELBAGAI ARAS.

Oleh

ZAINAL HAFIZ BIN RAMLY

Disember 2007

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Tesis ini memperkenalkan pembangunan model baru kehilangan laluan untuk bidang perhubungan bergerak berpunca daripada perambatan gelombang ke dalam bangunan berbilang aras. Pengukuran kekuatan medan dari empat tapak pemancar dan penerima gelombang (BTS) yang bertempat di kampus Universiti Putra Malaysia (UPM) serta Taman Desa Serdang telah dilakukan di dua buah bangunan dengan menggunakan penganalisis spektrum Advantest U3641 dan antena berkala log AHS519-4. Satu pengaturcaraan komputer telah dibangunkan untuk memperolehi data pengukuran kekuatan medan dari penganalisis spektrum dan menukar nilai-nilai yang diperolehi kepada kehilangan laluan menggunakan perisian Agilent VEE. Perambatan garisan pandangan (untuk kawasan terbuka) dan perambatan garisan ketakpandangan (untuk penghalangan dinding bangunan) telah disiasat. Data kehilangan laluan yang diukur

telah dibandingkan dengan keputusan yang diperolehi menggunakan pelbagai model ramalan kehilangan laluan seperti garisan pandangan COS7231 (CLOS), garisan ketakpandangan COS7231 (CNLOS), Gahleitner-Stochastic (GS), Paulsen-Microcell (PMI) dan Paulsen-Macrocell (PMA). Keputusan-keputusan menunjukkan persetujuan buruk di antara kehilangan laluan yang diukur dengan ukuran sebenar. Untuk kes garisan pandangan; model CLOS, GS, PMI dan PMA telah melebihi anggaran kehilangan laluan setinggi 16.1%, 78%, 8.61% dan 35.8% secara berturut. Untuk kes ketakpandangan garisan; model CNLOS, GS, PMI dan PMA telah melebihi anggaran kehilangan laluan setinggi 14%, 91%, 5.56% dan 56.17% secara berturut di dalam kesemua frekuensi-frekuensi pengukuran. Satu versi model PMI yang dibaiki telah dibangunkan dan diuji yang mana nilai-nilai ralat min didapati hampiran 2.5% untuk kesemua frekuensi-frekuensi pengukuran. Sebagai tambahan, perisian bersepadu UPMIPL untuk ramalan kehilangan laluan perambatan gelombang di dalam kedua-dua kes pandangan garisan dan ketakpandangan garisan telah dibangunkan dan dilaksanakan menggunakan Agilent VEE. Pengaturcaraan UPMIPL membekalkan kegunaan untuk pengiraan ciri isyarat terhadap laluan perambatan radio dan dilaksanakan di dalam versi masa larian.

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I certified that an Examination Committee met on **DATE OF VIVA** to conduct the final examination of Zainal Hafiz B Ramly on his Master of Science thesis entitled "Path Loss Study For Mobile Radio Wave Propagation Into A Multi Floored Building" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulation 1981. The committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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Date: 10 April 2008

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

ZAINAL HAFIZ RAMLY

Date:

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LIST OF ABBREVIATIONS

e^{jwt}	Implicit time dependence
$\vec{E}$	Electric field strength vector
$\vec{H}$	Magnetic field strength vector
$\vec{D}$	Electric flux induced
$\vec{B}$	Magnetic flux
ρ_q	Charge density
Pr	Receive input signal
G	Power ratios
L	Path loss
P_T	Effective isotropic transmit power
P_t	Power delivered to the transmitter antenna
G_t	Transmitter antenna gain
R_c	Reflection coefficient due to the ground surface
D	Distance between transmitter and receiver
FSL	Represent free-space loss
F	Represents frequency in Megahertz
h_r	Receiving antenna with height
S	Physical distance between the external antenna and the external wall
Wge	Additional loss in dB in the external wall
Wi	Loss in the internal walls
θ	Angles
G_h	Floor height gain in dB/floor

L_{total}	Total path loss from base to mobile
L(d)	Empirical path loss model
L_{we}	External wall attenuation
L_{wi}	Internal wall attenuation
N_w	Number of internal walls separating transmitter and receiver
N_f	Floor number, ground floor is zero
N	Number of external walls relevant for a certain floor
P_{An}	Outdoor transmitter power (in mW)
w_e	‘Linear’ wall attenuation factor of external wall
M	Number of internal wall categories
w_m	‘Linear’ wall attenuation factor of wall category m
k_{mn}	Number of walls of category m, traversed by a line drawn from the receiver
h_s	Height or receiver above ground level
Vi	Angle of incidence
Vh	Deviation from horizontal plane
MSC	Mobile switching centre
HLR	Home location register
GTD	Geometrical theory of diffraction
BSS	Base station subsystem
BSC	Base station controller
BTS	Base transceiver station
VEE	Visual environment engineering
LOS	Line-of-sight

NLOS	Non-line-of-sight
PMA	Paulsen Macrocell model
PMI	Paulsen Microcell model
GS	Gahleitner stochastic model
CLOS	COST231 line-of-sight model
CNLOS	COST231 non-line-of-sight model
GPS	Global positioning system
DAQ	Data acquisition
PDF	Probability density function
EOL	End of line
NMTs	Nordic mobile telephones
TACS	Total access communication system
UPMIPL	UPM indoor path loss model
WI	Walfisch Ikegami model
RME	Relative mean error
PEL	Represent earth surface loss
Loutside	External path loss

LIST OF PLATES

CHAPTER 1

INTRODUCTION

1.1 An Overview of Wireless Communication

The first generation mobile system introduced in 1980s was based on analogue transmission techniques. During that time, there was no worldwide (or even Europe-wide) coordination for the development of technical standards for mobile communication. Nordic countries deployed Nordic Mobile Telephones or NMTs, while UK and Ireland went for Total Access Communication System or TACS, and so on. In the early stage of wireless communication, roaming was not possible.

The goal of every operator company is to give a good prediction of radio wave propagation. Since most cellular users spend most of the time inside buildings, the level of service which they perceives will depend heavily upon the signal strengths provided inside the building. With the introduction of high-speed multimedia services, the demand for indoor coverage will become more important. A prerequisite for improving indoor coverage in a cost-efficient way is the detailed knowledge of the actual and the planned indoor coverage. This information can be obtained from predictions or measurements. A widely used approach to forecast indoor coverage in radio network planning is to use a low-resolution macro-cell model and to apply an additional indoor penetration margin (Saunders, 1999). With such a procedure, however, only a rough estimation of indoor coverage is possible. Furthermore, the only possibility to determine the large-area indoor coverage by measurements is to measure each floor in each building individually. This is a very time consuming and expensive process. In the case of access restrictions to buildings, it is even not possible to make such measurements. Therefore, a so-called outdoor-to-indoor coverage prediction method is required, which predicts indoor coverage by outdoors, BTS. The method has to consider both the complex propagation process occurring between the BTS and the building as well as the building penetration process itself.

Since the rapid growth of mobile communication technology and increasing number of users, the path loss prediction models have been developed in order to estimate the systems capacity and futures needed. Signal penetration into a building is dependent on the distance of the external base station from the building as well as the effective radiated power of the base station transmitter. It may also be dependent on both the frequency and the environments.

Since the transmission between base station and a mobile device is rarely line-of-sight, the received signal consists of a number of waves reflected from, or a diffracted around, objects in close proximity to the mobile. The received signal is thus no deterministic and the resulting propagation models are statistical. Measurements of the received signal have to be made in areas where radio communication is likely to be generated or received to evaluate the parameters of these models.

Indoor radio propagation is dominated by the same mechanisms as outdoor such as reflection, diffraction and scattering. Conditions also are much more variable.

Example signal levels vary greatly depending on whether interior doors are open or closed inside a building.

1.2 Problem Statement

Several researchers have proposed path loss models for wave propagation due to base station transceiver (BTS) into multi-storey building. Outdoor models that describe wave propagation in open and urban areas are not sufficient, as propagation into buildings involve more complex multipath structure. The path loss of wave propagation into building depends on not only the distance between the BTS and the receiver in building but also on the BTS antenna height and output power, mobile antenna height and environment local to the mobile. Additionally, the path loss is also affected by other empirically observed variables such as building structure and layout of rooms. Theoretical models such as the geometrical diffraction model and uniform diffraction model are not used in practice as they often display a large error standard-deviation with respect to empirical models because of spatial offsets (COST231, 1999).

Most of the empirical models including the COST231 model are essentially based on improvement of earlier models (Saunders, 1999) which are distance-dependency of the path loss when the mobile is outside the building, plus building factors, which are included in the model to account for the increase in attenuation of the received signal observed when the mobile is moved from outside a building to inside. As different competing empirical models emerge, there is a need to compare the different models on the same data. This requires procedures for comparing model predictions with measurements and with each other.

An up-to-date literature search has been carried out to investigate existence of other previous works carried out in similar environment in Malaysia. It is found that only full indoor wave propagation works are reported and their operating frequencies at 2.4 GHz and 60 GHz were meant for WLAN (or HIPERLAN) application not mobile communication. Their signal sources were all located in the building and which actually is not similar and thus not similar to the work carried out for this study. None has been reported to-date in Malaysia about mobile communication “outdoor to Indoor” propagation where the signal sources were from fully operational commercial base station transmitters.

1.3 Objective

The objective of this study is to develop a program to convert measured field strengths to path loss using Agilent VEE graphical programming technique. The program is especially useful for telecommunication engineers as a cost-effective solution to obtain path loss values directly from the measured electric field strengths on any commercial spectrum analyzer without using additional instruments such as TEMS Cell Planner. The accuracy of the various path loss prediction models for mobile communication due to wave propagation into multifloored building will be investigated. The models involve both line-of-sight (LOS) wave propagation from BTS to building and the non-line-of-sight (NLOS) propagation into the building. The