UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF A PATH LOSS MODEL FOR WAVE PROPAGATION INTO SELECTED BUILDINGS AT UNIVERSITI PUTRA MALAYSIA

MARDENI HJ. ROSLEE.

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DEVELOPMENT OF A PATH LOSS MODEL FOR WAVE PROPAGATION INTO SELECTED BUILDINGS AT UNIVERSITI PUTRA MALAYSIA

By

MARDENI HJ. ROSLEE

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

May 2005

DEDICATION

Specially dedicated to:

My beloved

Father, Mother,

Brother, Sisters,

Soul mate,

and Friends.

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

DEVELOPMENT OF A PATH LOSS MODEL FOR WAVE PROPAGATION INTO SELECTED BUILDINGS AT UNIVERSITI PUTRA MALAYSIA

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May 2005

Chairperson : Zulkifly Abbas, PhD

Institute : Advanced Technology

In this thesis, the development of path loss prediction model for wave propagation into buildings at Universiti Putra Malaysia is described. Field strength measurements due to three base stations were carried out in three different buildings in the Universiti Putra Malaysia campus. The measurement setup consisted of an ADVANTEST U3641 Spectrum Analyzer and an AHS/SAS-519-4 log periodic antenna. A computer program has been developed to calculate the path loss from the measured field strength which in turn was used for comparison with available path loss models. The results indicate poor agreement between the measured and existing predicted path loss models where even the widely accepted COST 231 model deviated as high as 9.46%. The discrepancy between the measured and predicted path loss was even greater for other models such as the Microcell model (17.69%) and outdoor-indoor model (24.71%). An improved version of COST 231 model and an empirical path loss models have been proposed in this work to

replace the COST 231 model. The improved COST 231 model was found from an optimization procedure by fitting the original model to the measured data, whilst the empirical model was obtained from regression analysis. The accuracy of the Improved COST 231 and empirical models was tested on different buildings and found to agree with measured data within 6.31%, and 7.85%, respectively. The Agilent VEE software was used to develop and execute the integrated ITMAPL program for wave propagation into buildings. The ITMAPL program is a user friendly program to calculate and display the path loss of radio propagation paths. It is implemented in the run time format version and has three options which are COST 231 model (CST), improved COST 231 model (ICS) and ITMANE new empirical model.

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

PEMBINAAN MODEL KEHILANGAN LINTASAN BAGI RAMBATAN GELOMBANG KE DALAM BANGUNAN YANG DIPILIH DI UNIVERSITI PUTRA MALAYSIA

Oleh

MARDENI HJ. ROSLEE

Mei 2005

Pengerusi : **Zulkifly Abbas, PhD**

Institut : **Teknologi Maju**

Dalam tesis ini, pembinaan model untuk meramal kehilangan lintasan bagi rambatan gelombang ke dalam bangunan di Universiti Putra Malaysia akan diperihalkan. Kekuatan medan magnet dari tiga stesen punca telah dilakukan pada tiga bangunan yang berlainan di kawasan kampus Universiti Putra Malaysia. Alat pengukuran yang digunakan adalah Penganalisis Spektrum ADVANTEST U3641 dan Antena Berkala AHS/SAS-519-4. Satu program komputer telah dicipta untuk mengira nilai kehilangan lintasan daripada nilai pengukuran medan magnet di mana nilai ini digunakan untuk membuat perbandingan dengan nilai kehilangan lintasan yang sedia ada. Keputusan yang diperolehi menunjukkan ketidaksamaan antara nilai ukuran dan juga model kehilangan lintasan yang sedia ada walaupun model COST 231 menyisih sebanyak 9.46%. Penyisihan antara nilai ukuran dan juga ramalan kehilangan lintasan lebih tinggi bagi model yang lain seperti model microcell (17.69%) dan model outdoor-indoor

(24.71%). Versi model COST 231 yang diperbaharui dan juga model empirikal telah dicadangkan di dalam kerja ini untuk menggantikan model COST 231 yang asal. Model COST 231 yang diperbaharui diperolehi daripada presedur pengotimuman dengan menyesuaikan nilai ukuran dengan model asal. Model empirikal pula diperolehi daripada analisis regresi. Ketepatan model COST 231 yang diperbaharui dan model empirikal telah diuji pada bangunan yang berlainan dan telah menepati nilai data ukuran dengan nilai perbezaan 6.31% dan 7.83% masing-masing. Perisian Agilent VEE telah digunakan dalam pembinaan dan perlaksanaan program penggabungan kehilangan lintasan Institut Teknologi Maju (ITMAPL) untuk rambatan gelombang ke dalam bangunan. Program ITMAPL ini adalah program yang mudah digunakan untuk mengira dan menunjukkan nilai kehilangan lintasan bagi rambatan gelombang radio. Ianya dilaksanakan dalam versi format run time dan mengandungi tiga pilihan iaitu model COST 231 (CST), model COST 231 yang diperbaharui (ICS) dan juga model empirikal yang baru ITMANE.

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Wassalam.

I certify that an Examination Committee met on 25th May 2005 to conduct the final examination of Mardeni Hj. Roslee on his Master of Science thesis entitled "Development of a Path Loss Model for Wave Propagation into Selected Buildings at Universiti Putra Malaysia" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee are as follows:

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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.

MARDENI HJ.ROSLEE

Date: 18.7.05

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

L	-	Path Loss Total
f	-	Frequency
S	-	Physical distance between external transmitter and external wall
d	-	Perpendicular distance between internal walls and external walls
d_2	-	Distance between measured point and origin point
W_e	-	Loss in external walls
W_{Ge}	-	Additional loss in external walls
D	-	Perpendicular distance between external transmitter and external walls
W_i	-	Loss in the internal walls
θ	-	Grazing angle
dB	-	Decibels
m	-	meter
dBm	-	Decibels refer to 1 miliWatt
$dB\mu V/m$	-	Decibels micro volt per meter
dBW	-	Decibels watt
dBi	-	Decibels refer to isotropic
p	-	Number of penetrated walls
Lw_e	-	Loss in external walls
Lw_i	-	Loss in internal walls

N	-	Number of measured data
x	-	Measured data points
x_L	-	Predicted model value
$\bar{x}$	-	Mean of measured data points
σ	-	Standard deviation
π	-	pi
Y	-	Received signal
$p(Y)$	-	Normal distribution of signal strength
α_Y	-	Standard deviation of signal strength
$\alpha_Y{}^2$	-	Varians of signal strength
M_Y	-	Mean of signal strength
P	-	Field Strength
E	-	Measurement value
G_r	-	Isotropic gain of receiving antenna
P_r	-	Received power
P_t	-	Transmit power
lsqcurvefit	-	Least square curve fitting
ΔL	-	Uncertainties in path loss
ΔS	-	Uncertainties in distance 1
ΔD	-	Uncertainties in distance 2
Δf	-	Uncertainties in frequency
P.D.F	-	Probability Density Function

C.D.F	-	Cumulative Distribution Function
GPS	-	Global positioning system
MATLAB	-	Matrix laboratory
BA	-	Building complex A
BB	-	Building complex B
BC	-	Building complex C
GC	-	Geometry Coordinate
IP	-	Execute the master reset
AV	-	View the measurement data
CF	-	Center frequency
SP	-	Frequency span
MKR	-	Maker frequency
ML	-	Marker level
READ	-	Read data from measurement
ITMAPL	-	Institute of Advanced Technology Path Loss
CST	-	COST 231
ITMANE	-	Institute of Advanced Technology New empirical
ICS	-	Improved COST 231
MS	-	Mobile system
BS	-	Base station
NLOS	-	Non line of sight
LOS	-	Line of sight
VEE	-	Visual Environment Engineering
RF	-	Radio frequency

GSM	-	Global System Mobile
UHF	-	Ultra High Frequency
SHF	-	Super High Frequency
EHF	-	Extra High Frequency
VHF	-	Very High Frequency
VLF	-	Very Low Frequency
LF	-	Low Frequency
MF	-	Medium Frequency
HF	-	High Frequency
COST	-	Co-operation Scientific Technical
NTT	-	Nippon Telegraph and Telephone
JTACS	-	Japan Total Access Communication System
NMT	-	Nordic Mobile Telephone
AMPS	-	Advanced Mobile Phone Systems
TACS	-	Tactical Area Communications System
USDC	-	United States Path Capture
DECT	-	Digital European Cordless Transmission
DCS	-	Defense Communication Systems
PHS	-	Personal Handyphone System
CDMA	-	Code Division Multiple Access
TDMA	-	Time Domain Multiple Access

CHAPTER 1

INTRODUCTION

1.1 Introduction to Wireless Communication Channel

Communication in fixed links providing telephone service has been established since 1940 while satellite links are being used for intercontinental communication since 1960s. The idea of wireless communication begun when Maxwell predicted the existence of electromagnetic waves in 1873 followed by Hertz who demonstrated the radio waves in 1888 (Saunders, 1999).

In 1945, Clarke proposed geostationary communications satellites followed by launching of Sputnik 1 communication satellite by Soviet Union in 1957. In 1969, Bell Laboratories (US) invented the cellular concept and followed by NTT (1979) and JTACS (1988) cellular system in Japan. Then, it was continued by NMT in Scandinavia (1981), AMPS cellular frequencies allocated in US (1983), TACS in Europe (1985) and USDC in US (1991). In Europe (1991), the GSM cellular system was deployed followed by DECT and DCS (1993) while PHS cordless system was deployed in Japan in the same year. IS95 CDMA was introduced in US (1995) continued by the launching of Iridium global satellite system in 1998 and IMT-2000 third generation cellular mobile systems was deployed in 2002.

Before mid 1960s, research of mobile radio to fulfill the specific operational and economic needs was a minor action in terms of international scale even though the demand for mobile radio services was continuously increased. Since the existing systems had reached the development limit that can support the technology that time, the strategic research was justified and it obviously results in most of the developed countries. After that, it was apparently seen that the contribution in mobile radio has affected the national economy by the use of pocket radios, hand-held and vehicle-borne transceivers and pan-European digital systems using wideband TDMA techniques.

The research activities mainly involved characterization and modeling of radio propagation channel which are the principle contributor to problems and limitations occurred in mobile radio systems such as multipath propagation. The multipath propagation is a main characteristic of mobile channel caused by diffraction and scattering from terrain features and buildings. This leads to distortion in analogue communication systems and severely affects the performance of digital systems by reducing the carrier-to-noise and carrier-to-interference ratios.

Nowadays, cellular mobile communications industry becomes one of the fastest-growing industries with a great number of users increased rapidly. This has resulted in stimulation of financial investment in such systems as well as to the rise of a large number in technical challenges which required a deep understanding on the characteristics of the wireless channel for their solution.

1.2 Concept of a Wireless Channel

The study of wireless channel is an important element of the operation, design and analysis of any wireless system such as cellular mobile phones or mobile satellite systems. The design of generic communication system was originally presented by Claude Shannon of Bell Laboratories in his classic 1948 paper (Shannon, 1948). The generic communication system is used for all types of systems which are wireless or otherwise. In wireless channel, fading is considered to be one of the main causes of performance degradation in a mobile radio system. If fading is taken into account, it would affect the data transmission. There are three types of fading; path loss, shadowing or slow fading and fast fading or multi path fading. They are appearing as time-varying processes between the transmitter and receiver. It also varies with the relative position of both antennas (Saunders, 1999).

The fading processes presented the mobile receiver received the signal that moving away from the base station. Normally, the path loss is decreased in field strength with increasing distance between the transmitter and receiver. This phenomenon is due to the external distribution of waves from the transmitter and obstructing effects of buildings. Furthermore, the shadowing which is a superimposed on the path loss changes faster with large variations over distances of hundreds of meters and generally involving variations up to around 20 dB. It arises from the varying nature of the exacting obstructions between both antennas. Besides, the fast fading involves variations on the scale of a half-wavelength, about 50 cm at 300 MHz, 17 cm at 900 MHz and frequently introduces variations as large as 35 to 40 dB. The last results are from the beneficial and critical interference between multiple waves reaching the receiver from the transmitter. The total signal is the combinations of path loss, shadowing and fast fading.

1.3 The Electromagnetic Spectrum

The electromagnetic spectrum is an essential resource demoralized in wireless communication systems as seen in Table 1.1. From the figure, the frequencies around 3 kHz to 300 GHz is for radio communication where it corresponds to wavelengths in free space from 100 km to 1 mm. The conventional division of the spectrum into frequency bands is defined as in Table 1.2 from 3 kHz to 300 GHz. A further subdivision creates the UHF, SHF and lower EHF bands (Saunders, 1999).

The demand for wireless communication as the frequencies chosen for new systems have tended to enhance through the years due to the availability of huge bandwidths at the higher frequencies. The change has formed the technology challenges needed to support reliable communications as the advantage of antenna structures can be smaller in absolute size to support a given level of performance. This study will only be concerned in communication at VHF frequencies and above. The wavelength is typically small compared with the size of macroscopic obstructions like buildings. As the size of obstructions relative to a wavelength increases, their obstructing effects also tend to increase, reducing the range for systems operated at increasing frequencies.