UNIVERSITI PUTRA MALAYSIA

INDOOR RADIO PROPAGATION MEASUREMENTS IN DIFFERENT ENVIRONMENTS USING TWO TYPES OF TRANSMITTING ANTENNA

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By

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Thesis Submitted in the Partial Fulfillment of Requirements for the Degree of Master of Science in the Faculty of Engineering, Universiti Putra Malaysia

SEPTEMBER 1997

To my niece A. Eve

ACKNOWLEDGEMENTS

I express sincere appreciation and deep gratitude to Assoc. Prof. Dr. Borhanuddin Mohd. Ali (Chairman of my Supervisory Committee), for his wise counsel, guidance and encouragements and providing various logistic supports throughout my study period. Grateful appreciation is extended to Prof. Dr. Malay Mukerjee and Mrs. Ratna Kalos Zakiah Sahbudin for serving in my Supervisory Committee and providing precious suggestions and comments at different stages of this study.

Special thanks is extended to the Cellular Communication (M) Sdn Bhd, for the permission to use their facilities, and made this joint project possible. My deep appreciation is due to Mr. Daod Cottam, Mr. Jaime Castello, Mr. Kamarulzaman Ahmad, Mr. Harith Abdul Malik, for encouraging me to pursue this project.

Thanks also to all the staff who had in one way or another contributed to the successful completion of this study specially Mr. Md. Rabi Othman, Mr. Md. Adros Sharif, Mr. Norsapei Aziz, and hope that a foundation has been laid will lead to a more fruitful future co-operation between CELCOM and UPM.

I take pleasure to thank all my friends for providing very pleasant environment during my study at UPM.

Finally, I would like to express my indebtedness to my father, mother, brother, sister for their help. Special thanks to my brother Ameen for his moral support and his help in completing my study.

Above all, I should say "THANK GOD" who made it happen.

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LIST OF ABBREVIATIONS

AD	Antenna Diversity
AF	Attenuation Factor
AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
BS	Base Station
CCI	Co-Channel Interference
DOA	Direction of Arrival
ETACS	Enhanced Total Access Communications Systems
FAF	Floor Attenuation Factor
FSK	Frequency Shift Keying
GF	Ground Floor
GHz	Giga Hertz
GMSK	Gaussian Minimum Shift Keying
GSM	Global System Mobile
H/C	Hybrid Coupler
HF	High Frequency
HIPERLAN	High Performance Local Area Network
LOS	Line of Sight
LGF	Lower Ground Floor
MHz	Miga Hertz
MS	Mobile Station
mW	milli Watt
OAF	Obstacle Attenuation Factor
OBS	Obstructed Case
PCS	Personal Communication System
PDA	Personal Digital Assistant
PDF	Probability Density Function
PICD	Personal Information and Communication Device
R	Reflectivity
RF	Radio Frequency
SFH	Slow Frequency Hopping
SNR	Signal-to-Noise Ratio
SW	Standing Wave
R-T	Receiver Transmitter
UHF	Ultra High Frequency
VHF	Very High Frequency
WAF	Wall Attenuation Factor
W-LAN	Wireless Local Area Networks
W-PBX	Wireless Private Branch Exchanges

Abstract of thesis submitted to the Senate of Universiti Putra Malaysia in partial fulfillment of the requirements for the degree of Master of Science.

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SEPTEMBER 1997

Chairman: Associate Professor Dr. Borhanuddin Mohd. Ali

Faculty: Engineering

The tremendous growth in Wireless Communications System has greatly increased the need to improve the accuracy of predicting signal propagation. It is important to have a tool that can be used to predict the signal coverage area, a method to determine the path loss in microcells, the attenuation due to different partitions and the effect of the environments.

To understand radio propagation characteristics in buildings for Personal Communication Systems (PCSs), a comprehensive measurement was carried out in a shopping and business complex, The Mall, in Kuala Lumpur. Two types of Base Station (BS) antennas, Omni-directional and Panel antenna, were mounted on the ceiling and wall respectively. The Mobile Station (MS) uses an antenna with 3dB gain, height 0.5 m and 1.2 m respectively, at 935 MHz carrier frequency. Many test settings were chosen in the office, on the floor sharing with the atrium, lower ground floor and car park, with Line-of-Sight (LOS) and without LOS. The results show

some variations of signal strengths with distance that have distinct near and far field regions.

The buildings where the measurements were carried out typically have walls and columns constructed from concrete blocks. Within the building the time spread of arriving radio signals depends on reflections and scattering from the structure of the buildings. The results of these measurements are presented and discussed in order to investigate penetration losses in walls, soft boards and floors.

The results showed that shadowing due to the objects has a greater influence on the signal strength than the distance between the transmitting and receiving antenna. The path loss within a building is linearly dependent on the logarithm of the distance, on the number of obstacles blocking the signal, on the number of walls between transmitter and receiver antenna, and on the number of floors vertically between the transmitter and receiver antennas. Another important factor is the type of the environment it is operating in, which is given as the factor n. Comparisons between predicted and measured results have shown that the model is capable of predicting the attenuation within the building for different environment.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi sebahagian daripada syarat keperluan ijazah Master Sains.

PENGUKURAN DALAMAN PERAMBAT RADIO DALAM PERSEKITARAN YANG PERBEZA MENGGUNAKAN DUA JENIS ANTENA PEMANCAR

Oleh

LOUKMAN A. AMEEN

SEPTEMBER 1997

Pengerusi: Profesor Madya Dr. Borhanuddin Mohd. Ali

Fakulti: Kejuruteraan

Perkembangan pesat dalam sistem komunikasi wayarles telah meningkatkan keperluan untuk memperbaiki ketepatan ramalan perambatan isyarat. Adalah penting untuk mengadakan alat yang boleh digunakan untuk meramalkan perambatan isyarat di kawasan liputan, cara untuk menentukan kehilangan laluan pada sel mikro, pelemahan disebabkan oleh pembahagi yang berlainan dan kesan persekitaran.

Pengukuran yang menyeluruh di pusat membeli-belah dan perniagaan, The Mall di Kuala Lumpur, telah dijalankan untuk memahami perambatan isyarat radio untuk sistem Komunikasi Peribadi di dalam bangunan. Dua jenis antena stesen tapak pemancar telah digunakan iaitu antena 'Omni-arah' dan Panel, yang mana pemancar 'Omi-arah' dilekatkan di siling dan antena panel dipasangkan di dinding. Stesen Bergerak (MS) menggunakan antena dengan gandaan 3dB, dengan ketinggian 0.5m dan 1.5m masing masing, di frekuensi pembawa 935MHz. Beberapa set ujian telah dipilih di dalam tingkat pejabat yang berkongsi atrium, tempat letak kereta dan

tingkat bawah tanah, dengan garis nampak (Line-of-Sight, LOS) dan tanpa-garis-nampak (without LOS). Hasil pengukuran menunjukkan terdapat perubahan kekuatan isyarat dengan jarak yang mempunyai kawasan medan dekat dan jauh.

Bangunan di mana pengukuran dilakukan mempunyai dinding dan tiang yang dibina dari blok-blok konkrit. Di dalam bangunan, isyarat radio yang dikesan bergantung kepada pantulan dan perserakan dari struktur bangunan tersebut. Hasil pengukuran ini adalah dibentang dan dibincangkan untuk mengkaji kehilangan penembusan isyarat radio pada dinding, papan lembut dan lantai.

Keputusan menunjukkan bayang-bayang yang disebabkan oleh objek lebih mempengaruhi kekuatan isyarat jika dibandingkan dengan jarak di antara antena pemancar dan penerima. Kehilangan isyarat di dalam bangunan adalah bergantung dengan lelurus kepada logaritma jarak, bilangan halangan pada isyarat, bilangan dinding di antara pemancar dan penerima, dan bilangan lantai secara menegak di antara pemancar dengan penerima. Satu faktor lain ialah jenis persekitaran ia beroperasi, yang diberi sebagai faktor 'n'. Perbandingan keputusan di antara pengukuran dengan agakan menunjukkan model ini berkeupayaan untuk meramalkan pengurangan isyarat di dalam bangunan untuk persekitaran yang berbeza.

CHAPTER I

INTRODUCTION

Background

The move towards personal communications has led to the realization that not enough is known about radio propagation within buildings. Several researchers have studied the problem of receiving radio signals within buildings and modeled it as a simple distance power law, plus a signal attenuation per wall or floor. It is desirable to have a minimum set of communication channels, and used all the set of channels in every cells, but that would require a high degree of isolation between cells, to limits the interference.

Experiments have been done to obtain a relationship between the frequency and the cell size, and the frequency band with the environments, since the environment varies from one building to another, and that variation has so much effect on the signal strength, that a lot of work has to be done, in order to know which is the most appropriate frequency band for use inside a building, which type of antenna should be chosen, and where within the building it should be mounted.

Conventional methods of performing propagation predictions involve the use of a general purpose electromagnetic wave expression as a function of distance, frequency, antenna gains, antenna heights, etc. Changes in environment surrounding a base station are usually accounted by adding a net loss value found from experience for a specific set of conditions.

Another problem in designing a wireless systems is that it can be difficult to determine how many transceivers are needed within a building and the cells size. For economic reasons, transceivers should be strategically located so that only the desired areas of the building are covered, and so that neighboring coverage areas do not overlap significantly. Optimum placement of transceivers is complicated by the fact that indoor propagation losses are highly dependent on the type of the buildings, and on the locations and composition of walls within the building.

Cell sizes vary with the environment. Macro cells have an average diameter from 1 km up to a few kilometers. Microcells are useful for indoor and some outdoor applications, with a cell size smaller than 1 km and low elevation antennas. Nanocells and picocells for office sites will have a size less than 100m, a smaller size being suitable for buildings in order to increase the probability of LOS and to increase the capacity.

Within a building and stationary environment, the signals fluctuate over time, and the fluctuation may vary considerably and can reach signal strengths under the minimum level. To combat this random small-scale fluctuations induced by radio channels, propagation models were developed to help the communication engineer design radio links in a statistical sense, without realizing on complete understanding of the channel conditions at any particular time or location.

Techniques using to improve reception quality

Antenna Diversity (AD) and Slow Frequency Hopping (SFH) are used in many systems to improve significantly the transmission quality. The former technique combats multipath fading and shadowing while the latter show that averages the effects of co-channel interference. Simulation results on these two techniques showed that the transmission quality when both techniques are used simultaneously are improved.

Multipath fading on digital cellular channels causes time-variations in amplitude and phase that seriously affects high speed digital communication. To maintain acceptable bit-error rates (BER), the systems operate at an effective data rate that is far below channel capacity. In order to maintain high speed communications, fading channel requires significantly greater power to achieve the same error rate performance as the equivalent non-fading channel. Equalization is used in adaptive digital filtering techniques to reduce intersymbol interference as much as possible prior to symbol-by-symbol detection.

Research Objectives

In indoor environment it has been previously found that propagation is highly affected by the condition of transmission, i.e. the presence of partial LOS or the absence of LOS.

The primary emphasis in this study is to examine the signal propagation for different environments, to determine the type of antenna which is more appropriate, and to recommend the place where it should be mounted in order to get better coverage. It is also aimed to investigate the signal variability due to the effect of obstacles in the environments.

Chapter 2 traces a brief discussion about radio propagation scenarios, channel modeling, bringing up the main events that have contributed to the signal propagation. It analyzes the radio propagation phenomena, such as path loss, shadowing, time dispersion and gives an overview of the main points to be considered in cellular system design. Further the chapter describes and analyzes building penetration of RF signals, examines the performance of physical coupling of near-field and far-field and propagation in rural environment. Finally, the chapter ends with a description of the system performance.

Chapter 3 is concerned with environment where the measurements were taken, such as building construction and floor specifications. The chapter also describes the transmitting system and measurements system. It outlines the main points to be considered in experimental procedures. Then the measured results (path loss and signal strength) were given in different floors for both systems (ETACS and GSM). The penetration losses were presented, and calculations were made to find the effective launched power at each antenna and the effective isotropic radiated power. Two models were given for the same floor and different floor measurement. Finally the chapter examines the comparison between prediction and measurements.

Chapter 4 summarizes the radio wave propagation experiment, describes the fundamental and the effects of radio propagation in indoor environments. Finally the results were discussed.

The objective of this study are as follows:

- To find the transmission path in both directions (left hand side and right hand side) and to compare their results.
- To find the path loss in different environments using two types of base station antenna, omni-directional and panel antenna.
- To find the signal strength in different environments using two types of base station antennas, omni-directional and panel antenna.
- To find the path loss in the car park floor, which is specified as a low floor (with a low elevation transmission antenna). The car was separated all over the floor, with a large number of columns, beams and air-condition ducts.
- To find the signal attenuation due to penetration through soft walls, brick walls, floors and to determine the attenuation factors related with each obstacle.
- To find the signal propagation in the floors with different heights.
- To find the effective receiving antenna height. Two levels were used.
- To find out a model which can be used to predict the signal strength within indoor environment.
- To find the effect of environment, partitions and building construction.

CHAPTER II

REVIEW ON PROPAGATION MEASUREMENTS

Introduction

The past decade has seen a phenomenal growth in wireless communication. It is permeating business and personal communications across the globe and the demand is driving availability and performance to new levels. There is a need to provide two way calling plus high bandwidth data, voice and video transmission service to a large number of users. Consumers are demanding small hand held or pocket communicator to meet their wireless voice and data communication needs. Cellular radio systems, paging systems, mobile satellite systems, cordless telephones and future personal communication systems all aim to provide ubiquitous access to the system. The demand for ubiquitous communications has lead to the development of new wireless systems like PCS (Personal Communication System), W-LAN (Wireless Local Area Networks), W-PBX (Wireless Private Branch Exchanges) and parasitic cellular systems. The consumers have indicated a strong interest in small hand held devices like the PDA (Personal Digital Assistant), and PICD (Personal Information and Communication Device), which are all packed in a small, easy to use package.

W-LAN will allow networking of fixed and portable computers via a wireless data link inside office buildings, airports, banks and other locations where flexible, reconfigurable computer networks are needed on demand. Licensed systems in the 18 GHz band also provide W-LAN capabilities at data rates close to the 10 Mbps Ethernet standard, with complete Ethernet handshaking. A portion of the US PCS band will be dedicated to W-LAN service for laptop computers, and Europe's new HIPERLAN initiative in the 5.6 GHz band will support 20 Mbps data rate for W-LAN applications.

In cellular radio systems, the coverage region is divided into small areas called cells. Each cell has its own base station and specific set of channels. These channels are used to provide duplex communications. To increase spectrum utilization, the cellular systems use the frequency reuse concept in which one frequency can be used again in a different cell. Two such cells that use the same group of frequencies are called co-channel cells, and must be separated by a minimum distance to keep co-channel interference (CCI) between acceptable limits.

PCS differs from a cellular system in that it will provide a range of telecommunication services by using low power base transmitters (10-100 mW) and smaller cell size (200-400m) in the 1.8-2.2 GHz band. PCS will provide two way calling plus high bandwidth data, voice, video transmission services to a large number of users in small areas. PCS will merge cellular and cordless telephone concepts and is likely to provide data and video transmission service.

To implement any of the personal wireless systems, there is a demand that RF channel models based on electromagnetic theory and measurements be developed to determine propagation characteristics for an arbitrary installation. It is important to predict propagation power loss, interference, spatial distribution of power and RF dispersion in time and frequency domain in order to properly anticipate conditions in static channels, mobile channels (for walking speed) and for both narrow-band and (flat fading) wide-band (frequency selective) channels. Recently, a number of measurements have been carried out to determine the statistical and site specific properties of RF propagation for personal communications in order to develop and verify propagation models.

Design of parasitic system and performance evaluation of emerging wireless systems require that building penetration of radio waves be modelled. Accurate prediction of received signal strength inside a building due to a transmitter outside the building, and vice-versa, will also help in understanding the co-system problems that arise when two or more systems are installed in two adjacent buildings. Such prediction will also allow optimum frequency reuse and an efficient utilization of limited bandwidth resources.

Propagation Issues

There are four basic propagation scenarios for PCS, as shown in Figures 1 to 4. These may be classified as indoor/indoor, indoor/outdoor, outdoor/indoor and outdoor/outdoor propagation. The indoor/indoor co-system interference (Figure 1) occur when two or more indoor wireless systems are operating in the same building in the same frequency band. These co-channel systems need to be able to co-exist, even if they employ different multiple access methods. Another example where indoor/indoor propagation issues become important is for the case where co-channel transmitters are used on different floors or in different rooms of the same building. The level of adjacent channel, co-channel and co-system interference within buildings needs to be understood. Analysis of propagation between different floors in buildings will help to understand the co-channel interference problem due to systems using the same spectrum but operating on different floors.

Outdoor/indoor propagation issues (Figure 2) arise in systems like the parasitic cellular. As the outdoor cellular systems mature and the cell site transmitters come closer to the building (due to cell splitting), the parasitic system performance may degrade, since the number of interference-free channels available for use inside the building may decrease over time. For an accurate forecast of future capacity, a proper model for the building penetration of RF waves must be developed. For parasitic cellular systems, performance degradation may also be experienced by the outdoor system due to the radiation of the indoor system in a multi-floor office building. This will give rise to indoor/outdoor propagation problems (Figure 3), where sources inside a building may interfere with outdoor co-channel systems.

Outdoor/outdoor propagation issues (Figure 4) arise for two or more systems that operate in adjacent buildings, in streets, or on a campus, while using the same frequency band. The system which concert with this scenario are PCS, microcellular systems and indoor W-LAN in the tall buildings.

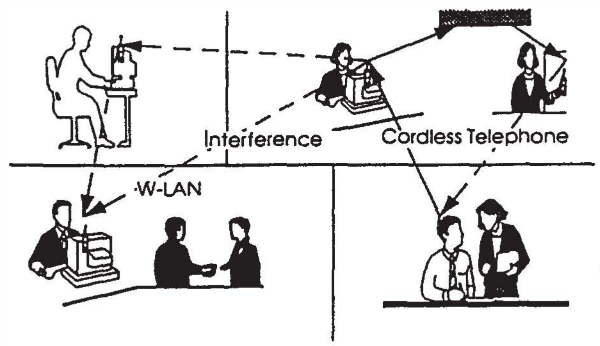

Figure 1: Indoor/Indoor Co-system Interference

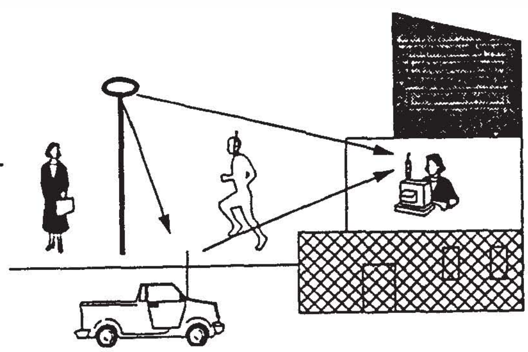

Figure 2: Outdoor/Indoor Interference