UNIVERSITI PUTRA MALAYSIA

A STATISTICAL MULTI-CLUSTER INDOOR CHANNEL MODEL IN AN OFFICE ENVIRONMENT FOR ULTRA-WIDEBAND SIGNALS

SHARLENE THIAGARAJAH.

A STATISTICAL MULTI-CLUSTER INDOOR CHANNEL MODEL IN AN OFFICE ENVIRONMENT FOR ULTRA-WIDEBAND SIGNALS

By

Sharlene Thiagarajah

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

April 2005

DEDICATION

" To my parents ……."

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

A STATISTICAL MULTI-CLUSTER INDOOR CHANNEL MODEL IN AN OFFICE ENVIRONMENT FOR ULTRA-WIDEBAND SIGNALS

By

Sharlene Thiagarajah

April 2005

Chairman: **Professor Borhanuddin Mohd. Ali, PhD**

Faculty: **Engineering**

This thesis presents a new statistical multi-cluster indoor channel model for ultra-wideband (UWB) communications between 0.1 to 2 GHz. The proposed model has been developed based on 924 measured channel impulse responses conducted at 24 different locations over a single floor in a typical modern office environment.

The multi-cluster channel characteristics are modeled according to 10 independent channel parameters extracted from the large-scale and small-scale statistical analysis of the received energy delay profiles (EDP). Three new channel parameters were introduced to better describe the time and energy dispersion statistics of the UWB signal. They are the maximum excess delay (MED), decay factor, γ within the MED and energy gains variations between adjacent bins, χ.

The pulse propagation characteristics were further modeled according to several path topographies. In addition, two new path loss prediction models were developed to take into account the attenuation factor (AF) due to gypsum and brick wall, the two main obstructing walls in this experiment.

The proposed multi-cluster channel model improves the prediction accuracy of the UWB pulse characteristics for various path topographies due to its detailed parameterization of the channel statistics. In comparison, the channel model of Cassioli et al. in 2001 was developed using only three independent lognormal parameters, i.e. shadowing, σ, decay factor, γ and the energy gains ratio, r. Furthermore, Cassioli et al. proposed a single cluster channel model without topographical classification. The channel model of Alvarez et al. in 2003 however was developed based on five channel parameters extracted from analysis conducted in the frequency domain. This method does not accurately capture the time delay statistics of the transmitted pulse.

The experimental results indicate the UWB signal's high immunity against fades and its attractiveness for propagation in tunnels. In addition the UWB channel was observed to exhibits a wide-sense-stationary-uncorrelated-scattering (WSSUS) characteristic which simplifies the transfer function between the time and frequency domains via a single Fourier transform.

Abstrak tesis yang dikemukakan kepada Senat of Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

MODEL PERANGKAAN BERBILANG KELOMPOK UNTUK SALURAN DALAM RUANG PEJABAT MENGGUNAKAN GELOMBANG JALUR ULTRALEBAR

Oleh

Sharlene Thiagarajah

April 2005

Pengerusi: **Profesor Borhanuddin Mohd. Ali, PhD**

Fakulti: **Kejuruteraan**

Tesis ini akan mengemukakan sebuah model perangkaan baru berbilang kelompok untuk saluran komunikasi dalam bangunan menggunakan gelombang jalur ultralebar (UWB) dari 0.1 ke 2 GHz. Model yang dikemukakan ini telah digubal berasaskan 924 ukuran gerakbalas dedenyut saluran dari 24 lokasi yang berbeza di aras tingkat yang sama dalam sebuah ruang pejabat moden yang lazim.

Ciri-ciri saluran berbilang kelompok dimodelkan mengikut 10 parameter saluran bebas yang dihasilkan dari analisa perangkaan skala besar dan skala kecil menggunakan gambaran susutan tenaga yang diterima (EDP). Tiga parameter saluran baru telah diperkenalkan untuk menggambarkan perangkaan serakan masa dan tenaga gelombang UWB dengan jelas. Ia terdiri daripada tempoh susutan

maksimum (MED), faktor susutan, γ dalam lingkungan masa MED dan perbezaan tenaga gandaan di antara bin yang bersebelahan, χ.

Ciri-ciri perambatan dedenyut telah dimodelkan selanjutnya mengikut beberapa laluan topografi. Sebagai tambahan, dua model ramalan kehilangan laluan baru telah dibangunkan dengan mengambil kira faktor pengecilan (AF) yang disebabkan oleh dinding gipsum dan batu, iaitu dua jenis dinding penghadang utama yang terdapat dalam ujikaji ini.

Model saluran berbilang kelompok yang disarankan ini dapat memperbaiki ramalan kejituan ciri dedenyut UWB untuk pelbagai laluan topografi disebabkan hasil perangkaan saluran yang terperinci yang telah dikemukakan. Ini berbanding dengan model saluran Cassioli et al. pada 2001 yang dibangunkan menggunakan hanya tiga parameter lognormal bebas, iaitu pembayangan, σ, faktor susutan, γ dan nisbah tenaga gandaan, r. Tambahan pula, Cassioli et al. telah mencadangkan model saluran sekelompok tanpa perbezaan topografi. Model saluran Alvarez et al. pada 2003 pula telah dibangunkan mengikut lima saluran parameter yang dihasilkan menerusi analisa domain frekuensi. Namun kaedah ini tidak dapat menawan perangkaan susutan masa dedenyut pemancar dengan jitu.

Hasil keputusan ujikaji menunjukkan bahawa gelombang UWB mempunyai daya kekalisan yang tinggi terhadap resapan dan sangat sesuai untuk perambatan dalam terowong. Tambahan pula, saluran UWB didapati menunjukkan sifat lebar-pegun-

tanpa-hubungan-penyerakan (WSSUS) yang memudahkan fungsi menjelmaan di antara domain masa dan frekuensi iaitu menerusi satu aliran penjelmaan Fourier.

ACKNOWLEDGEMENTS

I would like to thank my parents who were instrumental in setting me on my quest for new knowledge. Thank you for the encouragement and for always believing in me. To my siblings, Subrina, Baevinraj and Belina, my brother-in-law Previndran and sister-in-law Romila, who have always been there providing perspective, diversion, encouragement and nourishments throughout the course of this thesis, I thank thee. To my young nephew and niece, Thej Eashen and Zerin Prisha, I thank you for the weekly distractions. To my love, Vernon Seaton, thank you for sacrificing your weekends to watch me 'take measurements'. By the way, the answer is '*yes*' to the question if I have finally finished my PhD, and of course '*yes*', to the rest.

A special thanks to my main supervisor Professor Dr. Borhanuddin Mohd Ali who has guided me since my M.Sc. days. Thank you for your guidance and constructive ideas that have helped speed up the progress of my work. Sincere thanks also to supervisors Assoc. Prof. Dr. Mahamod Ismail and Dr. Sabira Khatun for always making time to meet with me and understanding my hectic schedule.

I would also like to thank my friends and colleagues at TMR&D Sdn. Bhd., namely En. Abdullah Jasin, Rajesh Kumar Mahalingam, Anas Abas and Farah Nadia Mohd Isa from the Antenna Propagation Unit, who have tirelessly helped me with the equipment set up and floor plan for my work.

Special thanks to En. Mohd Izhan Mohd Yusof, from the Forecasting Technology and Network Simulation Unit at TMR&D for taking the time to give me a crash course on statistics. Your patience in answering all my questions will not be forgotten. Special thanks also to Cdr. (R) Hamdan Othman for vetting through my work and asking the five important questions that have added great depth to my thesis.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES