Analysis of Radiation from Wireless Communication Systems Using Parallel Electromagnetic Simulation

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Master Thesis

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Abstract

Considering the continuous increasing deployment of wireless communication system, the radiation level and communication quality are always highly concerned. Compared to the conventional approach for radiation and communication quality assessment based on electromagnetic field measurement, the use of computational method can better help to find out the field strength at locations where measurement is difficult to be undertaken, and even helps to forecast the change of the field distribution due to any adjustment of the base-station antennas and propagation environment. For achieving the objective of analyzing the radiation and communication quality of wireless communication systems in a city or a region in a city using computational electromagnetics, the structure to be simulated includes buildings with dielectric materials and base-station antennas. Usually, this kind of full-wave electromagnetic simulation belongs to electrically-large problem.

In this thesis, analyzing method based on parallel MoM with higher order basis functions for various wireless communication networks is proposed. As the Method of Moments (MoM) has advantages in accuracy for electrically-large computational electromagnetic simulation and high computation efficiency among different computational electromagnetics methods. It can be used to support the optimization by the evaluation of the field distribution, signal quality, pilot pollution, and the radiation safety level of the communication environment. For Wi-Fi and GSM network, the field strength will be simulated and compared with the on-site measurement to provide analysis of the communication quality and radiation safety. For UMST network, both the field strength and signal to interference ratio will be calculated to provide analysis on UMTS network. In addition, signal quality and pilot pollution problem are

also analyzed. All the electromagnetic simulations above have 0.3 to 0.5 million unknowns which are considered as electrically large problems.

For base-station antenna modeling, 6 base-station antennas and 2 Wi-Fi antennas will be designed and techniques in improving the performances of the antenna were proposed. All the base-station antennas are directional antennas and the classification of them bases on their operation frequency, antenna gain, horizontal and vertical bandwidth etc. The Wi-Fi antennas include directional antenna and omni-directional antenna.

In addition, order reduction technique will be studied for increasing computation efficiency while the accuracy is kept. In this technique, the model will be rebuilt and the order of the basis functions in MoM with HOBs will be reduced for some shadowed regions or transition regions. In the example being studied, the proposed order reduction technique successfully decreases the computation time by 45.12% and the memory requirement is reduced by 34.38% while the simulation accuracy is almost kept.

All the corresponding techniques in modeling of antennas and building structures, analysis and detail discussions will be given in the following chapters. Moreover, simulation and experimental comparison are given to verify the correctness of the proposed analyzing model.

To this end, the above studies have been summarized in the following technical papers:

1. C.-K. Chio, S.-W. Ting, X. W. Zhao, K.-W. Tam, "Prediction model for radiation from base-station antennas using electromagnetic simulation," 2012 Asia-Pacific Microwave Conference, Dec 2012, pp. 1082-1084.

2. C.-K. Chio, S.-W. Ting, K.-W. Tam, "Prediction model for radiation from base-station antennas using MoM with high order basis functions and order reduction technique," 13th IEEE HK/Macau AP/MTT Postgraduate Conference, Oct 2012.

3. C.-K. Chio, S.-W. Ting, K.-W. Tam, "Radiation analysis for co-existing GSM900 and UMTS900 networks," 2013 IEEE International Symposium on Antennas and Propagation, July 2013.

4. C.-K. Chio, S.-W. Ting, K.-W. Tam, “Coverage analysis of outdoor public Wi-Fi hotspot using full-wave electromagnetic simulation,” 2013 IEEE International Symposium on Antennas and Propagation, July 2013.

5. C.-K. Chio, S.-W. Ting, E.-H. Lim, K.-W. Tam, “Compact dual-band quasi-elliptic bandpass filter with transmission-zero control,” 2012 IEEE MTT-S Int. Microwave Symp. Dig., June 2012.

6. C.-K. Chio, S.-W. Ting, K.-W. Tam, “Compact Dual-Band Quasi-Elliptic Bandpass Filter with Improved Upper-Stopband Performance,” APMC2013, Dec 2012.

7. C.-K. Chio, S.-W. Ting, E.-H. Lim, K.-W. Tam, “Novel Reconfigurable Multiple-Band Quasi-Elliptic Bandpass Filter using Defected Ground Structure,” 2013 IEEE MTT-S Int. Microwave Symp. Dig., June 2013.

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Table of Contents

Table of Contents

List of Figures

List of Tables

Glossary

3D	Three Dimensions
CEM	Computational Electromagnetics
DT	Drive Test
Ec/No	Energy per modulating bit to the noise spectral density
EFIE	Electric Field Integral Equation
FDDE	Frequency Domain Differential Equation
FDIE	Frequency Domain Integral Equation
FDMA	Frequency-Division Multiple Access
FDTD	Finite- Difference Time- Domain Method
FEM	Finite Element Method
GSM	Global System for Mobile Communications
GTD	Geometrical Theory of Diffraction
HOBs	Higher-Order Basis Functions
HOBBIES	Higher Order Basis Based Integral Equation Solver
ICNIRP	International Commission on Non-Ionizing Radiation Protection
MLFMA	Multilevel Fast Multipole Algorithm
MoM	Method of Moments
NURBS	Non-Uniform Rational B-spline
PO	Physical Optics
RSCP	Received Signal Code Power
RSSI	Received Signal Strength Indication
RWG	Rao-Wilton-Glisson
TDDE	Time Domain Differential Equation
TDIE	Time Domain Integral Equation
UMTS	Universal Mobile Telecommunications System
WCDMA	Wideband Code Division Multiple Access