ADVANCED INTERCONNECT AND DEVICE-FIELD MODELING

FINAL TECHNICAL REPORT

BY

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***Abstract*:**
This final report describes the progress that has been made with the different tasks of this project. The highlights are that most of the tasks planned for this project have been carried out and completed successfully with some delay owing to some technical problems that could not be avoided. Those tasks concerned the development of OOP codes using C++ based on the Method of Moments for microwave interconnections analysis considering different geometrical configurations (i.e. multiconductor and multilayer structures) and physical parameters (e.g. conductor loss) using the Method of Moments and the Method of Lines. Furthermore, a novel approach based on the FDTD method has been developed for the global modeling of RF and microwave circuits and antennas which couples the EM and the active devices equivalent circuits' models. Also, a GUI has been developed using C++ for the FDTD code together with a Web based RF and Microwave Intercommunions Simulator using JavaScript Language in the framework of two MSc theses.
Seven graduate students have contributed to the development of all these tasks. Five of them obtained their Ph D degree and three of them already work as Assistant Professors in different Moroccan universities. Two MS students have also contributed to the development of those tasks and are now pursuing towards the Ph D degree. Some results obtained in the framework of this project have been published in international specialized journals, conferences and symposia.

Key words : Interconnects, Active devices, EM modeling, Global Modeling, Multi-layer, Multiconductor, Losses, Finite metallization thickness, Method of Lines, Method of Moments, Closed-form Green's functions, MPIE, FDTD, TLM, OOP, Freeda®

1. Progress

1.A Overview
The format of this report is to discuss the progress related to the tasks presented in the original proposal. The main tasks run for the duration of the project.

1.B Progress by Task

The four tasks have the aim of creating a database of elements for a general purpose mixed-mode circuit simulator.

Task 1 Two Dimensional Structure Modeling

Task 1A

Develop a Freeda model for a microstrip line of finite uniform cross-section. The model will consider a ground plane, finite conductor and substrate loss, and finite thickness isotropic dielectric on which a microstrip line of finite thickness resides. Frequency dependent effects (such as due to the skin effect) will be included accurately. The input to the model will be the physical parameters, the material parameters, frequency and length of line. This first model may initially use FORTRAN routines. Validation will be undertaken by comparing with the results of other computer programs. The Method of Lines will be used.
TASK COMPLETED

Task 1B

Study the types of two dimensional structures to be found in planar environments. Develop a class structure that facilitates the reuse of structure characterizations. Working with the international community develop concepts for representing two dimensional structures that are compatible with layout programs (generally these are point based so that a three dimensional object is specified as being at a point with dimensions referenced to that point rather than having reference planes as with early microwave CAE models of these structures.
TASK COMPLETED

Task 1C

Prepare a catalogue of the types of interconnects to be modeled. Develop the hierarchy of models with the view of establishing C++ class structures. Consider the implications of handling arbitrary cross-section to accommodate, for example, the effects of etching on interconnects resulting in nonrectangular cross-sections.
TASK COMPLETED

Task 1D

Design of a C++ class (interconnect3D class) for quasi-planar interconnect structures. Given frequency (which can vary) and material and physical parameters, the class will calculate y parameters. (This task may be modified by the results of Task 1C.)
TASK COMPLETED

Task 1E

Design of a C++ class (interconnect2D class) for quasi-planar interconnect structures of uniform cross-section. Given frequency (which can vary) and material and physical parameters other than length the class will calculate propagation constant and characteristic impedance parameters or other length independent parameters deemed more appropriate. Update design of interconnect3D class. (This task may be modified by the results of Task 1C.)
TASK COMPLETED

Task 1F

Implement interconnect3D class and interconnect2D class. (This task may be modified by the results of Task 1C.)
TASK COMPLETED

Task 1G

Implement microstrip model described in task 1A using object oriented paradigm (using *interconnect3D* and *interconnect2D classes*).
TASK COMPLETED

Task 1H
Convert the microstrip model of Task 1G to use the Method of Moments.
TASK COMPLETED

Task 1I
Implement C++ asymmetric lossy stripline model. The Method of Moments will be used.
TASK COMPLETED

Task 1J
Implement C++ lossy coplanar waveguide model. The Method of Moments will be used.
TASK COMPLETED

Task 1K
Implement C++ lossy coplanar strip model. The Method of Moments will be used.
TASK COMPLETED

Task 1L
Implement multilayer lossy strip model accommodating multiple lines, multiple dielectric layers of varying cross-section and permittivity, and one or two ground planes. The Method of Moments will be used.
TASK COMPLETED

Task 1M
Develop LaTeX documentation for the models developed in this task.
Documentation has been developed for completed tasks

Task 2 Three Dimensional Multilayer Static Green's Function

2A The Study of the program UIUC2D has been performed. Furthermore, the closed-form Green's function formulation using the method of moments proposed by Prof. Andreas Cangellaris, from Illinois University, has been studied. Furthermore, a 3-D extension of this technique is being developed.
2B Extend UIUC2D to the 3D static case.
2C Based on task 2B, develop a report on using the 3D closed form Green's function to develop lumped circuit models for transmission line discontinuities.

TASK COMPLETED

Task 3 Three Dimensional Structure Modeling
3A Study the types of three dimensional structures to be found in planar environments. Develop a class structure that facilitates the reuse of structure characterizations. Working with the international community develop concepts for representing three dimensional structures that are compatible with layout programs (generally these are point based so that a three dimensional object is specified as being at a point with dimensions referenced to that point rather than having reference planes as with early microwave CAE models of these structures).
TASK COMPLETED

3B Design appropriate class structures for three dimensional interconnects. Calculate a y parameter matrix.
3C Implement class structures for three dimensional interconnects.
3D Develop a via model. Use the method of moments.

3E Develop a spiral inductor model. Use the method of moments. Validate using commercial tools by considering extremes (e.g. zero thickness).

TASK COMPLETED

3F Develop a model of crossover of two lines.

TASK COMPLETED

Task 4 Device Field Interaction

Task 4A: We have performed a comparison between the FDTD and TLM methods in terms of theoretical formulation, numerical performances and coverage in the specialized literature.
TASK COMPLETED

Task 4B: We have developed a novel formulation based on the nonlinear lumped network FDTD method for the analysis of the electromagnetic waves interaction with active devices. A Fortran code has been developed from the proposed formulation and is being tested.
We have also studied the circuit model proposed by Prof. Samir El-Ghazaly, from Arizona State University, for the global modeling of microwave circuits involving passive and active elements from a theoretical point of view. A Fortran code has been developed based on this theory and has been successfully tested.
TASK COMPLETED

Task 4C: Design a C++ class structure for semiconductor device-circuit interaction.

TASK COMPLETED

Task 4D: Implement the class structure in Task 3C.
TASK COMPLETED

Task 4E: Implement the model for this st**ructure in a general purpose circuit simulator.**
TASK COMPLETED

APPENDIX

1. LIST OF PUBLICATIONS

1.1. Ph D and MSc Dissertations:

Alia Zakriti, Full wave modeling of microstrip lines and discontinuities using the Method of Lines, Ph D Thesis, Abdelmalek Essaadi University, 2002 (in French)

Samira Khoulji, Quasi Static Modeling of Microstrip transmission Lines and Interconnects using the MoL, Ph D Thesis, Abdelmalek Essaadi University, 2003 (in French)

Mohammed El Brak, Rigorous Modeling of Microstrip Discontinuities and Antennas using the FDTD Method, Ph D Thesis, Abdelmalek Essaadi University, 2004 (in French)

Otman El Mrabet, Global Modeling of RF and Microwave Circuits and Antennas Using the FDTD Method, Ph D Thesis, Abdelmalek Essaadi University, 2004 (in French)

Khalid El Ouahabi, Full Wave Modeling of Multilayer Multiconductor interconnects Using the Method of Moments, Ph D Thesis, Abdelmalek Essaadi University, 2006 (in French)

Khalid Mahdi, GUI for 3D Electromagnetic modeling using FDTD, ,MSc Thesis, Abdelmalek Essaadi University, 2006 (in English)

Rl Yazid Dari, Towadrs a Web based RF and Microwave Intercommunions Simulator using JavaScript Language, MSc Thesis, Abdelmalek Essaadi University, 2006 (in English)

1.2. Books Chapter

M. Essaaidi and O. El Mrabet, Effects of Dielectric Substrates Anisotropy on Microstrip Structures, in Electromagnetics of Complex Media, by S. Zouhdi and A. Sihvola (Co-editors), Kluwer Academic Publisher, 2003.

M. Essaaidi, Electromagnetic Modeling Usig the FDTD and the TLM Methods, Electromagnetic Modeling, pp. 77-88 , Serbia and Monte Negro, 2004.

1.3. Refereed Journal Articles

O. El Mrabet and M. Essaaidi, “Global modeling of microwave Three Terminal Active Devices using the FDTD Method;”, IEICE Electronics Express, Vol. 1, No. 12, pp. 1-6, Jan. 25, 2005 (Japan)

A. Zakriti and M. Essaaidi, "Full-Wave analysis of microstrip lines with variable thickness substrates using the method of lines", IEICE Electronics Express, Vol. 1, No. 7, pp. 1-6, July 2004. (Japan)

M. Iben Yaich, M. Khalladi and M. Essaaidi, "Efficient Modeling of Chiral Media Using SCN-TLM Method," Serbian Journal of Electrical Engineering, Vol. 1, No. 2, pp. 249-254, June 2004.

O. El Mrabet and M. Essaaidi, "An Efficient Algorithm for the Global Modeling of RF and Microwave Circuits Using a Reduced Nonlinear Lumped Network (RNL²N)-FDTD Approach," IEEE Microwave and Wireless Components Letters, Vol. 14, No. 2, Feb. 2004.

M. El Brak and M. Essaaidi, "Rigorous Modeling of Arbitrary Conformal Microstrip Filters and Spiral Inductors Using the FDTD Method," Microwave and Optical Technology Letters, Vol. 39, No.3, pp. 216-221, Nov. 2003.

M. El Brak and M. Essaaidi, "Rigorous Analysis of Conformal Microstrip Patch Antennas Using the FDTD Method", Microwave and Optical Technology Letters, Vol. 35, No. 6, pp. 372-376, 2003

S. Khoulji and M. Essaaidi, "Quasi-Static Parameters Extraction For Microstrip Lines Printed on Varying Thickness Substrates Considering Finite Metallization Thickness", International Journal on RF and Microwave Computer-Aided Engineering, Vol. 13, No. 3, pp. 194-205, 2003.

O. El Mrabet and M. Essaaidi, "Comments on Rigorous Modeling of Packaged Schottky Diodes by the NonLinear Lumped Network (NL2N)-FDTD Approach", IEEE Transaction on Microwave Theory and Techniques, Vol. 50, No. 10, Oct. 2002.

S. Ahyoud, A. El Moussaoui, M. Essaaidi and M. Khalladi, " Rigorous Modeling of Microstrip Lines Printed on Arbitrarily Varying Thicckness Substrates by the TLM Method", Microwave and Optical Technology Letters, Vol. 31, No. 7, July 2002.

S. Khoulji and M. Essaaidi, "Quasi Static Analysis of Microstrip Lines printed on Arbitrarily Varying Thickness Substrates Using the MoL ",Microwave and Optical Technology Letters, Vol. 31, No. 5, May 2002.

A. Zakriti and M. Essaaidi, "An Accurate Calculation of Microstrip Step Discontinuities Three Set of Lengths for the Transverse Resonance Technique by The Method of Lines," Microwave and Optical Technology Letters, Vol. 30, August 5, 2001.

1.4. Refereed Conference Proceedings

FDTD analysis of a novel compact planar monopole antenna for UWB communications
O. El Mrabet, H. Rmili, M. Aznabet, M. N. Srifi and M. Essaaidi
Mediterranean Microwave Symposium 2006
19-21 September, 2006, Genoa, Italy.

A Multiband Reconfigurable Microstrip conformal Antenna with MEMS Switches
M. El Brak and M. Essaaidi
Information and Communication Technologies International Symposium 2005
3-6 June 2005, Tetuan, Morocco

Global Modelling of Microwave Active Circuits using the Finite-Difference Time-Domain (FDTD) Method
Otman El Mrabet, M. Essaadi, and M. Drissi
Mediterranean Microwave Symposium 2005
Volume 1, 6-8 September, 2005, Athens, Greece.

Rigorous Modeling of Arbitrary Conformal Microstrip Structures Using The FDTD Method
M. El Brak and M. Essaaidi
Microwave Mediterranean Symposium 2003
Volume 1, 6-8 May, 2003, Cairo, Egypt.

Quasi-Static Modeling of Conformal Microstrip Interconnects Including Conductor and Substrate Losses
M. Iben Yaich, M. Khalladi and M. Essaaidi
Microwave Mediterranean Symposium 2003
Volume 1, 6-8 May, 2003, Cairo, Egypt.

Quasi-Static Parameters Extraction For Microstrip Lines Printed on Varying Thickness Substrates Considering Finite Metallization Thickness
S. Khoulji and M. Essaaidi
Microwave Mediterranean Symposium 2002
Volume 1, 26-28 June 2002, Cáceres, Spain.

Full-Wave Analysis of Microstrip Resonators With Substrates With Arbitrary Varying Thickness Using The MoL
A. Zakriti and M. Essaaidi
Microwave Mediterranean Symposium 2002
Volume 1, 26-28 June 2002, Cáceres, Spain.

"Quasi-Static Analysis of Microstrip Lines Printed on Variable Thickness Bi-anisotropic Substrates Using The MoL
S. Khoulji and M. Essaaidi
NATO Advanced Research Workshop : Bianisotropics 2002, 99th Conference on Electromagnetics of Complex Media
8-11May, 2002, Marrakech, Morocco.

Rigorous Analysis of Curved Microstrip Patch Antennas Using The FDTD Method
M. El Brak and M. Essaaidi
NATO Advanced Research Workshop : Bianisotropics 2002, 99th Conference on Electromagnetics of Complex Media
8-11May, 2002, Marrakech, Morocco.

Study of Substrates Bi-anisotropy Effects on Microstrip Patch Antennas Using The FDTD Method

O. El Mrabet and M. Essaaidi
NATO Advanced Research Workshop : Bianisotropics 2002, 99th Conference on Electromagnetics of Complex Media
8-11May, 2002, Marrakech, Morocco.

Dielectric Substrates Anisotropic Effects on The Characteristics of Microstrip Structures
M. Essaaidi
NATO Advanced Research Workshop : Bianisotropics 2002, 99th Conference on Electromagnetics of Complex Media
Invited paper, 8-11May, 2002, Marrakech, Morocco.

1.4.Technical reports

Four technical reports have been submitted to the US ARO in London reporting the progress made with this project few years ago.

2. LIST OF ALL PARTICIPATING SCIENTIFIC PERSONNEL

Full Name	Degree earned	Year	Current position
Alia Zakriti	Ph D	2002	Assistant Professor
Samira Khoulji	Ph D	2003	Assistant Professor
Mohamed El Brak	Ph D	2004	Assistant Professor
Otman El Mrabet	Ph D	2004	Post Doc
Khalid El Ouajabi	Ph D	2006	Post Doc
Khalid Mahdi	MS	2006	Ph D Student
El Yazid Dari	MS	2006	Ph D Student

2. Reprints of some papers published from this project