



AIN SHAMS UNIVERSITY

FACULTY OF ENGINEERING

Electronics Engineering and Electrical Communications

Solutions of Microwave Problems Using VIE

A thesis submitted in partial fulfillment of the requirements of

Master of Science in Electrical Engineering

(Electronics Engineering and Electrical Communications)

By

Ehab Adel Mahmoud Ali El-fayome

Bachelor in Electrical Engineering

(Electronics Engineering and Electrical Communications)

Supervised by

Prof. Dr. Hadia mohamed El-Hennawy

Prof. Dr. Aladin Kamel

Faculty of Engineering – Ain Shams University
Electronics and Communication Engineering Department

Thesis title “**Solutions of Microwave Problems Using VIE**”

Submitted by: **Ehab Adel Mahmoud Ali El-fayome**

Degree: Master of Science in Electrical Engineering

Examiner’s Committee:

Prof. Dr. Hadia S. ElHennawy

Ain Shams University, Faculty of Engineering,

Electronics and Communications Department.

Prof. Dr. Aladin H. Kamel

Advanced Industrial, Technical and Engineering Center

Prof. Dr. Amr Mohammed Ezzat Safwat

Ain Shams University, Faculty of Engineering,

Electronics and Communications Department

Prof. Dr. Amr Shaarawy

American University in Cairo

Date:

Statement

This thesis is submitted as a partial fulfillment of Master of Science in Electrical Engineering, Faculty of Engineering, Ain Shams University. The author carried out this work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

Ehab Adel Mahmoud Ali El-fayome

Signature

.....

Date:

Researcher Data

Name: Ehab Adel Mahmoud Ali El-fayome

Date of Birth: 20/9/1988

Place of Birth: dokki, el_Gizah, Egypt

Last academic degree: Bachelor of engineering

Field of specialization: Electronics And Communications Engineering

University issued the degree: Thebas academy for engineering

Date of issued degree: May 2010

Current job: engineer officer at ministry of interior

Acknowledgment

I am mostly grateful to Allah for bestowing upon me the chance, strength, and ability to complete this work. I wish to express my most gratitude to my supervisors Prof. Dr. Aladin H. Kamel and Prof. Dr. Hadia S. ElHennawy, for their guidance, encouragement, and useful discussions.

I am very grateful to Dr. Aladin H. Kamel who has been more than a supervisor to me, I have learned from him both on the technical and the personal level. I would like to thank Prof. Dr. Hadia S. ElHennawy who taught me dedication in work and respecting the department traditions. Many thanks to my father (May God have mercy on him) and my mother for the care and the support.

Last but not least, I would like to thank my fiancée for her patience, care, and love which guided me.

Ehab Adel Mahmoud Ali El-fayome

Electronics and Communication Engineering Department

Faculty of engineering

Ain Shams University

Cairo, Egypt

2016

Abstract

Faculty of Engineering – Ain Shams University

Electronics and Communication Engineering Department

Thesis title “**Solutions of Microwave Problems Using VIE**”

Submitted by: **Ehab Adel Mahmoud Ali El-fayome**

Degree: Master of Science in Electrical Engineering

Abstract

This thesis is an attempt to solve non trivial inverse problems using a global minimization technique as well as radial basis neural network.

In general, we have two kinds of electromagnetic problems: forward problems and inverse problems.

Forward problems are a calculation of scattered electromagnetic field when we know the material properties of the scatterer, The inverse problem is to find the material properties of the scatterer when we measure the scattered electric field due to a known electric field source.

For the inverse problem solution, we need, at first, a forward problem solver.

We use our Maxwell's equations solvers to solve the forward problem; our Maxwell's solvers are new semi-analytical formulations for the computation of the scattered electromagnetic fields from vertically stratified lossy perfect dielectric media.

Our Maxwell's equations solvers are compared with those for a number of cases with known analytical solutions and are shown to be very accurate and efficient.

We developed these approaches to overcome some of the limitations and difficulties of the existing approaches (Finite-Difference Time-Domain (FDTD), Finite Element Method (FEM), Boundary Element Method (BEM) ...).

And then solve the corresponding global minimization problem using simulated annealing algorithm alternatively solve the inverse problem by training a radial basis neural network.

Summary

Faculty of Engineering – Ain Shams University

Electronics and Communication Engineering Department

Thesis title “**Solutions of Microwave Problems Using VIE**”

Submitted by: **Ehab Adel Mahmoud Ali El-fayome**

Degree: Master of Science in Electrical Engineering

Summary

The thesis is divided into 7 chapters as listed below:

Chapter 1

Chapter 1 has been an introduction to the work, including an overview of different methods for solving inverse problems and forward problems

Chapter 2

Chapter 2 shows Maxwell's equations in the integral equation form on the induced electric polarization current.

Chapter 3

Chapter 3 is a new formulation for solving Maxwell's equations based on combining 1-D eigen value problems with volume integral equations.

Chapter 4

Chapter 4 is another new formulation for solving Maxwell's equations based on combining radiating/one way nonradiating currents with volume integral equations.

Chapter 5

Chapter 5 has been an introduction to inverse problem solution using global minimization technique (simulated annealing).

Chapter 6

Chapter 6 has been an introduction to another inverse problem solution using radial basis neural networks.

Chapter 7

Chapter 7 concludes the thesis work with possible directions for the future work.

Contents

Abstract	xi
Summary	xii
Contents	xv
List of figures	xx
List of Tables	xxii
Abbreviations	xxiii
Symbols	xxv
1 Introduction	
1.1 Introduction.....	1
1.2 Motivation.....	1
1.3 Challenges.....	2
1.4 Thesis Outline.....	3
2 Background	
2.1 Maxwell's equations.....	4
2.1.1 Methods for solving Maxwell's equations.....	5
2.1.2 The general limitations for all the numerical method.....	5
2.2 Maxwell's equation in the integral form in the induced electric polarization current	6
3 Maxwell's equation solver using eigen current method.....	9
3.1 Formulation.....	9
3.1.1 1-D Integral Equation Eigen Value.....	9
3.1.2 Scattered Field Computation.....	11

3.2	Results.....	11
3.3	Conclusions.....	18
4	Maxwell's equation solver using Radiating /one way non radiating current.....	19
4.1	Introduction.....	19
4.2	Formulation.....	19
4.2.1	Volume Integral Equation.....	20
4.2.2	Radiating / NonRadiating Currents.....	20
4.2.3	Radiating /one way NonRadiating Currents.....	20
4.2.4	Scattered Field Computation.....	23
4.3	Results.....	23
4.4	Conclusions.....	27
5	Inverse problem solution using global minimization techniques.....	28
5.1	Introduction.....	28
5.2	Formulation.....	31
5.3	Design of the algorithm.....	32
5.3.1	Initial Guesses Preparation.....	32
5.3.2	Exponential Cooling Schedule (ECS).....	33
5.3.3	Fast Cooling Schedule (FCS).....	35
5.3.4	Boltzmann Cooling Schedule (BCS).....	36
5.4	Analysis of the results.....	38
5.5	Conclusions.....	39
6	Inverse problem solution using radial neural network.....	40
6.1	Introduction.....	40
6.2	Traditional neural networks.....	41
6.3	Radial basis function techniques.....	42
6.3.1	Exact Design (NEWRBE).....	46
6.3.2	Approximate Radial Basis Functions Network(RBA).....	46

6.3.3	Generalized Regression Neural Network (GRNN).....	46
6.4	Network design.....	47
6.4.1	Training and Generalization Sets Preparation.....	47
6.4.2	Material which gradually increased in relative permittivity and conductivity values.....	51
6.4.2.1	The result for exact radial basis function with noise & spread=15	51
6.4.2.2	The result for the approximate radial basis function with noise & spread=15.....	54
6.4.2.3	The result for regression radial basis function with noise & spread=15	57
6.4.2.4	The result for exact radial basis function with noise & spread=120.....	60
6.4.2.5	The result for the approximate radial basis function with noise & spread=120.....	63
6.4.2.6	The result for regression radial basis function with noise & spread=120.....	66
6.4.2.7	The result for exact radial basis function without noise & spread=15.....	69
6.4.2.8	The result for the approximate radial basis function without noise & spread=15.....	72
6.4.2.9	The result for regression radial basis function without noise & spread=15.....	75
6.4.3	Material which gradually decreased in relative permittivity and conductivity values.....	78
6.4.3.1	The result for exact radial basis function with noise & spread=15.....	78
6.4.3.2	The result for the approximate radial basis function with noise & spread=15.....	81
6.4.3.3	The result for regression radial basis function with noise & spread=15.....	84

6.4.3.4	The result for exact radial basis function with noise & spread=120.....	87
6.4.3.5	The result for the approximate radial basis function with noise & spread=120.....	90
6.4.3.6	The result for regression radial basis function with noise & spread=120.....	93
6.4.3.7	The result for exact radial basis function without noise & spread=15.....	96
6.4.3.8	The result for the approximate radial basis function without noise & spread=15.....	99
6.4.3.9	The result for regression radial basis function without noise & spread=15.....	102
6.4.4	Material which decreased and then increased in material properties values.....	105
6.4.4.1	The result for exact radial basis function with noise & spread=15.....	105
6.4.4.2	The result for the approximate radial basis function with noise & spread=15.....	108
6.4.4.3	The result for regression radial basis function with noise & spread=15.....	111
6.4.4.4	The result for exact radial basis function with noise & spread=120.....	114
6.4.4.5	The result for the approximate radial basis function with noise & spread=120.....	117
6.4.4.6	The result for regression radial basis function with noise & spread=120.....	120
6.4.4.7	The result for exact radial basis function without noise & spread=15.....	123
6.4.4.8	The result for the approximate radial basis function without noise & spread=15.....	126
6.4.4.9	The result for regression radial basis function without noise & spread=15.....	129

6.4.5	Material which increased and then decreased in material properties values.....	132
6.4.5.1	The result for exact radial basis function with noise & spread=15.....	132
6.4.5.2	The result for the approximate radial basis function with noise & spread=15.....	135
6.4.5.3	The result for regression radial basis function with noise & spread=15.....	138
6.4.5.4	The result for exact radial basis function with noise & spread=120.....	141
6.4.5.5	The result for the approximate radial basis function with noise & spread=120.....	144
6.4.5.6	The result for regression radial basis function with noise & spread=120.....	147
6.4.5.7	The result for exact radial basis function without noise & spread=15.....	150
6.4.5.8	The result for the approximate radial basis function without noise & spread=15.....	153
6.4.5.9	The result for regression radial basis function without noise & spread=15.....	156
6.5	Analysis of the results.....	159
6.6	Conclusion.....	159
7	final conclusion and possible direction for the future work.....	160
7.1	final conclusion.....	160
7.2	future work.....	161

List of figures

1.1	our example problem.....	1
1.2	schematic diagram of the basic structure of GPR.....	2
3.1	Real $E_{zr}(k_x, 0)$ with k_x/k_0 (from 0 to 2.01) for $k_0L = 40$ and $N=30$ (using eigen polarization current method).....	12
3.2	Imaginary $E_{zr}(k_x, 0)$ with k_x/k_0 (from 0 to 2.01) for $k_0L = 40$ and $N=30$ (using eigen polarization current method).....	12
3.3	Real $E_{zr}(k_x, 0)$ with k_x/k_0 (from 0 to 2.01) for $k_0L=80$ and $N=60$ (using eigen polarization current method).....	12
3.4	Imaginary $E_{zr}(k_x, 0)$ with k_x/k_0 (from 0 to 2.01) for $k_0L=80$ and $N=60$ (using eigen polarization current method).....	12
3.5	Real $E_{zr}(k_x, 0)$ with k_x/k_0 (from 0 to 2.01) for $k_0L=120$ and $N=90$ (using eigen polarization current method).....	12
3.6	Imaginary $E_{zr}(k_x, 0)$ with k_x/k_0 (from 0 to 2.01) for $k_0L=120$ and $N=90$ (using eigen polarization current method).....	12
4.1	Real $E_{zr}(k_x, 0)$ with k_x/k_0 (from 0 to 1.1) for $k_0L = 40$ and $N=1000$ (using radiating /nonradiating polarization current method).....	24
4.2	Imaginary $E_{zr}(k_x, 0)$ with k_x/k_0 (from 0 to 1.1) for $k_0L=40$ and $N=1000$ (using radiating /nonradiating polarization current method).....	24
4.3	Real $E_{zr}(k_x, 0)$ with k_x/k_0 (from 0 to 1.1) for $k_0L = 80$ and $N=1500$ (using radiating /nonradiating polarization current method).....	25
4.4	Imaginary $E_{zr}(k_x, 0)$ with k_x/k_0 (from 0 to 1.1) for $k_0L=80$ and $N=1500$ (using radiating /nonradiating polarization current method).....	25
4.5	Real $E_{zr}(k_x, 0)$ with k_x/k_0 (from 0 to 1.1) for $k_0L = 120$ and $N=1500$ (using radiating /nonradiating polarization current method).....	26
4.6	Imaginary $E_{zr}(k_x, 0)$ with k_x/k_0 (from 0 to 1.1) for $k_0L=120$ and $N=1500$ (using radiating /nonradiating polarization current method).....	26
5.1	local and global optimum.....	28
5.2	Histogram distribution of the initial guess values of the relative permittivity of the fourth layer($\epsilon_{r,4}$)	33

5.3 Histogram distribution for the percentage error of the relative permittivity of the fourth layer, ($\epsilon_{r,4}$), for the ECS with zero noise (using simulated annealing technique).....	34
5.4 Histogram distribution for the percentage error of the relative permittivity of the fourth layer, ($\epsilon_{r,4}$), for the ECS with $\pm 1\%$ noise (using simulated annealing technique).....	34
5.5 Histogram distribution for the percentage error of the relative permittivity of the fourth layer ($\epsilon_{r,4}$), for the FCS with zero noise (using simulated annealing technique).....	35
5.6 Histogram distribution for the percentage error of the relative permittivity of the fourth layer ($\epsilon_{r,4}$), for the FCS with $\pm 1\%$ noise (using simulated annealing technique).....	36
5.7 Histogram distribution for the percentage error of the relative permittivity of the fourth layer ($\epsilon_{r,4}$), for the BCS with zero noise (using simulated annealing technique).....	37
5.8 Histogram distribution for the percentage error of the relative permittivity of the fourth layer ($\epsilon_{r,4}$), for the BCS with $\pm 1\%$ noise (using simulated annealing technique).....	37
5.9 Cooling schedules: Squares represent the ECS, '+' signs represent the FCS and the solid line represents the BCS(using simulated annealing technique).....	38
6.1 Minimum BP networks to solve parity-7 problem: (a) standard MLP network; (b) FCC networks; (c) BMLP networks; Red dash lines are connections across layers.....	41
6.2 Single neuron with N inputs and M outputs.....	41
6.3 RBF network with N inputs, L hidden units and M outputs.....	43