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Wavelets in Electromagnetics and Device Modeling

GEORGE W. PAN

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Wavelets in Electromagnetics and Device Modeling

Wavelets in Electromagnetics and Device Modeling

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Tempe, Arizona*

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Dedicated to my father Pan Zhen and mother Lei Tian-Lu

Contents

Preface	xv
1 Notations and Mathematical Preliminaries	1
1.1 Notations and Abbreviations	1
1.2 Mathematical Preliminaries	2
1.2.1 Functions and Integration	2
1.2.2 The Fourier Transform	4
1.2.3 Regularity	4
1.2.4 Linear Spaces	7
1.2.5 Functional Spaces	8
1.2.6 Sobolev Spaces	10
1.2.7 Bases in Hilbert Space H	11
1.2.8 Linear Operators	12
Bibliography	14
2 Intuitive Introduction to Wavelets	15
2.1 Technical History and Background	15
2.1.1 Historical Development	15
2.1.2 When Do Wavelets Work?	16
2.1.3 A Wave Is a Wave but What Is a Wavelet?	17
2.2 What Can Wavelets Do in Electromagnetics and Device Modeling?	18
2.2.1 Potential Benefits of Using Wavelets	18
2.2.2 Limitations and Future Direction of Wavelets	19
2.3 The Haar Wavelets and Multiresolution Analysis	20
	vii

2.4 How Do Wavelets Work?	23
Bibliography	28
3 Basic Orthogonal Wavelet Theory	30
3.1 Multiresolution Analysis	30
3.2 Construction of Scalets $\varphi(\tau)$	32
3.2.1 Franklin Scalet	32
3.2.2 Battle–Lemarie Scalets	39
3.2.3 Preliminary Properties of Scalets	40
3.3 Wavelet $\psi(\tau)$	42
3.4 Franklin Wavelet	48
3.5 Properties of Scalets $\hat{\varphi}(\omega)$	51
3.6 Daubechies Wavelets	56
3.7 Coifman Wavelets (Coiflets)	64
3.8 Constructing Wavelets by Recursion and Iteration	69
3.8.1 Construction of Scalets	69
3.8.2 Construction of Wavelets	74
3.9 Meyer Wavelets	75
3.9.1 Basic Properties of Meyer Wavelets	75
3.9.2 Meyer Wavelet Family	83
3.9.3 Other Examples of Meyer Wavelets	92
3.10 Mallat’s Decomposition and Reconstruction	92
3.10.1 Reconstruction	92
3.10.2 Decomposition	93
3.11 Problems	95
3.11.1 Exercise 1	95
3.11.2 Exercise 2	95
3.11.3 Exercise 3	97
3.11.4 Exercise 4	97
Bibliography	98
4 Wavelets in Boundary Integral Equations	100
4.1 Wavelets in Electromagnetics	100
4.2 Linear Operators	102

4.3 Method of Moments (MoM)	103
4.4 Functional Expansion of a Given Function	107
4.5 Operator Expansion: Nonstandard Form	110
4.5.1 Operator Expansion in Haar Wavelets	111
4.5.2 Operator Expansion in General Wavelet Systems	113
4.5.3 Numerical Example	114
4.6 Periodic Wavelets	120
4.6.1 Construction of Periodic Wavelets	120
4.6.2 Properties of Periodic Wavelets	123
4.6.3 Expansion of a Function in Periodic Wavelets	127
4.7 Application of Periodic Wavelets: 2D Scattering	128
4.8 Fast Wavelet Transform (FWT)	133
4.8.1 Discretization of Operation Equations	133
4.8.2 Fast Algorithm	134
4.8.3 Matrix Sparsification Using FWT	135
4.9 Applications of the FWT	140
4.9.1 Formulation	140
4.9.2 Circuit Parameters	141
4.9.3 Integral Equations and Wavelet Expansion	143
4.9.4 Numerical Results	144
4.10 Intervallic Coifman Wavelets	144
4.10.1 Intervallic Scalets	145
4.10.2 Intervallic Wavelets on $[0, 1]$	154
4.11 Lifting Scheme and Lazy Wavelets	156
4.11.1 Lazy Wavelets	156
4.11.2 Lifting Scheme Algorithm	157
4.11.3 Cascade Algorithm	159
4.12 Green's Scalets and Sampling Series	159
4.12.1 Ordinary Differential Equations (ODEs)	160
4.12.2 Partial Differential Equations (PDEs)	166
4.13 Appendix: Derivation of Intervallic Wavelets on $[0, 1]$	172
4.14 Problems	185
4.14.1 Exercise 5	185
4.14.2 Exercise 6	185
4.14.3 Exercise 7	185

4.14.4 Exercise 8	186
4.14.5 Project 1	187
Bibliography	187
5 Sampling Biorthogonal Time Domain Method (SBTD)	189
5.1 Basis FDTD Formulation	189
5.2 Stability Analysis for the FDTD	194
5.3 FDTD as Maxwell's Equations with Haar Expansion	198
5.4 FDTD with Battle–Lemarie Wavelets	201
5.5 Positive Sampling and Biorthogonal Testing Functions	205
5.6 Sampling Biorthogonal Time Domain Method	215
5.6.1 SBTD versus MRTD	215
5.6.2 Formulation	215
5.7 Stability Conditions for Wavelet-Based Methods	219
5.7.1 Dispersion Relation and Stability Analysis	219
5.7.2 Stability Analysis for the SBTD	222
5.8 Convergence Analysis and Numerical Dispersion	223
5.8.1 Numerical Dispersion	223
5.8.2 Convergence Analysis	225
5.9 Numerical Examples	228
5.10 Appendix: Operator Form of the MRTD	233
5.11 Problems	236
5.11.1 Exercise 9	236
5.11.2 Exercise 10	237
5.11.3 Project 2	237
Bibliography	238
6 Canonical Multiwavelets	240
6.1 Vector-Matrix Dilation Equation	240
6.2 Time Domain Approach	242
6.3 Construction of Multiscalelets	245
6.4 Orthogonal Multiwavelets $\check{\psi}(t)$	255
6.5 Intervallic Multiwavelets $\psi(t)$	258

6.6	Multiwavelet Expansion	261
6.7	Intervallic Dual Multiwavelets $\tilde{\psi}(t)$	264
6.8	Working Examples	269
6.9	Multiscalelet-Based 1D Finite Element Method (FEM)	276
6.10	Multiscalelet-Based Edge Element Method	280
6.11	Spurious Modes	285
6.12	Appendix	287
6.13	Problems	296
6.13.1	Exercise 11	296
	Bibliography	297
7	Wavelets in Scattering and Radiation	299
7.1	Scattering from a 2D Groove	299
7.1.1	Method of Moments (MoM) Formulation	300
7.1.2	Coiflet-Based MoM	304
7.1.3	Bi-CGSTAB Algorithm	305
7.1.4	Numerical Results	305
7.2	2D and 3D Scattering Using Intervallic Coiflets	309
7.2.1	Intervallic Scalelets on $[0, 1]$	309
7.2.2	Expansion in Coifman Intervallic Wavelets	312
7.2.3	Numerical Integration and Error Estimate	313
7.2.4	Fast Construction of Impedance Matrix	317
7.2.5	Conducting Cylinders, TM Case	319
7.2.6	Conducting Cylinders with Thin Magnetic Coating	322
7.2.7	Perfect Electrically Conducting (PEC) Spheroids	324
7.3	Scattering and Radiation of Curved Thin Wires	329
7.3.1	Integral Equation for Curved Thin-Wire Scatterers and Antennae	330
7.3.2	Numerical Examples	331
7.4	Smooth Local Cosine (SLC) Method	340
7.4.1	Construction of Smooth Local Cosine Basis	341
7.4.2	Formulation of 2D Scattering Problems	344
7.4.3	SLC-Based Galerkin Procedure and Numerical Results	347
7.4.4	Application of the SLC to Thin-Wire Scatterers and Antennas	355

7.5 Microstrip Antenna Arrays	357
7.5.1 Impedance Matched Source	358
7.5.2 Far-Zone Fields and Antenna Patterns	360
Bibliography	363
8 Wavelets in Rough Surface Scattering	366
8.1 Scattering of EM Waves from Randomly Rough Surfaces	366
8.2 Generation of Random Surfaces	368
8.2.1 Autocorrelation Method	370
8.2.2 Spectral Domain Method	373
8.3 2D Rough Surface Scattering	376
8.3.1 Moment Method Formulation of 2D Scattering	376
8.3.2 Wavelet-Based Galerkin Method for 2D Scattering	380
8.3.3 Numerical Results of 2D Scattering	381
8.4 3D Rough Surface Scattering	387
8.4.1 Tapered Wave of Incidence	388
8.4.2 Formulation of 3D Rough Surface Scattering Using Wavelets	391
8.4.3 Numerical Results of 3D Scattering	394
Bibliography	399
9 Wavelets in Packaging, Interconnects, and EMC	401
9.1 Quasi-static Spatial Formulation	402
9.1.1 What Is Quasi-static?	402
9.1.2 Formulation	403
9.1.3 Orthogonal Wavelets in $L^2([0, 1])$	406
9.1.4 Boundary Element Method and Wavelet Expansion	408
9.1.5 Numerical Examples	412
9.2 Spatial Domain Layered Green's Functions	415
9.2.1 Formulation	417
9.2.2 Prony's Method	423
9.2.3 Implementation of the Coifman Wavelets	424
9.2.4 Numerical Examples	426
9.3 Skin-Effect Resistance and Total Inductance	429
9.3.1 Formulation	431
9.3.2 Moment Method Solution of Coupled Integral Equations	433

9.3.3	Circuit Parameter Extraction	435
9.3.4	Wavelet Implementation	437
9.3.5	Measurement and Simulation Results	438
9.4	Spectral Domain Green's Function-Based Full-Wave Analysis	440
9.4.1	Basic Formulation	440
9.4.2	Wavelet Expansion and Matrix Equation	444
9.4.3	Evaluation of Sommerfeld-Type Integrals	447
9.4.4	Numerical Results and Sparsity of Impedance Matrix	451
9.4.5	Further Improvements	455
9.5	Full-Wave Edge Element Method for 3D Lossy Structures	455
9.5.1	Formulation of Asymmetric Functionals with Truncation Conditions	456
9.5.2	Edge Element Procedure	460
9.5.3	Excess Capacitance and Inductance	464
9.5.4	Numerical Examples	466
	Bibliography	469
10	Wavelets in Nonlinear Semiconductor Devices	474
10.1	Physical Models and Computational Efforts	474
10.2	An Interpolating Subdivision Scheme	476
10.3	The Sparse Point Representation (SPR)	478
10.4	Interpolation Wavelets in the FDM	479
10.4.1	1D Example of the SPR Application	480
10.4.2	2D Example of the SPR Application	481
10.5	The Drift-Diffusion Model	484
10.5.1	Scaling	486
10.5.2	Discretization	487
10.5.3	Transient Solution	489
10.5.4	Grid Adaptation and Interpolating Wavelets	490
10.5.5	Numerical Results	492
10.6	Multiwavelet Based Drift-Diffusion Model	498
10.6.1	Precision and Stability versus Reynolds	499
10.6.2	MWFEM-Based 1D Simulation	502
10.7	The Boltzmann Transport Equation (BTE) Model	504
10.7.1	Why BTE?	505
10.7.2	Spherical Harmonic Expansion of the BTE	505

xiv CONTENTS

10.7.3 Arbitrary Order Expansion and Galerkin's Procedure	509
10.7.4 The Coupled Boltzmann–Poisson System	515
10.7.5 Numerical Results	517
Bibliography	524
Index	527

Preface

Applied mathematics has made considerable progress in wavelets. In recent years interest in wavelets has grown at a steady rate, and applications of wavelets are expanding rapidly. A virtual flood of engineers, with little mathematical sophistication, is about to enter the field of wavelets. Although more than 100 books on wavelets have been published since 1992, there is still a large gap between the mathematician's rigor and the engineer's interest. The present book is intended to bridge this gap between mathematical theory and engineering applications.

In an attempt to exploit the advantages of wavelets, the book covers basic wavelet principles from an engineer's point of view. With a minimum number of theorems and proofs, the book focuses on providing physical insight rather than rigorous mathematical presentations. As a result the subject matter is developed and presented in a more basic and familiar way for engineers with a background in electromagnetics, including linear algebra, Fourier analysis, sampling function of $\sin \pi x / \pi x$, Dirac δ function, Green's functions, and so on. The multiresolution analysis (MRA) is naturally delivered in Chapter 2 as a basic introduction that shows a signal decomposed into several resolution levels. Each level can be processed according to the requirement of the application. The application of MRA lies within the Mallat decomposition and reconstruction algorithm. MRA is further explained in a fast wavelet transform section with an example of frequency-dependent transmission lines. Mathematically elegant proofs and derivations are presented in a smaller font if their content is beyond the engineering requirement. Readers with no time or interest in this depth of mathematics may always skip the paragraphs or sections written in smaller font without jeopardizing their understanding of the main subjects.

The main body of the book came from conference presentations, including the IEEE Microwave Theory and Techniques Symposium (IEEE-MTT), IEEE Antennas and Propagation (IEEE-AP), Radio Science (URSI), IEEE Magnetics, Progress in Electromagnetic Research Symposium (PIERS), Electromagnetic and Light Scattering (ELS), COMPUMAG, Conference on Electromagnetic Field Computation (CEFC), Association for Computational Electromagnetic Society (ACES), International Conference on Microwave and Millimeter Wave Technology (ICMTT), and

International Conference on Computational Electromagnetics and its Applications (ICCEA). The book has evolved from curricula taught at the graduate level in the Department of Electronic Engineering at Canterbury University (Christchurch, New Zealand) and Arizona State University. The material was taught as short courses at Moscow State University, CSIRO (Sydney, Australia), IEEE Microwave Theory and Techniques Symposium, Beijing University, Aerospace 207 Institute, and the 3rd Institute of China. The participants in these courses were electrical engineering and computer science students as well as practicing engineers in industry. These people had little or no prior knowledge of wavelets.

The book may serve as a reference book for engineers, practicing scientists, and other professionals. Real-world state-of-the-art issues are extensively discussed, including full-wave modeling of coupled lossy and dispersive transmission lines, scattering of electromagnetic waves from 2D/3D bodies and from randomly rough surfaces, radiation from linear and patch antennas, and modeling of 2D semiconductor devices. The book can also be used as a textbook, as it contains questions, working examples, and 11 exercise assignments with a solution manual. It has been used several times in teaching a one-semester graduate course in electrical engineering.

The book consists of 10 chapters. The first six chapters are dedicated to basic theory and training, followed by four chapters in real-world applications. Chapter 1 summarizes mathematical preliminaries, which may be skipped on the first reading. Chapter 2 provides some background and theoretical insights. Chapter 3 covers the basic orthogonal wavelet theory. Other wavelet topics are discussed in Chapters 4 through 10, including biorthogonal wavelets, weighted wavelets, interpolating wavelets, Green's wavelets, and multiwavelets. Chapter 4 presents applications of wavelets in solving integral equations. Special treatments of edges are discussed here, including periodic wavelets and intervallic wavelets. Chapter 5 derives the positive sampling functions and their biorthogonal counterparts using Daubechies wavelets. Many advantages derive from the use of the sampling biorthogonal time domain (SBTD) method to replace the finite difference time domain (FDTD) scheme. Chapter 6 studies multiwavelet theory, including biorthogonal and orthogonal multiwavelets with applications in the edge-based finite element method (EEM). Advanced topics are presented in Chapter 7, 8, and 9, respectively, for scattering and radiation, 3D rough surface scattering, packaging and interconnects. Chapter 10 is devoted to semiconductor device modeling using the aforementioned knowledge of wavelets. Numerical procedures are fully detailed so as to help interested readers develop their own algorithms and computer codes.

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