

---

**ELECTROMAGNETIC  
WAVES** **PIER 44**

---

**Progress**

**In**

**Electromagnetics**

**Research**

© 2004 EMW Publishing. All rights reserved.

No part of this publication may be reproduced. Request for permission should be addressed to the Publisher.

All inquiries regarding copyrighted material from this publication, manuscript submission instructions, and subscription orders and price information should be directed to: EMW Publishing, P. O. Box 425517, Kendall Square, Cambridge, Massachusetts 02142, USA. FAX: 1-617-354-9597.

For up-to-date information, visit web site at <http://www.emwave.com>.

This publication is printed on acid-free paper.

ISSN 1070-4698

ISBN 0-9679674-8-1

Manufactured in the United States of America.

---

**ELECTROMAGNETIC  
WAVES** **PIER 44**

---

**Progress**

**In**

**Electromagnetics  
Research**

**Chief Editor: J. A. Kong**

EMW Publishing  
Cambridge, Massachusetts, USA



# CONTENTS

## Chapter 1. A FAST MULTIPOLE METHOD FOR EMBEDDED STRUCTURE IN A STRATIFIED MEDIUM

*Y. C. Pan and W. C. Chew*

<b>1</b>	<b>Introduction</b> .....	<b>2</b>
<b>2</b>	<b>Stratified Medium Green's Function</b> .....	<b>4</b>
2.1	Integral Representation of the Spherical Harmonics ....	4
2.2	Integral Representation of the Stratified Medium Green's Function .....	6
<b>3</b>	<b>Stratified Medium O2L Translators</b> .....	<b>11</b>
3.1	Integral Representation of the Free-Space O2L Translators	11
3.2	Integral Representation of the Multilayer O2L Translators	12
3.3	Special Case: Source and Observation Points Are above Dielectric Interface.....	13
3.4	General Case: Source and Observation Points Are Embedded in a Multilayer Medium .....	15
<b>4</b>	<b>Singularities in the Integrals</b> .....	<b>17</b>
4.1	Singularities in the Generalized Reflection and Trans- mission Coefficients .....	20
4.2	Weighting Functions .....	21
<b>5</b>	<b>SMFMM for General 3D Structures</b> .....	<b>21</b>
5.1	General Formulation .....	21
5.2	Brief Overview of Multilevel Free-Space Fast Multipole Method .....	23
5.3	Description of SMFMM .....	24
5.4	Numerical Results .....	31
<b>6</b>	<b>Conclusion</b> .....	<b>35</b>
	<b>Acknowledgment</b> .....	<b>35</b>
	<b>Appendix A.</b> .....	<b>35</b>
	<b>References</b> .....	<b>36</b>

## Chapter 2. ANALYSIS OF APERTURE ANTENNAS ABOVE LOSSY HALF-SPACE

*B. A. Arand, M. Hakkak, K. Forooraghi, and J. R. Mohassel*

<b>1</b>	<b>Introduction</b> .....	<b>40</b>
<b>2</b>	<b>Aperture above Ground Surface</b> .....	<b>41</b>
<b>3</b>	<b>Current Element</b> .....	<b>42</b>
	3.1 Complex Image Formulation .....	43
	3.2 Complex Coefficients .....	44
	3.3 Selection of $T_0$ and $N$ .....	45
<b>4</b>	<b>The Equivalent Images for Current Sources (VED, VMD, HED, and HMD)</b> .....	<b>46</b>
	4.1 Vertical Electric Dipole (VED) .....	46
	4.2 Horizontal Electric Dipole (HED) .....	46
	4.3 Vertical Magnetic Dipole (VMD) .....	47
	4.4 Horizontal Magnetic Dipole (HMD) .....	47
<b>5</b>	<b>Current Distribution on the Aperture Antenna</b> .....	<b>48</b>
<b>6</b>	<b>Radiation Fields</b> .....	<b>49</b>
	6.1 Numerical Results .....	50
<b>7</b>	<b>Conclusion</b> .....	<b>53</b>
	<b>Acknowledgment</b> .....	<b>54</b>
	<b>References</b> .....	<b>54</b>

## Chapter 3. TIME-DOMAIN AND FREQUENCY-DOMAIN METHODS COMBINED IN THE STUDY OF OPEN RESONANCE STRUCTURES OF COMPLEX GEOMETRY

*Y. K. Sirenko, L. G. Velychko, and F. Erden*

<b>1</b>	<b>Introduction</b> .....	<b>58</b>
<b>2</b>	<b>OR of Classical Geometry</b> .....	<b>58</b>
<b>3</b>	<b>Dispersive Resonators with Gratings</b> .....	<b>67</b>
<b>4</b>	<b>Conclusions</b> .....	<b>78</b>
	<b>References</b> .....	<b>78</b>

## Chapter 4. A TIME DOMAIN INCREMENTAL THEORY OF DIFFRACTION: SCATTERING OF ELECTROMAGNETIC PULSED PLANE WAVES

*A. M. Attiya, E. El-Diwany, A. M. Shaarawi, and I. M. Besieris*

<b>1</b>	<b>Introduction</b> .....	<b>82</b>
<b>2</b>	<b>Frequency Domain Incremental Theory of Diffraction</b> .....	<b>85</b>
<b>3</b>	<b>Time-Domain Formulation of the Scattering of an Electromagnetic Pulsed Plane Wave from a Perfectly Conducting Circular Disk</b> .....	<b>86</b>
3.1	The Physical Optics Term .....	86
3.2	The Diffracted and the Physical Optics Shadow-Boundary-Line Terms .....	87
3.3	Time Domain Formulation of the Incremental Theory of Diffraction .....	90
<b>4</b>	<b>TD-ITD Results for the Diffraction of a Pulsed Plane Wave Normally Incident on a Perfectly Conducting Circular Disk</b> .....	<b>93</b>
<b>5</b>	<b>Concluding Remarks</b> .....	<b>95</b>
	<b>Appendix A.</b> .....	<b>96</b>
	<b>Appendix B.</b> .....	<b>97</b>
	<b>References</b> .....	<b>99</b>

**Chapter 5. SCATTERING OF X-WAVES FROM A CIRCULAR DISK USING A TIME DOMAIN INCREMENTAL THEORY OF DIFFRACTION**

*A. M. Attiya, E. El-Diwany, A. M. Shaarawi, and I. M. Besieris*

<b>1</b>	<b>Introduction</b> .....	<b>104</b>
<b>2</b>	<b>The Incident Transverse Electric (TE) X-Wave</b> .....	<b>106</b>
<b>3</b>	<b>Scattering of TE X-Waves from a Perfectly Conducting Circular Disk Using a TD-ITD Approach</b> .....	<b>107</b>
3.1	The Physical Optics Field .....	108
3.2	The Shadow-Boundary-Line and the Edge-Diffracted Fields .....	111
<b>4</b>	<b>TD-ITD Results for the Diffraction of a TE X-Wave Normally Incident on a Perfectly Conducting Circular Disk</b> .....	<b>115</b>
<b>5</b>	<b>Four-Sensor Correlated Detection of X-Waves Scattered from a Circular Disk</b> .....	<b>119</b>
<b>6</b>	<b>Resolving Power of the Four-Sensor Scheme for an Incident TE X-Wave</b> .....	<b>122</b>
<b>7</b>	<b>Concluding Remarks</b> .....	<b>126</b>
	<b>References</b> .....	<b>127</b>

**Chapter 6. NUMERICAL ANALYSIS OF TWO  
DIMENSIONAL TAPERED DIELECTRIC  
WAVEGUIDE**

*Asok De and G. V. Attimarad*

<b>1</b>	<b>Introduction</b> .....	<b>132</b>
<b>2</b>	<b>Generalized Scattering Matrix Technique</b> .....	<b>132</b>
<b>3</b>	<b>Analysis of Discontinuity</b> .....	<b>134</b>
	3.1 Scattering Matrix Formulation (TE Case) .....	134
<b>4</b>	<b>Numerical Results</b> .....	<b>139</b>
<b>5</b>	<b>Conclusion</b> .....	<b>141</b>
	<b>References</b> .....	<b>141</b>

**Chapter 7. PLANE WAVE DIFFRACTION BY  
DIELECTRIC LOADED THICK-WALLED  
PARALLEL-PLATE IMPEDANCE WAVEGUIDE**

*Y. Hameş and İ. H. Tayyar*

<b>1</b>	<b>Introduction</b> .....	<b>144</b>
<b>2</b>	<b>Analysis</b> .....	<b>145</b>
	2.1 Even Excitation .....	145
	2.2 Odd Excitation .....	157
<b>3</b>	<b>Analysis of the Diffracted Field</b> .....	<b>160</b>
<b>4</b>	<b>Concluding Remarks</b> .....	<b>166</b>
	<b>References</b> .....	<b>167</b>

**Chapter 8. EFFECTIVE PERMITTIVITY OF A  
STATISTICALLY INHOMOGENEOUS MEDIUM  
WITH STRONG PERMITTIVITY FLUCTUATIONS**

*N. P. Zhuck, K. Schünemann, and S. N. Shulga*

<b>1</b>	<b>Introduction</b> .....	<b>170</b>
<b>2</b>	<b>Statement of the Problem</b> .....	<b>172</b>
<b>3</b>	<b>Renormalized Equation of Scattering</b> .....	<b>174</b>
<b>4</b>	<b>Calculations</b> .....	<b>176</b>
<b>5</b>	<b>Illustrative Examples</b> .....	<b>180</b>
<b>6</b>	<b>Conclusions</b> .....	<b>186</b>
	<b>Acknowledgment</b> .....	<b>187</b>
	<b>Appendix A.</b> .....	<b>187</b>
	<b>Appendix B.</b> .....	<b>190</b>



Appendix C. ....	192
References .....	194

**Chapter 9. THE PROPER CURRENT SPECTRA OF AN OPEN INTEGRATED MICROSTRIP WAVEGUIDE**

*J.-S. Lee and D. P. Nyquist*

1 Introduction and Geometrical Configuration .....	198
2 Continuous Spectrum Current .....	200
3 The Characteristic Impedance .....	206
4 Numerical Results .....	207
5 Conclusion .....	212
References .....	213

**Chapter 10. COOPERATIVE TARGETS DETECTION AND TRACKING RANGE MAXIMIZATION USING MULTIMODE LADAR/RADAR AND TRANSPONDERS**

*M. Haridim, H. Matzner, Y. Ben-Ezra, and J. Gavan*

1 Introduction .....	218
2 Overview of the LADAR Sub-System Mode .....	218
3 RADAR Sub-Systems Modes .....	221
4 Active Transponder Operation Range .....	223
5 Detection and Tracking Procedure .....	225
6 Discussion .....	227
7 Conclusions .....	227
References .....	228

**Chapter 11. WIDE-ANGLE RADAR TARGET RECOGNITION WITH SUBCLASS CONCEPT**

*D.-K. Seo, K. T. Kim, I.-S. Choi, and H.-T. Kim*

1 Introduction .....	232
2 The Feature Vector Extraction Technique Using Central Moments and Principal Component Analysis	234
2.1 The Calculation of Central Moments .....	234
2.2 Feature Space Mapping .....	235
2.3 The Feature Extraction with PCA .....	236
3 The Classification with Subclass Concept .....	237

3.1	Subclass Concept .....	237
3.2	The Classifier with a Subclass Concept .....	241
<b>4</b>	<b>The Selection of the Number of Subclasses .....</b>	<b>242</b>
<b>5</b>	<b>Experimental Results .....</b>	<b>243</b>
<b>6</b>	<b>Conclusion .....</b>	<b>247</b>
	<b>Acknowledgment .....</b>	<b>247</b>
	<b>References .....</b>	<b>248</b>

**Chapter 12. THE SURFACE IMPEDANCE OF A  
HOMOGENEOUS TM-TYPE PLANE WAVE AT  
SKEW INCIDENCE UPON AN INCLINED  
ANISOTROPIC HALF-SPACE**

*G. A. Wilson and D. V. Thiel*

<b>1</b>	<b>Introduction .....</b>	<b>250</b>
<b>2</b>	<b>General Solutions for an Anisotropic Medium .....</b>	<b>251</b>
<b>3</b>	<b>General Solutions for Propagation in Air .....</b>	<b>256</b>
<b>4</b>	<b>TM-Type Wave Incidence .....</b>	<b>257</b>
<b>5</b>	<b>Discussion .....</b>	<b>259</b>
<b>6</b>	<b>Conclusion .....</b>	<b>264</b>
	<b>Acknowledgment .....</b>	<b>265</b>
	<b>References .....</b>	<b>265</b>

**Chapter 13. IMPEDANCE BOUNDARY CONDITIONS  
ON A CHIRAL FILM**

*P. Hillion*

<b>1</b>	<b>Introduction .....</b>	<b>268</b>
<b>2</b>	<b>Electromagnetic Wave Propagation Inside Chiral Media .....</b>	<b>270</b>
<b>3</b>	<b>Horizontally and Vertically Polarized Fields .....</b>	<b>272</b>
3.1	Horizontal Polarization .....	272
3.2	Vertical Polarization .....	275
3.3	Electromagnetic Wave Scattering on 1D-Chiral Films ..	276
<b>4</b>	<b>Arbitrary Polarized Incident Field .....</b>	<b>279</b>
4.1	Impedance Boundary Condition on $e'_y$ .....	280
4.2	Impedance Boundary Conditions on $h'_y$ .....	281
<b>5</b>	<b>TE Wave Scattering .....</b>	<b>281</b>
<b>6</b>	<b>Discussion .....</b>	<b>285</b>

Appendix A. ....	285
References .....	286

**Chapter 14. ELECTROMAGNETIC ANALYSIS OF A  
NON-INVASIVE 3D PASSIVE MICROWAVE  
IMAGING SYSTEM**

*I. S. Karanasiou, N. K. Uzunoglu, and A. Garetsos*

<b>1 Introduction</b> .....	<b>288</b>
<b>2 Mathematical Formulation — Dyadic Green’s Func- tion of the Layered Sphere</b> .....	<b>289</b>
<b>3 Numerical Results and Validation of the Method</b> ....	<b>294</b>
<b>4 Experimental Procedure and Results</b> .....	<b>300</b>
4.1 Experimental Set-up .....	300
4.2 Temperature Resolution .....	301
4.3 Spatial Resolution .....	302
<b>5 Discussion and Conclusions</b> .....	<b>305</b>
Appendix A. ....	306
References .....	307

**Chapter 15. RADIATION CHARACTERISTICS OF AN  
AXIALLY ASYMMETRICAL SLOT ANTENNA ON A  
PERFECTLY-CONDUCTING PROLATE SPHEROID  
COATED WITH HOMOGENEOUS MATERIALS**

*M. Zhang and A. A. Sebak*

<b>1 Introduction</b> .....	<b>310</b>
<b>2 Formulation of the Problem</b> .....	<b>311</b>
2.1 Geometry .....	311
2.2 Spheroidal Wave Functions .....	312
2.3 Excitation Field .....	313
2.4 Radiated and Transmitted Fields .....	314
2.5 Formation of Boundary Conditions .....	316
2.6 Radiation Patterns and Power .....	320
<b>3 Numerical Computation and Results</b> .....	<b>320</b>
3.1 Radiation Patterns .....	322
3.2 Radiated Power .....	324
<b>4 Conclusion</b> .....	<b>332</b>
References .....	332