

---

**ELECTROMAGNETIC  
WAVES** **PIER 34**

---

**Progress**

**In**

**Electromagnetics**

**Research**

© 2001 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 09668143-2-0

Manufactured in the United States of America.

---

**ELECTROMAGNETIC  
WAVES** **PIER 34**

---

**Progress**

**In**

**Electromagnetics  
Research**

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

EMW Publishing  
Cambridge, Massachusetts, USA



# CONTENTS

## Chapter 1. SCATTERING OF AN $E_{//}$ -POLARIZED PLANE WAVE BY ONE-DIMENSIONAL ROUGH SURFACES: NUMERICAL APPLICABILITY DOMAIN OF A RAYLEIGH METHOD IN THE FAR-FIELD ZONE

*C. Baudier and R. Dusséaux*

<b>1</b>	<b>Introduction</b> .....	<b>2</b>
<b>2</b>	<b>Formulation of the Problem and Rayleigh Integral</b> ...	<b>3</b>
<b>3</b>	<b>Method of Resolution: Method of Moments</b> .....	<b>6</b>
<b>4</b>	<b>Numerical Application</b> .....	<b>8</b>
4.1	Numerical Parameters $Mc$ and $M$ .....	8
4.2	Convergence Test as a Function of $M$ .....	9
4.3	Convergence Test as a Function of $Mc$ .....	12
4.4	Conclusion of the Two Convergence Tests .....	16
4.5	Comparison with the Theoretical Limits .....	18
4.6	Advantages of the Variable Supports of the Basis Functions	20
<b>5</b>	<b>Conclusion</b> .....	<b>22</b>
<b>Appendix A.</b> .....		<b>23</b>
A.1	Expressions of Scattered Fields $\vec{E}_d$ and $\vec{H}_d$ in the Far-Field Zone .....	23
A.2	Expression of the Power Balance Criterion .....	24
<b>References</b> .....		<b>25</b>

## Chapter 2. PLANE WAVE DIFFRACTION BY TANDEM IMPEDANCE SLITS

*B. Polat, A. Buyukaksoy, and G. Cinar*

<b>1</b>	<b>Introduction</b> .....	<b>30</b>
<b>2</b>	<b>Analysis</b> .....	<b>31</b>
<b>3</b>	<b>Even Excitation</b> .....	<b>31</b>
<b>4</b>	<b>Odd Excitation</b> .....	<b>49</b>
<b>5</b>	<b>Analysis of the Diffracted Field</b> .....	<b>55</b>
<b>6</b>	<b>Numerical Results</b> .....	<b>56</b>
<b>7</b>	<b>Concluding Remarks</b> .....	<b>59</b>
<b>References</b> .....		<b>60</b>

**Chapter 3. SCATTERING OF A PLANE WAVE BY A  
1-DIMENSIONAL ROUGH SURFACE STUDY IN A  
NONORTHOGONAL COORDINATE SYSTEM**

*R. Dusséaux and R. de Oliveira*

<b>1</b>	<b>Introduction</b> .....	<b>64</b>
<b>2</b>	<b>Presentation of the Problem</b> .....	<b>65</b>
<b>3</b>	<b>Rayleigh Integral and Far Field</b> .....	<b>66</b>
<b>4</b>	<b>Theory — Method of Moments in the Spectral Domain</b>	<b>67</b>
4.1	Components of Fields and Differential System .....	67
4.2	The Scattering Matrix .....	69
4.3	Properties of the Scattering Matrix and of the Eigenvalue Spectrum .....	70
4.4	Scattering Field and Angular Power Density .....	72
<b>5</b>	<b>Results</b> .....	<b>75</b>
5.1	Convergence Tests .....	75
5.2	Comparison with the Exact Results for Schwartz Profiles	79
<b>6</b>	<b>Conclusion</b> .....	<b>82</b>
<b>Appendix A. Coefficients of the Scattering Matrix</b> .....		<b>83</b>
<b>References</b> .....		<b>86</b>

**Chapter 4. RIGOROUS COUPLED WAVE ANALYSIS OF  
RADIALLY AND  
AZIMUTHALLY-INHOMOGENEOUS, ELLIPTICAL,  
CYLINDRICAL SYSTEMS**

*J. M. Jarem*

<b>1</b>	<b>Introduction</b> .....	<b>90</b>
<b>2</b>	<b>Rigorous Coupled Wave Analysis Formulation</b> .....	<b>93</b>
<b>3</b>	<b>Mathieu Function Validation Solution</b> .....	<b>101</b>
<b>4</b>	<b>Numerical Results</b> .....	<b>102</b>
<b>5</b>	<b>Summary and Conclusions</b> .....	<b>113</b>
<b>References</b> .....		<b>114</b>

**Chapter 5. METHOD OF MOMENTS ANALYSIS OF ELECTRICALLY LARGE THIN SQUARE AND RECTANGULAR LOOP ANTENNAS: NEAR- AND FAR-ZONE FIELDS**

*C.-P. Lim, L.-W. Li, and M.-S. Leong*

<b>1</b>	<b>Introduction</b>	<b>118</b>
<b>2</b>	<b>General Formulation of Current Distributions</b>	<b>119</b>
<b>3</b>	<b>General Formulation of EM Radiated Fields</b>	<b>121</b>
<b>4</b>	<b>Numerical Results</b>	<b>128</b>
<b>5</b>	<b>Conclusions</b>	<b>130</b>
<b>Appendix A. Analytical Expressions of Current Distributions</b>		
	A.1 Case I: $\frac{\lambda}{8} \times \frac{\lambda}{4}$ rectangular loop	130
	A.2 Case II: $\frac{\lambda}{4} \times \frac{\lambda}{2}$ rectangular loop	131
<b>Appendix B. Explicit Expressions of Coefficients of the Series</b>		
	<b>Acknowledgment</b>	<b>139</b>
	<b>References</b>	<b>139</b>

**Chapter 6. FAST AND EFFICIENT ANALYSIS OF INSET DIELECTRIC GUIDE USING FOURIER TRANSFORM TECHNIQUE WITH A MODIFIED PERFECTLY MATCHED BOUNDARY**

*H. Jia, K. Yasumoto, and K. Yoshitomi*

<b>1</b>	<b>Introduction</b>	<b>144</b>
<b>2</b>	<b>Modified Perfectly Matched Boundary Condition</b>	<b>145</b>
<b>3</b>	<b>Formulation</b>	<b>146</b>
<b>4</b>	<b>Numerical Results</b>	<b>153</b>
<b>5</b>	<b>Conclusion</b>	<b>158</b>
<b>Appendix A. Proof of the Modified PMB Condition</b>		
	<b>References</b>	<b>162</b>

**Chapter 7. ANALYSIS OF AN H-SHAPED PATCH ANTENNA BY USING THE FDTD METHOD**

*S.-C. Gao, L.-W. Li, M.-S. Leong, and T.-S. Yeo*

<b>1</b>	<b>Introduction</b>	<b>166</b>
----------	---------------------	------------

<b>2</b>	<b>Analysis of H-Shaped Patch Antenna Using FDTD Method</b> .....	<b>167</b>
2.1	Outline of the FDTD Method .....	167
2.2	Comparisons between Calculated and Measured Results	168
<b>3</b>	<b>A Parametric Study of the H-Shaped Patch Antenna</b>	<b>169</b>
3.1	Resonant Frequency .....	169
3.2	Electric Field and Current Distribution .....	173
3.3	Radiation Patterns .....	185
<b>4</b>	<b>Conclusions</b> .....	<b>185</b>
	<b>References</b> .....	<b>186</b>

**Chapter 8. CONTRAST SOURCE INVERSION  
METHOD: STATE OF ART**

*P. M. van den Berg and A. Abubakar*

<b>1</b>	<b>Introduction</b> .....	<b>190</b>
<b>2</b>	<b>Notation and Problem Statement</b> .....	<b>192</b>
<b>3</b>	<b>Contrast Source Inversion Method</b> .....	<b>194</b>
3.1	The Local Minima .....	194
3.2	Updating of the Contrast Sources .....	196
3.3	Updating of the Contrast .....	198
3.4	Total Variation as a Multiplicative Constraint .....	199
3.5	Weighted $L^2$ Total-Variation Factor .....	202
<b>4</b>	<b>Root Test</b> .....	<b>203</b>
<b>5</b>	<b>Numerical Examples</b> .....	<b>203</b>
5.1	Concentric Squares .....	204
5.2	'Austria' Profile .....	209
5.3	Extended 'Austria' Profile .....	213
5.4	'Finger' Profile .....	214
<b>6</b>	<b>Conclusions</b> .....	<b>215</b>
	<b>Acknowledgment</b> .....	<b>215</b>
	<b>References</b> .....	<b>216</b>

**Chapter 9. EM FIELDS INSIDE A PROLATE SPHEROID  
DUE TO A THIN CIRCULAR LOOP: A  
HIGHER-ORDER PERTURBATION APPROACH**

*L. W. Li, M. S. Yeo, and M. S. Leong*

<b>1</b>	<b>Introduction</b> .....	<b>220</b>
----------	---------------------------	------------

<b>2</b>	<b>Formulation of the Problem</b>	<b>221</b>
2.1	Current Source	221
2.2	Spheroid	222
2.3	Electric Field	223
2.4	Magnetic Field	225
2.5	Boundary Conditions	226
2.6	Current Distribution	227
<b>3</b>	<b>Determination of Expansion Coefficients</b>	<b>228</b>
3.1	Perturbation Technique	228
3.2	Zeroth Order Coefficients	230
3.3	First Order Coefficients	231
3.4	Second Order Coefficients	232
3.5	Third Order Coefficients	234
<b>4</b>	<b>Numerical Computations</b>	<b>236</b>
4.1	Transmission and Scattering Coefficients with Varying $\nu$	236
4.2	Transmission and Scattering Coefficients with Varying Frequencies	238
4.3	Transmission and Scattering Coefficients in Free Space	239
4.4	Electric Fields along $\theta = 0$ and $\pi$ Directions	239
4.5	Near-Zone Field Pattern in Free Space	239
4.6	Convergence of Electric Fields	241
4.7	Higher Order Approximations for Electric Fields	242
4.8	SAR Varying with Antenna Positions	243
4.9	Varying Antenna's Size	245
<b>5</b>	<b>Conclusions</b>	<b>246</b>
	<b>Appendix A. Intermediate Integrals</b>	<b>246</b>
	<b>References</b>	<b>249</b>

**Chapter 10. ANALYSIS OF RADIATION  
CHARACTERISTICS OF AN OPEN CIRCULAR  
WAVEGUIDE ASYMMETRICALLY COVERED BY A  
DIELECTRIC LAYERED HEMI-SPHERICAL  
RADOME**

*M. S. Leong, L. W. Li, X. Ma, P. S. Kooi, and T. S. Yeo*

<b>1</b>	<b>Introduction</b>	<b>254</b>
<b>2</b>	<b>Statement of the Problem</b>	<b>255</b>
<b>3</b>	<b>Formulation of EM Fields</b>	<b>255</b>

<b>4 Numerical Results</b> .....	<b>263</b>
4.1 Lateral Displacement of Source Location .....	263
4.2 Cross-Polarization: Horizontally Displaced Source .....	265
<b>5 Conclusion</b> .....	<b>267</b>
<b>Acknowledgment</b> .....	<b>268</b>
<b>References</b> .....	<b>268</b>

**Chapter 11. IMAGE RECONSTRUCTION OF BURIED DIELECTRIC CYLINDERS BY TE WAVE ILLUMINATION**

*C.-C. Chiu and C. J. Lin*

<b>1 Introduction</b> .....	<b>271</b>
<b>2 Theoretical Formulation</b> .....	<b>272</b>
<b>3 Numerical Results</b> .....	<b>276</b>
<b>4 Conclusion</b> .....	<b>281</b>
<b>Appendix A.</b> .....	<b>281</b>
<b>References</b> .....	<b>283</b>

**Chapter 12. A TRIAL ON HIERARCHICAL EXTRACTION OF HIGHER ORDER CORRELATION BETWEEN ELECTROMAGNETIC AND SOUND WAVES AROUND A VDT ENVIRONMENT — PRACTICAL USE OF BACKGROUND NOISE AND PROBABILITY PREDICTION**

*M. Ohta and H. Ogawa*

<b>1 Introduction</b> .....	<b>286</b>
<b>2 General Theory</b> .....	<b>288</b>
2.1 Regression Relationships between Two-Wave Environmental Factors .....	288
2.2 Prediction of Specific Probability Distribution Based on Regression Information .....	289
2.3 Extraction of Mutual Correlation Information Based on a Positive Utilization of the Statistics of a Background EM Noise .....	290
<b>3 Concretization of Theory</b> .....	<b>291</b>
<b>4 Experiment</b> .....	<b>293</b>
<b>5 Conclusions</b> .....	<b>295</b>
<b>Acknowledgment</b> .....	<b>296</b>

References ..... 296

**Chapter 13. HYPOTHESIS OF NATURAL RADAR TRACKING AND COMMUNICATION DIRECTION FINDING SYSTEMS AFFECTING HORNETS FLIGHT**

*J. Gavan and J. S. Ishay*

**1 Introduction ..... 300**  
**2 Hornets Communication Direction Finder Investigation General Concepts ..... 305**  
**3 Hornets Direction Finder Technique Applications and Simulations ..... 309**  
**4 Conclusions ..... 310**  
References ..... 311

**Chapter 14. APPLICABILITY OF COMBINED MICROWAVE AND OPTICAL DATA FOR SURFACE WATER QUALITY RETRIEVALS**

*Y. Zhang, J. Pulliainen, S. Koponen, and M. Hallikainen*

**1 Introduction ..... 314**  
**2 Remote Sensing Theory ..... 315**  
**3 Applicability of Combined SAR and TM ..... 318**  
**4 Retrieval Method ..... 320**  
    4.1 Multivariate Approach ..... 320  
    4.2 Validation against In Situ Data ..... 321  
**5 Results and Discussion ..... 321**  
    5.1 Turbidity Retrieval ..... 323  
    5.2 Secchi Disk Depth Retrieval ..... 324  
    5.3 Suspended Sediment Concentration Retrieval ..... 327  
**6 Conclusion ..... 329**  
Acknowledgment ..... 330  
References ..... 330