

Tropical Forest Monitoring using Synthetic Aperture Radar
- Theories and Applications -

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合成開口レーダによる熱帯森林のモニタリング
- 理論と応用

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Declaration

This document certifies that the research and its results in this dissertation have never been submitted elsewhere for an award of any degree or diploma.

Chiba, January 2002

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To my lovely wife Innes Indreswari, son Johannes Pandhito Panji Herdento,
parents Michael Suman Juswaljati and Florentina Srindadi
for their love, support and encouragement.

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Abstract

Recently, remote sensing technology, especially Synthetic Aperture Radar (SAR) sensor, has been an efficient and helpful tool to monitor tropical forest area where always in cloudy condition. However, SAR data are not easily interpreted due to the complex relations of the radar scattering mechanism between microwaves and tropical forest parameter (i.e. diameter of tree trunk, thickness of burnt coal seam, surface roughness and soil moisture). Hence, in this research, numerical methods were developed to analyse the interaction of L Band microwaves with a tree trunk of tropical forest and burnt coal seam of forest fire scars.

In analysis of scattered wave from a tropical tree trunk, the proposed method approximates a trunk as an infinite length of two and three layers of cylindrical dielectric media. These layers are skin and heartwood; and skin, xylem and heartwood. The horizontally and vertically polarised scattered fields are derived in order to calculate the relationship between trunk diameter and backscattering coefficient. The analysis result is confirmed by simulating the scattered wave from a tree trunk using Finite Difference Time Domain (FDTD) method. The model uses the equations of scattered electromagnetic fields that are derived from Maxwell's equations. Both analysis and simulation results are similar. Then the relationship is used to estimate tree trunk diameters of pine forest around Saguling lake and tropical forest at Mount Gede Pangrango National Park, west Java, Indonesia from Japanese Earth Resources Satellite (JERS-1) SAR data.

In analysis of scattered wave from burnt coal seam, two types of methods (simple and complicated) are conducted to analyse scattered waves from burnt coal seam in order to estimate thickness of forest fire scars. The model is composed of three media namely; free space (air), burnt coal seam and peat (a perfectly conductor). For computation purposes, the equivalent circuit of this model is conducted using classical transmission line circuit method for a simple analysis, and the advanced stationary-phase approximation is used to analyse scattered wave from complicated rough burnt coal seam. The relationship between backscattering coefficient and thickness of burnt coal seam is obtained. The analysis result is confirmed by simulation using FDTD method. The simulation is done using a two-dimensional finite-difference model for scattered waves from the burnt coal seam. Both analysis and the simulation results are similar. Subsequently, the developed model is applied to estimate the thickness of burnt coal seam in central Borneo fire events in 1997 using JERS-1 SAR data. The estimated result agrees with ground measurement that was collected in period of 1995 to 1997.

論文概要

近年、リモートセンシング技術の進歩によって、特に合成開口レーダ (SAR) による熱帯森林を対象とする地球表面のモニタリングがローカルからグローバルなスケールまで容易に行われるようになった。しかし、インドネシアのような熱帯地域では雲、霧、煙が多いため、この地域を観測するためには、これらの影響を最も受けにくい SAR の利用が有効である。しかし、SAR 画像からマイクロ波と熱帯地域特性 (樹幹の直径、森林火災の痕跡の深さ、土壌水分、地表面の粗度など) の相互作用を解明するために複雑な解析が必要となる。そのため、本研究では L バンドのマイクロ波と熱帯森林における樹幹と森林火災痕跡の相互作用の数値解析方法を提案した。さらに、その応用も紹介する。

熱帯森林の樹幹による散乱電磁波の解析では、樹幹は無限長の円柱媒質二層と三層のモデルを仮定した。これらのモデルでは媒質層はそれぞれ皮と心材、皮と木部と心材である。レーダの後方散乱係数と樹幹直径の関係を計算するために水平偏波と直交偏波の散乱電磁波を導出した。この解析結果を検証するために、時間領域差分法を利用して、樹幹による電磁波散乱のシミュレーションを行った。その結果、解析結果とシミュレーション結果が一致することが分かった。そこで、本研究の結果を日本の地球資源観測衛星 (JERS-1) の SAR センサーから取得された画像よりインドネシアのサグリング湖の周辺とゲデパンラングオ国立公園における松 (*Pinus Merkusii*) とラサマラ (*Altingia exelsa*) の直径の推定に応用した。推定結果は現地調査データとほぼ一致することが分かった。

本研究では、森林火災痕跡の深さを推定するために燃焼した石炭層による散乱電磁波の解析方法に対してシンプルな方法と複雑な方法の 2 おりを提案した。解析モデルは 3 つの媒質である自由空間、燃焼石炭、泥炭地から構成される。シンプルな解析方法を導出するために古典的な伝達線路法を利用して、各媒質の等価回路を求めた。一方、複雑な解析方法では停留近似法で粗な地表面からの散乱電磁波を解析した。その結果、レーダの後方散乱係数と森林火災痕跡の深さの関係が得られた。シンプルな方法から得られた解析結果を検証するために、本研究では時間領域差分法を用いて燃焼石炭層による散乱電磁波の 2 次元的なシミュレーションを行った。その結果、解析結果とシミュレーション結果が一致することが分かった。しか

し、シンプルな方法と複雑な解析方法による両結果は誤差が生じた。これは地表面の組度による影響から生じたものと推測される。本研究の結果を、JERS 1 SAR画像を用いて1997年に起こった東南アジア森林火災地域の中部ボルネオ島における森林火災痕跡の深さの推定に応用した。この結果、本研究による推定結果と現地調査データが一致した。

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Contents

Title (in English)	i
Title (in Japanese)	iii
Declaration	v
Dedication	vii
Abstract (in English)	ix
Abstract (in Japanese)	xi
Acknowledgements	xiii
Contents	xv
List of Appendices	xix
List of Figures	xxi
List of Tables	xxviii

Chapter I. Introduction

1.1 Motivations and objectives	1
1.2 Deforestation and forest fire	2
1.3 Japanese Earth Resources Satellite (JERS-1) Synthetic Aperture Radar	6
1.4 Physical characteristic measurements	8
References	13

Chapter II. Analysis of Scattered Waves from Two Layers of Tree Trunk

2.1 Introduction	17
2.2 Analysis	18
2.3 Simulation	22
2.4 Results and discussion	29
2.5 Application	33
2.5.1 Study area	33
2.5.2 Data processing	33
2.6 Conclusions	37
References	38

Chapter III. Analysis of Scattered Waves from Three Layers of Tree Trunk

3.1 Introduction	41
3.2 Analysis	42
3.3 Simulation	47
3.4 Results	49
3.5 Application	55
3.5.1 Study area	55
3.5.2 Data processing	60
3.6 Conclusions	63
References	65

Chapter IV. Analysis of Scattered Waves from Burnt Coal Seam

4.1 Introduction	67
4.2 Analysis	78
4.3 Simulation	82
4.4 Results	84
4.5 Application	89
4.5.1 Study area	89
4.5.2 Data processing	94
4.6 Conclusions	96
References	98

Chapter V. Analysis of Scattered Waves from Rough Burnt Coal Seam

5.1 Introduction	101
5.2 Analysis	102
5.2.1 Scattered fields on burnt coal seam surface (1) or interface 1	106
5.2.1.1 Scattering field on medium 1	106
5.2.1.2 Scattering field on medium 2	108
5.2.2 Scattering field on peat surface or interface 2	110
5.2.3 Scattering field on burnt coal seam surface (2) or interface 1	113
5.2.3.1 Scattering field on medium 2	113
5.2.3.2 Scattering field on medium 1	115
5.2.4 Scattering coefficient	117

5.3 Results and Discussion	124
5.4 Application	126
5.4.1 Study area	126
5.4.2 Data processing	126
5.5 Conclusions	128
References	129
Chapter VI. Summary and Recommendations	
6.1 Summary	131
6.2 Future work and Recommendations	132
Appendices	135
Publication list	183
Biography	187

List of Appendices

Appendix A	Analysis of Scattered Waves on Two Layers of Tree Trunk (TM mode)	135
Appendix B	Analysis of Scattered Waves on Three Layers of Tree Trunk (TM mode)	139
Appendix C	Finite Difference Time Domain Method (TE mode)	143
Appendix D	Ground Data Around Opening Peatland Area (One Million Hectares Peatland Project, central Borneo, Indonesia)	149
Appendix E	Wave Analysis in Cylindrical Coordinate System (TM mode)	157
Appendix F	Ground Data : Mount Gede Pangrango National Park	159
Appendix G	Derivation of the Scattered Fields in the Medium 1 at Air and Burnt Coal Seam Interface	165
Appendix H	Derivation of the Scattered Fields in the Medium 2 at Burnt Coal Seam and Peat Interface	169
Appendix I	Derivation of the Scattered Fields in the Medium 2 on Air and Burnt Coal Seam Interface	173
Appendix J	Derivation of the Scattered Fields in the Medium 1 on Air and Burnt Coal Seam Interface	177
Appendix K	Derivation of Horizontally and Vertically Polarized Surface-Current Density	181

List of Figures

Figure 1.1	Distribution of tropical forest at Indonesia archipelago	2
Figure 1.2	The spread of forest plantations across Indonesia and the species planted in each province	3
Figure 1.3	Borneo's forest cover and 1997-1998 fire hot spots	5
Figure 1.4	Instruments onboard on JERS-1 satellite (source: NASDA)	7
Figure 1.5	Synthetic Aperture Radar on JERS-1 satellite (source: NASDA)	7
Figure 1.6	Photograph of dielectric constant measurements	
	(a) Tree trunk	9
	(b) Burnt coal seam	9
Figure 1.7	Dielectric constant of burnt coal seam	10
Figure 1.8	(a) Dielectric constants measurement of tropical forest tree trunk (skin): r-real part and i-imaginary part	11
	(b) Dielectric constants measurement of tropical forest tree trunk (xylem): r-real part and i-imaginary part	12
Figure 2.1	Photograph and Geometry of the analysis.	
	(a) Photograph of a cross section of pine (<i>Pinus merkusii</i>) trunk.	19
	(b) Geometry of scattered waves from a pine trunk.	19
Figure 2.2	Simulation model.	25
Figure 2.3	Pulse of incident wave.	
	(a) Gaussian pulse.	27
	(b) Fast fourier transformed Gaussian pulse.	27
Figure 2.4	Geometry of incident wave	28

Figure 2.5	Scattered waves in simulation space from $t = 50\Delta t$ s to $300\Delta t$ s. A and B are scattered waves from skin and heartwood, C and D are scattered wave from trapped waves in skin layer, E is forwarded wave that occurred by clipping pulse that flows on the trunk surface and scattered to back of trunk, F and G are heartwood and skin, respectively. P is the observed point.	30
Figure 2.6	Scattered waves at observed point P: A and B, C and D are scattered pulse from skin and heartwood, and trapped wave in the skin layer, respectively.	31
Figure 2.7	Relationship between tree trunk diameter and backscattering coefficient	32
Figure 2.8	Map of the study area	34
Figure 2.9	Photograph of pine forest in the study area and the supervised classification results of JERS-1 SAR data (path 106, row 312, 13 May 1997).	35
Figure 3.1	Tree trunk media	42
Figure 3.2	Geometry of analysis	43
Figure 3.3	Geometry of simulation space. Remarks: P is observed point. A, B and C are heartwood, xylem, and skin, respectively. Simulation space is divided into $INX \times INY$ grids of meshes.	48
Figure 3.4	Distribution of scattered electric field intensity E_y^S with $t = 50\Delta t$ to $300\Delta t$ s.	51

Figure 3.5	Distribution of scattered electric field E_y^s in $t = 300\Delta t$ s, where A, B and C are scattered wave from skin, xylem and heartwood, respectively. P is observed point. E, F and G are skin, xylem and heartwood, respectively. D is forwarded wave that is occurred by clipping wave that flows on the trunk surface and scattered to the backward of tree trunk.	52
Figure 3.6	Scattered electric field intensities at observed point P. A, B and C are scattered pulse from skin, xylem and heartwood, respectively.	53
Figure 3.7	Analysis and simulation results for four species of Indonesian tropical forest, where the diameter of tree trunk is equal with $2c$, where c is radius of tree trunk.	54
Figure 3.8	JERS-1 VNIR data of the study area (Path 107 Row 312, 19970930): Gede Pangrango National Park, west Java, Indonesia. Remark: A and B show northern and southern part of the National Park, respectively.	56
Figure 3.9	JERS-1 SAR data of the study area (Path 107 Row 312, 19970810): Gede Pangrango National Park, west Java, Indonesia. Remark: A and B show northern and southern part of the National Park, respectively.	57
Figure 3.10	Altitude distribution of the study area : Mount Gede Pangrango National Park, west Java, Indonesia.	58
Figure 3.11	Location of the study area: Gede Pangrango National Park (part of area A in figure 3.8 and 3.9)	59
Figure 3.12	Classification result assigned the distribution of classes in the study area. Test area shows classes distribution in ecosystem zones and its terrain conditions. Ecosystem zones are settlement and paddy (sp), sub-montane (sm) and montane (mt).	61

Figure 4.1	Photographs of field survey expeditions in period 1995 to 1997. A and B show main vegetations that found around study sites; Tengkawang (<i>Dipterocarpaceae spp.</i>) and <i>purun</i> grass, respectively. C shows burnt forest that remained burnt tree trunk and burnt coal seam. D shows staffs measured thickness of coal seam.	68
Figure 4.2	(a) Digital map of the study area: One Million Hectares Peatland Project (PLG), central Borneo, Indonesia (DEPHUTBUN 1999). (b) Study area: master plan of ‘One Million Hectares Peatland Project (PLG)’ at central Borneo, Indonesia. This figure shows thickness of coal seam that collected in field survey expeditions in period 1995 to 1997. Dotted lines show the area covered by JERS-1 SAR and SPOT HRV data. (c) Distribution of the thickness of coal seam: One Million Hectares Peatland Project, District B (PLG-B) at central Borneo, Indonesia (d) Distribution of the thickness of coal seam: One Million Hectares Peatland Project, District D (PLG-D) at central Borneo, Indonesia	69 70 71 72
Figure 4.3	SPOT HRV data of fire events in the study area (a) 6 June 1997 (prior to the fire). (b) 29 July 1997 (during fire). (c) 7 August 1997 (during fire). (d) 8 September 1997 (after fire).	74 75 76 77
Figure 4.4	Geometry of analysis (a) Analysis model. Remarks: : burnt coal seam-obstacles scattering; : obstacles – burnt coal seam scattering (b) equivalent circuit	79 79

Figure 4.5	Geometry of wave propagation in two media.	80
Figure 4.6	Measurement of burnt coal seam sample using dielectric constant kit HP85070B (see sub-figure)	80
Figure 4.7	Simulation model.	83
Figure 4.8	Scattered waves in simulation space.	85
Figure 4.9	Intensity of scattered wave in observed point Q.	
	(a) Electric field E_y^S	87
	(b) Magnetic field H_z^S	87
Figure 4.10	Relationship between burnt coal seam thickness and backscattering coefficient in two dimensional analysis and simulation.	88
Figure 4.11	(a) Raw data of JERS-1 SAR: 15 May 1996	90
	(b) Raw data of JERS-1 SAR: 3 February 1997	91
	(c) Raw data of JERS-1 SAR: 29 July 1997: dotted line is the study area in this study	92
Figure 4.12	Composite of JERS-1 SAR data: red – 29 July 1997, green – 3 February 1997, blue – 15 May 1996	93
Figure 4.13	A SPOT-HRV data and supervised classification results of a JERS-1 SAR data (path 95, row 305, 27 July 1997).	95
Figure 5.1	Geometry of the scattered waves analysis.	103
Figure 5.2	Relationship between the backscattering coefficient and the thickness of burnt coal seam.	125
Figure A.1	Geometry of analysis of scattered TM mode wave (two layers)	135
Figure B.1	Geometry of analysis of scattered TM mode wave (three layers)	139
Figure C.1	Portion of the finite-difference grid.	145
Figure D.1	Opening of peatland area at central Borneo, August 1996 (a).	149

Figure D.2	Opening of peatland area at central Borneo, August 1996 (b).	149
Figure D.3	Vegetations around peat swamp at Mentangai river near Bunter lake 'One million hectares peatland project (PLG)', August 1996.	150
Figure D.4	Vegetation at peatland (\pm 8m) around Kurun river (Black water river), PLG area, August 1996.	150
Figure D.5	Converting peatland area to be agricultural area at Dadahup, central Borneo, August 1996.	151
Figure D.6	Canals at Tabukan, central Borneo, August 1996.	151
Figure D.7	Staffs are boring peatland to explore the depth and type of peatland at central Borneo, August 1996.	152
Figure D.8	Converted peatland area at Siantan, west Borneo, 1995.	152
Figure D.9	Peatland identification with \pm 8m pipe at backswamp around Kurun river (black water river), central Borneo, August 1996.	153
Figure D.10	Burnt tengkawang and pule grass around Bunter lake, reaches of Mentangai river, central Borneo, August 1996.	153
Figure D.11	Purun grass as main vegetation at backswamp (Kurun river) to indicate that this area is ferrit land, August 1996.	154
Figure D.12	Burnt peatland at Berengbengkel, Kecamatan Pakandut, Kodya Palangkaraya, central Borneo, 1995.	154
Figure D.13	Paddy field at Sakalagun, central Borneo, 1995.	155
Figure F.1	Map of field survey that was held in July 2000.	159
Figure F.2	Mount Gede (right) and Pangrango (left), west Java, Indonesia (figure F.1)	160

Figure F.3	Hill of Mount Gede (900m asl), Rasamala forest, rock, and tea plantation around Cipelang river that flows from Mount Gede to Selabintana, Sukabumi (figure F.1).	160
Figure F.4	Tea plantation around Mount Gede at Pasiripis district, Pondok Halimun, Cipelang Selabintana Sukabumi (figure F.1).	161
Figure F.5	Hill of Mount Gede with variation of grass, fern, and rasamala. Pondok Halimun district in Gede Pangrango National Park. Land surface around this area is wavy (figure F.1)	161
Figure F.6	Tea and tobacco plantation at Wanasari district, Sukabumi, with background Mount Gede Pangrango (figure F.1).	162
Figure F.7	Rasamala forest and tea plantation near Cipelang river (850m asl)(figure F.1)	162
Figure F.8	Variation of Montane forest, fern, moss and bush (950m asl)(figure F.1)	163
Figure F.9	Small tree trunk of rasamala that nominates hill of Mount Gede Pangrango (1030m asl) in Cicurug National Park (figure F.1).	163
Figure F.10	Rasamala (<i>Altingia exelsa</i>) in Mount Gede Pangrango with diameter 50 – 200cm and height about 7 – 20m. It grows at attitude 700 – 1750m asl (figure F.1).	164

List of Tables

Table 1.1	Specification of JERS-1 Synthetic Aperture Radar (SAR)	8
Table 1.2	Specification of the dielectric probe kit HP85070B	9
Table 1.3	List of tropical forest species at Indonesia	10
Table 2.1	Classification and estimation results	36
Table 3.1	Dielectric constants of Indonesian tropical forest trees at the frequency of JERS-1 SAR ($f = 1.275$ GHz)	47
Table 3.2	Relationship between backscattering coefficients and tree trunk diameters of rasamala forests in the study area	62
Table 4.1	Thickness of burnt coal seam in the study area	96
Table 5.1	Thickness of burnt coal seam in the study area	127