View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by NASA Technical Reports Server

N O T I C E

THIS DOCUMENT HAS BEEN REPRODUCED FROM MICROFICHE. ALTHOUGH IT IS RECOGNIZED THAT CERTAIN PORTIONS ARE ILLEGIBLE, IT IS BEING RELEASED IN THE INTEREST OF MAKING AVAILABLE AS MUCH INFORMATION AS POSSIBLE

REMOTE SENSING OF EARTH TERRAIN

National Aeronautics and Space Administration
Goddard Space Flight Center
Contract NAG 5-270

NOV 1985
RECEIVED
NASA STI FACILITY
ACCESS DEPT.

SEMI-ANNUAL REPORT

covering the period

March 1, 1985—August 31, 1985

(NASA-CR-176284) REMOTE SENSING OF EARTH TERRAIN Semiannual Report, 1 Mar. - 31 Aug. 1985 (Massachusetts Inst. of Tech.) 9 p
HC A02/MF A01 CSCL 08B
N86-11645
Unclas
G3/43 27631

prepared by

J. A. Kong

August 1985

Massachusetts Institute of Technology
Research Laboratory of Electronics
Cambridge, Massachusetts 02139

REMOTE SENSING OF EARTH TERRAIN

Principal Investigator: Jin Au Kong

SEMI-ANNUAL PROGRESS REPORT

Under the sponsorship of the NASA Contract NAG5-270, we have published 14 articles in refereed journals, 15 conference papers, and 13 technical reports and 4 student theses for the research on the remote sensing of earth terrain.

We have made progress on (1) the investigation of the anisotropy of the terrain media, such as vegetation canopy and sea ice, and (2) the study of the fluctuation-dissipation theorem in conjunction with the application of strong fluctuation theory for passive remote sensing of snowpacks, during the period March 1, 1985 to August 31, 1985.

The Feynman diagrammatic technique is used to derive the Dyson equation for the mean field and the Bethe-Salpeter equation for the correlation or the covariance of the field for electromagnetic wave propagation and scattering in an anisotropic random medium. With the random permittivity expressed in a general form, the bilocal and the nonlinear approximations are employed to solve the Dyson equation and the ladder approximation to the Bethe-Salpeter equation. The mean dyadic Green's function for a two-layer anisotropic random medium with arbitrary three-dimensional correlation functions has been investigated with the zeroth-order solutions to the Dyson equation under the nonlinear approximation. The effective propagation constants are calculated for the four characteristic waves associated with the coherent vector fields propagating in an anisotropic random medium layer, which are the ordinary and extraordinary waves with upward and downward propagating vectors.

The snow-covered ice field has been studied by a three-layer model, with an isotropic random medium layer simulating snow and an anisotropic random medium layer simulating sea ice. Both snow and ice exhibit volume scattering effects which are due to the granular ice particles and the brine inclusions, respectively. We have calculated the dyadic Green's functions of the three-layer medium and the scattered electromagnetic intensities with Born approximation. The backscattering cross sections are evaluated for active microwave remote sensing. In the model, the correlation functions are assumed to be Gaussian laterally and exponential vertically for both of snow and sea ice. The average physical sizes and the strengths of the volume scattering of the ice particles and the brine inclusions are characterized by the corresponding correlation lengths and normalized variances. The theoretical approach can be extended to derive the bistatic scattering coefficients. After integrating the bistatic scattering coefficients over the upper hemisphere and substracting from unity, we can also compute the radiometric brightness temperatures for passive microwave remote sensing by invoking the principle of reciprocity. The theoretical results are illustrated for thick first-year sea ice covered by dry snow at Point Barrow and for artificial thin first-year sea ice covered by wet snow at CRREL. The radar backscattering cross sections are seen to increase with snow cover for snow-covered sea ice, because volume scattering is greater from snow than from ice. The results are also used to interpret experimental data obtained from field measurements.

The brightness temperature of the snowpack simulated by a bounded layer of random discrete scatterers embedded in a homogeneous medium is obtained in the zeroth and first order approximation by using the fluctuation-dissipation theorem with the strong fluctuation approach. The functional dependence of wavelength, polarization, observation angle, medium depth, scatterers' constituents (for instance, ice particles and water drops in dry and wet snow), and other important physical parameters are established. The theory can also be extended to multi-layer media. The effects due to a thin frozen ice surface over snowpack are also calculated. A thin frozen ice layer over snowpack causes complicated oscillation and interferences such that the thermal radiation is shielded or reflected. Therefore, less brightness temperature is observed. From data matching of brightness temperature versus water equivalent for snowpack, it is shown that the scattering due to first order approximation is significant for large water equivalent which corresponds to more lossy scatterers. Also, it is shown that the scattering darkening effects are included in the use of the auxiliary permittivity, the effective permittivity, and the first order solution. The permittivity of the homogeneous medium is important at small observation angles, while the sizes and the permittivities of the scatterers are important at large observation angles and higher frequencies, since the contribution from the homogeneous medium or the randomly distributed scatterers becomes significant. The increase of scatterer size decreases brightness temperature, thus aged snowpacks have lower thermal radiations.

PUBLICATIONS SUPPORTED BY NASA CONTRACT NAG-5-270

A. Refereed Journal Articles

A1. Wave scattering and guidance by dielectric waveguides with periodic surface (S. L. Chuang and J. A. Kong), *Journal of the Optical Society of America*, vol.73, 669–679, May 1983.

A2. Dyadic Green's functions for layered anisotropic medium (J. K. Lee and J. A. Kong), *Electromagnetics*, vol.3, 111–130, 1983.

A3. Passive and active remote sensing of atmospheric precipitation (Y. Q. Jin and J. A. Kong), *Applied Optics*, vol.22, 2535–2545, September 1983.

A4. Scattering of electromagnetic waves from a half-space of densely distributed dielectric scatterers (L. Tsang and J. A. Kong), *Radio Science*, vol.6, 1260–1272, Nov–Dec 1983.

A5. Strong fluctuation theory for electromagnetic wave scattering by a layer of random discrete scatterers (Y. Q. Jin and J. A. Kong), *Journal of Applied Physics*, vol.55, 1364–1369, March 1984.

A6. Radiative transfer theory for active remote sensing of a layer of nonspherical particles (L. Tsang, J. A. Kong, and R. T. Shin), *Radio Science*, vol.19, 629–642, March–April 1984.

A7. Microwave thermal emission of periodic surface (J. A. Kong, S. L. Lin, and S. L. Chuang), *IEEE Transactions on Geoscience and Remote Sensing*, vol.GE–22, 377–382, July 1984.

A8. Scattering of electromagnetic waves from a randomly perturbed quasiperiodic surface (R. T. Shin and J. A. Kong), *Journal of Applied Physics*, vol.56, 10–21, July 1984.

A9. Active microwave remote sensing of an anisotropic random medium layer (J. K. Lee and J. A. Kong), *IEEE Trans on Geoscience and Remote Sensing*, 8410

A10. Passive microwave remote sensing of an anisotropic random medium layer (J. K. Lee and J. A. Kong), *IEEE Trans on Geoscience and Remote Sensing*, 8410

A11. Wave approach to brightness temperature from a bounded layer of random discrete scatterers (Y. Q. Jin), *Electromagnetics*, vol.4, 323-341, 1984.

A12. Ladder and cross terms in second-order distorted Born approximation (Y. Q. Jin and J. A. Kong), *J. Mathematical Physics*, vol.26(5), 994-1011, May 1985.

A13. Strong fluctuation thoery for scattering, attenuation, and transmission of microwave through snowfall (Y. Q. Jin and J. A. Kong), *IEEE Transactiions on Geoscience and Remote Sensing*, vol.GE-23, No.5, 754-760, September 1985.

A14. Electromagnetic wave scattering in a two-layer anisotropic random medium (J. K. Lee and J. A. Kong), *Optical Society of America*, December 1985.

B. Conference Articles

C1. Theoretical models for microwave remote sensing of vegetation and soil moisture (J. A. Kong), *AgRISTARS Symposium*, Houston, Texas, December 1-2, 1982.

C2. Thermal microwave emission from a scattering medium with rough surfaces (R. Shin and J. A. Kong), *URSI Symposium*, Boulder, Colorado, January 5-7, 1983.

C3. Remote sensing of soil moisture and vegetation (J. A. Kong, S. L. Lin, S. L. Chuang, and R. T. Shin), *URSI Symposium*, Boulder, Colorado, January 5-7, 1983.

C4. Mie scattering of electromagnetic waves by precipitation (Y. Q. Jin and J. A. Kong), *Optical Society of America Topical Meeting on Optical Techniques for Remote Probing of the Atmosphere*, Lake Tahoe, Nevada, January 10-12, 1983.

C5. Scattering of electromagnetic waves from a half-space of densely distributed dielectric scatterers (L. Tsang and J. A. Kong), *IEEE/AP-S Symposium and URSI Meeting*, Houston, Texas, May 23-26, 1983.

C6. Theory of microwave remote sensing of dense medium (L. Tsang and J. A. Kong), *URSI Symposium*, San Francisco, 1983.

C7. Wave scattering by a bounded layer of random discrete scatterers (Y. Q. Jin and J. A. Kong), *National Radio Science Meeting*, Boulder, Colorado, January 11-13, 1984.

C8. Scattering of electromagnetic waves by a randomly perturbed quasi-periodic surface (R. T. Shin and J. A. Kong), *National Radio Science Meeting*, Boston, Massachusetts, June 25-28, 1984.

C9. Modified radiative transfer equation in strong fluctuation approach (Y. Q. Jin and J. A. Kong), *National Radio Science Meeting*, Boston, Massachusetts, June 25-28, 1984.

C10. Active and passive microwave remote sensing of layered anisotropic random medium (J. K. Lee and J. A. Kong), *National Radio Science Meeting*, Boston, Massachusetts, June 25-28, 1984.

C11. Electromagnetic characterization of inhomogeneous media exhibiting volume scattering effects (J. A. Kong), *Workshop on Waves in Inhomogeneous Media*, Schlumberger-Doll Research, Ridgefield, Connecticut, August 8-9, 1985.

C12. Radar backscattering from snow-covered ice (F. C. Lin, J. K. Lee, J. A. Kong, and R. T. Shin), *Proceedings Snow Symposium V*, Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire, August 13-15, 1985

C13. Mean dyadic Green's function for a two-layer anisotropic random medium: nonlinear approximation to the Dyson equation, (J. K. Lee and J. A. Kong), *International Symposium on Antennas and Propagation*, Kyoto, Japan, August 20-22, 1985.

C14. Strong fluctuation theory of random medium and applications in remote sensing (Y. Q. Jin and J. A. Kong), *International Symposium on Antennas and EM Theory (ISAE)*, Beijing, China, August 26-28, 1985.

C15. Electromagnetic wave scattering by a two-layer anisotropic random medium, (J. K. Lee and J. A. Kong), *IGARSS 85 and URSI Meeting*, Unversity of Massachusetts, Amherst, MA, October 7-9, 1985.

C. <u>Reports and Theses</u>

R1. Emissivity of a two-layer random medium with anisotropic correlation function, (R. T. Shin and J. A. Kong), Technical Report No. EWT-RS-41-8303, MIT, 1983.

R2. Estimation of Snow Depth with Measured Brightness Temperatures (H. Z. Wang), Technical Report No. EWT-RS-43-8304, MIT, 1983.

R3. Estimation of Snow Depth from Backscattering Cross Section Obtained from Active Microwave Remote Sensing (H. Wang), Technical Report No. EWT-RS-45-8306, MIT, 1983.

R4. Extended Boundary Condition Approach to Wave Scattering by Periodic Structures (S. L. Chuang and J. A. Kong), Technical Report No. EWT-RS-55-8312, MIT, 1983.

R5. Microwave Remote Sensing of a Scattering Medium with Rough Surfaces (R. T. Shin and J. A. Kong), Technical Report No. EWT-RS-64-8402, MIT, 1984.

R6. Modified Radiative Transfer Equation in Strong Fluctuation Approach (Y. Q. Jin and J. A. Kong), Technical Report No. EWT-RS-67-8406, MIT, 1984.

R7. Active Microwave Remote sensing of an Anisotropic Random Medium Layer (J. K. Lee and J. A. Kong), Technical Report No. EWT-RS-68-8407, MIT, 1984.

R8. Behavior of Circularly Polarized Waves in Active Remote Sensing of Two-layer Random Media (F. C. Lin), Technical Report No. EWT-RS-70-8410, MIT, 1984.

R9. Ladder and Cross Terms in Second Order Distorted Born Approximation (Y. Q. Jin and J. A. Kong), Technical Report No. EWT-RS-71-8412, MIT, 1984.

R10. Passive Microwave Remote Sensing of an Anisotropic Random Medium Layer (J. K. Lee and J. A. Kong), Technical Report No. EWT-RS-72-8412, MIT, 1984.

R11. Wave Approach to Brightness Temperature from a Bounded Layer of Random Discrete Scatterers (Y. Q. Jin), Technical Report No. EWT-RS-73-8412, MIT, 1984.

R12. Electromagnetic Wave Scattering in a Two-layer Anisotropic Random Medium (J. K. Lee and J. A. Kong), Technical Report No. EWT-RS-74-8506, MIT, 1985.

R13. Radar Backscattering from Snow-covered Ice (F. C. Lin, J. K. Lee, J. A. Kong, and R. T. Shin), Technical Report No. EWT-RS-75-8508, MIT, 1985.

T1. Lin, Sching Lih, "Microwave thermal emission from a periodic surface," S.M. Thesis, May 1983.

T2. Park, Dongwook, "Passive remote sensing of layered random media with strong permittivity fluctuations," S. M. Thesis, May 1984.

T3. Shin, Robert Tong-ik, "Theoretical models for microwave remote sensing of earth terrain," Ph.D. Thesis, September 1984.

T4. Lee, Jay Kyoon, "Electromagnetic wave propagation and scattering in layered anisotropic random medium," Ph.D. Thesis, February 1985.