26. Electromagnetic Wave Theory and Remote Sensing

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26.1 Electromagnetic Waves

Joint Services Electronics Program (Contract DAAG29-83-K-0003)

Jin Au Kong, Abdurrahman Sezginer, Jeff Kiang

Electromagnetic waves are studied with applications to geophysical subsurface probing,[1,2,3] Smith-Purcell radiation from metallic gratings,[4] scattering from interconnecting plates,[5] and with the recently discovered focus wave mode,[6] The electromagnetic fields due to dipole antennas in a two-layer dissipative medium such as the sea is solved using the quasistatic approximation.[1] The solutions in integral forms are calculated with brute force numerical integration methods, the multi-image approach with the steepest descent method, the modal approach by finding the residues, and a hybrid approach combining the latter two methods. The Smith-Purcell radiation problem which takes into account the penetrable properties of metallic gratings is solved.[4] An electron beam moving across the surface of a metallic grating will cause emission of electromagnetic radiation. It is shown that maximum radiation occurs when the surface plasmon mode is excited. The scattering problem involving interconnecting plates is solved with the help of the method of moments.[5] By defining independent basis functions on overlapping domains and then joining them at the common edges, we can model complex structures efficiently while satisfying Kirchhoff's current law on the surface of the conductors. The focus wave modes refer to electromagnetic pulses that remain localized in the three-dimensional space and propagate at the speed of light without dispersing. We have shown that such modes must have infinite electromagnetic energy in the source-free, three-dimensional space.[6] A general formulation that constructs a complete set of focus wave modes with Hermite-Gaussian transverse variation is developed.

26.2 Remote Sensing with Electromagnetic Waves

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Jin Au Kong, Leung Tsang

Theoretical models of random media including the anisotropic effects, discrete scatterers, random distribution of discrete scatterers, rough surface effects, have been studied for remote sensing with electromagnetic waves. These models are used to simulate snow-ice fields, forest, vegetation canopy, plowed field, sea ice, and atmosphere.[7-19] Scattering and emission of electromagnetic waves by random media bounded by rough interfaces are investigated.[7-9] Multiple scattering effects of electromagnetic waves by a layer of densely distributed discrete scatterers are studied.[10-13] The strong fluctuation approach is applied to derive the modified radiative transfer equation which accounts for the multiple scattering effects.[14-16] Also, active remote sensing with dipole antennas and line sources have been studied for both monochromatic and pulse excitations.[1-3]

26.3 Acoustic Wave Propagation Studies

Schlumberger-Doll Research Center

Jin Au Kong, Weng C. Chew, Tarek M. Habashy, Shun-Lien Chuang, Abdurrahman Sezginer, Sching L. Lin, Soon Yun Poh

The transient electric field due to a step excited line source, located on the axis of a dielectric cylinder buried in another dielectric medium is evaluated by the singularity expansion method, and by an approximate explicit inversion approach.[2,3] The explicit inversion approach is facilitated with a technique that preserves the principle of causality. The singularity expansion method and the explicit inversion technique complement each other as the former provides accurate results for the smoothly varying parts of the time-domain response and the latter accurately reproduces abrupt changes in the response. In addition, geophysical subsurface probing by dipole antennas[1] and the Smith-Purcell radiation from penetrable grating problems have been studied.[4]

26.4 Remote Sensing of Vegetation and Soil Moisture

National Aeronautics and Space Administration (Contract NAG5-141)

Jin Au Kong, Robert T. Shin, Sching L. Lin

In the remote sensing of vegetation and soil moisture, scattering effects due to volume inhomogeneities and rough surfaces play a dominant role in the determination of radar backscattering coefficients and radiometric brightness temperatures.[13] The scattering of electromagnetic waves by a randomly perturbed quasi-periodic surface is studied for active remote sensing of plowed fields.[17] Thermal emission from plowed fields have been solved using a rigorous modal theory which has been developed with the extended boundary condition approach.[19] These models have been used to interpret the remote sensing data from plowed fields which show strong dependence to the change in the viewing direction relative to the row direction. The strong fluctuation theory is also applied to the study of electromagnetic wave scattering by a layer of random discrete scatterers.[14-16] The strong fluctuation theory is particularly pertinent for vegetation canopy since the contrast of permittivity between vegetation, which is essentially water droplets, and air is very large.

26.5 Passive Microwave Snowpack Experiment

National Aeronautics and Space Administration (Contract NAS5-26861)
Robert T. Shin, Jin Au Kong

For the purpose of investigating the volume scattering effect and the diurnal change of the snowpack, microwave radiometers at the frequencies of 10.8, 18, and 37 GHz are used to conduct the snowpack experiment in North Danville, Vermont area during the winter of 1983–1984. The test sites are prepared before snowfall so that microwave emission can be continuously monitored throughout the winter as snow accumulates on these specially prepared sites. Aluminum-plate covered ground, artificial rough ground to simulate the plowed agricultural field, and natural ground have been prepared. Due to the weather cycles in the area, there were prominent ice layers created in the snowpacks. These ice layers cause the interference effects which modify the emission characteristics of the snowpack. Analysis of preliminary results indicates that there are distinctive interference effects due to ice layers that appear in the incidence angle dependence of the brightness temperature of the snowpack.

26.6 Remote Sensing of Earth Terrain

National Aeronautics and Space Administration (Contract NAG5-270)
Jin Au Kong, Robert T. Shin, Yaqiu Jin, F. Lin

Realistic theoretical models that are applicable to the active and passive remote sensing of plowed fields, atmospheric precipitation, vegetation, and snow fields have been developed. The development of our theoretical models has been strongly motivated by the need of the data analysis and interpretation, and scene simulation for various types of earth terrain which show distinctive characteristics. The problem of microwave scattering from sinusoidal or quasi-periodic randomly perturbed surfaces has been studied to explain the large differences in the radar backscattering cross sections and the radiometric brightness temperatures between the cases where the incident wave vector is parallel or perpendicular to the row direction.[17] To accommodate in the random medium model and the discrete scatterer model the strong azimuthal dependence shown in the observed data, we have developed the anisotropic random medium model [7-9] and the discrete scatterer model with nonspherical particles.[10] The theory of electromagnetic waves scattering from randomly distributed dielectric scatterers are employed to relate the remote sensing data to the actual physical parameters.[11-14] Both the rigorous random discrete scatterer theory and the strong fluctuation theory are used to derive the backscattering cross section in terms of the actual physical parameters and the results agree well with the data obtained from the snow fields.[14-16]

26.7 Active and Passive Remote Sensing of Ice

U.S. Navy - Office of Naval Research (Contract N00014-83-K-0258)
Jin Au Kong, Robert T. Shin, Jay Kyoon Lee, Maurice Borgeaud

In the remote sensing of ice, one of the dominant effects in the determination of the radar backscattering cross sections and radiometric brightness temperatures is the anisotropy of the medium due to the structures on the brine inclusions in sea ice and air bubble shapes in lake ice. We have derived the dyadic Green's function for a two-layer anisotropic medium and further apply it to the interpretation of the experimental results.[7-9] The Born approximation is used along with the dyadic Green's function for the two-layer anisotropic medium to calculate the scattered fields. The principle of reciprocity is invoked to compute the brightness temperature. The bistatic scattering coefficients are first calculated and then integrated over the upper hemisphere to be subtracted from unity, in order to obtain the emissivity for the random medium layer. The backscattering cross sections for a two-layer anisotropic random medium have also been derived. Under the consideration that sea ice is a tilted uniaxial medium, the observed strong cross-polarized return in the bistatic scattering coefficients is successfully predicted from the theoretical model.

26.8 Electromagnetic Wave Propagation in High-speed Digital Integrated Circuits

International Business Machines, Inc.
Jin Au Kong, Qizheng Gu, Abdurrahman Sezginer, Jeff Kiang, Ying E. Yang

The study of electromagnetic wave propagation in integrated circuits is motivated by the need to achieve condensed circuit packages, shorter rise times, and smaller pulse widths without causing large signal distortion and crosstalks. The parallel signal lines with crossing lines above in the integrated circuit design can be viewed as nonuniformly coupled transmission lines. We have studied the transient response with the combination of the method of characteristics and perturbational series under given circuit parameters.[20] From the simplest model of the above structure, a parallel-plate transmission line with transverse ridges, useful information is obtained by sectional approximation[21] or by the method of moments. The space-time integral equation formulation is being developed for calculating signal distortion as it propagates along vias, or vertical transmission lines in the multi-layered integrated circuit.

References

1. T.M. Habashy, J.A. Kong, and L. Tsang, "Quasistatic Electromagnetic Fields due to Dipole Antennas in Bounded Conducting Media," IEEE Trans. Geosci. Remote Sensing, accepted for publication.
2. A. Sezginer and J.A. Kong, "Transient Response of Line Source Excitation in Cylindrical Geometry," National Radio Science Meeting, Boston, Massachusetts, June 25-28, 1984.
3. A. Sezginer and J.A. Kong, "Transient Response of Line Source Excitation in Cylindrical Geometry," Electromagnetics, 4, 35-54, 1984.
4. S.L. Chuang and J.A. Kong, "Enhancement of Smith-Purcell Radiation from a Grating with Surface-Plasmon Excitation," J. Opt. Soc. Am. A, 1, 672-676, June 1984.
5. J.F. Kiang and J.A. Kong, "Method of Moments for Interconnecting Plates in Electromagnetic Wave Scattering Problems," National Radio Science Meeting, Boston, Massachusetts, June 25-28, 1984.
6. A. Sezginer, "A General Formulation of Focus Wave Modes," J. Appl. Phys., to be published.
7. J.K. Lee and J.A. Kong, "Active and Passive Microwave Remote Sensing of Layered Anisotropic Random Medium," National Radio Science Meeting, Boston, Massachusetts, June 25-28, 1984.
8. J.K. Lee and J.A. Kong, "Active Microwave Remote Sensing of an Anisotropic Random Medium Layer," IEEE Trans. Geosci. Remote Sensing, submitted for publication.
9. J.K. Lee and J.A. Kong, "Passive Microwave Remote Sensing of an Anisotropic Random Medium Layer," IEEE Trans. Geosci. Remote Sensing, submitted for publication.
10. L. Tsang, J.A. Kong, and R.T. Shin, Radiative Transfer Theory for Active Remote Sensing of a Layer of Nonspherical Particles," Radio Sci., 19, 629-642, March-April 1984.
11. Y.Q. Jin and J.A. Kong, "Wave Scattering by a Bounded Layer of Random Discrete Scatterers," URSI Symposium, Boulder, Colorado, January 11-14, 1984.
12. Y.Q. Jin and J.A. Kong, "Ladder and Cross Terms in Second Order Distorted Born Approximation," J. Math. Phys., accepted for publication.
13. Y.Q. Jin, "Wave Approach to Brightness Temperature from a Bounded Layer of Random Discrete Scatterers," Electromagnetics, accepted for publication.
14. Y.Q. Jin and J.A. Kong, "Strong Fluctuation Theory for Electromagnetic Wave Scattering by a Layer of Random Discrete Scatterers," J. Appl. Phys., 55, 1364-1369, March 1984.
15. Y.Q. Jin and J.A. Kong, "Modified Radiative Transfer Equation in Strong Fluctuation Approach," National Radio Science Meeting, Boston, Massachusetts, June 25-28, 1984.
16. Y.Q. Jin and J.A. Kong, "Strong Fluctuation Theory of Random Medium and Applications in Remote Sensing," International Symposium on Antennas and EM Theory (ISAE), Beijing, China, August 24-26, 1985, submitted for publication.
17. R.T. Shin and J.A. Kong, "Scattering of Electromagnetic Waves by a Randomly Perturbed Quasi-periodic Surface," National Radio Science Meeting, Boston, Massachusetts, June 25-28, 1984.
18. R.T. Shin and J.A. Kong, "Scattering of Electromagnetic Waves from a Randomly Perturbed Quasiperiodic Surface," J. Appl. Phys., 56, 10-21, July 1984.

19. J.A. Kong, S.L. Lin, and S.L. Chuang, "Microwave Thermal Emission of Periodic Surface," IEEE Trans. Geosci. Remote Sensing, GE-22, 377-382, July 1984.
20. Y.E. Yang, J.A. Kong, and Q. Gu, "Time Domain Perturbational Analysis of Nonuniformly Coupled Transmission Lines," IEEE Trans. Microwave Theory Tech., submitted for publication.
21. Q. Gu and J.A. Kong, "A Transient Analysis of Single and Coupled Lines Comprising Different Admittance Sections and Capacitances Loaded at Junctions of Line Sections," IEEE Trans. Microwave Theory Tech., submitted for publication.