14. Electromagnetic Wave Theory and Remote Sensing

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14.1 Electromagnetic Waves

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

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Electromagnetic waves are studied with applications to microstrip antennas,[1,2] geophysical subsurface probing,[3,4] scattering from helical structures[5,6] and Smith–Purcell radiation from metallic gratings.[7] Radiation and resonance characteristics of two coupled circular microstrip disk antennas are studied rigorously using numerical techniques, matched asymptotic analysis, and the newly developed Hankel transform analysis.[1,2] The electromagnetic fields due to dipole antennas in a two-layer dissipative medium is solved using the quasistatic approximation.[3] The solutions in integral forms are calculated with brute force numerical integration methods, the multi-image approach with the steepest descent method, the normal mode approach with the residue method, and a hybrid approach with combinations of the above methods. Electromagnetic wave scattering from helical structures has been studied using the physical optics and modal approaches. The fields scattered by a thin wire helix of finite extent is investigated using physical optics and the geometrical theory of diffraction.[5] The geometrical theory of diffraction result is obtained as a high frequency limit of the physical optics approximation by applying the saddle point technique to the integral representation of the physical optics field. The electromagnetic wave scattering by a tape helix of infinite extent is studied by using Floquet wave expansion for its guided modes and scattered fields.[6] The Smith–Purcell radiation problem is solved taking into account the penetrable properties of metallic gratings.[7] When an electron beam streams across the surface of a metallic grating, emission of electromagnetic radiation occurs. It is shown that maximum radiation occurs when the surface plasmon mode is excited.

14.2 Remote Sensing with Electromagnetic Waves

National Science Foundation (Grant ECS82-03390)
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Remote sensing with electromagnetic waves has been studied with the theoretical models of random media, discrete scatterers, and random distribution of discrete scatterers. These models are used to stimulate snow–ice fields, forest, vegetation, and atmosphere.[8-10] Scattering and emission of electromagnetic waves by such media bounded by rough interfaces are investigated.[11-17] Multiple scattering effects of electromagnetic waves by a half-space of densely distributed discrete scatterers are studied.[18-20] The quasi-crystalline approximation is applied to truncate the hierarchy of multiple scattering equation and the Percus–Yevick result is used to represent the pair distribution function. Also, active remote sensing with dipole antennas and line sources has been studied for both monochromatic and pulse excitations.[3,4]

14.3 Acoustic Wave Propagation Studies

Schlumberger–Doll Research Center
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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.[4] 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, wave scattering from a half–space of densely distributed discrete scatterers,[19,20] radiation and resonance of two coupled circular microstrip disks,[1,2] geophysical subsurface probing by dipole antennas,[3] and scattering of waves from helical structures have been studied.[5,6]

14.4 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.[9,13] The scattering of electromagnetic waves by a randomly perturbed quasi-periodic surface is studied for active remote sensing of plowed fields.[21] Thermal emission from plowed fields has been solved using a rigorous modal theory which has been developed with the extended boundary condition approach.[11,12] These models have been used to interpret the remote sensing data from plowed fields which show strong dependence to the change in look direction relative to the row direction.[14,17] The strong fluctuation theory is also applied to the study of electromagnetic wave scattering by a layer of random discrete scatterers. 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.

14.5 Passive Microwave Snowpack Experiment

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

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 covered ground, rough ground, 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.

14.6 Remote Sensing of Earth Terrain

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

Numerous 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 to interpret the data obtained from various types of earth terrain which show distinctive characteristics. The problem of microwave scattering from sinusoidal 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.[11,12,21] The radiative transfer theory is used to interpret the active and passive data as a function of rain rate.[8,10] Both the random medium model and the discrete scatterer model are used to study the remote sensing of vegetation fields.[9,13] Due to the non-spherical geometry of the scatterers there is strong azimuthal dependence in the observed data. Thus, the anisotropic random medium model[16] and the discrete scatterer model with nonspherical particles[15] have been developed. In order to relate the remote sensing data to the actual physical parameters, we have studied scattering of electromagnetic waves from randomly distributed dielectric scatterers.[18-20] 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.[14,17]

14.7 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

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 due to the structures on the brine inclusions in sea ice and air bubble shapes in lake ice. Due to the absence of a useful dyadic Green's function, there has been a fundamental difficulty in solving problems of radiation and scattering of electromagnetic waves in layered uniaxial media. Therefore, we have derived the dyadic Green's function for a two-layer anisotropic medium.[16] The anisotropic medium is assumed to be tilted uniaxial. The backscattering cross sections and the bistatic scattering coefficients for a two-layer anisotropic random medium have also been derived. The Born approximation is used along with the dyadic Green's function for the two-layer anisotropic medium to calculate the scattered fields.

References

1. T.M. Habashy, S.M. Ali, and J.A. Kong, "Impedance Parameters and Radiation Pattern of Two Coupled Circular Microstrip Disk Antennas," J. Appl. Phys. 54, 2, 493–506 (1983).
2. T.M. Habashy and J.A. Kong, "Asymptotic Evaluation of Resonance Frequencies for Two Coupled Circular Microstrip Disk Resonators," IEEE MTT–S International Microwave Symposium, Boston, Massachusetts, May 31–June 3, 1983.
3. T.M. Habashy, J.A. Kong, and L. Tsang, "Quasistatic Electromagnetic Fields Due to Dipole Antennas in Bounded Conducting Media," to be published.
4. A. Sezginer and J.A. Kong, "Transient Response of Line Source Excitation in Cylindrical Geometry," to be published.
5. A. Sezginer and J.A. Kong, "Physical Optics Approach for Scattering by Thin Helical Wires," Radio Sci. 18, 639-649 (1983).
6. A. Sezginer, S.L. Chuang, and J.A. Kong, "Modal Approach to Scattering of Electromagnetic Waves by a Conducting Tape Helix," IEEE Trans. Antennas Propag., to be published.
7. S.L. Chuang and J.A. Kong, "Smith–Purcell Radiation from a Charge Moving Above a Penetrable Grating," IEEE MTT–S International Microwave Symposium, Boston, Massachuetts, May 31–June 3, 1983.
8. Y.Q. Jin and J.A. Kong, "Passive and Active Remote Sensing of Atmospheric Precipitation," Appl. Opt. 22, 2535–2545 (1983).
9. J.A. Kong, S.L. Lin, S.L. Chuang, and R.T. Shin, "Remote Sensing of Soil Moisture and Vegetation," URSI Symposium, Boulder, Colorado, January 5–7, 1983.

10. Y.Q. Jin and J.A. Kong, "Mie Scattering of Electromagnetic Waves by Precipitation," Optical Society of America Topical Meeting on Optical Techniques for Remote Probing of the Atmosphere, Lake Tahoe, Nevada, January 10-12, 1983.
11. S.L. Chuang and J.A. Kong, "Wave Scattering and Guidance by Dielectric Waveguides with Periodic Surface," J. Opt. Soc. Am. 73, 669-679 (1983).
12. J.A. Kong, S.L. Lin, and S.L. Chuang, "Microwave Thermal Emission of Periodic Surface," IEEE Trans. Geosci. Remote Sensing, accepted for publication.
13. R.T. Shin and J.A. Kong, "Thermal Microwave Emission from a Scattering Medium with Rough Surfaces," URSI Symposium, Boulder, Colorado, January 5-7, 1983.
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., accepted for publication.
15. L. Tsang, J.A. Kong, and R.T. Shin, "Radiative Transfer Theory for Active Remote Sensing of a Layer of Nonspherical Particles," Radio Sci., accepted for publication.
16. J.K. Lee and J.A. Kong, "Dyadic Green's Functions for Layered Anisotropic Medium," Electromagnetics, accepted for publication.
17. 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.
18. L. Tsang and J.A. Kong, "Scattering of Electromagnetic Waves from a Half-Space of Densely Distributed Dielectric Scatterers," Radio Sci. 18, 1260-1272 (1983).
19. L. Tsang and J.A. Kong, "Scattering of Electromagnetic Waves from a Half-Space of Densely Distributed Dielectric Scatterers," IEEE/APS Symposium and URSI Meeting, Houston, Texas, May 23-26, 1983.
20. L. Tsang and J.A. Kong, "Theory of Microwave Remote Sensing of Dense Medium," URSI Symposium, San Francisco, California, 1983.
21. R.T. Shin and J.A. Kong, "Scattering of Electromagnetic Waves From a Randomly Perturbed Quasi-Periodic Surface," to be published.