ELECTROMAGNETIC WAVE PROBING OF EARTH'S EVNIRONMEMT

National Aeronautics and Space Administration
Goddard Space Flight Center
Contract NAG 5-889

FINAL REPORT

covering the period

February 1, 1987—December 31, 1987

prepared by

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Polarimetric radar backscattering from anisotropic earth terrain such as snow-covered ice fields and vegetation fields with row structures provides a challenging modelling problem from the electromagnetic wave point of view. Snow, ice and vegetation all exhibit volume scattering effects. For snow, the scattering is caused by the granular ice particles; for ice, the air bubbles and the brine inclusions; and for vegetation, the leaves, the trunks, and other inhomogeneities. We model earth terrain covers as random media characterized by different dielectric constants and correlation functions. In order to model sea ice with brine inclusions and vegetation with row structures, the random medium is assumed to be anisotropic. A three-layer model will be used to simulate a vegetation field or a snow-covered ice field with the top layer being snow or leaves, the middle layer being ice or trunks, and the bottom layer being sea water or ground.

The strong fluctuation theory with the distorted Born approximation has been applied to the solution of the radar backscattering coefficients. The top layer will be considered to be isotropic with a spherical correlation function whereas the middle layer will be assumed to be anisotropic with an exponentially decaying correlation function. Furthermore, the permittivity of the middle layer will be first described as "discrete", constituted by a background permittivity being either isotropic or anisotropic and a scatterer permittivity being isotropic. Associated with the discrete model, a fractional volume density will represent the amount of scatterers. The discrete random medium model will then be

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mapped onto a continuous random medium to obtain a permittivity function depending upon position.

In order to take into account the polarimetric information, we relate the backscattered Stokes vector to the incident Stokes vector by the Mueller matrix, which completely describes the scattering (in amplitude, phase, frequency, and polarization) from the three-layer anisotropic random medium. The Mueller matrix properties, as well as the covariance matrix issues, relevant to the radar backscattering will be examined. It is shown that for an isotropic medium, eight of the sixteen elements of the Mueller matrix are identically zero. However, the tilted anisotropic permittivity of the middle layer (sea ice or trunks) generates a full nonzero Mueller matrix.

The volume scattering effects of snow-covered sea ice are studied with a three-layer random medium model for microwave remote sensing. The strong fluctuation theory and the bilocal approximation are applied to calculate the effective permittivities for snow and sea ice. The wave scattering theory in conjunction with the distorted Born aproximation is then used to computer bistatic coefficients and backscattering cross sections. Theoretical results are illustrated by matching experimental data for dry snow-covered thick first-year sec ice at Point Barrow. The radar backscattering cross sections are seen to increase with snow cover for snow-covered sea ice, due to the increased scattering effects in the snow layer. The results derived can also be applied to the passive remote sensing by calculating the emissivity from the bistatic scattering coefficiets.

Faraday Polarization Fluctuations (FPF) of transionospheric radio waves in the presence of random density irregularities have been studied. The irregularities are anisotropic and modeled by a correlation function containing different correlation lengths in the directions parallel and perpendicular to the Earth's magnetic field. Expression for the FPF variance is obtained under the underdense ionospheric plasma condition. The results show that the FPF variance depends on the ratio of the perpendicular to the parallel correlation lengths and the anisotropic irregularity effect becomes more appreciable for the longitudinally propagating modes.

The ionospheric modification caused by an HF or MF heater wave can be enhanced with the subsequent illumination of the ionosphere by a powerful VLF wave. The proposed scenario of ionospheric modifications by the two heater waves is based upon the following physical processes. Let the HF or MF heater be operated in a pulse-wave mode to assure the excitation of short- rather than large-scale ionospheric density irregularities. These excited ionospheric density striations can effectively scatter the VLF wave into a lower hybrid wave via the nonlinear mode conversion provided that the scale lengths of ionospheric irregularities are much less than the wavelength of the VLF wave. For example, the wavelength of a VLF wave at the frequency of 10 kHz is of the order of 500 meters in the ionospheric F region. The preferential excitation of meter-scale ionospheric irregularities by the HF or MF heater wave can provide the subsequently injected VLF wave with a favorable condition for the nonlinear mode conversion. These density striations, in fact, can also be intensified by the powerful VLF wave via a plasma instability that can concomitantly generate lower hybrid waves. The ionosphere modified by the two heater waves is expected to have intense lower hybrid waves and short-scale ionospheric striations. These VLF wave-produced electrostatic waves can effectively heat the ionospheric plasma. Enhanced modification effects in, for instance, airglow and height distribution of plasma lines are expected. The proposed experiment can provide the controlled study of the spectral broadening effect of propagating VLF waves.

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Nearly monochromatic signals at 13.6 kHz ±1 Hz injected from a ground-based VLF transmitter can experience a broadband expansion as high as 10% ($\sim$ 100 Hz) of the incident wave frequency as they traverse the ionosphere and reach satellite altitudes in the range of 600–3800 kilometers [*Bell et al.,*1983]. We investigate two different source mechanisms that can potentially result in the observed spectral broadening of injected monochromatic VLF waves. One is the nonlinear scattering of VLF signals by induced ionospheric density fluctuations that renders the nonlinear mode conversion of VLF waves into lower hybrid waves. These quasi-electrostatic modes result when the injected VLF waves are scattered by ionospheric density fluctuations with scale lengths less than $0.7(c/f_p)(f_e/f_o)^{1/2}$, where c, f_p, f_e, and f_o are the speed of light in vacuum, the plasma frequency, the electron cyclotron frequency, and the VLF wave frequency, respectively. A second mechanism involves the excitation of electrostatic waves (lower hybrid waves, low frequency quasi-modes) by the injected VLF waves. This process tends to produce a spectrally broadened transmitted pulse with peaks at a discrete set of frequencies on both sides of the nominal carrier frequency.

PUBLICATIONS

Polarimetric microwave remote sensing of anisotropic earth terrain with strong fluctuation theory (M. Borgeaud, J. A. Kong, and R. T. Shin), *IGARSS 87 and URSI Meeting*, University of Michigan, Ann Arbor, MI, May 18–21, 1987.

Theoretical models for active and passive microwave remote sensing of snow-covered sea ice (F. C. Lin, J. A. Kong, and R. T. Shin), *IGARSS 87 and URSI Meeting*, University of Michigan, Ann Arbor, MI, May 18–21, 1987.

On the Faraday polarization fluctuations of radio waves (S. V. Nghiem, J. Murad, and M. C. Lee), *the Proceeding of Ionospheric Effect Symposium*, May 1987.

Ionospheric modifications by two heater waves (M.C. Lee, K.M. Groves, H.C. Han, and J.A. Kong) *the Proceeding of Ionospheric Effect Symposium*, May 1987.

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