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SCATTERING MODELS AND BASIC EXPERIMENTS IN THE MICROWAVE REGIME

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1. Introduction

The objectives of the research over the next three years are:
(1) To develop a randomly rough surface scattering model which is applicable over the entire frequency band.
(2) To development computer simulation method and algorithm to simulate scattering from known randomly rough surfaces, Z(x,y).
(3) To design and perform laboratory experiments to study geometric and physical target parameters of an inhomogeneous layer.
(4) To develop scattering models for an inhomogeneous layer which accounts for near field interaction and multiple scattering in both the coherent and the incoherent scattering components.
(5) Comparison between theoretical models and measurements or numerical simulation.

Although various new approaches in rough surface scattering have appeared in the literature, they are generally restricted to either low or high frequency regions because of the simplifying assumptions used. General theories which are not restricted by such simplifying assumptions are so complex that either no explicit solutions are available or only the scattered field is available because the average scattered power is too involved to compute. In order to obtain a general scattering model for randomly rough surface which is explicit and simple to use it is necessary to determine a sufficiently accurate surface current including just enough multiple scattering terms to have the correct behavior over the entire frequency band but not too involved to deny an explicit solution. This is our goal for a rough surface scattering model. In volume scattering problems most theories are restricted to either a sparsely populated medium or coherent scattering in a dense medium. Incoherent scattering which is of major interest in remote sensing has been investigated mainly by either the Born or the distorted Born approximation in the field approach and the radiative transfer formulation in the intensity approach. Other methods are needed to include multiple incoherent scattering in the field approach and techniques are needed to determine the autocorrelation function in the coherent field calculation in dense inhomogeneous medium. Currently, the use of Percus Yevick approximation and the associated pair distribution function for hard spheres in coherent scattering computation leads to nonphysical results when the volume fraction of the medium is around 0.6.

All theoretical scattering models involve some simplifying assumptions. To verify these models it is best to have controlled experiments so that target parameters can be varied and any given experiment can be repeated. In the case of random surfaces it is possible to use computer simulation. This is not only cost effective compared with full scale field measurements but it is also more convenient to change target parameters than in any controlled experiment.

2. Approach

The approach to be used to develop the proposed random surface model is to use the integral equation method. We have used this method successfully to develop a scattering model for a perfectly conducting surface in the past year and we intend to generalize it to dielectric surfaces. To perform computer simulation for the rough surface problem we intend to investigate first the generation of a two- dimensional random surface with specified autocorrelation function. This is a major effort because algorithms and techniques for this purpose have been restricted to one-dimensional surfaces. From the numerical oint of view this is also a large job requiring large capacity computer. Past experience on a one-dimensional surface indicates that it is desirable to have at least a 10,000 point surface to insure convergence of statistical parameters and it is desirable to have a 50,000 point surface to allow scattering computation at different frequencies. Once the surface is available the standard moment method will be used for scattering coefficient computations. Here again it is necessary to generalize from one to two dimensions and numerically this is a problem because we cannot allow the computation-size to increase like a square.

The measurement program will be divided into two major tasks, (1) the design and construction of a versatile volumetric target structure, and (2) the measurement of radar backscatter cross section as a function of system and target parameters. The target is designed and constructed to simulate vegetation type structures. The target can be used to provide a variety of both geometric and electrical characteristics to include, leaf density in three dimensions, leaf orientation and location, leaf size and shape,and permittivity characteristics of the volumetric structure including relative permittivity and conductivity. The target is designed to allow a number of different parameters to be evaluated while maintaining the basic target shape. Measurements will include the effects of leaf distribution, shape, orientation and location on radar backscatter. Initial experiments will minimize the effects of the stalk structures, however, future measurement programs could include these interaction effects as well. The measurements will be made in an indoor Radar Cross Section Range. The measurements will include amplitude and phase measurements at X band,K band, incident angles from 0 to 50 degrees, and the four linear transmit/receive polarization states.

In view of the difficulties with the current theoretical approaches as stated in the introduction to the volume scattering problem, we propose to use the eikonal approximation for incoherent scattering computation and the solution of the master equation for determining a more realistic autocorrelation function. It should be noted that the pair distribution function was derived for use in a dynamic medium such as a fluid. Hence, for a medium with random but rigid distributions of particles it is not appropriate and does lead to nonphysical results.

3. Results to Date

Over the past year we have developed a scattering model for an inhomogeneous layer containing needle- shaped leaves. We have made comparisons between scattering from such a layer and another layer containing disc-shaped leaves. The significant difference between the two types of vegetation is that the backscattering angular curve for the disc-type has a hump in the mid angular region while the needle-type has a dip in the same region when the size of the leaves is comparable to the incident wavelength(see Figures 1 and 2). In addiction, study has also been carried out to determine the effects of Fresnel phase in the scattering phase matrices on scatterers that are comparable to the incident wavelength but are much smaller than the wavelength in at least one dimension. The conclusion is that the inclusion of the Fresnel phase gives a more accurate frequency trend dependence (see Lee;1984). Also studied is the effect of closer spacings between scatterers accounted for in the scattering phase matrix. Results indicate that a more accurate target parameter can be inferred from such a model than is possible using a standard radiative transfer method (Fung and Eom;June,1984). The inversion from measurements for albedo and optical depth was studied by Fung and Eom (August,1984) with the conclusion that at least a first-order theory must be used in the radiative transfer formulation for emission from an inhomogeneous layer.

A scattering model for a perfectly conducting, randomly rough surface has been developed which is valid over the entire frequency band (Pan;1984). It has been demonstrated analytically that the general solution obtained reduces correctly to the geometrical optics solution in the high frequency limit and to the first-order small perturbation solution in the low frequency limit. In the intermediate region it has a behavior which can be very different from either limiting solution but is liable to be misinterpreted as one or the other. The reason is that it could resemble the low frequency solution in polarization behavior but follow the general angular trend of the Kirchhoff solution(see Figure 3). Also developed was the scattering model for a perturbed sinuscidal surface (Eom and Fung,1984). This was done to account for soil surfaces with row directional dependence.

A plastic model for a layer of leaves of either circular or elliptic shape has been designed which permits the leaf angular distribution, leaf size, leaf density, leaf dielectric value, and row direction effects to be studied under laboratory conditions. It is expected that measurements conducted with this target will be able to provide reliable data for the verification of existing volume scattering models.

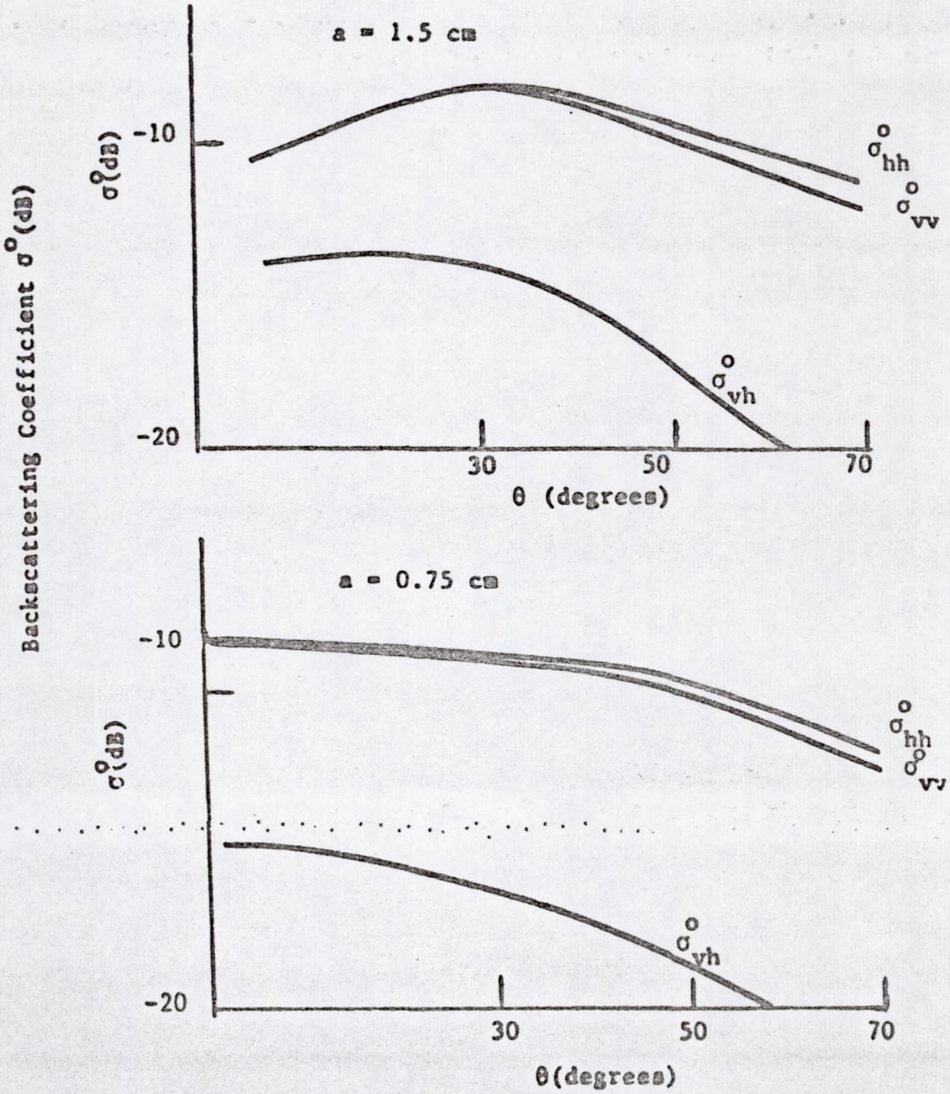

FIG 1. SIZE DEPENDENCE OF DISC-SHAPED VEGETATION (a= radius of disc)

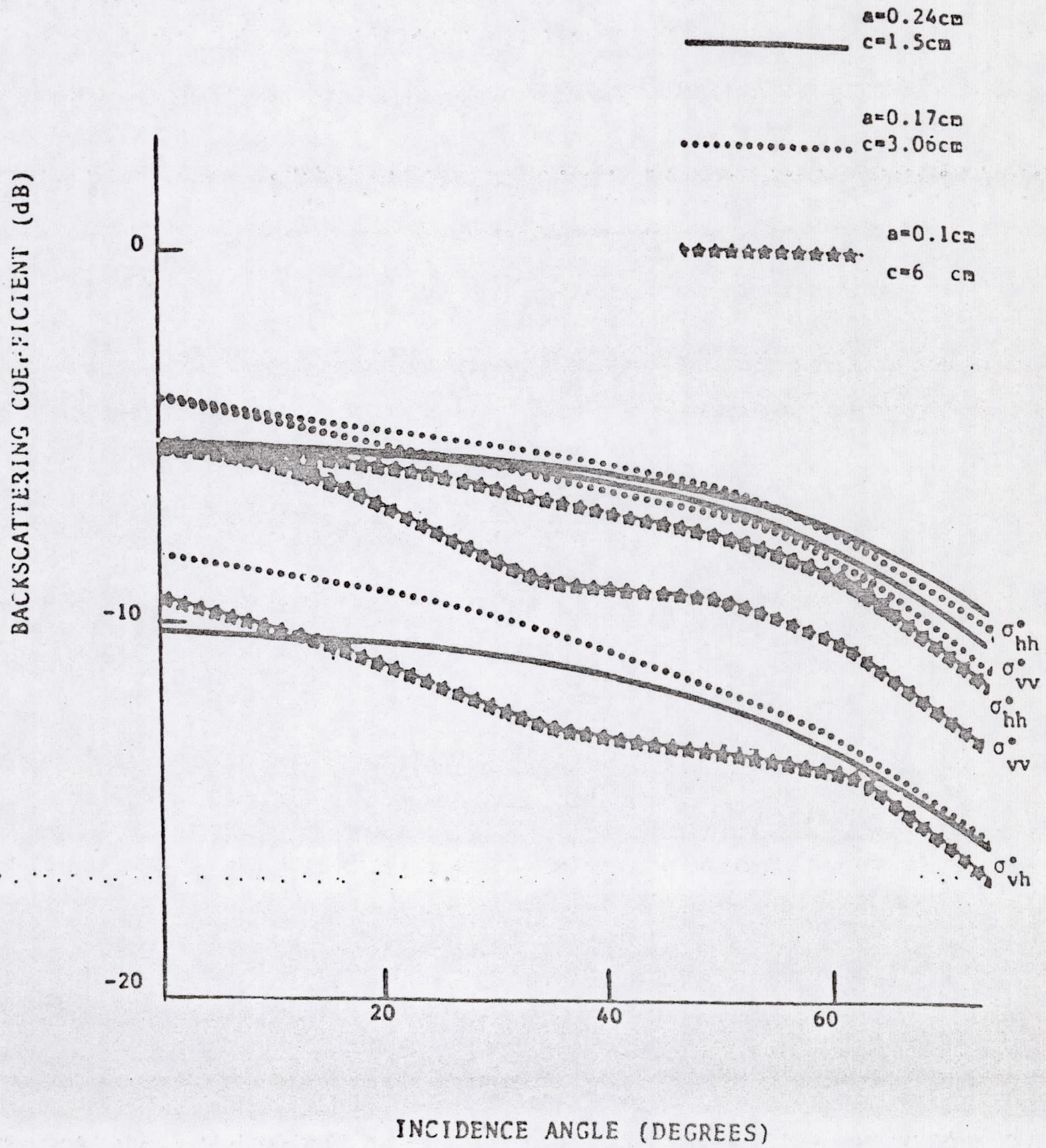

FIG 2 SIZE DEPENDENCE OF NEEDLE-SHAPED VEGETATION (a= radius; c= length of needle)

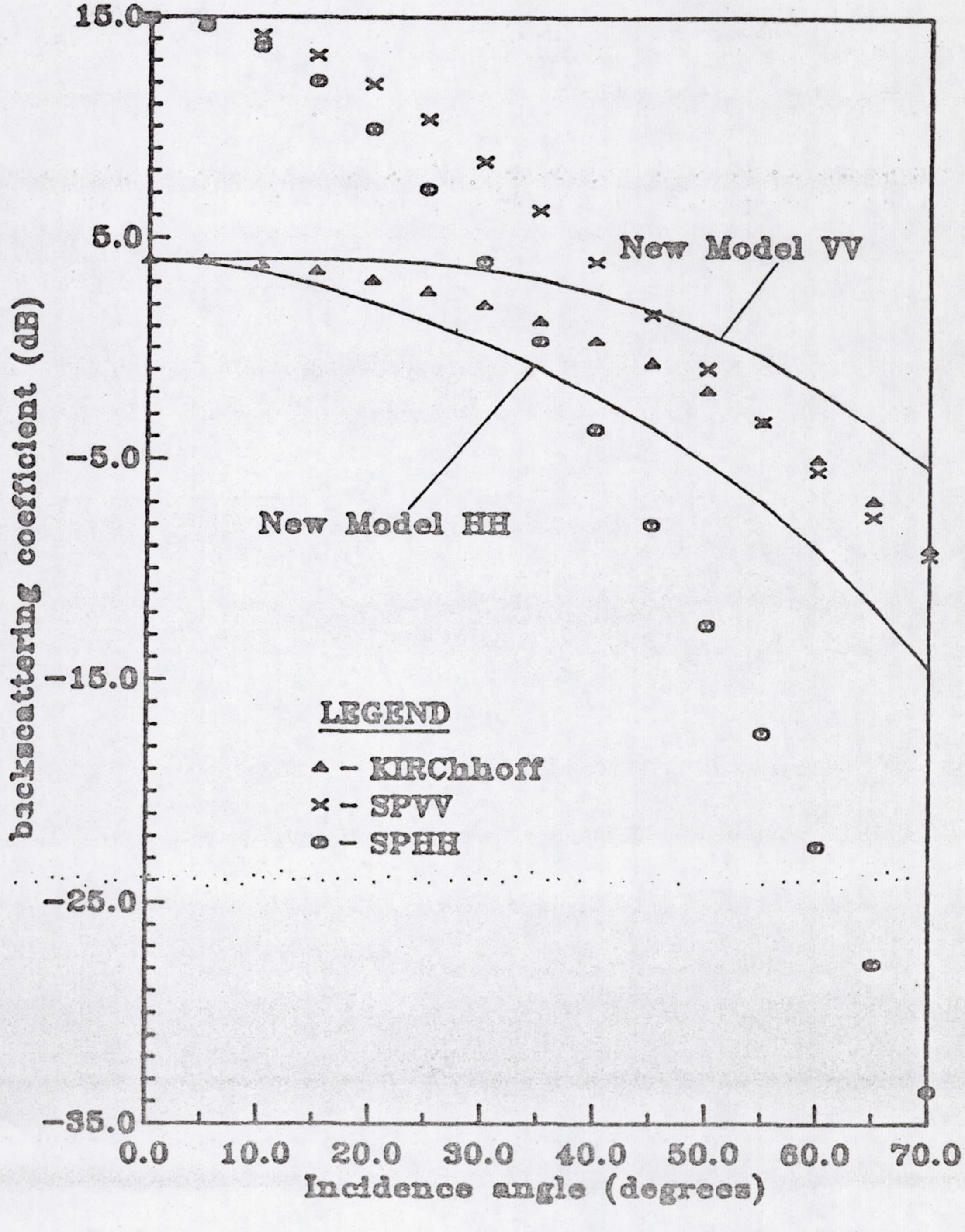

FIG 3 Comparison of INEQ with FOSP and KM ($k\sigma$=1.0 and $k\ell$=2.79).