SEMI-ANNUAL STATUS REPORT
(1 May 1965 to 31 October 1965)

Technical Report EE-130

by

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ABSTRACT

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This report presents a summary of the work performed under NASA Grant NsG 129-61 during the last six months. This work is aimed at determining the surface properties, both electromagnetic and roughness, of a scattering body from measurement of the polarized return power. The major areas of investigation are the monostatic reflection from a statistically rough sphere, determination of electromagnetic properties of a smooth sphere from bistatic power measurement, and development of an acoustic differential reflectivity. Also presented is a short discussion of areas of future work.

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1.0 Introduction

This report presents a summary of the theoretical work accomplished during the period 1 May 1965 to 31 October 1965 together with the topics for future study. In general, the purpose of the work completed and that presently continuing has been to devise means of obtaining better estimates of the electromagnetic properties and surface roughness of scattering surfaces, and in particular of those scattering surfaces presently inaccessible to man. The general approach has been that through the use of the polarization properties of both the transmitted and received signals, the surface properties may be separated and determined individually. A major tool in this work has been the concept of differential reflectivity which was developed by the authors.[1] The major portion of the work done during this report period has been on: 1) back-scatter from a statistically configured surface and 2) determination of electromagnetic properties of a smooth sphere from two bistatic power measurements. Additional work was accomplished on the development of an acoustic differential reflectivity.

2.0 Theoretical Studies

2.1 Monostatic Scattering from Statistical Surfaces

The investigation of reflection of beam-limited radiation from a statistically rough sphere (i.e., a rough moon or planet) is continuing. The surface has been assumed to have a gaussian distribution of heights about a mean sphere and a gaussian correlation function.

[1] Erteza, A., J. A. Doran, D. H. Lenhert, "Concept of Differential Reflectivity as Applied to the Reflection of Beam-Limited Radiation by a Convex Body," RADIO SCIENCE, Journal of Research NBS/USNC-URSI, Vol. 69 D, No. 2, February, 1965.

Under the assumption that induced current densities on the surface reach steady state almost instantaneously, most researchers have calculated the reflected power in the pulsed radiation case using the steady state time averaged Poynting vector (i.e., $\vec{S} = \frac{1}{2}\,\mathrm{Re}\left\{\vec{E} \times \vec{H}^*\right\}$). Our original integral formulation of the expected direct- and cross-polarized powers used this method. However, upon integration, the time averaged power showed an $e^{-i2\omega_0 t}$ term during certain time intervals, which indicated that the steady state assumption is not valid during these time intervals. These were the time intervals in which either the nose or the intersection of the beam-edge and the surface lies between the leading and trailing edges of the propagating pulse. No such term appeared for times between the above two intervals.

Our problem was reformulated using the non-time averaged Poynting vector requiring time averaging after completion of the surface integration. The preliminary results indicate that the use of the time averaged Poynting vector as used by others is only valid during a portion of the intermediate time interval.

Additional problems have been encountered in the integration and evaluation of the expected values. These problems make it more difficult to truncate the infinite series of integrals that appear in the solution. This work is expected to be completed by Spring of 1966, and a separate report covering the theoretical results will be issued.

2.2 Bistatic Scattering from Deterministic Surfaces

An investigation of the bistatic (source and observation points non-coincident) case of reflection has been carried out. The integral equations were formulated for all possible locations of the source and observation point, however these were solved for the case in which the entire illuminated area was visible to the observer. This analysis indicated that from a determination of the ratio of the power densities received by two quadratically opposed antennas, measured at two different configurations of source, target, and observation points, both

μ and ϵ may be determined for a smooth homogeneous sphere of sufficiently large radius. It is felt that with three observations μ, ϵ, and σ could be determined.

A paper covering this work has been submitted to RADIO SCIENCE Journal of Research NBS/USNC-URSI for publication.

2.3 Acoustic Scattering from Surfaces

During the summer an investigation was begun with the objective of formulating a differential reflectivity for acoustic waves scattered from a surface. This acoustic differential reflectivity term would then be compared to the electromagnetic differential reflectivity in an attempt to obtain better justification than exists at present for the use of the acoustic simulator.

The acoustic wave was described in terms of a scalar potential and a vector potential. It appeared that when the source and observer were immersed in water that the reflected field from a solid would be equivalent to an electromagnetic reflected field from an inhomogeneous body. This occurs due to the different transverse and longitudinal velocities of propagation of an acoustic wave in a solid. If the effects of the transverse wave could be neglected, the resulting acoustic scattered field would correspond to the electromagnetic scattered field from a homogeneous body.

This work was set aside due to the loss of personnel and will be reinstated as soon as sufficient personnel can be found.

3.0 Future Work

3.1 Continuation of Monostatic Scattering Study

The investigation described in Section 2.1 will be continued, obtaining separate solutions for both the direct- and cross-polarized expected power integrals. On completion of the integration and time averaging, the variance of surface heights and correlation distance will be evaluated approximately for the case of the moon by comparison with lunar radar data taken by other researchers. When this work has been completed, a separate report will be submitted.

3.2 Bistatic Scattering from a Statistical Surface

Bistatic scattering from a rough spherical surface will be investigated with a view to determining various parameters which describe the surface and affect the scattering from it. Among these parameters are those statistical ones relating to the surface roughness such as distribution of heights, correlation distance, etc. In addition, there are those relating to the electromagnetic properties of the medium considered on a macroscopic basis such as permeability, permittivity, and conductivity. Other characteristics of the surface such as a layered nature can be postulated and the components of the scattered field studied to determine in what manner the layering can be detected from afar.

3.3 Comparison of the Kirchhoff-Huygens and the Differential Reflectivity Approaches

The Kirchhoff-Huygens approach assumes that the total field at the surface of the scattering body is known and then obtains the scattered field at an observation point by integrating over the surface current and charge densities equivalent to the total fields. In order to obtain the total field at the surface it is necessary to obtain the reflected fields by either an exact or approximate solution to boundary value problem. One method of approximating the boundary value problem is the assumption that the incident electromagnetic wave is reflected at every point of the surface as though an infinite plane wave were incident upon an infinite tangent plane at the point.

The differential reflectivity approach asserts that the reflected Hertzian potential field is describable by a surface integral of a dyadic differential reflectivity operating on the incident field. The dyadic differential reflectivity utilizes the reflection of a weighted plane wave family corresponding to the incident field at a point on the body. An assumption is made that any member of the plane wave family is reflected by an infinite tangent plane at the point.

Both methods require surface integration and that the reflected field at a point is obtained through the use of the "tangent plane approximation." A point of dissimilarity is that the Kirchhoff-Huygens approach approximates the incident field at a point by an infinite plane wave and the differential reflectivity approach does not make this assumption. Consequently, an investigation will be made of the comparison of the two methods with the objective of determining the relationship of the two methods.

4.0 Papers Submitted

"A Bistatic Radar Method for the Determination of ϵ and μ for a Smooth Spherical Target," by A. Erteza and J. A. Doran. (Submitted to RADIO SCIENCE, Journal of Research of NBS/USNC-URSI, Section D.)

5.0 Travel

The following trip was made by research personnel for the purpose of discussing research work, attending technical conferences, and exchanging research notes with other people in this and allied fields.

Mr. J. A. Doran attended the fall URSI meeting at Dartmouth College, Hanover, N. H., in October, 1965.