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Some Remarks on the Use of Statistics in Radar Astronomy

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In a recent note H. S. Hayre presented a discussion of the relationship between terrain roughness statistical parameters, and he concluded that a statistical analysis of the radar return from a rough surface can yield useful information in terms of these parameters. While his conclusions in this connection are certainly justified by the results of terrestrial radar scattering experiments, the validity of these conclusions in general, at least insofar as the detailed results are concerned, is still open to question.

Hayre's [1963] conclusions are based partly on a theoretical analysis and partly on assumptions which are empirical in nature. The fact that *terrestrial* measurements have borne out the conclusions can therefore be regarded as a justification for their use in interpreting *terrestrial* radar data. It does not follow, however, that the same justification exists for their use in interpreting lunar radar scattering data. This fact is indicated somewhat in recent work on related problems. Thus, R. K. Moore and A. K. Fung [1963], in an analysis of radar scattering from lunar and terrestrial surfaces, have come to the conclusion that a single exponential function is not sufficient to represent the autocorrelation function for surface height deviation from the mean at both normal incidence and grazing incidence. If the mean surface is flat this fact should be of little consequence since grazing incidence return is separated experimentally from normal incidence return in this case. However, in lunar measurements the mean surface is spherical, and this separation is not possible for geometrical reasons. Moreover, a theoretical analysis of the statistical distribution of specular points on a randomly perturbed spherical surface [I. Kay and P. Swerling, 1963] indicates that basic differences in the geometry of the mean surfaces may result in significant differences in the perturbation statistics for the two cases when the most natural assumptions are made in each case.

In any case, a more fundamental question arises in connection with the use of statistical analysis to interpret radar scattering data from a distant body such as the moon. This question has to do with the nonuniqueness of the possible models which explain the scattering phenomena. The fact that a theory is self-consistent does not necessarily indicate that it is correct. The doubt which should exist about the correctness of a theory, despite its self-consistency, varies inversely with the amount and variety of experimental data available. In the case of the lunar scattering data, it seems quite clear that it is insufficient to permit a decision on the validity of the rival lunar scattering theories to which Hayre referred in his introduction. A reference to the various papers cited indicates that all of the theoretical models are consistent with the available radar scattering data, and in fact that the theory of Senior and Siegel is, in addition, consistent with completely independent experimental results, namely, the results of passive radiation measurements as well as the active radar measurements.

A major objection to an overemphasis of the fact that a semiempirical statistical theory of lunar radar scattering is self-consistent is that it tends to obscure the real point at issue between the rival theories. This point has to do primarily with the differing values of the lunar surface permittivity predicted by the theories. A careful examination of the arguments leads one to the conclusion that the lack of agreement in the prediction of the surface permittivity has nothing to do with the use or nonuse of a statistical theoretical model. This disagreement is a result, simply, of a disagreement as to the number of lunar surface specular points which contribute to the initial unresolved radar return from the moon's leading edge. If it is assumed that the leading edge is so smooth that only a single specular point contributes to this unresolved return the surface permittivity predicted will be considerably higher than is the case when it is assumed that many specular points contribute to the unresolved return. Thus, in order to settle the argument it would be necessary to perform a radar scattering experiment in which a much smaller region around the leading edge of the moon is resolved without question.

As for the general validity of using a statistical model to describe properties of a rough surface, both theory and experiment have, indeed, supported the value of such models. However, some caution should be exercised in such applications of statistics, in particular to a single sample from a random population. Whenever the results of such an analysis refer to averages of random samples one may be able to justify this type of procedure. However, it is questionable whether the lunar scattering experiments are in effect taking random samples of the moon's surface. Thus, the presently recorded radar return from the leading edge of the moon may not be due to a typical sample from the population of surfaces which characterizes the statistics of the lunar surface. The question of what would constitute an adequate sample is, in fact, further complicated by the geometrical configuration in this case.

5. References

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