SURFACE SCATTERING PROPERTIES FROM LUNAR RADAR POLARIZATION DATA

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Radar backscatter images of the moon have been collected since the 1960's. Recent improvements in the spatial resolution of these measurements (Zisk *et al* ; Thompson, this volume) has led to a resurgence of interest in the study of scattering mechanisms as indicators of geologic surface properties. This report summarizes our efforts to define relations between polarized and depolarized radar echoes and the dominant surface scattering mechanism.

Lunar radar images are constructed by the delay-doppler technique (1). The data under study consist of digital images, whose digital number (dn) values correspond to varying levels of returned echo strength in polarized and depolarized modes. Circularly polarized energy is transmitted and received. The energy which returns in the same polarization as the transmitted signal is termed depolarized, while energy received in the opposite handedness to the transmitted signal is termed polarized (or expected).

Several factors influence the strength of returned radar echoes. The dominant mechanisms affecting polarized and depolarized returns are roughness (affected by surface rock exposure or regolith sculpturing), local tilt (deviation from local horizontal), dielectric constant variations (related directly to reflection coefficient), and changes in surface facet population (defined below). Each mechanism produces mathematically related changes in polarized and depolarized echo. The relations between the two received polarizations for the various scattering mechanisms and viewing geometries allow us to identify areas for which the variations in returned signals exhibit the behavior of a single mechanism.

Radar backscatter energy is considered to be a sum of two components: quasi-specular and diffuse. Quasi-specular returns are thought to be caused by reflections from surface facets, whose surface normals coincide with the incident radar ray. The population of these facets has been modeled by Hagfors as a one-parameter set of slope distributions which yield theoretical expressions for quasi-specular backscatter as a function of incidence angle (2). The mean backscatter from the lunar surface peaks at low incidence angles (near nadir), and approaches a cosine behavior at high angles. This mechanism produces only polarized return energy.

Diffuse scatter is probably produced by multiple reflections of the radar energy by irregularities on or just beneath the surface. It is observed (5) that the mean behavior of the moon for this mode is Lambertian; incident energy is radiated isotropically over the entire emission angle range. The observed cosine dependence of diffuse power with incidence angle is thus due entirely to projected area effects. By definition, diffusely scattered energy is split evenly between the depolarized and polarized modes. The depolarized echo strength thus equals the diffuse component of the polarized return. This relation allows us to separate the two components of the polarized echo.

The relations between polarized and depolarized echoes for each scattering mechanism are now summarized. An increase in surface roughness from some mean value will produce equivalent power increases in both polarizations. This occurs because roughness affects only the diffuse return, and any change in this component is distributed evenly between both modes. A deviation in surface slope from local horizontal causes the diffuse and quasi-specular returns to shift along their respective cosine and Hagfors (C-factor) behavior curves. Changes in dielectric constant manifest themselves as multiplicative increases in the power returned in both modes. The ratio of the multiplying factors for the two polarizations may depend on the terrain characteristics, particularly the regolith depth and percentage of exposed rock.

The mean backscatter behavior of the moon at several wavelengths has been tabulated (3). The 70 cm. wavelength data under study (4) are presented as a digital image whose dn values are the logarithmic representation of the ratio between observed backscatter power and that expected from the published tables. Figure 1 presents a scatter plot of depolarized and polarized dn values for an area of cratered highlands (5°S-45°S, 5°W- 5°E). Figure 2 presents a similar plot for a mare region (10°S-15°S, 15°W-55°W). The intersection of the two lines represents points on the lunar surface for which the expected and observed power are the same. The four quadrangles defined by these axes bound dn pairs which are produced by combinations of the above-mentioned scattering mechanisms. The quadrangles (sectors) are numbered by mathematical convention. Sectors 1 and 3 contain dn pairs with symmetric sign deviations from the mean; i.e., in sector 1, both polarized and depolarized echo power exceed their expected values. These pairs occur due to changes in roughness, dielectric constant, or local tilt, which affect both modes as explained above.

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Dn pairs which fall in quadrangle 2 require a polarized return power above the mean accompanied by a depolarized echo below the mean. This is thought to occur due to an earth-facing local tilt accompanied by a drop in surface roughness. In such a situation, the increase in quasi-specular return due to the tilt would offset the loss in the diffuse polarized component caused by the decrease in roughness. The depolarized power, unaffected by the quasi-specular component, would simply reflect the drop in diffuse return. The low frequency with which this occurs in the data (less than 2% for both areas studied) indicates that it is not a common phenomenon.

Quadrangle 4 contains dn pairs for which depolarized power is above the mean and polarized power is below that expected. Such a situation requires a drop in facet population, and thus quasi-specular return, large enough to offset the increase in diffuse return caused by roughness, tilt, or dielectric variations. Decreases in facet population (C-factor) may be linked to increases in surface roughness, which reduce the surface area available to the quasi-specular mechanism. At low incidence angles, where small changes in C-factor produce large variations in the expected polarized power, this should be an important behavior. This hypothesis is supported by the distribution of incidence angles among quadrant 4 points in both study areas. The majority of these points occur at low incidence angles (less than 30°), with the population of pixels dropping dramatically with increasing angle.

REFERENCES

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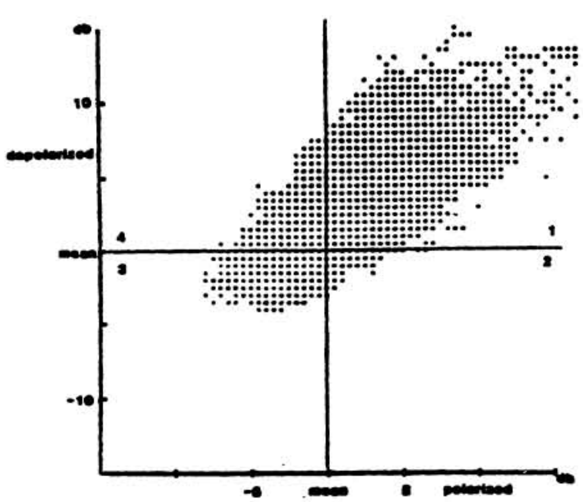

Figure 1

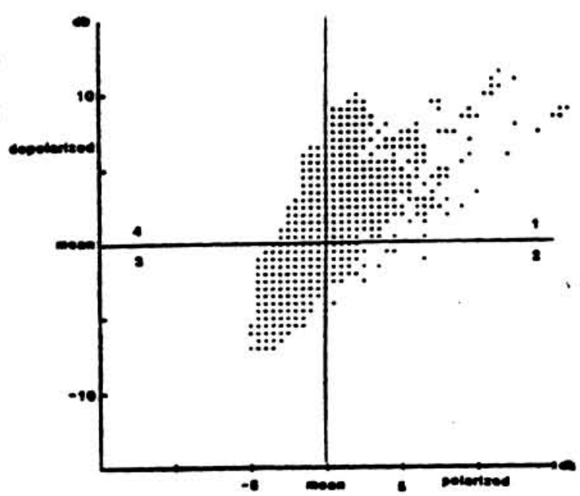

Figure 2

FIGURE CAPTIONS

[1] Scatter plot of depolarized vs. polarized dn values (in db) for a cratered highland terrain. Location: 5°S-45°S, 5°W-5°E. Sample size: 40,000 data points. Graph quadrants labeled.
[2] Scatter plot of depolarized vs. polarized dn values (in db) for a mare terrain. Location: 10°S-15°S, 15°W-55°W. Sample size: 20,000 data points. Graph quadrants labeled.