LUNAR DIELECTRIC CONSTANTS FROM RADIO THERMAL EMISSION MEASUREMENTS; J.L. Margot[1], D.B. Campbell[1], B.A. Campbell[2], and B.J. Butler[3], [1]Department of Astronomy and Space Sciences, Cornell University, Space Sciences Building, Ithaca, NY 14853, [2]Center for Earth & Planetary Studies, National Air & Space Museum, Washington, DC, 20560, [3]National Radio Astronomy Observatory, P.O. Box 0, Socorro, NM 87801.

Thermal emission from the Moon at 21 cm was measured in all four Stokes parameters with the Very Large Array (VLA). The polarization properties of the emission are determined primarily by the dielectric constant of the regolith material, the fraction of the emergent radiation that is diffused, and the surface roughness on scales larger than the wavelength. Estimates of the dielectric constant were obtained at ~90 km resolution and the smooth sphere values range from ~2 to ~4. Results are illustrated for the Crisium area where the mare regions have dielectric constants ~2.7 and highland regions have values of ~2.4. A map of the dielectric constant shows that the various regions correlate well with 70 cm radar data. Using a facet model, it is shown that the observed variations around Crisium cannot be accounted for by roughness at very large scales. Previous estimates of lunar rms surface slope are used to provide absolute measurements of the dielectric constant. For negligible diffusion of the emission by wavelength-scale structure at the surface, the values of the dielectric constant corrected for roughness are ~2.7 for Mare Crisium and ~2.5 for the surrounding highlands. These variations could be explained by near-surface density changes (mare density ~1.52 gcm^{-3}, highlands density ~1.41 gcm^{-3}), where the dichotomy is consistent with heavier basaltic materials dominating the mare regolith.

The observations were performed with the VLA[1] in its most compact (D) configuration on April 12–13, 1995. A single 6 hour observation was sufficient to provide adequate sampling of the visibility function. At a wavelength of 21 cm, the synthesized resolution is 50", or ~90 km at the center of the lunar disk. Emission was measured in two circular polarizations from which the Stokes parameters were derived. Deconvolution of the data was performed in each Stokes parameter using the Clean algorithm. The cleaning process was started with an initial guess based on the expected polarization response from a smooth dielectric sphere. Residual rms temperature noise values are 1.7 K, 0.3 K, and 0.4 K in the I, Q, and U Stokes parameters respectively.

Estimates of the dielectric constant can be obtained due to differences in the thermal emission parallel and perpendicular to the plane of emission at the regolith-vacuum interface. For a smooth surface with dielectric constant ϵ and zero conductivity, the ratio of brightness temperatures is [1]

$$\frac{T_{\parallel}}{T_{\perp}} = \frac{\epsilon(\cos\theta + \sqrt{\epsilon - \sin^2\theta})^2}{(\epsilon\cos\theta + \sqrt{\epsilon - \sin^2\theta})^2}, \tag{1}$$

where θ is the emission angle. This ratio can be related to the degree of linear polarization $m = (Q^2 + U^2)^{1/2}/I$. Images of the I, Q and U Stokes parameters are used to compute these quantities on a pixel by pixel basis, and equation (1) is inverted numerically.

A map of the dielectric constant around Mare Crisium is shown in figure 1 (a). These values are not corrected for large-scale roughness or surface diffusion of the emergent radiation. Figure 1 (b) is an Arecibo 70 cm radar backscatter map of the same region [2]. Comparison of the two figures reveals that the mare units display higher dielectric constants than the surrounding highlands. As shown by the histogram on figure 1 (c), a typical range of values for the Crisium area highlands is $\epsilon = 2.4$, with $\epsilon = 2.7$ for the mare regions. A facet model similar to that used by Golden [3] and Arvidson et al. [4] demonstrates that such a change cannot be accommodated by large-scale

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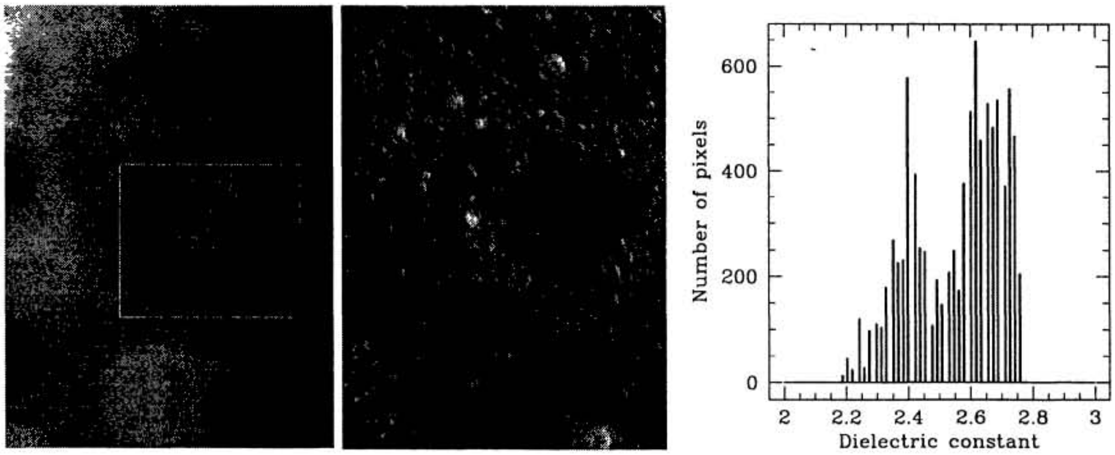

Figure 1: (a) Dielectric constant map in orthographic projection of the Mare Crisium area obtained from thermal emission at 21 cm. Selenographic latitudes are from -10° to 42°, longitudes are from 30° to 70° East. Emission angles vary from 50° to 70°. Mare Fecunditatis is seen at the bottom of the image and the edge of Mare Tranquillitatis is seen at the left. (b) Arecibo radar backscatter map of the same region at 70 cm. (c) Histogram of dielectric constant values from the rectangular area in (a).

roughness variations for reasonable values of lunar rms surface slope. Previous estimates of the rms surface slope in highland regions indicate values of 8° [5] to 10° [6]. Assuming negligible diffusion of the emergent radiation by wavelength-scale structure, the values of the dielectric constant corrected for rms slope variations are $\sim$2.7 for Mare Crisium and $\sim$2.5 for the surrounding highlands. A contribution from diffuse emission at the boundary would tend to raise both of these values. Using a relationship between dielectric constant and density [7], these measurements yield densities of $\sim$1.52 gcm^{-3} and $\sim$1.41 gcm^{-3} respectively. This change is consistent with the greater density of the basalts which make up the mare regolith, in contrast to the lighter materials which comprise the highlands.

References

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