HIGH-RESOLUTION RADAR MAPS OF THE LUNAR SURFACE
AT 3.8-cm WAVELENGTH

S. H. ZISK, G. H. PETTENGILL,* and G. W. CATUNA
Haystack Observatory, Massachusetts Institute of Technology, Westford, Mass., U.S.A.

(Received 30 June, 1973)

Abstract. The entire earth-facing lunar surface has been mapped at a resolution of 2 km using the 3.8-cm radar of Haystack Observatory. The observations yield the distribution of relative radar backscattering efficiency with an accuracy of about 10% for both the polarized (primarily quasi-specular or coherent) and depolarized (diffuse or incoherent) scattered components. The results show a variety of discrete radar features, many of which are correlated with craters or other features of optical photographs. Particular interest, however, attaches to those features with substantially different radio and optical contrasts. An anomaly near 63° is noted in the mean angular scattering law obtained from a summary of the radar data.

1. Introduction

Observations of the Moon by radar over the past two decades have produced much information on the average backscattering properties of the lunar surface over a wide range of wavelengths. The observed distribution of echo power with delay and/or doppler frequency has been interpreted as caused by reflections from a relatively smooth, undulating surface, with the shape of the distribution determined by the average slope of this surface**. In addition to this coherent, quasi-specular component, an incoherent, largely unpolarized diffuse component is seen in the echoes originating some distance from the center of the disk and has been interpreted as originating in wavelength-sized structure, primarily associated with rocks on or near the surface. This interpretation has been strengthened by the discovery of anomalously enhanced, incoherent radar echoes from the region of the crater Tycho (Pettengill and Thompson, 1968), a crater known to be bright on optical photographs, to possess an extensive system of surface rays, and to display a strong thermal enhancement under eclipse conditions.

The first article in this series (I) discussed the general method of high-resolution measurements of the radar backscatter from the lunar surface (Pettengill et al., 1973). Article II (Thompson, 1973) contains the results of such a set of measurements at a wavelength of 70 cm. In this article (III), we present a set of measurements at 3.8-cm wavelength. At this wavelength we expect to be sensitive to roughness at a scale of from 1 to 50 cm, as compared to a scale of 20 to 1000 cm at 70-cm wavelength. A comparison of the data at the two wavelengths with each other and with optical photographs and other data yields clues to the age and history of many features of the

* Now at Department of Earth and Planetary Sciences, M.I.T.
** See Evans and Hagfors (1971) for an excellent review and bibliography.
lunar surface. Some rudimentary conclusions from the 3.8 cm data alone are given at
the end of this paper. The last article (IV) in this series presents a more elaborate
analysis of a variety of lunar features, incorporating both sets of radar data as well as
other sources of information.

The high-resolution radar maps have revealed a number of unusually strong radar
backscattering regions, some of which are correlated with bright optical features and
some with regions having atypically large thermal conductivity. It appears that the
radar data may permit differentiation among surface features that are not so clearly
distinguished by other means.

This paper describes the latest 3.8-cm measurements of the Moon, and presents a
summary of the results as a series of maps of the ‘polarized’ and ‘depolarized’ radar
echoes*. Section 2 of this paper contains a description of the experiment insofar as it
differs from the general description given in Article I, and explains the calibrations and
sources of inaccuracy in determining the selenographic coordinates and backscattered
power. Section 3 describes the results in general terms, and also contains a brief anal-
ysis of several regions of the surface in some detail.

2. Experiment

A. GENERAL DESCRIPTION

The purpose of the radar measurements presented here was to obtain highly resolved
maps of the surface scattering characteristics at a wavelength of 3.8 cm from the
entire earthside hemisphere of the Moon. While the radar surface resolution of about
2 km is only slightly worse than the best obtainable at optical wavelengths with earth-
based telescopes, the scattering in the two cases is presumable associated with very
different scales of surface structure. Thus the combination is a powerful aid in under-
standing surface geometry. The radar resolution was obtained with coherent-pulse
analysis (‘delay-doppler mapping’) as described in Article I, using the Haystack radar
and post-processing system. The detailed parameters used in the observations are
listed in Table I.

Each lunar observation (run) at Haystack, using the two-way, half-power angular
beam diam of 3.1 arc min, could cover a projected area on the lunar surface with an
extent of about 400 km. For simplicity, a standard mapping unit on the lunar surface
with a size of approx 380 km was adopted. Through the selection of one of five
different pulse lengths (see Table I) the delay resolution projected on the lunar surface
was kept at approx 2 km for all observations. A series of 190 successive time samples,
at intervals of the pulse length, covered the standard mapping unit in each case.

A similar adjustment of the frequency resolution was made through the choice of
interpulse interval (reciprocal of the pulse repetition frequency), so that the corre-
sponding surface resolution would also be approx 2 km in the direction of maximum

* The term ‘polarized’ as used in this paper has the usual meaning: that sense of echo polarization
which corresponds to specular reflection from a smooth plane interface at normal incidence. The term
‘depolarized’ corresponds to the orthogonal sense.