EARTH-BASED MEASUREMENT OF LUNAR TOPOGRAPHY USING DELAYED RADAR INTERFEROMETRY; N.J.S. Stacy and D.B. Campbell, National Astronomy and Ionospheric Center and Dept. of Astronomy, Cornell University, Ithaca, New York 14853.

Radar interferometry has been applied to radar mapping of the surface of Venus to resolve the ambiguity in the backscatter from the areas with the same delay-Doppler coordinates [1]. For observations of the Moon these points are usually isolated by the small extent of the area illuminated by the radar beam so interferometric techniques can be used to determine a third dimension to the location of the radar backscatter [2]. Recent observations of Sinus Iridum (45.1°N, 31.0°W) using the Arecibo Observatory S-Band radar system (12.6 cm wavelength) in April and August 1992 have yielded a pair of images viewed with a very small 0.042° difference in incidence angle. These images can be used as a delay interferometric pair and have been correlated to generate phase fringes that are related to topography. The spatial resolution of the images are 18 m in delay and 33 m in cross range (Doppler). The anticipated topographic resolution once the phase fringes have been unwrapped is approximately ±10 m.

In 1972 Zisk [3, 4] used the Haystack radar system with a nearby communications antenna as an interferometer with a baseline of 1.2 km to map the Alphonsus-Arzaehel region on the Moon at a pixel resolution of 1-2 km and height accuracy better than 500 m. In such an interferometric experiment one antenna transmits a signal to the Moon and both antennas simultaneously receive the echo. Two complex (as in magnitude and phase) delay-Doppler images of backscatter cross section are processed from the two receive signals. The interferometric information is contained in the phase difference between individual pixels, estimated from the phase in the complex product of one image with the complex conjugate of the second image.

Recent Arecibo Observatory S-Band radar observations of the Lunar surface have resulted in several images with spatial resolutions better than 40 m. Unfortunately due to the design of this radar system the main antenna can not receive the Lunar echo because of the small round trip time so the auxiliary antenna, previously used with the main antenna for interferometric observations of Venus, is used as the receiving antenna. An alternative to having two antennas simultaneously receive the same echo is to image the same area twice with a small difference in viewing geometry. This two pass method of radar interferometry, which we refer to as “delayed interferometry”, has been successfully used with data from SAR systems orbiting the Earth such as Seasat [5] and the Shuttle Imaging Radar B (SIR-B) [6]. The constraint on the viewing geometry difference can be defined in terms of a viewing geometry correlation function [7],

\[
\rho_{view}(\Delta \theta) = 1 - \frac{2 \delta_{sr}}{\lambda \tan \theta_i} \Delta \theta
\]

where \( \delta_{sr} \) is the slant range resolution and \( \theta_i \) is the incidence angle so \( \delta_{sr} / \tan \theta_i \) is the height of the range resolution projected onto a plane orthogonal to the Earth-Moon vector. If \( \Delta \theta \) is zero then the two images have been viewed with exactly the same geometry and there will be no decorrelation due to viewing geometry and there will also be no topographic information. If \( \Delta \theta = \lambda \tan \theta_i / 2 \delta_{sr} \), the two-way beam width of the projection of the range pixel, then the data in the two images are decorrelated and the phase difference will have no topographic information. For the high resolution S-Band Lunar observations the slant range resolution is 15 m so the maximum viewing geometry difference is 0.24 \( \tan \theta_i \) degrees. Such a small difference in viewing geometry requires a very close alignment of the Earth-Moon system. Since observations of the Moon from Arecibo Observatory are restricted to the period in each month when the Moon is above the equator and the period each day when the Moon is near zenith there are a limited number of observation times with closely repeated geometries. A careful examination of the Lunar 1992 ephemeris found three opportunities where the viewing geometry was less than the viewing decorrelation limit. Data was successfully acquired for one of these opportunities in April and August for a 200 km by 400 km area centered on Sinus Iridum at 45.1°N, 31.0°W. Twenty four minutes of data from each observation were processed using a new focused delay-Doppler technique to images of complex radar backscatter. The preliminary results from correlation of two 512 by 512 pixel regions is shown in Figure 1. The incidence angle of the observation is 57° so the projected height of the range resolution is approximately one tenth the fringe spacing. The regular spacing of the phase fringes indicates that this is a relatively flat region of the Moon. The phase
fringe can be seen to deviate around the 2 km crater in the upper right part of the image indicating that the rim of this crater may be 300 m higher than the surrounding terrain.

References


Figure 1: Images of the delay-Doppler backscatter and interferometric fringes in the center of the April and August Sinus Iridum data sets. Each image is corresponds to an area on the Moon approximately 17 km by 9.2 km. The original image resolution is 18 m in delay and 33 m in Doppler. The two backscatter images have been averaged by a factor of 4 in delay and 2 in Doppler to 72 m by 66 m pixels to reduce speckle noise. A phase ramp with period of 9.5 pixels has been removed from the phase image which was then averaged by a factor of 4 in range and 2 in Doppler to reduce noise.