LABORATORY MEASUREMENTS OF RADAR TRANSMISSION THROUGH DUST WITH IMPLICATIONS FOR RADAR IMAGING ON MARS. K.K. Williams and R. Greeley, Department of Geological Sciences, Arizona State University, Tempe, AZ 85287-1404, e-mail: kkw@asu.edu.

Introduction: As NASA’s exploration plan for Mars advances with additional missions, the type and abundance of data increase. High-resolution images are revealing numerous wind-related features and suggest widespread distribution of aeolian deposits. These deposits reflect the current and past wind regimes on Mars, but they also obscure some of the bedrock geology. A complementary experiment to those already proposed for Mars would be a Synthetic Aperture Radar (SAR) mission [1]. Because such a mission is constrained by antenna size and power, it is important to understand radar penetration through aeolian materials such as sand and dust so that the most effective radar frequencies would be used.

Background: There have been many studies of radar penetration of sand in arid areas such as the Sahara Desert [2,3] and the U.S. Southwest [4]. The earliest works showed that L-band (λ=24 cm) radar was able to penetrate 1-2 meters of extremely dry sand [e.g. 3] to return images of the subsurface obscured by the sand. These radar images of the subsurface revealed ancient river channels that existed prior to the Sahara Desert [2] and have greatly added to the understanding of the climatic history of that region.

A previous study of the ability of radar to penetrate sand involved laboratory measurements of the attenuation of a radar signal as it passed through quartz sand [5]. That experiment was conducted over a frequency range of 0.5-12.6 GHz and for moisture contents of 0.3-10.7 % [5]. Results showed that the lowest frequency (longest wavelength) signals penetrated through dry sand with an attenuation of less than 5 dB/m. Those frequencies enable deeper subsurface imaging but require a larger antenna. The experimental results for higher frequencies showed higher attenuations and thus less ability to penetrate. However, depending on the sensitivity of a Mars SAR, the higher frequencies could be used to penetrate several meters of sand using a smaller antenna.

The results of [5] provide information on the ability of radar to penetrate sand over a large frequency range; however, a Mars radar imaging system could also penetrate dust (i.e., possibly 20 μm). Although some dust deposits on Earth have been covered in radar images, most radar penetration studies of geologic materials have focused on sand. Because a large part of Mars could be mantled by dust, it is important to understand the ability of radar to penetrate dust.

Experimental method: The Electromagnetic Anechoic Chamber at Arizona State University was used to measure the radar signal transmitted through a sample container holding the dust (Fig. 1). The base of the container was made of plywood and the sides were made of Plexiglas. The radar emitter was supported above the sample container and the receiver was under the container. The transmitted signal was measured over four frequency ranges: 0.5-2, 2-6, 6-8, and 8-12 GHz. 801 measurements were made over each frequency range. Transmission was measured with the empty sample container in place and at dust thickness levels of 10, 20, 30, and 40 cm.

Fig 1. Experimental setup showing surrogate Mars dust (CRC) in Plexiglas sample box. Radar emitter is above the sample and the receiver is below the sample box.

Average grain size of the dust used in the experiment is 2 μm [6]. It was desired to emplace the dust in a way that would model dust deposition out of a dust cloud (e.g. [6]), but the time necessary for 40
cm of dust to settle out of a cloud restricted that method. Instead, a combination of a sieving box with two screens and a hand sifter was used to deposit the dust to measurement levels.

**Results:** The transmission data are processed by normalizing the measurements to those of the empty box. This removes the effects of the box and allows consideration of the change in transmitted signal at the various dust thickness levels (Fig. 2). Because the plywood base of the box is a dielectric material, it causes absorption of the signal at certain frequencies. In this experiment, the absorption occurs at frequencies of 2 and ~4.5 GHz, and these patterns cause peaks and dips in the data normalized to the empty box. Further processing and masking of the data will remove those effects.

**Fig. 2.** Graph showing normalized radar signal transmitted through dust with thicknesses of 10, 20, 30, and 40 cm.

Even though the interference patterns cause jumps in the curves, figure 2 still shows how the normalized radar signal decreases as the dust thickness increases. Figure 2 also displays the greater decrease at higher frequencies that is expected for radar penetration. The measurements of transmission are used to calculate attenuation values that can be compared to other measurements of radar penetration. At frequencies less than 2 GHz (corresponding to wavelengths of 15-60 cm), the calculated attenuation is less than 6 dB/m. At 9.6 GHz (X-band), the attenuation rises to 67 dB/m. Calculations of attenuation are important for understanding the potential of radar systems at various frequencies to penetrate estimated thicknesses of geologic materials.

A comparison of attenuations calculated from figure 2 to values calculated for dry quartz sand [5] illustrates the importance of considering the compositions of Martian sand and dust. At frequencies <2 GHz, Carbondale Red Clay (CRC) dust causes attenuations ~6 dB/m whereas dry quartz sand causes <4 dB/m. At 9.6 GHz, CRC dust causes 67 dB/m and dry sand causes 23 dB/m. The greater attenuation caused by the dust is likely due to the presence of hematite resulting in a higher dielectric constant of the material. However, the higher attenuation of the CRC dust is ~3 times lower than values calculated for sand with a 5% moisture content [5].

Although the aeolian materials on Mars are expected to contain iron-rich materials such as hematite, an orbital imaging radar could be used to reveal subsurface geology that has been obscured by those materials if appropriate radar frequencies are used. Size constraints of the antenna for a Mars SAR mission need to be considered when choosing the frequencies that will be used, and results from this experiment and others will be beneficial in choosing those frequencies.

**Summary:** From these results, we suggest that a SAR at P-band or L-band frequencies would be able to penetrate through dust mantling as great as 3 m to record the subsurface geology. This suggestion takes into account the two-way distance through the sand that the radar signal must travel. It also assumes that the SAR system would be able to detect a reflected signal that has been decreased by 35 dB due to the radar signal traveling through the dust.

**Acknowledgement:** We thank G. Beardmore and D. Ball at ASU and C. Birtcher in the ASU Electromagnetic Anechoic Chamber. This work was supported in part by a NASA Graduate Student Researchers Program fellowship through JPL.