

A ROVER DEPLOYED GROUND PENETRATING RADAR ON MARS. J.A. Grant¹, B.A. Campbell¹, and A.E. Schutz², ¹Smithsonian Institution, Center for Earth and Planetary Studies, MRC 315, Washington, DC 20560, grantj@nasm.si.edu, ²Geophysical Survey Systems, Inc., 13 Klein Drive, North Salem, NH, 01950.

Introduction: Radar is a fundamental tool capable of addressing a variety of geological problems on Mars via collection of data suitable for interpreting variations in surface morphology and reflectivity [e.g., 1-5]. Surface-deployed ground penetrating radar (GPR) can help further constrain the geology and structure of the near surface of Mars by directly measuring the range and character of *in situ* radar properties [6-7]. In recognition of this potential, a miniaturized, easily modified GPR is being developed for possible deployment on a future Mars rover and will enable definition of radar stratigraphy at high spatial resolution to depths of 10-20 meters. [7-8].

Ongoing development of a Mars impulse GPR with industry partners at Geophysical Survey Systems, Inc., focuses on design and testing of a prototype transducer array (with both high frequency bistatic and low frequency monostatic components) in parallel with fabrication of a low power, mass, and volume control unit. The operational depth of 10-20 meters is geared towards definition of stratigraphy, subsurface blocks, and structure at the decimeter to meter scale that is critical for establishing the geologic setting of the rover. GPR data can also be used to infer the degree of any post-depositional pedogenic alteration or weathering that has subsequently taken place, thereby enabling assessment of pristine versus secondary morphology at the landing site.

As is the case for most remote sensing instruments, a GPR may not detect water unambiguously. Nevertheless, any local, near-surface occurrence of liquid water will lead to large, easily detected dielectric contrasts. Moreover, definition of stratigraphy and setting will help in evaluating the history of aqueous activity and where any water might occur and be accessible. Most importantly perhaps, GPR can provide critical context for other rover and orbital instruments/data sets. Hence, GPR deployment along well positioned transects in the vicinity of a lander should enable 3-D mapping of stratigraphy and could serve to guide direct subsurface sampling.

Platform Constraints: Development of a GPR compatible with deployment on Mars requires consideration of rover interfaces, operational requirements, and associated likely limits on instrument mass, power, volume. We adopt the Mars Exploration Rovers (MER) design being tested for the 2003 Mars mission as a proxy for rovers to be operated on Mars in the next 10 years. Interface requirements associated with these

rovers influence our targeted mass, power, and volume limits of 0.5 kg, 3W (peak), and 3400 cc, respectively. Because many rover components (including the wheels) will likely be metallic, and because electrostatic charging by dust may be important, the GPR will need to be in a sealed metal box and grounded to the rover frame. More significant design modifications required by electrostatic charging are unlikely: the above ground deployment of a bistatic transducer precludes the need for isolation from the rover and any unexpected problems associated with the low frequency component could ultimately be mitigated by utilizing the rover as part of the antenna.

Transducer Design: Development of a “breadboard” GPR antenna (Fig. 1) has produced a “generic” array that permits easy modification for optimizing performance (e.g., by changing the width of the high frequency antenna fans to increase or decrease the center operating frequency). Because antenna frequency is a function of antenna length such modifications have no appreciable effect on system electronics.

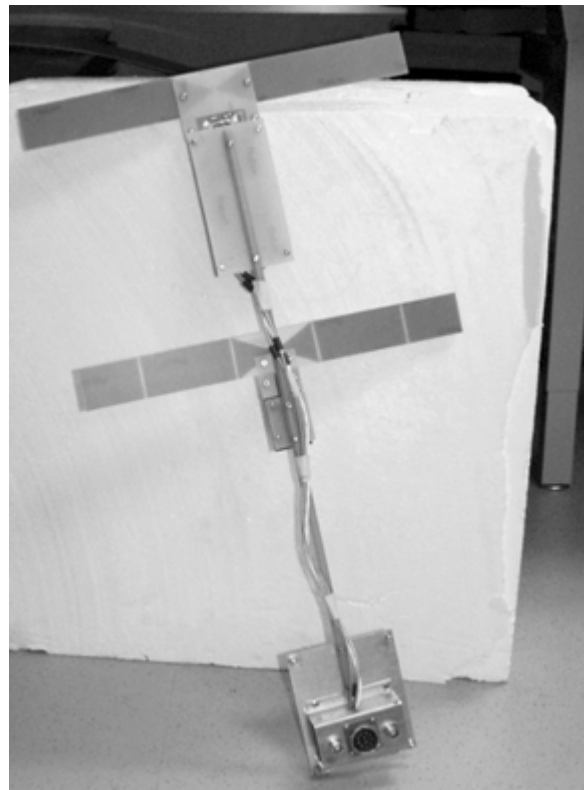


Figure 1. Field-tested breadboard transducer that has successfully defined radar stratigraphy to depths of ~15 meters (see Figs. 2 and 3). Note table leg for scale.

As a starting point, we assume that most Martian surfaces will be dry, possess dielectric values generally between 3-10, and have corresponding loss tangents of $\sim 0.01 \pm 0.005$ [e.g., 5, 9].

The transducer array includes both high frequency bistatic and low frequency monostatic “rat-tail” components. Each consists of a high-speed sample hold circuit that can incorporate an rf amplifier on its front end if desired. Deployment will likely involve a retractable bar with antenna components mounted at the outboard end, thereby enabling good separation from the rover (see Fig. 1).

Sample output from the high frequency antenna component is displayed in Figure 2. The bistatic nature of the high frequency antenna minimizes the “clear time” required and the antenna operates at 1.68 ns/cycle. The antenna possesses a center frequency of 600 MHz, and is capable of distinguishing radar reflections corresponding to stratigraphy to depths of ~ 15 meters. Construction involved standard parts and utilizes 38 cm-long resistively loaded dipoles mounted on a dielectric rod at a height of 15 cm above the ground.

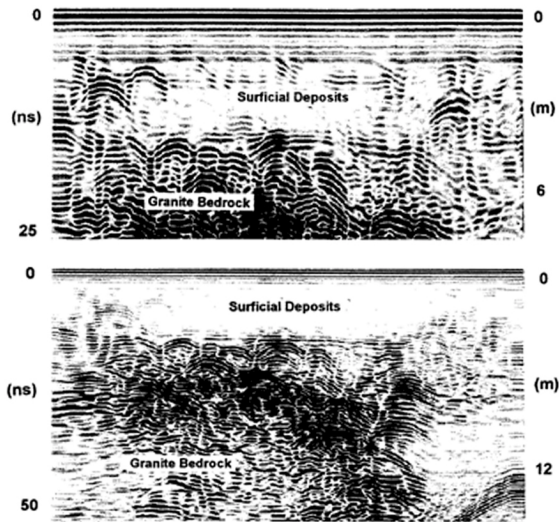


Figure 2. Sample data from high frequency bistatic transducer component. Data reveals stratigraphy associated with test-bed overlying unconsolidated sediments and granitic bedrock.

A prototype of a low frequency “rat-tail” antenna has also been tested (Figure 3). Initial operation required use of bi-statically configured, 40 cm long, resistivity loaded monopoles as antennas (central frequency 100 MHz) and confirmed the ability to distinguish reflections up to 15 m below the surface. A near-surface blind zone induced by ringing should be reduced by use of an improved T/R switch under development. Nevertheless, overlapping data from the higher frequency antenna component provides high resolution coverage of the “blind” zone.

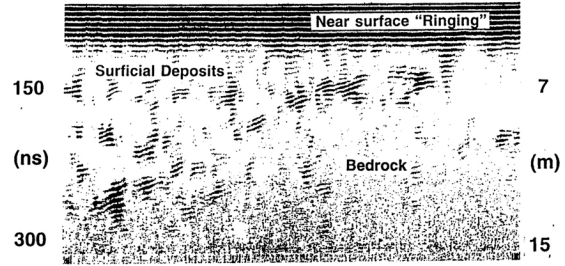


Figure 3. Sample data from the low frequency transducer component. Data corresponds to unconsolidated sediments overlying granitic bedrock.

GPR System Design: Design and construction of a complete “breadboard” impulse GPR is occurring simultaneously and involves consolidation of electronics and function to minimize mass and volume (e.g., onto a single board). Such a prototype rover-deployable GPR is a major stride towards achieving the stated mass, power, and performance requirements. The system will utilize the described antenna array and will operate at a range of up to 1000 nanoseconds. Antennas can be unshielded, as there will be no overhead objects that will behave as clutter targets, and because possible reflections from the rover will be stationary and therefore removable via post-processing of the data.

Synergy with a SAR: A Mars GPR provides an unique means of constraining data sets collected using alternate landed and orbital instruments. GPR data would be especially complementary, however, with that collected by an orbital synthetic aperture radar (SAR). An orbital SAR [10] operating at wavelengths comparable to a GPR (e.g., P-band or ~ 68 cm) can help constrain surface roughness, minimum thickness of surficial mantles, and occurrence of strongly absorbing deposits (e.g., carbonates). Hence, it could help target suitable landing sites for more detailed exploration using the rover-deployed GPR. Work funded by NASA PIDDP Grant NAG5-9658.

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