Radar Sounding of Mars: A Focus on MARSIS. A. Safaeinili[1], D. Biccari[2], O. Bombaci[3], D. Gurnett[4], W.T.K. Johnson[1], R.L. Jordan[1], R. Orosei[5], G. Picardi[2], J. Plaut[1], R. Seu[2], E. Zampolini[3], and C. Zelli[3]

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Radar has the unique capability of looking under the dry and cold surfaces of Mars. The depth of penetration of radio waves depends on a number of surface and subsurface parameters such as surface topography, subsurface geological structure and surface and subsurface electromagnetic properties. Among these parameters, the surface topography is known best largely due to valuable data provided by Mars Global Surveyor's MOLA instrument. However, little information is available on the electromagnetic properties and subsurface characteristics of Mars.

In early 2004, Mars Advanced Radar for Subsurface and Ionospheric Sounding (MARSIS) will attempt to reduce these uncertainties and look for evidence of present and/or past water on Mars. MARSIS is the result of an international collaboration between NASA, the Italian Space Agency (ASI) and European Space Agency (ESA) and is designed to sense the planets crust to a depth of up to 5 km. MARSIS' main objective is to search for water if it exists in liquid form under the surface. It will also attempt to map and characterize the subsurface geological structure of Mars. In addition to its subsurface exploration goals, MARSIS will study the ionosphere of Mars providing an extensive amount of direct measurements of the Martian ionosphere on a global scale. MARSIS is a challenging project and its design is pushing the envelope in all aspects including transmitter design, lightweight antenna design and on-board processing. MARSIS is designed with a high relative bandwidth over a frequency range extending from 0.1 MHz to 5.5 MHz. In the subsurface sounding mode, MARSIS has four distinct 1-MHz frequency bands centered at 1.8, 3.0, 4.0 and 5.0 MHz. Since operation at a low frequency is necessary in order to penetrate to a depth of up to 5 km below the surface, MARSIS has to be able to correct for the distortions that are introduced by the ionosphere. The ionosphere affects the MARSIS operation in three distinct ways: 1) radio wave dispersion, 2) radio wave attenuation, and 3) Faraday rotation.

The dispersion, if not compensated, impacts the depth resolution of the radar through broadening of the compressed radar pulse [1,2]. This broadening is a function of ionosphere electron column density and its profile shape (especially for frequencies close to the peak plasma frequency). For MARSIS, the ionospheric correction is carried out on the ground to maximize performance. In addition to dispersion, the ionosphere will also attenuate the radio wave. The level of attenuation depends on the ionosphere's electron density and its profile shape and the electron-neutral collision frequency [3,4,5]. Fortunately, information from past missions can provide some information on the expected level of attenuation. Figure 1 shows expected total radio wave attenuation under three different ionospheric conditions.

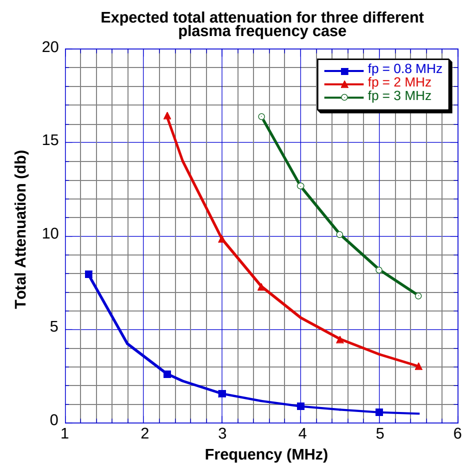

Figure 1: Expected ionospheric attenuation versus frequency for three different ionospheric conditions: 1) peak plasma frequency of 0.8 MHz (evening or High Solar Zenith Angle), 2) peak plasma frequency of 2 MHz corresponding to mid to late afternoon and 3) peak plasma frequency of 3 MHz corresponding to early afternoon conditions.

The third mechanism for the ionospheric distortion is the Faraday rotation [6]. When MARSIS was designed, the prevailing assumption was that the Mars magnetic field is so weak that, at HF frequency range, the impact due to the Faraday rotation is negligible. Recent MGS results have shown that this assumption does not hold for some areas of Mars, particularly in the southern hemisphere where regions with high magnetic field have been identified. Figure 2 shows the maximum expected Faraday rotation for about 80% of Mars where a maximum magnetic field of 50 nT is expected.

Due to limitations in the data down-link rate, on-board signal processing is required to reduce the data redundancy and maintain a reasonable data volume in order to achieve a significant coverage on a global scale.

This presentation will provide an overview of the spaceborne HF radar sounder operation at Mars with a focus on MARSIS operation environment and processing strategy. We will also discuss implications of lessons learned so far, in dealing with issues such as surface clutter and ionosphere, on the design of future orbiting sounders.

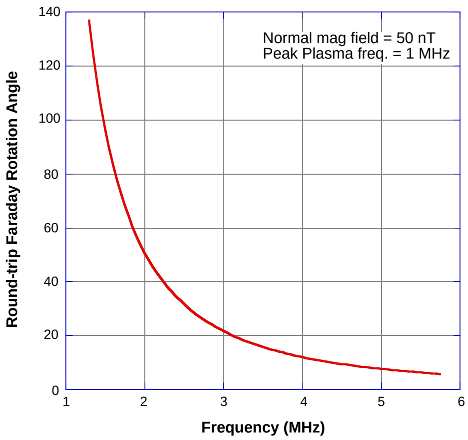

Figure 2: Expected Faraday rotation phase (degrees) for different frequencies when the peak plasma frequency of the ionosphere is 1 MHz and the surface-normal magnetic field component is 50 nT.

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