Can MARSIS Measure the Low-Altitude Components of the Mars Magnetic Field? A. Safaeinili, Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA 91109, *ali.safaeinili@jpl.nasa.gov*.

Introduction: Measuring the magnetic field anomaly of Mars at low altitudes (e.g. 100-200 km) can be an interesting application of Mars Advance Radar for Subsurface and Ionospheric Sounder (MARSIS). Due to a low HF operation frequency, the radio wave propagating in the ionosphere of Mars, over the magnetic anomaly regions, will be affected and distorted by the localized magnetic field. This distortion in the sounder signal is due to the Faraday rotation and provides information about the strength of the magnetic field. MARSIS is especially sensitive to the radial magnetic field at altitudes where the electron density in the ionosphere peaks (i.e. 100-200 km). Consequently, MARSIS is potentially capable of providing measurements for the radial component of the magnetic field at altitudes between 100 to 200 km that are normally out of reach for orbital magnetometers (with the exception of the aero-braking phase). Such low-altitude measurements would be complementary to already existing measurements at 400 km by MAG-ER on Mars Global Surveyor. This paper will explain the sensitivity of MARSIS as a magnetometer and the method envisioned to measure the radial magnetic field component.

MARSIS (Picardi et al.), the first major planetary radar sounder, is the result of an international collaboration between NASA, the Italian Space Agency (ASI), and European Space Agency (ESA), and will arrive at Mars in early 2004 for a two-year mission. MARSIS has a frequency range between 0.1-5.5 MHz and is designed to penetrate the subsurface to a depth of a few kilometers. MARSIS' primary objective is to map and characterize the subsurface geological structure of Mars, and search for subsurface liquid water reservoirs. The secondary objective of MARSIS is to study the ionosphere of Mars providing the most extensive amount of data on Martian ionosphere to date.

In addition to MARSIS, a second radar sounder named SHARAD (SHallow RADar) with operation frequency of 15-25 MHz is under development. SHARAD is an Italian instrument (Seu et. al) that will fly on NASA's Mars Reconnaissance orbiter in 2005. SHARAD can also provide magnetic measurements, however, it is not expected to be as sensitive as MARSIS to magnetic field variations.

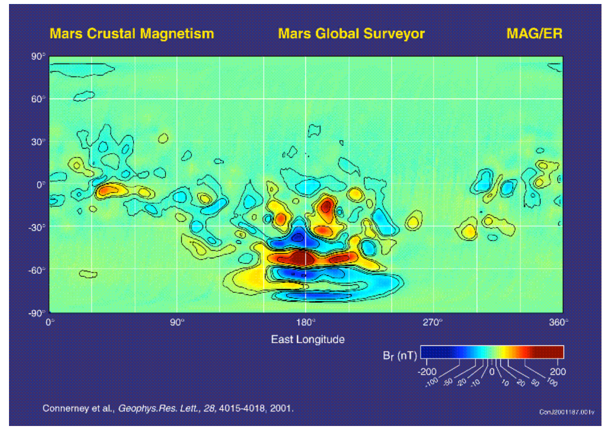

Figure 1: Radial component of the magnetic field at 400 km on Mars (from Connerney et al., 2001)

Magnetic Field Information In MARSIS Data: MARSIS echoes will contain information on the local magnetic field behavior. Generally, MARSIS is most sensitive to magnetic field when the electron density is high. However, even for orbits with night-time pericenter passes, there will be a detectable Faraday rotation for most magnetic anomaly regions including the one at 180 longitude in the southern hemisphere.

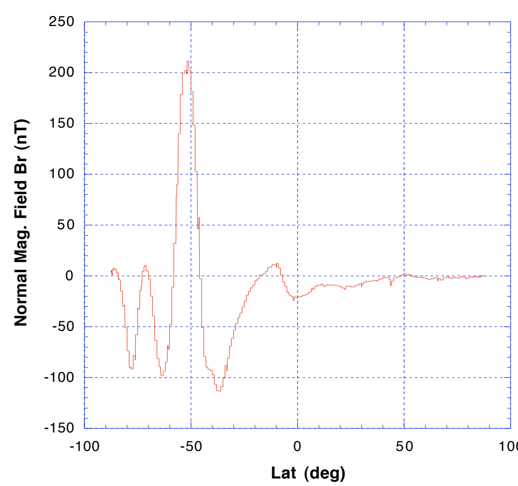

Figure 2: Radial component of the Mars magnetic field for a MARSIS orbit as a function of latitude.

Figure 2 shows the radial magnetic profile for MARSIS orbit with pericenter at the southern hemisphere (data from MAG_ER experiment data). The values are for magnetic field at 400 km altitude. The relationship between the magnetic field and the Faraday rotation can be written as (safaeinili et al.)

$$\frac{d\Omega(\omega)}{dz} = \frac{q_e}{2m_e c}\frac{\omega_p^2(z)B_r(z)}{\omega\sqrt{\omega^2 - \omega_p^2(z)}},$$

where q_e is the electron charge density, m_e is the mass of an electron, c is the speed of light, $B_r(z)$ is the altitude dependent radial component of the magnetic field, $\omega_p(z)$ is the altitude dependent plasma frequency, and ω is the angular frequency. The total Faraday rotation can be expressed as

$$\Omega(\omega) \approx 9.33*10^5\frac{1}{\omega^2}\int_0^h B_r(z)n_e(z)dz,$$

where $n_e(z)$ is the altitude dependent electron density. Since the electron density profile is concentrated in a narrow range of altitude between 100-200 km, the above integral can be approximated to by

$$\Omega(\omega) \approx 9.33*10^5\frac{1}{\omega^2}\left[\int_{h_p-\Delta z}^{h_p+\Delta z} B_r(z)n_e(z)dz + \varepsilon\right]$$

where h_p is the location of the peak electron density and Δz is the width of the region around the peak that includes sufficient percentage of the electrons in the ionosphere (e.g. >90%) such that ε can be made sufficiently small. An approximate value for the magnetic field at h_p (~150 km) is given by

$$B_r(h_p) = \frac{\Omega(\omega)\omega^2}{9.33*10^5\int_{h_p-\Delta z}^{h_p+\Delta z} n_e(z)dz}$$

An estimate for the electron content can be provided from the dispersion characteristic of the radar chirp. MARSIS has a relatively high fractional bandwidth that allows for accurate estimation of the electron content. Figures 3 and 4 show the amplitude variation of MARSIS signal due to the Faraday rotation for a center frequency of 5 MHz and two different density of electrons $I_{16} = 0.03$ and $I_{16} = 0.5$. As shown in Fig. 3 and 4, at some points in orbit the Faraday rotation causes a complete fading of the signal. The rate of variation in received signal energy depends on the rate of absolute variation in the radial component of the magnetic field.

In conclusions, it seems that by exploiting the above stated relationship between MARSIS signal modulation by the Faraday rotation and radial component of the magnetic field, it is possible to use MARSIS subsurface sounding data for estimation of the radial component of the Mars magnetic field, however, further detail will have to wait until future work is carried out.

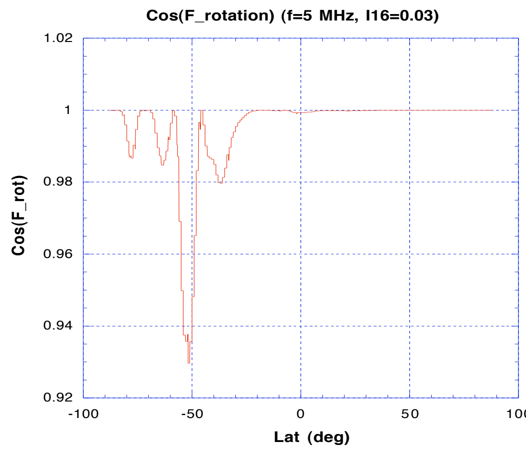

Figure 3: MARSIS radar signal amplitude variation due to the Faraday rotation for the magnetic region shown in Fig. 2. Signal is for MARSIS band 4 with center frequency of 5 MHz and the total electron content is assumed to be $I_{16} = 0.03$.

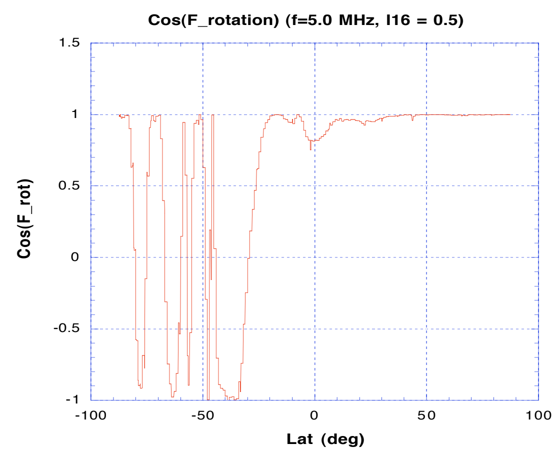

Figure 4: MARSIS radar signal amplitude variation due to the Faraday rotation for the magnetic region shown in Fig. 2. Signal is for MARSIS band 4 with center frequency of 5 MHz and the total electron content is assumed to be $I_{16} = 0.5$.

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References:

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[2] Connenrey, J.E.P. et al. (2001) *Geophysical Research Letters* , Vol. 28, Iss. 21, pp. 4015-4018.