SIGNAL STRENGTH AND BANDWIDTH FOR MAGNETOTELLURIC SOUNDING OF THE MOON.

M. O. Fillingim[1], G. T. Delory[1], J. S. Halekas[1], and R. E. Grimm[2], [1]Space Sciences Laboratory, University of California, Berkeley (matt@ssl.berkeley.edu), [2]ASouthwest Research Institute, Boulder, CO.

Introduction: Electromagnetic (EM) sounding is a group of geophysical methods used to characterize the interiors of planetary bodies from the near-surface (~ 1 m) to the deep interior (> 1000 km). Previous EM soundings of the Moon performed during the Apollo Era utilized a transfer function method requiring both orbiting and surface magnetometers. In the magnetotelluric (MT) method, the orthogonal components of the horizontal electric and magnetic fields on the surface are used to discern the subsurface conductivity structure. Sensor suites commonly used in space physics (electrometers and magnetometers) can make measurements for EM sounding on the surface of the Moon. The Moon encounters a wide variety of plasma regimes and EM source signals over a broad range of frequencies. Here, our goal is to consolidate previous observations to develop a catalog of EM disturbances at the Moon that will be useful for surface MT measurements. This work is an important step toward understanding the depth and resolution that could be obtained from these measurements on future missions.

Source Signals: On the terrestrial planets, electromagnetic discharges (lightning) or magnetic field variations due to interactions with the solar wind can provide MT source signals. On airless bodies such as the Moon, solar wind turbulence and other plasma waves can create source signals.

Below is a table listing expected target layers, depths, and EM frequency ranges necessary for MT sounding of the Moon.

Target	*Depth*	*Frequency*
Crust	0 – 60 km	> 1 Hz
Mantle	60 – 1500 km	10^{-3} – 1 Hz
Core	> 1500 km	< 10^{-3} Hz

The Moon spends ¾ of its orbit in the solar wind. Observations show that solar wind turbulence can provide a robust source of electromagnetic fluctuations spanning frequencies from < 10^{-4} Hz to > 10^2 Hz [1-4]. Figure 1 shows the power spectral density of magnetic fluctuations as a function of frequency in the solar wind.

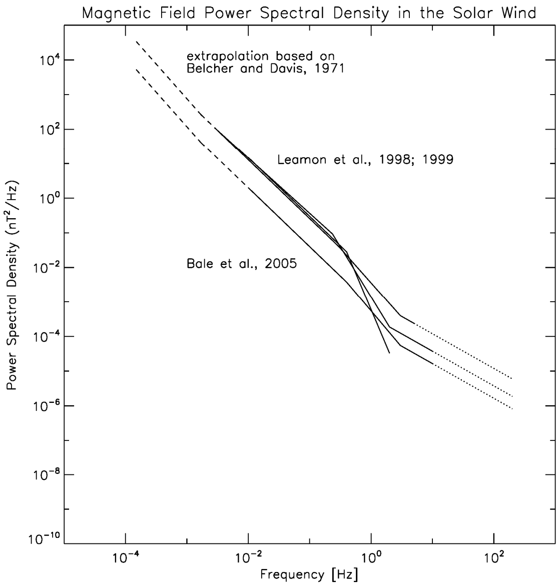

Figure 1: Power spectral density of magnetic fluctuations as a function of frequency in the solar wind.

The Moon spends the remaining ¼ of its orbit in Earth's magnetosphere. Waves in Earth's magnetosphere also provide a robust source of electromagnetic fluctuations from 10^{-4} Hz < f < 10^2 Hz [5-7]. Figure 2 shows the power spectral density of magnetic fluctuations as a function of frequency in Earth's magnetosphere in the region from $-30\ R_E < X < -10\ R_E$. At the highest frequencies, source signal strengths appear slightly lower in the magnetosphere than in the solar wind.

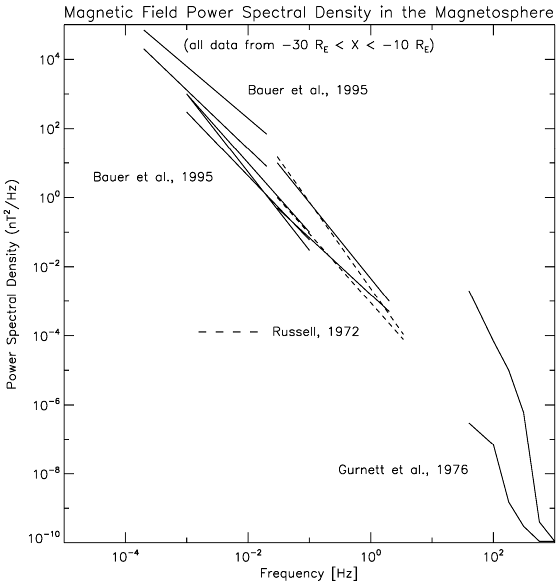

Figure 2: Power spectral density of magnetic fluctuations as a function of frequency in Earth's magnetosphere.

Analysis Method: In MT, assuming a simple planar geometry, the apparent resistivity as a function of frequency, ρ_a, is determined from the measured electric field, E, and magnetic field, B:

$$\rho_a = \frac{1}{5f}\frac{E_y^2(uV/m)}{B_x^2(nT)} \text{ ohm-m} \qquad (1)$$

with each wave penetrating the subsurface according to its skin depth, δ, given by

$$\delta = \frac{1}{\sqrt{\pi f \mu \sigma}} \sim 500\sqrt{\frac{\rho}{f}} \text{ m} \qquad (2)$$

Using (1) and (2), standard inversion procedures convert apparent resistivity, ρ_a, to true resistivity as a function of depth, $\rho(z)$.

This result can be generalized to spherical geometries at longer wavelengths using a response function, $c(\omega)$, as outlined by [8]:

$$c(\omega) = E(r_M,\omega)/i\omega B(r_M,\omega) \;\; \rightarrow \;\; \rho_a = \omega\mu\left|c(\omega)\right|^2$$

Again, the apparent resistivity, ρ_a, can be inverted to find conductivity versus depth.

References: [1] Belcher J. W. and Davis L. Jr. (1971) *JGR*, *76*, 3534-3563. [2] Leamon R. J. et al. (1998), *JGR*, *103*, 4775-4787. [3] Leamon R. J. et al. (1999), *JGR*, *104*, 22,331-22,344. [4] Bale S. D. et al. (2005) *PRL*, *94*, 215002. [5] Russell C. T. (1972) *Planet. Space Sci.*, *20*, 1541-1553. [6] Gurnett D. A. et al. (1976) *JGR*, *81*, 6059-6071. [7] Bauer T. M. (1995) *JGR*, *100*, 9605-9617. [8] Weidelt P. (1972) *Z Geophys*, *38*, 257-289.