Modeling Magnetic Induction From Transient Events Impinging Upon a Conducting Moon

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Abstract

Electromagnetic sounding measurements utilize magnetic induction to constrain the interior geophysical properties of planetary bodies. Under some conditions, the Earth's Moon can be approximated by the response of a conducting sphere in a vacuum. Transient magnetic fields originating from the Sun can interact directly with the Moon, producing eddy currents that in turn generate an induced magnetic field. These induced fields can be modeled by assuming a conductivity structure for the lunar interior. The model interior structure can be adjusted until good agreement between the observed and modeled induced fields is obtained, resulting in a constraint on the interior structure of the Moon. This technique is capable of resolving the boundaries between the lunar crust, mantle, and core regions, and can also provide insight into their thermal state. These interior properties bear directly on lunar formation and origin theories and are highlighted as a top priority for NASA within the next decade [3]. Time domain electromagnetic sounding was performed during the Apollo era [1], however, there are several complexities of the lunar plasma environment which require an intensive computational solution which has never been solved before in its entirety [4]. The frequency domain response of a model lunar body has been solved using COMSOL Multiphysics® by Grimm and Delory [2]. This paper describes how COMSOL Multiphysics and the AC/DC Module are used to solve the full time domain response of 2D and 3D models of the Moon of varying electrical conductivities. As a simple case, given an input magnetic field with a step function, the induced fields will display radial damping at the poles and overshoot in equatorial tangential components as displayed in Figure 1. Ultimately, we desire to arrive at a full time-dependent solution for arbitrary signal inputs, such that the input and induced fields measured by the ongoing ARTEMIS lunar mission can be compared to our model. This project is in its initial stages and will further develop conductivity constraints based on statistical results from induced signal data.

Reference

1. Palmer Dyal and C. W. Parkin, Electrical Conductivity and Temperature of the Lunar Interior from Magnetic Transient-Response Measurements, Journal of Geophysical Research, v.76, p.5947–5969, (1971).
2. Robert Grimm and G. T. Delory, Next-generation electromagnetic sounding of the Moon, Advances in Space Research, v.50, p.1687–1701, (2012).
3. National Research Council, Vision and Voyages for Planetary Science in the Decade 2013-2022, edited by the Space Studies Board, National Academies Press, Washington D.C, (2011).
4. C.P. Sonett, Electromagnetic induction in the Moon, Reviews of Geophysics and Space Physics, v.20, p.411–455, (1982).

Figures used in the abstract

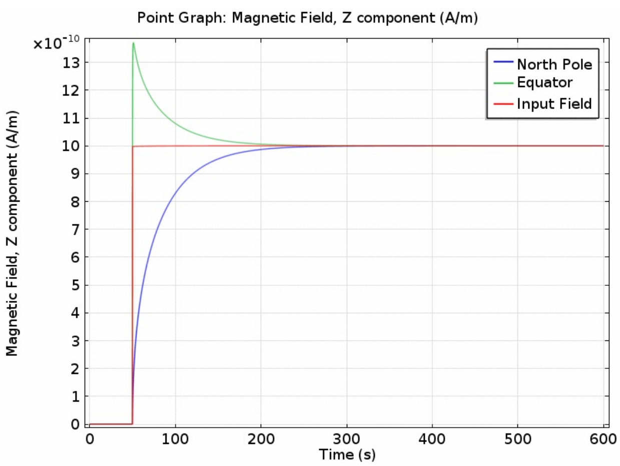

Figure 1: Time Domain response for a homogeneous Moon (conductivity 10-4 S/m) in vacuum to an input step function (red) show damping in the radial component (North Pole, blue) and overshoot (Equator, green) in the tangential components.