

Digital Fluxgate Magnetometer Optimized for Lunar Networks

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Introduction

Grimm and Delory [NLSI Lunar Science Conference, #2075, 2008], and references therein, discuss the importance of magnetic field measurements for studies of the structure of the moon. Such studies can use magnetotellurics, where electric and magnetic fields are measured to determine the impedance of the medium, or inductance, where the magnetic fields induced by a change in the external magnetic fields are measured. Both require magnetometers, such as the classic fluxgate magnetometer, to measure low frequency magnetic fields with high precision in a variety of environments.

UCLA has a long heritage in building space-qualified fluxgate magnetometers, and here we describe our recent efforts in building a magnetometer suitable for deployment on the lunar surface. We have recently received a prototype of a multi-stack-module (MSM) implementation of UCLA's digital magnetometer known as the Pierce-Rowe Magnetometer (PRM). The PRM has evolved from earlier efforts in migrating the original analog design to the digital domain, via magnetometers built for Space Technology 5 and the DSX mission. Here we will review that development, as well as our objectives for a magnetometer that can be deployed on the moon.

Space Technology 5

Space Technology 5 (ST5) was a three-spacecraft low Earth-orbit mission designed to investigate the feasibility of miniaturization of various spacecraft subsystems [Slavin et al., GRL, 2008]. The ST5 spacecraft included a low power and mass magnetometer built by UCLA. This magnetometer used ~ 500 mW of power, with sensor mass of 55 g, and electronics mass ~ 500 g, including 300 g for the chassis. Figure 1 shows a photograph of the ST5 engineering unit boards and sensor, with Figure 2 showing the engineering boards and the chassis. The ST5 magnetometer used a Field Programmable Gate Array (FPGA) to move some of the analog functions to the digital domain. The ST5 magnetometer was required to be low power and also provide 17 bit resolution data. This necessitated the use of low radiation-tolerant Analog to Digital Converters (ADCs).

Figures 3 and 4 show data from the ST5 spacecraft and the FAST spacecraft [Carlson et al., GRL, 1998]. Figure 3 shows the time series data, but with the ST5 data reversed so that they have the same footprint distance from the point of conjunction. Figure 4 shows the data projected into polar coordinates. These figures show that the ST5 measurements were comparable to the FAST measurements, but the ST5 magnetometer required about one third of the resources used by the FAST magnetometer.



Figure 1



Figure 2

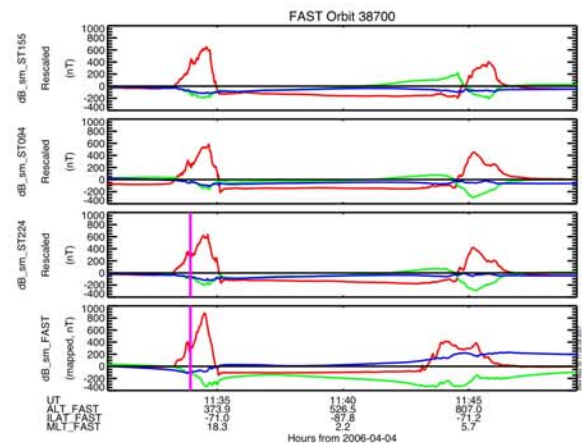


Figure 3

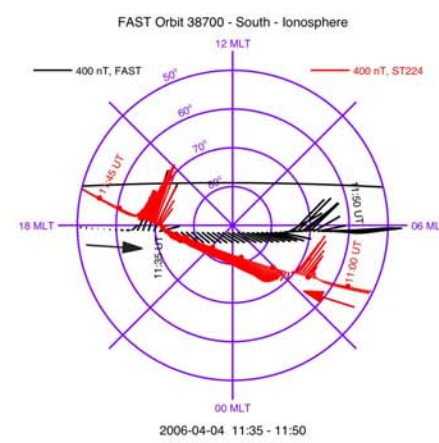


Figure 4

DSX - Pathfinder for the Pierce Rowe Magnetometer

Figure 5 shows the functional block diagram for the DSX magnetometer, and Figure 6 shows a flight board. This magnetometer follows on from the ST5 design, in that it also uses an FPGA to replace much of the analog function of earlier magnetometers. In addition, the DSX magnetometer removes the need for high radiation-tolerant ADCs. The ADC function is built into the magnetometer itself, rather than having the ADCs solely converting the output from the magnetometer to a digital signal for subsequent processing.

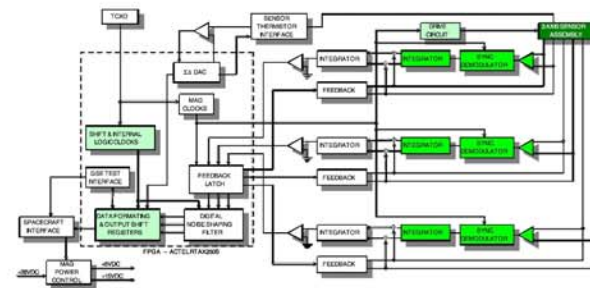


Figure 5



Figure 6

Multi-Stack-Module for the PRM

Figure 7 shows the functional block diagram for the Multi-Stack-Module (MSM) implementation of the PRM. Figure 8 shows the Magnetospheric Multi-Scale (MMS) sensor and the prototype of the 3D Plus MSM module. The MMS sensor acts as a prototype for the MSM-PRM magnetometer, but is representative of the current sensor technology we are using. The sensor occupies a volume of ~ 125 cm³, and has a mass of 63 g. The MSM-PRM module is 4 cm x 4 cm x 2 cm, and has a mass of 51 g. Figure 9 shows the PRM module attached to its test board.

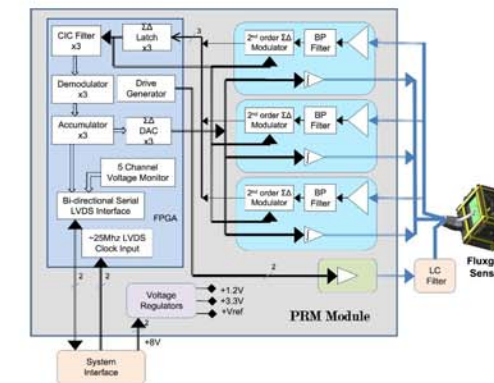


Figure 7

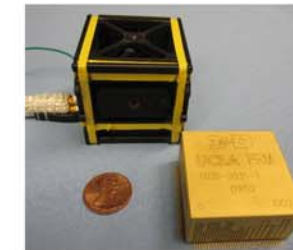


Figure 8



Figure 9

Instrument Development Objectives

Based on the development to date of the PRM, we have the following objectives for a magnetometer suitable for deployment on the lunar surface:

- A complete 24-bit 3-axis Fluxgate Magnetometer
- 120 dB Signal to Noise Ratio @ 1.0 – 50 Hz
- 100 dB Total Harmonic Distortion 0.1 – 1.0 Hz
- Up to 70,000 nT continuous full scale range, 100 Hz bandwidth, 1 pT rms noise floor
- Operate from single 8V supply, power < 1W, Low power operating mode < 600 mW
- 100 kRad-Hard version available (prototype ~ 25 kRad)
- Wide electronics operating temperature range -50 – +70 C
- Internal heater for electronics to extend ambient operating temperature to -100 C
- No active components on sensor allowing wide operating range
- Simple 6 wire interface including power using CAT-5 cable, lengths can be > 150 meters
- Sensor volume less than 100 cm³, mass less than 100 g
- Electronics volume 7 cm x 7 cm x 5 cm, mass 100 g

We are in the process of testing the MSM-PRM prototype to determine the noise and thermal characteristics of the magnetometer, as well as the harmonic distortion characteristics. Other areas of activity include the migration to a rad-hard FPGA.