Design and Fabrication of a Miniaturized Fluxgate Magnetometer

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Objectives

Magnetometers are instruments used to measure the magnitude and direction of surrounding magnetic fields. Our objective is to develop a miniaturized fluxgate magnetometer (FGM) to be flown on the **SIGMA** cubesat and on the **ISINGLASS** rockets. A fluxgate magnetometer consists of a toroid made from permeable material around which wiring is wound (figure 1a). This primary winding is encased in a sleeve with a secondary sensing coil (figure 1b). This will be mounted in a protective housing to the boom (figure 5) of the low earth orbit cubesat, SIGMA, being developed by the **Kyung Hee University** (KHU) of South Korea, and internal to the payload (figure 2) of the ISINGLASS rocket being developed by the **University of New Hampshire** (UNH).

Figure 1a: Prototype for a permalloy core with the primary winding, scaled with a metric ruler.

Figure 1b: Sleeve encasing primary core with secondary sense winding.

Challenges

◆**Develop 5 FGM for 2 missions**

- 1 on **SIGMA**, to be complete by 2015
- 4 on **ISINGLASS,** to be complete by 2016

◆**Minimize size of the instrument**

- Reduce volume by a factor of 20
- Weight < 35 grams
- Use one core for all three axes (x, y, z)
- Have Noise floor < 150 pT, normally < 10 pT, sacrificing precision for size
- No known relations on how to reduce size

◆ **Design a housing structure**

- Must hold cores tightly, enough to keep secure during launch
- Cannot touch wires
- Maintain structural integrity

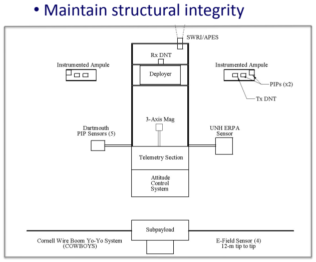


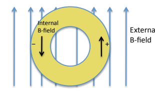
Figure 2: Payload of ISINGLASS rocket. The fluxgate magnetometer is located in the center of the structure. The uniqueness of our design is not only in its size, but also in its ability to measure the magnetic field on all three axes using just one core, the norm being to use a minimum of two.

Theory

How a magnetometer works, aside from the electronics, is quite simple. There are two pieces to our fluxgate magnetometer; the primary "drive" core, and the secondary "sense" coil (figure 1a and 1b respectively).

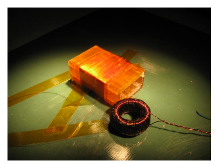
Drive Core:

- Wound with wire ≤ 40 gauge = drive coil
- Has AC sent through that saturates, de-saturates, re-saturates the core, according to the graph in figure 3[1].
- The surrounding background field creates a difference in flux from the two halves of core

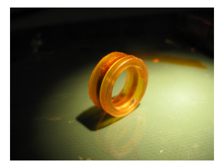


Secondary Core:

- Wound with 40 gauge wire = sense coil
- Sense coil has current impulses induced by the difference in flux



(a)



(b)

Figure 3: A drive core and secondary core designed and manufactured by our lab using delrin plastic and and a milling machines. The designs were drawn up using SolidWorks. The photo on the right (b) is the drive core with two layers of permalloy material around the circumference. The photo on the left (a) is the drive core with 32 gauge wire wrapped twice around and the secondary core with 40 gauge wire wrapped as a solenoid.

The current through the drive winding creates a magnetic field that aligns the domains within the permalloy core to a point of maximum alignment where it is said to be saturated; no amount of current can make the material more magnetized. The current then reverses direction, saturating the core in the opposing direction. The surrounding magnetic field will increase the field on one side of the toroid, and decrease the net field on the opposing side, causing a flux through the solenoid secondary winding. This is fed to an analog to digital board that relates the voltage to the magnitude of the surrounding field.

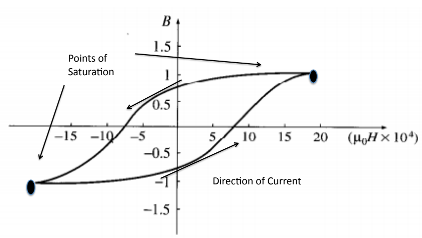


Figure 4: Hysteresis Loop showing the paths to saturation (D. Griffiths, *Introduction to Electrodynamics,* 3rd ed. Chap.6 (New Jersey: Prentice Hall 1999))

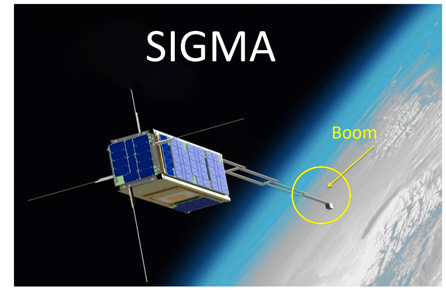


Figure 5: A visual model of the cubesat being developed by the Kyung Hee University in South Korea. The boom highlighted is where the magnetometer will be placed, away from the electronic noise of the satellite.

The Mission

This cubesat is part of a larger mission to understand lunar magnetic anomalies. The KHU is developing a lunar orbiter that will house a cubesat containing our fluxgate magnetometer. The mother ship will orbit the moon, measuring the magnetic field with a Magneto Resistive sensor, which is currently being tested on the Earth orbiter CINEMA, **C**ubesat for **I**on, **N**eutral, **E**lectron, **MA**gnetic fields. The fluxgate sensor we are developing will be tested on SIGMA, **S**cientific cubesat with **I**nstruments for **G**lobal **M**agnetic field and r**A**diation, that will be launched in 2017. The lunar cubesat is set to be launched by 2020. Once the orbiter is in place, it will eject the cubesat containing the fluxgate along a linear trajectory to impact the lunar surface, as depicted in figure 5, to measure the field at close ranges which have previously not been well documented.

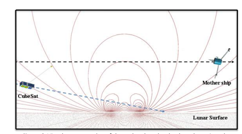


Figure 6: Visual representation of the path to be taken by the cubesat into the lunar surface.

Summary

This project's goal is to develop a fluxgate magnetometer that will be flown on SIGMA, a cubesat being developed by KHU. This is part of a larger mission for lunar exploration of magnetic anomalies. This instrument will also be on the ISINGLASS rocket from UNH to study the effects of auroral precipitation on the ionosphere. The difficulty lies in trying to significantly reduce the size of the magnetometer, for which there is no set theory, while also retaining a level of precision. The second challenge will be to use one ring core to measure the magnitude of the B-field on all three axes.