Resolution Metrics for Auroral Multipoint Measurements with Satellite Swarms

J. Brent Parham, Brian Walsh, and Joshua Semeter
Boston University, 8 Saint Mary’s St., Boston, MA 02215

Abstract
With the growing accessibility of low-cost satellite measurements, Boston University set out to create a space-based sensor called ANDESITE to do multipoint magnetometer measurements of the auroral current systems. Here, we show a model of the system and a rigorous, physically consistent, method to model its capability. With this methodology, any formation geometry can be evaluated for its ability to resolve postulated plasma wave phenomena that are superimposed onto the field-aligned currents in the aurora. These investigations inform the current design and future mission concepts that could help decipher energy transport in the magnetospheric-ionospheric coupling that occurs at high latitudes.

I. Doing More with Small Satellites

Problem:
The fine-scale structure of the near-earth electromagnetic environment is not well understood due to lack of in situ measurements.

Possible Solution:
• Ideal problem to demonstrate small distributed space-based sensors
• Cubedats offer a platform for development and deployment of cheaper spacecraft and are ideal for such scientific measurements

II. The Spacecraft Sensor

The image to the far left shows the finalized printed circuit board design of sensor node (the picosatellite). The magnetometer payload is the top right corner of the image.

The right photograph shows an engineering model of the same satellite in the Helmholtz cage used for the below calibration.

As seen above, although we are using a relatively inexpensive magnetometer and housing it inside the spacecraft, the standard deviation of the noise stays within 10 nT on each axis throughout a dynamic range of 120,000 nT. Any offsets due to non-orthogonality, inherent structural momenta, and other hardware dependent causes are calibrated out with extensive probing of the spacecraft at multiple angles of attack with the Helmholtz cage.

This achievement is due to careful design considerations and electromagnetic shielding placed within the spacecraft. The easiest way to check the feasibility of a sensor concept is to build and test hardware and not rely on preconceived notions.

The image below shows an analytical reference and sampling. Below is the harmonic expansion of the magnetic field (vectors in the image) and it’s corresponding current density (gradient color representing the magnitude). The image also shows a hypothetical ANDESITE swarm and the nodes at which data is acquired.

IV. The Real Test—Launch.

ANDESITE was designed to push the limits of spatial resolution and here we developed a rigorous methodology to examine the performance of satellite swarms like it, ultimately showing that we are mostly limited by the spatial separation of our sensor measurements and not the magnetometer sensitivity. We did still prove the capability of the system to resolve kilometer scale phenomena that include the domain of postulated in situ Alfvén waves. Future work along this direction will be better understand the role of measurement uncertainty with the approach defined herein. Through understanding the uncertainty we can then better inform the magnetometer design for future mission and rigorously examine the one chosen for ANDESITE.

However, the real test is when the sensor is launched. No amount of ground-based testing or modeling can accurately characterize a system and predict what we may measure once on orbit.

Relevant References for Science Mission

E-mail: jbparham@bu.edu Phone: (857) 756-4693