Forthcoming Measurements of Plasma Waves by the EMFISIS Investigation on the RBSP Spacecraft

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Abstract

Radiation belt particle acceleration and loss is intimately connected to wave-particle interactions. To measure these interactions, NASA will launch the two-satellite Radiation Belt Storm Probes (RBSP) mission in 2012. The Electric and Magnetic Field Instrument Suite and Integrated Science (EMFISIS) investigation on RBSP is an integrated set of instruments consisting of DC magnetic field measurements from DC to 30 Hz and AC electric and magnetic fields from 10Hz to 400 kHz. Examples of key wave science such as VLF hiss, magnetosonic equatorial noise, electromagnetic ion cyclotron waves, and chorus are presented along with the mission and instrument complement.

1. Introduction

The physics of the creation, loss, and transport of radiation belt particles is intimately connected to the electric and magnetic fields which mediate these processes. A large range of field and particle interactions are involved in this physics from ions and ring current magnetic fields to microscopic kinetic interactions such as whistler-mode chorus waves with energetic electrons. To measure these kinds of radiation belt interactions, NASA will launch the two-satellite Radiation Belt Storm Probes (RBSP) mission in 2012. As part of the mission, the Electric and Magnetic Field Instrument Suite and Integrated Science (EMFISIS) investigation is an integrated set of instruments consisting of a tri-axial fluxgate magnetometer (MAG) and a Waves instrument which includes a tri-axial search coil magnetometer.

2. The RBSP Mission

The NASA RBSP mission consists of two identical satellites in a common, elliptical, near-equatorial orbit with perigee at 700 km and apogee and 5.7 R_E. The orbital configuration is set up such that one satellite gradually separates from the other along orbital path, running ahead until it eventually overtakes the first satellite after a period of about 9 months. The mission is well instrumented to measure the radiation belt environment including measurements of electrons and ions from a few eV to several MeV and higher. These particle measurements cover the key particle energies in the Earth's radiation belts, the ring current, and the plasmasphere. The field measurements consist of DC and AC electric and magnetic field measurements covering the important frequencies of interest for the geoelectric and geomagnetic fields, as well as the electromagnetic waves that fill the Earth's inner magnetosphere.

This mission will be the first to provide dual point measurements throughout the inner magnetosphere. With this capability, we will, for the first time, be able to understand how different parts of the equatorial inner magnetosphere are (or are not) correlated and how they evolve as a function of magnetospheric drivers. With the full complement of measurements, RBSP will be able to distinguish between the various particle energization, transport and loss processes that have been proposed to explain the dynamic character of the radiation belts. When coupled with theoretical development, this mission will enable more powerful, physics-based models to let us move closer to the frontier of predictive capability for the radiation belt environment.

3. The EMFISIS Investigation

The EMFISIS investigation is a multi-instrument team composed of experimentalists and modellers at several institutions. The lead institution is the University of Iowa which coordinates the entire investigation and also provides the hardware for the Waves portion of the investigation including the tri-axial magnetic search coil sensors. The tri-axial fluxgate magnetometer and associated electronics are provided by the Goddard Space Flight Center.

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The suite's central data processor is provided by the University of New Hampshire. Modelling and data analysis efforts are being provided by the University of California, Los Angeles, the Los Alamos National Laboratory, Charles University of Prague, and in Institute for Space Research in Graz, Austria.

The DC magnetic field measurements are made using a three-axis fluxgate magnetometer and provide a full vector magnetic field vector at a rate of 64 vectors/s, corresponding to a frequency range of 0-30 Hz. The magnetometer has two primary ranges covering magnitudes of 0-65536 nT with 2 nT resolution and 0-4096 nT with 0.13 nT resolution.

The Waves portion of EMFISIS provides two types of wave measurements. The first type is a three axis electric and magnetic field measurement covering the frequency range of 10-12000 Hz. The EMFISIS investigation has developed the magnetic search coil sensor and associated electronics and the electric field signals are sent to the EMFISIS electronics from the Electric Field and Waves (EFW) investigation. By combining both electric and magnetic measurements, digitized simultaneously by common electronics, RBSP will have a full vector electric and magnetic field measurement to enable calculation of key quantities such as Poynting flux, polarization, planarity, and ellipticity for key wave moves such as VLF hiss, magnetosonic equatorial noise, and chorus. The second type of wave measurement is a single axis electric field measurement over the frequency range 10-400 kHz. This measurement is targeted at identifying emission at the upper-hybrid frequency which will be used to determine background plasma density.

The fluxgate magnetometer measurements, when combined with the electric field measurements of the EFW investigation, will provide the full vector measurements needed for studying lower frequency waves such as electromagnetic ion cyclotron (EMIC) waves and ring current as well providing the background field direction for analysing particle measurements. A summary of the field measurement ranges is shown in Figure 1 which includes the FEW measurements as well as those of the EMFISIS investigation.

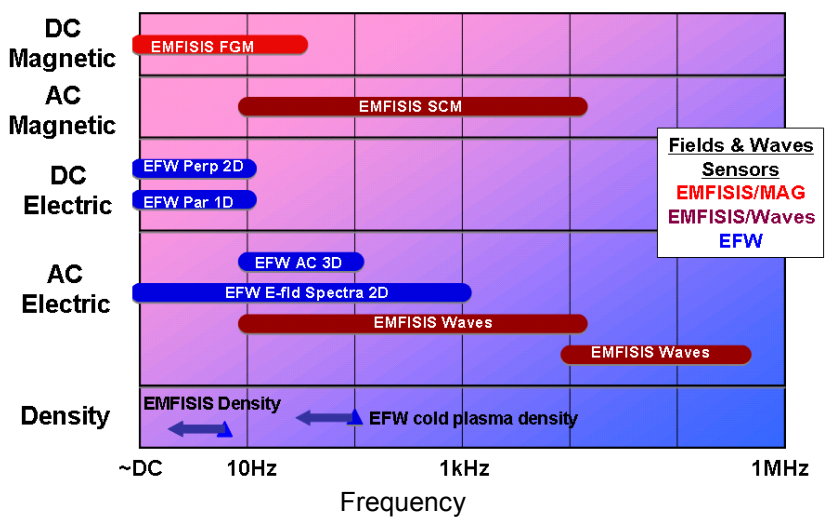

Figure 1. RBSP electric and magnetic field measurement ranges.

4. Summary

The EMFISIS investigation for NASA's RBSP mission provides the essential measurements of vector magnetic and electric fields to unravel the physics of wave-particle interactions that are responsible for acceleration, transport and loss of radiation belt particles. Additionally, the EMFISIS measurements of DC magnetic fields will provide information on much lower frequency phenomena such as EMIC waves and ring current variation. With these field measurements combined with excellent coverage of particle measurements, the RBSP mission promises to reveal the clearest picture ever obtained of radiation belt physics.