Initial Results from the Radiation Belt Storm Probes EMFISIS/Waves Instrument

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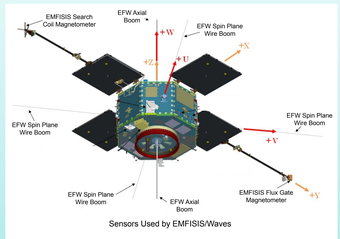
Abstract

The twin Van Allen Probes were launched on or after August 30, 2012. The Electric and Magnetic Field Instrument Suite and Integrated Science (EMFISIS) investigation includes a plasma wave instrument (Waves) designed to measure three orthogonal components of the wave magnetic field from ~10 Hz to 12 kHz and, with the support of the Electric Fields and Waves (EFW) instrument sensors, three components of the wave electric field from ~10 Hz to 12 kHz and a single electric component up to 500 kHz. For the wave magnetic fields, Waves uses a set of orthogonal triaxial search coils. EFW utilizes two spin-plane booms with tip-to-tip lengths of 100 m and a spin axis boom with a nominal tip-to-tip length of ~13 m to be determined on orbit. Commissioning of the spacecraft and their instruments was completed within about two months of launch, at the end of October. In this paper we plan to provide initial observations from Waves including an assessment of in-flight performance and early observations of plasma waves thought to play significant roles in the acceleration and loss of radiation belt. The various classes of waves we anticipate studying include whistler-mode chorus, plasmaspheric hiss, and magnetosonic equatorial noise. EMFISIS/Waves may, at times, be able to measure the upper frequency extent of electromagnetic ion-cyclotron waves. At the other end of the spectrum, the Waves instrument will also detect electron cyclotron harmonic emissions and the band at the upper hybrid resonance frequency. The latter band will be used to determine the local electron density as an important parameter of the plasma required for various modeling and simulation studies.

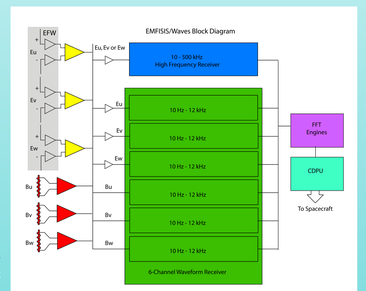
The two triaxial search coil assemblies for Van Allen Probes A and B are shown on pre-launch test fixtures. The search coils consist of 40-cm mu-metal rods and 10,000 turns of fine wire. Radiation tolerant preamps are housed in the cylindrical fixture which doubles as the structure holding the search coils at the end of one of the sensor booms. Performance of this system is excellent, given the superb dynamic range afforded by the 16-b A/D converters used in the 6-channel Wavefrom Receiver

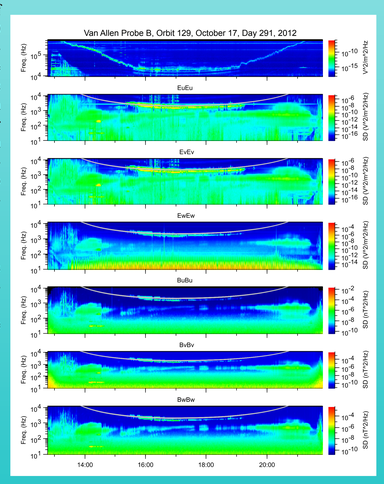
EMFISIS/Waves has a number of operating modes, but they can be considered a basic survey mode plus various burst modes which provide additional temporal and/or spectral resolution over the survey mode:

- The survey mode provides spectral matrices for the 10 Hz - 12 kHz frequency range based on 468 ms waveforms from all 6 sensors plus an HFR spectrum.
- Burst modes, including:
  - Continuous waveforms -- nearly 6 seconds of waveforms from all 6 sensors
  - 30 msec mode -- spectral matrices every 30 milliseconds
  - Fast survey -- survey spectral matrices every second
  - Onboard WNA -- wave propagation parameters as fast as every 30msec



Sensors Used by EMFISIS/Waves

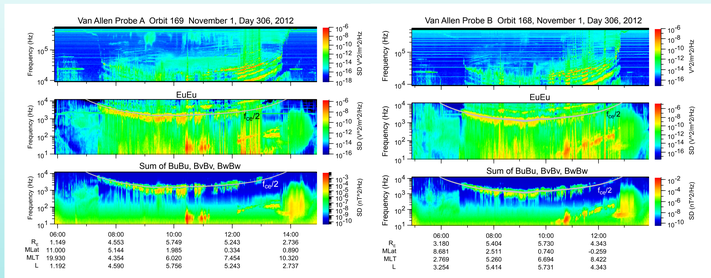


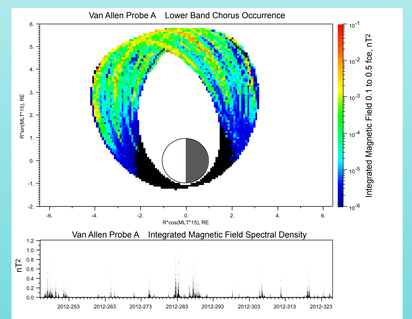


The EMFISIS/Waves instrument on the twin Van Allen Probes utilize a complete array of plasma wave sensors. Three orthogonal components of the wave magnetic field are obtained from a triaxial search coil magnetometer on a 3-m boom. Three orthogonal electric field components are obtained from the EFW (Electric Fields and Waves) sensors including 2 spin plane booms 100 m tip-to-tip and an axial boom approximately 13.4 m, tip-to-tip.

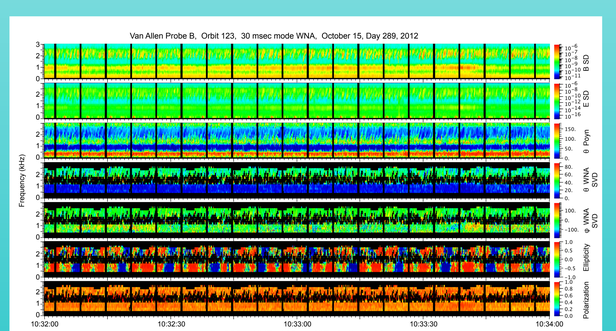
The Waves instrument comprises a 6-channel waveform receiver for frequencies between 10 Hz and 12 kHz and a high frequency receiver (HFR) covering frequencies up to 500 kHz. A set of four FFT engines are floating point accelerators optimized for Fast Fourier Transforms. In addition, they compute spectral matrices required for carrying out wave-normal analyses (WNA). The FFT engines are controlled by the CDPU which also includes the capability to complete WNAs and determine various propagation characteristics of waves onboard.

The basic survey output of the EMFISIS/Waves instrument is a set of spectral matrices covering the frequency range of 10 Hz to 12 kHz utilizing six channels (3 E and 3 B) and a single-channel spectrum for the HFR frequency range of 10 kHz to 500 kHz. While this spectrogram shows little in the way of amplitude differences between the channels, the spectral matrices capture phase differences between the various wave components and allow later determination of wave propagation parameters.



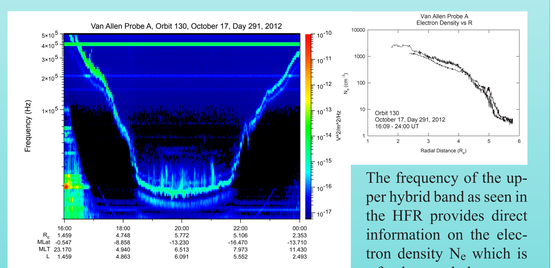


An obvious capability of the Van Allen Probes plasma wave measurements is to enable synoptic studies of the occurrence of plasma wave phenomena such as whistler-mode chorus which is known to be an effective accelerator of electrons as well as a loss mechanism through pitch-angle scattering. The upper panel shows data from probe A early in the mission representing the intensity of lower band chorus (0.1 to 0.5 f_{ce}) as a function of MLT and radial distance. Clearly, there are intensifications in the chorus during times of enhanced activity as shown in the time history of the intensity of the lower-band chorus shown in the lower panel.

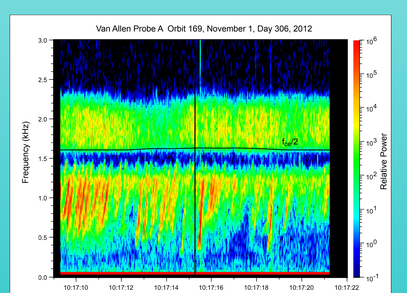


A basic capability of the Waves multi-component waveform measurements is the determination of wave propagation characteristics such as wave-normal angle, Poynting flux, polarization, etc. These parameters -- magnetic and electric spectral density, polar angle of the Poynting flux, wave-normal angles, ellipticity, and polarization were all computed on-board at 30 msec intervals. As is now expected, the chorus near 2 kHz propagates away from the equator.

The major premise of the Van Allen Probes mission is that having two spacecraft traversing the radiation belts with an evolving orbital phase between them provides an array of multipoint measurements of a highly dynamic system. In this comparison of data from the two probes, spacecraft B is trailing A in orbit by about an hour. While the basic wave spectra are very similar between the two positions, they are not identical. Such comparisons will enable the determination of the temporal and/or spatial evolution of the radiation belts. These spectrograms represent the HFR data in the upper panels, and the electric and magnetic field spectra in the middle and bottom panels, respectively. The duration of each plot is about 9 hours, or one orbit from periapsis to periapsis. A gray line at $f_{ce}/2$ is included in the bottom panels to highlight the boundary between upper- and lower-band chorus. Narrowband electron cyclotron harmonic emissions are seen at higher frequencies and plasmaspheric hiss and equatorial magnetosonic waves at lower frequencies.



The frequency of the upper hybrid band as seen in the HFR provides direct information on the electron density N_e which is a fundamental plasma parameter required for numerous magnetospheric models.



The basic data collected by Waves are waveforms. This is an example of the continuous waveform burst capability, acquired in two 6-second intervals. While all 6 components are captured, this panel only shows the spectrum for the B_u component. An onboard algorithm selects such captures based on the amplitudes in the chorus bands above and below f_{ce}. The EM-quiet spacecraft and 16-b dynamic range make for an excellent data set.