

## The Juno Waves investigation

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### Abstract

The Juno spacecraft was successfully launched on 5 August 2011 to begin its journey to Jupiter. With its arrival in the summer of 2016, the latest in a series of missions to Jupiter will begin. Juno will explore the origins of not only Jupiter, but also the solar system as a whole by understanding the interior of the planet and its atmospheric composition and dynamics. Juno will also be the first mission to explore Jupiter's polar magnetosphere and auroras. The Waves investigation is part of a suite of instruments which will contribute to this latter objective. Waves will measure wave electric fields in the frequency range from 50 Hz to 40 MHz and magnetic fields in the range of 50 Hz to 20 kHz to study radio and plasma waves in Jupiter's polar magnetosphere. Most importantly, Waves will contribute to understanding auroral processes at the giant planet via in situ observations of the sources of Jovian hectometric and decametric radiation as well as plasma waves which likely accelerate particles as part of the auroral process.

### 1. Objectives

The Waves investigation on Juno will contribute to the following objectives supporting the exploration of Jupiter's polar magnetosphere including (1) determine the nature of coupling between Jupiter's internal magnetic field, the ionosphere, and the magnetosphere, (2) Investigate and characterize the three dimensional structure of Jupiter's polar magnetosphere, and (3) Identify and characterize auroral processes at Jupiter.

Measurements of plasma waves in Jupiter's auroral regions will help to determine the nature of the auroral acceleration region by identifying the major current systems coupling the magnetosphere to the

ionosphere. These will also help to determine the role of wave-particle interactions in Jupiter's auroras. Expecting to find similarities between terrestrial and Jovian auroral processes, it is likely that Juno will find auroral hiss, electron and ion phase space holes, and observe auroral radio emissions at and near their sources. These measurements will help to determine whether there are fundamental differences between auroras in the main auroral oval associated with currents to regions where corotation breaks down, polar auroras connecting to open field lines, and satellite footprint auroras.

### 2. Instrumentation

The Juno Waves instrument consists of sensors and receivers designed to detect and analyze wave electric fields in the frequency range from 50 Hz to 40 MHz and wave magnetic fields from 50 Hz to 20 kHz. A block diagram of the instrument is given in Figure 1.

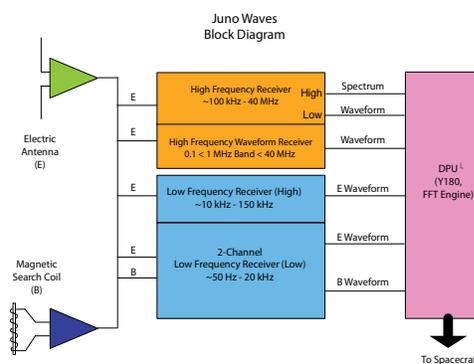


Figure 1: Waves block diagram.

## 2.1 Sensors

The Waves sensors include a short electric dipole antenna and a magnetic search coil (MSC). The electric antenna consists of two elements of 2.8 m in length extended in a plane rotated 45° to the aft of the aft flight deck and with a subtended angle of 120° as shown in Figure 2. The antenna is located aft of the solar panel wing that includes the magnetometer boom in such a manner as to be symmetric with the wing. The search coil is body-mounted to the aft flight deck with its axis parallel to the spacecraft z axis, that is, parallel to the spacecraft spin axis. This is to minimize the effects of the very strong Jovian magnetic field rotating as the spacecraft spins at a 2 rpm rate near periapsis. The MSC consists of a coil with 10,000 turns of fine copper wire wrapped around a mu-metal core 15 cm in length.

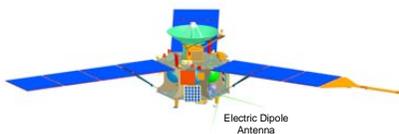


Figure 2: Location of Waves electric antenna

## 2.2 Receivers

As depicted in the block diagram in Figure 1, Waves includes two receivers, the low frequency receiver LFR and the high frequency receiver HFR. Each of these comprises a number of channels. The LFR includes two identical channels covering the frequency range from 50 Hz to 20 kHz. One configuration for these two channels allows for simultaneous sampling of the electric and magnetic sensors. However, an additional use of these channels (and the primary one) is to use a signal from the Juno Power Distribution Unit reflecting voltage fluctuations on the bus to be used in a noise cancelling mode with the electric or magnetic signals being analysed in the second channel. The third channel in the LFR is a high band, covering the spectrum from 10 kHz to 150 kHz and is used for electric signals, only. This band can also incorporate noise cancellation.

The high frequency receiver (HFR) actually consists of two, nearly identical receivers. One is used for survey data, covering the frequency range from 100 kHz to 40 MHz. The other allows for high resolution waveform measurements in a 1-MHz band including the electron cyclotron frequency (based on magnetic field measurements by the fluxgate magnetometer instrument). Each of these has two types of receivers. The baseband receiver consists of a variable gain amplifier followed by a 100 kHz to 3 MHz bandpass filter which, in turn, is followed by a 12-bit analog-to-digital converter. The other type of receiver is a double sideband heterodyne receiver which will detect the amplitude of signals in 1-MHz bandwidths from 3 to 40 MHz as a swept frequency receiver.

## 2.2 Data Processing Unit

The Waves Data Processing Unit (DPU) consists of two systems on a chip (SoC) implemented in Actel field programmable gate arrays (FPGAs) because of their radiation hardness. The first FPGA includes a Y180 intellectual property core designed to carry out the basic operations of the Waves instrument including command handling and data output functions as well as scheduling instrument observations and onboard analyses. The second FPGA is a floating point arithmetic unit optimized to carry out fast Fourier transforms and other basic signal processing tasks. Since the primary output of most of the receivers are digitized waveforms, this latter processor effectively moves signal analyses from the analog to the digital domain. The second FPGA is responsible for spectrum analysis, spectral binning and averaging and the noise cancellation process.

## 3. Summary

As the first polar orbiting satellite at Jupiter, Juno promises to bring a new understanding of the deep interior of the planet and its origins. It also promises to yield exciting new observations of those processes feeding the brightest auroras in the solar system. The Waves investigation will complement other particle, field, and remote sensing investigations on Juno in understanding the drivers of the auroras and how they relate to the extraordinary energy source in Jupiter's intense rotating magnetic field and the robust plasma source in Io's volcanic activity.