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Software-type Wave-Particle Interaction Analyzer (SWPIA) by RPWI for JUICE

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Abstract

Software-type Wave-Particle Interaction Analyzer (SWPIA) will be realized as a software function of Low-Frequency receiver (LF) running on the DPU of RPWI (Radio and Plasma Waves Investigation) for the ESA JUICE mission. SWPIA conducts onboard computations of physical quantities indicating the energy exchange between plasma waves and energetic ions. Onboard inter-instruments communications are necessary to realize SWPIA, which will be implemented by efforts of RPWI, PEP (Particle Environment Package) and J-MAG (JUICE Magnetometer). By providing the direct evidence of ion energization processes by plasma waves around Jovian satellites, SWPIA contributes scientific output of JUICE as much as possible with keeping its impact on the telemetry data size to a minimum; we estimate that SWPIA outputs 0.2 kB at the smallest from 440 kB waveform and particle raw data.

1. Introduction

Fukuhara et al. (2009) proposed Wave-Particle Interaction Analyzer (WPIA) to measure the energy transfer process between energetic particles and plasma waves. Software-type WPIA (SWPIA) was firstly implemented in the ERG satellite of JAXA to measure interactions between relativistic electrons and whistler-mode chorus in the Earth's inner magnetosphere [Miyoshi et al., 2012; Katoh et al., 2013, 2014; Hikishima et al., 2014]. In the ESA JUICE mission, we apply SWPIA to ion-scale wave-particle interactions occurring in the Jovian magnetosphere. SWPIA will be realized as a software function of Low-Frequency receiver (LF) running on the DPU of RPWI (Radio and Plasma Waves Investigation). The prime target of SWPIA in JUICE is ion cyclotron waves (~1 Hz) and related wave-particle interactions occurring in the region close to Ganymede and other Jovian satellites. SWPIA uses wave electromagnetic field and ion velocity vectors provided by RPWI sensors and PEP (Particle Environment Package), respectively, with referring three-components of the background magnetic field detected by J-MAG (JUICE Magnetometer). For the particle data, SWPIA uses particle counts detected by JDC (Jovian plasma Dynamics and Composition) of PEP in the energy range from 1 eV/q to 25 keV/q.

2. Inter-instrument Collaboration to Realize SWPIA

SWPIA measures a relative phase angle between the velocity vector $\boldsymbol{v}_i$ of i-th particle and the wave electric field vector at the timing of particle's detection ($\boldsymbol{E}(t_i)$) and computes an inner product $W(t_i) = q_i\, \boldsymbol{E}(t_i) \cdot \boldsymbol{v}_i$, where $W(t_i)$ corresponds to the gain (positive) or the loss (negative) of the kinetic energy of the i-th particle. The net amount of the energy exchange between waves and particles can be obtained by accumulating W for detected particles in the region of interest. The accumulation of the measured W also contributes to the reduction of the amount of data to be transferred to the ground. By assuming 128 Hz sampled waveform of LF data and 32 kB particle data for every m/q of PEP/JDC data obtained during 8 sec, the size of raw data becomes 440 kB for each nominal data amount of SWPIA (80 sec observation in total). By integrating the measured W for the kinetic energy, pitch angle, and relative phase angle between waves and particles, the telemetry data size

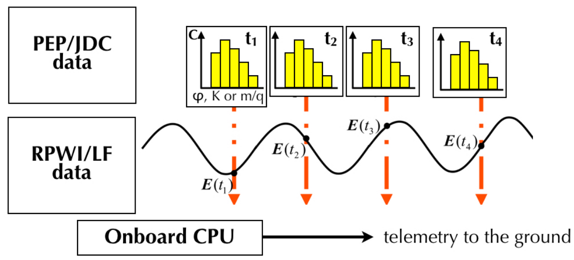

Figure 1: Schematic of the plasma wave and particle data used in SWPIA.

of SWPIA output can be estimated to be 0.2-27 kB for 1 m/q step.

Figure 1 illustrates the time sequence of the plasma wave and particle data to be used in SWPIA. The number of counts C as a function of azimuth (φ), or the kinetic energy (K), or mass-per-charge (m/q) etc. are stored with a time-tag showing the timing of the measurements. The time-tag will be used to identify the relative phase angle between the velocity vectors of detected particles and the wave electric field vectors. The synchronization of related instruments is essential to realize SWPIA in the time resolution better than the time scale of wave-particle interactions. For waves of frequency around 1 Hz, which corresponds to the typical cyclotron frequency of oxygen ions in the Ganymede's polar magnetosphere, the time resolution better than 100 msec should be required to measure the relative phase angle between wave and velocity vectors better than 40 degree. This time resolution can be realized in JUICE by inter-instrument collaboration.

3. Summary

SWPIA conducts onboard computations of physical quantities indicating the energy exchange between plasma waves and energetic ions. Onboard inter-instruments communications are necessary to realize SWPIA, which will be implemented by efforts of RPWI, PEP and J-MAG. The in-flight SWPIA computation significantly reduces the data volume to be downlinked to ground. By providing the direct evidence of ion energization processes by plasma waves around Jovian satellites, SWPIA contributes scientific output of JUICE as much as possible with keeping its impact on the telemetry data size to a minimum.

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