A Novel Calibration Method of Short Time Waveform Signals and its Approcation for the PWE/WFC Data

*Masahiro Kitahara[1], Shoya Matsuda[2], Yuto Katoh[3], Yoshiya Kasahara[4], Hirotsugu Kojima[5], Yoshizumi Miyoshi[1], Mitsuru Hikishima[2]

1. Institute for Space-Earth Environmental Research, Nagoya University, 2. Institute of Space and Astronautical Science/Japan Aerospace Exploration Agency, 3. Department of Geophysics, Graduate School of Science, Tohoku University, 4. Information Media Center, Kanazawa University, 5. Research Institute for Sustainable Humanosphere, Kyoto University

The Waveform Capture (WFC) is a receiver of the Plasma Wave Experiment (PWE) on board the Arase satellite. The WFC measures the electric and magnetic field waveform in the frequency range from a few Hz to 20 kHz and aims to detect plasma waves related to the electron acceleration, such as whistler mode chorus emissions. A new-type instrument named Software-type Wave-Particle Interaction Analyzer (S-WPIA) is also installed in the Arase satellite to measure energy and momentum exchange between plasma waves and particles directly and quantitatively. The S-WPIA requires the high-accuracy calibration of both amplitude and phase of waveform data detected by the WFC with a reasonable processing load so as to realize the onboard calibration. In a typical calibration process, raw data passed through a system comprising of antennas, amplifiers, and filters should be (1) tapered by a window function to reduce the side lobe effect, (2) Fourier-transformed into a spectrum, (3) divided by a transfer function of the system in the frequency domain, (4) inverse-transformed into a waveform, and (5) divided by the window function in the time domain. However, the calibrated waveform data are distorted in the time domain in the case of using a short-time window consisting of several hundred of data points.
In this study, we reveal that the main lobe expansion caused by a window function yields the phase shift of the window function in the process (3) and the process (5) dividing by an un-shifted window function results in the distortion of waveforms in the time domain. To perform accurate calibration with a short-time window, we suggest a novel calibration method to estimate the phase shifts of a window function from the gradient of a transfer function and remove the distortion by dividing the shifted window functions at each frequency in the time domain. We applied the proposed method to simple sinusoidal signals and evaluated the frequency response of the accuracy of the calibrated data. As a result, we conclude that the proposed method can reduce errors to less than one percent of the signals even in the short-time window cases of using several hundred of data points. The accuracy tends to decrease at the low frequency range close to the frequency of a window function and at the high frequency range close to the Nyquist frequency. We also applied the methods to actual electric field data of chorus emissions observed by the PWE/WFC. In consequence, although the proposed method requires longer calculation time as compared to other conventional methods, the proposed method can reproduce the seamless waveforms of chorus emissions with errors of one percent of the wave amplitude or less in the case of using a band pass filter at the frequency range of the typical chorus emissions. We need to take account of the relation between the frequency range of the electromagnetic waveform and the window function in interpreting observation results.

Keywords: the Arase satellite, Plasma waves, waveform calibration