あらせ衛星搭載のプラズマ波動観測器によって計測された波形データの精密較正

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Accurate calibration of waveform data measured by the Plasma Wave Experiment on board the ARASE satellite

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The Plasma Wave Experiment (PWE) is installed on board the ARASE satellite to measure the electric field in the frequency range from DC to 10 MHz, and the magnetic field in the frequency range from a few Hz to 100 kHz using two dipole wire-probe antennas (WPT) and three magnetic search coils (MSC), respectively. In particular, the Waveform Capture (WFC), one of the receivers of the PWE, can detect electromagnetic field waveform in the frequency range from a few Hz to 20 kHz. Whistler mode chorus emissions, electrostatic electron cyclotron harmonic waves, and other plasma waves related to acceleration and scattering of energetic electrons are expected to be detected in the frequency range covered by WFC. A new type of instruments named Software-type Wave Particle Interaction Analyzer (S-WPIA) is installed on the ARASE satellite to measure the energy exchange between plasma waves and particles directly and quantitatively. Since S-WPIA uses the waveform data measured by WFC to calculate the relative phase angle between the wave magnetic field vector and velocity vectors of energetic electrons, the high-accuracy is required to calibration of both amplitude and phase of the waveform data.

Generally, the calibration procedure of the signal passed through a linear time invariant system consists of three steps; the transformation into spectra in the frequency domain, the calibration by the transfer function reflecting in the characteristics of the system, and the inverse transformation of the calibrated spectra into the time domain. Practically, in order to reduce the side robe effect, a raw data is filtered by a window function such as a Hamming window in the time domain before applying short time Fourier transform. However, for the case that a first order differential coefficient of the phase transfer function of the system is not negligible, the phase of the window function convoluted into the calibrated spectra is shifted differently at each frequency, resulting in a discontinuity in the time domain of the calibrated waveform data. To eliminate the effect of the phase shift of a window function, we suggest several methods to calibrate a waveform data accurately and carry out simulations assuming simple sinusoidal waves as an input signal and using transfer functions of WPT, MSC, and WFC obtained in pre-flight tests. In consequence, we conclude that the following two methods can reduce an error contaminated through the calibration to less than 0.1 % of amplitude of input waves; (1) a Turkey-type window function with a flat top region of one-third of the window length and (2) modification of the window function for each frequency by referring the estimation of the phase shift due to the first order differential coefficient from the transfer functions.