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Onboard Data Processing for Plasma Wave Instruments Implemented into Japanese Spacecraft

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Abstract

In the present paper, we introduce onboard data processing techniques realized on Japanese plasma wave instruments. In order to develop a high-performance and multi-functional software receiver, it is necessary to implement various kinds of digital signal processing method into onboard software adjusting the scientific targets. Another problem to be solved is that these techniques shall be simple and fast enough to function in quasi-real-time under restricted resources such as computation time and memory capacity. We have been tackling this subject and adopted our method for the plasma wave instruments onboard the lunar orbiter "KAGUYA" and the "MMO (Mercury Magnetospheric Orbiter)" etc. We report several functions implemented in the instruments and the results of evaluation.

1. Introduction

Plasma wave measurements provide many scientific clues to plasma dynamics in the magnetosphere, solar wind and the other various regions in the solar system. Especially the importance of waveform measurements was highly recognized since the discovery of electrostatic solitary waves (ESW) by the GEOTAIL spacecraft. It is also essential to measure wave fields with high-time and high-frequency resolution for the investigation of wave-particle interaction in a micro-scale. However, the amount of raw data from the plasma wave instrument is too huge to downlink all data to the ground because the scientific objectives require a wide coverage of frequency range. Intelligent digital signal processing on the onboard software is therefore indispensable because many kinds of operational modes can be implemented without changing the hardware configuration.

On the other hand, because of the severe restrictions of resources such as computation time, memory capacity and data transmission speed, it is necessary to develop these processing methods as simple as possible. We have been developed signal processing methods such as data compression and selection for plasma wave instruments, and some of them were already implemented on the SS-520 rocket [1], the lunar orbiter "KAGUYA" [2, 3] and the "MMO (Mercury Magnetospheric Orbiter)" [4]. In the paper, we introduce several functions together with their evaluation results. We also present a future plan for the application of the Japanese new mission named "ERG", which aims to clarify plasma dynamics in the Earth's inner-magnetosphere.

2. Concept of Software Receiver

As was described in "Introduction", our plasma wave instruments are categorized as "software receiver" which was available for various kinds of digital signal processing adjusting the scientific targets. In our wave receiver, the wave signals detected by electric/magnetic sensors are first converted to digital signals by ADCs (analog-digital converters) and are stored in the onboard memories. We measure waveforms below a few hundreds hertz, which amounts to a few Mbps of data production rate in general. On the other hand, the available telemetry rate is several percent of the raw data rate at most and it is only one thousandth for a planetary mission. Then onboard software is required to perform necessary data processing for data reduction such as filtering, FFT (Fast Fourier Transform), data compression and selection in order to obtain maximum scientific output.

For example, we introduced a lossless data compression technique and an automatic data selection algorithm for the WFC (Wave Form Capture) onboard KAGUYA which measures 2

components of electric waveform below 100 kHz. We implemented optional decimation filters in the DSP and operated an automatic filter selection algorithm, in which maximum amplitude or averaged power at each frequency band is firstly evaluated to determine optimum filtering parameters and the onboard software adaptively produces telemetry data which contains an intermittent waveform covering higher frequency range with a lower duty ratio or a semi-continuous measurement in the lower frequency range. The threshold level for the decision at each frequency range can be changed by command. This technique makes it possible to downlink the significant waveform to the ground in shorter time duration and to capture new series of waveform data with higher duty ratio. The function was evaluated applying the same process on the ground to the datasets when the WFC was not in the data selection mode, in which raw waveform up to 100 kHz was downlinked without elimination. It was found that the duty ratio was raised about 4 times on average by adopting the selection process and the algorithm adopted on the KAGUYA/WFC was basically adequate.

We also developed a fast sweep frequency analyzer which measures 2 components of electric spectrum below 1MHz onboard KAGUYA. It achieves very high time and frequency resolution on spectral observation by using hybrid ICs called PDCs (Programmable down converters). The PDCs convert the wideband input signals into narrow band signals and down-sample the data. Finally, the output data from the PDCs are converted into the spectral data by the DSP using the FFT.

As for the MMO spacecraft which explores the Mercury's magnetosphere, the restriction of onboard resources and telemetry budget are much severer than the Earth's explorer missions. We implemented a lossy compression method as a function of waveform receiver and a decimation filter which reduces the upper cut-off frequency down to 1/64 of the original one for the detailed observation of ion mode waves.

These kinds of onboard processing method will be also implemented on the plasma wave instrument onboard ERG, which is a Japanese small satellite mission to investigate dynamics of the inner magnetosphere. In order to achieve comprehensive observations of plasma, particles, fields, and waves, more intelligent processing is required to implement for the ERG mission and we plan to optimize our software to obtain maximum scientific output of the Earth's inner magnetosphere.

2. Summary and Conclusions

In the present paper, we briefly summarized our onboard data processing techniques realized on Japanese plasma wave instruments. In order to develop a high-performance and multi-functional software receiver, it is necessary to implement various kinds of digital signal processing method adjusting the scientific targets. Another problem to be solved is that these techniques shall be simple and fast enough to function in quasi-real-time under restricted resources. We have already implemented our methods into plasma wave instruments onboard KAGUYA and MMO etc., but further sophisticated logic is under development to minimize the size of digital board for the future missions.

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