EPSC Abstracts
Vol. 9, EPSC2014-260, 2014
European Planetary Science Congress 2014

Evaluation of Data Compression Techniques Applicable for Plasma Wave Instruments

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Abstract

Measuring plasma wave is one of important clues to understand solar-terrestrial physics. Especially the importance of waveform measurements was highly recognized, but the amount of raw data from the plasma wave instrument is too huge to downlink all data to the ground. Intelligent digital processing by the onboard software is therefore indispensable because many kinds of operational modes can be implemented without changing the hardware configuration. In the present paper, we introduce several techniques for data compression and the results of evaluation from the view point of compression ratio, computation load and data quality.

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. Recent wave instruments are designed to measure raw waveforms because the importance of waveform measurements was highly recognized since the discovery of electrostatic solitary waves (ESW) by the GEOTAIL spacecraft. On the other hand, measuring wave spectrum and/or covariance matrix of orthogonal components of electric and magnetic fields with high-time and high-frequency resolution are also important to study wave normal direction of the waves and wave-particle interaction. However, the amount of raw data from the plasma wave instrument is too huge to downlink all data to the ground. In the present paper, we introduce techniques for onboard data compression to be implemented on the wave instruments and the results of evaluation of them from the view point of compression ratio, computation load and data quality.

2. Performance of data compression

We studied intelligent data processing applicable for a wave receiver categorized as “software receiver”, that is, 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. The data production rate amounts to a few Mbps when we measure waveforms below several tens kilo-hertz. But the available telemetry rate is several percent of the raw data rate at most and it is only one thousandth for a planetary mission. Data compression is therefore necessary for data reduction, but it is strongly required that the compression algorithms should suppress distortion of the data as well as achieve high data compression ratio.

First we evaluated lossless and lossy compression method for spectrum data. We adopted an entropy coder as lossless compression method. It was found that compression ratio using entropy coder was ~70% on average. We also examined lossy compression for spectrum data based on JPEG algorithms in order to make effective use of limited data transfer rate. As a result, the expected data compression ratio was around 30%. Correlation coefficient between original and decompressed spectrum was from 0.87 to 0.93 and the result was generally better than the cases using frequency or time averaging when we restrict total amount of telemetry data.

Data compression algorithms for waveform data was also developed and evaluated. When we apply lossless compression based on entropy coding, the compression ratio was ~70%. The developed method was actually implemented into the waveform capture (WFC) onboard the Japanese lunar orbiter named “KAGUYA” [1]. Lossy compression using sub-band filtering was also developed for the plasma wave instruments onboard the Mercury orbiter “MMO” [2]. According to our evaluation, however, the expected compression ratio will be generally 50% in order to suppress the data distortion both in the time and frequency domains. In the case of plasma wave instruments onboard MMO, data processing will be executed by a CPU, and thus the computation speed

is not fast enough to enable real-time processing. As a next step, implementation of data compression using sub-band coding module into FPGA is under development. Currently the processing speed was satisfactory enough to process 5 components of waveform (2 components of electric field and 3 components of magnetic field) with their sampling frequencies of 65kHz, which is a nominal sampling frequency of PWI onboard MMO.

3. Summary and Conclusions

In the present paper, we introduce several techniques for data compression and the results of evaluation from the view point of compression ratio, computation load and data quality. In order to achieve the maximum science outputs under the severe restriction of telemetry data rate, it is necessary to implement intelligent data compression techniques which work efficiently with the smallest data distortion. These techniques also 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.

References

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