Development of the chip implemented as high-speed current detection circuits for particle sensors

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Plasma filling the space is very rarefied. Ions and electrons in space plasma do not exchange their kinetic energies through their collisions but through plasma waves. This is so-called “wave-particle interaction,” and it is indispensable for understanding space electromagnetic environments. The WPIA (Wave-Particle Interaction Analyzer) is a new sophisticated method that allows us to understand wave-particle interactions quantitatively. The WPIA was initially installed in the Arase satellite. The WPIA processes instantaneous wave vectors observed by a plasma wave receiver and velocity vectors of each particle observed by a plasma instrument. The high relative time precision for detecting vectors of plasma waves and particles is essential in the WPIA. This requires a synchronous performance of plasma wave receivers and particle instruments. We introduce a system that feeds particle detection pulses of particle detectors into plasma wave receivers to achieve the synchronization. This system can use the sampling clocks for waveforms to keep the high relative time precision between instant values of plasma waves and particle detections. The present study focuses on the part of the circuits dedicated to particle detections and feeds of corresponding pulses into plasma wave receivers. We use the ASIC (Application Specific Integrated Circuit) for integrating the above circuits as one small chip. The chip we developed consists of two stages. The first stage is the current-voltage conversion circuit. Outputs of particle detectors are a series of weak electron current pulses with their pulse widths less than a few tens of nanoseconds. The first stage picks up each current pulse and converts into voltage signals with enough amplitudes to drive the second stage. We designed high-speed circuits dedicated to the first stage. The second stage contains comparator and peak-hold circuits. The comparator ensures picking up real signals by setting a threshold level and the peak-hold circuit has a role to keep the level to connect to the next stage. In this study, we set the count rate of 106/s as the target value and we designed the circuits so that it is within 1 μs from the arrival of a particle to the convergence of the detection signal. Conventional circuits are made of discrete electronic parts. That requires large resources in their sizes and weights. However, the chip we developed is small and light-weight. In this study, we integrate detection circuits using ASIC technology and we aim to accommodate at least 16 channels of circuits within 5 mm square chip.

In this presentation, we show the details of the chip designed for the particle detection circuits. We also examine the verification test results in the operation of those circuits. Furthermore, we describe the development plan for future WPIA system integration.

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