Development and Integration of the High-Speed Current Detection Circuits in Particle Sensors Dedicated to Wave-Particle Interaction Analyzer

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In the terrestrial inner magnetosphere, there is a population of particles whose energies are in ~MeV range and much higher than those of the solar wind. The magnetosphere is so tenuous that particle to particle binary collisions rarely occur. Therefore, particles exchange their energies through plasma waves. However, especially for high-frequency waves, it is not easy to observe a direct clue of the energy transfer from the particles to waves and vice versa.

A conventional observation method of wave-particle interaction has a problem that phase difference information of the plasma wave vector and the particle velocity vector is lost. For this reason, it is difficult to calculate the amount of energy transfer quantitatively. However, WPIA (Wave-Particle Interaction Analyzer) is recently introduced for observation of the wave-particle energy transfer [1]. It calculates inner product of plasma wave vectors and particle velocity vectors for each particle detection event on a satellite and determines the amount of energy conversion directly. The high relative time precision for detecting vectors of plasma waves and particles is essential in WPIA. This requires a synchronous measurement of plasma wave receivers and particle detectors. We introduce a system that feeds feeble current pulses generated by particle detectors into plasma wave receivers to achieve the synchronization. The developing system is a chip consists of two stages based on an ASIC (application specific integration circuit) technology. The first stage is the current-voltage conversion circuit. It picks up a current pulse and converts into a voltage signal with enough amplitude to drive the second stage. The second stage contains a comparator and a peak-hold circuit. They ensure picking up the real signals with availability of threshold settings. Because of the ASIC technology, our system is highly compact in size and weight compared to conventional circuits which are made of discrete electronic components. When our system is onboard micro-satellites, simultaneous multipoint observation of wave-particle interactions can be realized at low cost.
In this study, we develop the circuit which can output detection signals within 30ns after the arrival of particles. These signals can be reset within 12ns from the reset command. The size of one channel of the developed circuit is 210μm×570μm. Since the conventional circuit was several centimeters in size, we have reduced the area of this circuit by more than one tenth.

In this session, we show the details of the chip designed for the particle detection circuits including experimental results.

[1] H. Fukuhara, H. Kojima, Y. Ueda, Y. Omura, Y. Kato, and H. Yamakawa. ” A new instrument for the study of wave-particle interactions in space: One-chip Wave-Particle Interaction Analyzer.” Earth Planets Space 61 (2009) : 765-778.

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