

Study on chip-type wave-particle correlator onboard spacecraft

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Wave-particle correlator (WPC) is a direct measurement system to observe the interactions between waves and particles, which exchange their energies in space plasma. Since space plasmas are collisionless, their kinetic energies are transported through plasma waves. It is important that we identify the wave-particle interaction process to know generation of plasma waves. However, it is difficult to study the interaction process by using the previous plasma instruments with low time resolutions in the order of milliseconds, since the wave-particle interaction occurs in such a short time as $1\mu\text{s}$. The wave-particle correlator realizes the calculation of the correlation between observed wave phase and particles with high time resolution onboard spacecraft/rocket [1-3]. We proposed the new WPC system on the basis of the digital technology [4]. In the present paper, we designed and developed the prototype of this new WPC system (Fig. 1).

The developed new WPC system is the one-chip type wave-particle correlator. The algorithm of calculating correlations is programmed into one FPGA (Field Programmable Gate Array) chip. It realizes flexible observations as well as the high-speed processing. We designed 3-channels of digital filter (bandpass filter) with variable cut-off frequency and installed onto the FPGA. The filters limit the frequency bandwidth of the observed waveforms. The waveforms with limited frequency bandwidth are processed by the correlation calculation algorithm (see Fig. 2) in the FPGA. We can dynamically change the cut-off frequency of filters depending on the observed phenomena. In our algorithm, the correlation index (C) is calculated as following formula,

$$C = \int \text{sign}(E) \times f(v) dt$$

Further, we developed the algorithm for synchronizing particle data with filtered wave data.

Since measurements of plasma particles are operated independently of waveform measurements, this synchronous control is one of the most important parts of the present WPC system. To confirm our algorithm, we conducted the functional tests using the dummy waveform data which are input from the signal generator. The correlation of the dummy waveforms was calculated with the periodic pulses as dummy particle signals generated via a digital module in FPGA and we confirmed that our algorithm functions properly.

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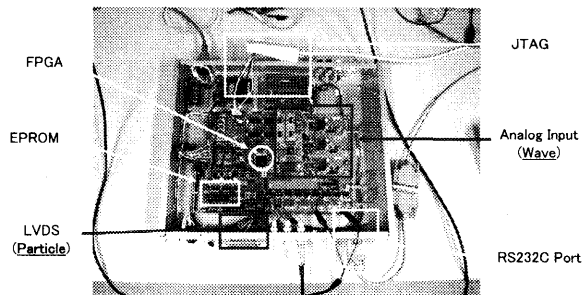


Fig 1: Test board for wave particle correlator.

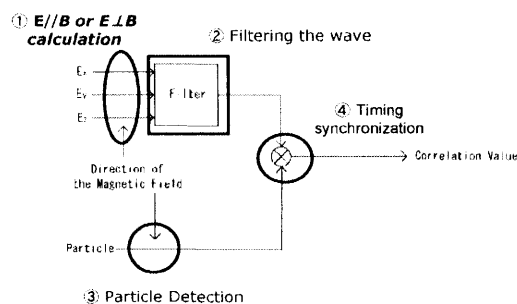


Fig 2: Block diagram of correlation calculation between waves and particles