Improvement of space environment tolerance in a plasma waveform receiver by using ASIC technology

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We have been investigating plasma waves (A few Hz to 10 kHz) to understand the magnetospheric dynamics. To capture plasma waves, we use a waveform receiver. It is required reduction of physical resources (mass, volume and power etc.), a wide operating temperature range (-60 to +100 Celsius degrees) and a high radiation tolerance (350 krad or more). We have been developing a waveform receiver by using ASIC (Application Specific Integrated Circuit) technology in order to reduce physical resources with a high tolerance for space environments. However, the conventional ASIC waveform receiver (hereinafter called ASIC receiver) was not accepted the requirements of environment tolerance. The main purpose is to achieve -60 to +100 Celsius degrees of operating temperature range and 350 krad or more of radiation tolerance for the ASIC receiver.

The conventional ASIC receiver did not operate at -60 Celsius degree in the circuit simulation result. The reference currents for the amplifiers in the conventional ASIC receiver are supplied by an external bias resistance (32k ohms) connected to the voltage source. The fluctuation rates of reference current are approximately plus or minus 6% in -60 to +100 Celsius degrees. It is not sufficient, because a threshold voltage of CMOS changes by ambient temperature. We added a temperature compensation circuit into the new ASIC receiver in order to supply the reference currents without the external bias resistance. By using the circuit simulation, we estimated the effects of the temperature compensation circuit on the operating temperature range (-60 to +100 Celsius degrees). From the simulation results, the fluctuation rates of reference current supplied by the temperature compensation circuit were approximately plus or minus 30% (-60 to +100 Celsius degrees), which is better for improving the operating temperature range. The new ASIC receiver can operate in the requirement of operating temperature range.

The radiation tolerance of conventional ASIC receiver cannot satisfy the requirement of 350 krad or more because the based amplifiers of the conventional ASIC receiver are weak for radiation. To improve the radiation tolerance, the surface area of amplifier in the new ASIC receiver was designed approximately 3.5 times larger than that for the conventional ASIC receiver. We did the radiation test for the conventional and new ASIC receivers by using the gamma ray of 400 krad to evaluate the radiation tolerances. From the radiation test results, the output noise (at 2.5 Hz) of conventional ASIC receiver degraded by approximately 6 dB from 310 krad. However, the output noise of new ASIC receiver was no change during the radiation test (until 400 krad). We consider the large surface area of amplifier can decrease occurrence rate of electron-hole pairs by radiation. The new ASIC receiver can operate in high radiation environments like a planetary mission.

In this presentation, we will present the improvement of space environment tolerance in a plasma waveform receiver by using ASIC technology in detail.