SPACEWIRE APPLICATION FOR THE X-RAY MICROCALORIMETER INSTRUMENT ONBOARD THE ASTRO-H MISSION

Session : SpaceWire missions and applications

Short Paper

Yuichiro Ezoe[1], Yoshitak Ishisaki[1], Takaya Ohashi[1], Keisuke Shinozaki[2], Yoh Takei[2], Noriko Y. Yamasaki[2], Kazuhisa Mitsuda[2], Kosuke Sato[3], Ryuichi Fujimoto[3], Yukikatsu Terada[4], Makoto Tashiro[4], Richard L. Kelley[5], and Jan-Willem den Herder[6]

[1] *Tokyo Metropolitan University, 1-1 Minami-Osawa, Hachioji, Tokyo, Japan*

[2] *ISAS/JAXA, 3-1-1 Yoshinodai, Sagamihara, Kanagawa, Japan*

[3] *Kanazawa University, Kakuma-machi, Kanazawa, Ishikawa, Japan*

[4] *Saitama University, 255 Shimookubo, Sakura, Saitama, Japan*

[5] *NASA/GSFC, Greenbelt, MD 20771, USA*

[6] *SRON, Sorbonnelaan 2, 3584 CA, Utrecht., Netherland*

E-mail : ezoe@phys.metro-u.ac.jp, ishisaki@phys.metro-u.ac.jp, ohashi@phys.metrou.ac.jp, shinozaki@astro.isas.jaxa.jp, takei@astro.isas.jaxa.jp, yamasaki@astro.isas.jaxa.jp, mitsuda@astro.isas.jaxa.jp, ksato@astro.s.kanazawau.ac.jp, fujimoto@astro.s.kanazawa-u.ac.jp, terada@phy.saitama-u.ac.jp, tashiro@phy.saitama-u.ac.jp, Richard.L.Kelley@nasa.gov, J.W.A.den.Herder@sron.nl

Abstract

SpaceWire application for the X-ray microcalorimeter instrument onboard the Japanese Astro-H mission (2013) is presented. The instrument, Astro-H SXS (Soft X-ray Spectrometer), will be the first satellite-borne microcalorimeter experiment, and will investigate the hot-gas dynamics in galaxies and in clusters of galaxies with >20 times better energy resolution of <7 eV (FWHM) at 5.9 keV than the previous experiments. The Astro-H SXS will make use of SpaceWire as high speed data and command interfaces. In this paper, we present the data network architecture and the development status.

1 ASTRO-H SXS

The X-ray microcalorimeter detects heat pulses by X-ray photons in X-ray absorbing pixels. By precisely measuring the temperature increase, >20 times better resolution spectroscopy at 5.9 keV than X-ray CCDs with high quantum efficiency becomes possible.

Astro-H is a Japanese medium size satellite (∼2600 kg) which will be launched into the low earth orbit in 2013 [1]. Its objective is a wide-band spectroscopy provided by multi-layer coating X-ray telescopes, semiconductor detectors, scintillation crystals and a microcalorimeter named SXS (Soft X-ray Spectrometer) [2]. The SXS is composed of the SXS-XCS (X-ray Calorimeter Spectrometer) and SXS-SXT (Soft X-ray Telescope).

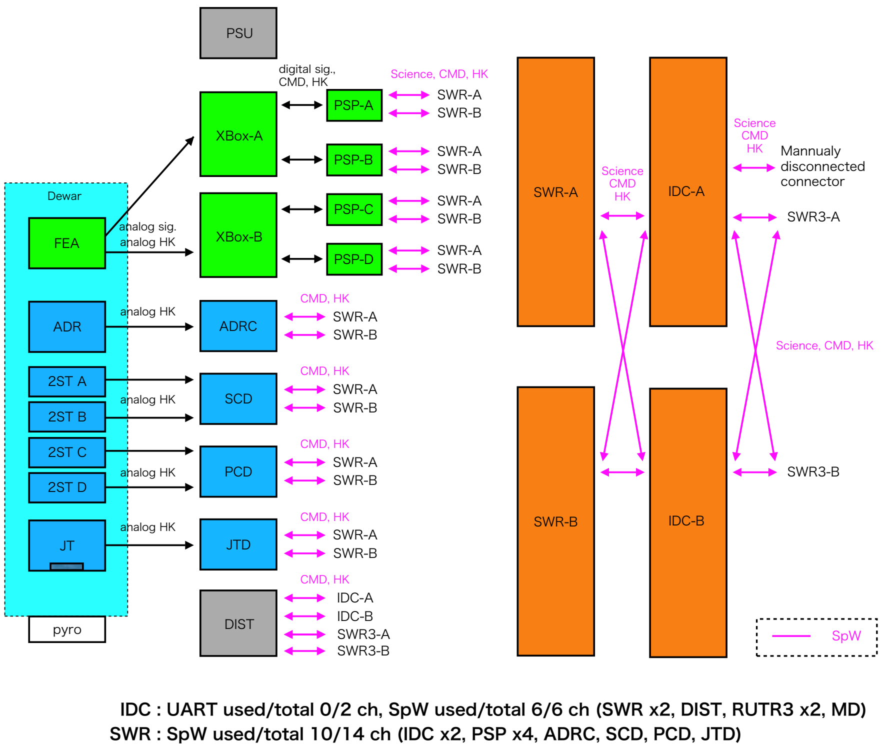

Figure 1: The data block diagram of the Astro-H SXS-XCS.

2 DATA BLOCK DIAGRAM

In Astro-H, we will employ SpaceWire as a high-speed standard data link. The data block diagram of the Astro-H SXS-XCS is shown in figure 1. This diagram is designed so as to avoid a single point failure at the SpaceWire network such as cable connections, data handling units, and so on, as possible as we can. It also enables flexible ground operations without turning on the spacecraft and considers the power-on sequence. The diagram can be divided into four subsystems.

- Detector subsystem (green boxes in figure 1). X-ray pulse signals detected in the microcalorimeter array, which is within FEA (Front End Assembly) in the dewar, are sent to XBoxes (X-ray Box : Analog electronics and ADC converters) and then to PSPs (Pulse Shape Processor : Digital pulse analyzer). Each XBox (-A and -B) handles pulse signals from 32 of 64 pixels, while each PSP (-A, -B, -C, and -D) analyzes 16 pixel data.

- Cryogenic subsystem (blue). To cool the microcalorimeter down to 50 mK, we employ 2-stage Stirling coolers (2ST), a ^{3}He Joule-Thomson cooler (JT), superfluid He, and a 2-stage adiabatic demagnetization refrigerator (ADR). SCD (Shield Cooler Drive : two 2STs for dewar internal radiation shields), PCD (Pre Cooler Drive : two 2STs for JT precoolers), JTD (JT Cooler Drive), and ADRC (ADRC Controller) control the 2STs, JT, and ADR, respectively.

- Data handling subsystem (orange). IDC (Instrument digital control) is a command and telemetry interface with the spacecraft system via two Space Wire routers (SWR3-A and

-B). IDC-B and SWR-B are cold redundant units. IDC has functions to check cooler temperatures, to control the JT start up, and to communicate with the ground support equipment (GSE) during the ground operations. SWR (SpaceWire Router) is a router to distribute commands and receive data from units. IDC generates CCSDS packets and sends the data to the spacecraft system. The expected data rate between IDC and the spacecraft is < 20 kbps for the science data and $\sim$1.5 kbps for the HK data. The GSE can be directly connected to IDC-A via SpaceWire for ground operations.

- Power subsystem (grey). DIST (Distributor) distributes the spacecraft bus power of 32–50 V to all the SXS-XCS units. It can be controlled by either the spacecraft system or IDC. Since DIST can be powered from the GSE and controlled by IDC, we can operate the SXC-XCS without turning on the spacecraft bus on ground. PSU (Power Supply Unit) recieves the primary bus power from DIST and provides regulated power, isolated from the primary power, to XBoxes. It has no data interface.

3 DEVELOPMENT OF SPACEWIRE UNITS

3.1 IDC and SWR

Current designs of the two data handling units, IDC and SWR, are shown in table 1. They will be manufactured by NEC Corporation. The design of IDC is based on Space Cube 2 which will be onboard the JAXA SDS-1 small satellite to be launched in 2009, while SWR is newly developed. Both of them will be universal SpaceWire units for future satellites. In fact, the hardware of IDC will be the same as that of the spacecraft system unit onboard Astro-H.

IDC will have a high-speed radiation-hard CPU named HR5000 (64 bit, 200 MHz at maximum), moderate-size system memories (2 MB EEPROM, 4 MB Burst SRAM, and 4 MB Asynchronous SRAM), and large data recorder memories (1 GB Asynchronous SDRAM and 1 GB Flash Memory). The TRON realtime OS, T-Kernel, will be employed as an operating system. IDC will be equipped with only two modes (ON or OFF). When it is powered on, the IDC onboard software automatically starts up, and begins command and telemetry handling.

Table 1: Current designs of IDC and SWR.

	IDC	SWR
Size	W71×D221×H180 mm	W150×D110×H60 mm
Mass	2 kg	1.2 kg
Power	OFF 0 W, ON 14±1 W	OFF 0 W, ON 5±1 W
SpaceWire port	6 port/Router	14 port/Router
- link rate	50 Mbps	50 Mbps
RS422/UART port	2 port	–
- link rate	19200 bps	–

While SWR is a simple router using the cross bar switching technology, IDC has various functions as described in section 2. To fulfill the requirements, the mission specific software must be developed. To distinguish general tasks such as SpaceWire RMAP I/O and command/telemetry handler from the mission specific tasks such as CCSDS packet forming and ADR control, the JAXA standard middleware will be defined and prepared by the Japanese SpaceWire team. Development of the middleware, especially the SpaceWire API, is ongoing.

IDC will make use of the SpaceWire time code which is defined in the SpaceWire protocol. Its delay and/or jittering within the Astro-H system will be less than a few μs. Referring to GPS signals or an internal clock circuit if the former is unavailable, a spacecraft system unit will distribute the time code (6 bit, 1/64-sec time resolution) to IDC.

3.2 PSP

PSP will be composed of four Universal SpaceWire Boards and Space Cards, both of which are developed by Mitsubishi Heavy Industries Ltd.. One pair of them is used to handle the data from 16 of 64 pixel data. The Universal SpaceWire Board will have two FPGAs with 32 MB SDRAM. In this board, X-ray pulses are detected and pulse shapes are recorded. The Space Card will have an SH4 compatible CPU with 64 MB SDRAM and FPGA with 2 MB EEPROM, 4 MB SRAM, and 32 MB SDRAM. Intelligent data analysis such as second pulse detection, pulse shape filtering, and packet generation is conducted in this board. Development of the pulse analysis software for ground microcalorimeter application and the SXS-XCS is described in [3]. Similar to IDC and SWR, these two types of boards are universal modules and will be used in other instruments onboard Astro-H.

3.3 The other units

SpaceWire interfaces of the other electrical units in figure 1 will be implemented by the SpaceWire IP Core for FPGA (Field Programmable Gate Arrays). One FPGA will support two SpaceWire ports. The type of FPGA is to be determined. A candidate for the data and command transfer between IDC and each unit is to RMAP write from IDC and then to RMAP read by IDC. Thus IDC controls timings of command and telemetry.

4 CONCLUSION

Development of SpaceWire hardware and software for the Astro-H SXS-XCS is being carried out. Based on heritages of coming SpaceWire missions before Astro-H, e.g., SDS-1 and the JAXA small satellite project, we would like to establish the SpaceWire system for the SXS-XCS.

Reference

[1] T. Takahashi et al., "The NeXT mission", 2008, SPIE, 7011, 70110O

[2] K. Mitsuda et al., "The x-ray microcalorimeter on the NeXT mission", 2008, SPIE, 7011, 70112K

[3] T. Hagihara et al., "Digital signal processing systems of an X-ray microcalorimeter array for ground and space applications", this conference