SPACEWIRE IN THE SIMBOL-X HARD X-RAY MISSION

Session: SpaceWire missions and application

Short Paper

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ABSTRACT

SIMBOL–X is a hard X–ray mission, operating in the 0.5–70 keV range [1], which is proposed by a consortium of European laboratories for a launch around 2013. Relying on two spacecrafts in a formation flying configuration, SIMBOL–X will allow to elucidate fundamental questions in high energy astrophysics, such as the physics of accretion onto Black Holes, of acceleration in quasar jets and in supernovae remnants, or the nature of the hard X–ray diffuse emission.
The instrument combines three type of detectors: a silicon low energy detector on top of a cadmium telluride high energy detector and a scintillator which surrounds them except for the solid angle corresponding to the focused beam from the mirror. Instrument performance is expressed in particularly in term of dead time, which defines in turn the time tagging resolution and relative accuracy of the events from the three detectors. Therefore the SIMBOL-X instrument requires an accuracy of 100 ns. In the presentation we will focus on the SpaceWire [2] standard Time-Code [3] use limitation and provide a way to improve it with a minor upgrade of the standard to reach the expected performances.

1 INTRODUCTION

The SIMBOL-X instrument is an X-ray imager relying on two focal planes to fulfil the energy range requirement: the 0.5 keV to 12 keV sub-range is covered by the silicon detector while the 8 keV to 70 keV sub-range is covered by a 2 mm thick cadmium telluride detector. Each focal plane is a 128 by 128 pixel matrix. A possible cause of performance limitation of such type of instrument is due to cosmic background noise, which decrease its overall efficiency. A basic way to reduce this background is to surround the detector, except in front, with a multilayer shield made of materials having various atomic masses. Depending on its atomic mass and thickness each material traps incoming particles in complementary energy sub-ranges. However the efficiency of this shield is not 100%. Better results may be even

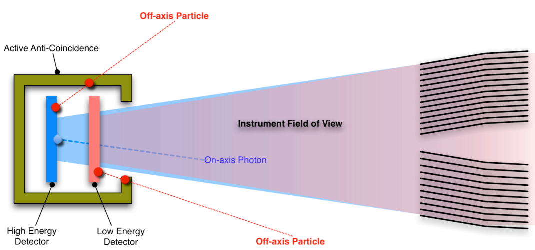

Figure 1 – Instrument layout

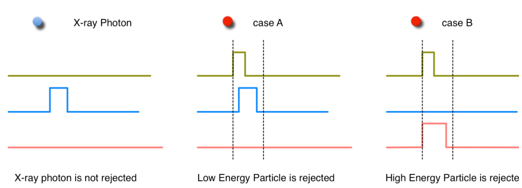

Figure 2 – Active anticoincidence

obtained by adding an active shield to this passive shield. This active shield is made of a scintillator material (CsI, crystal, …) which generates photons when crossed by noise particles. These photons are then detected by means of either photo-multiplier tubes or photo-diodes. Almost immediately after this first interaction the particle hits the focal plane detector and in turn generates an event. The resulting instrument optical layout is illustrated in figure 1.

Therefore rejection of background events is simply achieved by eliminating time-correlated events between the active shield detector and the focal plane detector. The so-called anticoincidence mechanism is illustrated in figure 2 in the case of two focal plane detectors as in SIMBOL-X. The major contribution is the reduction of the telemetry volume: when observing faint sources the X-ray photon rate could be as low as a few counts per second while the background-generated events reaches a rate of several hundreds.

In order to take into account various uncertainties (electronic noise, propagation delay jitter, …) an anticoincidence window is defined: all events occurring within this window shall be rejected. However the width of this window shall be carefully chosen since it determines the efficiency in term of unavailability of the instrument also called the *dead time*. The Figure 3 shows the impact on the *dead time* for window width varying between 10 ns and 100 µs for 10000 events per second. The required 1% of *dead time* for the SIMBOL-X instrument limits the window width to 1 µs.

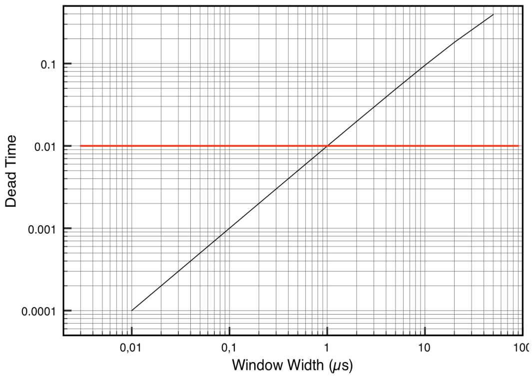

Figure 3 – *Dead time* vs Window width

As shown in figure 4 the instrument comprises 3 detection sub-systems: high energy, low energy and active shielding. In turn each sub-system comprises the detector located in the instrument focal plane and the associated control electronics. A last sub-system (the Data Processing Assembly) is in charge of the whole instrument control and the processing of both scientific and engineering data. In order to optimise interface definition the SpaceWire standard was adopted to handle this bidirectional data flow. Detection sub-systems act has destination nodes while DPA acts as transmission node. Among the exchanged data the events defined by an amplitude, a position and a time tag are received by the DPA. Then the DPA shall check time correlation between events to reject unwanted ones by comparing the time tags of the incoming events within the coincidence window. The time tag accuracy is assumed to be one 10^{th} of the window width. Therefore the SIMBOL-X performance requirement implies a relative time tag accuracy of 100 ns between detection sub-systems. The following table summarizes the various data flows exchanged with the DPA. As shown maximum peak data is limited to 20 Mbps: it determines the SpaceWire operating signalling rate. Each data flow is using a dedicated virtual channel identified by mean of specific *protocol id* and *packet type ids*.

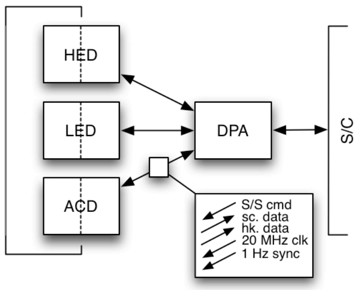

Figure 4 – Instrument Overview

Direction	Data flow	S/S		
		HEDEA	LEDEA	ACDEA
Downstream	Scientific Data	0.35 Mbps	0.80 Mbps	0.01 Mbps
	(peak)	< 20 Mbps	< 20 Mbps	
	Engineering Data	0.024 Mbps	0.024 Mbps	0.002 Mbps
Upstream	S/S Commands	< 0.1 Mbps	< 0.1 Mbps	< 0.1 Mbps

2 SPACEWIRE STANDARD & EXTENSION

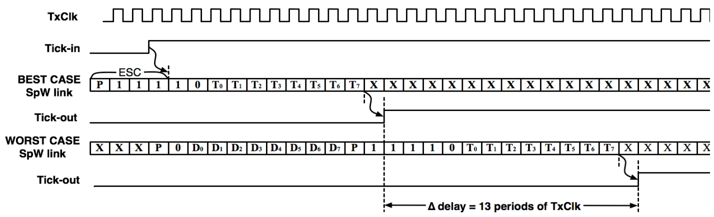

Figure 5 - Best and Worst TIME-CODE transmission delay

The SpaceWire standard specifies the TIME-CODE character to propagate the time across the network [4]. Currently TIME-CODE transmission request occurs asynchronously with respect to the transmitted character stream. Therefore the delay between the TIME-CODE request and the effective character transmission is equal to the time left for the transmission of the current character. The delay difference between the best and the worst cases is then 13 transmission clock periods: best is when an ESC transmission is about to end, worst is when a Data Character has just started. Best and worst case timings are represented in Figure 5. The best achievable time synchronization accuracy through SpaceWire links will be then 1.3 µs for a 20 Mbps transmission rate or 100 ns for a 260 Mbps transmission rate. The increase of the interface frequency well above the need for instrument data transmission - 20 Mbps- is not acceptable since it adds constraints to the design and to the power budget. Alternative solution could be to add a dedicated interface devoted to synchronization, but again with an impact on system budget.

Finally the decision was taken to work around the existing TIME-CODE to increase its accuracy and especially by taking into account the highest priority of this TIME-CODE defined by the standard. First of all the idea is to measure the delay between TIME-CODE request and its effective transmission and then to find a way to send this delay to the destination node in order to compensate this delay. Thanks to priority scheme the only solution is to send a second TIME-CODE immediately after the first one, which carries the measured delay. It allows creating a constant delay between the TIME-CODE transmission request in the transmission node and a synchronisation signal in the destination nodes.

3 IMPLEMENTATION

The block diagram of the SpaceWire and the proposed extension is given in Figure 6. Added functions are the “Time_TX” and “Time_RX” functions. No modification of the SpaceWire standard core is required except the Ack_Time signal, which is added to the “Tx” function and used by the new “Time_TX” function. To be noticed: to enable the implement of this extension, access to TIME-CODE recovery clock and acknowledgement signal is needed. The extension implementation is low resource consuming: it requires only 62 of 4024 (1.5%) combinational cells and 42 of 2012 (2%) sequential cells of an RTSX-SU72 ACTEL FPGA.

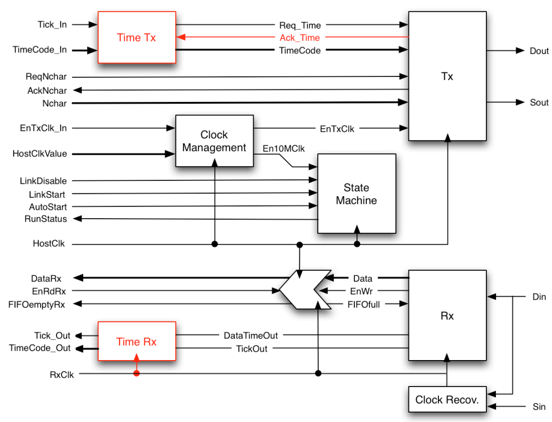

Figure 6 – SpaceWire with extension

4 RESULTS AND DISCUSSIONS

To validate the performance of the extension a prototype of the SpaceWire network was realized: a home made PCI acquisition board implementing four SpaceWire interfaces simulates the DPA while two detector acquisition boards simulate the HED and ACD electronics respectively. The block diagram of this test configuration is depicted in Figure 7.

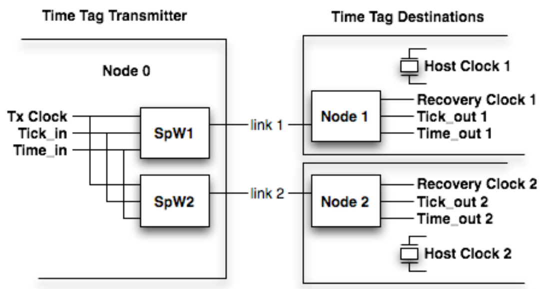

Figure 7 – Block diagram of the tested configuration

First timing measurement on this prototype is shown in Figure 8. The upper trace is the TICK_IN signal of the transmitter and the two next traces (Red and Green) are TICK_OUT signals of the two destination nodes. The rising edge of the TICK_OUT signal is not re-synchronized and then a large jitter of almost 160 ns is measured. This jitter corresponds to what could be obtained with a standard SpaceWire. The falling edge of the same signal is re-synchronized with the extension. The resulting jitter is as low as about 4 ns and is due to cables length and propagation delay mismatches. Practically in the SIMBOL-X instrument the TICK_IN TICK_OUT interface will be used to propagate a 1 Hz synchronisation signal generated by the DPA and synchronous to the satellite on-board time, which will reset time tag counters in each detector electronic. These counters will be incremented by mean of the SpaceWire recovery clock in order to avoid any time drift between detectors.

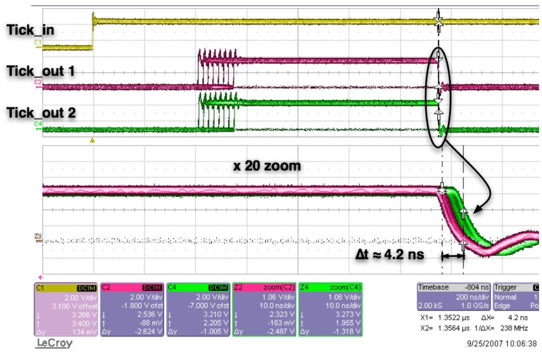

Figure 8 – Timing Diagram

5 CONCLUSION

With the proposed extension a single interface standard fulfil all the needs in terms of data transmission: both scientific, engineering and command and time synchronisation for the SIMBOL-X instrument. It optimizes overall instrument architecture, simplifies integration tasks and test equipment design. The extension fits perfectly within limited available hardware especially in the detector electronics were only small FPGA are foressen. Further improvements such as calibration and compensation of propagation delay mismatch could be done.

6 REFERENCES

[1] Ph Ferrando and al. “SIMBOL-X: mission overview”, *proc. SPIE 6266, p.62660 (2006).*

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