STAR Fire: SpaceFibre diagnostic interface and analyser

SpaceWire Test and Verification, Short Paper

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Abstract— SpaceFibre is a new technology for use onboard spacecraft that provides point-to-point and networked interconnections at Gigabit rates with Quality of Service. SpaceFibre carries SpaceWire packets over virtual channels and provides a broadcast capability similar to SpaceWire time-codes. In order to assist with the development, testing and validation of the first SpaceFibre system a SpaceFibre diagnostic interface and analyser unit, called STAR Fire, was built by STAR-Dundee.

This paper describes STAR Fire, the first complete test and development solution available for SpaceFibre. STAR Fire has two independent SpaceFibre interfaces compliant with the SpaceFibre standard, each one with an embedded link analyser and multiple very high data rate hardware data generators and checkers. The unit can be configured in interface or sniffer mode. The sniffer mode is used to monitor protocol and user data produced by an external unit passing in both directions along a SpaceFibre link, similar to the STAR-Dundee SpaceWire Link Analyser. The STAR Fire unit can also be used as a bridge between SpaceWire and SpaceFibre links, using an embedded router that interconnects some SpaceFibre virtual channels with the two SpaceWire ports provided.

These and other functionalities are easily configured using a Graphical User Interface software in the host PC. The user can supervise the status of the unit and set the parameters of each link, broadcast channel, virtual channel data rate, Quality of Service and error injection. The link analyser module decodes and shows the SpaceFibre protocol and user data stream which can be analysed at character, word or frame level.

STAR Fire has been designed to support the rapid and painless adoption of the SpaceFibre technology within the SpaceWire community.

***Index Terms*—SpaceFibre, SpaceWire, STAR Fire**

I. Introduction

SpaceFibre is a very high-speed serial link designed specifically for use onboard spacecraft and to be compatible with SpaceWire protocol [1]. The aim of SpaceFibre is to provide point-to-point and networked interconnections for Gigabit rate instruments, mass-memory units, processors and other equipment, on board a spacecraft. SpaceFibre is designed to be compatible with the SpaceWire protocol at packet level but providing a much higher data rate.

STAR-Dundee in collaboration with the University of Dundee has developed STAR Fire, a complete SpaceFibre diagnostic unit configured through a Graphical User Interface (GUI) which also provides status information and analysis capabilities. Hence, STAR Fire provides a complete SpaceFibre test and development solution.

STAR Fire hardware unit features two independent SpaceFibre interfaces compliant with the latest draft of SpaceFibre ECSS standard [2], each one with an embedded link analyser and multiple very high data rate hardware data generators and checkers. Furthermore, STAR Fire unit provides two SpaceWire ports and an embedded SpaceWire router. It also provides hardware triggering capabilities and the ability to access the data of the embedded analyser using two logic analyser MICTOR connectors or a PC, by using specific software. Additionally, STAR Fire unit allows user update through the USB port. In this way, it is easy for users to keep track of new developments and functionalities added to the design.

STAR Fire software is based on a GUI that allows the configuration of the SpaceFibre interfaces and the use of the embedded link analyser. It also controls the parameters of the data generators and monitors the status of the data checkers for virtual channels and broadcast data. Furthermore, there is a trigger module that decodes the SpaceFibre data stream which can be analysed using the word or the frame based view.

II. SpaceFibre Overview

SpaceFibre high-speed serial link carries SpaceWire packets over multiple channels, called virtual channels (VC), each one with a defined Quality of Service (QoS) and provides an improved broadcast mechanism similar to SpaceWire time-codes but offering much more capability. SpaceFibre has two

types of user interfaces to send data. The VC interface comprises a number of virtual channel buffers for sending SpaceWire packets and the same number for receiving SpaceWire packets. SpaceFibre is compatible with the packet level of the SpaceWire standard. This means that applications developed for SpaceWire can be readily transferred to SpaceFibre. The broadcast interface is designed to send short messages of up to 8 bytes with very low latency across the network, in a similar manner as the SpaceWire time-codes, but providing not only timing distribution but also signalling and interrupt services. SpaceFibre currently operates at 10 times the maximum data-rate of SpaceWire – i.e. link speed of 2.5 Gbps – and can run over fibre optic (up to 100 m) or copper media (up to 8 m).

SpaceFibre provides a completely reliably link with the fastest possible error recovery time for transient and persistent errors. This is fulfilled with a retry mechanism that guarantees reliability in the communications link. This allows recovering from transients and persistent errors on the SpaceFibre link. The retry mechanism uses the following Fault Detection, Isolation and Recovery (FDIR) mechanisms:

- Notification of data or control information using positive and negative acknowledgements (ACKS/ NACKS)
- Error detection using sequence numbers, 8B10B error detection capabilities and CRC codes
- Automatic resending of data frames, broadcast frames and flow control tokens using a Go-Back-N scheme when sporadic errors occurs
- Automatic re-initialisation of the link when an error is persistent

In addition, SpaceFibre provides timely data delivery and determinism using a medium access controller that determines which channels can send data and in which order. The QoS is independently configurable for each VC. Three mechanisms can be configured and combined:

- Priority: provides less latency to virtual channels with higher priority
- Bandwidth allocation: provides a minimum guaranteed throughput
- Scheduling: provides deterministic packet delivery

These different QoS parameters work together in a consistent manner. Hence, it is possible to work at the same time with a VC that requires minimum latency for command and control operations, a VC with a guaranteed throughput for payload data, and a deterministic delivery for packets that need to be sent and processed in a specific order.

III. System Architecture

The STAR Fire hardware unit consists of two SpaceFibre interfaces (eSATA connectors), two SpaceWire interfaces (micro-miniature D-type connectors), four external triggers (SMB connectors, three input and one output) for interfacing with external equipment and two logic analyser (MICTOR connectors) interfaces. The status of the SpaceWire and SpaceFibre interfaces is notified by LEDs. The hardware design provides, in addition to the SpaceFibre and SpaceWire ports, multiple very high data rate data generators, data checkers, link analysers and an embedded SpaceWire router. The system architecture is shown in Fig. 1.

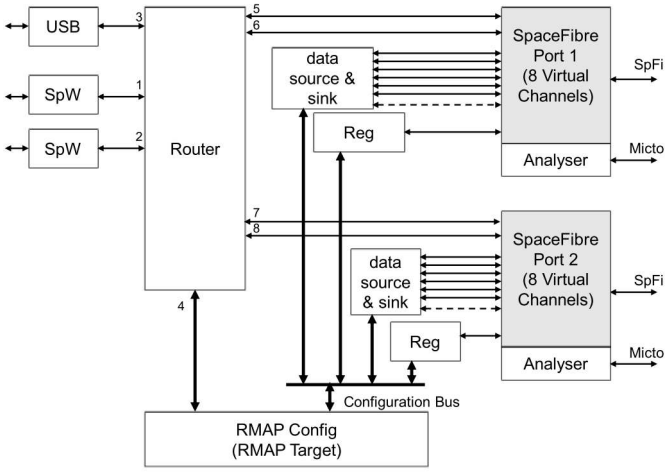

Figure 1 System Architecture

Each SpaceFibre port contains eight VCs that are arbitrated following the QoS requested. The SpaceWire interfaces and some SpaceFibre VCs are connected to an embedded SpaceWire router as shown in Figure 1. This allows SpaceWire packets from SpaceWire interfaces to go into SpaceFibre VCs and vice versa. However, in order to achieve the much higher data rate of SpaceFibre, the hardware data generators and checkers connected to virtual channels 2 to 7 can be used. Similarly, each SpaceFibre port also features a broadcast data checker and generator. Finally, an RMAP [3] target allows accessing to configuration and status registers of the SpaceFibre cores and the data generators and checkers. The RMAP target is accessed by the software through the router by a USB port but can also be accessed through the SpaceWire ports.

IV. STAR Fire Configurator SW and Trigger

STAR Fire also includes dedicated software developed to control and monitor the hardware unit. STAR Fire Configurator allows the configuration of the SpaceFibre interfaces and the use of the embedded link analyser. It also controls the parameters of the data generators and monitors the status of the data checkers for both VC and broadcast data. The software suite also includes STAR Fire Trigger. This Trigger module allows programming the trigger and decoding the SpaceFibre data stream. Two different display views for the decoded data are offered. Analysis of the data is possible using either Word or Frame based view.

Figure 2 presents a screenshot of the STAR Fire Configurator (top) and Trigger windows (bottom). There are different regions in the Configurator tool window which control the different parameters of the unit.

A. Unit

This region identifies the unit selected. Several units can be connected to the same computer and controlled from a single Configurator instance at the same time.

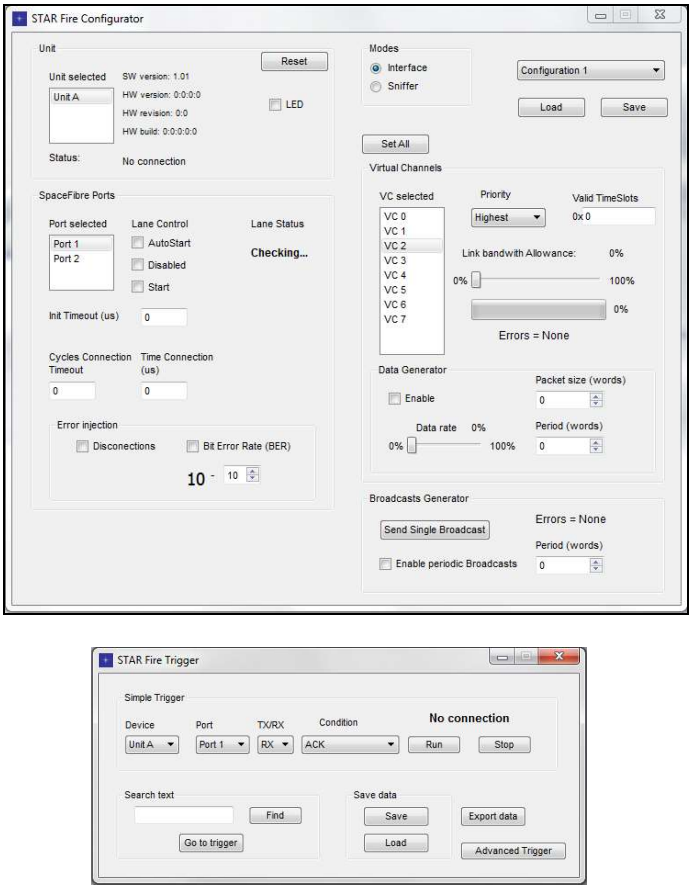

Figure 2 STAR Fire Configurator (top) and Trigger windows (bottom)

B. SpaceFibre Ports

The two SpaceFibre ports can be controlled in this region. The lane status of the port is displayed. The starting mode (Start or AutoStart) can be configured. Additionally, the initialisation timeout can be controlled for debugging purposes.

C. Modes

STAR Fire can be configured in sniffer or interface mode. When the sniffer mode is set the STAR Fire is only used to analyse the data stream of an external SpaceFibre capable unit. On the other hand, in interface mode each SpaceFibre port of the unit is a source and a destination of SpaceWire packets encapsulated in SpaceFibre frames. Besides, the whole setup of a unit can be saved and loaded into different files for faster configuration.

D. Virtual Channels

Each SpaceFibre interface has eight VCs. Independent data generators and checkers are connected to each of the input and output of VCs 2-7. The generation rate, packet size and working period can be controlled in this region. The generation rate specifies the duty cycle of the specified period. For example, if a 75% bandwidth and 100 word period are selected, the data generator will generate consecutive 75 words and remain idle for 25 words before starting to send data again.

VCs 0 and 1 are connected to an internal SpaceWire router and are used to transmit SpaceWire packets from the two SpaceWire ports.

QoS parameters (priority, bandwidth, scheduling) for each VC are also configured here. A bar shows the current generation rate of the selected channel and an error counter verifies that no errors are encountered in the data pattern.

E. Broadcasts Generator

Broadcast frames can also be generated. A single broadcast or periodic broadcasts can be sent through the SpaceFibre selected port with a configurable period. The data received is checked by a broadcast checker and the number of errors is displayed.

F. Error Injection

In addition to the status and control information, it is possible to automatically insert random disconnections on the selected link or a specific bit error rate in the form of a power of 10. This feature is useful when simulating persistent errors or bit flip conditions on the line.

G. Trigger

The Trigger window allows two operation modes. By default the Simple Trigger mode is shown. However, the Advanced Trigger mode can be selected in the GUI. This advanced mode shall only be used for debugging purposes or when using complex setups (e.g. several STAR Fire units connected to the same PC, using external trigger signals, cross-triggering between units, etc.). For the sake of simplicity only the Simple Trigger is shown.

When different units are connected to a PC, the Device drop-down list allows selecting the appropriate one. Port 1 and 2 can be selected for any unit, and also whether the trigger analyses the RX or TX side of the selected port. Finally, the condition that triggers the unit is selected in the Condition drop-down list. Any control word defined by SpaceFibre can be selected. The Advanced Trigger offers the possibility of triggering the unit not only on words but also on certain events, namely, disparity or not-in-table errors, data checker errors, etc. This can be useful for analysing specific situations during development. Furthermore, the Analyser will show by default the RX and TX sides of the selected Port. But the Advanced Trigger also offers the possibility of displaying the RX side of both ports of the selected Unit instead.

After setting up the trigger, the Run button activates it. The status of the trigger is continuously shown. When triggered, a Search Text box allows searching for particular strings in the captured data. The row in which the text is found is shown in the STAR Fire Analyser window. The data can also be saved or loaded, and exported to be analysed in other software if necessary.

V. STAR FIRE ANALYSER

The STAR Fire Analyser shows two separate views which analyse data captured by the trigger or loaded from a data file (Fig. 3). The main window is called the Word Viewer (top panel of Fig. 3) and shows the SpaceFibre words received. The Word Viewer presents the analysis of data at word level. Each SpaceFibre word consists of four 8B10B symbols or characters [4]. In the central part of the window the word is decoded, sometimes complemented with some additional information such as the frame sequence number. Apart from this information, the four different symbols composing a word are also displayed in the external part of the window.

Figure 3 STAR Fire Analyser: Word Viewer (top) and Frame Viewer (bottom)

The other window is the Frame Viewer (bottom panel of Fig. 3) and shows a more compact analysis of the data. The received data and broadcast frames of each side is displayed, with a separate column for each VC. Note that it is possible to have broadcast frames in the middle of data frames, but at any particular time selected by a row there can only be one VC data frame on each side (as these frames are being multiplexed through a single SpaceFibre link). If there is an EOP within a data frame it is shown together with the number in bytes of the SpaceWire packet that the EOP terminates. This allows a quick inspection of the SpaceWire packets travelling through the VCs.

Finally, both viewers share the same row numbers. Thus, their view is automatically updated to always show the selected row in both windows.

VI. CONCLUSION

The STAR Fire diagnostic interface and analyser unit has been presented here. This unit can be easily configured through a Graphical User Interface providing complete status information and analysis capabilities. STAR Fire provides a complete SpaceFibre test and development solution. It features an internal SpaceWire router which allows connecting two SpaceWire interfaces to the SpaceFibre virtual channels. Furthermore, STAR Fire also contains embedded data generators and checkers which can individually operate up to 2 Gbps, broadcast generators, and error and link disconnections insertion. An embedded analyser allows triggering on certain events (e.g. errors or specific data words) and to display and store the captured data. These hardware capabilities are combined with a software package which provides a GUI to control STAR Fire operation and triggering, and also to access the analyser with byte, word and frame level views. All in all, STAR Fire is a flexible and powerful tool which provides support for adoption of the SpaceFibre technology.

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