The SpaceWire Physical Layer Tester (SPLT)

SpaceWire Test and Verification, Short Paper

Pete Scott, Alan Spark
STAR-Dundee Ltd.
Dundee, Scotland, UK
pete.scott@star-dundee.com, alan.spark@star-dundee.com

Paul Crawford, Steve Parkes
University of Dundee
School of Computing
Dundee, Scotland, UK
psc@sat.dundee.ac.uk, sparkes@computing.dundee.ac.uk

***Abstract*—The STAR-Dundee SpaceWire Physical Layer Tester (SPLT) features hardware which enables it to perform tests across the SpaceWire standard from the physical and signal layer right up to the network and protocol layer. By incorporating components from other established STAR-Dundee products, including the Link Analyser Mk2 and Conformance Tester, the SPLT is the perfect tool that can be used throughout all stages of SpaceWire development from planning requirements through to production testing of flight components.**

The SPLT transmits SpaceWire LVDS signals at programmable swing and common mode voltages, slew, skew and bit speeds to test the capability of the Unit Under Tests (UUT) to maintain a SpW link without disconnecting. To do this, the SPLT can be configured as a SpaceWire interface on a SpW router. Alternatively, the SPLT can be configured to be placed in the middle of a SpW link between two SpW ports under test and manipulate the SpW signals in both directions.

Software running on a host Personal Computer (PC) is used in conjunction with STAR-Dundee's STAR-System device drivers and software to control the SPLT.

***Index Terms*—SpaceWire, Physical Layer, Signal Layer, Star-System, Spacecraft Test and Development Equipment**

I. Introduction

Throughout the specification, design, development and testing of a SpaceWire system, it is important that the system is tested and verified to the various levels of the standard. A number of tools already exist for testing a system's behaviour and performance at these levels, as is illustrated in Figure I-1.

Any problems in the physical and signal layer of the SpW system can be hard to detect and diagnose. This may be due to underlying problems not manifesting themselves in consistent, reliably reproducible symptoms. The SPLT's specialised hardware provides the capability to test and verify SpaceWire systems at these levels [1] [2].

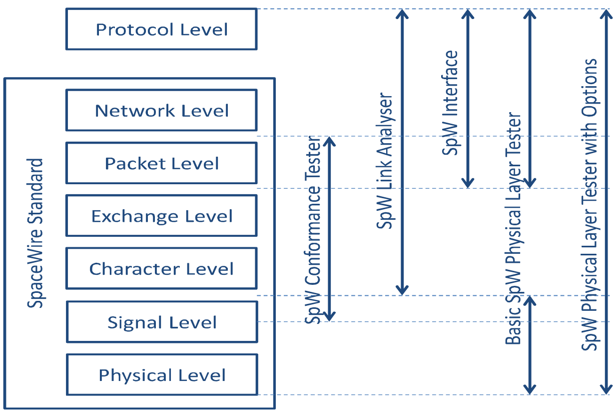

Figure I-1: Testing across the SpaceWire Standard

II. Overview of the SPLT

The front panel of the SPLT is shown in Figure II-1.

Figure II-1: Front panel of the SPLT

The SPLT features two Physical Layer Test SpaceWire ports, capable of performing tests at the physical and signal layers, as well as two normal SpaceWire ports. The configuration of these ports is shown in Figure II-2.

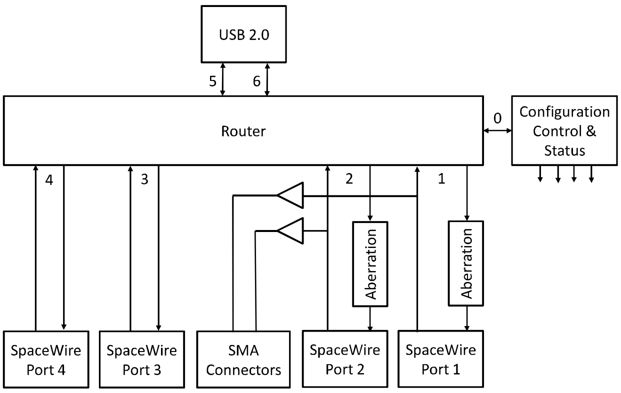

Figure II-2: Overview of the SPLT

The Physical Layer Tester is controlled by a USB 2.0 interface from a Host PC. This features two channels to the SpaceWire Router, allowing one channel to be used for control and configuration of the device and the other channel dedicated to SpW traffic data.

The outputs of the Physical Layer Test SpaceWire Ports (1 and 2) feature aberration circuitry, which is able to control the in-pair and data-strobe skew and jitter, as well as the slew, amplitude and common mode voltage of the LVDS signals.

The inputs from the Physical Layer Test SpaceWire ports are connected to high speed analogue buffers that allow easy interface of an oscilloscope to record the eye pattern of the SpaceWire LVDS signal received from the UUT.

III. SPLT SYSTEM OVERVIEW

The Physical Layer tester can be set up to interface to a UUT in three basic modes. In all three modes, the SpaceWire signals received from the UUT(s) can be buffered onto an oscilloscope. If the Link Analyser capability is selected, then a Logic Analyser may be interfaced to the mictor connector on the rear of the device to read the decoded SpaceWire traffic in a similar fashion to the STAR-Dundee Link Analyser Mk2 [3].

A. In-Line Margin Analysis

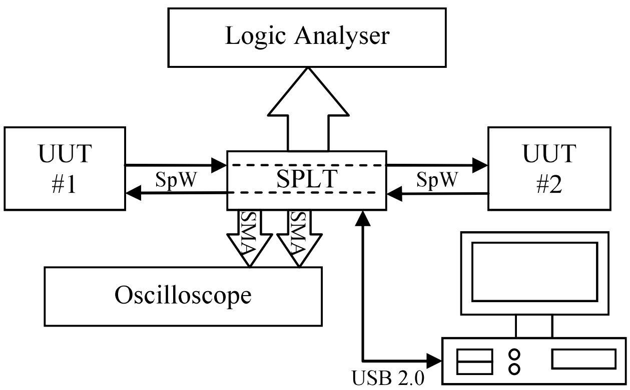

Figure III-1: In-Line Margin Analysis

The SPLT is placed in line with a SpaceWire link between two UUTs, or two SpW ports of the same UUT, as shown in Figure III-1. The SpaceWire data is passed transparently through the SPLT, allowing the two UUTs to communicate normally. Aberrations can be applied to the output SpW signals of the SPLT in one, or both, directions to explore the margins of either, or both, UUT devices.

B. Loop-Back Margin Analysis

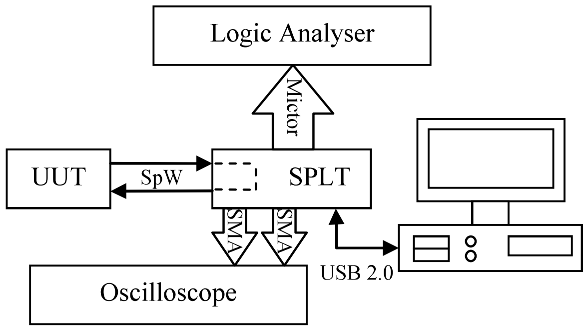

Figure III-2: Loop-Back Margin Analysis

A test can be performed where a UUT's transmitted SpW data is looped back to the same port through port 1 of the SPLT. Aberrations can be applied to the transmitted data to explore the receive margins of the UUT.

C. Interface, Routing Margin Analysis

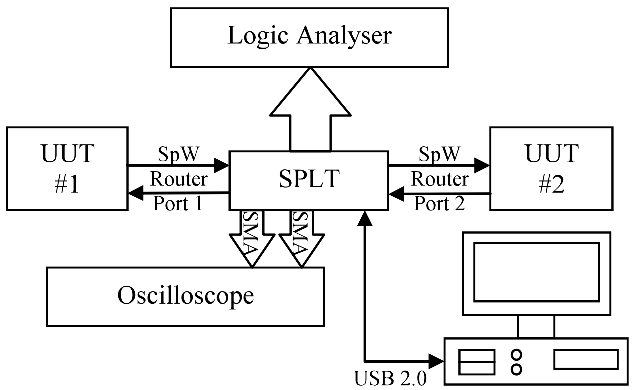

Figure III-3: Interface & Routing Margin Analysis

The SPLT can be configured in a similar way to the STAR-Dundee Brick Mk2 with the USB 2.0 port interfaced either directly to the four SpaceWire ports, or through a SpaceWire router, as illustrated in Figure II-2. This allows SpW data to be transmitted and received from the Host PC.

D. Conformance testing Analysis

If the Conformance testing option is selected on the SPLT, then the full suite of SpaceWire conformance tests can be performed from SpW link 1 [4]. The equipment is set up in the same way as shown in Figure III-2. This arrangement will be able perform a more comprehensive range of tests on the UUT than the existing STAR-Dundee Conformance Tester by taking advantage of the LVDS aberration capabilities of the SPLT.

IV. TESTING WITH THE SPLT

The SPLT Software provides Margin and Production testing modes, which were discussed in [2]. The control software now features graphical representations of the aberrations that are being applied. The user interface is shown in Figure IV-1. The graphical representations are described in sections IV.A and IV.B.

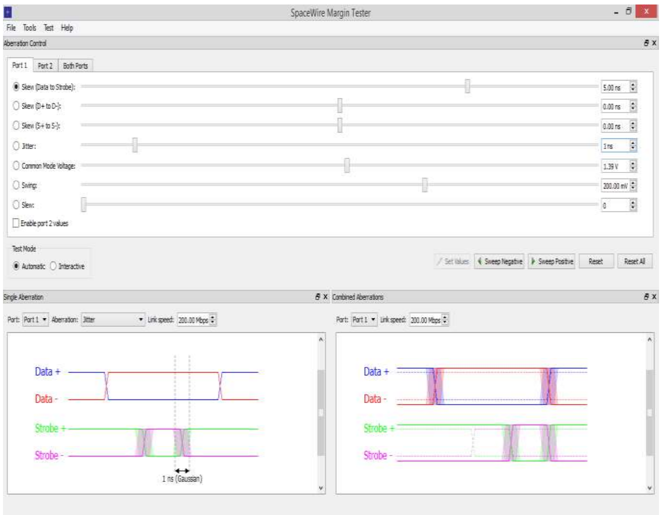

Figure IV-1: SPLT Control Software

A. Graphical representation of single aberrations

In order to assist the user in understanding the aberrations that they are applying to the signals, a graphical representation of the aberrations is provided in software. Figure IV-2 shows a SpaceWire link running with Nulls.

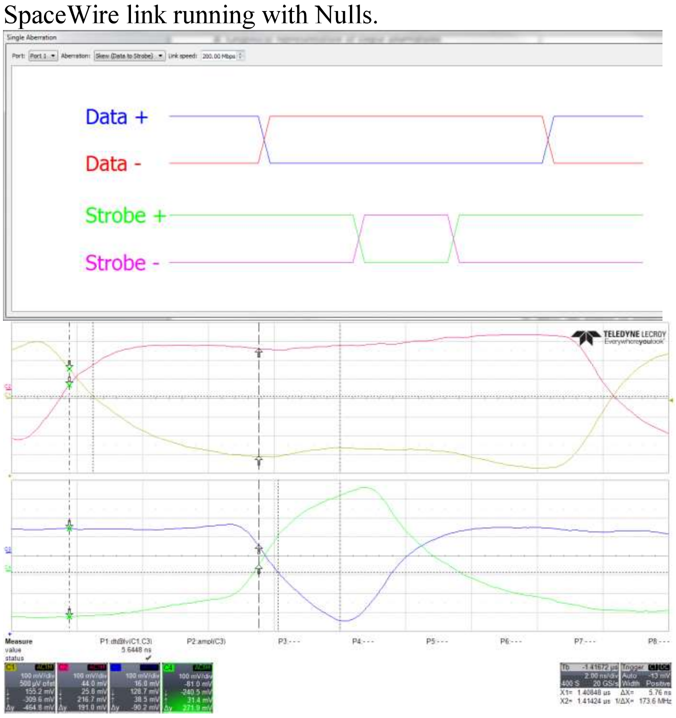

Figure IV-2: SPLT configured without aberrations

The top two waveforms in Figure IV-2 show a software representation of some SpaceWire transitions based on no aberrations being present. The bottom screenshot shows a measurement of the SpaceWire signal transmitted out of the Physical Layer Test Port, measured at the termination resistor on the other end of the link. Two vertical cursors have each been placed on adjacent transitions of the Data and Strobe.

In all oscilloscope screenshots in this paper, the Data is shown at the top of the oscilloscope screenshot, and the Strobe is shown at the bottom. The timebase is 2 ns per division, and the voltages are all shown at 200 mV per division. The scope is 1MΩ AC coupled. Measured Voltages must be divided by 2 to correct for the ×2 gain of the SPLT buffers that were used to obtain these waveforms.

A Skew of -2 ns is then set up in the software. The graphical representation of this aberration is shown in Figure IV-3. A dotted outline of the waveform shows how far from its ideal position it's being moved. In interactive mode, as the skew slider is moved sideways, the graphical representation is updated in real-time with the value of aberration and cursors to demonstrate the magnitude of aberration being applied. The user then commits this aberration to the SPLT by clicking "Set Values". In automatic mode, the graphical representation is updated in real-time as the increasing value of the aberration is sent to the SPLT.

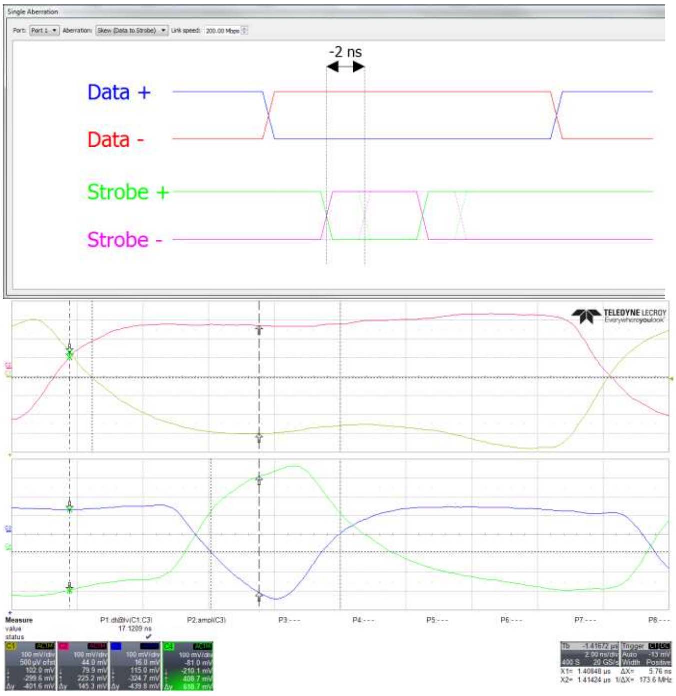

Figure IV-3: SPLT configured with 2 ns Skew

B. Graphical representation of combined aberrations

Labelling multiple aberrations with cursors and markers clutters the graphical representation. A second window is used to show the effects of combined aberrations. This window, along with the captured waveform, is shown in Figure IV-4

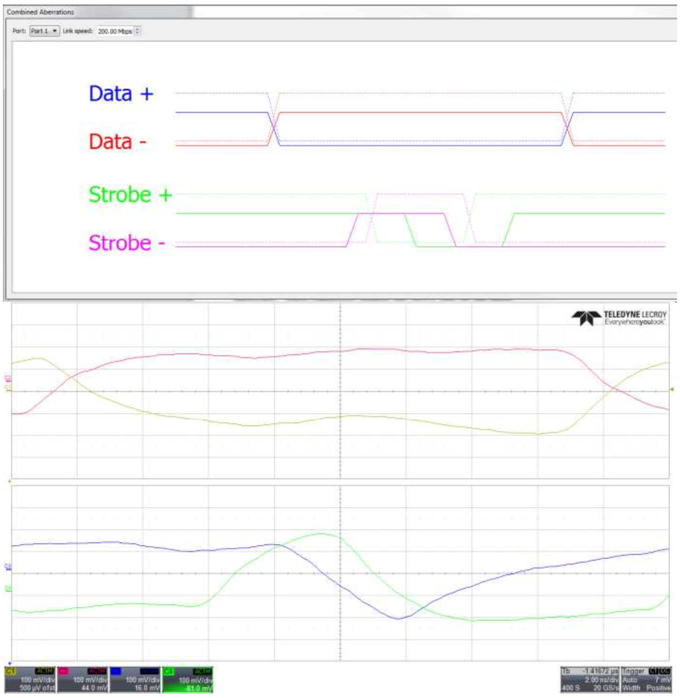

Figure IV-4: SPLT driving combined aberrations

The SPLT was configured to drive the following aberrations in Figure IV-4:

- -1 ns Data to Strobe Skew
- -3 ns of Strobe Plus to Strobe Minus in pair skew
- 1.16 Volts Common Mode
- 200 mV of Swing

The Graphical representation at the top of Figure IV-4 shows the many different ways in which the LVDS signal is now being deviated from its ideal parameters. The oscilloscope confirms the poorly degraded signal that is being driven out from the SPLT. Occasional disconnects are observed under these conditions.

V. User Calibration of the SPLT

The SPLT's physical layer test ports feature several analogue components that are calibrated from the factory for each individual unit. Users may wish to check this calibration, which may need updating as the environment in which the device is operated may vary, and as the components age. Users may also wish to calibrate the SPLT to a particular cable that they will be using with the SPLT.

The Software supplied with the SPLT includes a calibration application. In order to use this, the SPLT must be configured with a SpaceWire cable between ports 1 and 2 of the SPLT, and an oscilloscope connected to the analogue buffers on the receiver of the SPLT. This is shown in Figure V-1

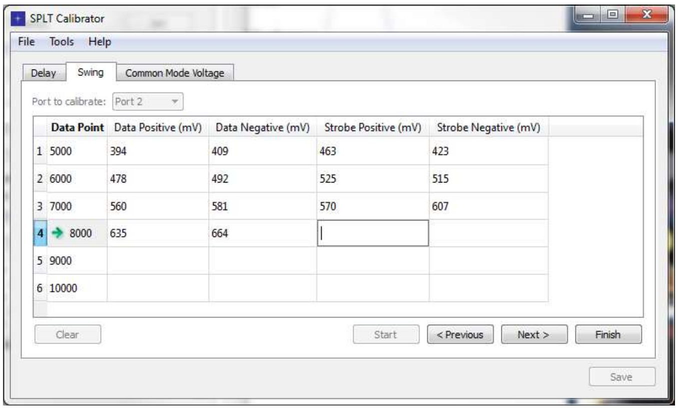

Figure V-1: SPLT Calibration Software

In Figure V-1, the LVDS Swing driven by Port 2 is being calibrated by the Calibration software. The SpaceWire cable loops this data into Port 1 so that these signals can be monitored on an oscilloscope. The calibration software steps through a number of linear data points to increase the swing. Measurements taken from the oscilloscope are entered into the appropriate boxes indicated by the green arrow on the left hand side of the current data point.

Once all of the data points are entered, the Software shows the calibration constants taken from these measurements against the factory calibration constants that the device was initially despatched with. The user calibration data can be uploaded to the SPLT for future use.

VI. Conclusion

The SPLT performs production and margin tests at the physical and signal layer in addition to higher level tests on a SpaceWire system. Protection against single point of failure in the device makes it suitable for interfacing to sensitive flight hardware. Such capability makes the SPLT one of the most comprehensive pieces of SpaceWire test equipment on the market.

VII. References

[1] P. Scott, S. Parkes, P. Crawford and J. Ilstad, "Testing SpaceWire systems across the full range of protocol levels with the SpaceWire Physical Layer Tester." International SpaceWire Conference, San Antonio, USA, 8 - 10 November. 2011

[2] A. Spark, P. Scott, S. Parkes, P. Crawford "Margin testing of SpaceWire devices" International SpaceWire Conference, Gothenburg, Sweden, 10 - 14 June. 2013

[3] Pete Scott, Steve Parkes, "SpaceWire Link Analyser Mk2: A New Analysis Device for SpaceWire Systems", International SpaceWire Conference 2010, St Petersburg, 22nd – 24th June 2010.

[4] Steve Parkes, Martin Dunstan, "Debugging SpaceWire Devices using the Conformance Tester", International SpaceWire Conference 2007, Dundee, 17th – 19th June 2010.