Enabling technologies to meet future onboard data processing needs

Session 1 : Technology Roadmaps and Needs

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***Abstract*— This paper presents an overview of the application needs for passive components from the on-board data processing perspective. On one hand mass reduction of onboard data processing equipment is a recurring topic, while on the other hand signal integrity and EMI is of concern, particularly at high data rates. As payload data rates reach several gigabits per second (Gbit/s) on a single communication link, the combination of mass reduction, good signal integrity and EMC is challenging. To meet future demands it is required to use suitable space qualified high-speed data cables and connectors which not only are in compliance with the aforementioned requirements, but also straightforward to assemble. In addition, as data rates reach Gbit/s internally to the spacecraft data processing unit, it is required to use space qualified backplane connectors offering impedance matched differential signaling in a high-density pin configuration. A modular connector approach is certainly an attractive solution as internal-to-unit needs are broad in relation to I/O performance, power distribution and discrete signaling. On-going ESA funded TRP activities on low mass SpaceWire, which reduces the SpW cable mass by 50%, and preliminary results towards a SpaceWire backplane standard (under ECSS) with emphasis on the connector, will be presented. The latter aims for modular impedance matched connector where SpaceWire signaling and dedicated I/O for discrete signaling and power distribution can be integrated in one connector housing. The paper will also inform on the needs related to the SpaceFiber standard physical layer where data rates over copper cables is expected to reach 2-3 Gbit/s.**

***Index Terms*—SpaceWire, SpaceFiber, Highs Speed Serial links, connector, cable.**

I. Introduction

In the terrestrial application domain we have become accustomed to the continuous drive to miniaturize electronic components and systems while increasing their performances at mindboggling rates. Take the mobile phones and portable computer as an example how the capabilities have changed over the last decades. Much of this philosophy applies to spacecraft design as well as one seek to acquire as much science data as possible at the lowest possible cost which most often is directly linked to reduced mass and power consumption. At the same time high reliability and availability is a primary concern, which for the terrestrial world of applications particularly consumer electronics, appears to be less and less critical. Although there are many concepts that may be taken from the terrestrial world of applications in to the space domain, they often cannot be applied for space applications without significant design adaptations. For onboard data processing one can look at e.g. SpaceWire (SpW) or SpaceFiber (SpFi) where some concepts have been taken from the terrestrial domain (e.g. IEEE1355 for SpW) but adapted by introducing more robust elements such as e.g. other types of cables and connectors.

II. SpaceWire Backplane

When SpaceWire is used for onboard communication one might intuitively think of the SpaceWire cable as the transmission media between two units as the standard [2] does not specify use of SpaceWire over e.g. a backplane. The ESA initiated activity “SpaceWire Backplane” funded under Technology Research Program (TRP) aims to provide a complement to the SpaceWire standard that specifies module-to-module communication over a backplane. The first objective of the activity aims to identify a suitable backplane connector that meets the primary needs such as good signal integrity, mechanical robustness and suitable materials for space environment and secondly a connector that is able to support at least 8 SpaceWire links as well as cater for power supply lines and discrete I/O lines. The physical layer of SpaceWire consist of ANSI TIA/EIA 644a LVDS which requires 100ohm differential impedance, hence the connector must meet this requirement to ensure good signal quality at high data rates. One can imagine that a connector designed after this principle may be suitable also for much higher data rates than the commonly used 200 – 400 Mbps used for SpW. In addition due to its modularity it can be applied to newer generations of onboard computers, mass memories, high data rate transmitters for X and Kx band as well as modular remote terminal units (RTU). Although these various applications may have vastly different needs in terms of I/O capabilities and power supply, a modular connector with plug-in modules may provide a one-size-fits-all solution, while at the same time providing the capability to transition to high data rate links if required. One can also imagine that such a connector solution could provide a commonality that would make module standardization easier as to allow interoperability between different equipment/module vendors i.e. an important element to realize the SAVOIR architecture [1].

The second objective of the SpaceWire backplane activity is to provide a draft ECSS standard document that defines details such as connector pin-out, standard modules and mechanical formats to ensure interoperability at the physical level. Although there are many backplane connectors for terrestrial applications which would meet the high data rates requirements as well as offering vast number of low speed I/O's as well as power supply lines, there are few that are suitable for space applications due to either lack of robustness or inappropriate materials or manufacturing processes for space use. Standards such as cPCIexpress Backplane (PICMG 1.3), OpenVPX, Advanced TCA etc. all specify different connectors which provide the required I/O capabilities for SpW backplane needs and some of these can even be procured as ruggedized versions. However, the ruggedized versions are often built using standard terrestrial connector elements while being ruggedized at the mechanical level using robust metal frames or support framework, or potential suitable connectors are burdened with ITAR restrictions which makes procurement lengthy and costly.

SEA Ltd. in partnership with Hypertac Ltd. are developing a new modular connector (fig.1) that meet or exceeds the requirements first defined for the SpaceWire backplane activity. The connector allows for various configurations due its modularity and can as such be applied in number of applications, not only for SpaceWire applications. The matched impedance differential signal module offers sufficient performance to accommodate next generation high-speed serial links (HSSL) such as SpaceFiber.

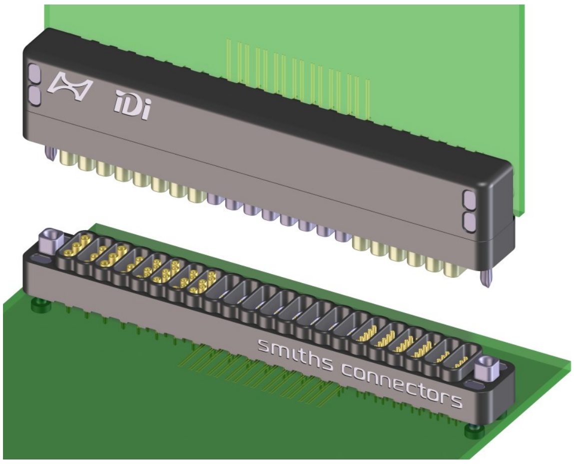

Fig. 1. Unmated 3U connector, shown on 100mm PCBs

Systems Engineering and Assessment (SEA) defined the minimum requirements for the connector with reference to ESCC specifications where applicable. Table 1 contains the requirements as defined by SEA.

Requirements Table

Req. No.	*Requirement*	*Comment*
010	The SpW backplane connector shall fit 3U and 6U size cards.	To support the 2 proposed card sizes.
020	The SpW backplane connector shall permit 20mm pitch boards.	
030	The mass of the connector shall be minimised within the scope of environmental and material constraints.	
040	Both the connector body and contact materials shall be compatible with ECSS standards for flight connectors.	ECSS-Q-ST-70C [REF 1] ECSS-Q-70-71 [REF 2] ECSS-Q-ST-70-02 [REF 3]
050	The connector shall meet ECSS standards for durability.	ECSS-Q-ST-70C [REF 4]
060	The connector shall allow for through hole solder fitting to both the backplane and daughter-card.	
070	Alignment pins shall be provided on the connector.	To aid connector mating and prevent contact damage.
080	A minimum of 8 connector polarisation or keying options shall be provided.	To allow selective mating between connectors on different card types.
090	The connector shall support a minimum of 4 SpW links.	A SpW link is a full duplex communication path as supported by a standard SpW cable, (4 differential pairs).
100	Each differential pairs shall have an impedance of 100 Ω .	This is for all 4 differential pairs within a SpW link. To allow high speed communications.
101	Each SpaceWire differential pair shall be shielded from cross-talk.	
110	Each SpW pair shall support a data rate of at least 2.75Gbit/s.	To allow the use of SpFi Copper without changing the contact types. Ideally, the SpW pair should support a data rate of up to 10Gbit/s.
120	The SpW connector shall have 12 power pins and 12 returns (24 contacts) capable of 5A constant carry and a minimum of 85V rating for each contact.	Voltages envisaged to be +50V, +28V, +15V, +12V, -12V, +5V, -5V, +3.3V, 0V
130	The SpW connector shall have a minimum of 60 discrete contacts, each capable of 200mA (de-rated) constant carry and a minimum of 50V rating for each.	For carrying non-SpW signals.
140	There shall be a minimum of 12 contacts with a differential impedance of 100 Ω within the provided discrete contacts.	For use as LVDS clocks.

Table 1: SpaceWire backplane connector requirements.

The connector will also meet the requirements of ESCC 3401, ECSS-Q-ST-70-08C & ECSS-Q-ST-70-38C where applicable. In addition to the requirements defined by SEA and ESA Smiths Connectors identified further requirements that were deemed attractive and incorporated those elements into the design of the connector.

III. LOW MASS SPACEWIRE CABLE

The SpaceWire standard [2] specifies in detail the construction of the cable to be used for a SpaceWire link. It defines a cable that for some applications can be considered too rigid and heavy. The typical mass of the cable is 85 g/m, however choosing lighter materials or using a different cable construction one can achieve significant mass saving. Further, the cable currently defined in the standard may not meet performance requirements in terms of bandwidth especially over longer distances (>10m). One way to open up for different cable designs appropriate for particular applications is to specify the electrical parameters that must be adhered to over a transmission medium as opposed to a detailed cable design.

The ESA funded Low Mass SpaceWire activity was initiated in 2010 by the Axon Cable, Star Dundee and EADS Astrium. The aim was to identify suitable materials and construction methods to reduce cable mass as much as possible. The goal set forth was to reduce mass by up to 50% while keeping both electrical and mechanical performances comparable to the original SpaceWire cable as defined in the ECSS-E-ST-50-12C standard.

A secondary objective has been to propose possible changes to chapter 5 of the SpaceWire standard to allow for different cables to be used depending on mission or application requirements. To achieve this it is necessary to perform measurement of a standard SpaceWire cable to extrapolate electrical parameters such as characteristic impedance, insertion loss, crosstalk and signal skew.

A third objective has been to identify an alternative connector(s), which has better performance in terms of impedance matching than the 9-pin MDM connector.

During the course of the activity Axon Cable produced several low mass SpW cables variants have been both electrical and mechanically tested. One key area where mass savings can be readily achieved is modification to the shields. Using materials based on silver plated aluminum as well using variations of PTFE materials for the cable outer jacket, have shown that significant mass savings can be achieved while maintaining or even exceeding performances those of a standard SpW cable.

The chosen cable variant is a twisted pair type of cable with mass of 42g/m. Reduction of the cable mass is obtained by exchanging silver plated copper shields with silver plated aluminum. Further mass reduction is achieved by replacing the outer jacket with PTFE and polyimide tapes. The electrical performances show similar or even better performances compared to the original ESCC 3902/003 variant 1 and 2, in particular for what concerns insertion losses.

Concerning connector alternatives offering matched impedance the survey conducted during the course of the activity revealed no suitable connectors from European sources that match well with the twisted pair cable construction used for SpaceWire cables. The difficulty is to ensure proper 360° termination of the inner shields, however outer shield termination could also be improved. Although one solution could be to use twinax inserts in a MIL-DTL 38999 housing, the solution was dropped in the end due to project constraints. Connector manufacturers are encouraged provide suitable lightweight connector solutions offering impedance matched differential pairs as well as proper shield termination yet simple to assemble and to ensure EMI tight mating between the connector pairs, - the latter a weakness of the MDM connector.

Fig. 2. Low Mass SpaceWire cable – Axon Cable

IV. SPACEFIBER – PHYISCAL LAYER NEEDS

As payloads become more sophisticated and instrument sensors provide science data at finer fidelity, the onboard data rates increase along side with onboard mass memory storage capability and down link bandwidth. The SpaceWire based onboard data links may not provide sufficient bandwidth for the next generation synthetic aperture radars (SAR) or high-resolution multispectral optical instruments. To be able to cope with Gbit/s data rates one either has to impose challenging multilink SpaceWire onboard networks that are hard to manage at protocol level or use high data rate serial links which in most cases do nothing more than transferring data with only a limited set of protocol capabilities i.e. there is a lack of proper link initialization, limited flow control capabilities or retransmission when bit error occurs among other required features for space applications. The next generation onboard high data rate communication protocol, SpaceFiber [5], encompasses not only the lower physical layer such as current mode logic differential signaling and 8/10 bit encoding allowing for data rates from 2.5Gbit/s and beyond over copper media, but also link initialization, multi lane links (2 or more links to increase throughout), retry, broadcasting, time code and virtual channels mechanisms. For the remainder of this section the focus will be on the needs related the physical layer i.e. to passive components and high-speed impedance matched connectors and high performance cables. One SpaceFiber link consists of only 2 differential pairs (Tx and Rx), as opposed to SpW, which requires 4 differential pairs due to data-strobe encoding. Further in SpaceFiber the CML based physical layer is implemented as an AC coupled connection with termination resistors terminated to receiver's common mode input specification [3].

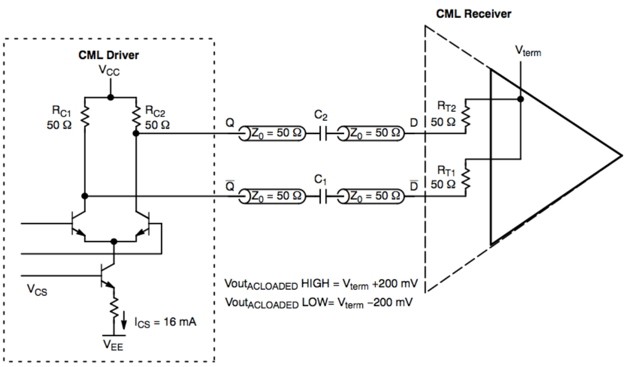

Fig. 3. CML termination

Thus suitable cables for CML can be a dual 50ohm coaxial configuration per differential pair requiring in total 4 coaxial cables per link or 100ohm differential twisted pair. However at very high data rates the twisted pair may not be able to ensure sufficient signal quality and will typically introduce more jitter as a function of length than a coaxial cable, due to small irregularities in the shielded twisted pair (STP) [4]. However the coaxial cable has the downside of higher attenuation per unit length than a STP cable.

Needles to say, in order to ensure good signal quality, it is required that all elements of the transmission medium provide matched impedances as well high quality cables with low losses.

An ideal solution for a copper based SpaceFiber link consists of compact connectors and low mass cables for easy assembly and connection between units. This is usually in conflict with the signal quality requirement. As SpaceFiber has the capability to use 2 or more links to increase the aggregate throughput from a data source (multi lane much like PCIexpress), the use of standard coaxial cables and coaxial connectors can result in quite bulky implementations, thus suitable multi link connectors and compact cable assemblies are high on the wish list. There are interesting connectors candidates on the market that appear suitable for SpaceFiber; the Quadrax inserts, offered by e.g. Sabritec and the split pair Quadrax[6] solution offered by Amphenol Aerospace appears appropriate to achieve compact and robust solutions, however space qualification of these products remains unclear.

For backplane connections the solution described chapter II results in a neat multi-gigabit implementation also suitable for SpaceFiber, or other high-speed differential signal standards.

V. Conclusion

This paper has given an overview on the needs for passive components in the application domain of onboard data processing and presented ongoing ESA funded activities that aim to reduce mass and/or improve signaling rate performances. As onboard data systems become more sophisticated and demanding higher data rates, there is a need to introduce new technologies that are suitable for the stringent requirements applied in space applications. For what concerns passive components, cables and connectors are still areas that can be further developed to allow higher data rates to be achieved while at the same time ensuring that the cable assembly and connector mating is lightweight and straightforward to assemble.

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