# The Evolution of SpaceWire Electrical Interconnect

### Faster, Lighter, Smaller

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#### 1 Introduction

As a manufacturer of classic Micro-D connectors and also of a wide variety of cables and interconnect used in Space, Axon' Cable is very well versed in the pros and cons of "classic" 9-way micro-D SpaceWire links. In previous SpaceWire conference papers Axon' presented its developments in Low Mass SpaceWire cable, and also an overview of the new MicroMach<sup>®</sup> impedance-matched SpaceWire connector development.

In this paper, Axon' reviews key results from the ongoing evaluation testing of this new MicroMach<sup>®</sup> SpW connector, developed under ESA Technology Research Project TRP AO/1-7985. In addition, a performance comparison is provided between the existing and the new technologies, allowing users to make an informed choice according to their differing system requirements.

For additional clarification, the paper also provides a brief recap of all Axon's recent developments in physical layer componentry, and where they sit with respect to the various ESA standards and specifications, either published or in progress.

Finally, Axon' explores a novel new concept of potential SpaceWire transmission over flat flexible cable (FFC), and the paper looks at some other potential wider uses for the MicroMach<sup>®</sup> connector.

#### 2 Variants Developed

For the Evaluation phase, 3 different PCB variant connectors have been developed and manufactured.

#### 2.1 MicroMach panel-mount SMT Variant

This version is used to interface to a PCB while optimizing space (edge PCB connection)



Fig-2.1-1 MicroMach SMT Variant exploded view

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Fig 2.1-2 View of the soldered termination on the PCB

#### 2.2 MicroMach panel-mount Wired Variant

This version allows greatest flexibility to make connections to the PCB with flexible twisted pair outputs.







Fig 2.2-2 View of the soldered termination on the PCB

#### 2.3 MicroMach panel-mount Flex Variant

This version helps create a rapid and safe connection to the PCB using a matched impedance flex circuit. Terminations are compatible with castellated chip carriers, devices which can be soldered in one step.



Fig 2.3-1 MicroMach panel mount Flex Variant exploded view



Fig 2.3-2 View of the Flex soldered termination on the PCB

#### 2.4 Inline Connector Variants

Concerning the inline connectors, AXON' has developed two principal variants: the male and the female panel-mount:



Fig 2.4-1 Male inline connector exploded view



Fig 2.4-2 View of a male cable termination







Fig 2.4-4 View of a female cable termination

#### 3 Improved mating with mechanical guidance

To secure the mating sequence, two special guide pins are used which, as well as securing the backshell to the connector, makes "blind mating" possible.



Fig 3-1 Guiding sequence

#### 4 Performance Comparisons / maximum speed

From the electrical Evaluation Testing carried out to date, we can see the following key differences between SpaceWire links made using the classic 9pin micro-D, and the new MicroMach<sup>®</sup> adapted

connector. The media is also a possible way of improvement using parallel pair instead of twisted one.

#### 4.1 Crosstalk comparison

In comparison to the standard 9way Micro-D cabling, the MicroMach<sup>®</sup> variant offers a significant improvement in crosstalk (around -20dB less @ 1Ghz). Thanks to the 4 independent 100 Ohm cavities, the signal coupling between contacts pairs is reduced to a minimum.



Fig 4.1-1 Worst case Crosstalk MD9 versus MicroMach® link

#### 4.2 Eye Pattern comparison

One of the requested improvement features achieved within the study was to have a 100 Ohms matched characteristic impedance between each pair of signal pins, which gives rise to improved signal integrity as can be seen in the screenshots below: The overshoot on the signal measured on the Micro-D terminated link is much more significant than with the MicroMach<sup>®</sup> version.



Fig 4.2-1 Eye Pattern on Micro-D 9pins terminated 1m link @400Mb/s



Fig 4.2-2 Eye Pattern on MicroMach® terminated 1m link @400Mb/s

#### 4.3 Shielding effectiveness

With enhanced EMC design, the MicroMach<sup>®</sup> variant offers a noticeable improvement in shielding effectiveness (around -10dB better up to 18Ghz – the maximum frequency tested). This improvement is possible, partly thanks to the improved inner and outer shield termination between cable and connector, and partly due to improved EMC interface between male and female connector bodies.



Fig 4.3-1 Shielding effectiveness measurement on test vehicles. One is terminated with standard 9pins Micro-D connectors, the other with MicroMach<sup>®</sup>.

#### 4.4 Maximum speed

A cable with four, impedance-matched twisted shielded pairs is the baseline for SpaceWire links, however, in an effort to try and further improve electrical features, Axon' added a cable variant with four parallel pairs as two of the test vehicles in the study. This cable improves two of the key electrical features : Skew & Insertion Loss.

The maximum speed reached on a 4m link was performed on this new variant cable made with parallel pair compared to the qualified ESCC3902 version with twisted pair construction. The maximum speed on this 4m test vehicle is located between 800Mb/s and 1600Mb/s as shown in the screenshots below.



Fig 4.3-1 Eye Pattern on MicroMach terminated 4m parallel pair link @800Mb/s



Fig 4.3-2 Eye Pattern on MicroMach terminated 4m parallel pair link @1600Mb/s

#### 5 Recap of Axon' high data rate componentry

For additional clarification, the chart in Fig 5-1 provides a brief recap of all Axon's recent developments in physical layer componentry, and where they sit with respect to the various ESA standards and specifications, either published or in progress.

Component	Standardised?	Features and Advantages
"Classic" SpW cable, AWG 26		
and AWG 28	ESCC3902 002 and 003	Long heritage. Many programmes
Space grade MDSA micro-D		Long heritage, existing Type A SpW connector
connector	EPPL2 iaw ESCC3401 029	Potted, non-dismountable, robust connector
		Good early heritage developing (Solar Orbiter, JUICE,
		ExoMars, Metop)
		Half the mass, easier screening arrangement, more
Low Mass SpW cable, AWG 28	ESCC3902 004	flexible, lower bend radius, better radiation resistance
		Adapted 100 ohm impedance, better EMC design, much
MicroMach® adapted SpW		improved crosstalk, improved skew
connector	Not yet, TRP in progress	Suitable for both SpaceWire and EtherSpace applications
		Very high data rate (10GBps per channel) connector,
		available in single pair to 4 pair versions. Suitable for
AxoMach® HDR connector	Pending ESCC3907 001	SpaceFibre and WizardLink applications
		As above, in cable assembly form, using a pair of RF
		quality Ax2.4 coaxial cables per way
		Heritage on all AxoMach® product includes MAVEN,
AxoMach® HDR assemblies	Pending ESCC3907 002	NISAR, MTG, SENTINEL, SaRAH and SWOT
		A variant of the HDR connector range, optimised for single
		channel SpaceFibre transmission, with all 4 coaxial
AxoMach <sup>®</sup> SpFi connector	Pending ESCC3907 001	contacts space optimised within the connector body.

Fig 5-1 Chart of Axon' HDR components and their status

Additionally, the chart in Fig 5-2 provides a pictorial representation of some of the key products mentioned, and where they sit in terms of intended usage, either by increasing data rate, or by the type of media or network protocol.



Fig 5-2 HDR components organized by data rate and application

#### 6 Faster, Lighter, ... Flatter ?

Aside from Axon's well-known activities in space, micro-D manufacture and high data rate products, the company is also a large manufacturer of Flexible Flat Cable (FFC), commonly used in consumer electronics, office automation and automotive applications. Axon' Flexible flat cable is used in around 20% of the world's cars, providing a clock-spring-style connection behind the steering wheel to drivers' airbags.



Fig 6-1 A typical FFC harness for automotive air-bags

A first prototype of a **Flat Flexible SpaceWire link** has been assembled using shielded flat cable and a new, flat shaped connector derived from the MicroMach<sup>®</sup> design parts with electric welding technology. This trial product opens the possibility of a new automated manufacturing solution improving flexibility and saving space. At the same time the media is improved in skew and characteristic impedance regularity features.



Fig 6-2 Flat shaped MicroMach® connector termination



Fig 6-3 Overview of the FFC MicroMach® SpW prototype

The benefits of such a product are principally in space and weight saving. The cable, even with shielding, is less than 1 mm thick, and can therefore run in and around tight areas previously impossible with conventional round cable, and additionally can be bent within a very small radius.

Initial testing of this first prototype has shown quite promising performance, even up to 400 Mb/s, and over a reasonable sample length of 2m.



Fig 6-4 Eye Pattern on 2m FFC SpW prototype link @400Mb/s

Reducing the bit rate a little to 300Mb/s, and extending the length right up to 10m still manages to achieve a (borderline) satisfactory performance.



Fig 6-5 Eye Pattern on 10m FFC SpW prototype link @300Mb/s (measured skew around 1ps/m)

Shielding designs are ongoing to select the best compromise between shielding efficiency and size/flexibility. Shielding Effectiveness simulations have been performed with different shield configurations e.g. one side shielding and 360° shielding.



Fig 6-6 "double sided ground plane" shielding SE simulation



Fig 6-7 Full 360° wrapped shielding SE simulation

#### 7 Further possibilities for MicroMach®

## 7.1 Possible use of the new MicroMach connector for Ethernet, XAUI ("Zowie") or EtherSpace applications :

There are other possible alternative uses for this connector, due to its electrical features and pin allocation. Ethernet cable can be mounted on it, in order to build a robust Ethernet link. The Ethernet cable construction is close to that of SpaceWire and can be an interesting solution to interconnect equipments up to 10Gb/s. AWG28, 27 and 26 are all compatible with the MicroMach<sup>®</sup> termination. The possibility to use AWG24 is not yet developed but is a potential future development.

### 7.2 Possible use of the new MicroMach<sup>®</sup> connector for SpaceFibre applications.

A MicroMach<sup>®</sup> connector variant will be compatible with Axon' space approved 2.4mm coaxial cable to propose an alternative solution for very high data rate links such as SpaceFibre or to increase the length for common mode links (e.g CML technology extensively used in ICs).

In overall summary, we can see that the MicroMach<sup>®</sup> system has an exciting future. It electrically out-performs the 9pin micro-D in nearly all aspects: crosstalk, impedance matching, skew, shielding effectiveness, and EMC design for both inner and outer shield termination and mating. It is a versatile solution and can be used with classic SpW cable in both AWG 26 and 28, as well as Low Mass SpaceWire. It also has promising potential use as a higher data rate option for multi-gigabit protocols such as SpaceFibre or EtherSpace.

The traditional micro-D connector cannot be discounted just yet, however. It was initially selected for a combination of its small size and robust design, and it remains very effective for both these reasons. As data rates increase the 9pin micro-D is likely to eventually become obsolete in HDR protocols, but this tiny workhorse is set to be with us for still some time to come.

Keywords – Ethernet, EtherSpace, High Data Rate, HDR, Low Mass, Micro-D, MicroMach<sup>®</sup>, Flexible Flat Cable, FFC, SpaceFibre, SpFi, SpaceWire, SpW, XAUI, Zowie



Fig 7-1 MicroMach<sup>®</sup> link with Low Mass SpW cable at SpaceTech Expo, Bremen, with STAR-Dundee SpW test equipment