14027-ESR-Axon-D3
Issue : 1 **Date : 20/12/2019**

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EXECUTIVE SUMMARY REPORT
ESA Contract No. 4000113741/15/NL/SW
Compact Impedance Matched Connectors for SpaceWire Links Development and ESCC Evaluation (T708-411QT)

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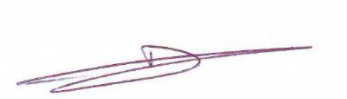
CONFIDENTIALITY CLASSIFICATION		
Category	Industrial	
	Company	Program
Space	**Capable**	***IBDM***
TENDER CATEGORY :		
TRADE OR CONTRACT		
Customer Organization		Trade or Contract No.
ESA		**TRP AO1-798514** **4000113741/15/NL/SW**

Binding document	Program	Contractual batch	Extension	Work batch
	IBDM			

TITLE : MicroMach® Executive Summary Report

AUTHOR(S)	ENDORSER	APPROVAL
Initials : DiA	Initials: SH	Initials: LT
Name : D. ANGENIEUX	Name: S. HERMANT	Name: L.TUROT
Signature: 	Signature: 	Signature: 

DATE	DOCUMENT REFERENCE	QUANTITATIVE DATA			
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20/12/2019	14024-ESR-Axon-D3 Issue 1	15	-	-	-

AUTHOR's SUMMARY

Computer references	File ref.: *14027-FR-Axon-D3* (Executive Summary *Report)* Software : *Word 7* Type of computer : *PC*	Document language : *EN* Legal language : *EN*

KEY WORDS :	DISTRIBUTION CATEGORY:
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1 MICROMACH® DEVELOPMENT

No connectors on the market reached the requirements of the SpaceWire protocol ECSS-E-ST-50-12C. The best option until now has been the ESCC3401/029 9 pin Micro-D connector. ESA launched in 2015 a Technology Research Project (TRP) to develop a more adapted connector and Axon' was selected in consortium with STAR-Dundee. A few years later, MicroMach® was born.

1.1 MicroMach® range of connectors

The connector range consists of a male inline cable plug, a female inline receptacle, plus a further 3 panel-mount receptacles for different styles of PCB termination – wired, SMT or Flex-rigid.

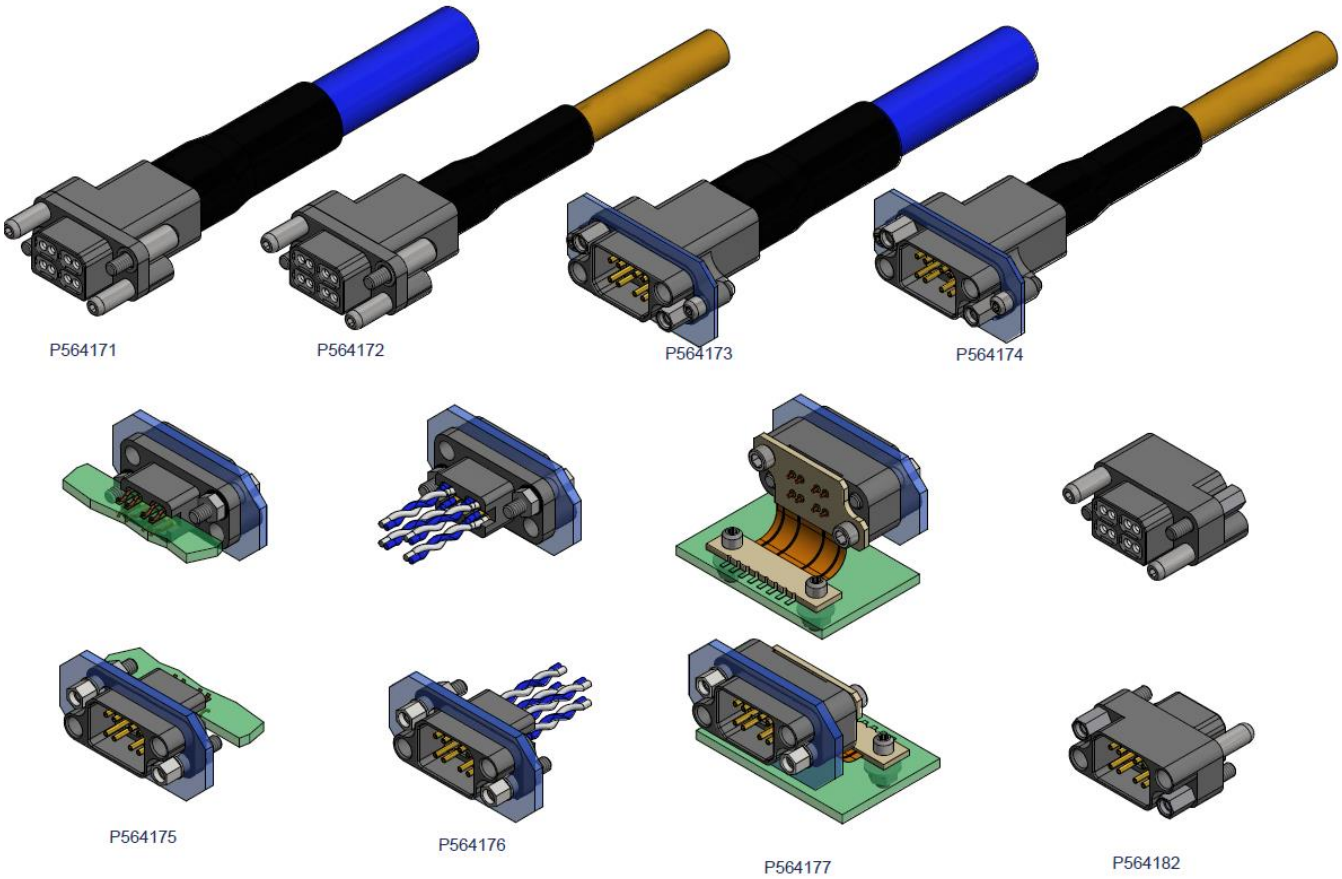


Figure 1: Overview of the MicroMach® range of products

1.1.1 IN-LINE VARIANTS

In-line variants have been designed for each SpaceWire cable variants with a specific back shell depending on the cable used. As a consequence there are 2 variants for In-line male connector and female panel mount. One for AWG26 and AWG28 standard SpaceWire cables, and one for the Low-Mass AWG28 SpaceWire cable.

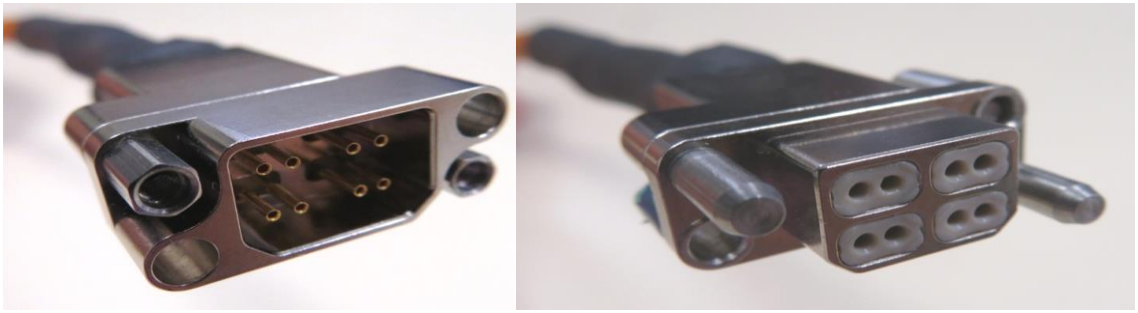


Figure 2: Views of in-line variants (female on the left, male on the right)

1.1.2 EQUIPMENT CONNECTORS

1.1.2.1 Edge PCB SMT Panel Mount Variant

This PCB connector variant is based on the female in-line shell. A solid AWG2401 conductor is crimped into the female contact and a PEEK insulator guarantees the impedance matching until the board. The locking system is the usual micro-D tightening solution.

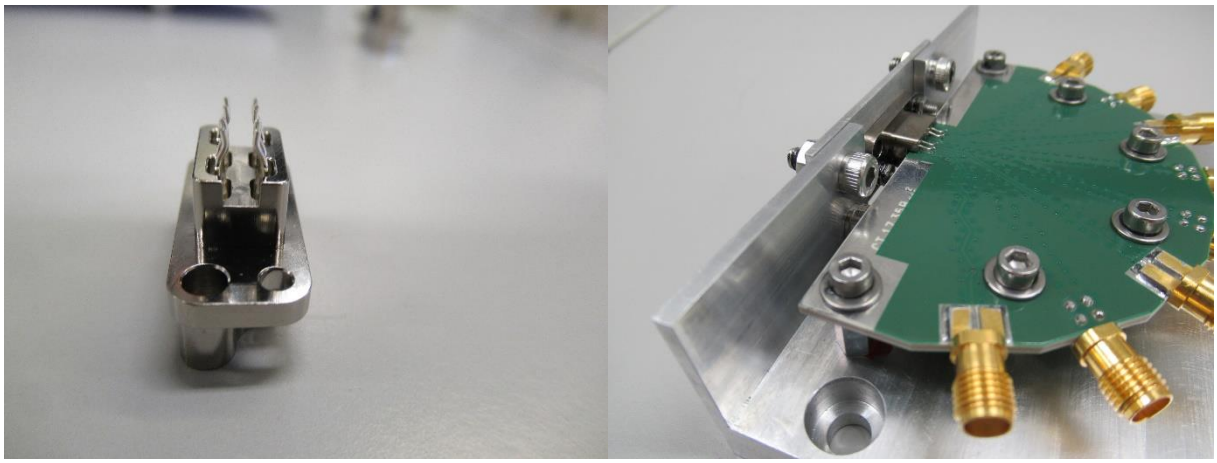


Figure 3: Views of Edge PCB SMT Panel mount variant

1.1.2.2 Wired PCB Panel Mount Variant

This connector has the same features as the Edge PCB SMT variant but the female contacts are terminated with a 100Ω twisted pair cable. This variant could be used as a Right Angle solution or for flexible link between the panel and the PCB.

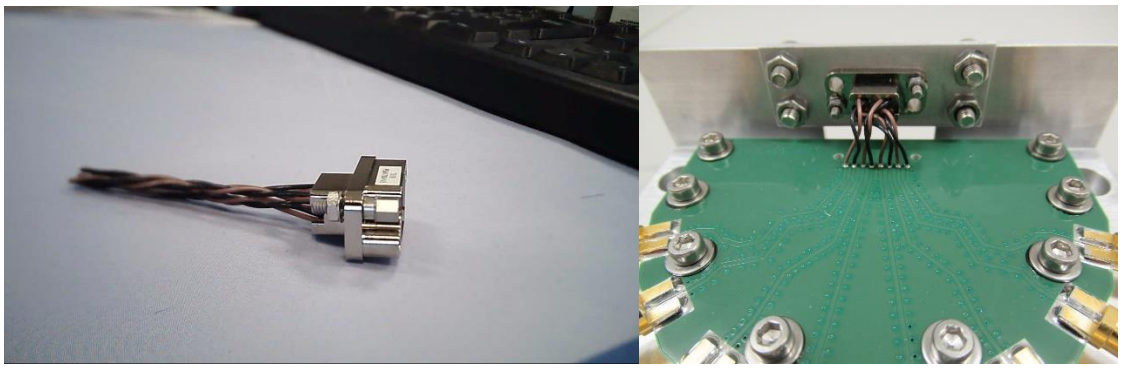


Figure 4: Views of Wired PCB Panel mount variant

1.1.2.3 Flex PCB panel Mount Variant

This connector is made with a flexible PCB between the panel and the board. This solution allows mechanical displacement and keeps the electrical performances of the connector until the PCB with matched impedance. The flex PCB is made with a complete ground plane and a signal layer.

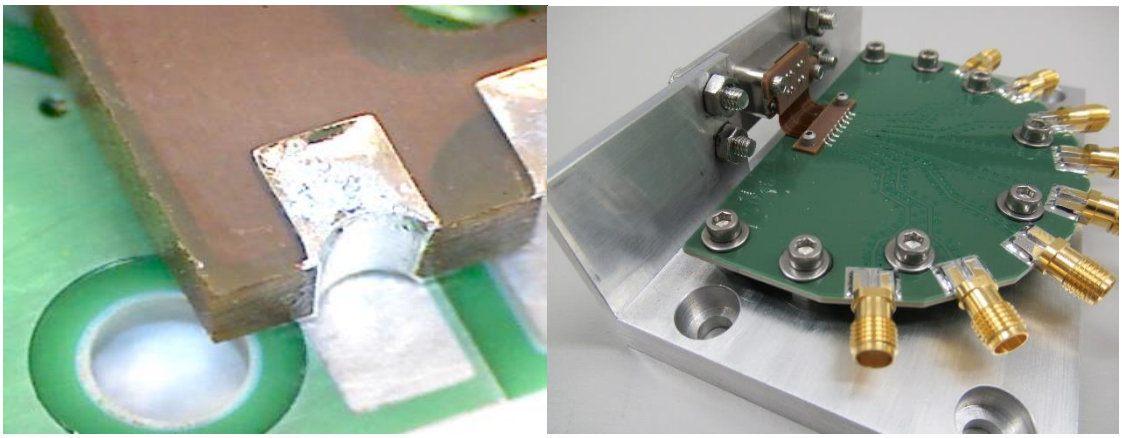


Figure 5: Views of Flex PCB Panel mount variant

This termination is listed in ECSS-Q-ST-70-38 and is compatible with castellated chip carrier device termination.

1.1.3 SAVER VARIANT

In order to save the connectors from too many matings during AIT phases, a saver was designed. It uses In-line female contacts with male twist pins crimped at one end.

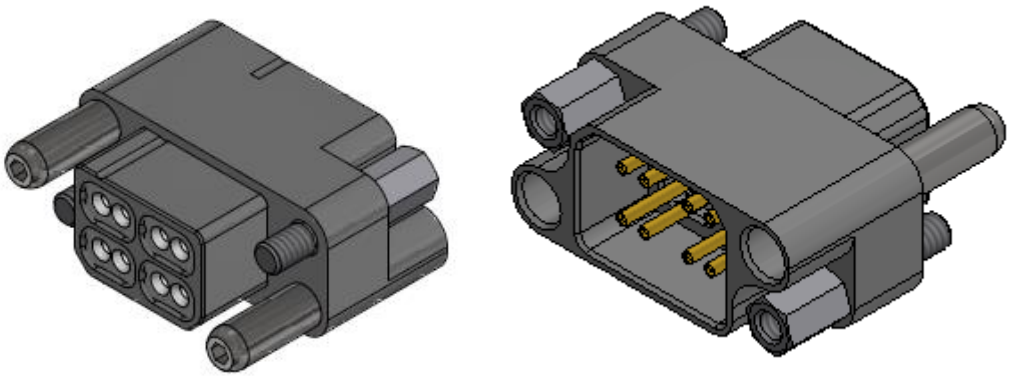


Figure 6: Views of Saver variant

2 MICROMACH® EVALUATION

With support of ESA, MicroMach® solution (cable assembly and PCB connectors) has been submitted to an extensive evaluation following ESCC requirements (vibrations, endurance, thermal cycles…) in

order to determine whether or not MicroMach® links fulfill the requirements of the cable assembly type B described in the SpaceWire ECSS standard.

2.1 Evaluation Test Plan

This evaluation has been performed from January 2018 to July 2019 following the plan below:

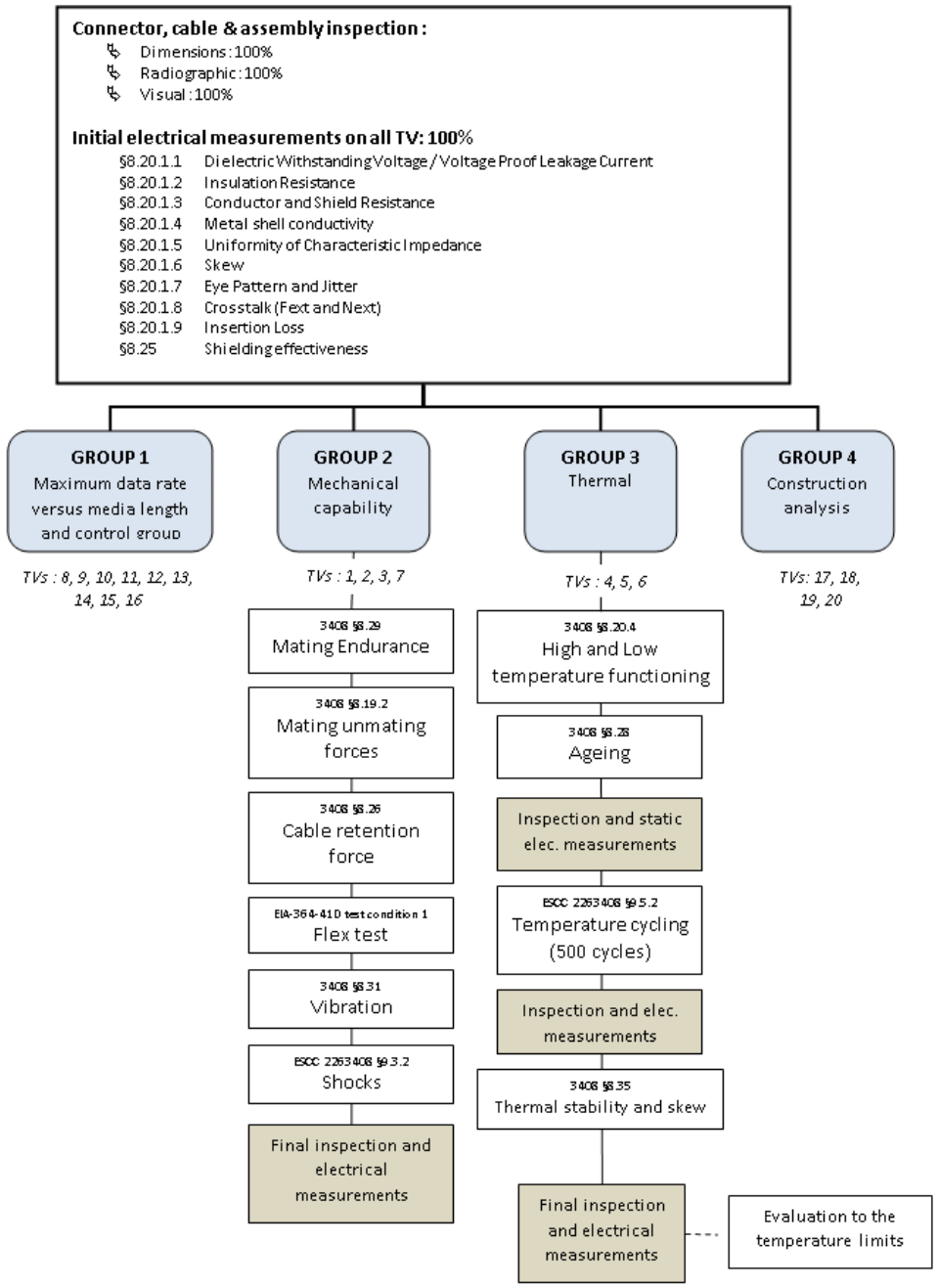


Figure 7: Evaluation Test Plan

2.2 Evaluation Test Vehicles:

The evaluation test plan is composed of 4 groups. For each group are defined test vehicles (TV) and test bases with different configurations, see the table below:

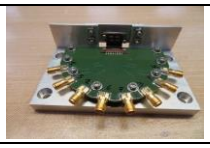
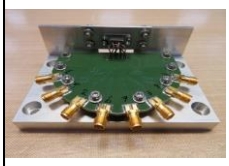
TV n°	Group	Cable	Length (m)	PCB	Pictures of PCB	Pictures of samples
8	Group 1	ESCC3902/003 Variant 02 Axon' part number P544806	1	SMT version		
9			4			
10			8			
11			10			
12		ESCC3902/004 Axon' part number P551259	1			
13			2			
14			4			
15		ESCC3902/004 Axon' part number P863123	1			
16			4			
1	Group 2	ESCC3902/003 Variant 02 Axon' part number P544806	1	Flex version		
4	Group 3		1			
2	Group 2	ESCC3902/004 Axon' part number P551259	1	Wire version		
7			1			
5	Group 3		1			
3	Group 2	ESCC3902/004 Axon' part number P863123	1	SMT version		
6	Group 3		1			

Figure 8: Evaluation Test Vehicles

2.3 General conclusion of the evaluation

The various measurements realized during the extensive evaluation gave very satisfying results which comfortably fulfill the requirements of the Cable assembly Type B described in the SpaceWire ECSS standard:

	ECSS-E-ST-50-12C requirements	MicroMach worst performances on the Evaluation vehicles
Shield bonding between outer shield of the cable and the connector	<10mΩ	<5mΩ
Shield bonding between inner shields of the cable and the connector	<10mΩ	<5mΩ
Shield resistance (Between the two connectors of a harness)	<1Ω	<25mΩ/m
Inter-pair skew	0,17ns	AWG26: 27ps/m LM AWG28: 14ps/m
Intra-pair skew	0,5 ns	
Crosstalk (FEXT and NEXT)	<-50dB up to 1GHz	<-50dB up to 1GHz

Figure 9: MicroMach® performances regarding the requirements of ECSS-E-ST-50-12C

It also allowed Axon to identify some design adjustments in order to do even better on some electrical performances such as the characteristic impedance (cabling process enhancement), the crosstalk (Modification of pins allocation) and the shielding effectiveness (Blind holes guide pins).

However, Axon has to deal with the three encountered anomalies.

2.4 Delta evaluation testing

After a root cause analysis, Axon has identified three corrective actions in order to prevent those issues to happen ever again:

- The cabling of parallel pairs cables have been improved by letting more slack between the crimping of the contacts and the crimping of the inner shields.
- The RNF-100 sleeves have been replaced by Viton sleeves, which have a higher thermal resistance (up to 250°C)
- A new termination conductor has been designed for the SMT connector

In order to validate at least those corrective actions, Axon has performed complementary tests on two new TVs, embedding the few design adjustments mentioned in the conclusion of the evaluation.

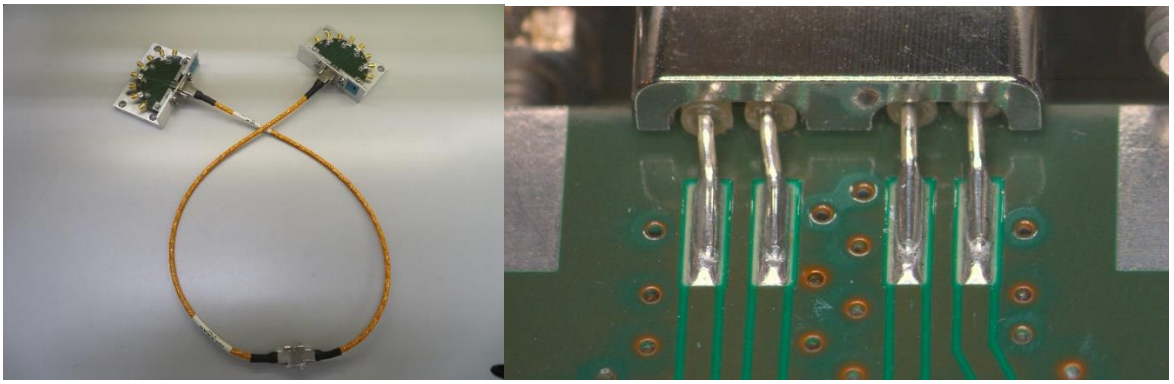


Figure 10: Views of Test Vehicles after 200 thermal cycles

All of those design changes successfully passed the delta evaluation testing.

3 MICROMACH PERFORMANCES

3.1 Comparative: MicroMach® versus Micro-D

The difference in size between the new SpW connector and a 9pin microD has been reduced to only **+32%** which is, regarding their respective size, very similar.

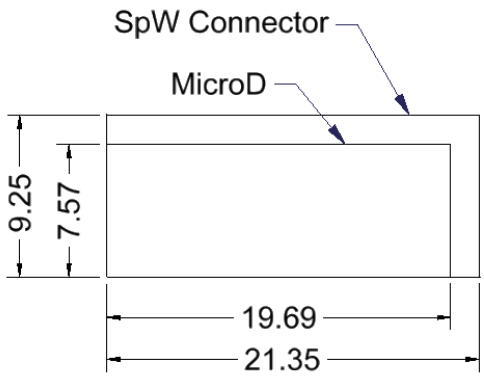


Figure 11: Size comparison between 9-pin MicroD connector and MicroMach® connector

Figure 12: View of a 9-pin MicroD connector next to the MicroMach® connector

However, the main advantage of MicroMach® links lies in its significant improvements compared to 9ways MicroD links.

3.1.1 CROSSTALK

Thanks to its geometry (1 cavity by transmission line), MicroMach® connectors are able to reach far lower Crosstalk levels than 9 ways MicroD connectors. During the evaluation, the 9 MicroMach TVs gave Crosstalk measurements (Fext and Next) on average 25dB lower than the 2 MicroD TVs on the whole bandwidth (up to 2GHz).

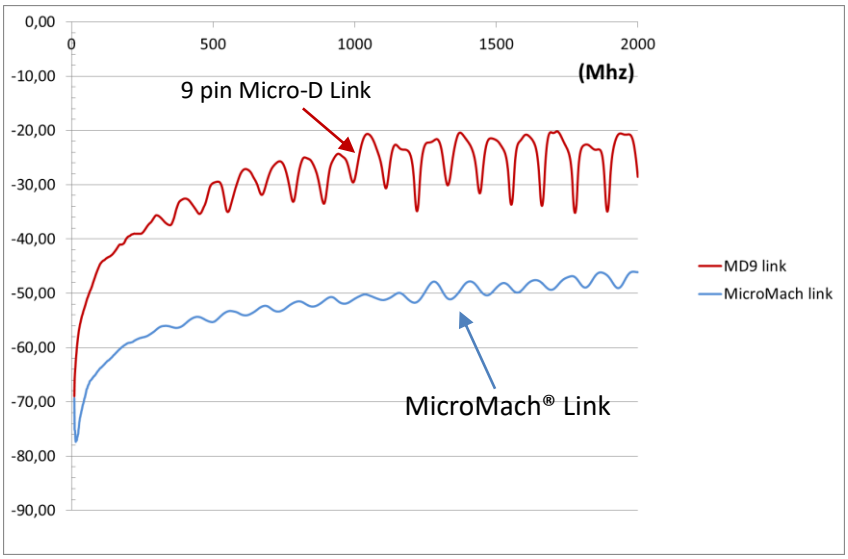


Figure 13: Crosstalk performances comparison between MicroD and MicroMach® links

3.1.2 SHIELDING EFFECTIVENESS

By doing 360° terminations for the overall cable screen and inner pair screens to connector shell, MicroMach connectors are able to reach far higher EMI levels than 9 ways MicroD connectors. During the evaluation, the 9 MicroMach TVs gave EMI measurements around 25dB better up to 5GHz.

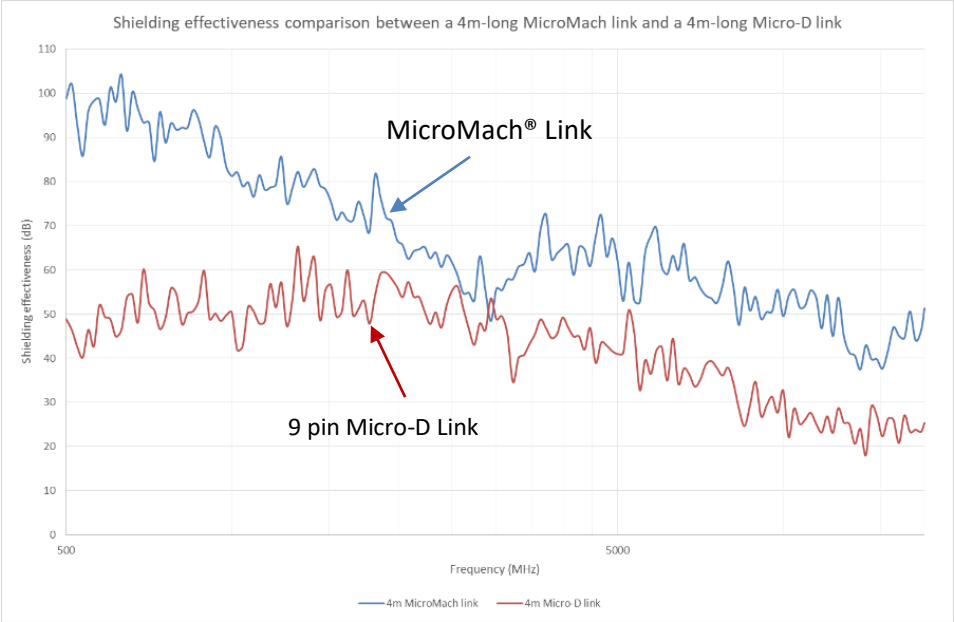


Figure 14: Shielding effectiveness performances comparison between MicroD and MicroMach® links

3.1.3 SIGNAL INTEGRITY

Thanks to its 100 Ohm matched characteristic impedance between the twin signal pins, MicroMach links have a significantly better signal integrity than MicroD links. Below are represented two Eye

Diagrams at 400Mb/s. Left one has been measured on a 1m MicroD link, and the right one on a 1m MicroMach link:

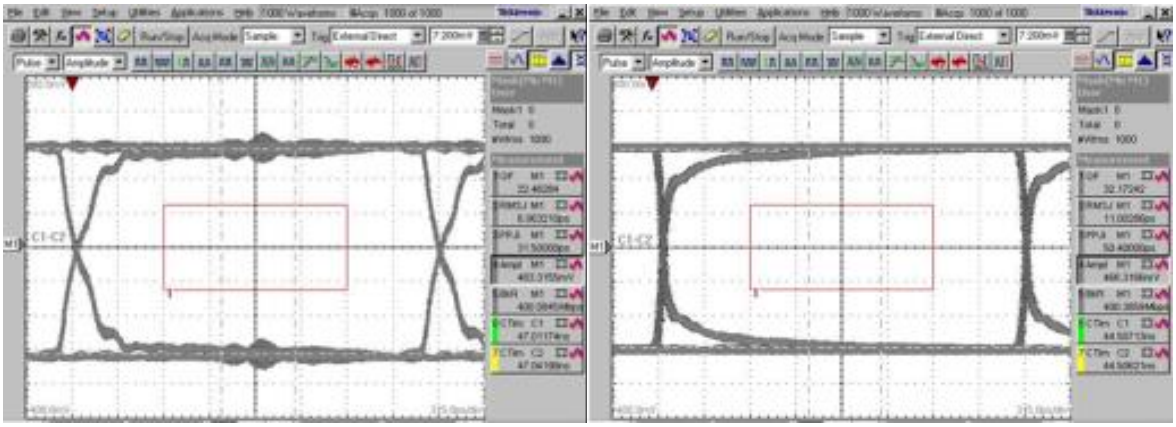


Figure 15: Eye-Pattern comparison between MicroD (left) and MicroMach® (right) links

By providing better signal integrity, MicroMach® links are able to reach far higher data rates (up to 3 GB/s) than MicroD links depending on the cable length

3.2 New set of ESCC HDR Detail Specifications

Following extensive evaluation of connectors and cables assemblies, Axon' worked on a new set of ESCC detail specifications dedicated to the MicroMach® range of product: MicroMach® cable assemblies and compatible equipment connectors. This new set of ESCC Detail Specification will be under review soon and official publication is expected early 2020.

EQUIPMENT CONNECTOR	CABLE ASSEMBLY
▪ Edge PCB SMT ▪ Wired PCB ▪ Flex PCB	Cable mount connector + SpaceWire or Low Mass SpaceWire cable
ESCC Generic Specification no. 3401	**ESCC Generic Specification no. 3409**
ESCC Detail Specification no. 3401-xxx *	ESCC Detail Specification no. 3409-00x *

Figure 16: Overview of the new set of ESCC HDR Detail Specifications

* … at the time of publication the specification numbers of the new set of MicroMach® ESCC Detail Specification is not assigned yet.

The main performances of a one-meter MicroMach® cable assembly extracted from the coming ESCC Detail Specification are the following:

Characteristic	Limits
Max. Operating Data Rate	3 Gb/s
Mating/Unmating Forces	MF < 25N 3N < UF < 25N
Shield Resistance	11 mΩ/m + 10 mΩ per couple of connectors

Mated shell conductivity		5 mΩ		
Characteristic Impedance		95Ω < ZC < 115Ω		
Crosstalk FEXT and NEXT		< -50dB up to 1 GHz		
Shielding Effectiveness		< -80dB up to 1 GHz		
		3902/003 SpaceWire		3902/004 Low Mass SpaceWire
		AWG26	*AWG28*	
Intra-pair Skew		Max. 80 ps/m		Max. 50 ps/m
Inter-pair Skew		Max. 130 ps/m		Max. 100 ps/m
Insertion Losses	*Up to 1.5 GHz*	-2.25 dB	-2.95 dB	-2.95 dB
	Up to 3 GHz	-3.70 dB	-4.90 dB	-4.90 dB
	Up to 4.5 GHz	-5.00 dB	-6.65 dB	-6.65 dB

Figure 17: One-meter MicroMach® link performances

3.3 Future ESCC Qualification Philosophy

Based on AxoMach cable assembly qualification lessons learned, Axon' will qualify the complete MicroMach solution, from one equipment to the other following the requirements of ESCC Generic Specification 3409, chart F4A. All Micromach® range of products will be tested and qualified using the following test vehicle construction (for Chart F4A, groups 1 and 2).

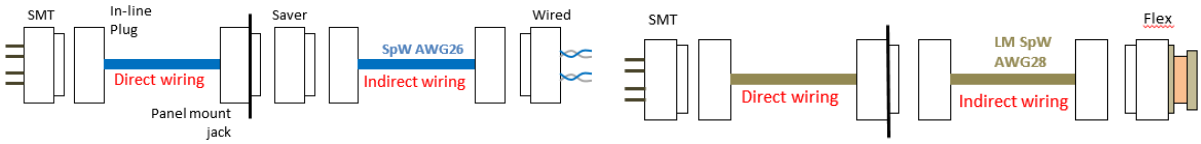


Figure 18: Overview of MicroMach ESCC qualification test vehicles