Low Mass SpaceWire

ESA Contract : ITT A0/1-126/09/NL/CO

ESA / ESTEC

Axon' Cable

Star Dundee

EADS Astrium

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Target of this study

SpaceWire cables and assemblies

- Mass reduction: 50% (half the mass)
- Retain existing electrical performance
- Improve shield bonding
- Improve radiation tolerance

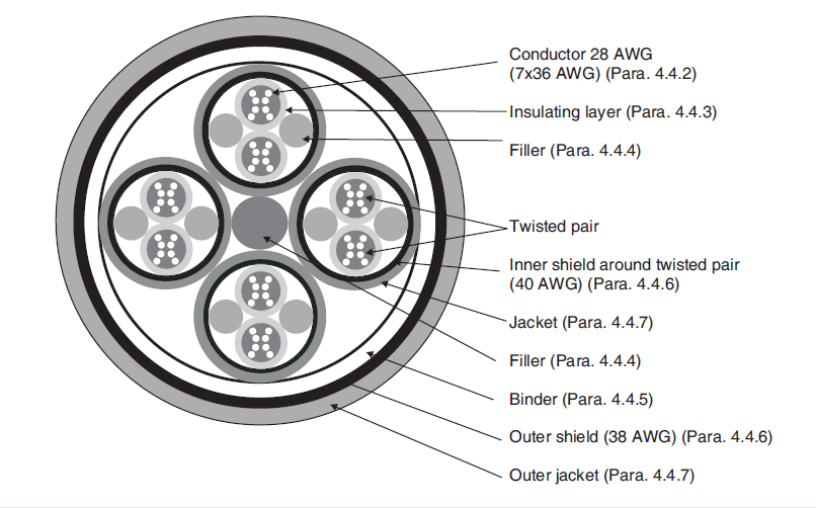
Note: In this presentation, we refer to Polyimide material by its common name, "**Kapton**"

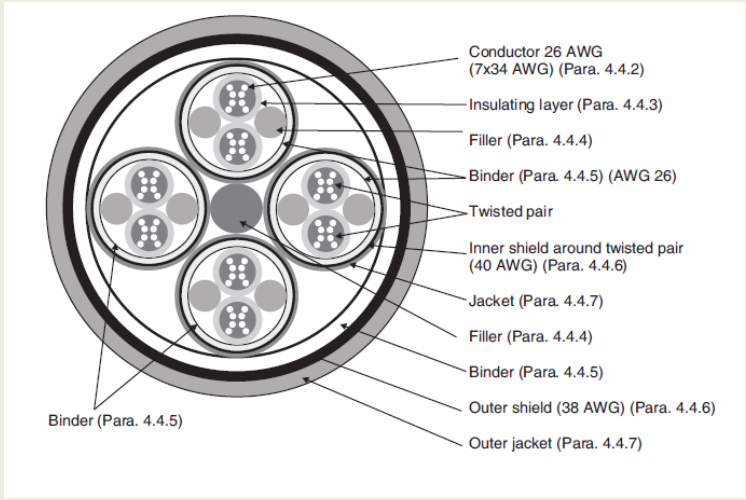
Existing SpaceWire cables

Generic specification ECSS-3902

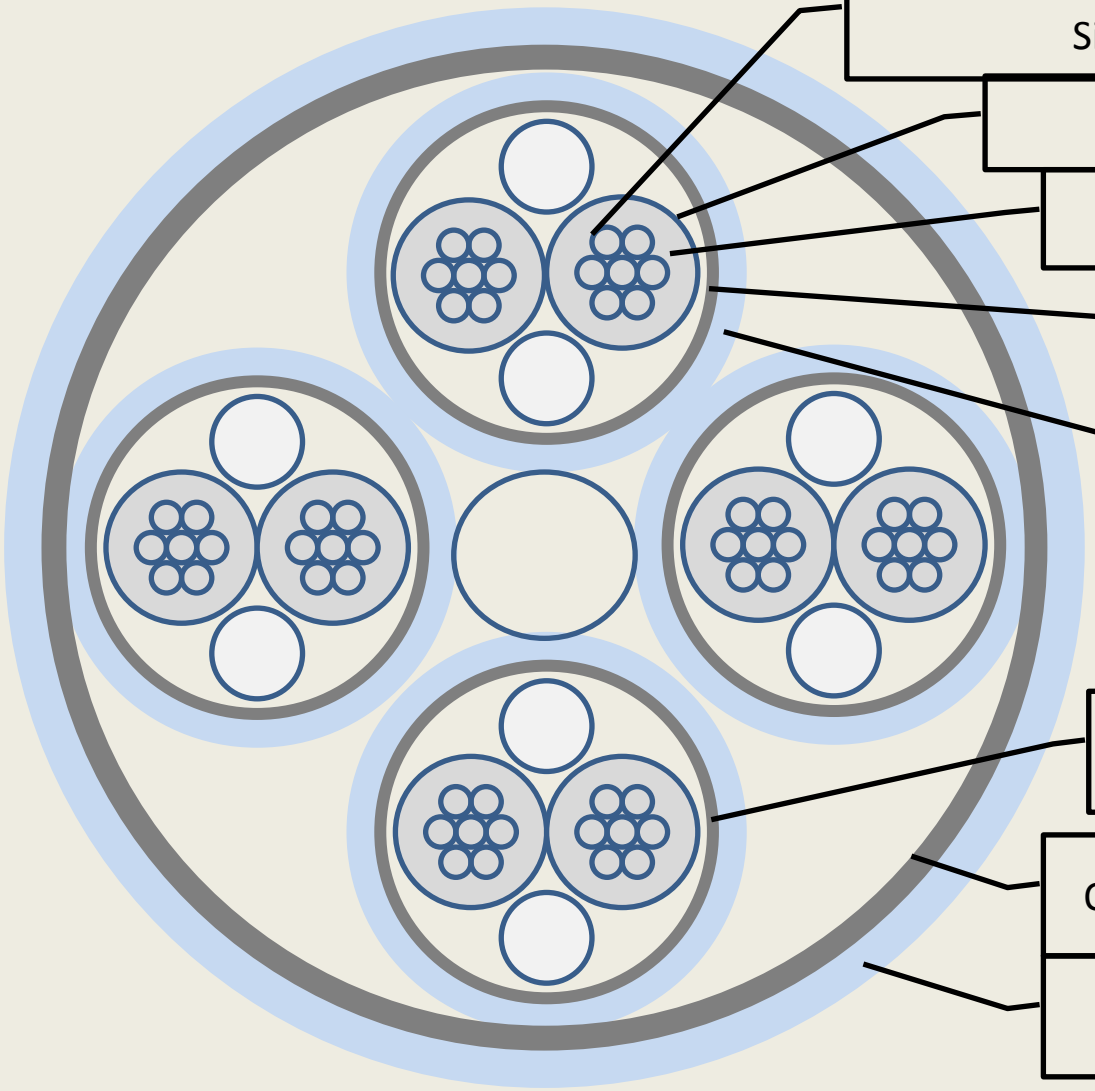
Detailed specification ECSS-3902-003

- Variant 01: 28AWG (7x36 AWG)
- Variant 02: 26AWG (7x34 AWG)





Existing ECSS 3902-003 cables



Conductor : 28AWG (7x36AWG) or 26AWG (7x34AWG)
Silver plated (2µm) copper alloy

Expanded PTFE insulation

Twisted pair with fillers (expanded PTFE)

Braid (40AWG silver plated copper)

PFA jacket

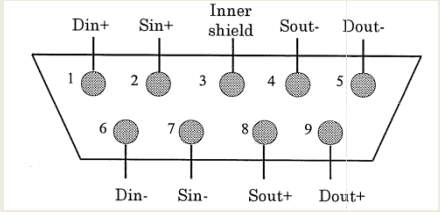
4 pairs and fillers

Overall braid (Silver plated copper 2µm)

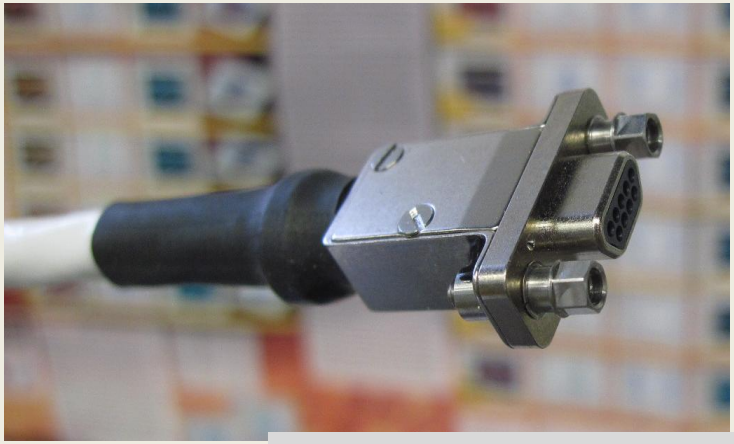
PFA jacket

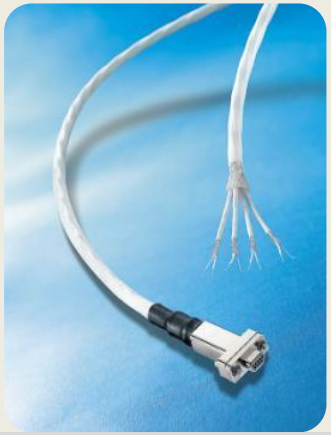
Specified connectors and layout

- **ECSS-E-ST-50-12C**
  - §5.3 Connectors : Refer to ESCC3401/029
  - **Micro-D connector shell size 9**



Contact number	Signal name
1	Din+
2	Sin+
3	Inner shield
4	Sout-
5	Dout-
6	Din-
7	Sin-
8	Sout+
9	Dout+



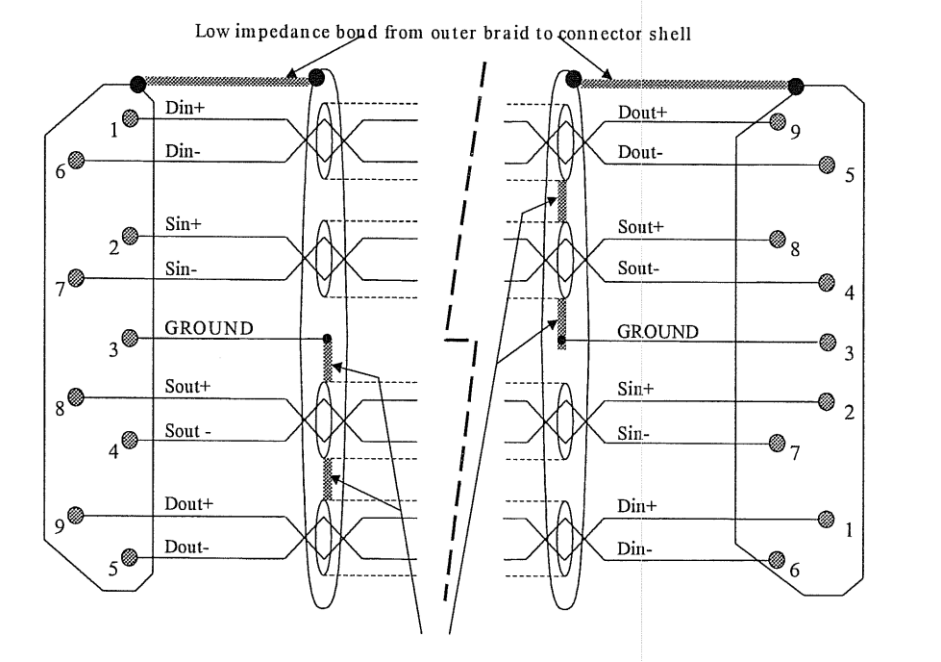


ESCC3401/029 axon is EPPL2 since 2006

Specified layout and bonding

Shield bonding:

- ✓ outer braid terminated to the backshell
- ✓ Inner braid only connected at one end to pin 3



Signal at A end	Pin at A end		Pin at B end	Signal at B end
A-Din+	1	- Connection -	9	B-Dout+
A-Din-	6	- Connection -	5	B-Dout-
A-Sin+	2	- Connection -	8	B-Sout+
A-Sin-	7	- Connection -	4	B-Sout-
A- (Drains of pairs 5,9 and 4,8)	3	- No Connection -	3	B-(Drains of pairs 5,9 and 4,8)
A-Sout+	8	- Connection -	2	B-Sin+
A-Sout-	4	- Connection -	7	B-Sin-
A-Dout+	9	- Connection -	1	B-Din+
A-Dout-	5	- Connection -	6	B-Din-
A-Shield	Shell	- Connection -	Shell	B-Shield

Existing SpaceWire performance

- **ECSS-3902-003 : SpaceWire cables**
  - **Mass < 80g/m**
  - Operating temperature range: -200, +180°C
  - Cable diameter: max 7mm
  - Bend radius : Max 45mm
  - Impedance : 100±6Ω
  - Maximum dc resistance 256Ω/Km
  - Capacitance: 50pF/m cond to cond, 90pF cond to shield
  - Skew: 0.08ns/m for a pair, 0.13ns/m between pairs

- **ESCC-E-ST-50-12C : SpaceWire assembly**
  - Skew : 0.5 ns
  - Jitter : 0.35ns at 400 Mb/s

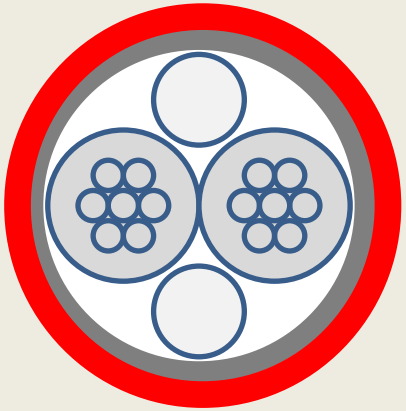
POSSIBLE WAYS OF REDUCING CABLE MASS

- Remove inner shield
  - Increases cross-talk
- Remove outer shield
  - i.e. Use just the inner shields of the 4 pairs
  - Decreases EMI performance.
- Reduce gauge
  - Increases attenuation
- Use lighter materials
  - Change copper shield to aluminium
  - Change materials e.g. **a-PTFE** insulator, Kapton tape for outer jacket
- Different construction techniques
  - Parallel (coax) line rather than twisted pair
  - Use flat transmission line

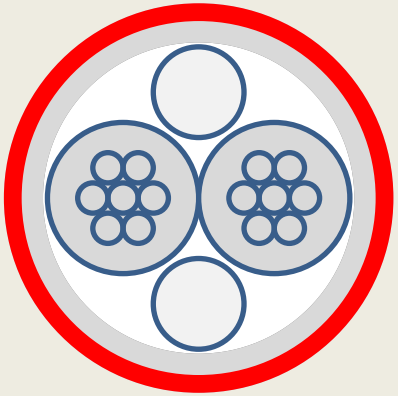
a-PTFE core

Change design of the pairs

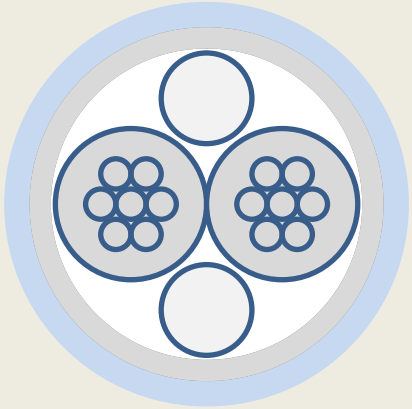
Changes to the existing Spw pair .



Pair type A
Change the jacket material from extruded PFA to wrapped Kapton



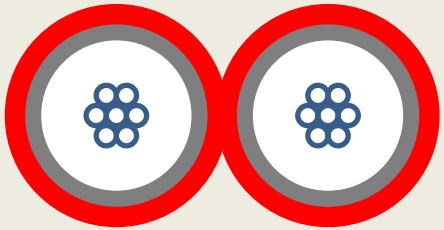
Pair Type B
Change the jacket material
From PFA to Kapton
+
Replace silver plated **Cu**
Braid with silver plated **Al**



Pair Type C
Remove the jacket entirely
+
Replace silver plated **Cu**
Braid with silver plated **Al**

Use of 50 Ω coaxial cables

Pair of coaxial cables.

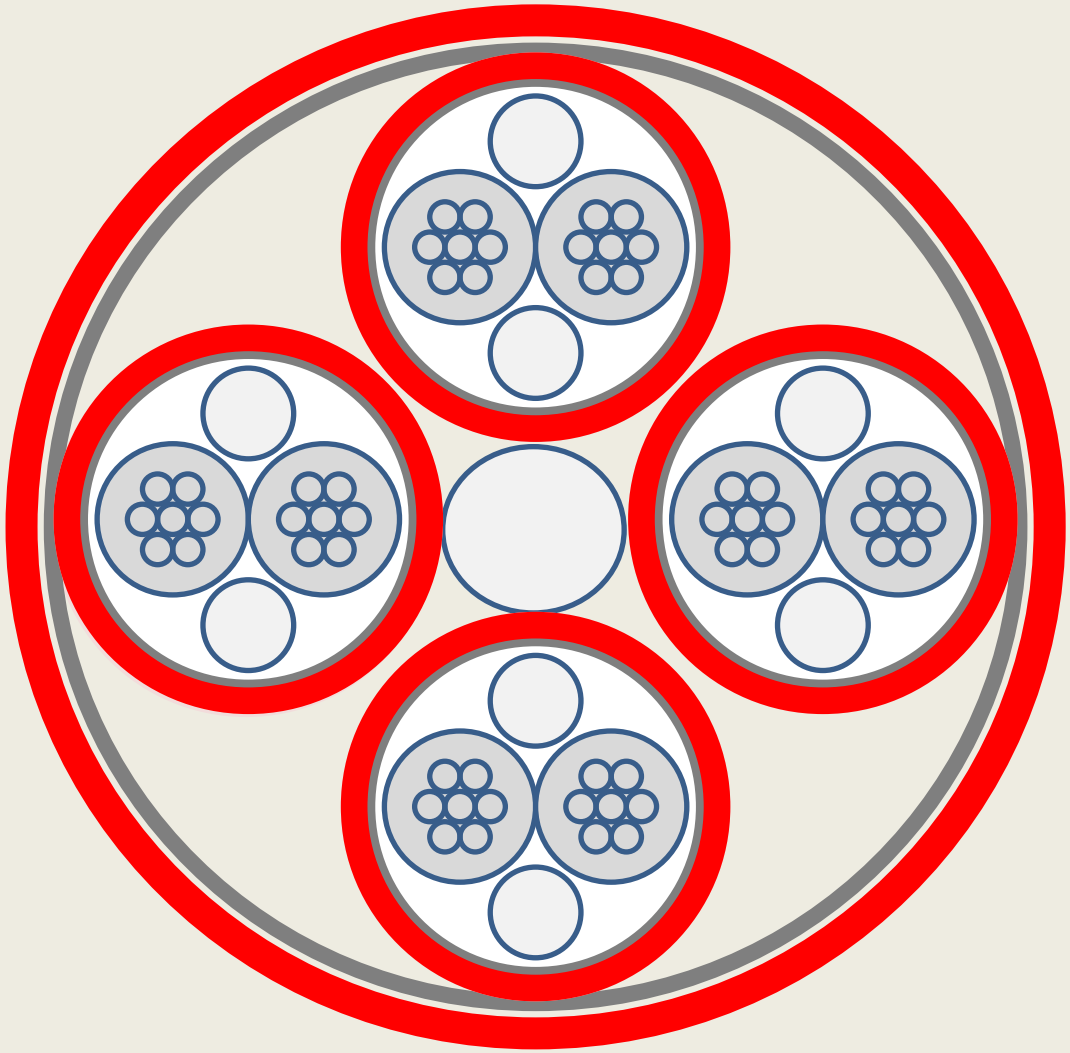


Pair Type D

Pair of 50Ω sub-miniature coaxial cables (Φ 1.00 mm).
AWG 1X34 silver plated copper alloy (2µm)
Zc in differential mode = 100 Ω
PTFE insulation
Kapton jacket.

Variant 3

Overall diameter : 6.1 mm - Mass= 61 g/m

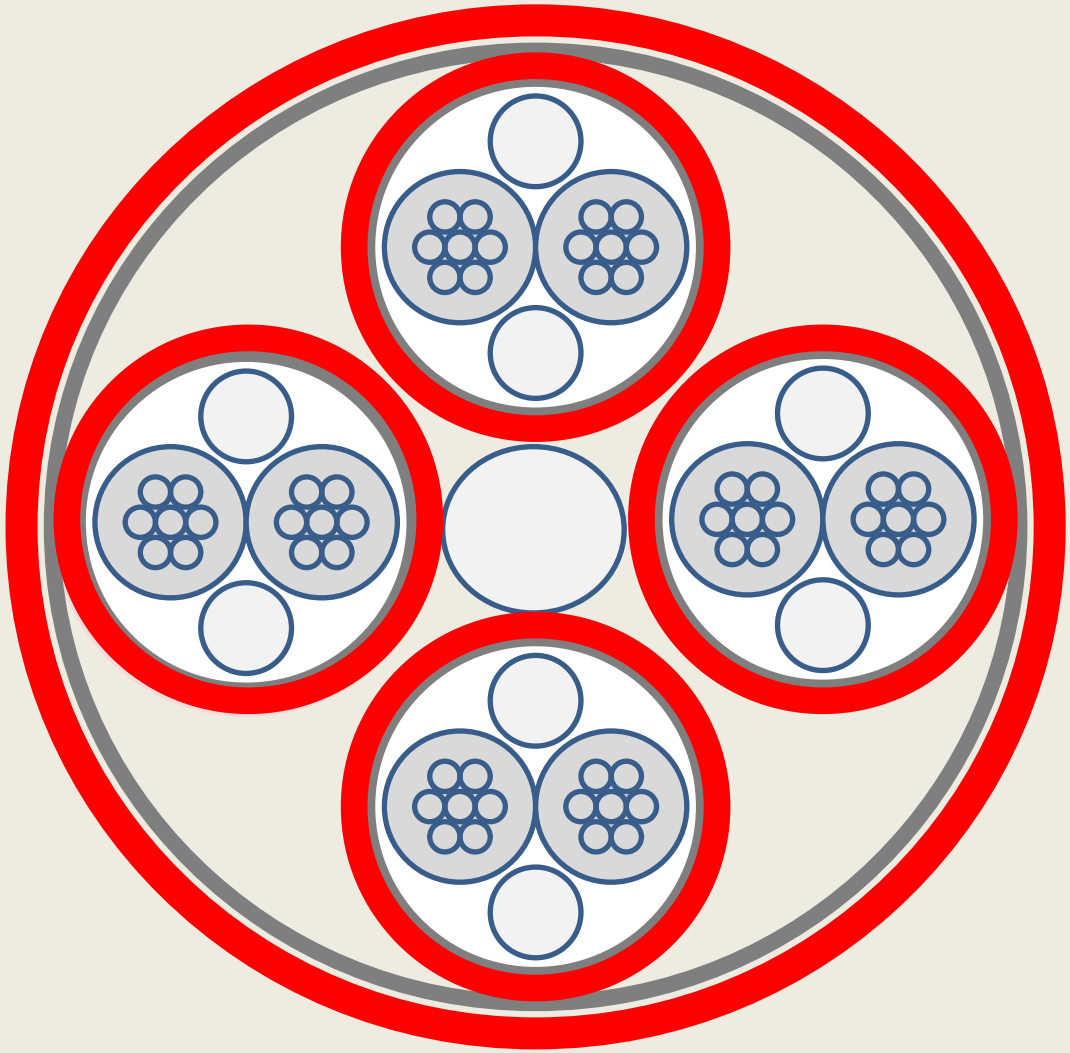


Variant: 03

1.) Pair type A
2.) Removal of the overall shield.
3.) Overall jacket in kapton

Variant 4

Overall diameter : 6.1 mm - **Mass= 43 g/m**



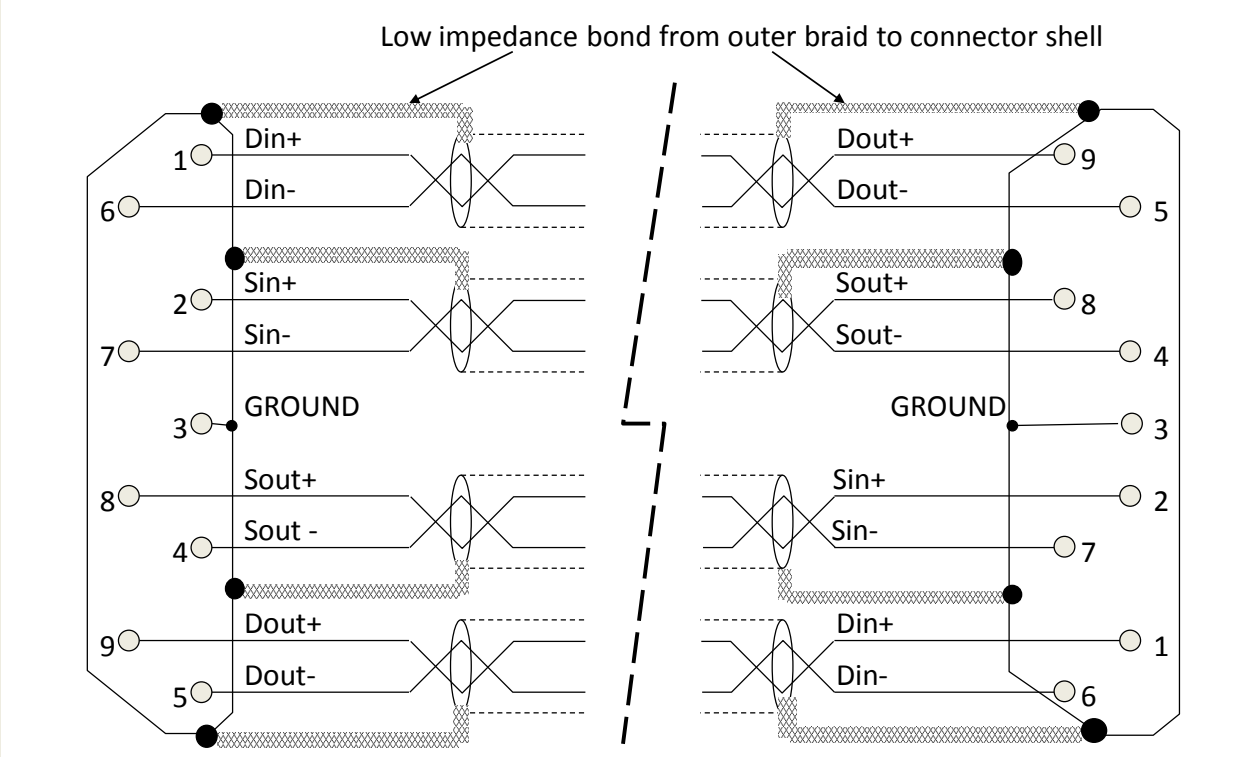
Variant: 04

1.) Pair type B
2.) Removal of the overall shield.
3.) Overall jacket in kapton

Bonding to micro-D connector

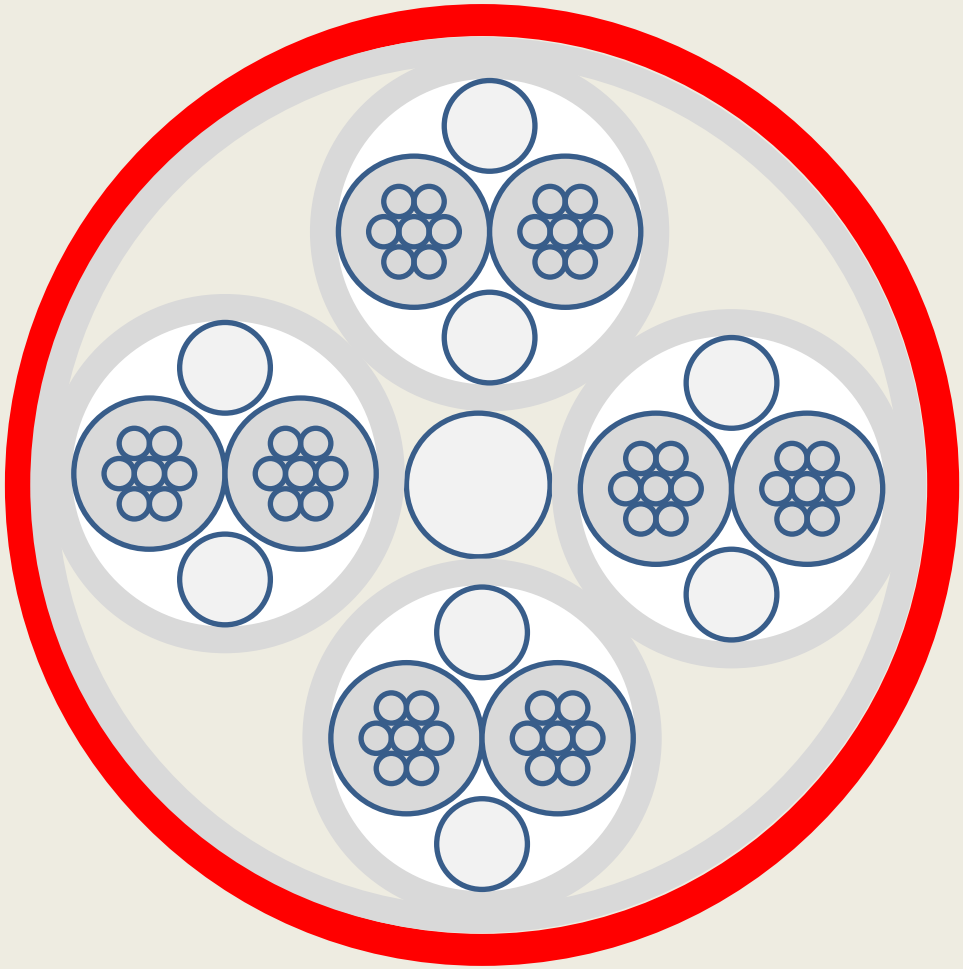
Variants 3 and 4 (cable with inner braids only)

✓ inner braids terminated to the backshell



Variant 5

Overall diameter : 6.1 mm - **Mass= 43 g/m**



Variant: 05

1.) 4 Pairs type C + filler

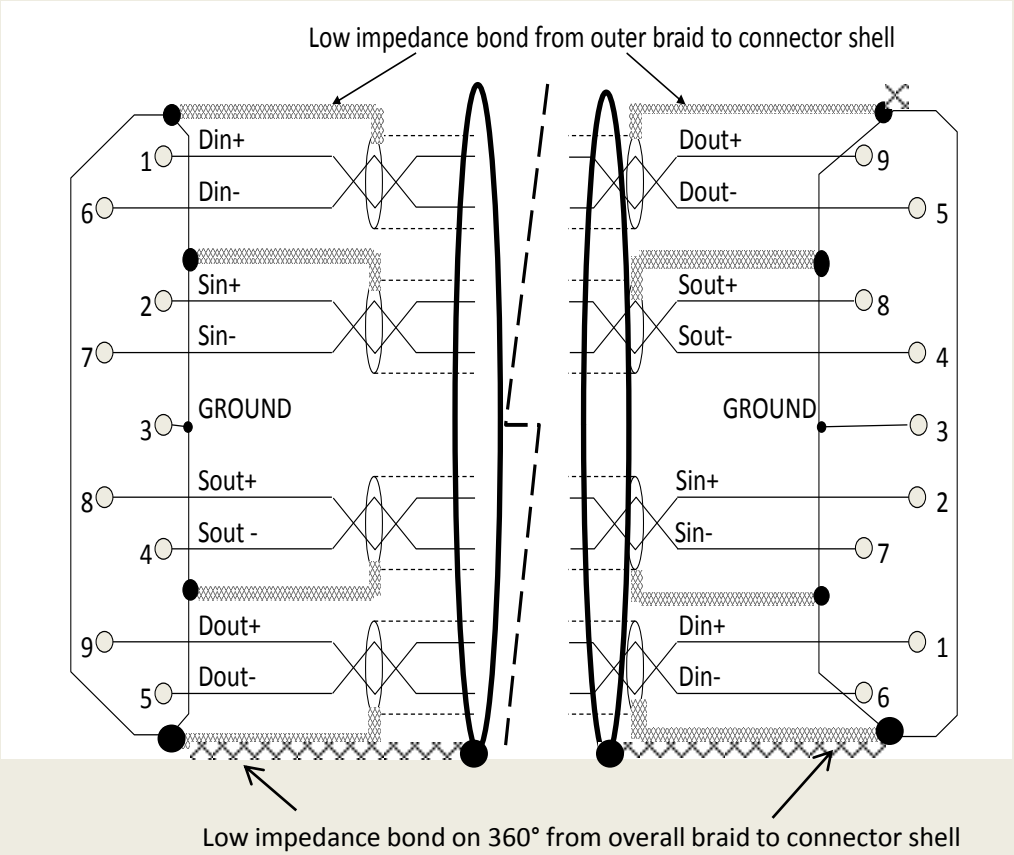
2.) Aluminium overall shield.

3.) Overall jacket in Kapton

Bonding to micro-D connector

Shield bonding on variant 5:

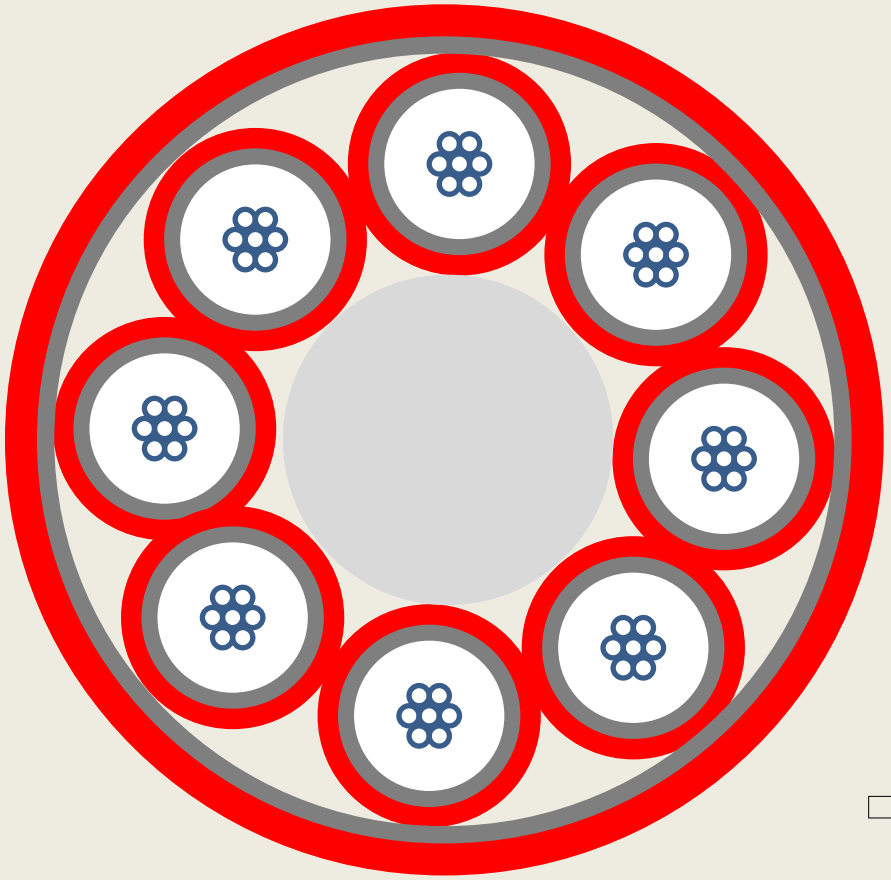
✓ inner shields and overall shield to the backshell



Variant 6 & 6F(lat)

Overall diameter : 4.5 mm - **Mass = 30 g/m**

(Variant 6F: 1.2mm x 12 - **Mass = 25g/m**)



Coaxial cable

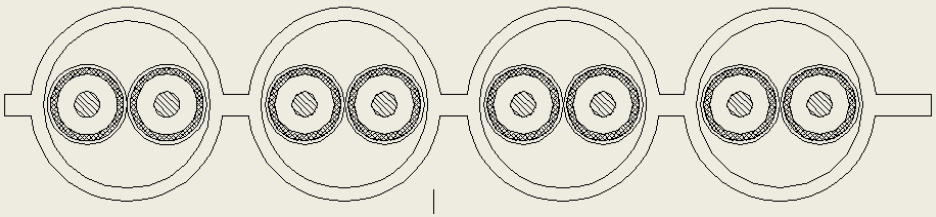
Pair of coaxial cables

4 coaxial pairs over a filler

Silver plated copper shield

Kapton jacket

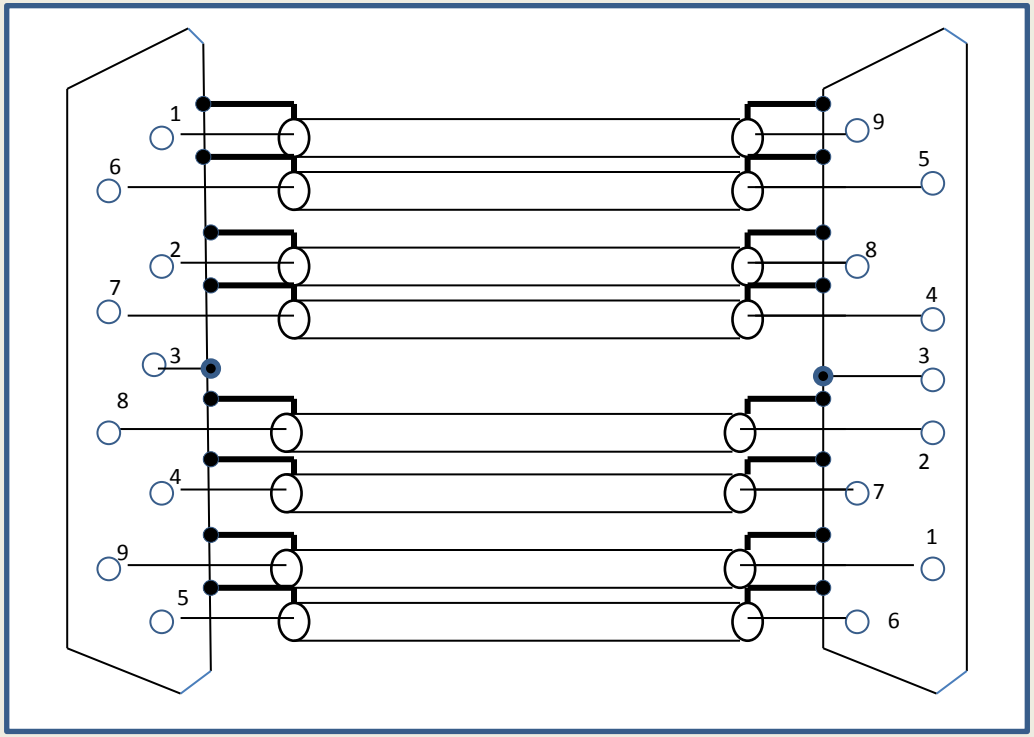
(Optional ribbon cable version)

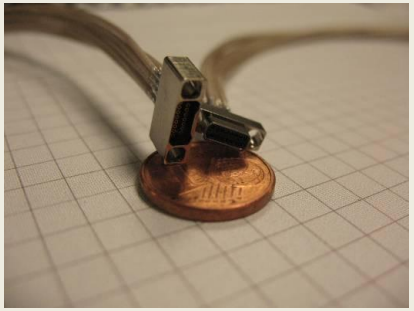


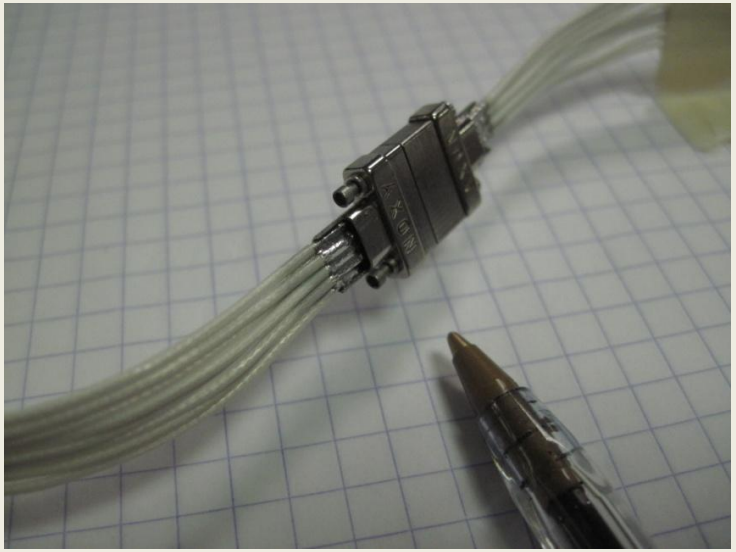
Bonding to nano-D connector

Shield bonding on variant 6:

✓ Outer braid & coaxial shields to nano-D backshell





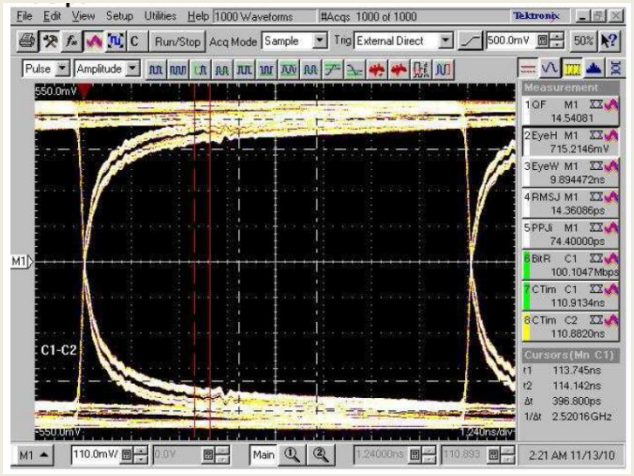


Extensive evaluation tests

- Listed in the test plan : **09048-TSD-A01-axon'**

Time domain

- ➢Characteristic impedance (Zc)
- ➢Skew
- ➢Eye diagram (jitter, Q factor)



Frequency domain

- ➢RLCG primary parameters
- ➢S parameters (return loss, insertion losses)
- ➢Transfer impedance (Zt)
- ➢Conductive Susceptibility (CS) test.
- ➢Crosstalk

Extensive evaluation test

- **Enviromental tests**
  - Alternate bending & torsion resistance
  - Cold bend radius at -80°C
  - Machanical load :
    - Random : ESCC 3401 § 9.11 : 0.2 g^2/HZ 30g RMS ,
    - Shocks : ESCC 3401 § 9.11 4 : 50 g , half sine 6 ms
  - Accelerated ageing stability : ESCC3902 §9.17
    - 5 cycles : -55°C during 30min; +125°C during 30 min.)
  - Ageing temperature:
    - +150°C +/-5°C during 7 days.

Low Mass SpaceWire Project

- **Status**
  - Evaluation tests on cable to be completed (50 %)
  - Evaluation tests on cable assembly to be done
  - Conductive Susceptibility test (**CS test**) : *Characterization of the robustness of the newly designed SpaceWire cable assembly against external EMI disturbances (ESD, Bulk current injection)*

- **Update of the SpW specifications**
  - ESCC3902/003 in process (draft available)
  - ECSS-ST-50-12 § 5.3

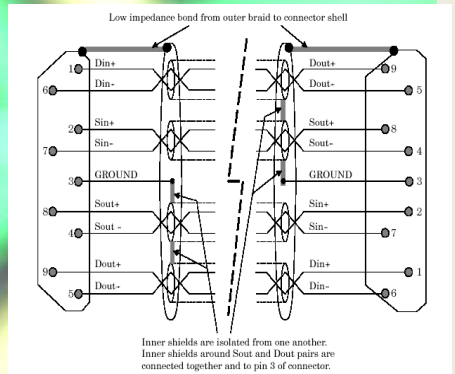
Performances of new variants

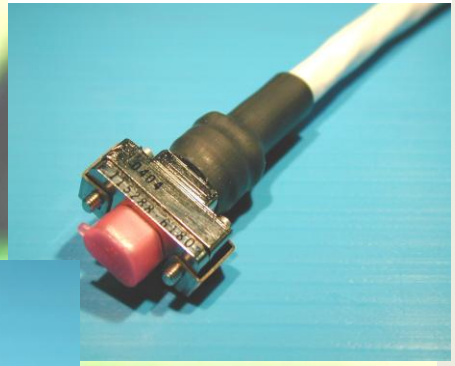
ESCC3902.003	Variant 1 (Current SpW)	Variant 3 P837578	Variant 4 P837580	Variant 5 P837582	Variant 6 P837585	Variant 6F (Flat)
Mass (g)	80 max	61 max	43 max	43 max	30 nom	25 nom
Overall Φ (mm)	7 max	6.1 max	6.1 max	6.1 max	4.5 max	1.2 mm x 12
Impedance (Ω)	100+/-6	100+/-6	100+/-6	100+/-6	2x50+/-2	2x50+/-2
Capacitance (pF)	<50 / 90	<50 / <90	<50 / <90	<50 / <90	<48 / <97	<48 / <97
Dc R (Ω/m)	0.23	0.23	0.23	0.23	0.9	0.9
Skew (pS/m)	<100	<20	<20	<20	<20	<20
Jitter (pS)@400Mb/s	64 L=5m	64 L=5m	64 L=5m	64 L=5m	25 L=1m	25 L=1m
Flexibility VS var1	0	++	+	+	++	+++
α (dB/m) @1Ghz L cable for -6dB	-1.5 4m max*	-1.5 4m max*	-1.5 4m max*	-1.5 4m max*	-2.5 2.4m max*	-2.5 2.4m max*
RL (dB) up to 2Ghz	-9 max	-9 max	-9 max	-9 max	-20 max	-20 max
Eye pattern Qfactor @400Mb/s	10 L=5m	10 L=5m	10 L=5m	10 L=5m	25 L=1m	25 L=1m

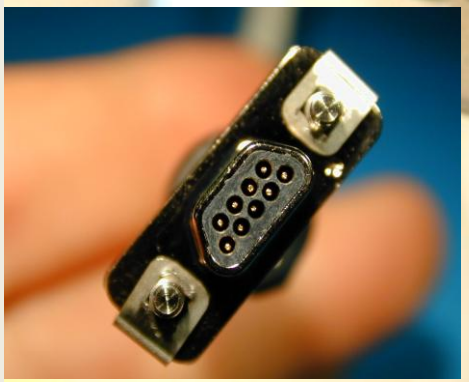
Conclusion

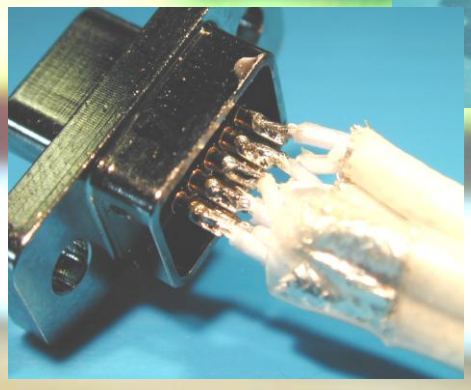
- ✓ Mass Target met
- ✓ No real performance degradation
  (to be confirmed by CS test)
- ✓ Very light and flexible solution for lengths <2.4m
- ✓ *Next challenge: 10Gb/s "SpaceFibre" data rate*
  - ✓ *Is it possible over copper?*

Thank you for your attention



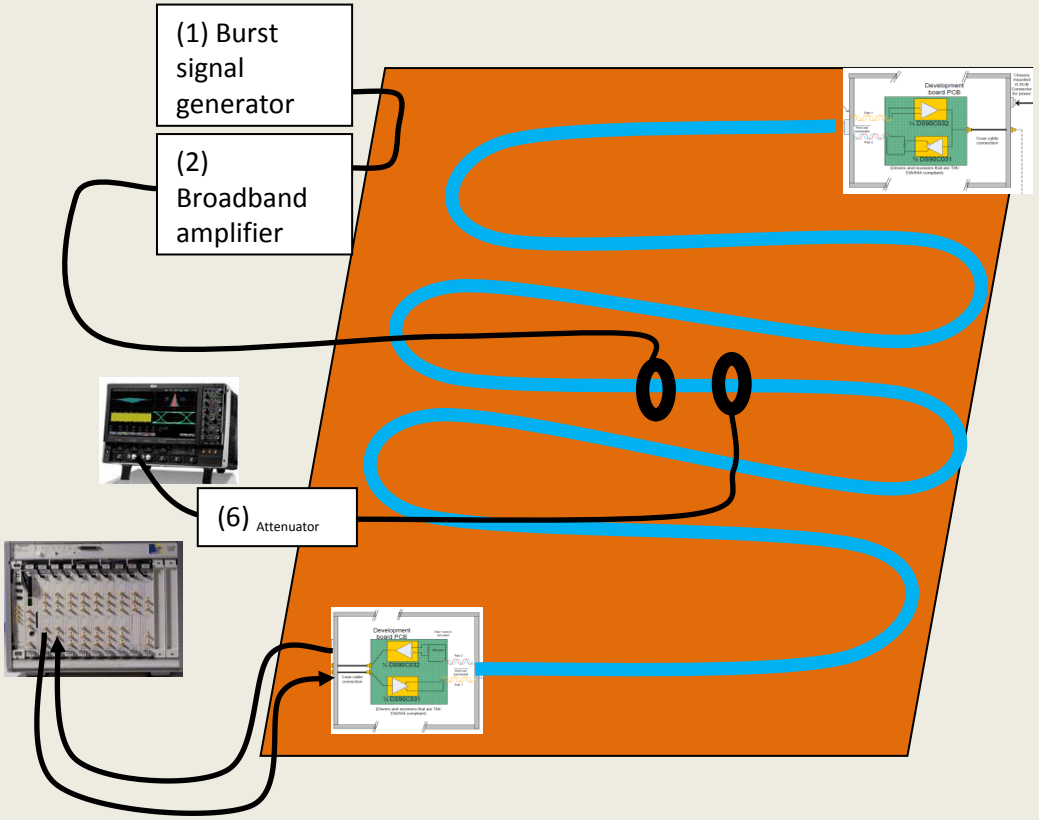






CS Test on low mass SpW assembly

- Bulk current injection : Pulse sine waves



Space Wire : @400Mb/s

	Data jitter t_{jitter} (ns)	Strobe jitter t_{jitter} (ns)	Skew t_{skew} (ns)	Min edge separation t_{ds} (ns)	Total (ns)
Encoder skew			0,20		
Encoder jitter	0,10	0,10			
PCB/connector skew			0,05		
Total transmitter	**0,10**	**0,10**	**0,25**		**0,45**
Cable jitter	0,35	0,35			
Cable skew (5m max. length)			0,50		
Total cable	**0,35**	**0,35**	**0,50**		**1,20**
PCB/connector skew			0,05		
Receiver jitter	0,10	0,10			
Decoder clock delay and hold				0,50	
Total receiver	**0,10**	**0,10**	**0,05**	**0,50**	**0,75**
Total system	**0,55**	**0,55**	**0,80**	**0,50**	**2,40**
Margin					0,10