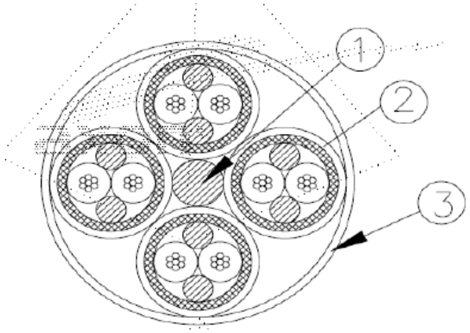
Low Mass SpaceWire Cable
ITT AO/1-6214/09/NL/LvH

J.ILSTAD
16th SpW WG meeting
22/03/2011

jorgen.ilstad æt esa.int



European Space Agency

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Activity Scope

1. Define and measure electrical parameters of the ECSS-E-ST50-12C cable as a reference for a new cable design
2. Identify the appropriate shielding for the cable
3. Connector/Cable bonding
4. Identify suited materials to obtain lower mass of the SpaceWire cable
5. Perform electrical performance validation and mechanical endurance tests
6. Provide a draft proposal for updating the ECSS-E-ST-50-12C cable specification

Characterisation of an ECSS-E-ST-50-12C Cable - Specification

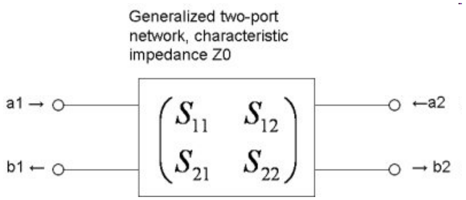
1. Axon SpaceWire Reference Sample (Product P532242)
   a. Qualified according to ESCC3902.003.01.
   b. Axon is QPL ESA test report N° 291

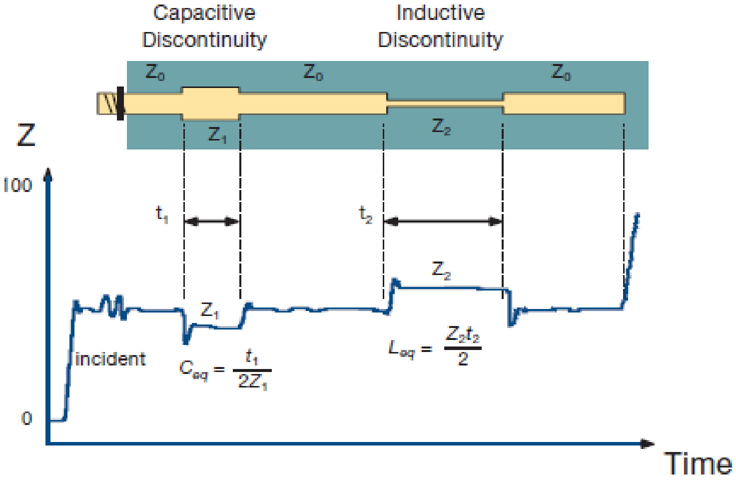
Performances	Type	Max	Nominal
Metrics	External diameter	7.5mm	6.9mm
	Mass	<85g/m	
Electrical	Electrical resistance	<239 Ω/Km	207 Ω/Km
	Insulation	>5 G Ω under 500Vdc	>5 G Ω under 500Vdc
	Capacitance	<50 pF/m	45pF/m
	Impedance	100Ω+/-6	100 Ω
	Insertion losses		<1dB/m @ 400Mhz
	Propagation factor	4.3ns/m	4.25ns/m
	EMI	>45dB	>60dB

Characterisation of an ECSS-E-ST-50-12C Cable - Test procedure

Define the test procedure to extract:

- Scattering parameters
- RLCG parameters
- Time Domain Reflectometry measurements
- Transfer impedance





Characterisation of an ECSS-E-ST-50-12C cable - Applicable electrical parameters

The most pertinent parameters to express are the:

S21 – Transmission coefficient (insertion loss)

S22 – Reflection coefficient (return loss)

NEXT – Near End Cross Talk

FEXT – Far End Cross Talk

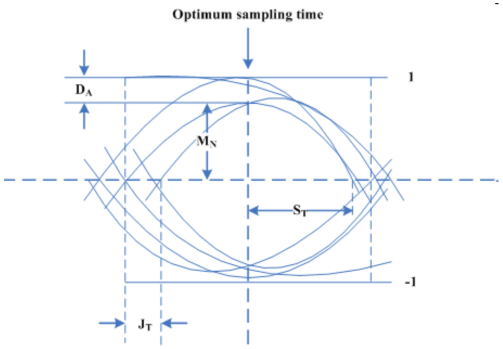
Primary and **Secondary** Parameters (RLCG)

Characteristic Impedance - Z_c

Skew - both intra-pair and pair to pair skew

Shield effectiveness - Z_t

Eye Pattern measurements is good way to verify many of the individual parameters

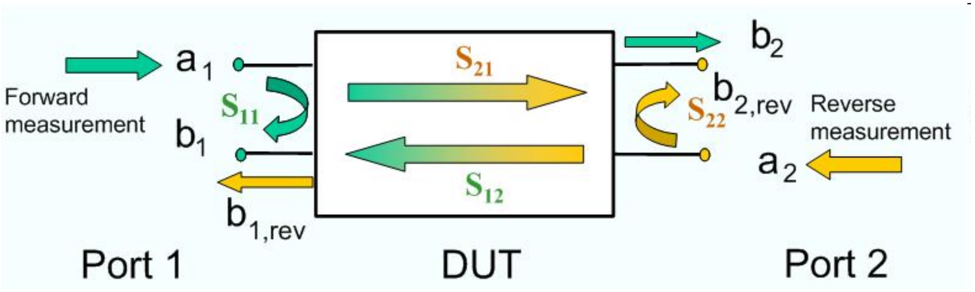


Characterisation of an ECSS-E-ST-50-12C cable - S parameters

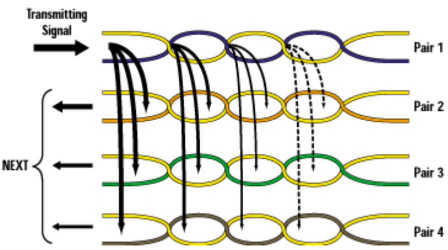
Average S21 and S22 values measured on a ECSS-E-ST-50-12C compliant cable.

Length / type of cable	Average s21@1GHz (dB)	Average S21@2GHz (dB)	Average Max S22
5.18m / SpW cable pair	-6.99	-12.43	- 8.5

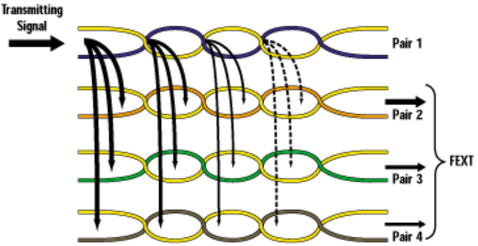
Length / type of cable	Average s21@1GHz (dB/m)	Average S21@2GHz (dB/m)	Average Max S22 @ f (dB/m)
SpW cable pair	-1.34	-2.40	- 1.64



Characterisation of an ECSS-E-ST-50-12C cable
- NEXT and FEXT parameters



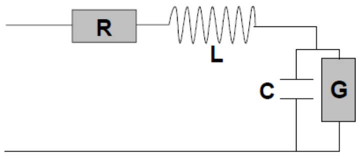
NEXT in SpW Cable (dB)	@GHz	@2GHz
Pair1 on Pair2	-50.8@1.16GHz	-62.2
Pair1 on Pair3	-37.2@1.16GHz	-54.2
Pair1 on Pair4	-43.7@0.905GHz	-51.8



Fext on cable (dB)	@Ghz	@2Ghz
Pair1 on Pair2	-52.3@0.721Ghz	-70
Pair1 on Pair3	-39.5@1.15Ghz	-55.9
Pair1 on Pair4	-42.6@1.27Mhz	-57.9

Characterisation of an ECSS-E-ST-50-12C cable - Primary and Secondary parameters

Impedance seen at one end of the transmission line when the other end is successively in Short circuit and Open circuit.



@1Mhz

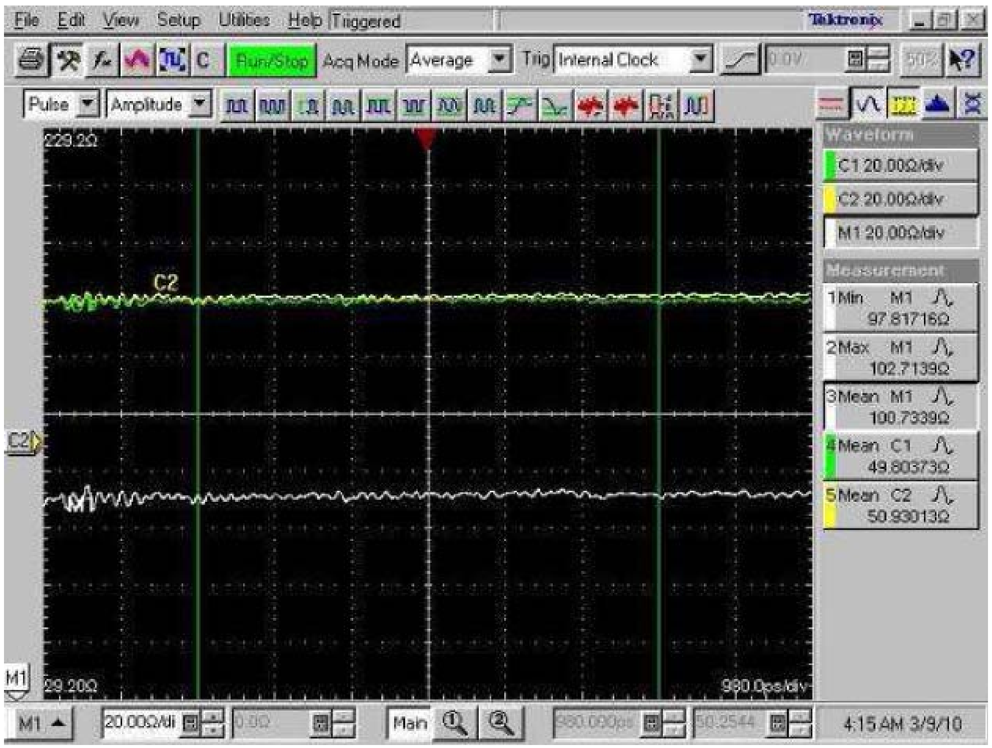
	R (Ω/m)	L (nH/m)	C (pF/m)	G (S/m)	A (mdB/m)	ß (mRad/m)	Zc (Ω)	ΦZc (mRad/m)	ΦZc (°/m)
Blue	0.854	566	29.8	(1)	26.8	27.3	140	-112	-6.44
White	0.869	571	29.6	(1)	27.0	37.3	141	-113	-6.49
Red	0.823	565	35.8	(1)	28.3	29.9	127	-109	-6.23
Grey	0.842	566	29.8	(1)	26.4	27.3	140	-111	-6.35

@20Mhz

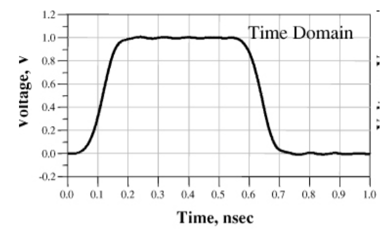
	R (Ω/m)	L (nH/m)	C (pF/m)	G (S/m)	A (mdB/m)	ß (mRad/m)	Zc (Ω)	ΦZc (mRad/m)	ΦZc (°/m)
Blue	2.95	474	35.5	(1)	107	488	116	-27.2	-1.56
White	3.14	473	33.5	(1)	11	473	119	-29.0	-1.66
Red	3.30	475	36.2	(1)	120	493	115	-30.4	-1.74
Grey	3.19	472	35.3	(1)	115	485	116	-29.5	-1.69

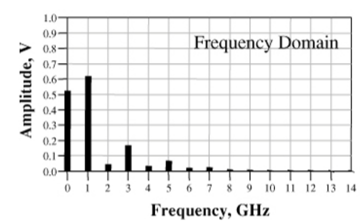
Characterisation of an ECSS-E-ST-50-12C cable - Zc and Skew

Characteristic Impedance of one pair from a Axon P532242 SpW cable shown using TDR measurement



Characteristic impedance (in Ω)
Max=104
Min=97.8
Mean=101

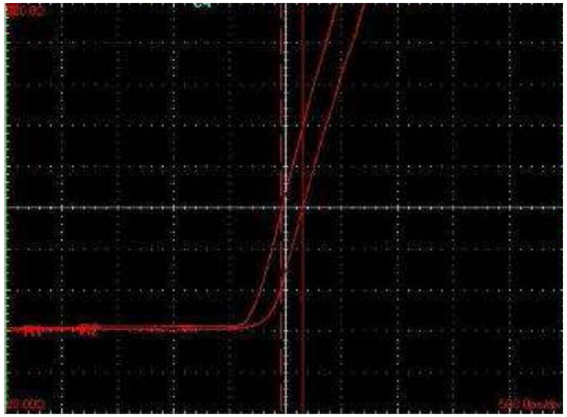


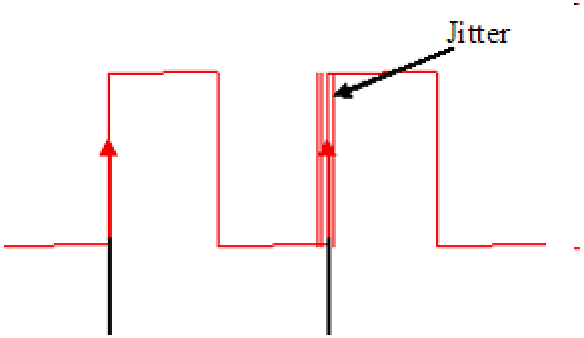


Characterisation of an ECSS-E-ST-50-12C cable - Skew

Skew measured for pairs of a Axon P532242 SpW Cable

Pair N°	Skew (in ps) for cable under test (L=5.18m)	Skew (in ps/m)
1	190	18.3
2	90	8.69
3	480	46.3
4	290	28

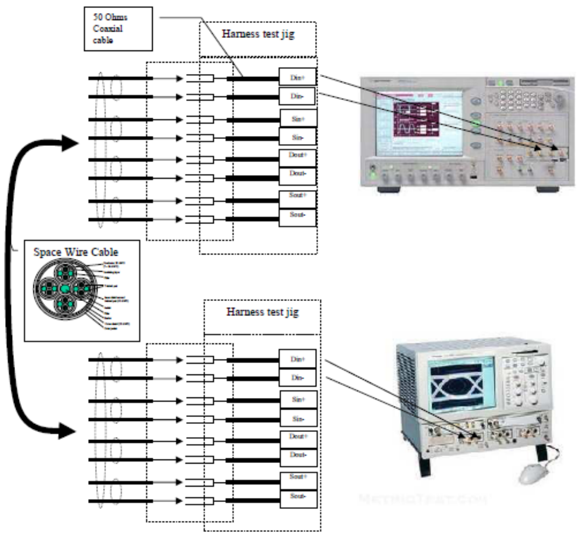




Characterisation of an ECSS-E-ST-50-12C cable - Eye pattern

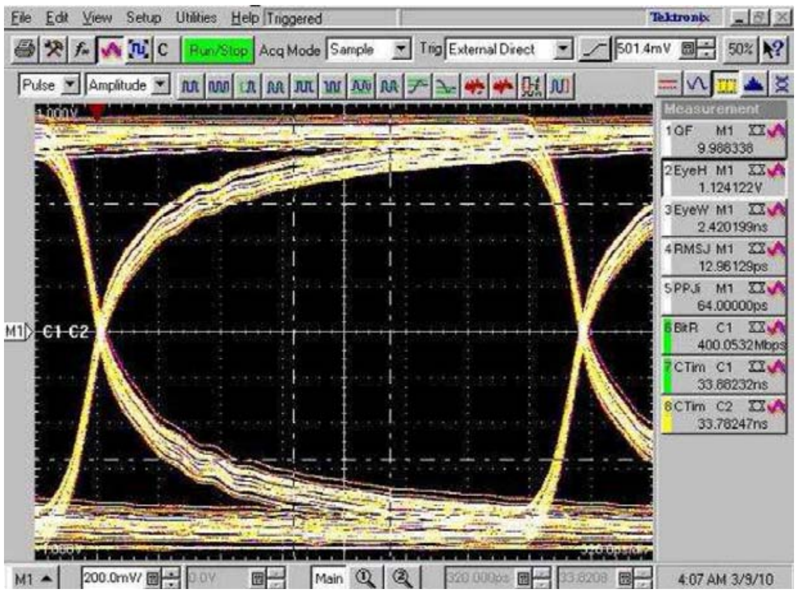
Test performed using a ParBERT81250 with PRBS 2^{31}-1 V_{pp} = 2V

	Q Factor	Eye Height (V)	Eye Width (ns)	RMS Jitter (ps)	PP Jitter (ps)
100Mb/s	15	1.42	9.87	18.2	74.4
200Mb/s	13.8	1.32	4.91	13.9	74.4
400Mb/s	9.99	1.24	2.42	13.0	64
800Mb/s	6.96	0.839	1.16	15.2	76.8

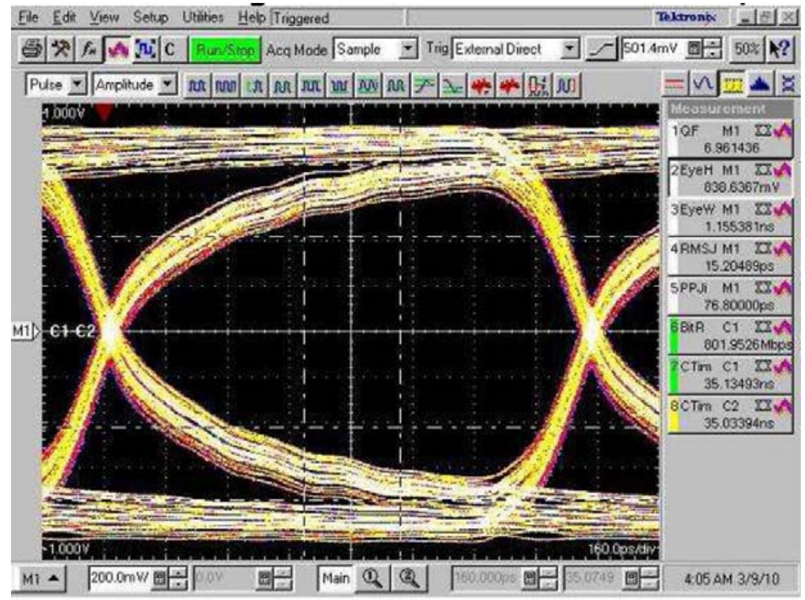


Characterisation of an ECSS-E-ST-50-12C cable - Eye pattern

Eye pattern measurements on a 5m Axon P532242 SpW Cable



P532242 length 5m @ a bit rate of 400Mb/s

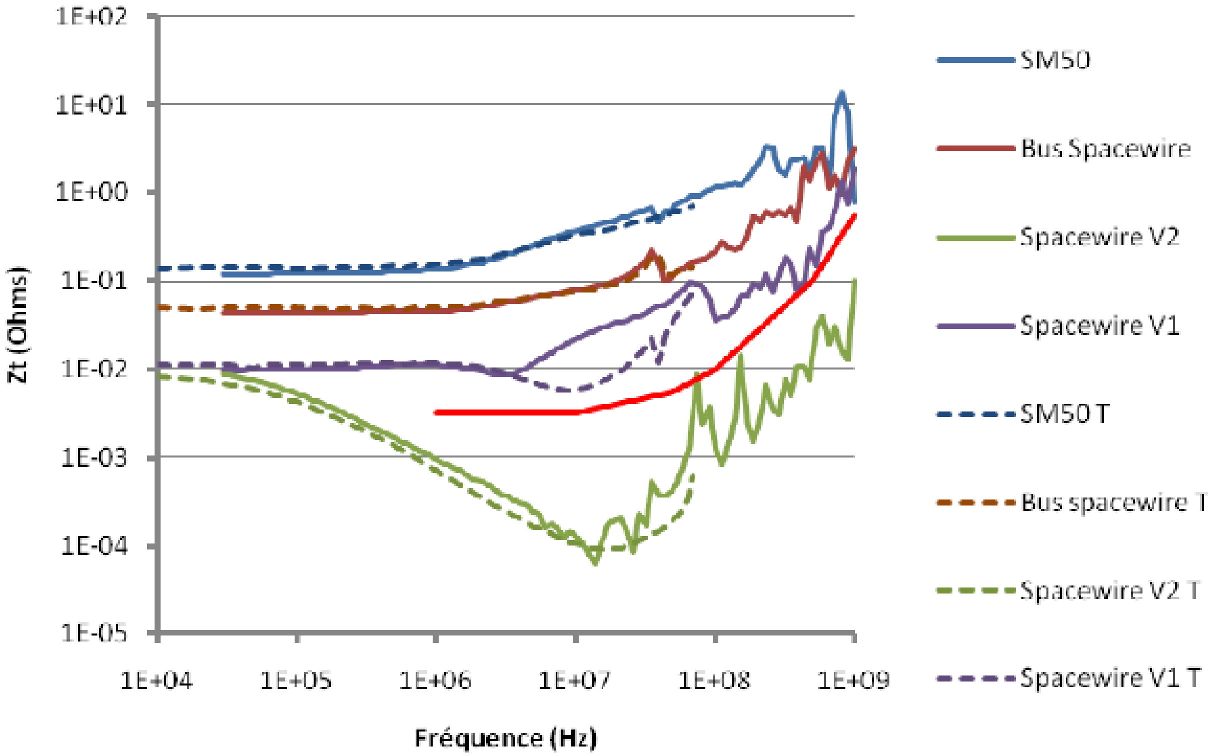


P532242 length 5m @ a bit rate of 800Mb/s

Characterisation of an ECSS-E-ST-50-12C cable - Transfer Impedance

Transfer impedance establishes shield performance

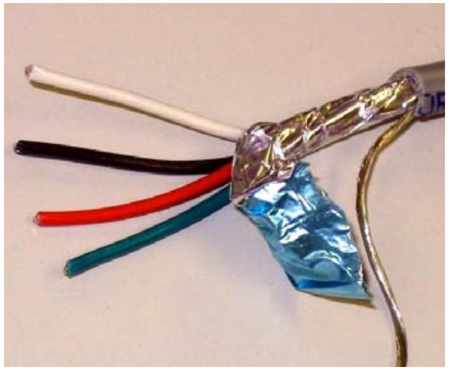
$$Z_t = \left(\frac{1}{I_o}\right) \cdot \left(\frac{dV}{dx}\right)$$



Bus – Inner shield of one pair

V2 - Outer Shield shorted with inner shield of one pair

V1 - Outer Shield only

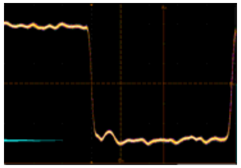


The lower the value of the transfer impedance, the more effective the shielding

Cable Shielding arrangement - Should it be changed?

Is the current recommended ECSS-E-ST-50-12C shielding appropriate?

Inner Shields are not really that effective for signals with fast rising / falling edges*



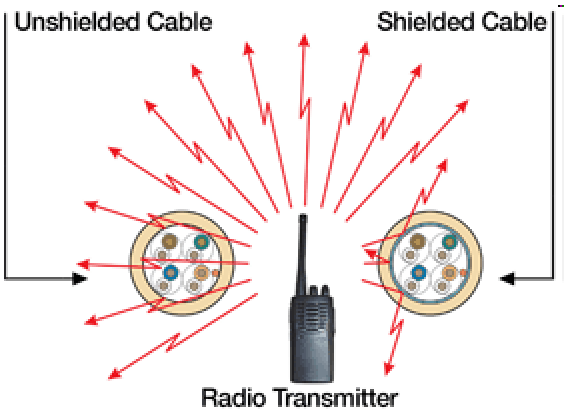
* S. Allen, "SpaceWire Physical Layer Issues", MAPLD 2006

Cable Shielding arrangement
- Suggested changes

The Cable Shield;

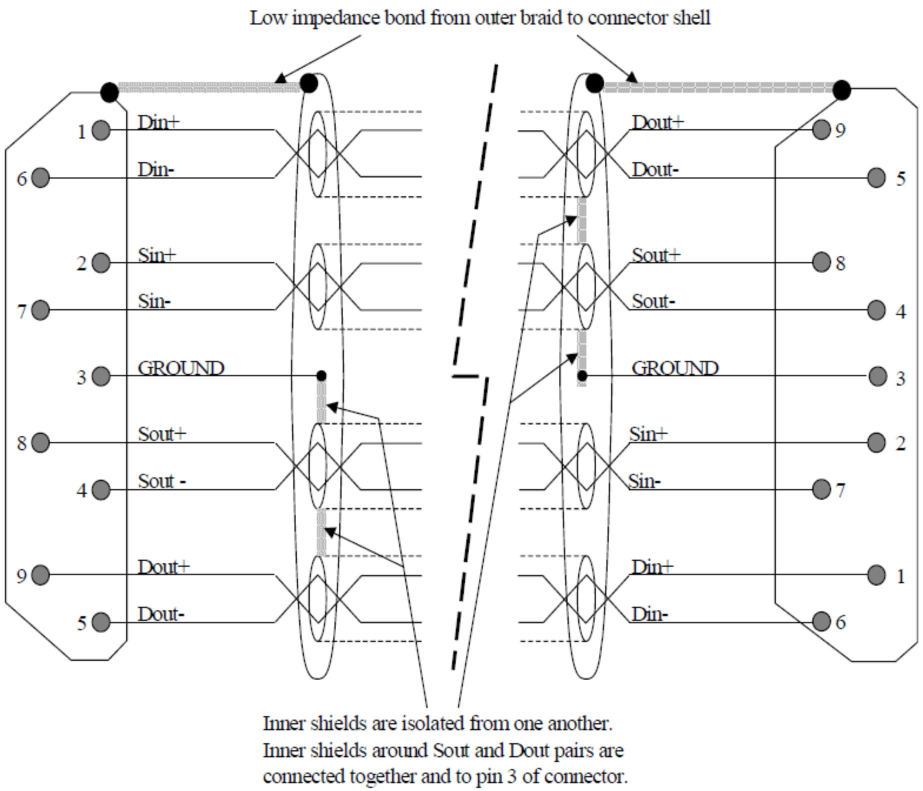
- Prevents excessive electromagnetic radiation and susceptibility
- Prevent cross-talk between signal pairs
- Provides return path for common mode current

* Survey applicable appropriate space craft grounding schemes
* Identified a set of changes which should be discussed within the SpW WG.



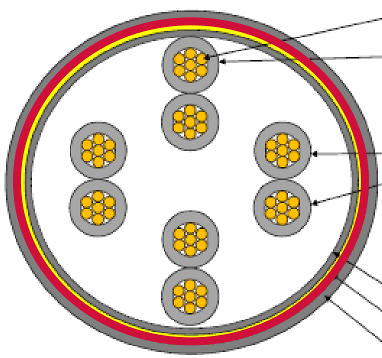
Cable Shielding arrangement - ECSS-E-ST-50-12C

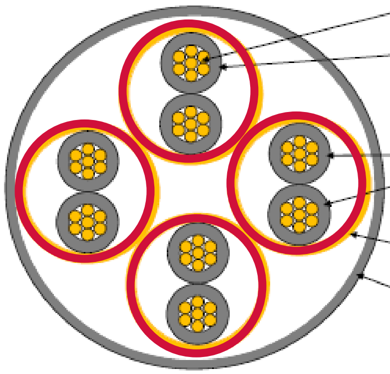
The inner shields connected to one side only



Cable Shielding arrangement
- Using only one shield

Survey pros and cons for a single shield solution





+ Simple 360 termination

+ permits 9p MDM through bulkheads

+ Reduces cable mass

- Increased cross-talk between signal pairs

- Possible shield degradation compared to using both inner and outer shields

- Less uniform Zc

+ avoids increased cross talk between pairs

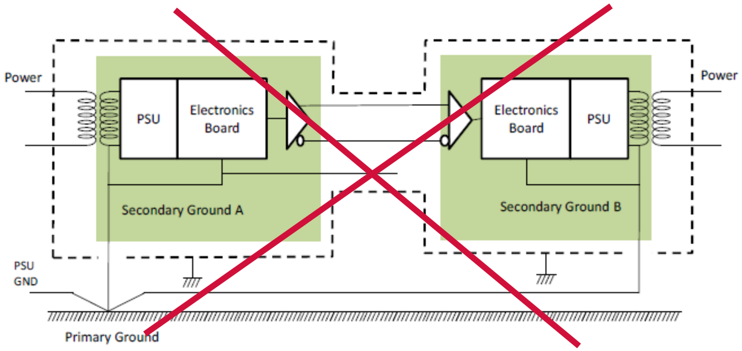
+ permits 9p MDM through bulkheads

+ Reduces cable mass

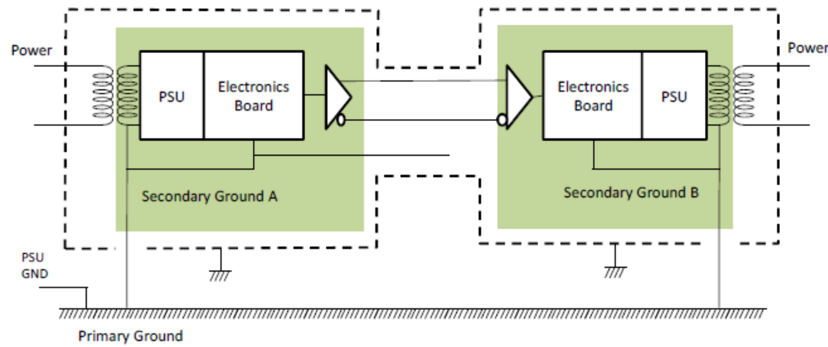
- Difficult 360 termination

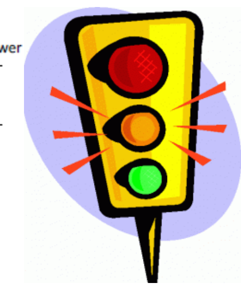
- Possible shield degradation compared to using both inner and outer shields

Cable Shielding arrangement - Grounding schemes

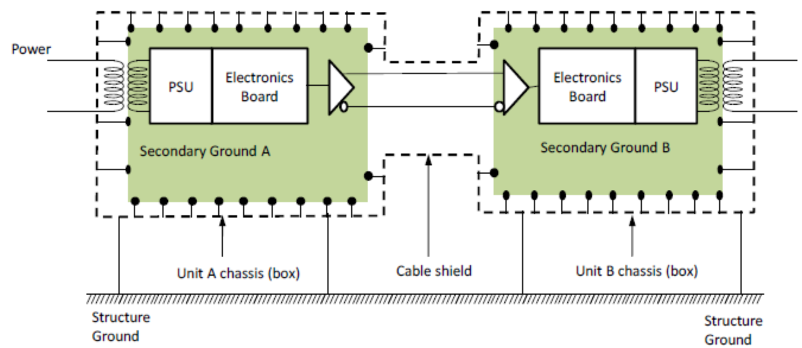


Single Point Ground





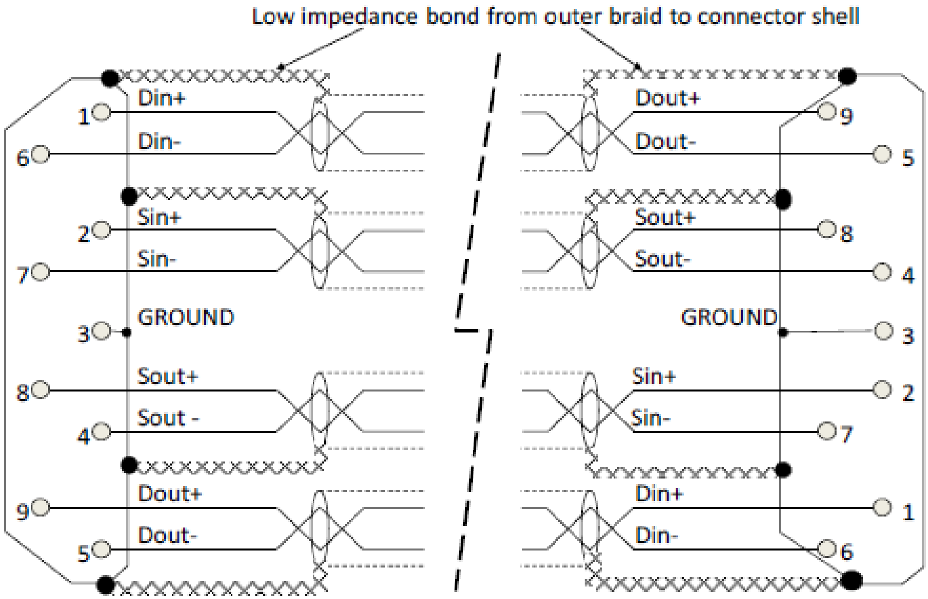
Multipoint Ground – single reference



Multipoint Ground – for high frequency signals

Cable Shielding arrangement - Conclusions

– EMC requirement in most satellite projects will not necessarily require double shielding.
– Shielding individual signal pairs and 360° termination to connector back-shell at both ends.
- Shield continuity through bulkhead connections is possible.



Several different cable constructions will be tested in the LMSpW activity.

Inputs for revised standard - Preliminary results

1. Replace detailed cable specification (clause 5.2) with key electrical parameters including limits (from S-parameters, to skew and jitter).
   a. Allows cable construction to be tailored to specific mission needs.
2. Introduce EYE mask constraints (skew, jitter, over and under-shoot limits) as part of the standard.
   a. The eye pattern gives all necessary parameters for entire physical channel i.e. not only the cable.
3. Inner shields of each individual DS pair of the cable is recommended 360° terminated to connector back shell (chassis) (< 10mΩ impedance connection). In this case the outer shield is no longer needed.
4. In the case of adoption of 3. the pin 3 of MDM is no longer used.

Project status

Initial phase completed:

- Requirements definition related to a Low Mass SpaceWire Cable
- Characterise current ECSS-E-ST-50-12C SpW cable
- Review shielding arrangement
- Define 4 candidate cable designs ranging from full ECSS-E-ST-50-12C compliance to completely new design.

Design and Test phase:

- Design review closure is foreseen in April 2011
- Manufacturing of candidate LMSpW Cable
- Validation tests – to be completed by July 2011
- Standardisation proposal to be completed by June 2011

Activity closure:

Planned Q3 -2011

Thank You

Back-up slides

Materials
- Fillers and outer jacket

Shield material and filler materials:

Recommendations for reduce shield mass:

Silver plated aluminium gives a 30% reduction compared to copper.

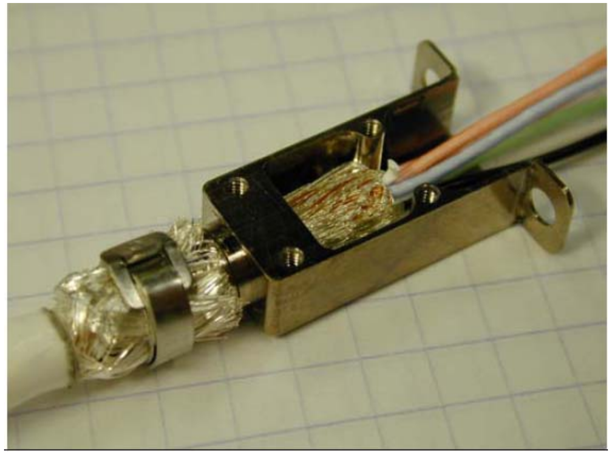
Braided shield

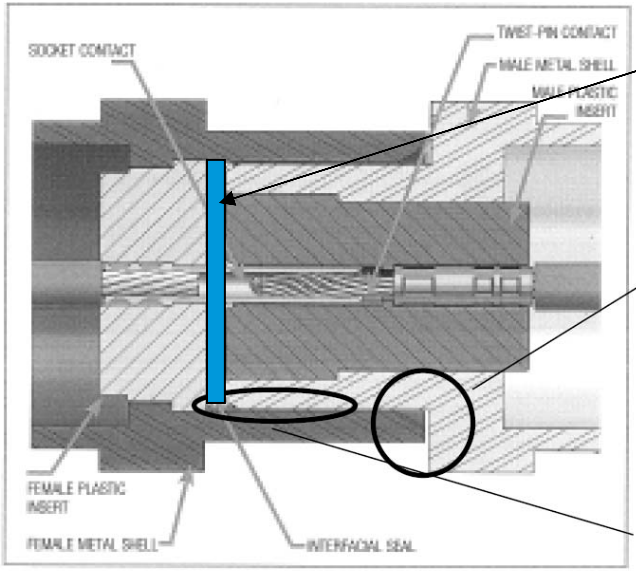
Recommendations for reduced core insulation material:

Expanded PTFE (CELLOFLON®) or alternatively ALVEOAR PTFE

Connector / Cable bonding

Establish the proper method of bonding shields to connector





Add EMI gasket

Gap between male and female shells

Electrical contact not fully garanteed

For connector under MIL or ESCC specification there is no real contact between the male and female shells.