

# **SPACEWIRE CABLE AND CONNECTOR VARIATIONS**

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# SpaceWire Connector Issues

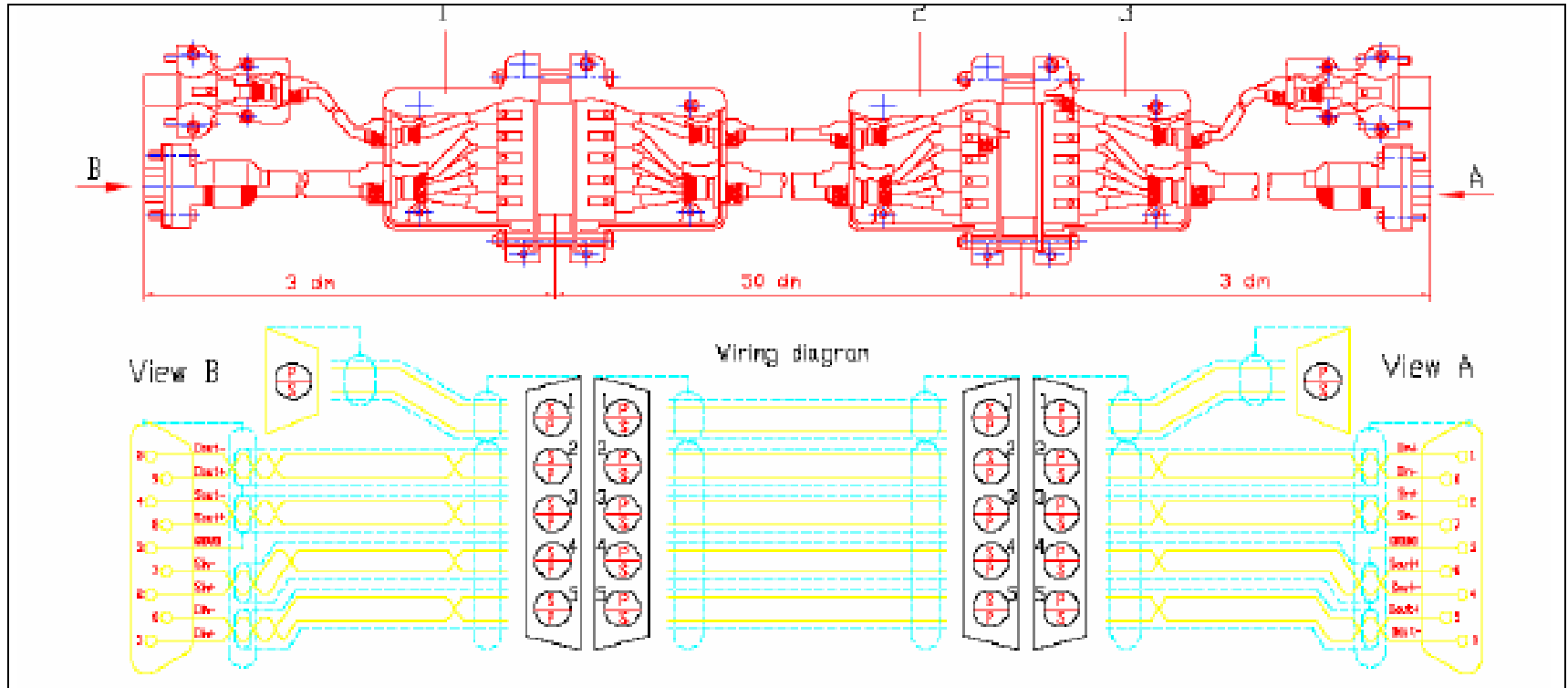
## ■ Connector Specification

- SpaceWire connectors have known issues
  - Not impedance-matched to the cable
  - Handling (mechanical) issues
- Need space-qualified matched impedance connector
  - alternative space-qualified connector
- Electrical Issues
  - Only a single ground pin
  - Inner shield does not pass through bulkhead
  - Near-end Crosstalk (NEXT) at the SpaceWire connector

## ■ Cable Specification

- Use of larger gauge cable in non-standard applications or to meet tight specifications

# Test Assembly



# Connector Testing

Final Production Tests IR, Continuity - 4 Samples

Visual inspection - 4 Samples

Eye-pattern - 3 Samples

Initial Differential Impedance - 3 Samples

Initial Inpair Skew - 3 Samples

Insertion Loss at  $23 \pm 2^\circ\text{C}$  - 3 Samples

Return Loss at  $23 \pm 2^\circ\text{C}$  - 3 Samples

Thermal Cycle,  $-40^\circ\text{C}$  to  $+60^\circ\text{C}$  - 3 Samples

Insertion Loss at  $23 \pm 2^\circ\text{C}$  - 3 Samples

Return Loss at  $23 \pm 2^\circ\text{C}$  - 3 Samples

Initial DWV Insulation Resistance 300 V DC

Vibration (Sine, Parts 1&2, + Random) - 3 Samples

Vibration (Sine, Part 1 only) - 3 Samples

Shock - 3 Samples

Insertion Loss vs. Temperature - 3 Samples

Return Loss vs. Temperature - 3 Samples

Shell to Shell Conductivity - 3 Samples

EMC - 3 Samples (IEC-60966-1)

Eye pattern - 3 Samples

Final Differential Impedance - 3 Samples

In pair skew - 3 Samples

Final Elect. Test - DWV , IR 300V DC - 3 Samples

Final visual Inspection - 3 Samples

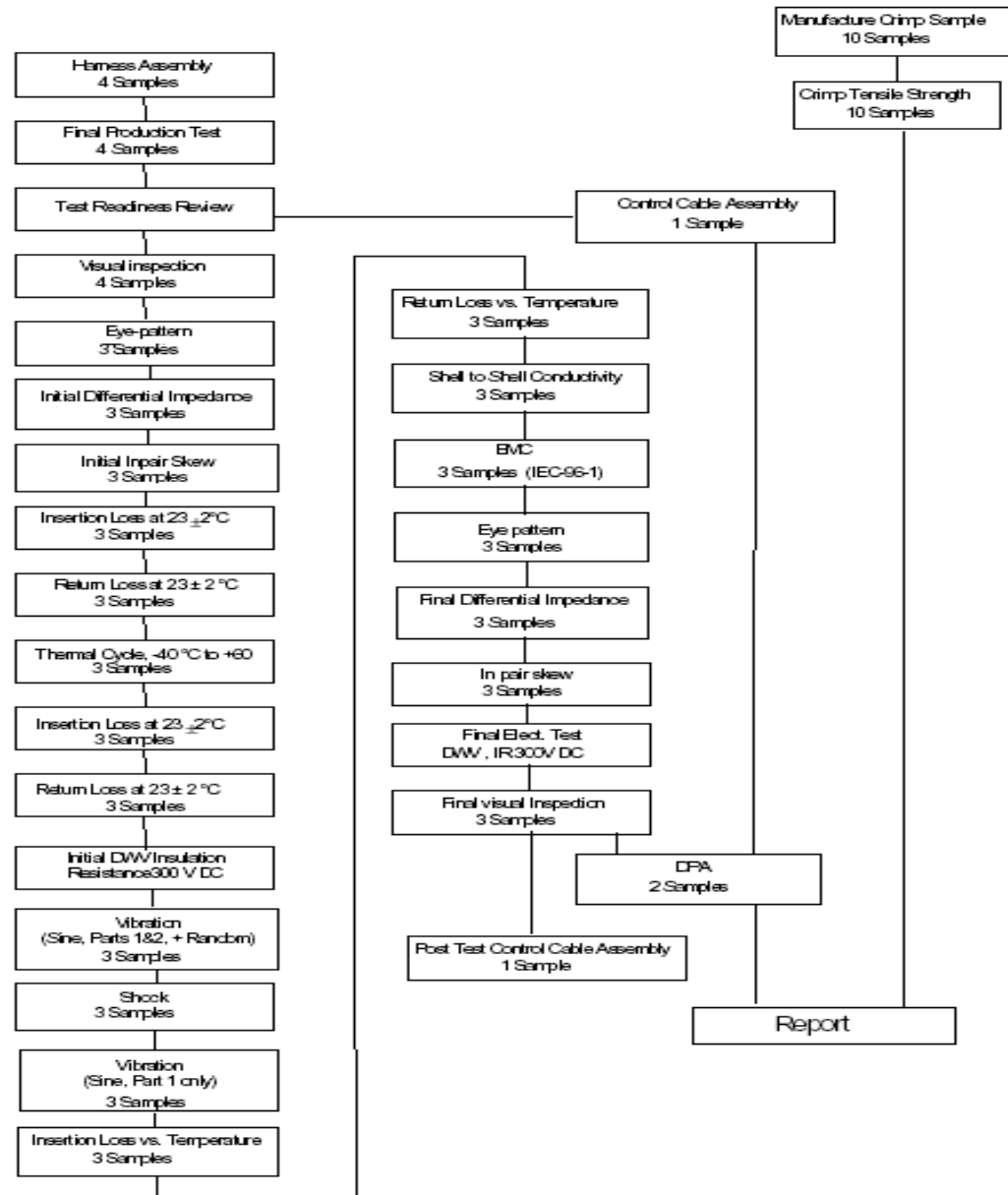
DPA - 2 Samples

Post Test Control Cable Assembly - 1 Sample

Manufacture Crimp Sample - 10 Samples

Crimp Tensile Strength - 10 Samples

## Test Flow



# Final Production Tests IR, Continuity

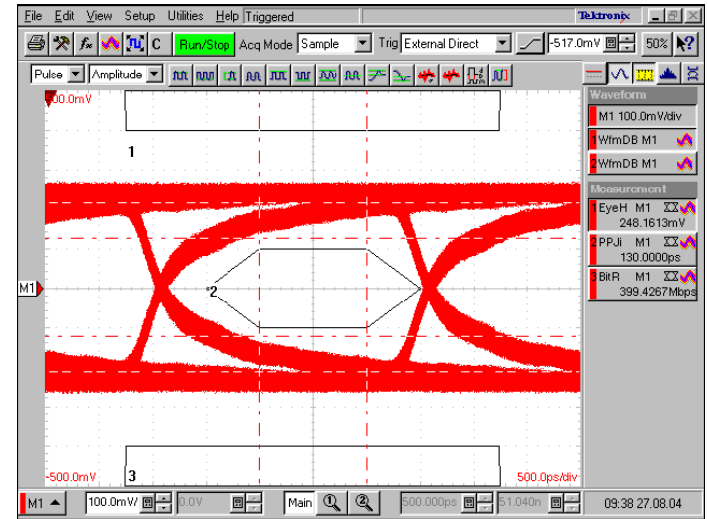
- Insulation resistance was tested between each insulated conductor. A test voltage of 300 VDC was applied for a time period of 1 minute. Requirement: Measured value shall be:  $\geq 100\text{M}\Omega$
- Continuity was measured out according to QTP GSC-10-82715-00 section 6.2.3 with a Micro-Ohm-Meter. Test temperature: 22°C

| Final Production Tests    | SN01     | SN02     | SN03     | SN04     |
|---------------------------|----------|----------|----------|----------|
| Final Physical Inspection | Passed   | Passed   | Passed   | Passed   |
| Mass                      | Measured | Measured | Measured | Measured |
| Insulation                | Passed   | Passed   | Passed   | Passed   |
| Continuity                | Measured | Measured | Measured | Measured |

# Eye-pattern

- The applied input voltage was 540mV peak to peak.
- **Requirement:** Eye height = 200 mV
- Peak to peak jitter =  $0.2 \times \text{bit time}$

|           | 65Mbit/s | 100Mbit/s | 200Mbit/s | 400Mbit/s |
|-----------|----------|-----------|-----------|-----------|
| Jitter pp | 3086ps   | 2000ps    | 1000ps    | 500ps     |



|         | Eye Height [mV] | Jitter pp [ps] | Eye Height [mV] | Jitter pp [ps] | Eye Height [mV] | Jitter pp [ps] | Eye Height [mV] | Jitter pp [ps] |
|---------|-----------------|----------------|-----------------|----------------|-----------------|----------------|-----------------|----------------|
| SN Q001 | 65Mbit/s        |                | 100Mbit/s       |                | 200Mbit/s       |                | 400Mbit/s       |                |
| Pair 2  | 436             | 123            | 401             | 120            | 333             | 120            | 248             | 130            |
| Pair 3  | 443             | 123            | 410             | 80             | 343             | 100            | 269             | 110            |
| Pair 4  | 436             | 123            | 402             | 80             | 332             | 120            | 252             | 130            |
| Pair 5  | 437             | 123            | 402             | 120            | 330             | 120            | 248             | 130            |
| SN Q002 | 65Mbit/s        |                | 100Mbit/s       |                | 200Mbit/s       |                | 400Mbit/s       |                |
| Pair 2  | 445             | 123            | 412             | 80             | 344             | 100            | 268             | 120            |
| Pair 3  | 435             | 123            | 401             | 120            | 331             | 140            | 245             | 160            |
| Pair 4  | 436             | 123            | 402             | 120            | 330             | 120            | 251             | 160            |
| Pair 5  | 435             | 123            | 401             | 120            | 331             | 120            | 250             | 140            |
| SN Q003 | 65Mbit/s        |                | 100Mbit/s       |                | 200Mbit/s       |                | 400Mbit/s       |                |
| Pair 2  | 436             | 123            | 399             | 120            | 331             | 100            | 249             | 140            |
| Pair 3  | 437             | 123            | 402             | 80             | 330             | 120            | 248             | 130            |
| Pair 4  | 437             | 123            | 403             | 120            | 332             | 120            | 246             | 140            |
| Pair 5  | 445             | 123            | 413             | 120            | 345             | 100            | 268             | 120            |

# Initial Differential Impedance

- Requirement:  $100 \pm 6 \Omega$

| <b>SN Q001</b> | <b>GSC-10-82789-003</b> | <b>GSC-10-82794-050</b> | <b>GSC-10-82787-003</b> |
|----------------|-------------------------|-------------------------|-------------------------|
| <b>Pair 2</b>  | 99.2                    | 102.2                   | 101.8                   |
| <b>Pair 3</b>  | 99.2                    | 101.9                   | 102.2                   |
| <b>Pair 4</b>  | 101.4                   | 105.4                   | 100                     |
| <b>Pair 5</b>  | 102.7                   | 102.7                   | 98.65                   |
| <b>SN Q002</b> | <b>GSC-10-82789-003</b> | <b>GSC-10-82794-050</b> | <b>GSC-10-82787-003</b> |
| <b>Pair 2</b>  | 99.5                    | 102.4                   | 100.5                   |
| <b>Pair 3</b>  | 100                     | 102.7                   | 101.9                   |
| <b>Pair 4</b>  | 101.1                   | 102.7                   | 98.4                    |
| <b>Pair 5</b>  | 102.7                   | 105.7                   | 100                     |
| <b>SN Q003</b> | <b>GS-1-8278-003</b>    | <b>GSC-10-82794-050</b> | <b>GSC-10-82787-003</b> |
| <b>Pair 2</b>  | 103.5                   | 104.9                   | 101.8                   |
| <b>Pair 3</b>  | 101.3                   | 102.4                   | 102.2                   |
| <b>Pair 4</b>  | 101.6                   | 102.4                   | 100                     |
| <b>Pair 5</b>  | 100.8                   | 102.4                   | 98.7                    |



# Initial In-Pair Skew

- Test was carried out differentially in S21 configuration. Precision baluns and appropriate a calibration kit was used. A two full port calibration was done.

|                   |       |                 |
|-------------------|-------|-----------------|
|                   | CH 1  | CH 2            |
| Centre frequency: | 70MHz | 323MHz          |
| Span frequency:   | 1MHz  | 156MHz          |
| Number of points: | 1601  | 1601            |
| IF-BW:            | 100Hz | 100Hz           |
| Sweep time:       | 15.8s | 15.8s           |
| Marker:           | 70MHz | 250MHz / 400MHz |

- Requirement: 80ps/m**

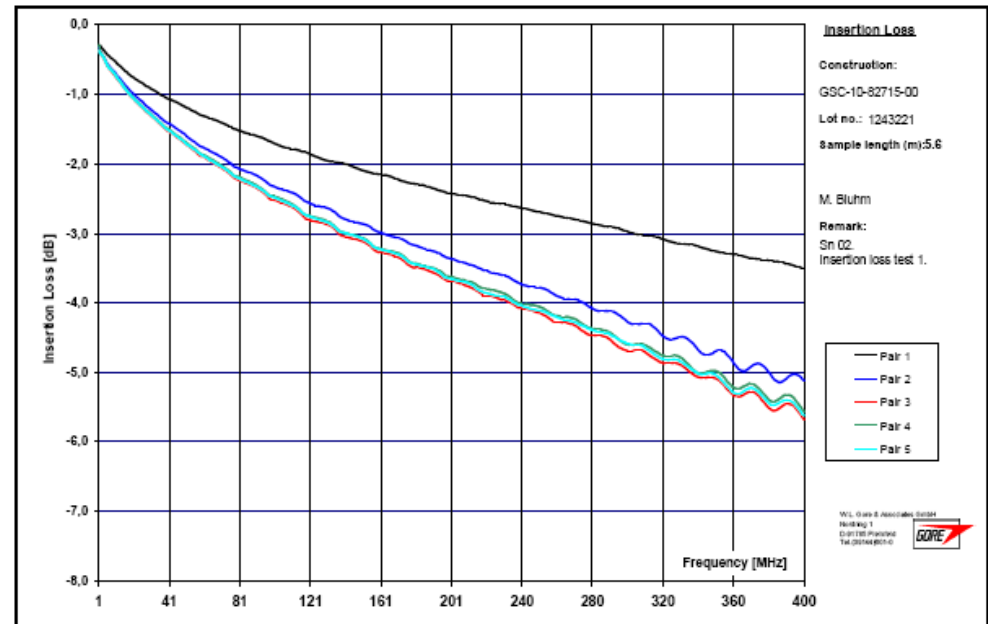
| SN Q001 | 70MHz | 250MHz | 400MHz |
|---------|-------|--------|--------|
| Pair 1  | 0.7   | 3.6    | 3.5    |
| Pair 2  | 1.7   | 6.6    | 6.8    |
| Pair 3  | 1.5   | 0.4    | 2.4    |
| Pair 4  | 14.3  | 6.3    | 5.2    |
| Pair 5  | 19.8  | 15.1   | 12.7   |
| SN Q002 | 70MHz | 250MHz | 400MHz |
| Pair 1  | 9.3   | 7.1    | 7.5    |
| Pair 2  | 3.2   | 1.9    | 1.7    |
| Pair 3  | 10.3  | 14.9   | 6.2    |
| Pair 4  | 8.5   | 2.8    | 4.2    |
| Pair 5  | 19.8  | 18.7   | 14.8   |
| SN Q003 | 70MHz | 250MHz | 400MHz |
| Pair 1  | 6.9   | 5.6    | 4.8    |
| Pair 2  | 0.5   | 3.6    | 0.5    |
| Pair 3  | 3.4   | 12.5   | 8.7    |
| Pair 4  | 5.7   | 10.5   | 5      |
| Pair 5  | 2.8   | 4.1    | 2.5    |

# Insertion Loss at 23 °C

- Test was carried out differentially in a frequency range from 1MHz to 400MHz. Precision baluns and an appropriate calibration kit were used. A two full port calibration was done on the interface of the used baluns.

|                   |      |                 |        |
|-------------------|------|-----------------|--------|
| Start frequency:  | 1MHz | Stop frequency: | 400MHz |
| Number of points: | 401  | IF-BW:          | 100Hz  |
| Measurement:      | S21  | Sweep time:     | 5s     |

| SN Q001 | 33MHz | 70MHz | 100MHz | 400MHz |
|---------|-------|-------|--------|--------|
| Pair 1  | -0.94 | -1.37 | -1.67  | -3.41  |
| Pair 2  | -1.34 | -2.02 | -2.48  | -5.58  |
| Pair 3  | -1.27 | -1.9  | -2.33  | -5.19  |
| Pair 4  | -1.34 | -2.02 | -2.48  | -5.66  |
| Pair 5  | -1.35 | -2.03 | -2.48  | -5.7   |
| SN Q002 | 33MHz | 70MHz | 100MHz | 400MHz |
| Pair 1  | -0.95 | -1.4  | -1.7   | -3.5   |
| Pair 2  | -1.27 | -1.89 | -2.32  | -5.13  |
| Pair 3  | -1.36 | -2.05 | -2.52  | -5.68  |
| Pair 4  | -1.34 | -2.01 | -2.46  | -5.56  |
| Pair 5  | -1.35 | -2.03 | -2.48  | -5.62  |
| SN Q003 | 33MHz | 70MHz | 100MHz | 400MHz |
| Pair 1  | -0.95 | -1.39 | -1.687 | -3.44  |
| Pair 2  | -1.35 | -2.03 | -2.49  | -5.63  |
| Pair 3  | -1.34 | -2.02 | -2.48  | -5.7   |
| Pair 4  | -1.35 | -2.03 | -2.49  | -5.63  |
| Pair 5  | -1.27 | -1.9  | -2.33  | -5.16  |

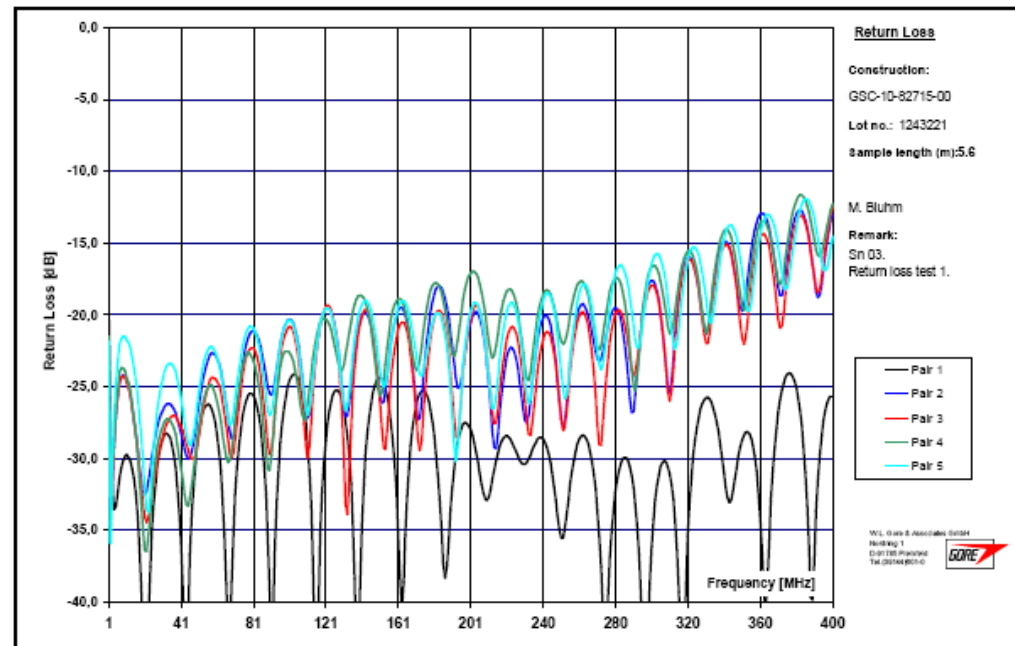


# Return Loss Measurements at 23 °C

- Test was carried out differentially in a frequency range from 1MHz to 400MHz. Precision baluns and an appropriate calibration kit were used. A two full port calibration was done on the BNO interface of the used baluns.

|                   |      |                 |        |
|-------------------|------|-----------------|--------|
| Start frequency:  | 1MHz | Stop frequency: | 400MHz |
| Number of points: | 401  | IF-BW:          | 100Hz  |
| Measurement:      | S21  | Sweep time:     | 5s     |

| SN Q001 | 100MHz | 200MHz | 400MHz |
|---------|--------|--------|--------|
| Pair 1  | -26.9  | -26.6  | -27.9  |
| Pair 2  | -21.3  | -18    | -12.8  |
| Pair 3  | -20.5  | -21.9  | -13.9  |
| Pair 4  | -21    | -20.1  | -12.5  |
| Pair 5  | -21.6  | -18.7  | -12.1  |
| SN Q002 | 100MHz | 200MHz | 400MHz |
| Pair 1  | -23.7  | -25.4  | -22.2  |
| Pair 2  | -20    | -21.1  | -15.3  |
| Pair 3  | -21    | -21.4  | -12.9  |
| Pair 4  | -22    | -18.6  | -12.5  |
| Pair 5  | -22.3  | -18.3  | -12.9  |
| SN Q003 | 100MHz | 200MHz | 400MHz |
| Pair 1  | -25    | -27.7  | -25.7  |
| Pair 2  | -20.4  | -21.1  | -13    |
| Pair 3  | -20.9  | -20.8  | -12.5  |
| Pair 4  | -22.5  | -17.3  | -12.3  |
| Pair 5  | -20.4  | -20.3  | -14.6  |



# Physical/Mechanical Tests

- Requirement: There shall be no electrical interruptions exceeding 1 microsecond. There shall be no disengagement of the mated connectors, evidence of cracking, breaking or loosening of parts.

|                        |                   |                                             |
|------------------------|-------------------|---------------------------------------------|
| - Resonance Search     | 20 - 2000 Hz      | 0.25 g                                      |
|                        | Sweep rate:       | 4.0 oct/min                                 |
| - Sine Qualification   | Frequency range:  | 5 - 100 Hz                                  |
|                        | Level:            | 5 - 21,3 Hz $\pm 11$ mm                     |
|                        |                   | 21,3 - 100 Hz 20 g                          |
|                        | Sweep rate:       | 2.0 oct/min                                 |
|                        | Duration:         | 1 sweep per axis                            |
| - Random Qualification | Frequency range:  | 20 - 2000 Hz                                |
|                        | Level:            | 20 Hz 0.026 g <sup>2</sup> /Hz              |
|                        |                   | 50 Hz 0.16 g <sup>2</sup> /Hz               |
|                        |                   | 800 Hz 0.16 g <sup>2</sup> /Hz              |
|                        |                   | 2000 Hz 0.026 g <sup>2</sup> /Hz            |
|                        | Total:            | 14.1 g <sub>RMS</sub>                       |
|                        | Duration:         | 180 sec per axis                            |
| - Resonance Search     | 20 - 2000 Hz      | 0.25 g                                      |
|                        | Sweep rate:       | 4.0 oct/min                                 |
| - Shock:               | Shape:            | Half-sine                                   |
|                        | Acceleration:     | 500 g                                       |
|                        | Duration:         | 1 ms                                        |
|                        | Number of shocks: | 1 per direction (2 per axis) total 6 shocks |

# Shell To Shell Conductivity

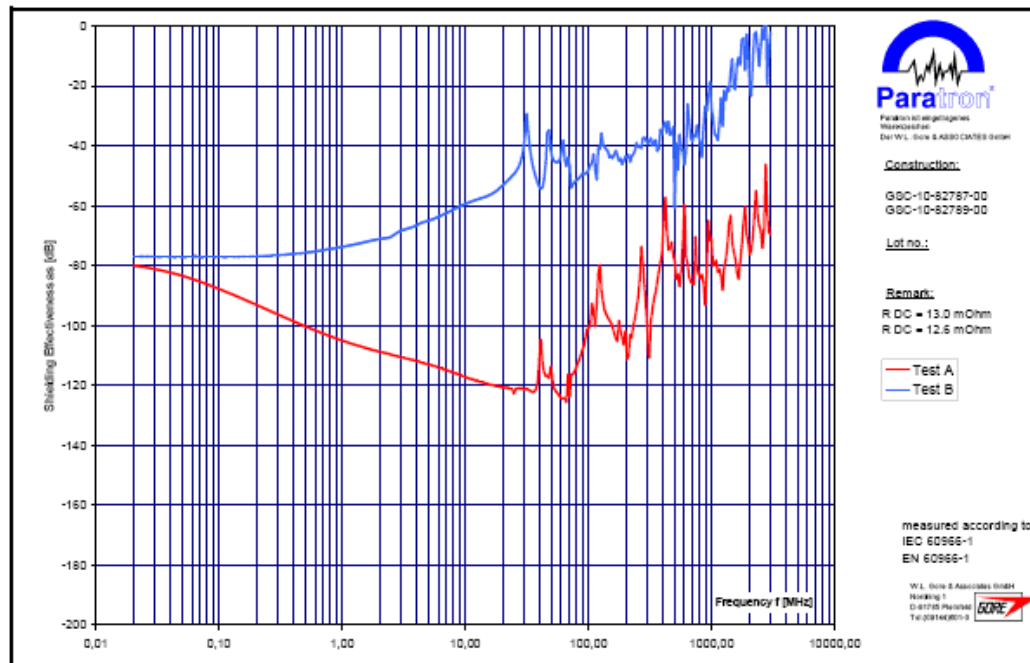
- Applied DC current was 1 ampere. Shell to shell conductivity was tested from backshell surface to backshell surface across the mated cascade assembly.
- Requirement: Measurement shall not exceed 65 mOhm.
- 9-pin MDM Connector: Backshell. 500T10M09H08
- Twinax Interconnect: Backshell. DW 214-09-1-82822-6-0314

|         | 500T10M09H08 | DW 214-09-1-82822-6-0314 |
|---------|--------------|--------------------------|
| SN Q001 | 47.093       | 57.037                   |
| SN Q002 | 46.247       | 56.334                   |
| SN Q003 | 46.357       | 57.274                   |

# Electromagnetic Compatibility ( Shielding Effectiveness)

- Shielding effectiveness will be measured in accordance with IEC-60966-1, Appendix C: Shielding Effectiveness, Transfer Impedance line injection method.
- EMC at 100 MHz: - 45 dB with respect to the signal

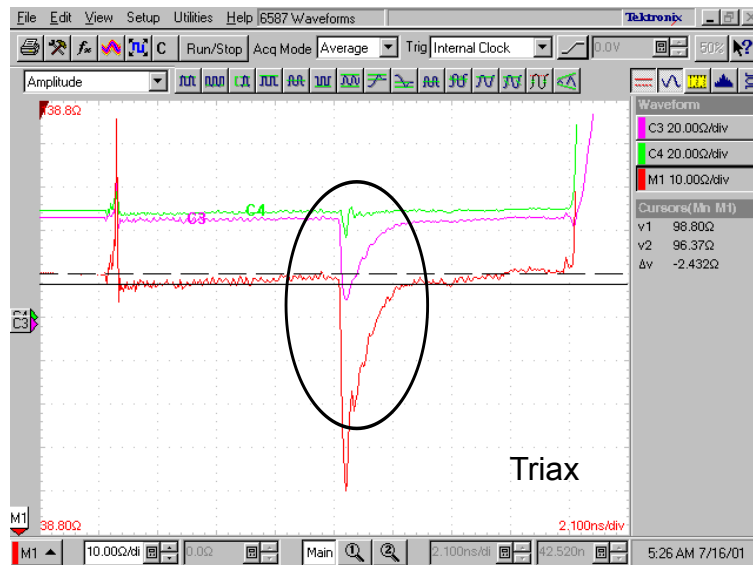
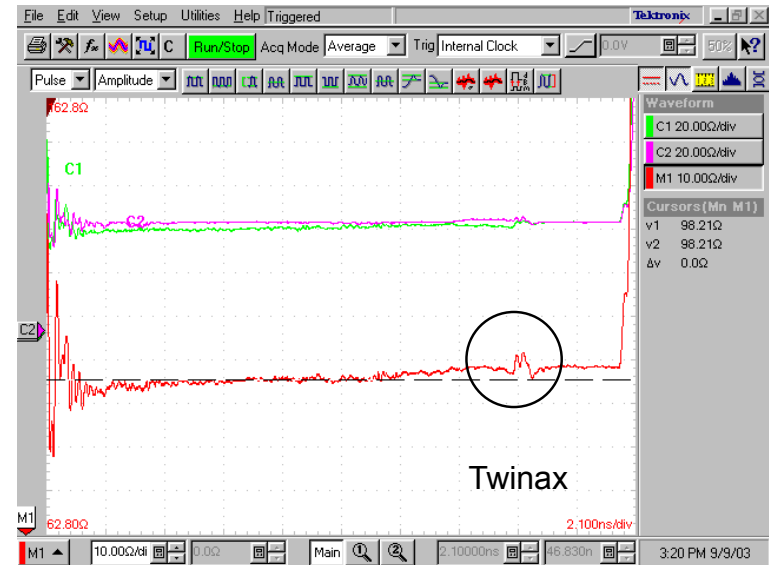
|         | DC Resistance [mohms] |        | EMC at 100MHz |        |
|---------|-----------------------|--------|---------------|--------|
|         | Test A                | Test B | Test A        | Test B |
| SN Q001 | 12.6                  | 13     | -101          | -48    |
| SN Q002 | 12.6                  | 12.8   | -105          | -45    |
| SN Q003 | 12.6                  | 12.8   | -103          | -46    |



# Testing Summary

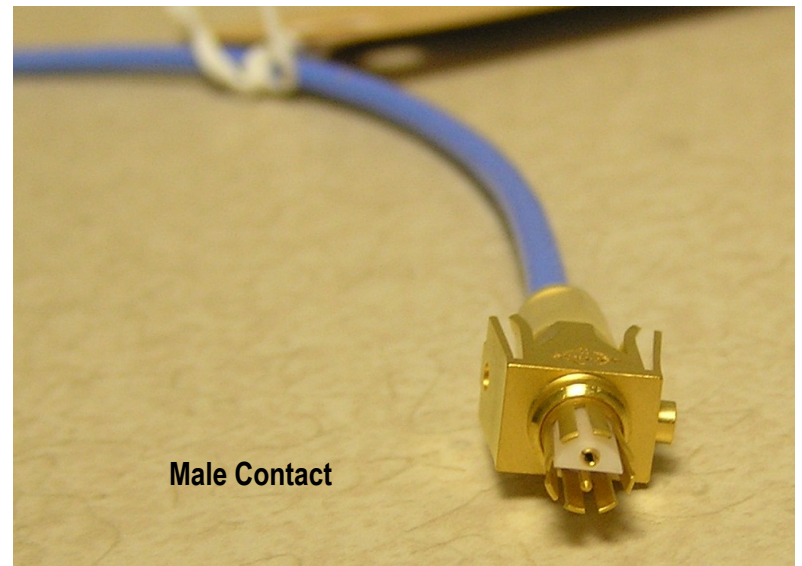
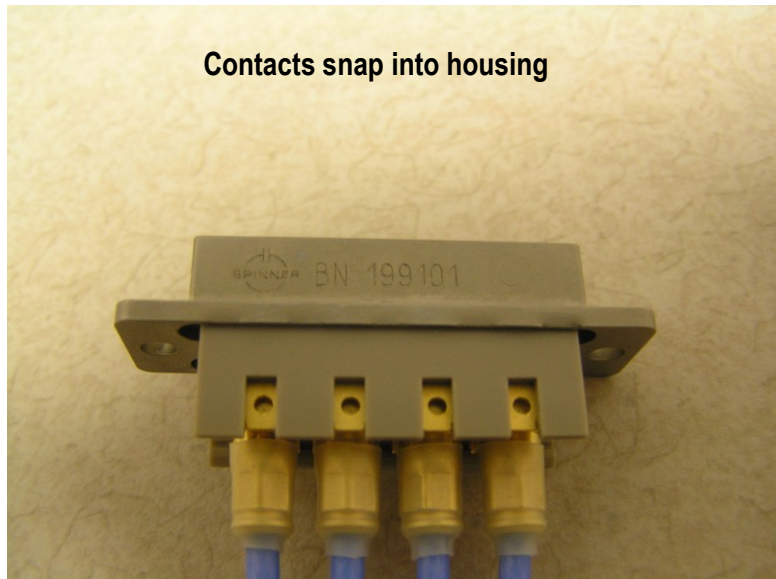
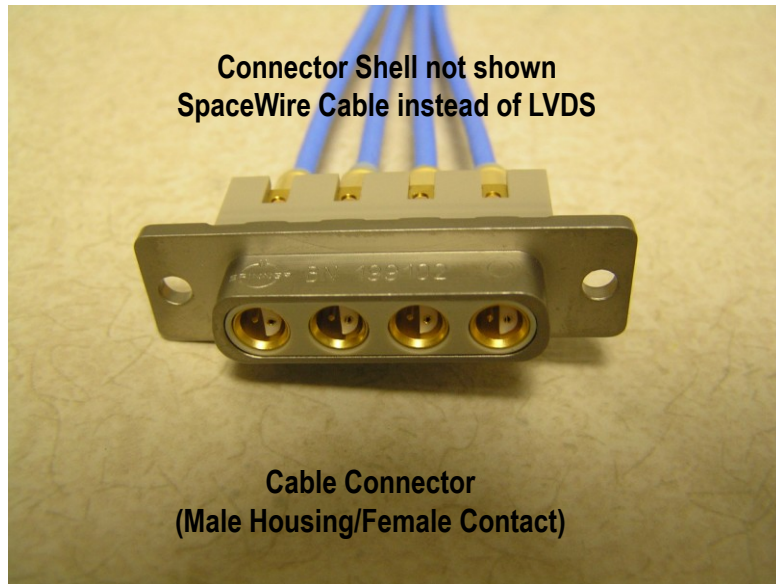
|                                                                |           |           |           |
|----------------------------------------------------------------|-----------|-----------|-----------|
| <b>Visual Inspection</b>                                       | Passed    | Passed    | Passed    |
| <b>Eye Pattern Measurements</b>                                | Passed    | Passed    | Passed    |
| <b>Initial Differential Impedance</b>                          | Passed    | Passed    | Passed    |
| <b>Initial In-Pair Skew</b>                                    | Passed    | Passed    | Passed    |
| <b>Insertion Loss at 23 °C</b>                                 | Passed    | Passed    | Passed    |
| <b>Return Loss Measurements at 23 °C</b>                       | Passed    | Passed    | Passed    |
| <b>Thermal Cycling</b>                                         | Performed | Performed | Performed |
| <b>Insertion Loss at 23 °C after thermal cycling</b>           | Passed    | Passed    | Passed    |
| <b>Return Loss Measurements at 23 °C after thermal cycling</b> | Passed    | Passed    | Passed    |
| <b>Initial DWV Insulation Resistance Test</b>                  | Passed    | Passed    | Passed    |
| <b>Sinusoidal Vibration, Part 1: Low-Level Sweep</b>           | Passed    | Passed    | Passed    |
| <b>Sinusoidal Vibration, Part 2</b>                            | Passed    | Passed    | Passed    |
| <b>Random Vibration</b>                                        | Passed    | Passed    | Passed    |
| <b>Shock</b>                                                   | Passed    | Passed    | Passed    |
| <b>Insertion Loss versus Temperature</b>                       | Passed    | Passed    | Passed    |
| <b>Return Loss versus Temperature</b>                          | Passed    | Passed    | Passed    |
| <b>Shell To Shell Conductivity</b>                             | Passed    | Passed    | Passed    |
| <b>Electromagnetic Compatibility (EMC)</b>                     | Passed    | Passed    | Passed    |
| <b>Eye Pattern Measurements</b>                                |           |           |           |
| <b>Final Differential Impedance</b>                            | Passed    | Passed    | Passed    |
| <b>In-Pair Skew</b>                                            | Passed    | Passed    | Passed    |

# Connector Impedance Comparison

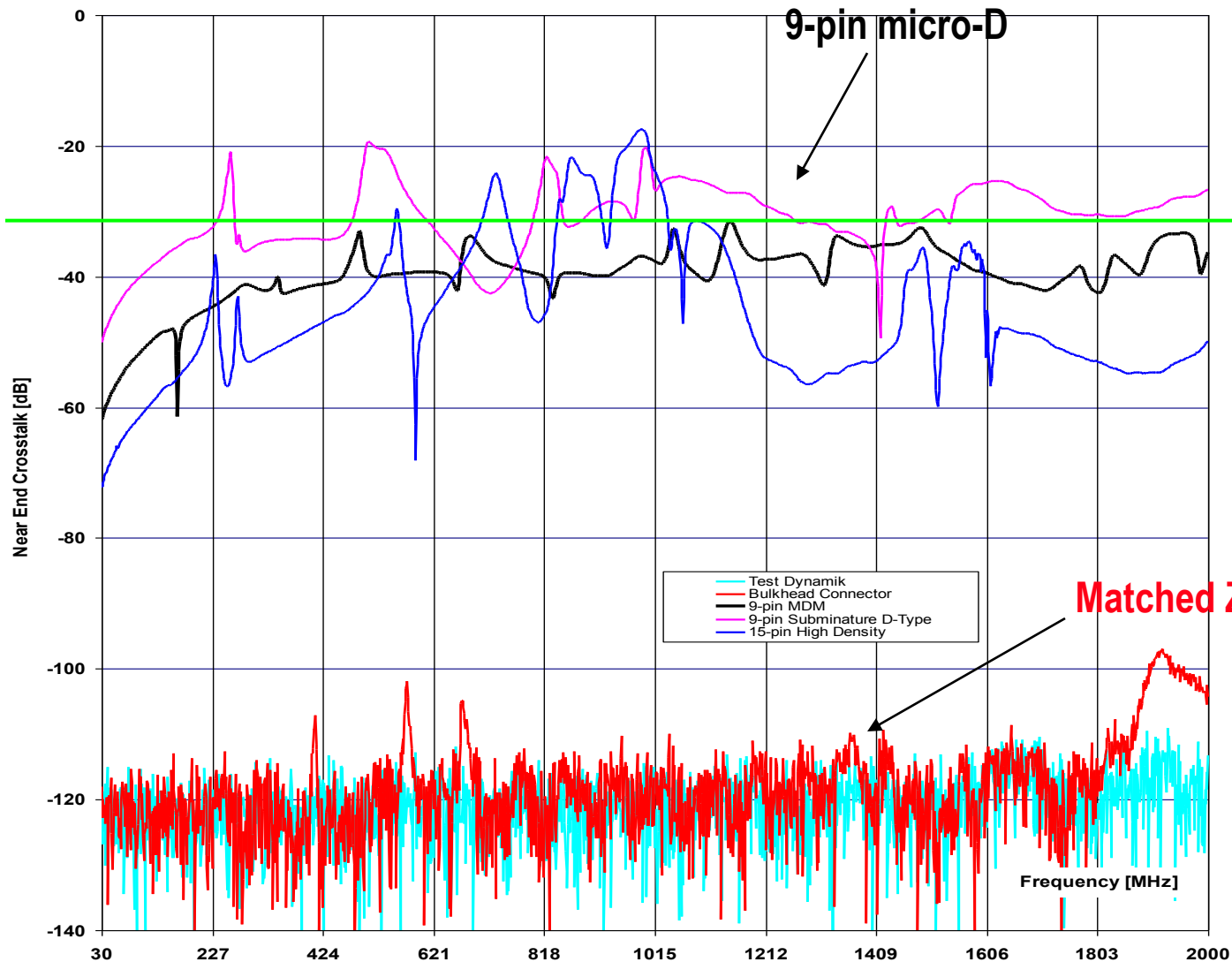




# 4-way Twinax Connector



# Near-end Crosstalk (NEXT):



## Near End Crosstalk

Construction:

Lot no.:

Sample length (m): 20m

16.07.2004

M. Bluhm

Remark:

Space Wire  
Cable Assembly  
B (20m)

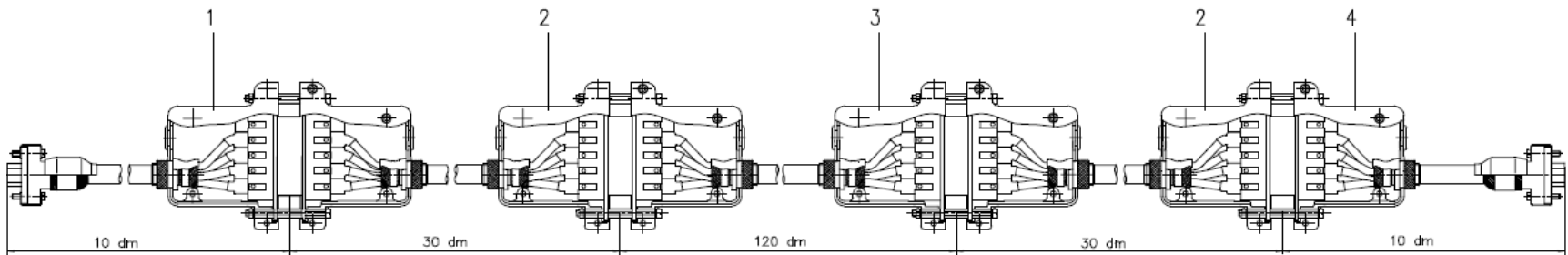
W.L. Gore & Associates GmbH  
Nordring 1  
D-91785 Pleinfeld  
Tel.: 091441601-0



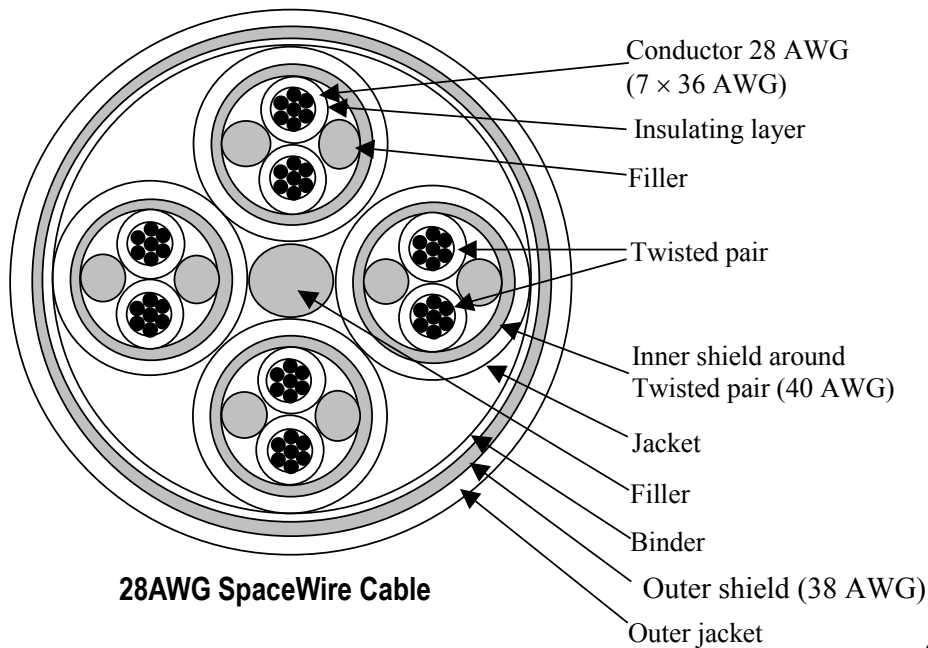
(5,9) Driven; (1,6) Quiet

# Cable Comparison (20m cascade)

- 20m cascade utilizing 5-way Twinax connector

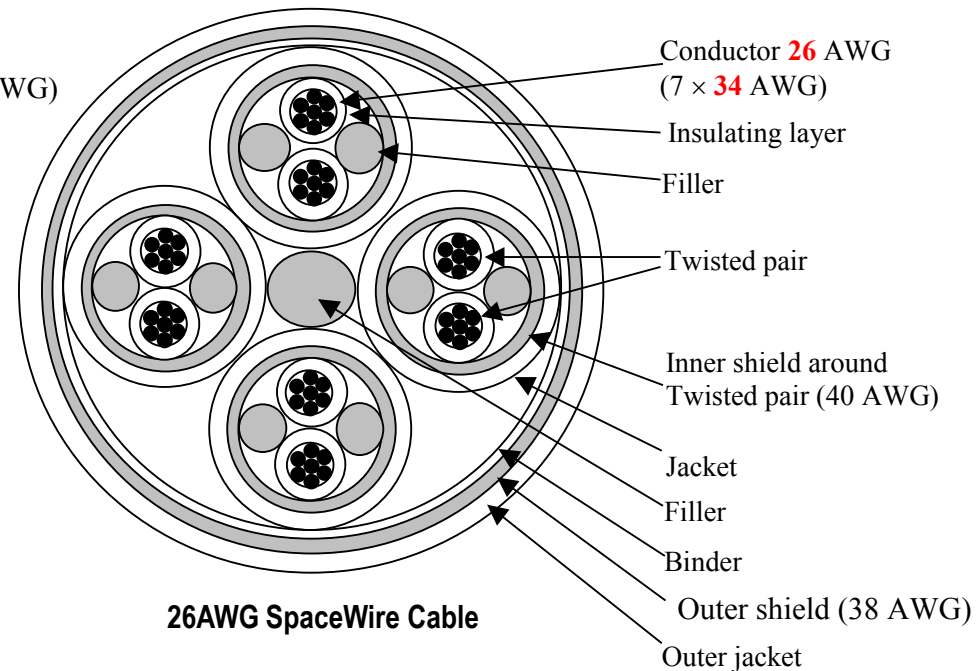


# SpaceWire Cable

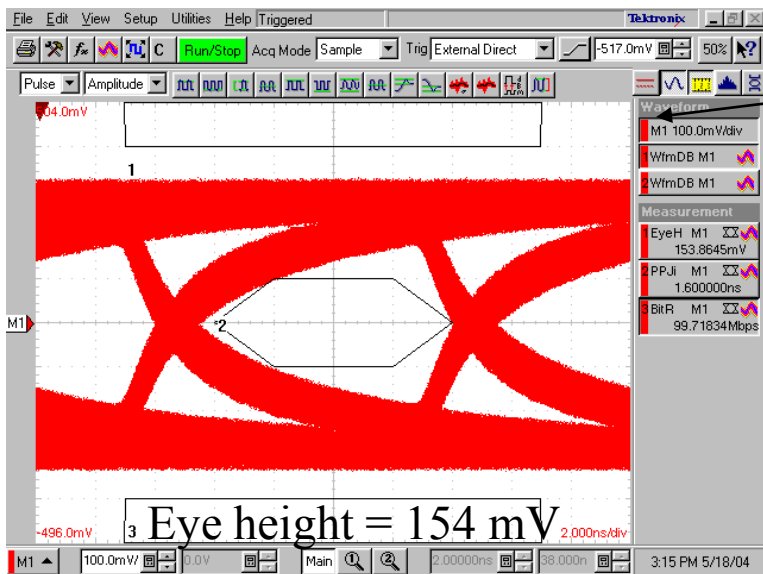


- Non-standard applications or tight requirements
- Increased technical margin

- SpaceWire cable specified in ECSS-E-50-12A Paragraph 5.2



# Eye Pattern at 100 Mbps



GSC-10-82636-00

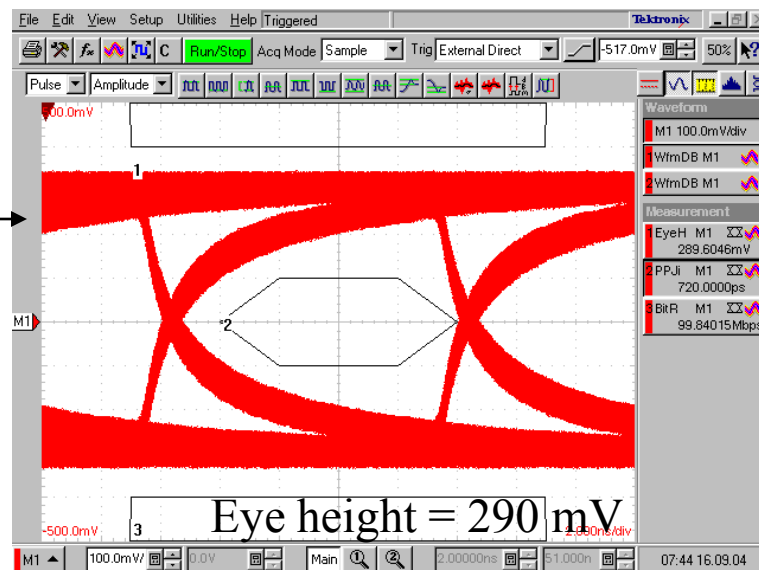
with standard SpaceWire cable

GSC-05-81757-00

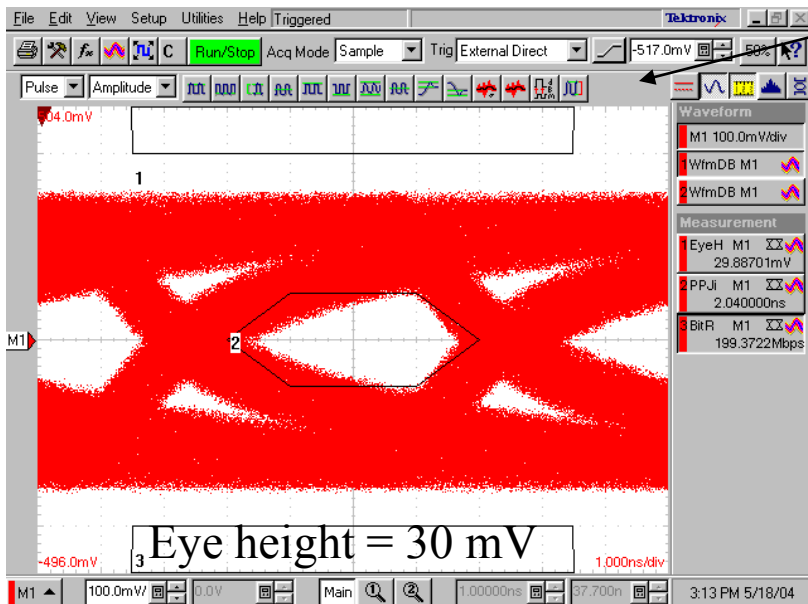
GSC-10-82738-00

with AWG 26 SpaceWire cable

GSC-05-82730-00



# Eye Pattern at 200 Mbps



GSC-10-82636-00

with standard SpaceWire cable

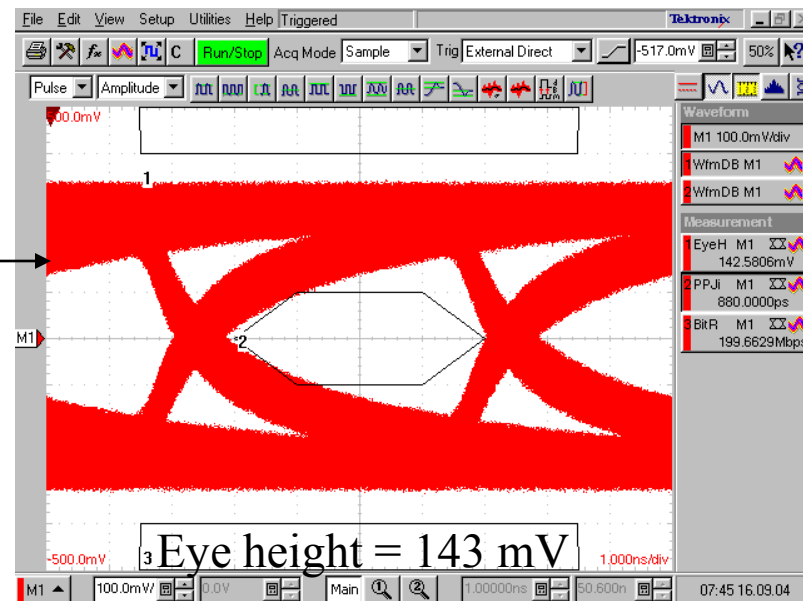
GSC-05-81757-00

GSC-10-82738-00

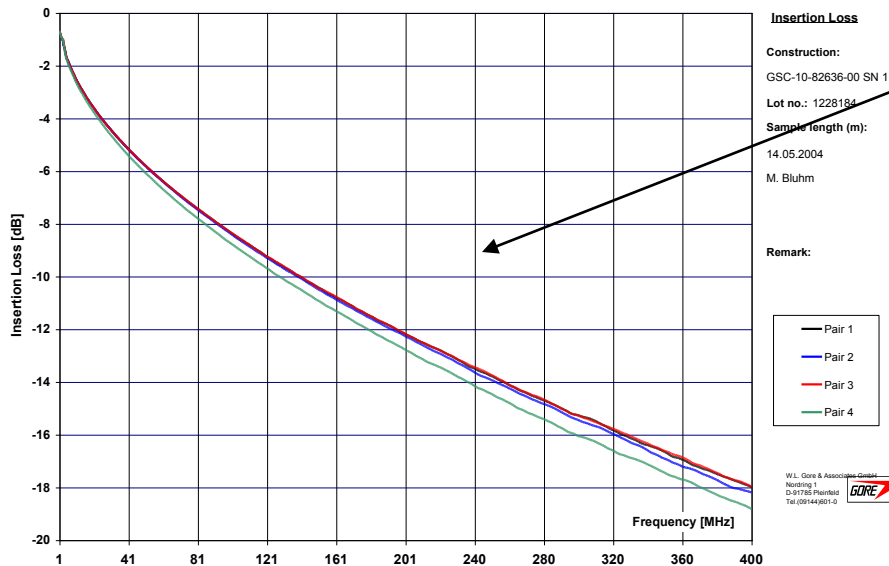
with AWG 26 SpaceWire cable

GSC-05-82730-00

**Change of wire gauge improves performance.**



# Insertion Loss



GSC-10-82636-00

with standard SpaceWire cable

GSC-05-81757-00

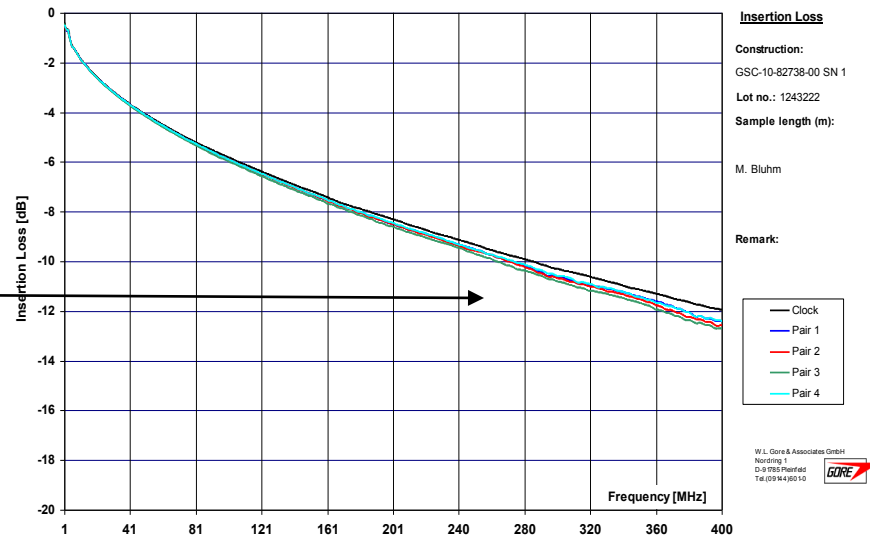
## Insertion Loss [dB/20m]

| f [MHz] | 70    | 250    | 400    |
|---------|-------|--------|--------|
| AWG 26  | -4.96 | -9.69  | -12.71 |
| AWG 28  | -7.23 | -14.46 | -18.81 |

GSC-10-82738-00

with AWG 26 SpaceWire cable

GSC-05-82730-00





# Summary

- AWG 26 SpaceWire cable has improved technical performance
- Twinax connector configurations useful in some applications
- Testing indicates good performance of Twinax Connectors
- Mass and size should be weighed against technical gains