Influence of Aging Effects on RF behavior Including Mode Conversion of STP and UTP Cables

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Influence of Aging Effects on Cables

* Schematic representation
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Physical Layer Medium

Cables and Communication Channel

- Physical layer medium between ECUs
- Two PCB connectors
- Link segment of twisted pair cables
- Length of 15 m
- 4 inline connectors

- Specified in IEEE 802.3bp Ch. 97.6 as link segment type A and OABR TC9 as Standalone Communication Channel (SCC)
### Cable Overview

<table>
<thead>
<tr>
<th></th>
<th>Cable type A</th>
<th>Cable type B</th>
<th>Cable type C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inner conductors</td>
<td>2 x 0.14 mm²</td>
<td>2 x 0.14 mm²</td>
<td>2 x 0.14 mm²</td>
</tr>
<tr>
<td>Core diameter</td>
<td>0.85 mm</td>
<td>1.26 mm</td>
<td>1.05 mm</td>
</tr>
<tr>
<td>Insulation material</td>
<td>PP</td>
<td>PP</td>
<td>PP</td>
</tr>
<tr>
<td>Intermediate jacket</td>
<td>-</td>
<td>-</td>
<td>PP</td>
</tr>
<tr>
<td>Shielding</td>
<td>-</td>
<td>Foil and braid</td>
<td>Foil and braid</td>
</tr>
<tr>
<td>Outer diameter</td>
<td>3.2 mm</td>
<td>4.3 mm</td>
<td>4.4 mm</td>
</tr>
</tbody>
</table>
RF Results
Cable Assemblies - New
Mode Conversion

Comparison of the Unbalance Attenuation of Different Cable Assemblies

- **S C D 1 1**
  - Differential mode excitation on logical port 1
  - Common mode response on logical port 1

**Excitation**
- DM \(+1\)
- CM \(+1\)

**Response**
- Logical Port 1
- Logical Port 2

**6 m**

Transverse conversion loss
- **TCL** = TCL
- **DM** = Differential mode
- **CM** = Common mode

![Graph showing mode conversion comparison](image)

- **Cable type A**
- **Cable type B**
- **Cable type C**

**Better**
Cross-Sectional Analysis

Cable Type B

- Elliptical shape of the shield (foil and braid)
- The geometry relation inside the shield is constant
- The shape rotates along one lay length

- Strong electrical field between shield and conductors
- Influence on wave impedance
- High mode conversion due to asymmetry of foil
Cross-Sectional Analysis

Cable Type C

- Stabilization of the twisted inner conductors
- Improvement of consistency and distance between inner conductors and shield along one lay length

- Weak electrical field between shield and conductors
- Positive influence on wave impedance
- Improved lower mode conversion
Shielding Effectiveness $a_S$

Measurement Setup

$$a_S = S_{21} - 10 \cdot \log_{10} \left( \frac{2 \cdot Z_S}{Z_L} \right) - 10 \cdot \log_{10} \left[ 1 - \left( \frac{50\Omega - Z_L}{50\Omega + Z_L} \right)^2 \right]$$

$Z_L = \text{Wave Impedance}$

VNA = Vectorial Network Analyser

Connectors

$Z_S = 150\Omega$

$R_1 = Z_L$
**Coupling Attenuation $a_C$**

**Measurement Setup**

![Diagram showing Measurement Setup]

- **VNA**: Vectorial Network Analyser
  - **Logical Port 1**: Differential mode excitation
  - **Logical Port 2**: Single ended response

- **Connectors**
- **$Z_S = 150 \, \Omega$**
- **$Z_{\text{diff}}$**: Differential mode wave impedance
- **$Z_{\text{com}}$**: Common mode wave impedance
- **$a_{\text{diff}}$**: Differential mode coupling attenuation
- **$a_{\text{com}}$**: Common mode coupling attenuation

**Formulas**

- Differential mode excitation on logical port 1
  \[ a_{\text{diff}} = S_{SD21} - 10 \cdot \log_{10} \left( \frac{2 \cdot Z_S}{Z_{\text{diff}}} \right) \]

- Common mode excitation on logical port 1
  \[ a_{\text{com}} = S_{SC21} - 10 \cdot \log_{10} \left( \frac{2 \cdot Z_S}{Z_{\text{com}}} \right) \]

- **Logical Port 1**
  - **$R_{\text{diff}}$**: Differential mode coupling resistance
  - **$R_{\text{com}}$**: Common mode coupling resistance

- **Logical Port 2**
  - **$R_1 = \frac{1}{2} Z_{\text{diff}}$**
  - **$R_2 = Z_{\text{com}} - R_1 || R_1$**
Results of Cable Type C
Comparison of Different Test Setups

- Shielding effectiveness
- Common mode coupling attenuation

✓ Good comparability

- Coupling attenuation
- Common mode
- Differential mode

✓ Test setup for coupling attenuation provide more information

Termination network

- Quasi coaxial
- Common/Differential mode

Cable type C

Graph showing attenuation in dB vs frequency in MHz with shielding effectiveness, common mode coupling attenuation, and differential mode coupling attenuation.
Aging Effects
Simulation of Aging and Resulting Influence
Simulation of Aging
Thermal and Mechanical Stress

- 1000 h
- Dry heat 105°C
- ISO 6722

- In climatic chamber
- Dry heat 40°C
- 60,000 cycles

Long term heat aging

Combined torsion and reverse bending stress

115°
Insertion Loss – Cable Type A and B

Long Term Heat Aging – Thermal Stress

- Aged for a period of 1000 h at 105°C
- Cable type A shows the biggest change
- Cable types B and C show only a small change
Polymer Analysis
Examination of the Insulation in Cable Type A

- Change of the insertion loss
- Change of the wave impedance

Differential Scanning Calorimetry (DSC)

- Change of melting curve shape and peak position
- Aged material is different to the unaged material

Thermogravimetric Analysis (TGA)

- Change of the thermal degradation behavior
- Degradation through chain scission

<table>
<thead>
<tr>
<th>15 m link</th>
<th>New state</th>
<th>After 1000 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity [C]</td>
<td>744 pF</td>
<td>756 pF</td>
</tr>
<tr>
<td>$\varepsilon_{\text{eff}}$ calculated</td>
<td>2.379</td>
<td>2.415</td>
</tr>
</tbody>
</table>

TGA and DSC show a change in the insulation material

Change of permittivity value

- Change of the insertion loss
- Change of the wave impedance

Cable type A
Results after Mechanical Stress
Combined Torsion and Reverse Bending Stress - 60,000 cycles

- Shielding attenuation of the cable type B
- Small change at frequencies below 1000 MHz
- Change approx. 11 dB at frequencies exceeding 1000 MHz
Mechanical Stress

Influence on Shielding

- Braid is in **good** condition
- Foil is damaged

New

Aged
Outlook
MultiGig & EMC
Outlook MultiGig

Insertion Loss

**UTP**
Unshielded Twisted Pair

**STP**
Shielded Twisted Pair

**S/UTP**
Stabilized Shielded Twisted Pair

**SPP**
Shielded Parallel Pair

**Coax**
Coaxial Cable

![Graph showing insertion loss for different cable types](image)

- **UTP**
- **STP**
- **S/UTP**
- **SPP**
- **Coax**

Frequency in GHz

Insertion Loss (IL) $|S_{dB21}|$ in dB

Cable length: 6 m
EMC of Cable Assemblies

Test Method and Parameters

**Unbalance attenuation**
- $a_u$
- DIN EN 50289-1-9
- Conversion attenuation from differential mode signals to common mode
- Link Type A SCC
- on 10mm foam
- Symmetric property of cable structure

**Screening attenuation**
- $a_s$
- DIN EN 62153-4-4
- Screening attenuation of metallic communication cable shields
- 3,5 m cable
- in tube
- Shielding efficiency

**Coupling attenuation**
- $a_c$
- DIN EN 62153-4-9
- Screening attenuation of differential mode and common mode signals of shielded cables
- 3,5 m cable
- in tube
- $\sim a_u + a_s$
- Symmetric property and Shielding efficiency

**Coupling attenuation**
- $a_c$
- IEC 62153-4-9
- Screening attenuation of differential mode signals of shielded and unshielded cables
- Link Type B
- with absorbing clamp
- Symmetric property and Shielding efficiency
Summary

Coating Material of UTP very important

When mixing UTP and STP:
Need of intermediate jacket

EMC of STP: Coupling attenuation
EMC of UTP: Unbalanced attenuation

Recommendation of SPP and Coax for MultiGig