IEEE P802.3
Multi-Gig Optical Ethernet (OMEGA) Study Group

Optical Fiber Harness for Multi-XG Automotive Applications

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Motivation

Can industry provide optical harnesses to meet OMEGA requirement?

- Support technical feasibility of multi-gigabit optical technology with test result of the optical loss performances and the reliabilities of a possible optical harness for automotive

- To estimate the optical loss budget for OMEGA application
Optical Harness for Automotive

Tested cable: Sumitomo BIMMF (Bend insensitive multimode fiber) cable
Tested connector: Sumitomo original duplex optical connector

Numerical aperture profile

GI-MMF Cable

Connector
Evaluation: Input condition

850nm VCSEL Optical Source (New Focus Model 1784)

Mode Converter (Arden ModCon)

50um 1.5m 50um 5m 50um 5m 50um 5m 50um 1.5m

C1 C2 C3 C4

4-connections Total length 15m

Chamber (-40°C ~ 105°C)

Encircled Flux Measurement system

Optical power meter

850nm VCSEL Optical Source (New Focus Model 1784)

Mode Converter (Arden ModCon)

Encircled Flux

Input Condition

Encircled Flux

0m 5m 10m 15m

>= 86% @ 19um
<= 30% @ 4.5um
Evaluation: Connection Loss

Mating Characteristics

Temperature Characteristics

Change of loss: ~0.1dB
(worst ~ 0.75dB: Fiber Channel
Grade: Std. Field Polish)

Cable length: 15m
Number of Conn.: 4

Change of loss: ~0.1dB
(worst ~ 0.4dB)
Evaluation: Bending Loss

Bend Radius: R25, R15, R7.5 mm
Condition: 1-turn

Change of loss: \(~0.1\) dB

Temperature Characteristics (R=7.5 mm)

Cable length: 5 m
Number of Bend: 1

Change of loss: \(~0.1\) dB
Evaluation: Tie-band Stress

Fixture
Outer diameter: 35mm
Acrylic cylinder: N = 6
Tie-bands for each cylinder: M=1~3

TIEMATE MK9RE-F
Hellermann Tyton
Setting: 3.75(~100N)
Evaluation: Tie-band Stress

Change of loss: ~0.1dB

Temperature Characteristics

N=6, M=3

Change of loss: ~0.1dB
Evaluation: Vibration Test

- Tolerance (Vibration)

Vibration with temperature overlap

Change of loss during evaluation was under 0.1dB.
Evaluation: Water Resistivity

Soak in water

High-pressure washing machine

Optical connector

No loss change

Optical connector

No loss change

Male connector

Spring

Sleeve

Female connector

Physical Contact

No Loss Change
Evaluation: Seat Stress Test

- Reliability (Harness layout)

Seat reclining test image

![Seat reclining test image]

- Test chamber
- AGF cable
- Inline

Loss change (dB)

- 65°C
- -30°C
- 20°C

- Design value
- Seat reclining test: Loss change < 0.1dB

Seat slide test image

![Seat slide test image]

- Test chamber
- AGF cable inside
- Inline

Loss change (dB)

- 65°C
- -30°C
- 20°C

- Design value
- Seat slide test: Loss change < 0.1dB
# Evaluation: Bending Test

## Test Condition
- Bending angle : ±90 degree
- Timing : 60 cycles/minute
- Mandrel radius : 6mm
- Weight : 400g
- Temperature : 23°C

<table>
<thead>
<tr>
<th>Cable</th>
<th>Cycles</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Optical Cable</td>
<td>1,000,000</td>
<td><img src="image" alt="No failure" /></td>
</tr>
<tr>
<td>Co-Axial Cable (ref.)</td>
<td>10,000</td>
<td><img src="image" alt="Disconnection of braid shield and conductor" /></td>
</tr>
</tbody>
</table>
# Reliability Test Results

## Optical Connector

<table>
<thead>
<tr>
<th>Test Item</th>
<th>Samples</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal pistoning</td>
<td>5</td>
<td>no pistoning</td>
</tr>
<tr>
<td>Temperature resistance</td>
<td>5</td>
<td>max. 0.09dB</td>
</tr>
<tr>
<td><strong>Temperature change</strong></td>
<td>5</td>
<td>max. 0.42dB</td>
</tr>
<tr>
<td><strong>Temperature stages</strong></td>
<td>5</td>
<td>max. 0.42dB</td>
</tr>
<tr>
<td>Humidity heat cyclic</td>
<td>5</td>
<td>max. 0.11dB</td>
</tr>
<tr>
<td>Temperature shock</td>
<td>5</td>
<td>max. 0.25dB</td>
</tr>
<tr>
<td>Torsion of contacts</td>
<td>3</td>
<td>no loss increase</td>
</tr>
<tr>
<td>Mechanical Shock</td>
<td>3</td>
<td>max. 0.01dB</td>
</tr>
<tr>
<td>Vibration with temperature overlap</td>
<td>3</td>
<td>max. 0.03dB</td>
</tr>
<tr>
<td>Impact test</td>
<td>3</td>
<td>no loss increase</td>
</tr>
<tr>
<td>Dust protection</td>
<td>3</td>
<td>max. 0.15dB</td>
</tr>
<tr>
<td><strong>Plugging frequency</strong></td>
<td>5</td>
<td>max. 0.38dB</td>
</tr>
<tr>
<td>Plug force and pull force</td>
<td>5</td>
<td>max. 20.6N</td>
</tr>
<tr>
<td>Pull-off force of the housing parts</td>
<td>5</td>
<td>min. 131.7N</td>
</tr>
<tr>
<td>Continuous pull/tension at the fiber</td>
<td>2</td>
<td>max. 0.05dB</td>
</tr>
<tr>
<td>Resistance against chemical material</td>
<td>2</td>
<td>max. 0.06dB</td>
</tr>
<tr>
<td>Resistance against noxious gas</td>
<td>4</td>
<td>no loss increase</td>
</tr>
</tbody>
</table>
## Loss Budget : L=15m

Fiber Channel Grade C (Standard Field Polish)

<table>
<thead>
<tr>
<th>L=15m</th>
<th>In-line conn. 1pc</th>
<th>In-line conn. 2pcs</th>
<th>In-line conn. 3pcs</th>
<th>In-line conn. 4pcs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connector Insertion Loss Random @ Room Temp.</td>
<td>Mean. &lt;= 0.30dB</td>
<td>Mean. &lt;= 0.60dB</td>
<td>Mean. &lt;= 0.90dB</td>
<td>Mean. &lt;= 1.20dB</td>
</tr>
<tr>
<td></td>
<td>Std.Dev. = 0.15dB</td>
<td>Std.dev. = 0.21dB</td>
<td>Std.Dev. = 0.26dB</td>
<td>Std.Dev. = 0.30dB</td>
</tr>
<tr>
<td></td>
<td>Max.(3σ) = 0.75dB</td>
<td>Max.(3σ) = 1.23dB</td>
<td>Max.(3σ) = 1.68dB</td>
<td>Max.(3σ) = 2.10dB</td>
</tr>
<tr>
<td>Connector ΔIL (Temp. Change)</td>
<td>&lt;= 0.4dB</td>
<td>&lt;= 0.8dB</td>
<td>&lt;= 1.2dB</td>
<td>&lt;= 1.6dB</td>
</tr>
<tr>
<td>Connector ΔIL (total)</td>
<td>&lt;= 1.15dB</td>
<td>&lt;= 2.03dB</td>
<td>&lt;= 1.88dB</td>
<td>&lt;= 3.70dB</td>
</tr>
<tr>
<td>Harness ΔIL (total)</td>
<td>&lt;= 0.3dB</td>
<td>&lt;= 0.3dB</td>
<td>&lt;= 0.3dB</td>
<td>&lt;= 0.3dB</td>
</tr>
<tr>
<td>(Aging) Margin</td>
<td>1.0dB</td>
<td>1.0dB</td>
<td>1.0dB</td>
<td>1.0dB</td>
</tr>
<tr>
<td>TOTAL (Worst)</td>
<td>2.45dB</td>
<td>3.33dB</td>
<td>4.18dB</td>
<td>5.00dB</td>
</tr>
</tbody>
</table>
## Loss Budget: \( L = 50m \)

**Fiber Channel Grade C (Standard Field Polish)**

<table>
<thead>
<tr>
<th>( L = 15m )</th>
<th>In-line conn. 1pc</th>
<th>In-line conn. 2pcs</th>
<th>In-line conn. 3pcs</th>
<th>In-line conn. 4pcs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connector Insertion Loss Random @ Room Temp.</td>
<td>Mean. ( \leq ) 0.30dB</td>
<td>Mean. ( \leq ) 0.60dB</td>
<td>Mean. ( \leq ) 0.90dB</td>
<td>Mean. ( \leq ) 1.20dB</td>
</tr>
<tr>
<td></td>
<td>Std.Dev. = 0.15dB</td>
<td>Std.dev. = 0.21dB</td>
<td>Std.Dev. = 0.26dB</td>
<td>Std.Dev. = 0.30dB</td>
</tr>
<tr>
<td></td>
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<td>Max.(3σ) = 1.68dB</td>
<td>Max.(3σ) = 2.10dB</td>
</tr>
<tr>
<td>Connector ΔIL (Temp. Change)</td>
<td>( \leq ) 0.4dB</td>
<td>( \leq ) 0.8dB</td>
<td>( \leq ) 1.2dB</td>
<td>( \leq ) 1.6dB</td>
</tr>
<tr>
<td>Connector ΔIL (total)</td>
<td>( \leq ) 1.15dB</td>
<td>( \leq ) 2.03dB</td>
<td>( \leq ) 1.88dB</td>
<td>( \leq ) 3.70dB</td>
</tr>
<tr>
<td>Harness ΔIL (total)</td>
<td>( \leq ) 0.9dB</td>
<td>( \leq ) 0.9dB</td>
<td>( \leq ) 0.9dB</td>
<td>( \leq ) 0.9dB</td>
</tr>
<tr>
<td>(Aging) Margin</td>
<td>1.0dB</td>
<td>1.0dB</td>
<td>1.0dB</td>
<td>1.0dB</td>
</tr>
<tr>
<td><strong>TOTAL (Worst)</strong></td>
<td><strong>3.05dB</strong></td>
<td><strong>3.93dB</strong></td>
<td><strong>4.78dB</strong></td>
<td><strong>5.60dB</strong></td>
</tr>
</tbody>
</table>
# Return Loss Budget

<table>
<thead>
<tr>
<th>Connector Return Loss (incl. ΔTemp)</th>
<th>In-line conn. 1pc</th>
<th>In-line conn. 2pcs</th>
<th>In-line conn. 3pcs</th>
<th>In-line conn. 4pcs</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; -20dB</td>
<td>&lt; -17dB</td>
<td>&lt; -15.2dB</td>
<td>&lt; -14dB</td>
<td></td>
</tr>
</tbody>
</table>

![Diagram of optical components and connections](image)

- Optical connector
- Optical in-line connector
- Optical cable
- Optical harness
Summary

Tested BIMMF based optical fiber cable and connector have a good performance and reliability for automotive applications

- Optical attenuation:
  - less than 0.3dB (15m),
  - less than 0.9dB (50m)

- Optical connection loss:
  - less than 3.7dB
    (4 in-line connections)

- Optical return loss:
  - less than -14dB
    (4 in-line connections)

- 15m, 4 inline connections:
  5.00dB (incl. 1.0dB margin)

- 50m, 4 inline connections:
  5.60dB (incl. 1.0dB margin)

More margin should be necessary to achieve 50Gbit/s or higher data rates
ISO/PWI 24581

TC22/SC32/WG10 is now working for the standardization of the optical fiber harness for automotive application.

**Title:**
General requirements and test methods of in-vehicle optical harnesses for up to 100Gbit/s communication

Optical header connector  Optical in-line connector  Optical cable

Optical harness

(Optical PMD transmitter and optical PMD receiver devices are not included)
http://www.autonetworks.co.jp