Photonic Transceivers for SpaceFibre Data Networks

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SpaceTech Expo Europe, Bremen, Germany, 25 October 2017
Outline

- **Problem:**
  - Reducing mass of 1-10 Gbps+ aerospace interconnects

- **Solution:**
  - Fiber optic interconnects

- **Approach:**
  - Rugged photonic transceivers

- **Results:**
  - Performance and environmental test

- **Summary and Conclusions**
Example application: 5 Gbps+ Spacecraft Interconnect

Coax Cables

Module 1

TX+
TX-
RX+
RX-

Module 2

TX+
TX-
RX+
RX-

100-Ohm Differential Data
4 Coax Cables

Fiber Optic Cables

Module 1

TX
RX

Module 2

RX
TX

2 Optical Fibers
2 Transceivers
Comparison

- Low Loss Space-Grade Coax
  - 223 g/m (Gore Type 21)

- 50-ohm SpaceFibre Coax
  - 48 g/m

- Fiber Optic Cable
  - 10 g/m+ (5g + 0.4 W) per XCVR

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Loss @ 10GHz vs Length

- Coax loss increases with frequency.
- Fiber optic link is zero loss – signal is regenerated at output.

![Graph showing comparison between Coax loss and Fiber optic loss](image-url)

- **SpaceFibre Coax**
- **Low-Loss Coax**
- **SpaceFibre Specification**
- **Max Coax Loss**
- **Fiber Optic = 0 dB**
Mass vs Length

- Fiber Optic cable + transceivers included in mass
- No connectors included
## 5 Gbps 5m Link Comparison

<table>
<thead>
<tr>
<th></th>
<th>Low-Loss Coax</th>
<th>SpaceFibre Coax</th>
<th>Fiber Optic</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Gore Type 21 Space-grade</td>
<td>(Axon AW2.2)</td>
<td>2 mm jacketed with 2 XCVR</td>
</tr>
<tr>
<td>Cables required</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Loss</td>
<td>1.5 dB</td>
<td>10.7 dB</td>
<td>0 dB</td>
</tr>
<tr>
<td>Cable mass (no connectors)</td>
<td>223 g/m</td>
<td>48 g/m</td>
<td>9.6 g/m</td>
</tr>
<tr>
<td>Optical XCVRs</td>
<td>0</td>
<td>0</td>
<td>9.4 g</td>
</tr>
<tr>
<td>5-meter total mass</td>
<td>1115g</td>
<td>240 g</td>
<td>57 g</td>
</tr>
<tr>
<td>Power consumption</td>
<td>0</td>
<td>0</td>
<td>0.8 W</td>
</tr>
</tbody>
</table>
Photonic Size 8 Contacts in Aerospace Panel-Mount Connectors
Size #8 Opto-Electronic Contact

- Fiber-Optic Transmitter / Receiver in a Size #8 Contact
- 50 Mbps to 5 Gbps today
- Support balanced CML protocols:
  - SpaceFibre, sRIO, GB Ethernet, FiberChannel, etc.

CML Data Input
3.3V @ 60 mA

ARINC 801 Optical Interface With Float

CML Data Out
3.3V @ 60 mA

Drive Amp/Bias Control
Hermetic VCSEL Laser

Hermetic Photodiode + TIA
Limiting Amp/Bias Control

US Patent 9,297,972
**5 Gbps Size 8 Opto-Electronic Contacts**

Rugged construction, simplified circuitry (passed gamma 165 krad TID)

Flex-circuit design provides critical optical float

![Diagram](image)

- 5-section Rigid-Flex PCB
- Limiting (RX) or Driver (TX) SiGe Amplifier
- Hermetic 5 Gbps GaAs PIN-TIA (RX) Or VCSEL (TX)
- Optical Contact Float to Support Blind-Mating Connectors

US Patent # 9,297,972

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Size 8 Contact Performance

RX Sensitivity @ 4.25 Gbps vs Temp

050-301-04R
Sensitivity over temperature @ 4.25 Gbps

PASS
FAIL

4.25 Gbps, -40C

4.25 Gbps, +90C
PCB-Mounted Photonic Transceivers

- High-speed electrical PCB-mount connector with screw attachment
- Glenair GC or ARINC801 removable fiber optic connector
- Same circuitry as Size 8 opto contacts
Typical Usage of Aerospace PCB-mount Transceiver

- PCB-mounted XCVR - panel connector - fiber cable
Glenair Aerospace Transceiver features compared to COTS

- Glenair Aerospace XCVR
  - Secure mounting to PCB preferred
  - Rugged optical and electrical connector
  - Compatible with SFF I2C standard

- COTS SFP, SFP+, QSFP+, etc.
  - Pluggable, commercial grade connectors
  - Not ruggedized for vibration or temperature
  - Larger footprints
  - Off-shore mfg and firmware loading
  - SFF XCVRs require soldering to PCB
Quality System, Design and Production Environment

- AS9102C quality system
- ANSI 2020 ESD-controlled manufacturing and inventory facilities
- IPC-610 certification of all operators
Manufacturing Methodology

- Use only qualified/audited component suppliers
- IPC Class 2/3 PCBAs with conformal coating
- 100% Production Testing to weed out early failures
  - 100% thermal cycling, -40 to +85C, 10 cycles
  - 100% operating burn-in at 85C
  - 100% operational test over temperature -40C to +85C
- Computerized database of all production test data
  - Monitor trends in data to spot potential problems
100% Production Test of all products

Automated Temperature Cycle
Production Test System

RX Sensitivity @ 4.25 Gbps vs Temp

PASS
FAI

4.25 Gbps, -40C

4.25 Gbps, +25C

4.25 Gbps, +90C

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Size #8 Opto-Electronic Contact Production Data

- Collect production data by serial number on every part
- >20,000 parts data collected to date
- Continuously monitor data trends to identify potential problems early
Environmental Test Results

- Accel. Aging: +85C, 2000 hours
- Radiation: >200 Krad gamma TID, $2.5 \times 10^{12}$ Neutrons/cm$^2$
- Temp. Cycling: 1000 cycles, -55C to +125C
- Vibration: 54 Grms, 2 hours per axis
- Shock: 650 G, 0.9 ms, 10 shocks/axis
- Humidity: MIL-STD 883, temp cycling, 10 days
- Altitude: 70,000 feet
- Explosive Decompression
- Passed all above tests
Accelerated Aging – Size 8 Optoelectronic Contacts

- 2000 hours operating at 85°C
Experiment in Gammacell II

<table>
<thead>
<tr>
<th>Step</th>
<th>Dose(krad)</th>
<th>Time(min)</th>
<th>Accumulated Dose(krad)</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>168.3</td>
<td>187</td>
<td>168.3</td>
<td>✔</td>
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</table>

Neutron irradiating results at room temperature 25ºC

<table>
<thead>
<tr>
<th>Step</th>
<th>Dose(neutron/cm(^2))</th>
<th>Time(s) + 13s(^1)</th>
<th>Accumulated Dose</th>
<th>Errors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>62.5 (\cdot 10^{10})</td>
<td>2718 + 13</td>
<td>62.5 (\cdot 10^{10})</td>
<td>No</td>
</tr>
<tr>
<td>2</td>
<td>62.5 (\cdot 10^{10})</td>
<td>2718 + 13</td>
<td>125 (\cdot 10^{10})</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>125 (\cdot 10^{10})</td>
<td>5435 + 13</td>
<td>250 (\cdot 10^{10})</td>
<td>No</td>
</tr>
</tbody>
</table>
Glenair 5 Gbps Transceiver
1000 Temperature Cycles -55C to +125C

- Optical Output Power and extinction ratio
Glenair 5 Gbps Transceiver
1000 Temperature Cycles -55°C to +125°C

- Receiver sensitivity at 4.25 Gbps
Glenair 5 and 10 Gbps Transceiver Modules
Operational Vibration & Shock

- Random Vibration, Operating
  - 54Grms 2 hours per axis

- Operating Shock
  - 650 G, 1ms, 10x per axis
  - 78 G, 12 ms, 10x per axis

- No bit errors
Products in Development

- 40 Gbps Parallel Optical Transceivers
  - 10 Gbps per fiber
  - Compatible with MT optical connector
- 120 Gbps TX and RX
- Rugged MT connectors
- 10 MHz – 40 GHz RF Photonic Links
  - Direct and External Modulation
  - L-band through Ka-band signal transport on optical fiber
Summary and Conclusions

- Developed rugged photonic transceivers for aerospace applications
  - Hermetic GaAs lasers and photodiodes
  - SiGe electronics
  - No microprocessors or EEPROMs
  - Widely deployed in mil/commercial aero applications

- Test results to date are promising for space
  - High shock, vibration, thermal extremes
  - >200 Krad Gamma and 2.5x10^12/cm^2 neutrons

- Future Plans
  - Protons, Heavy Ions
  - 10 Gbps parallel optics, RF over Fibre

- Collaborations are desired
- Visit the Glenair stand
For more information:

- Visit the Glenair stand

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