

Reliability of non-hermetic optical transceivers - ESA Study summary

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Reliability of non-hermetic optical transceivers

Presentation overview

1. Context and background
2. Transceiver selection
3. Test plan definition
4. Results
5. Conclusions



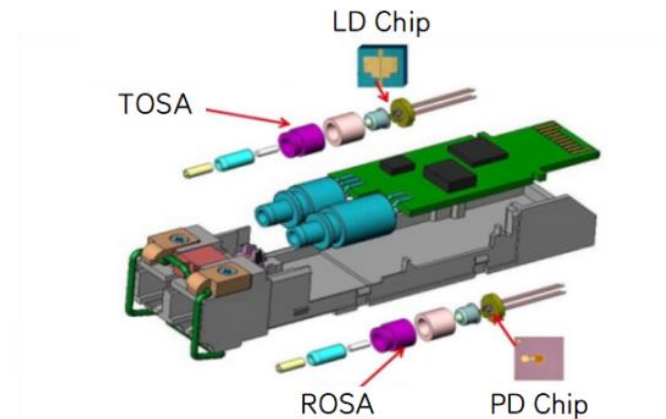
Reliability of non-hermetic optical transceivers

Context and background

Optical transceivers are increasingly used in space applications due to their high-speed, multi-gigabit data communication capabilities.

The main advantages over conventionally used copper-based RF systems:

- significant mass/size reduction.
- no interference issues between adjacent cables.
- no need for heavy RF shielding.
- electrically isolated from the environment due to their non-metallic assemblies, preventing potential on-board ground-loops.



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Context and background

Funding:

- ESA contract No. 4000133320/20/NL/FE



Ambition:

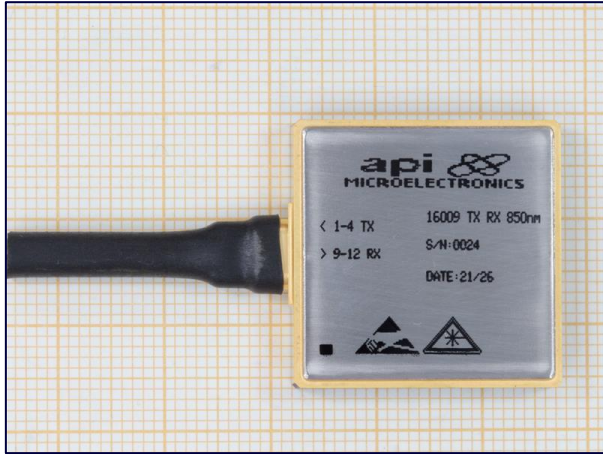
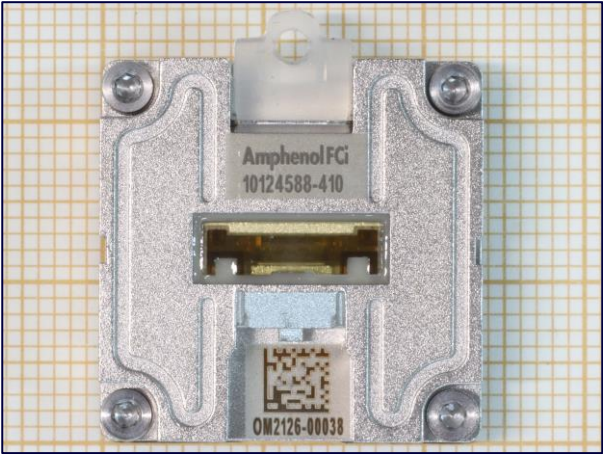
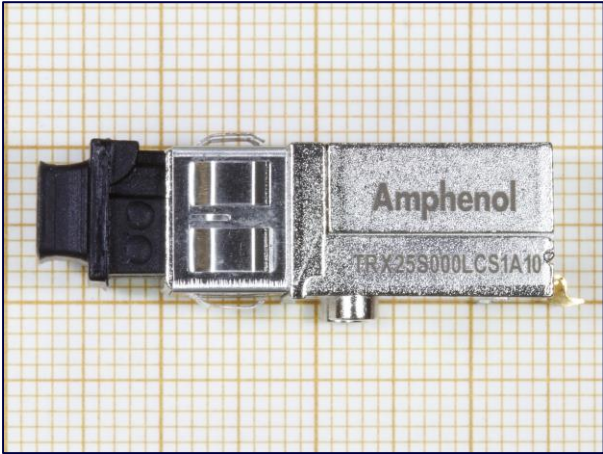
- To **assess the reliability** of commercial non-hermetic optical transceivers for use in space.

Objectives:

- Focus on **existing commercial** parts.
- Test campaign definition considering **non-hermeticity** of the samples.
- Selection from **European manufacturers** (at least two).

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Selection of non-hermetic COTS optical transceivers



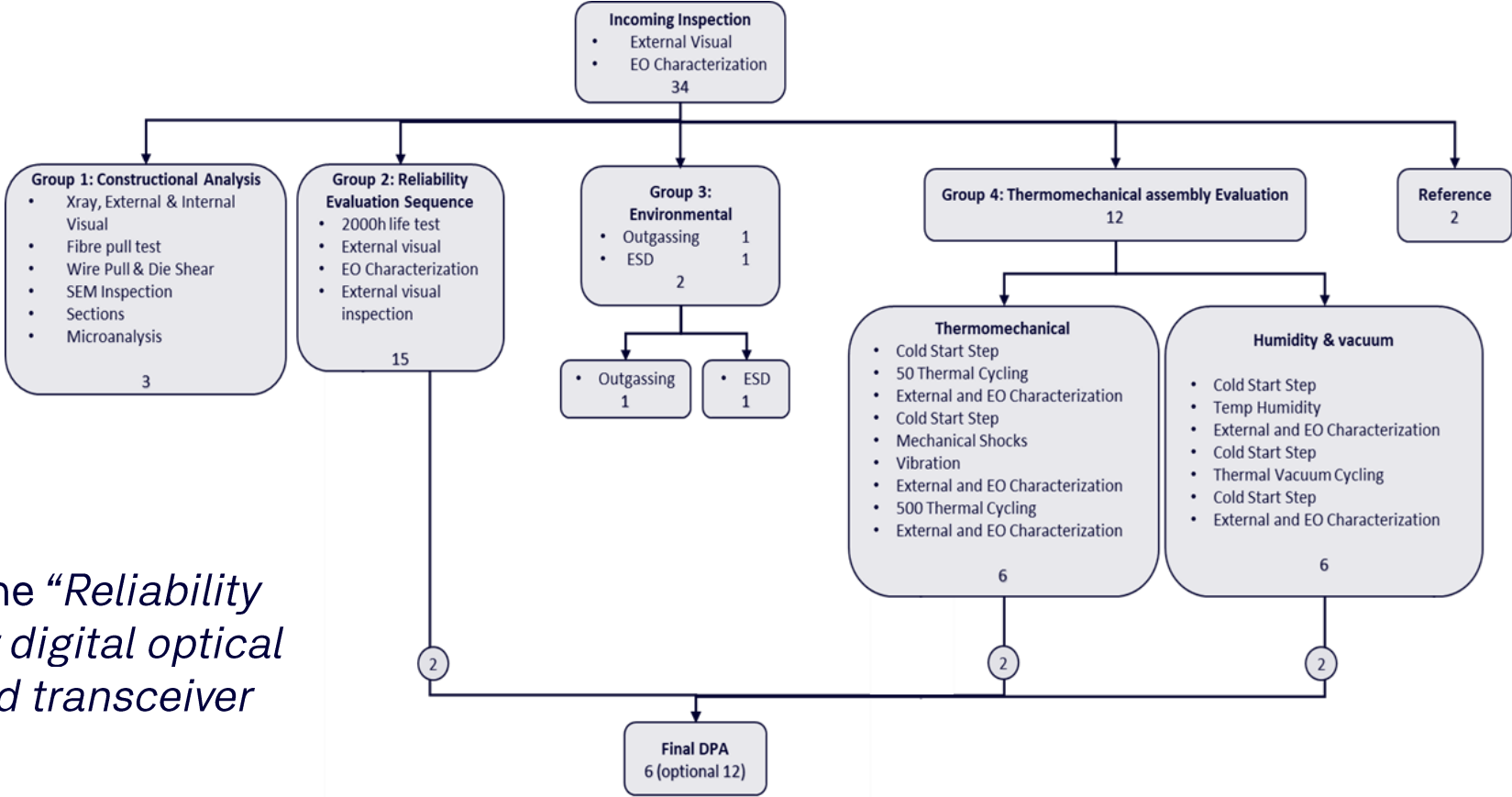
Device 1	SCFF
Manufacturer	Amphenol
Datarate	25 Gbps
Channels	1 ch
Wavelength	850 nm

Device 2	Leap® OBT
Manufacturer	Amphenol
Datarate	25 Gbps
Channels	12 ch
Wavelength	850 nm

Device 3	Opto-fire™ 16009
Manufacturer	Spectrum Control (formerly APITech)
Datarate	10 Gbps
Channels	4 ch
Wavelength	850 nm

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Test plan definition



Based on ISROS guideline “Reliability assurance guideline for digital optical transmitter, receiver and transceiver modules”

Reliability of non-hermetic optical transceivers

Results

Incoming Inspection

Group 1: Constructional analysis

Group 2: Reliability evaluation

Group 3: Environmental

Group 4a: Thermomechanical

Group 4b: Humidity and vacuum

Final DPA

- **Sample homogeneity** was difficult to meet on procured 34 samples.
 - Only device 2 was meeting **single date code** requirement
 - Device 1 samples were marked with different date codes but delivered at the same time
 - Device 3 samples were performed in different batches along few months, and different date codes were received.
- Visual inspection showed **foreign material** in two samples of device 3.
- During electrical characterization:
 - Issues were found on 3 samples of device 1. Samples were returned to manufacturer and replaced.
 - On device 3, characterization was found to be **less repeatable**. Measured BER values were not as stable as expected.

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Device construction is very different on both manufacturers.

- Spectrum Control device:
 - Is based on ceramic packaging, alumina and minimal component count.
 - Fibre pig-tail is included.
 - Sealed case.
- Amphenol devices:
 - Are based on multi-layer PCBs and SMT technology, including much more control electronics.
 - No fibre pig-tail is included. Optical interconnection is done through MT24 ferrule and LC connectors.
 - No sealed case.

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Devices 1 and 2 only showed a **void in the solder joint** and a **crack on the ceramic body** of one capacitor during the cross-sectioning tests performed at various inspection planes. All **remaining tests were successful** showing good construction of the devices.

However, on device 3 several issues were found:

- Lack of die attach was detected on the opened two samples.
- Wire pull test failed on 7 wires on one sample.
- Pure tin was found on the capacitors contact finish.
- Construction was not homogeneous on different samples, showing different coverage of the material fixing the optical fibre.

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2000h life test was performed at maximum operation temperature. RF input signal was applied to one channel of each transceiver.

- Devices 1 and 2 were **very robust** to the stress applied. No performance change was found.
- Device 3 showed **deviation in E/O performance** with degraded BER parameter. Two samples failed to pass the BER limit criteria after 240h and 500h of test, respectively.

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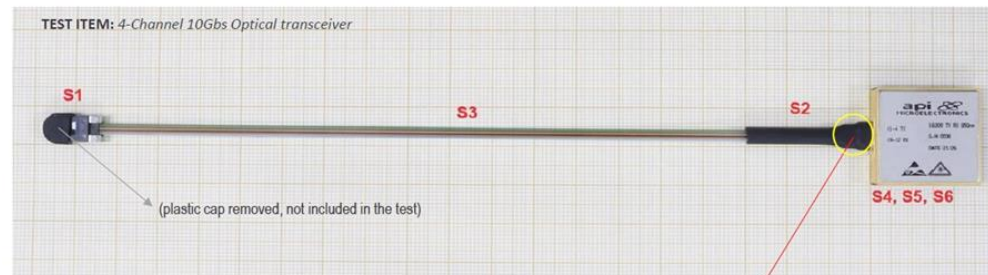
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Final DPA

Outgassing test was performed according to ECSS-Q-ST-70-02-C.

- Device 1 and 2 **met the limits** of the test method according to the acceptance criteria:
 - TML (Total Mass Loss) < 1.0%
 - RML (Recovered Mass Loss) < 1.0%
 - CVCM (Collected Volatile Condensable Material) < 0.1%.
- Device 3, that includes a fibre pigtail, **did not pass the test** according to CVCM criteria (only on items S1, S2, and S3).



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ESD test was performed according to MIL-STD-883 TM 3005 (HBM at 2 kV).

- On device 1, the sample was functional after the discharge, but a reduction was observed in the signal levels of the eye diagram (one and zero level). Consequently, eye height was also reduced with a variation of around 30%.
- Test was successful on device 2 with no performance changes.
- On device 3 two channels were not functional after the test.

Pulses were applied to **all pin combinations** on the same sample.

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Six samples of each device type underwent the following test flow:

- Thermal cycling MIL-STD-883 TM 1010.9 (50 cycles, -40°C/+85 °C)
- Mechanical shock MIL-STD-883 TM 2002.5 cond. B
- Vibration test MIL-STD-883 TM 2026 cond. I-F
- Extended thermal cycling MIL-STD-883 TM 1010.9 (500 cycles)
- Cold start at -35°C before and after each thermal cycling

Device 2 **passed all test** flow successfully showing to be very robust against thermomechanical stress.

One out of the six samples of device 3 **failed to pass** parametric test limits of BER.

Two samples of device 1 showed **functional failures** (one after vibration test, and the second one during the extended thermal cycling).

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Six samples of each device type underwent the following test flow:

- Temperature humidity test JESD22-A101 (+85 °C/85%RH for 1000h)
- Temperature cycling in vacuum (10 cycles, -40°C/+85 °C, $8 \cdot 10^{-4}$ mbar, under static bias)
- Cold start at -35°C before and after each test

Results showed that this subgroup was the **most challenging** for devices 1 and 2.

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Three samples of device 1 **failed during humidity test** with the same failure mode, showing some sensitivity to humidity ingress. Samples were not functional, but root cause was not confirmed.

One out of the six samples of device 2 **failed during humidity** and a second sample **after thermal vacuum test**. Both showed different functional failure modes, but the root cause could not be confirmed.

One of the six samples of device 3 **failed during measurements after thermal vacuum**. A crack was observed on the fibre pigtail that may have been caused by handling.

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Carried out on six samples taken from groups 2, group 4a and group 4b (two samples from each).

Tests revealed the **same anomalies previously identified** during the constructional analysis.

On device 1 samples, **additional defects** were detected. Some could be attributed to degradation that has occurred during the test, although it could not be confirmed.

Conclusions

- None of the samples passed all the tests in its current form. Each of them has **its own strengths and weaknesses** which require design or process adjustments.
- Unfortunately, **no correlation has been proved** between the non-hermeticity of the samples and the possible reliability issues found during the testing.
- Inclusion of a **fibre pigtail** as part of the component compromises meeting outgassing requirements and makes devices more sensitive to handling.
- The **non-homogeneity of the construction** of the samples is a risk that may jeopardize the outcome of the whole test campaign in components like optical transceivers.

Thank you for your attention!



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