Proc. International Conference on Space Optical Systems and Applications (ICSOS) 2012, 13-1, Ajaccio, Corsica, France, October 9-12 (2012)

The Alphasat GEO Laser Communication Terminal Flight Acceptance Tests

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Abstract

Tesat Spacecom has developed and tested a first prototype of Tesat`s 2nd Generation Laser Communication Terminal (2nd GEN LCT) for use on Alphasat for GEO-LEO-Links. LCT design, LCTs test philosophy and LCTs test results will be presented.

I. Introduction

Tesat has implemented coherent detection into its Laser Communication Terminals (LCT), that are spaceborne and operating since 2007 [1], [2]. These first LCTs are operating a 5.5Gbps optical link between LEOs or between LEO and ground. Tesat`s 2nd GEN LCTs are foreseen for data rates up to 1.8Gbps between GEO-LEO and space-ground links. This LCT uses same technology as the heritage device but it is scaled for the application. This documentation is related to the flight acceptance test of the first prototype of 2nd GEN LCT.

II. 2ND Gen. LCT Design

The LCT block diagram is shown in Figure 1. Major changes are: For the 2nd GEN LCT an Off Axis Telescope is chosen, the Optical Power Amplifier is changed to a 5W device, the receiver is optimized for 1.8Gbps data rate.

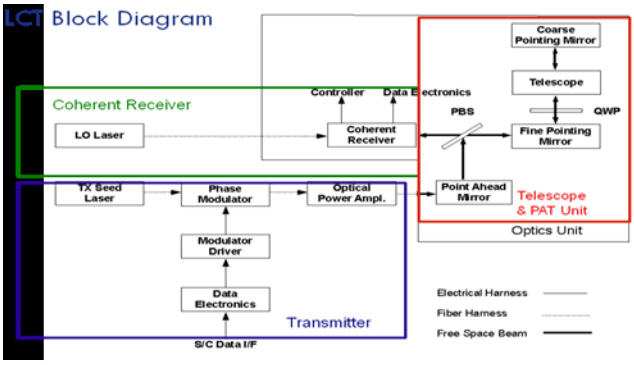

Figure 1. Tesat LCT block diagram.

For the GEO Orbit the electronics were redesigned to operate the adapted devices and to match with the GEO radiation environment for 15 years of continuous service. The thermal system is improved, the mechanics scaled for the bigger units.

III. LCT Generic Design/Qualification Approach

The LCTs are built such, that the LCTs for GEO and LEO application are same for its units design and their qualification. The GEO and LEO LCTs have identical optical space interfaces with same performance.

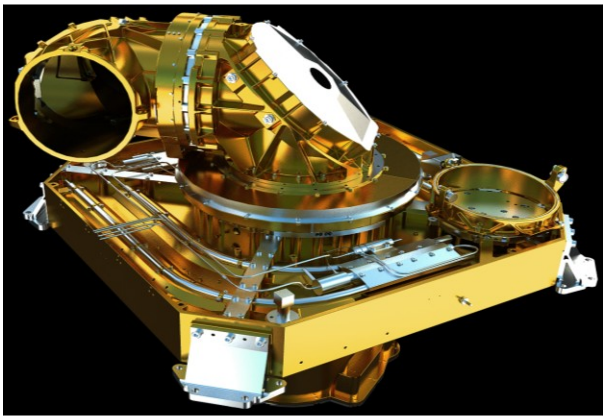

Figure 2. TESAT`s 2ND GEN LCT, showing the space side with hemispherical coarse pointing unit

For adaptation of the generic design 2nd GEN LCT to S/C application only S/C I/F (spacecraft interface) related items (e.g. bus voltage, Telemetry/Telecommand interface and thermal interface) are modified. In Figure 3. the Alphasat LCT is seen with its customized thermal interface for Alphasat S/C.

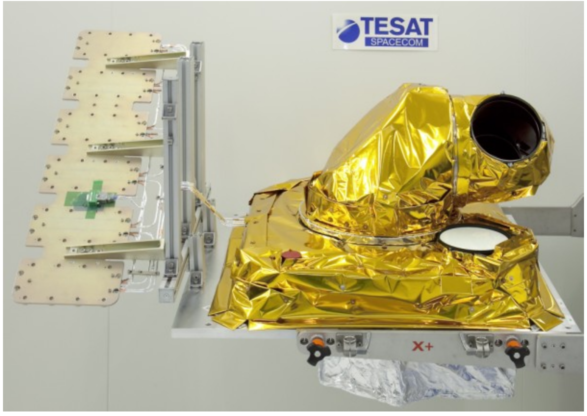

Figure 3. Alphasat LCT, equipped with MLI, with a Alphasat specific thermal Interface, mounted in its transportation frame

IV. Alphasat LCT Mechanical Test

The Alphasat LCT was tested against the specific Alphasat mechanical loads. The mechanical testing procedure is a standard procedure and not described her. The LCT prepared for the mechanical test (sine and random vibration) is shown in Figure 4. All tests were performed successfully, no performance degradation was observed after test.

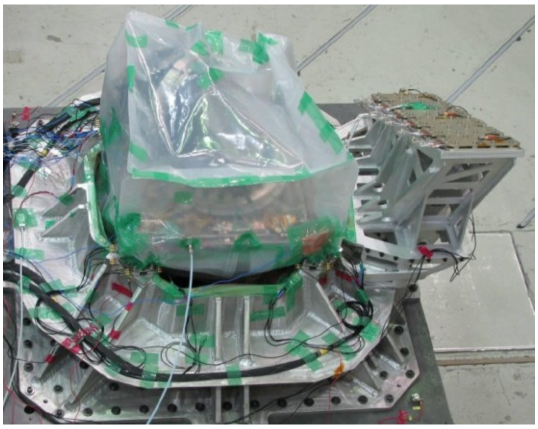

Figure 4. Alphasat LCT mounted on a vibration adapter, ready for vibration testing

V. Alphasat LCT EMC Test

The Alphasat LCT was tested against the specific Alphasat EMC loads. The EMC test procedure is a standard procedure and not described her. All tests were performed successfully.

VI. Alphasat LCT Thermal Test

Thermal test were performed in a very special thermal vacuum (TV) chamber. Figure 5. is showing the TV-chamber design. The TV-chamber allows full LCT functional testing in thermal vacuum condition. Vacuum tests are necessary, as the optics design of the LCT is built for vacuum. Most of the LCT tests in TV are generic LCT tests, but e.g. commanding the LCT will be performed with the Alphasat command set.

The TV test included IFT (initial function test) at ambient thermal conditions, thermal cycling over the survival temperature range of -30°C to + 60°C, start up of LCT at low temperature, LCT performance with cold condition, LCT performance with hot condition, LCT cold survival (and its demand for survival heater power, as the LCT is switched off) and FFT (final function test).

The test was a worst condition test. The test demonstrated that LCT heat pipes and controls were working as specified and the LCT meets thermal performance requirements for ALPHASAT.

Figure 5. Thermal vacuum chamber for LCT performance verification with several optical windows for LCT acccess. The bigger windows allow access to the LCT CPA aperture to perform communication and wave front error measurements, while smaller windows allow acces to the LCT pointing reference cube for pointing verification.

VII. LCT System Test Bed

For LCT performance testing a LCT System Test Bed is used. The functional block diagram of the LCT System Test Bed is depicted in Figure 6. It comprises the following main building blocks located in a clean room:

- Thermal vacuum chamber (TV chamber)
- Optical System Test Bed (OSTB)
- Counter Optical Terminal (COT)

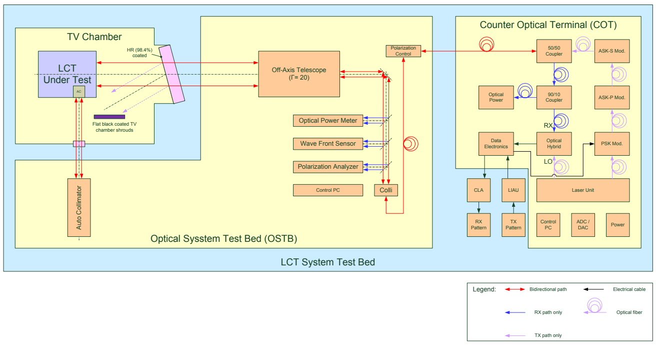

Figure 6. The optical system tesbed for testing the Alphsat LCT (not all units of the generic OSTB shown are used)

Electrical Functionality of LCT System Test Bed

The LCT System Test Bed provides electrical connectivity by means of a vacuum chamber feed through between the LCT under test residing inside the thermal vacuum chamber and chamber external GSE (Ground Support Equipment), e.g. spacecraft control computer simulator or S/C power supply.

Mechanical Functionality of LCT System Test Bed

The LCT System Test Bed provides inside the thermal vacuum chamber a mechanical mounting interface for the LCT. Within the TV Chamber the LCT is mounted such, that free rotating of CPA (coarse pointing assembly is possible.

In order to decouple the LCT and OSTB from building induced mechanical vibrations the OSTB as well as the vacuum chamber are equipped with passive damping means enabling optical beam pointing with micro-radiant stability.

Optical Functionality

The OSTB consists of Optical table, Beam expander, measurement instruments, autocollimators and a motorized Theodolite with auto collimation extension (not shown in Figure 6.)

The LCT System Test Bed is compliant to the LCT with an optical transmit and receive beam wavelength λ= 1064 nm ±1 nm.

The LCT System Test Bed is compliant to the LCT having in communication and/or tracking mode (for TX and RX direction) an external (space side) FoV1 of ±0.5 mrad (FoV: Field of View). Further on is the test bed compliant to a LCT having in acquisition mode (for TX and RX direction) an external (space side) FoV2 of ±2.5 mrad. However, the limited FoV of the staring OSTB optics requires a counter rotation of the DUT in cases where the TX (transmit) and/or RX (receive) beams are directed into the field.

The LCT System Test Bed building block OSTB transmits a free space circular polarized and collimated TX output beam towards the LCT. In RX direction of the LCT System Test Bed it is able to receive a free space circular polarized and collimated input beam from the LCT.

The LCT System Test Bed building block OSTB is able to characterize the optical input RX beam (LCT TX beam) in terms of power, polarization, beam profile and wave front error.

LCT pointing verification is supported by the OSTB via monitoring of the DUT's reference cube with an auto-collimator.

Thermal Functionality

The LCT System Test Bed provides inside the thermal vacuum chamber the thermal environment a LCT (covered with MLI (multi layer insulation) will experience in space. The two temperature extremes are:

- Thermal impact of direct Sun simulation
- Minimum non-operational temperature

Operational Functionality

The LCT System Test Bed is able to validate the LCT's internal TX/RX optical beam co-alignment calibration.

Further on the LCT System Test Bed enables the verification of the following operational LCT activities:

- Optical TX beam pointing verification.
- LCT link acquisition sequence verification. (The COT has no pointing capability; it is coupled to the OSTB via an optical fiber. The scenario simulation occurs in the COT with means of amplitude modulators for power attenuation and on/off switching.)
- Link communication sensitivity verification

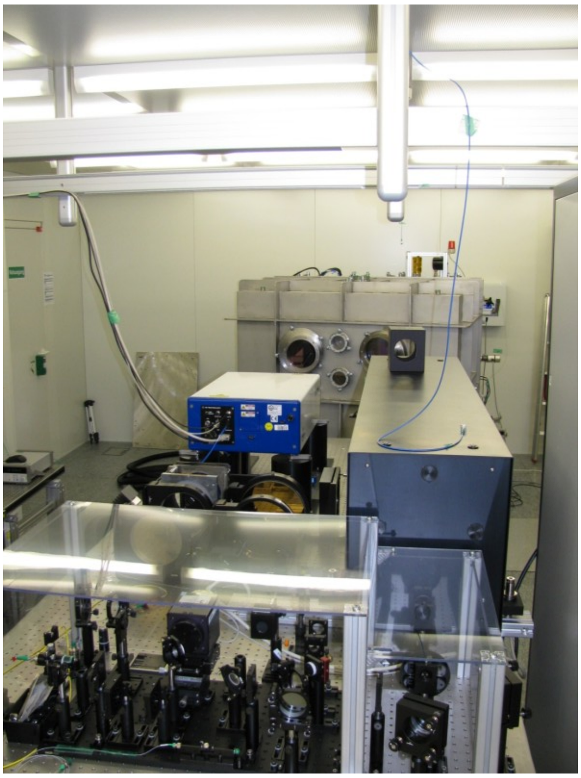

Figure 7. Optical System Testbed in front of the TV-Chamber, rear view

VIII. ALPHASAT LCT PERFORMANCE TEST RESULTS AND INTERPRETATION

For verification of LCT optical interface related performance the LCT was stimulated via external OSTB. Values given below are at LCT CPA aperture (space interface). This chapter summarizes the test results.

Transmit power is command able up to 4 W

The telescope performance matches to the prediction of a LEO-GEO link.

The acquisition receiver provides sufficient SNR (signal to noise ratio), no false hits were detected with TX power switched on to maximum power (no selfblinding).

The receive performance was measured at 600Mbps @BER 10E-8 -51dBm for the coherent data receiver. For receive performance at 1800Mbps @BER 10E-8 -47.8dBm (48 photons per user bit) was measured. High margins for tracking and OPLL control (up to -60dBm) were verified.

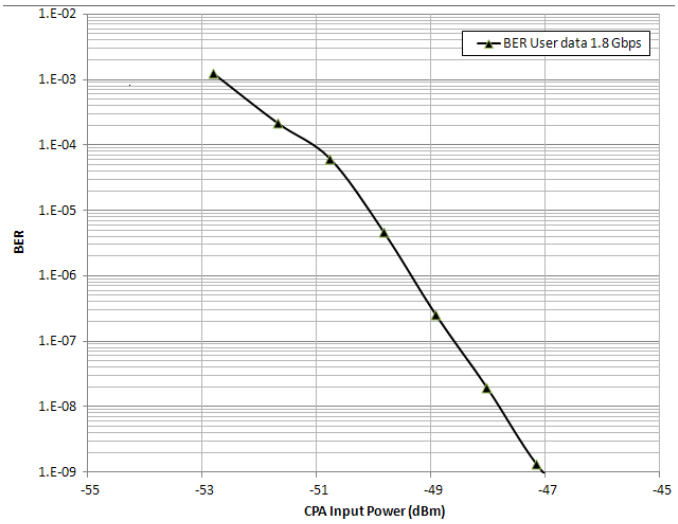

Figure 8. BER of LCT versus LCT CPA input power

BER was measured at IFT, cold, hot and FFT, the Diagram in Figure 8. **is** showing the FFT values.

The LCT simultaneously transmits and receives data and has a common optical path. It was measured, that there was no BER degradation in the receive path with TX operation even at maximum TX power.

Both axis need to be co-aligned to each other. The co-alignment of TX/RX beam axis was measured < 2µrad and is verifiable in orbit by a build in calibration feature.

The LCT was exposed to a beam of an artificial sun through the windows of the TV chamber to the LCT optical aperture simulating the heat input in the optical system during a link, were the counter LCT passes the sun. There was no degradation after sun exposure.

The 2nd GEN LCT is specified under S/C loads and for end of life, so the tests result cannot directly be taken for link estimation. The Alphasat LCT performance tests demonstrated that all link related requirements were met with sufficient margin.

The Alphasat LCT was the first LCT in a series of LCT for other S/Cs. Currently Tesat is under contract the LCT´s for the European Data Relay System accommodated on the Sentinel 1 A , Sentinel 2 A (LEO) and EDRS-A and EDRS-C GEO spacecrafts.

IX. SUMMARY:

Tesat Spacecom has successful developed, acceptance tested and delivered to the Alphasat space craft a first build of 2nd GEN TESAT LCT

ACKNOWLEDGMENT

This work was supported under the DLR contract 50YH0632.

[1] Smutny B. et al, “In-orbit verification of optical inter-satellite communication links based on homodyne BPSK”, Proc. SPIE 6877, (2008)

[2] Smutny B. et al, “5.6 Gbps optical inter-satellite communication link”, Proc. SPIE 7199, (2009)