Qualification of Direct Detection Technology for ESA MetOp-SG Space Mission

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Abstract— This contribution presents the ACST 89 GHz Schottky detector module performance and pre-qualification results towards the second European meteorological operational satellite program MetOp-SG. The detector flight module prototype has been assembled, characterized, and successfully implemented into the 89 GHz bread board receiver within the procurement activity for MetOp-SG. Performances of the detector and overall receiver are discussed.

INTRODUCTION

ACST GmbH is a leading European commercial supplier of Schottky diodes for millimeter wave and sub millimeter wave applications. With core business in the Schottky diode fabrication technology, ACST has recently extended its activity towards assembly and environmental testing of THz components and modules for Space missions. This brings gathering experience and know-how in different critical processes in house and provides opportunity for linkage between different stages within the development process of Space THz-electronics. Being involved in several space-related activities, ACST has become a strong partner in the area of development and qualification of THz electronics for space applications.

Millimeter wave space borne imaging and sounding radiometer instruments accommodate an increasing number of Direct Detection Radiometer (DDR) channels. With this rather compact installation, more hardware can be implemented in the focal plane of the instrument antenna. Medium power local oscillator sources are omitted with the direct detection approach, reducing mass, volume and power consumption of mm-wave receivers [1]. Still challenging is the design and implementation of reliable low noise amplifiers and low noise detectors at the radiometer RF input frequency. ACST has demonstrated the world wide best detector performance regarding signal to noise ratio with excellent linearity, based on matched Schottky diode parameters, detector design, and video amplifier design.

For the highest frequency channel in MetOp-SG with direct detection, ACST is carrying out the full Schottky diode and 89 GHz RF detector module development and qualification process. Starting from the fundamental technology process development of low noise zero-bias Schottky diodes [2], the suitability of the diode technology has been proven in an ESA study with preliminary reliability testing [3][4]. The RF module has been designed to meet the stringent MetOp-SG requirements and will be implemented as a core element of the 89 GHz receiver onboard of the MicroWave Sounder (MWS) and MicroWave Imager (MWI) instrument. The majority of RF module reliability testing was finished at the beginning of 2017, covering strength (bond pull, die shear), endurance (DC life, RF life) and environmental testing (humidity, mechanical shock/vibration, thermal cycling). Most of these tests are performed at ACST measurement and cleanroom facilities.

DIRECT DETECTION MODULE TOWARDS METOP-SG

The original module applied for reliability testing had to be adapted to meet the stringent MetOp-SG requirements [4]. The overall volume is reduced by a factor of 3.5, the interface is reworked and the video amplifier section is fine tuned to meet the deviating MWI and MWS requirements. The main technology processes has proved to be very reliable and remain unchanged for actual flight hardware.

PERFORMANCE AT 89 GHZ

Before being implemented into the 89 GHz receiver, the detector module (Fig. 1) undergoes separate full functional tests at ACST.

Detector module level

Main tests analyze the performance regarding RF voltage responsivity, linearity, input matching, noise performance, all at ambient temperature and over the mission temperature range.

Fig. 1 89 GHz detector module.

The RF voltage responsivity is in the range of 300 V/mW with a considered amplification factor of Av = 100. The required linearity of a maximum deviation of 0.04% within 3 dB dynamic is achieved for power levels up to -25 dBm. The minimum power level to meet the required SNR = 30 dB over the temperature range is -38 dBm. The target input power at detector level is -33 dBm to -30 dBm. The temperature stabilized RF voltage responsivity shows a maximum drift of 0.022dB/°C.

Receiver level

The receiver (Fig. 2) contains a low noise amplifier chain with technology from Fraunhofer IAF, noise and channel filters, a coupler for test port access, the detector module with video filtering and amplification, and the general video section for power supply and other electronics.

The breadboard receiver shows excellent performance results. The RF to video response matches the bandwidth specification over the temperature range for MWS and MWI. The radiometric gain is above 4.5 mV/K over the full temperature range with specification of minimum 3.5 mV/K. The noise figure stays below 3.5 dB, as specified.

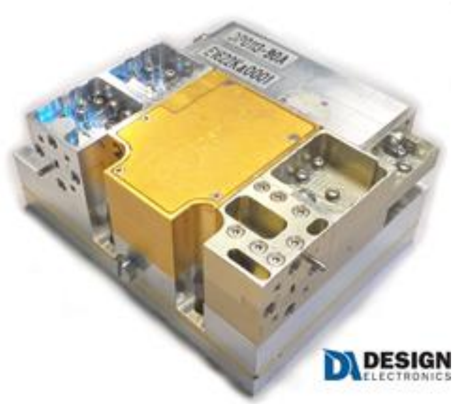

Fig. 2 89 GHz detector module (centre) implemented into the 89 GHz breadboard receiver by DA Design.

Reliability of direct detection technology from ACST

In the framework of the ESA study “Preliminary Reliability Assessment of Millimeter-wave Detectors”, several tests are performed on representative test samples, i.e. diodes on RF substrates. Therefore, not only the diode technology is investigated, but also the critical diode assembly on the RF substrates. The objective of the activity is to reveal and correct at an early stage possible degradation or failure mechanisms.

A reliable mounting process has been developed and verified with step stress tests, life tests, and environmental tests in Phase 1 of the activity. All tests have been finished successfully without a single failure of a diode or a diode assembly contact. In a second phase, the tests have been repeated with RF modules and extended test length. Additional tests are added with RF stress and life tests, as well as mechanical tests.

High humidity high temperature (HHHT – 85%/85°C) test with and without bias and thermal cycling (-55°C/+100°C) at ACST, as well as mechanical shock and vibration tests at MILLILAB did not reveal any weakness of the materials and processes within the required MetOp-SG test length and stress levels.

RF life tests with 2 dB margin on the operating power level of -30 dBm for 2000h, as well as 168h at -9 dBm (21 dB margin), did not show any sign of performance deviation.

The most demanding tests for the technology proved to be the DC life and storage tests, with its long test length >1500h, due to the technology limitation of the applied temperature test level. The test at 100°C showed an acceptable parameter drift. The test at the smaller high temperature level at 85°C is ongoing as the last preliminary reliability test.

Conclusions

Presented is the ACST 89 GHz detector module for direct detection radiometry. The detector is designed to meet the MetOp-SG specifications, and is intended to be used in the 89 GHz channel receivers on board MetOp-SG MWS and MWI. The concept is based on low-barrier Schottky diodes, developed for minimum white and 1/f noise contribution. From measurement results, all specifications are fulfilled at ambient temperature with excellent noise and linearity performance, only possible with detailed knowledge on noise reduction at diode, detector and amplifier level. The technology is verified with pre-evaluation tests, regarding long term operation on board the MetOp-SG satellites.

Acknowledgment

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