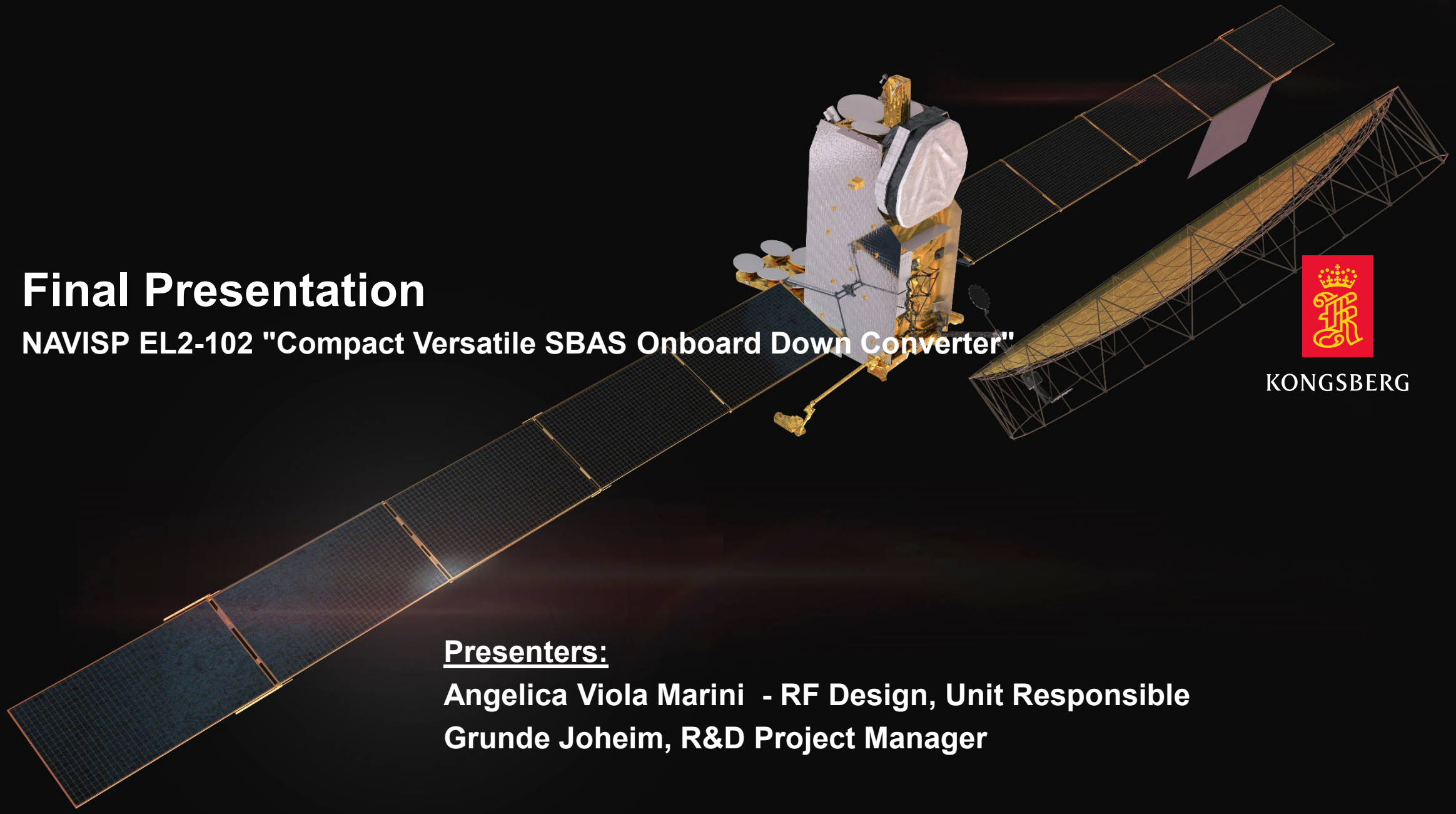
# Final Presentation

## NAVISP EL2-102 "Compact Versatile SBAS Onboard Down Converter"



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**Presenters:**

Angelica Viola Marini - RF Design, Unit Responsible

Grunde Joheim, R&D Project Manager


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HUGIN

# Three strong divisions

## Defence Systems

Defence Systems develops and delivers advanced air defence systems, including NASAMS, along with remote weapon stations, command-and-control systems, secure communication solutions, and unmanned tower systems for air traffic management.

## Missiles & Aerostructures

Missiles & Aerostructures develops and produces the Naval Strike Missile (NSM) and Joint Strike Missile (JSM) and designs and manufactures composite and titanium components, including key elements for the F-35 fighter aircraft.

## Discovery

Discovery develops advanced COTS and dual-use technologies for commercial, research, and defence applications. Space activities includes delivery of components, systems, and services to the space industry. Discovering from space to surface and seabed

# SPACE & SURVEILLANCE PRODUCTS & SERVICES

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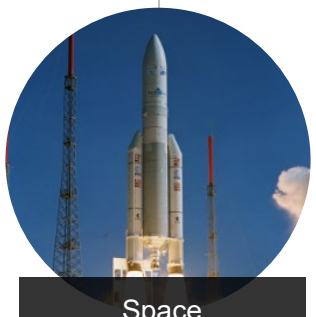
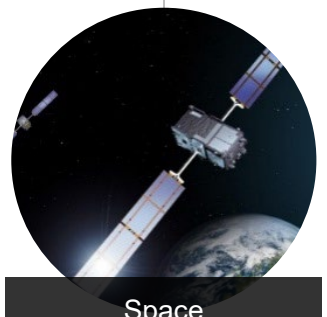
## Complete Value Chain



**Space Mechanisms**

Solar Array Drives
Antenna Pointing
Launcher Attachments
Launcher Products

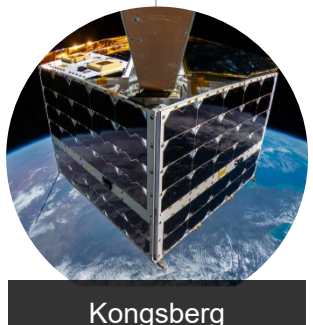


**Space Electronics**

Telecom P/L & Equipment
TCR
SAR Transponders
Data Downlink
Specialised Equipment
Opto Pyro Systems

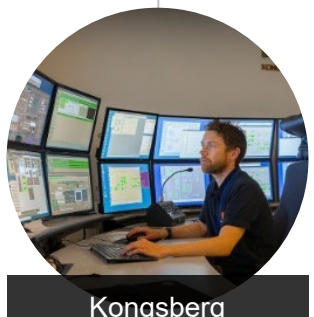
**Space Ground Systems**

Antennas
Receivers and Demodulators
Meteorological Receiving Stations
Copernicus System
Ground station Monitoring and Control Systems



**Kongsberg NanoAvionics**

Nano and Micro Satellite Buses
Cubesat components



**Kongsberg Satellite Services***

Ground station services

* 50 % ownership

**Kongsberg Norcontrol AS**

Maritime surveillance

# Kongsberg Space Electronics – At a Glance

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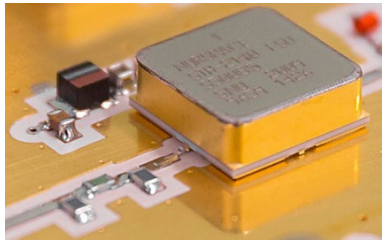
Workforce: 150
(100+ Engineering)



On-Board Satellite
Electronics Since 1984

AIRBUS, NORTHROP GRUMMAN, MAXAR, SURREY, OHB, BOEING, LOCKHEED MARTIN, ThalesAlenia Space, esa, MDA, ASTRANIS

Primes

SES, inmarsat, INTELSAT, telenor, hispasat, AIRBUS, OPTUS, SABS, SATMEX, Yahsat, ASTRANIS

Satcom Operators

KONGSBERG

Kongsberg Group
Since 2011

>250 Satellites
>2000 kg Delivered

RF Units
TTC/TCR
Downlink
SAW/Components

Horten, Norway

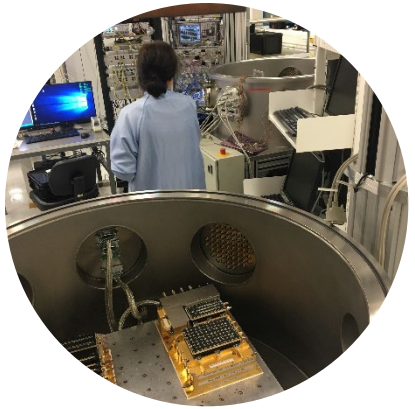
# MAIT Clean Room Facilities

- SAW Crystal Wafer and Thin Film Substrate Processing
- Class 100-1000
- 140 $m^2$

- SAW and Hybrid
- Automated Assembly, Inspection and Test
- Class 10 000
- 270 $m^2$

- Automated Printed Wire Board Assembly
- Unit Integration
- Class 100 000
- 240 $m^2$

- Electrical Test & Tune
- Temp/TVAC Cycling
- Class 100 000
- 650 $m^2$



# Space Electronics - Products

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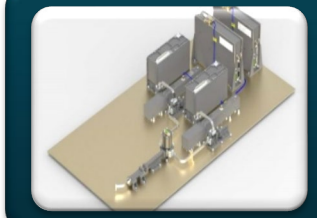
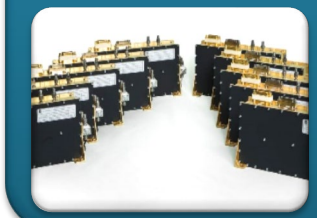


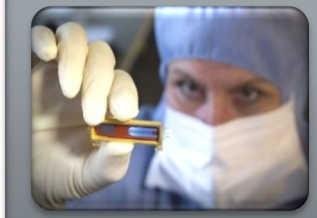
## Subsystems & Assemblies

- Communication Subsystems
- Converter Assemblies (MiCA)



## Equipments

- Frequency Converters, Pre- & Post-Processors
- Frequency Generation Units
- Low Noise Amplifiers
- Search & Rescue Transponders
- Data Transmitters
- TT&C / TC&R
  - Receivers, Transmitters, Tranceivers and Beacons
  - X-band Transponders



## Standard Modules

- SAW Filters
- Hybrid Amplifiers
- Local Oscillator Modules
- Reference Oscillators

# SBAS Dual DownConverter - Program Objectives

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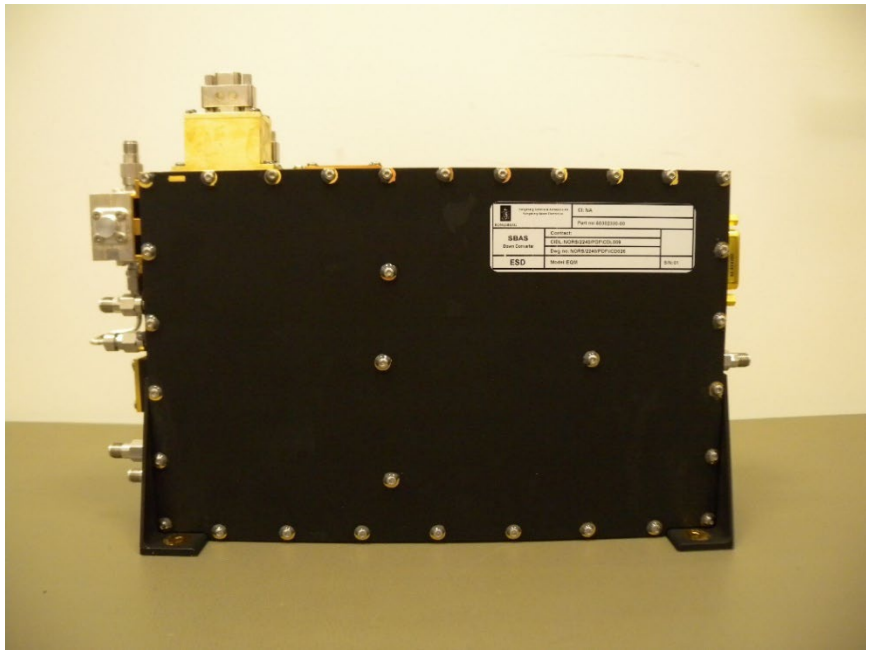
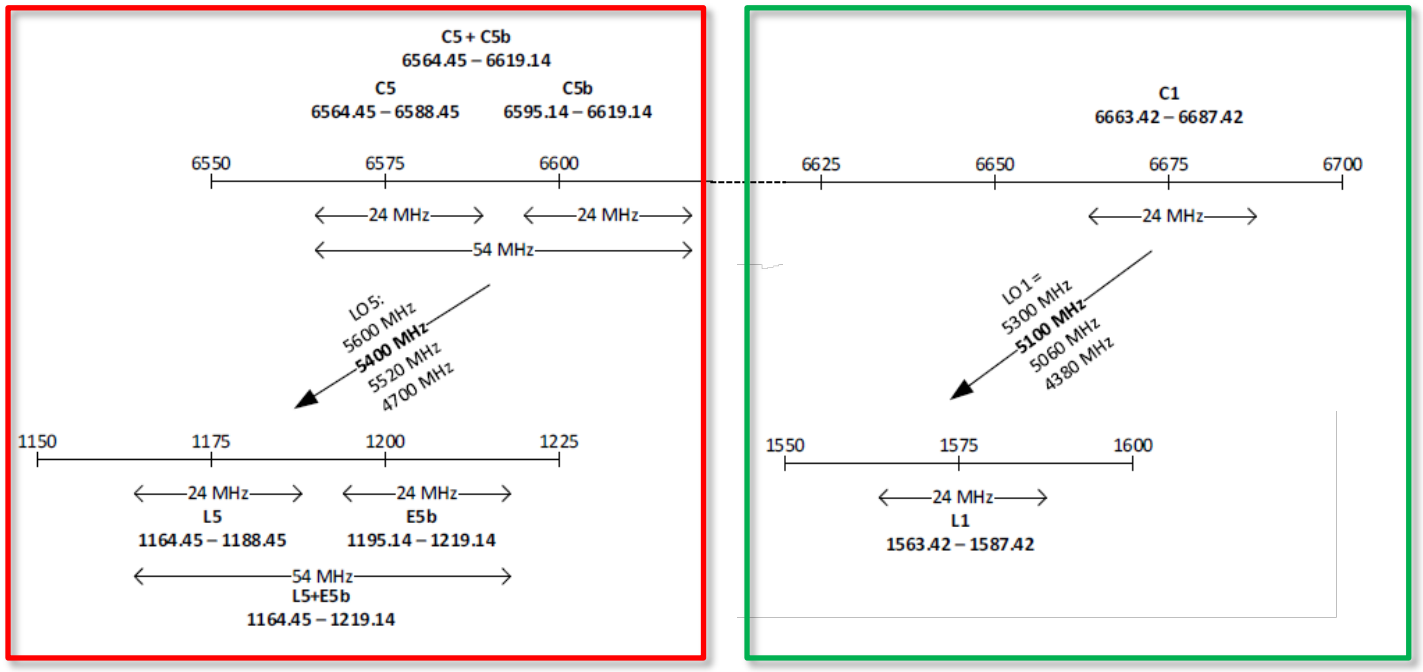
- Development and qualification of a Compact Versatile SBAS down converter, for use in GEO Satellites distributing augmentation data for more accurate positioning.
- Key words:
  - The unit shall be highly integrated, still flexible and versatile.
  - Generic; easily adaptable to
    - uplink band and frequency plan,
    - output frequency
    - platform interfaces.
  - Demonstrate through EQM development

# SBAS C to L Downconverter
## Overview

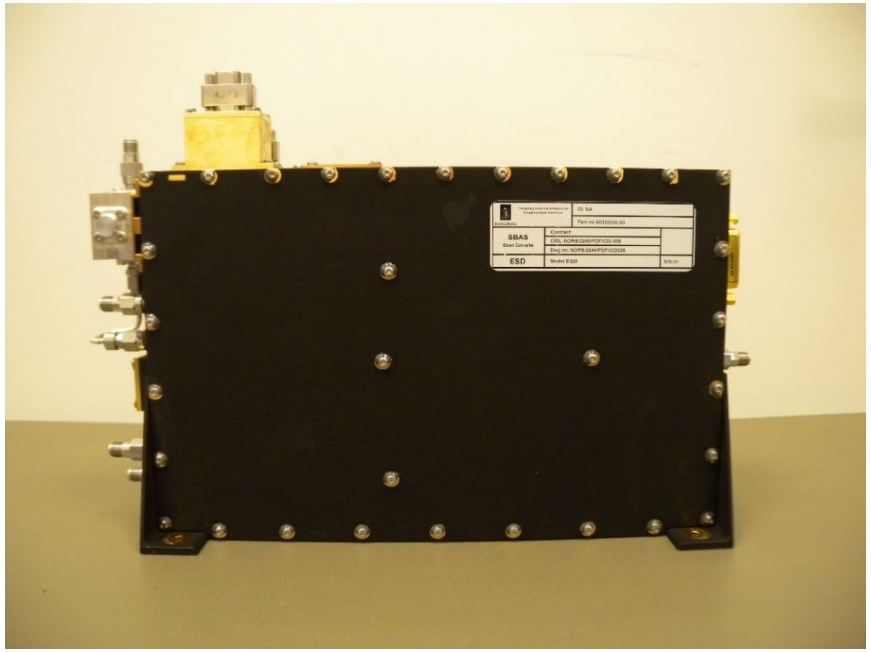


- SBAS DownConverter transforms an uplink signal at C-band to L-band

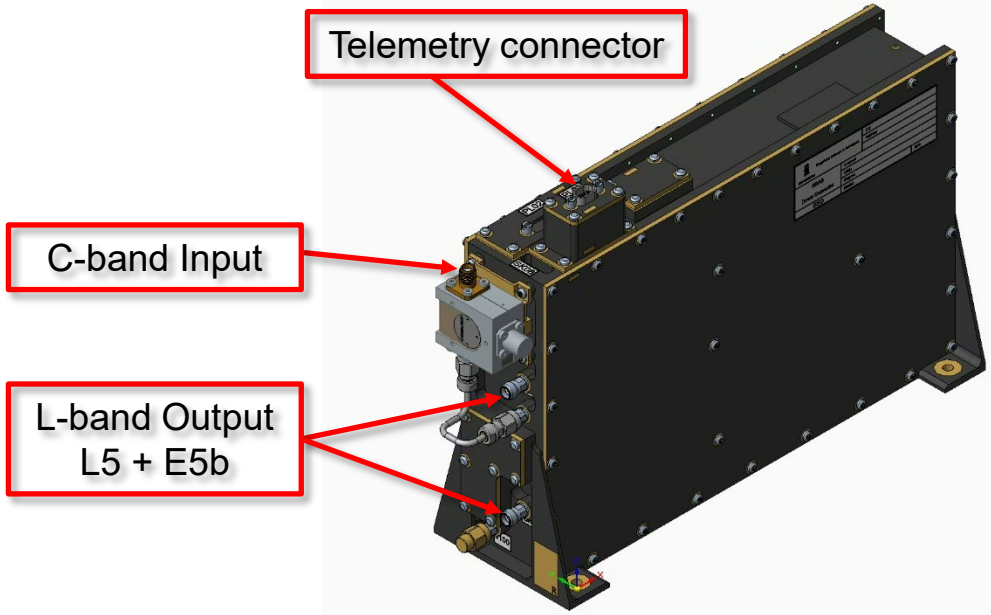


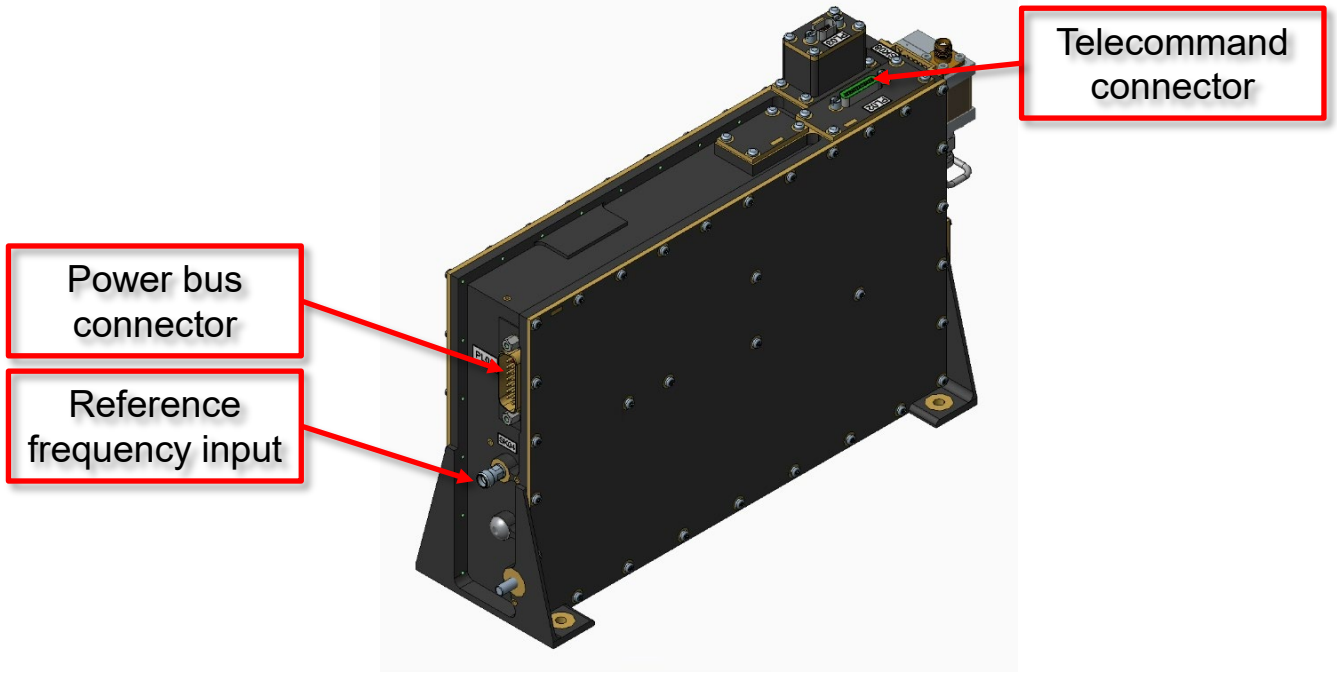

- SBAS configurations:
  - *Dual Channel (L5 and E5a)*
  - *Single Channel (L1)*

# SBAS C to L Downconverter
## Overview

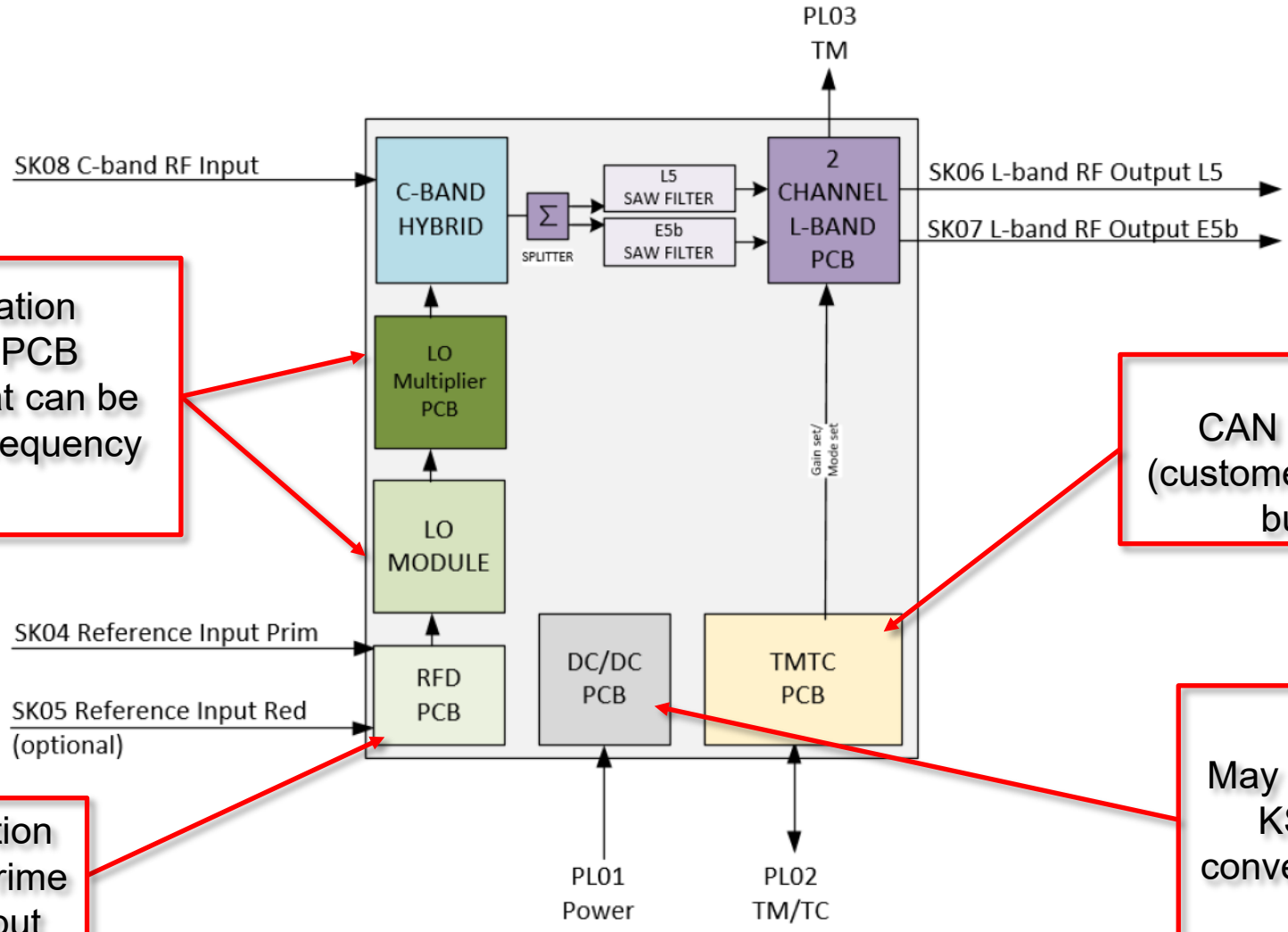


| Physical Size | Value |
|---|---|
| Mass | <1.6 kg |
| Envelope | 262 x 165 x 72 mm (LxHxD) |



# SBAS C to L Downconverter
## Flexibility of design – Modular Approach



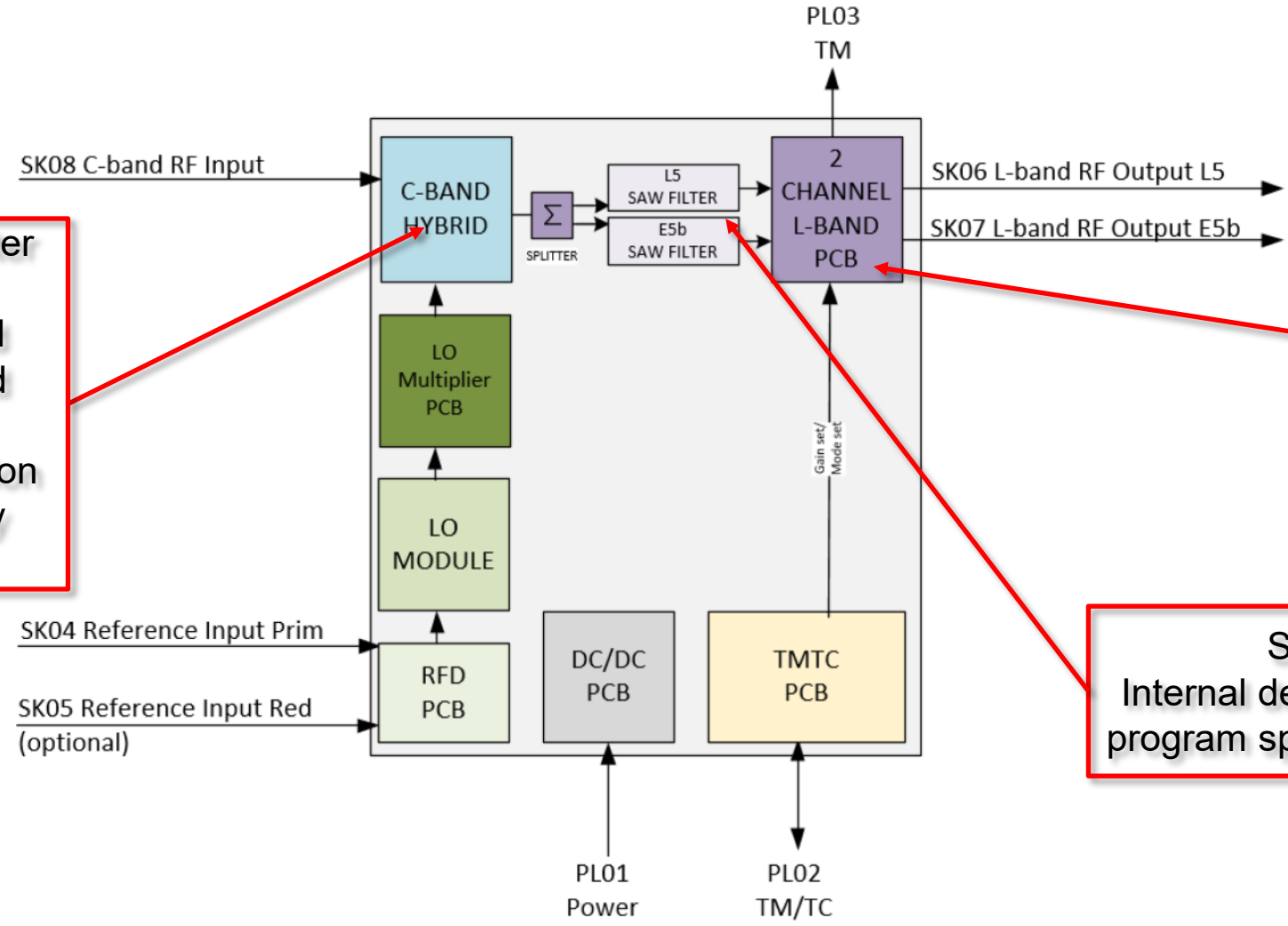

Frequency generation
SPLO / multiplier PCB
Standard designs that can be adjusted to specific frequency plan

TMTC interface
CAN interface is used. Other (customer specific) communication busses are available.

Reference Distribution
PCB prepared for Prime and Redundant input

DCDC Converter
May be replaced with other KSE standard DCDC converters for other satellite bus voltages

# SBAS C to L Downconverter
## Flexibility of design – Modular Approach

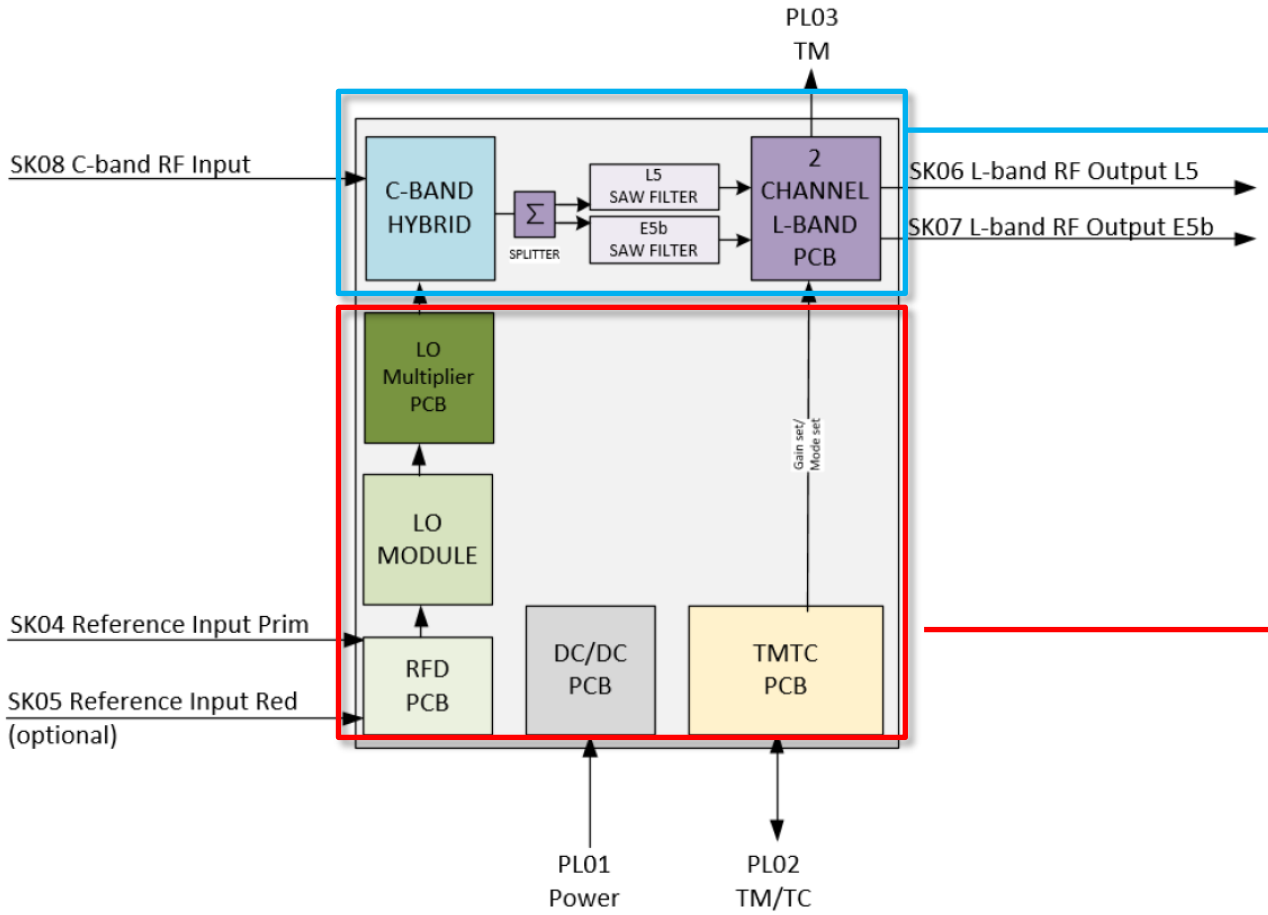



C to L-band Converter hybrid
Based on standard building blocks and filtering.
Similar implementation for other frequency bands (Ku)

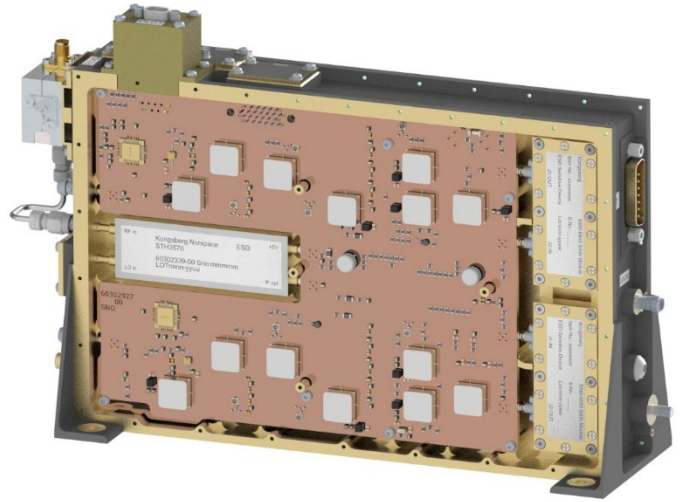
L-band Board
One (L1) or two channels (L5 + E5b) can be populated.
Based on standard hybrid building blocks

SAW filter modules
Internal designs that can be tuned to program specific filtering requirements

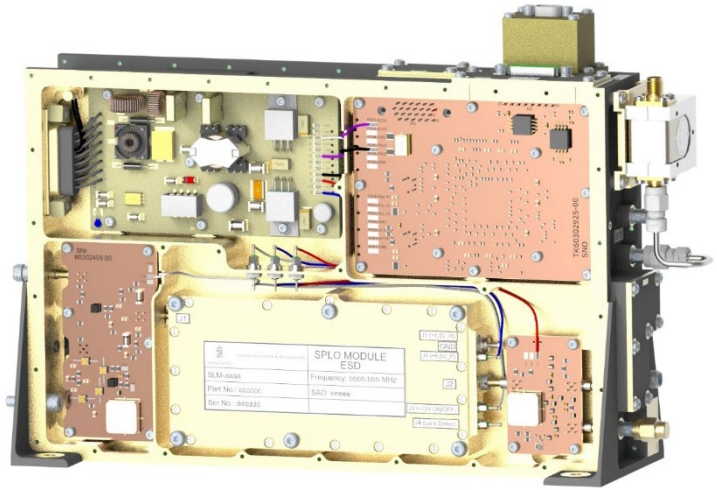
# SBAS C to L Downconverter
## Building blocks




Front side



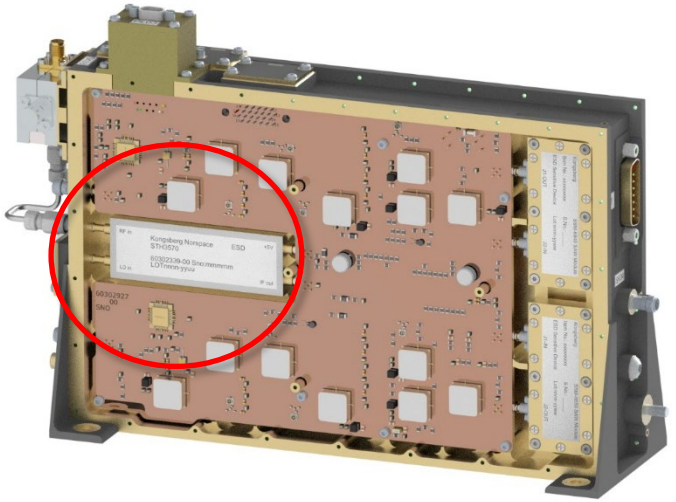
Back side



# SBAS C to L Downconverter
## Building blocks

### RF input section: Down converter Hybrid (C to L-Band)

- The C- to L-Band down converter hybrid converts the C-band input band to L-band with a project specific LO signal.
- Covers the full input band - identical for all Dual Channel and Single Channel SBAS Units.
- A band-pass filter is designed for image band rejection, before the mixing
- A low pass filter has been implemented for LO rejection and RF leakage.

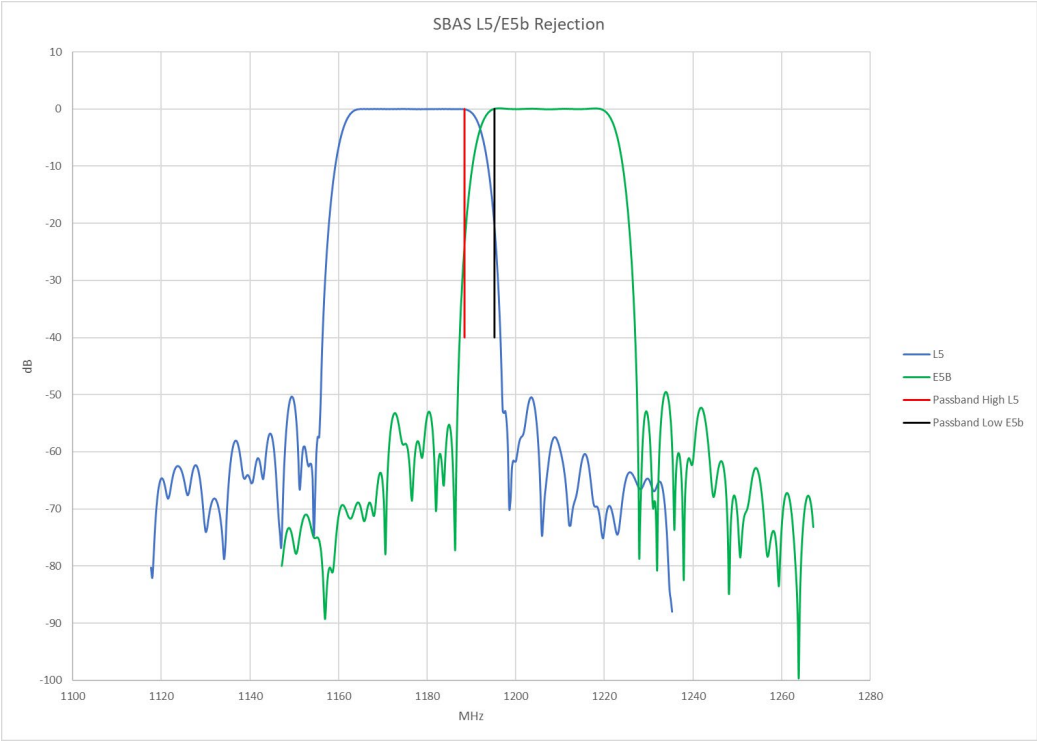


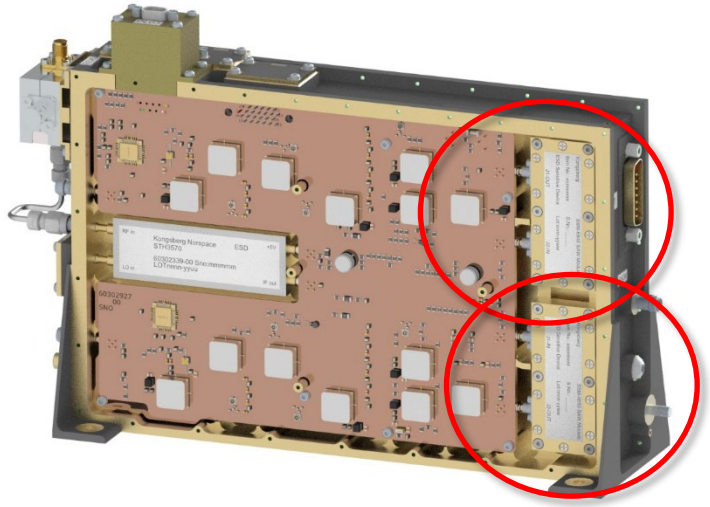
# SBAS C to L Downconverter
## Building blocks

### IF section : SAW filters and L-band PCB

*SAW filters*

- The SAW filtering modules are essential to achieve the desire channelization selecting the appropriate band.



- L5 and E5b band are close in frequency
- Top 2 MHz of L5 band and bottom 2 MHz of E5b band are attenuated worst case 20dB
- Excellent isolation between input and output

# SBAS C to L Downconverter building blocks

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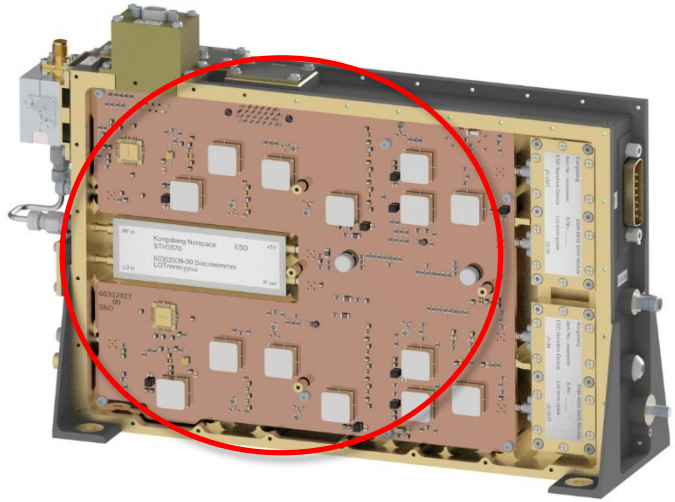


**IF section : SAW filters and L-band PCB**

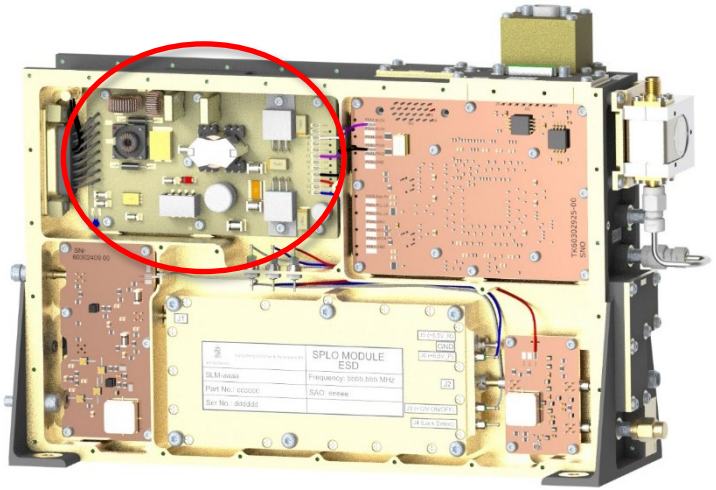
*L-band PCB*

- The output section of SBAS C – L Downconverters consists of the L-Band PCB, and provides further signal conditioning and filtering of the L-band signal.
- Features of L-band PCB:
  - Splitter for the combined bands into L5 and E5b bands
  - Automatic Control Loop (ALC) mode providing constant output power
  - Digitally controlled gain adjustments for both channels
  - Gain amplifiers sections and further filtering for harmonics for both channels
  - Analog telemetries for both channels:
    - Output Power telemetry
    - ALC Gain telemetry

# SBAS C to L Downconverter
## Building blocks

### DCDC converter

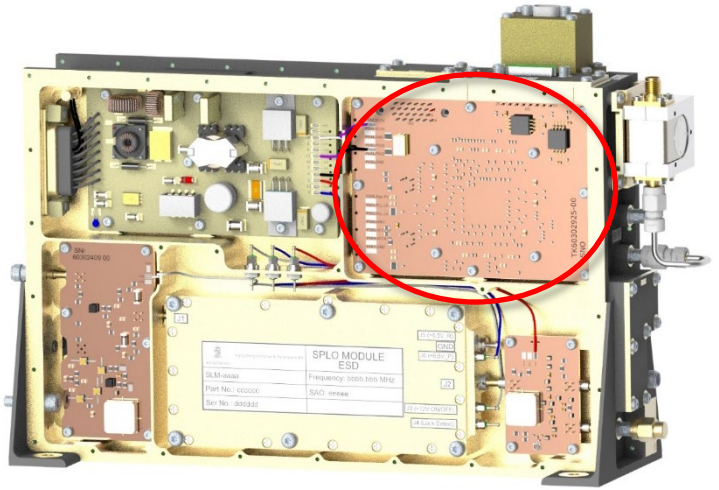
- The DC/DC converter is supplied from the Primary Bus through an input filter for damping of the ripple current towards the bus and the ripple voltage towards the converter. A Fly-back converter supplies all the outputs to the secondary voltages.
- The DC/DC includes:
  - Galvanic isolated telecommand interface for Tele-Command, Status Telemetry and Start-Up
  - Primary Under-Voltage Protection (UVP)
  - Protection from permanent short circuit from the load to the bus
  - Linear Regulators for secondary voltages that supply the unit



# SBAS C to L Downconverter
## Building blocks

### TMTC section

- The TM/TC section receives commands and transmits telemetry over a CAN-bus interface
- Main function of the CAN-bus interface:
  - Mute selection for both L5 and E5b channels
  - FGM/ALC selection for both L5 and E5b channels
  - FGM (Fixed Gain Mode) Gain step selection
  - ALC output power step selection



# SBAS C to L Downconverter
## Building blocks

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### LO section

- The LO signal for the down converting mixer is generated by phase and frequency locking to the 10MHz reference frequency.

*RFD PCB:*

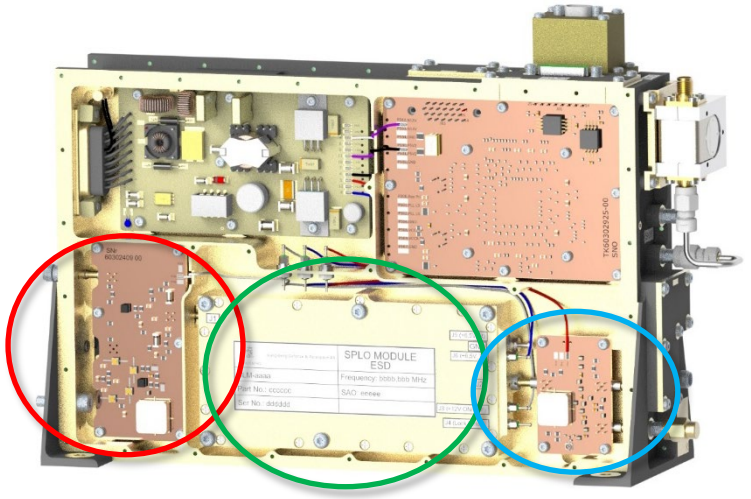
- provides a stable reference level to the SPLO Module over the specified MRO input levels.

*SPLO module:*

- phase-locks onto the 10MHz reference signal and provides an exact multiple of the reference frequency.

*LO Multiplier PCB:*

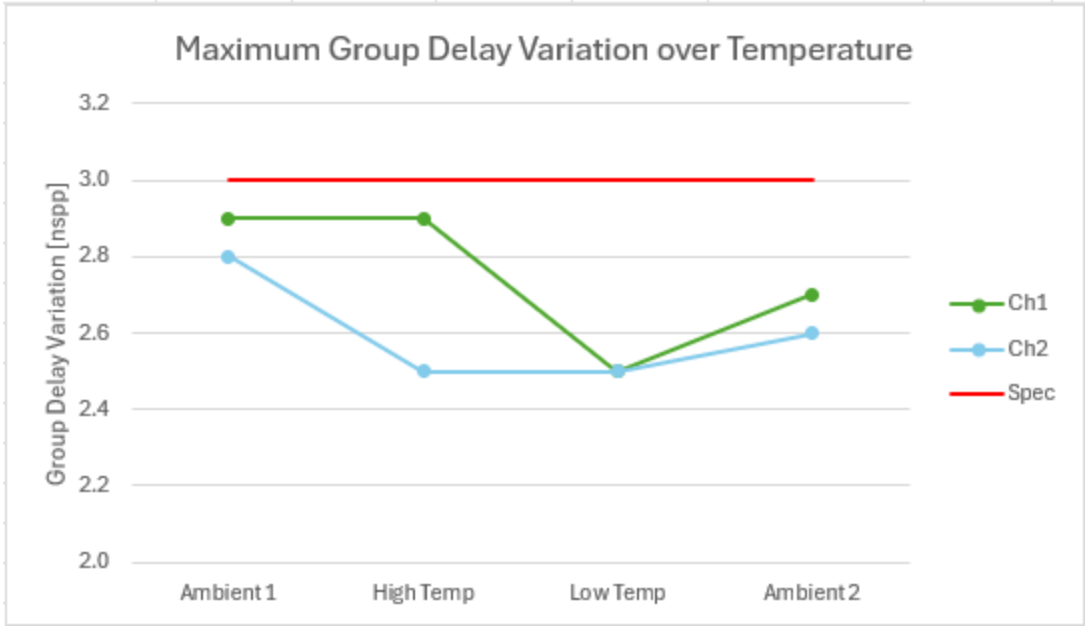
- Multiplies the LO signal further before the LO signal enters in the Hybrid for mixing.

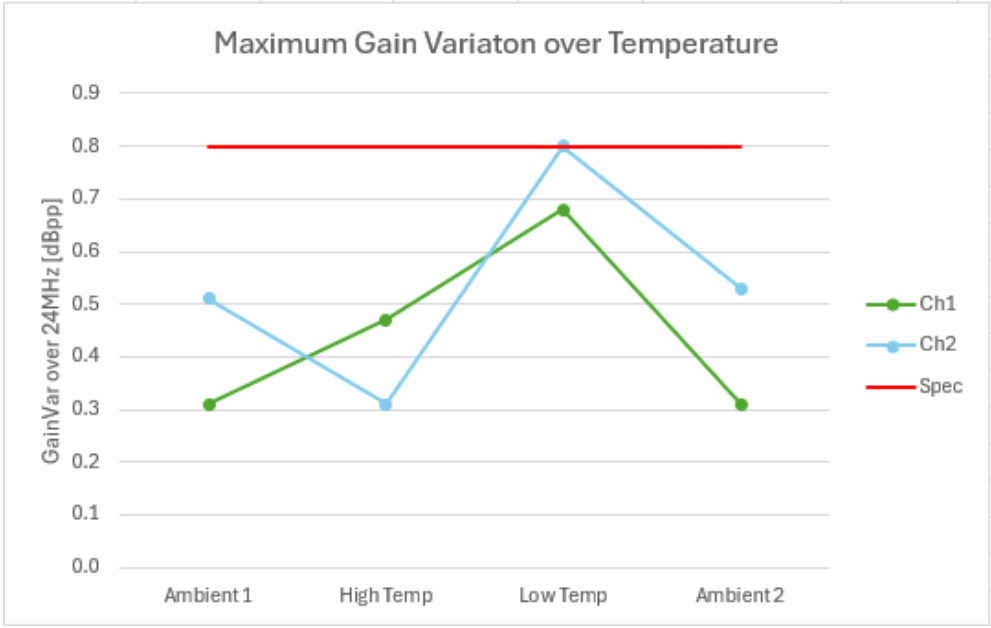


# SBAS C to L Downconverter
## Performances

- Stability over temperature
  - Gain and Output Power

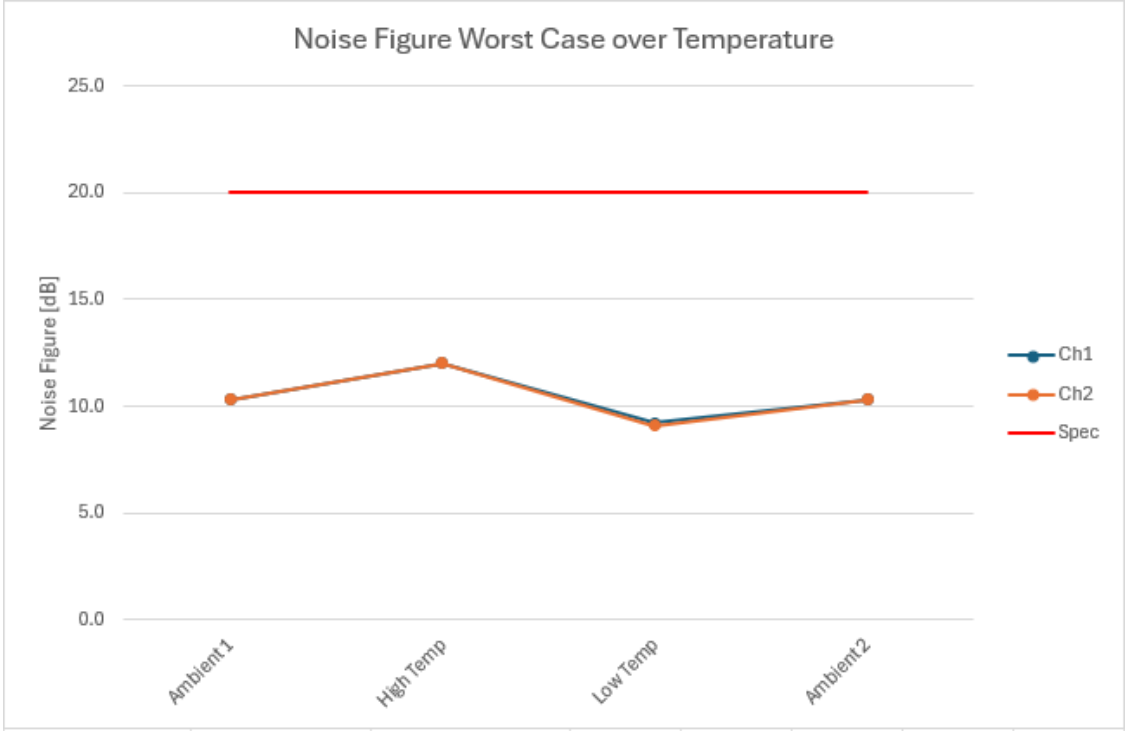
| | | CH1 | CH2 | Unit |
|---|---|---|---|---|
| FGM | Gain Variation per degree (worst case states 1-63) | 0.023 | 0.016 | dB/°C |
| | Gain var temp (worst case) | 1.4 | 1.1 | dB |
| ALC | Output power var temp (worst case) | 1.2 | 1.0 | dBm |



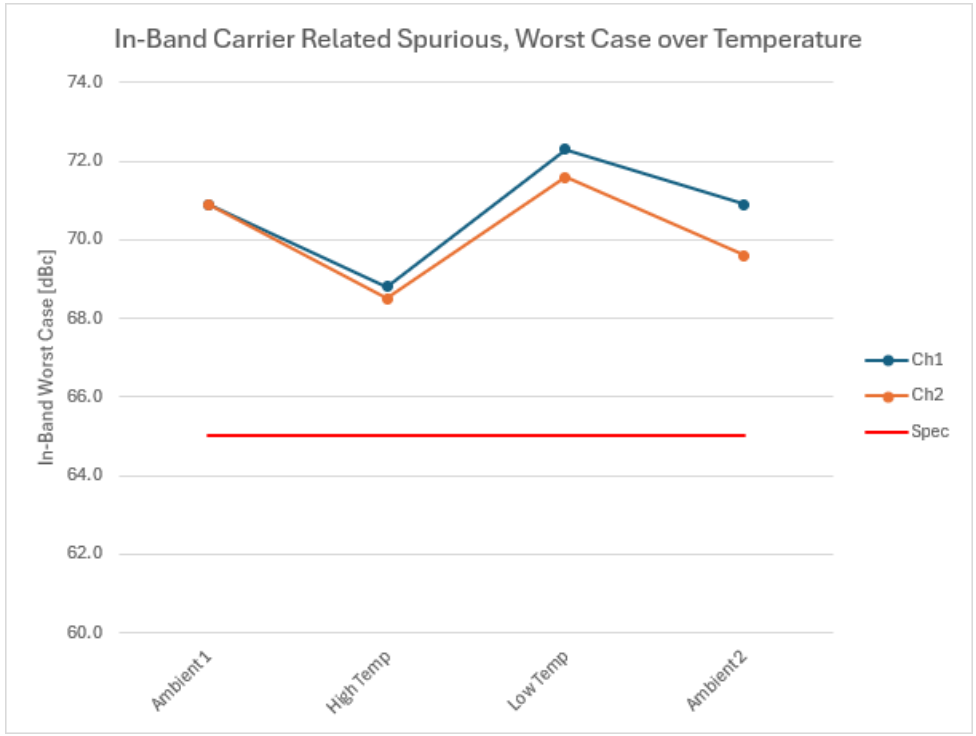
# SBAS C to L Downconverter
## Performances

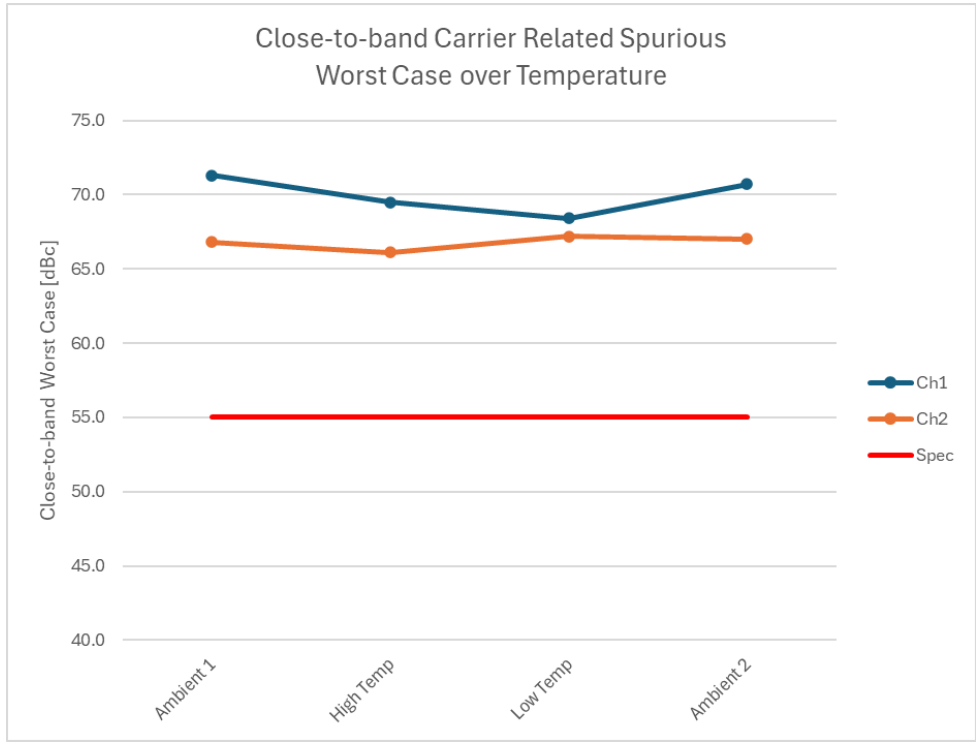
- Noise Figure



# SBAS C to L Downconverter
## Performances

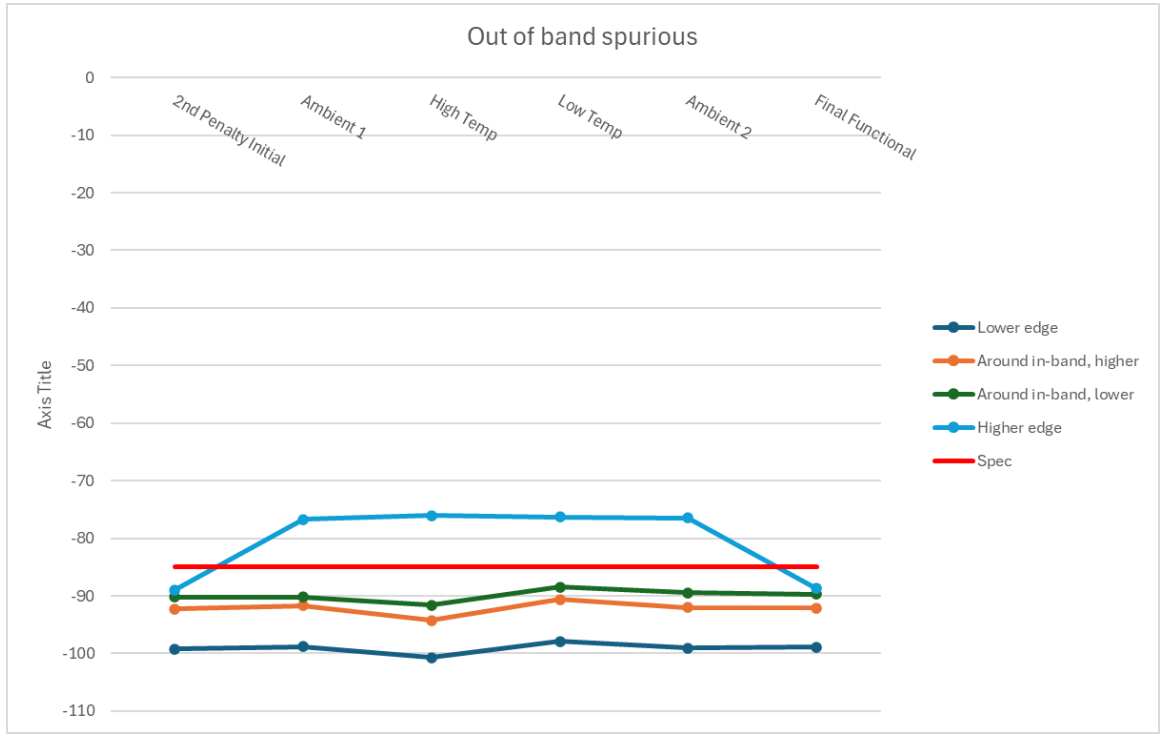
- Spurious



# SBAS C to L Downconverter
## Performances

- Spurious




# SBAS C to L Downconverter
## Performances

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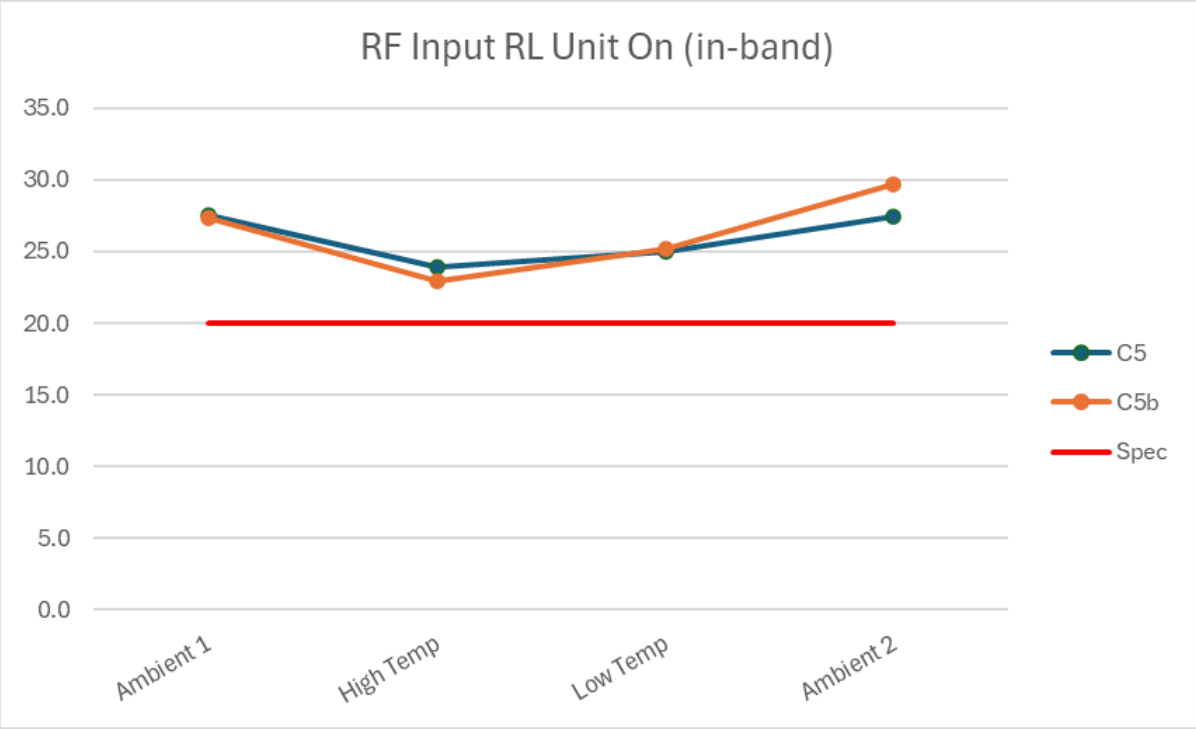
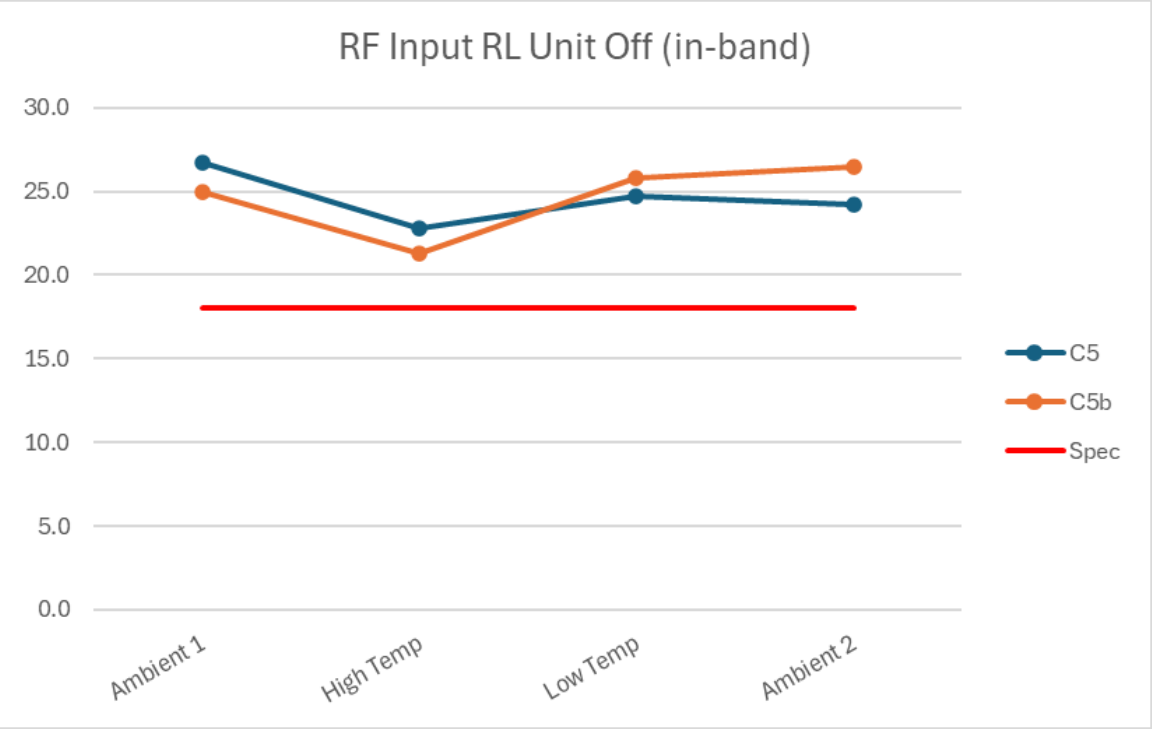
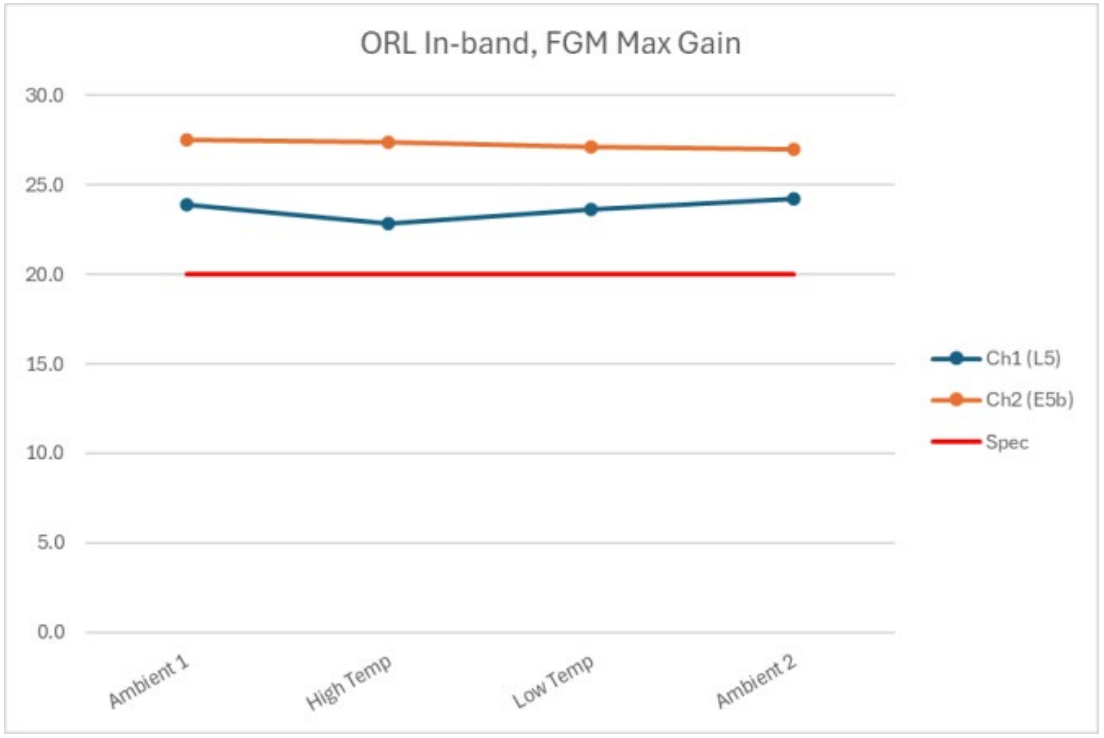
- Return Loss: input

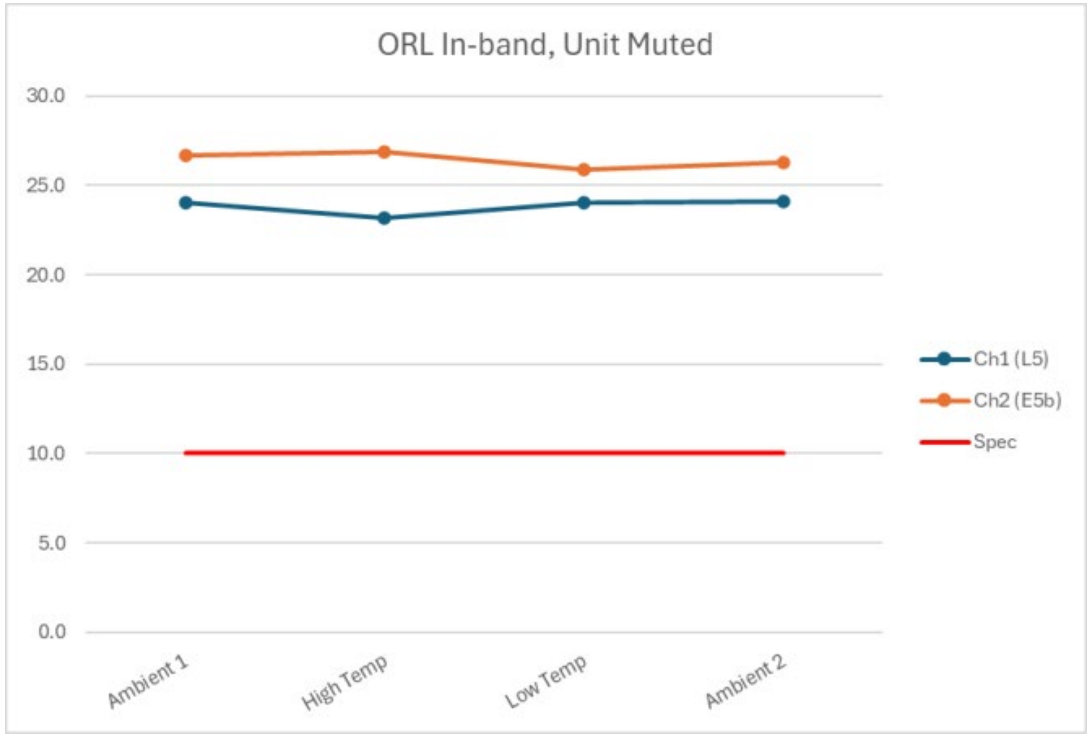


# SBAS C to L Downconverter
## Performances

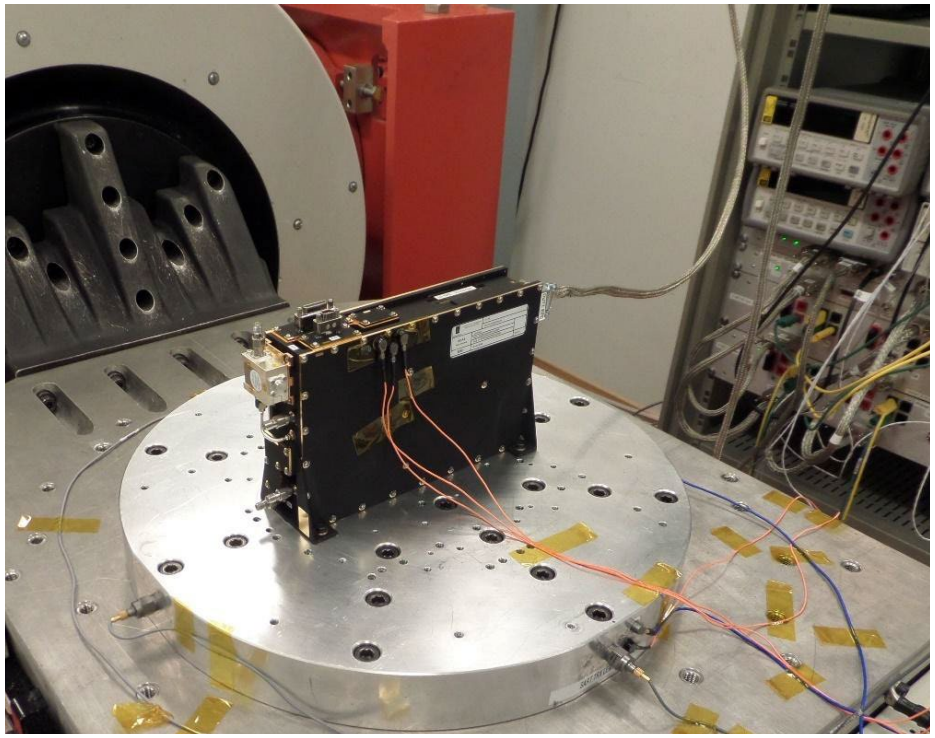
- Return Loss: output

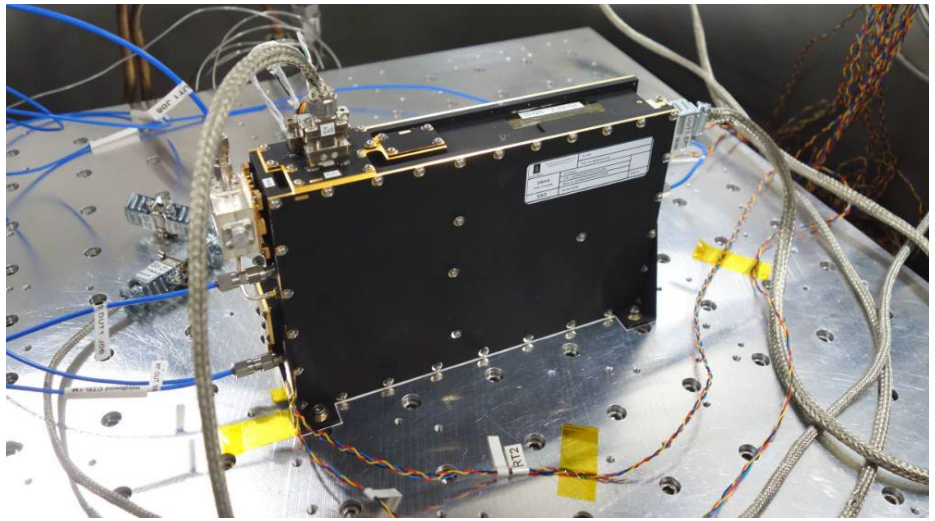


# Qualification Campaign

- Initial Electrical Test
- Vibration Test (Sine & Random)
  - Post Vibration Test
- Shock Test
  - Post Shock Test
- TVAC campaign
- EMC/ESD
- Final Electrical Test





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# Qualification Levels

## Vibration Test

**Table 3-1 Sinusoidal vibration levels**

| Sweep Rate | Frequency | Level |
|---|---|---|
| 2 oct/min | 5 Hz – 20 Hz | 11mm |
| | 20 Hz – 100 Hz | 20g |

**Table 3-2 Longitudinal vibration levels**

| Frequency | Level |
|---|---|
| 10 Hz – 20 Hz | +15.5 dB/octave |
| 20 Hz | 0.075 $g^2$/Hz |
| 90 Hz – 300 Hz | 1.5 $g^2$/Hz |
| 440 Hz | 0.23 $g^2$/Hz |
| 440 Hz – 2000 Hz | -5.3 dB/octave |
| Overall level | 23.25 $g_{RMS}$ |

**Table 3-3 Lateral vibration levels**

| Frequency | Level |
|---|---|
| 20 Hz – 100 Hz | +3 dB/octave |
| 100 Hz – 400 Hz | 0.16 $g^2$/Hz |
| 400 Hz – 2000 Hz | -5.2 dB/octave |
| Overall level | 10.8 $g_{RMS}$ |

## Shock Test

**Table 3-4 Shock levels**

| Frequency [Hz] | SRS [g] |
|---|---|
| 100 | 30 |
| 1000 | 1500 |
| 10 000 | 1500 |

## Thermal Vacuum Campaign

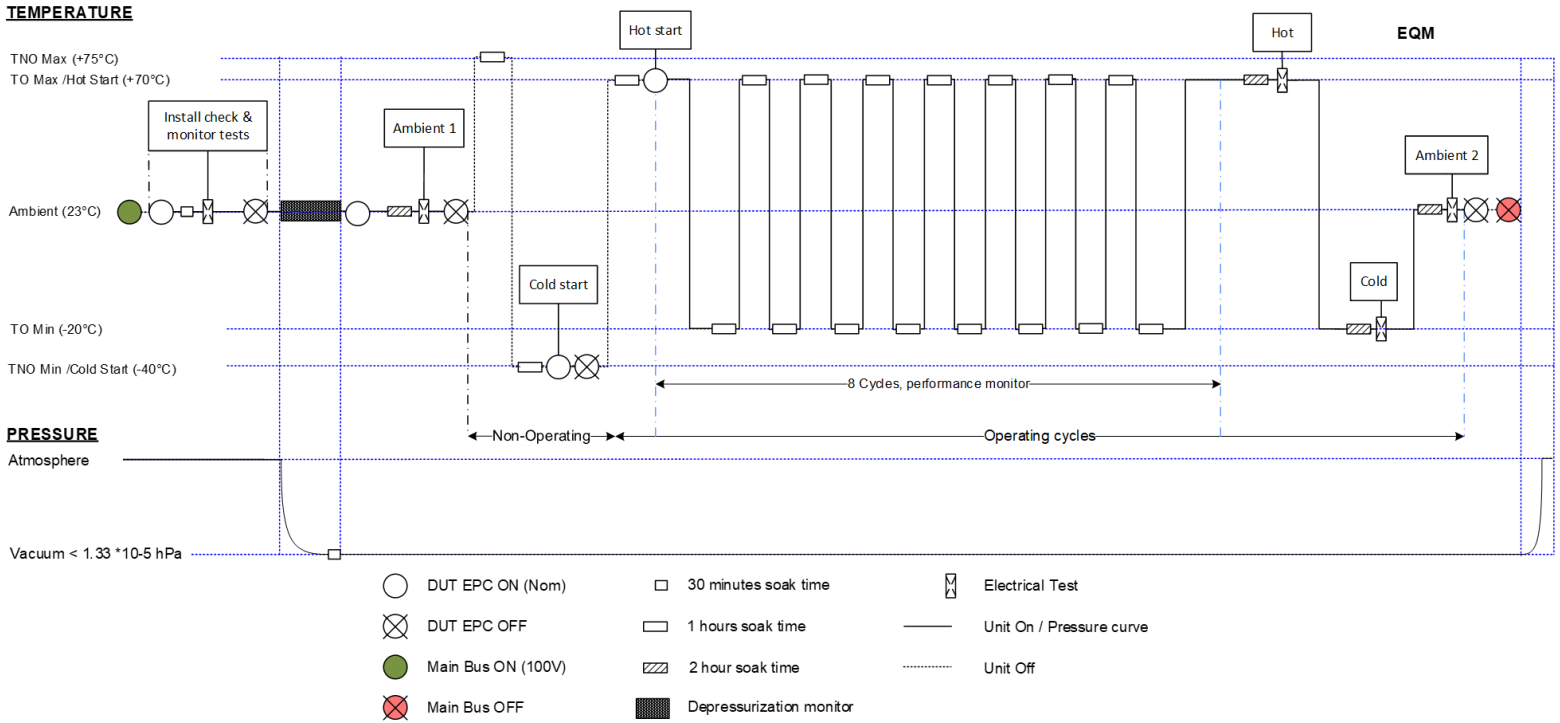


**Figure 3-1 EQM TVAC Profile**

**Table 7-2 Down Converter temperature ranges.**

| Condition | Temperature (°C) |
|---|---|
| Operating | -10 to +60 |
| Operating, Acceptance | -15 to +65 |
| Operating, Qualification | -20 to +70 |
| Non-Operating | -40 to +75 |
| Qualification Cold Start | -40 |

# Conclusions

- With the development of the SBAS DownConverter Unit
  - Kongsberg Space Electronics has further strengthened its competitive position within the market for navigation equipment.
  - Qualified a competitive and flexible product that already has resulted in flight contracts.

  - All in all, the outcome of this program has been very useful for Kongsberg and shows excellent use of ESA funding.

# Acknowledgement


- Kongsberg Space Electronics thanks ESA and in particular Technical Officer **Ricard Codina** and his team for the good cooperation and fruitful discussions during the program!


Thank You!
KONGSBERG