6TH SPACE PASSIVE COMPONENT DAYS - SPCD 2026
13-16 October 2026 | ESA/ESTEC
Noordwijk, The Netherlands

# Space Preliminary Evaluation Testing of Advanced Piezo on Insulator Technology

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# Space Preliminary Evaluation testing of advanced POI

## Presentation overview

1. ALTER presentation
2. Contest & background
3. Device and Performances
4. Preliminary Evaluation Testing Flow & Results
5. Conclusion - Further Steps



# ALTER PRESENTATION

- Part of the TÜV NORD Group, with more than 30 years of experience in the space sector.
- Extensive involvement in major space missions, including BepiColombo, JUICE, Solar Orbiter, Euclid, Sentinel-3, Meteosat and Galileo.
- Specialized in Product Assurance and technical advisory services, including support to DLR.
- Parts Procurement Agency Coordinator for numerous ESA missions, including PLATO, ARIEL, EnVision and LISA.
- Comprehensive testing capabilities, covering RVT, Lot Validation Testing, Screnning, Physical Analysis, RF testing and cryogenic testing.
- Development of innovative engineering services and tools, such as DoEEEt, VirtualLab and PRECEDER.
- Development of innovative technologies and execution of R&D projects focused on advanced testing capabilities, new methodologies and Innovative solutions for high-reliability applications.

# Space Preliminary Evaluation testing of advanced POI



Funded by
the European Union

## Context and background

### Homemade:

- High Q factOr MiniaturizEd low Mass (Accoustic) filters for highly DEmanding space applications

### Funding:

- HORIZON EUROPE Project No.101081785, Horizon-CL4-2021-SPACE-01

### Ambition:

- To **assess the reliability of SAW filters** for use in **space applications.**

### Objectives:

- Focus on developing a **new generation of Surface Acoustic Wave (SAW) filters** based on Piezo-On-Insulator (POI).
- **New Space SAW filters :** 5G NTN applications (S band and L+S)
- Deliver **space-qualified POI-based SAW filters** up to TRL 7.

# Space Preliminary Evaluation testing of advanced POI

## Context and background

- ❑ Evaluation of POI-based SAW technology to harsh environmental conditions.

- Study the constructions and limitations of the technology in terms of device reliability.
- Feed module design with deeper knowledge of the technology and its limitations.

- ❑ Qualify L/S band POI based SAW filters up to TRL7.

- ❑ **Preliminary Evaluation of the Advanced POI Technology.**



# Space Preliminary Evaluation testing of advanced POI

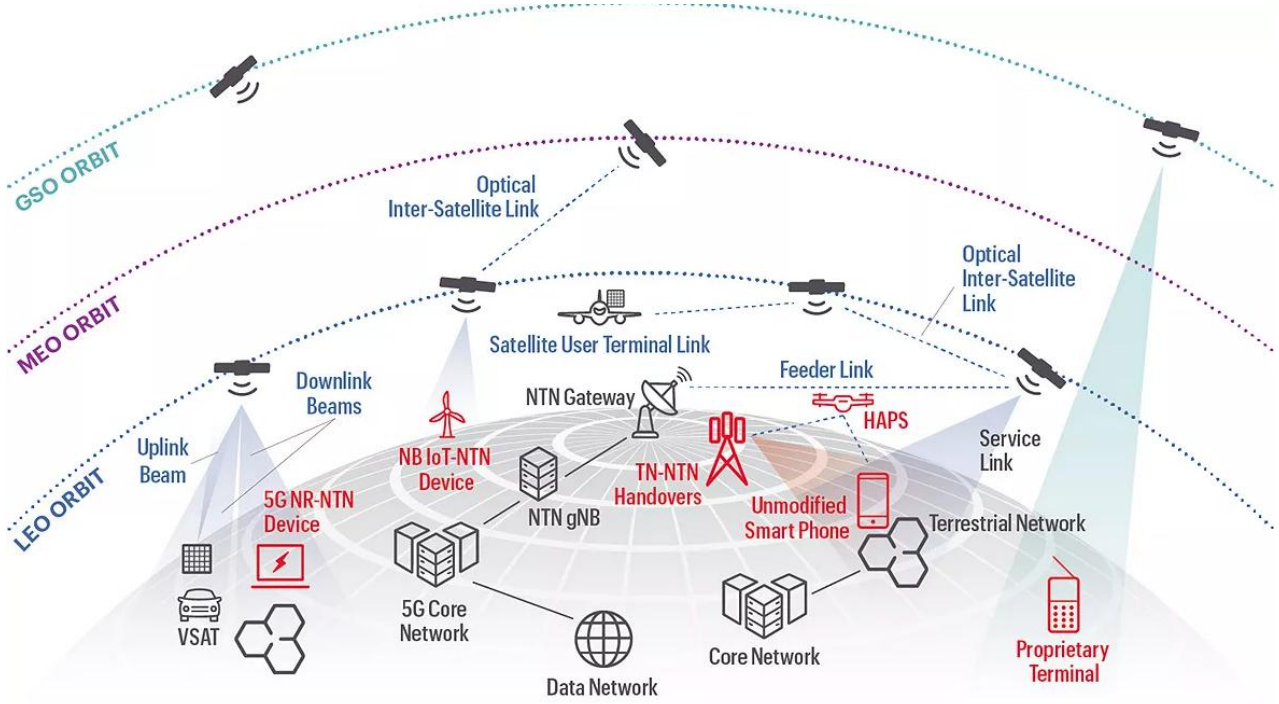
**High selectivity**
- Sharp isolation of the desired frequency bands
- Minimize adjacent channel interference

**Wide NTN support**
- Must accommodate wide 5G channels
- Support for multiple frequency bands (L, S, $K_a$, ...)

**Frequency stability**
- Maintain performance under space conditions (temperature variations, ...)

**High Power handling**
- Necessary for satellite transmit chains (prevent signal distortion)

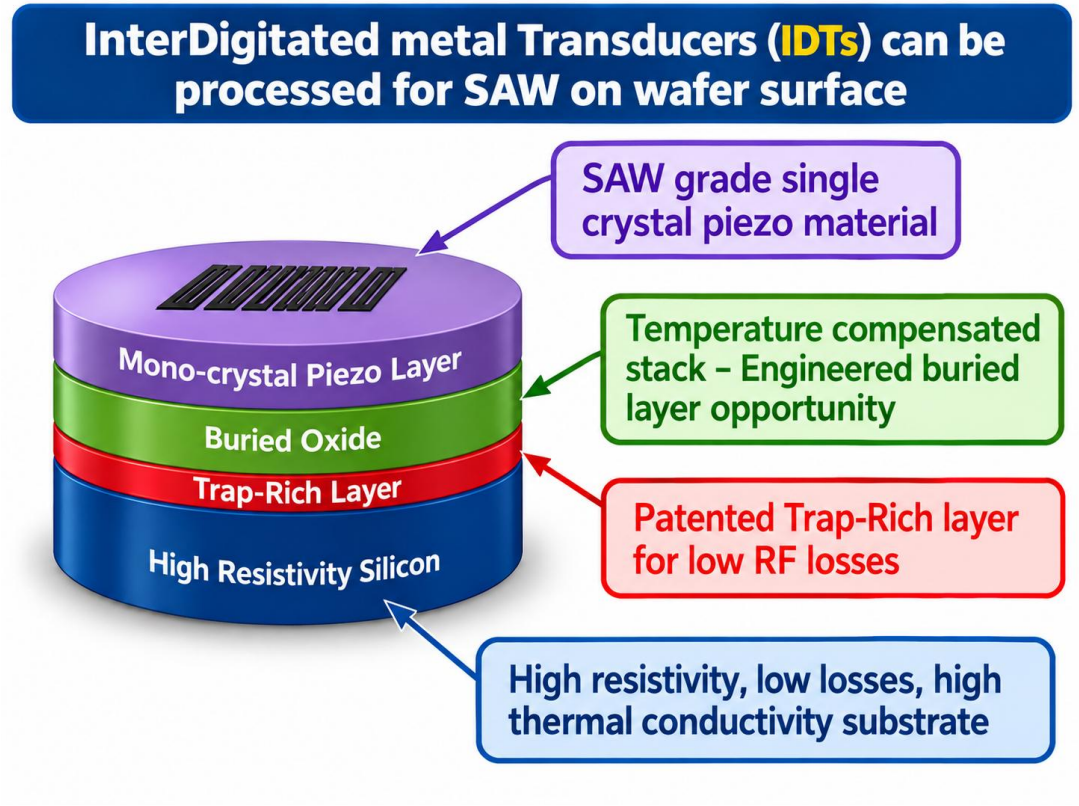
**Low insertion loss**
- Preserve weak signals received from space
- Direct impact on link budget and overall system performance




**Mains technical requirement for NTN filters**

# Space Preliminary Evaluation testing of advanced POI

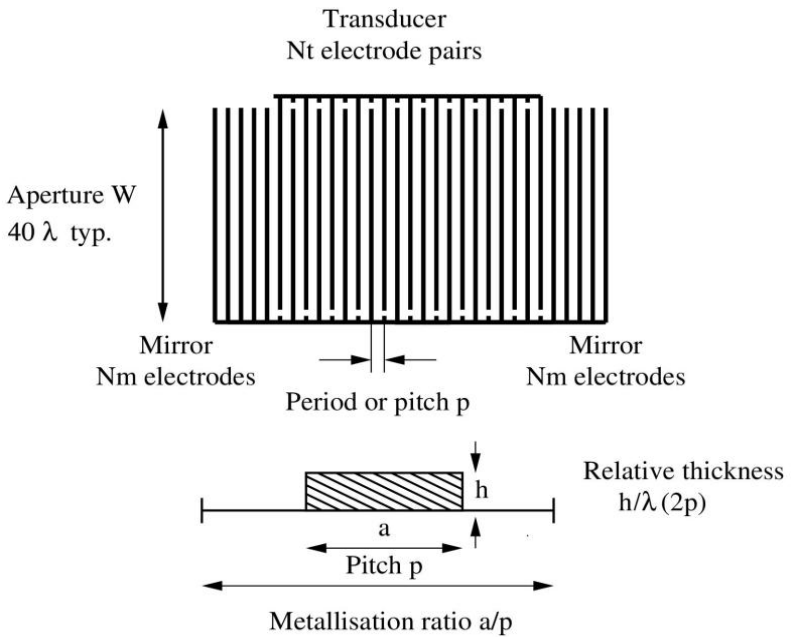
- ✓ POI substrates combine a thin piezoelectric layer with a silicon substrate.
- ✓ Smart-Cut™ enables the transfer of single-crystal $LiTaO_3$ or $LiNbO_3$ layers.
- ✓ A trap-rich layer reduces parasitic surface conduction and acoustic energy losses.
- ✓ POI waveguides enable coupling and reflection coefficients above 10%.
- ✓ Q factors can reach up to 5000 at 2 GHz.

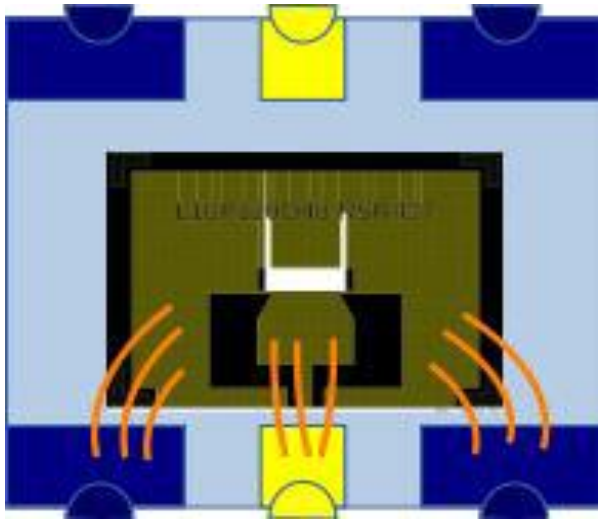



Typical structure of a POI substrate, combining a top piezoelectric layer on a Buried Oxide, a Si base substrate equipped with a **Trap-rich layer** and role of each stack element

# Space Preliminary Evaluation testing of advanced POI

## DEVICE DESIGN AND PERFORMANCES





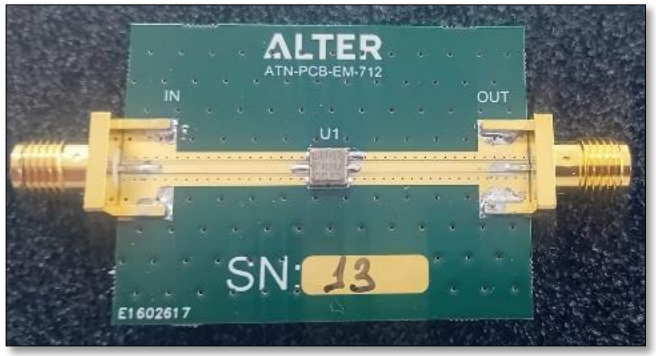

Saw resonator with 120 finger pair….

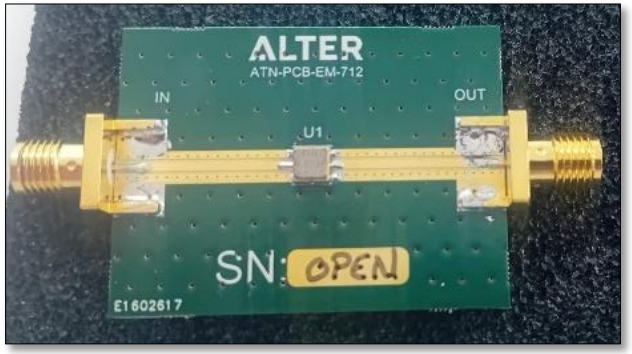
Assembly using the 3.8SQ package

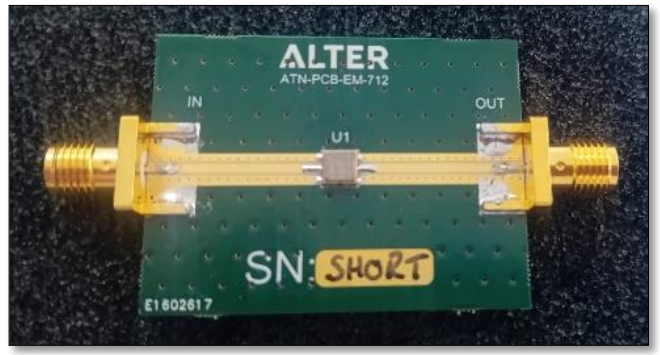
Packaged DUT

# Space Preliminary Evaluation testing of advanced POI

## DEVICE DESIGN AND PERFORMANCES



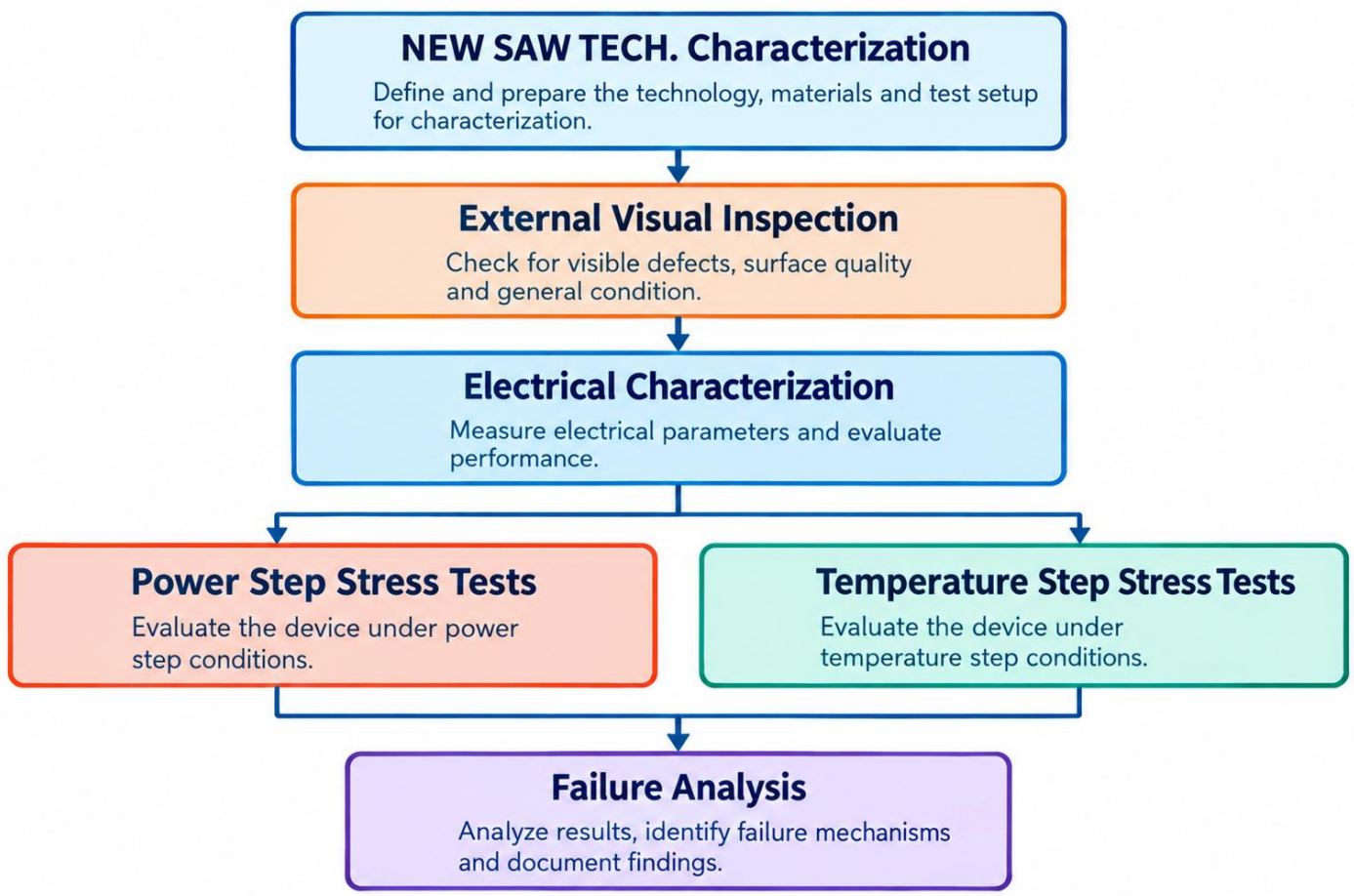

PCB for testing SAW resonators, featuring a soldered device under test, with open–short de-embedding standards

| New Trap-Rich - W92 | | $f_{res}$ (MHz) | $f_{Ares}$ (MHz) | $Q_{res}$ | $Q_{Ares}$ | $Q_{Bode}$(fit) | $K_s^2$(%) |
|---|---|---|---|---|---|---|---|
| Embedding | mean | 1596.3 | 1671.8 | 319.3 | 2708.3 | 2403.8 | 8.83 |
| | Std | 0.807 | 0.557 | 29.8 | 428.8 | 22.3 | $4.1 \times 10^{-2}$ |
| De-Embedding | mean | 1602.8 | 1674.0 | 990.0 | 2073.3 | 3960.3 | 8.32 |
| | std | 7.2996.e-01 | 0.628 | 171.8 | 182.8 | 88.1 | $2.9 \times 10^{-2}$ |

**Figures of Merit (FoM) to consider for the resonators to be tested**

# Space Preliminary Evaluation testing of advanced POI

## EVALUATION TESTING




**ESCC 2263502 “EVALUATION TEST PROGRAMME FOR SURFACE ACOUSTIC WAVE (SAW) DEVICES”**

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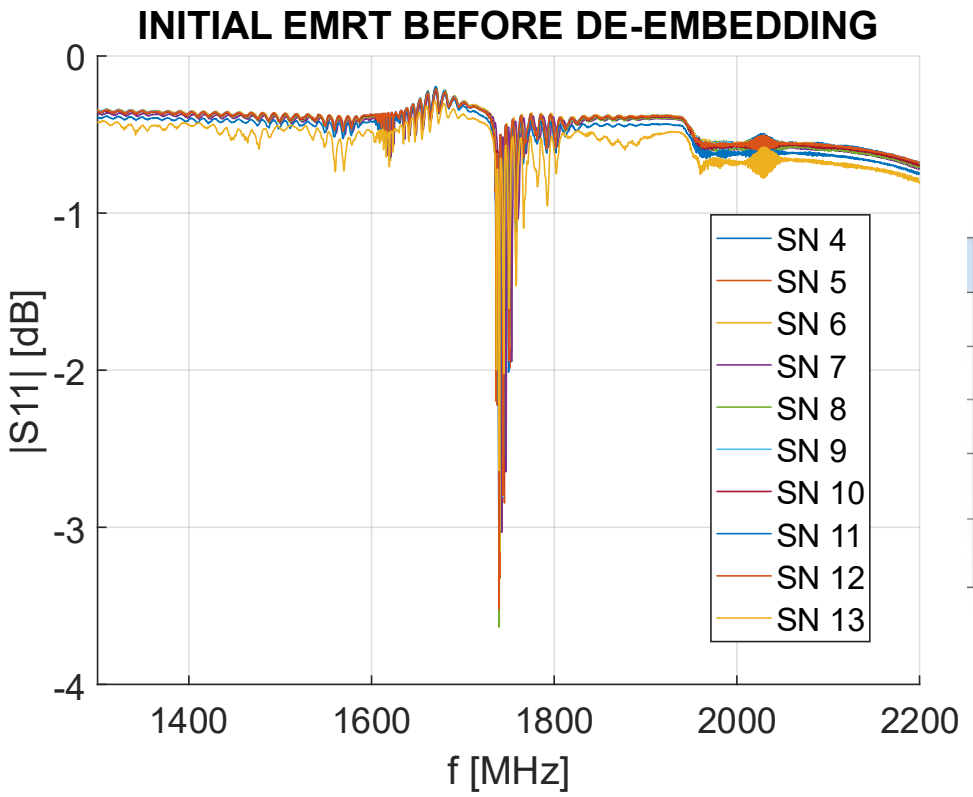
# Space Preliminary Evaluation testing of advanced POI

## EVALUATION TESTING

**ELECTRICAL CHARACTERISATION**

**TEMPERATURE STEP STRESS TESTS**

**POWER STEP STRESS TEST**




| Parameter | Equation | Description |
|---|---|---|
| $S_{11}$ | $S_{11}$ | Input return loss |
| $f_{res}$ (MHz) | $f_{res}$ | Resonance frequency |
| $f_{ares}$ (MHz) | $f_{ares}$ | Anti-resonance frequency |
| $K_s^2$ | $k_s^2 = 1 - \left(\frac{f_r}{f_a}\right)^2$ | Electroacoustic Coupling Coefficient |
| $Q_{Bode}$ | $Q_{Bode} = \frac{\omega\lvert S_{11}\rvert\tau_g}{1-\lvert S_{11}\rvert^2}, \quad \tau_g = \frac{\partial\phi}{\partial\omega}$ | Bode quality factor |

S11 initial measurement → Y11 and Z11 parameters → De-embedding Process → FoM

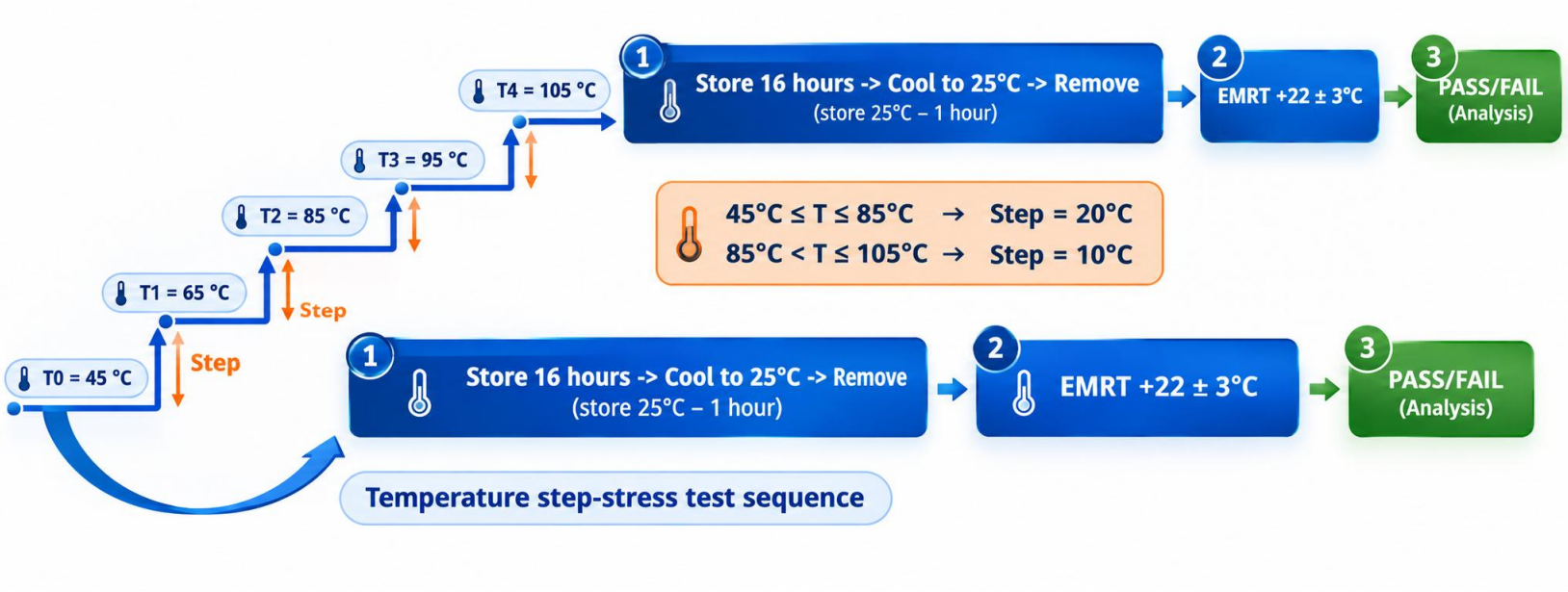
# Space Preliminary Evaluation testing of advanced POI

## EVALUATION TESTING

**ELECTRICAL CHARACTERISATION**

**TEMPERATURE STEP STRESS TEST**

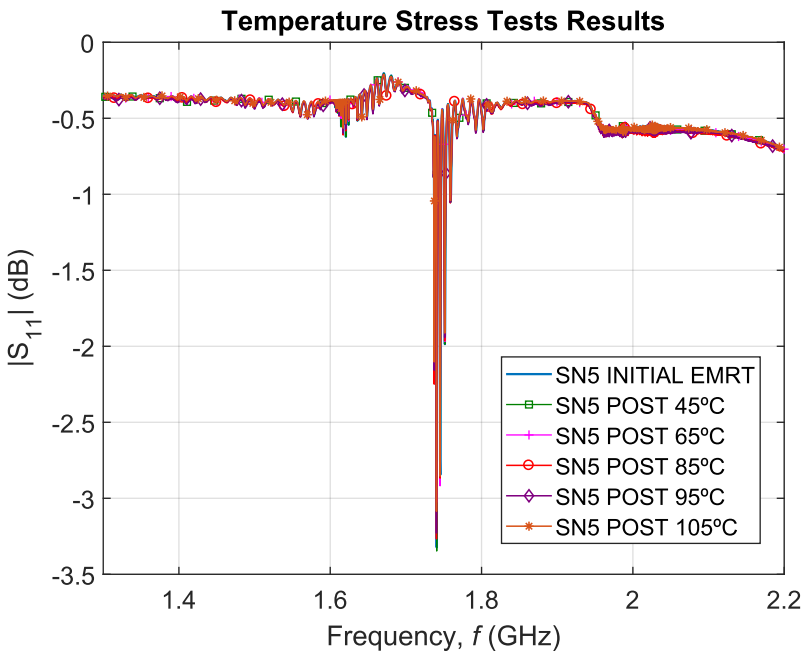
**POWER STEP STRESS TEST**

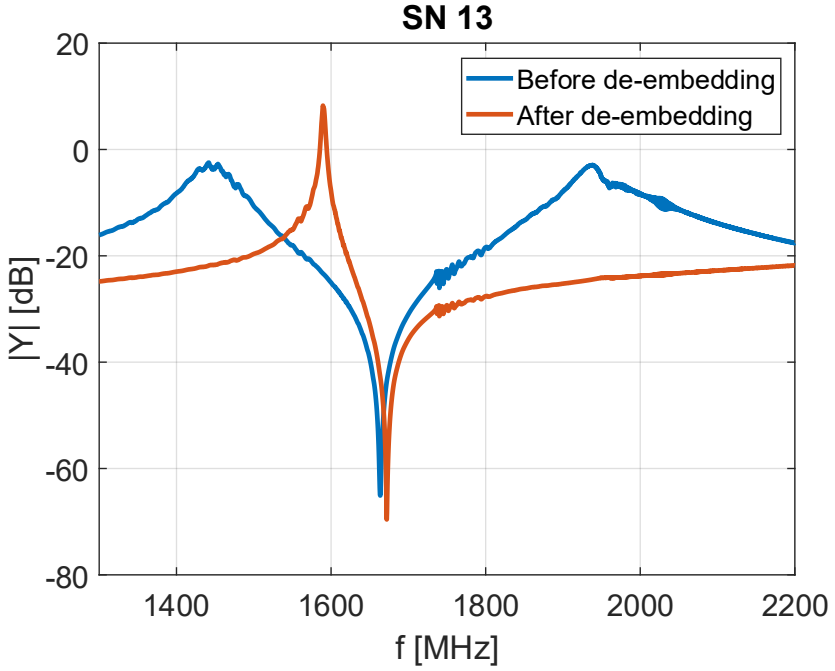



Temperature step-stress test sequence

# Space Preliminary Evaluation testing of advanced POI

## EVALUATION TESTING - Results




| Parameter | Equation | Description |
|---|---|---|
| $S_{11}$ | $S_{11}$ | Input return loss |
| $f_{res}$ (MHz) | $f_{res}$ | Resonance frequency |
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| $K_s^2$ | $k_s^2 = 1 - \left(\frac{f_r}{f_a}\right)^2$ | Electroacoustic Coupling Coefficient |
| $Q_{Bode}$ | $Q_{Bode} = \frac{\omega\lvert S_{11}\rvert\tau_g}{1-\lvert S_{11}\rvert^2}, \quad \tau_g = \frac{\partial\phi}{\partial\omega}$ | Bode quality factor |

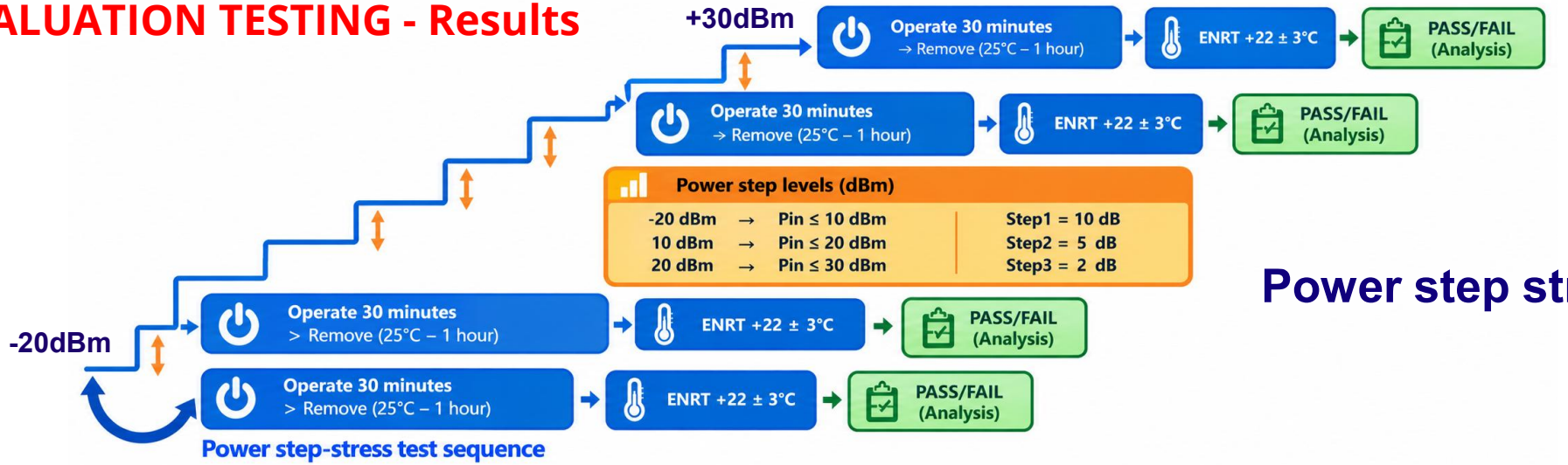
S11 measurement Pre and post TST

De-embedding Process

FoM

# Space Preliminary Evaluation testing of advanced POI

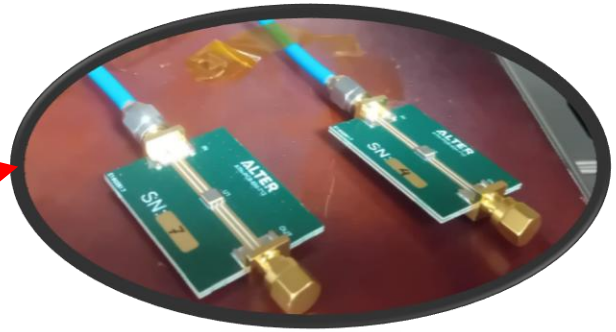
## EVALUATION TESTING - Results



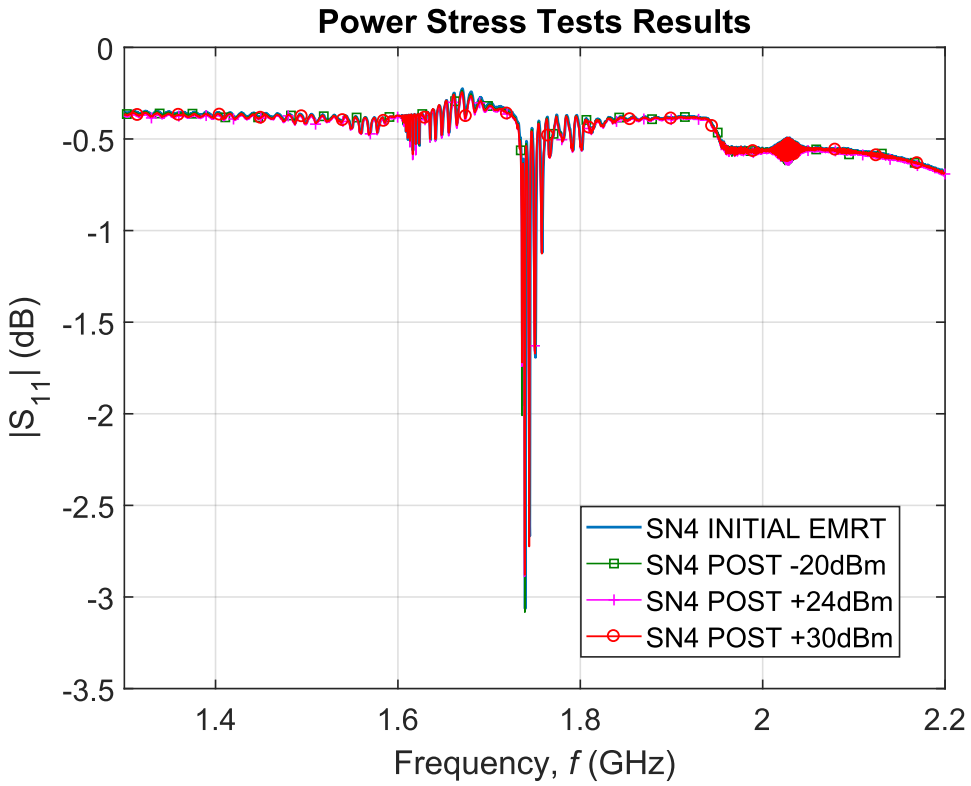

**Power step stress test sequence.**



**Pictures of the samples Inside the test chamber for power step-stress test**



# Space Preliminary Evaluation testing of advanced POI




- **S11 measurements during power step-stress testing, from the initial step through the final +30 dBm step**
- **FoM are extracted from the S11 data of the samples, as well as open and short measurements using a MATLAB-based analysis code.**

S11 Measurement post PST → De-embedding Process → FoM

# Conclusions

- **Preliminary Evaluation testing activities on SAW resonator using a stress-based methodology to identify potential failure modes under progressively increasing thermal and RF excitation.**
- **All tested resonators remained fully operational throughout the complete TST and PST stress sequences, with no failures or significant degradation observed.**
- **FoM parameters remained stable and repeatable, within the expected measurement uncertainty.**
- **FoM extraction is sensitive to the de-embedding procedure and its theoretical assumptions; therefore, the de-embedding methodology is being refined before reporting final parameters values.**
- **Future work will focus on larger sample populations, filter-level implementations, and higher-TRL qualification.**

# Acknowledgements


- **HOMEMADE PROJECT**
- **All HOMEMADE partners – valuable contributions and collaboration**
- **SOITEC Innovation Group - key role in the fabrication of advanced POI wafers**

**- For their contributions to the development of the new rap-Rich POI.**

# Thank you for your attention!

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