ALMA 第一頻段接收機
ALMA Band 1 Receiver performance and first light

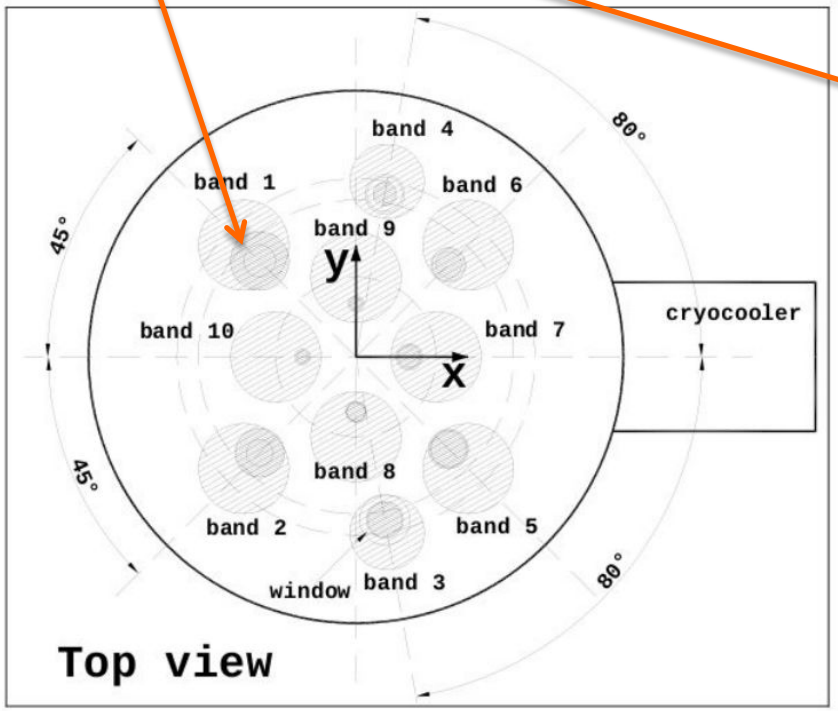
黃翊杰
Yu-Chieh(Teddy) Huang
On behalf of Band 1 team

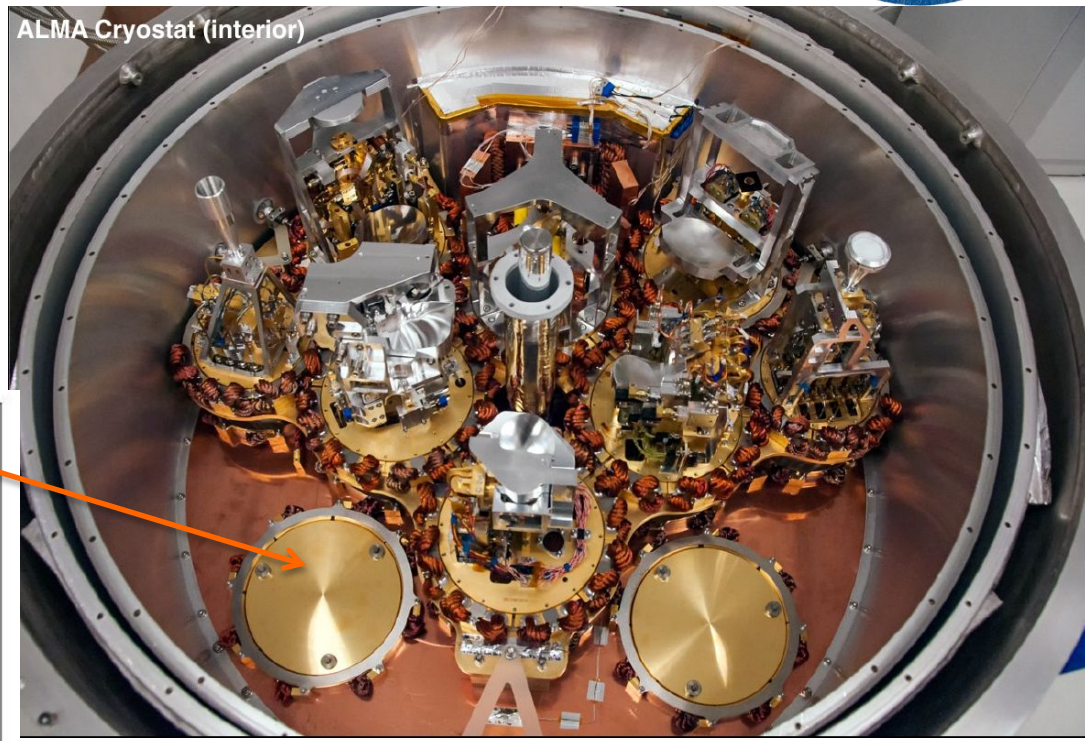
2023-11-22
2023 Advanced Telescope and Instrument Technology Conference

ALMA Band 1

- Goal: Give access to ALMA to the frequencies ~40 GHz at high resolution and sensitivity from the southern hemisphere
- ALMA-East Asia contribution to the ALMA Development. Led by ASIAA (Taiwan)
- As the PI institute, ASIAA is responsible to deliver the Band 1 cartridges within the cost envelope assigned to this project.
- Collaboration with NAOJ, Universidad de Chile, NRC Herzberg and NRAO

ALMA Band 1


band 4
band 1
band 6
band 9
y
band 10
band 7
x
cryocooler
band 8
band 2
band 5
window
band 3
45°
45°
80°
80°
Top view


ALMA Cryostat (interior)

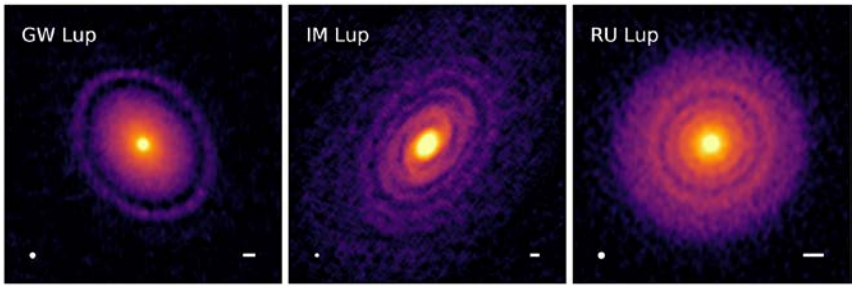
Specification

- **RF:** 35-50 GHz, 50 to 52GHz(Best effort)
- **LO:** 31- 38 GHz
- **IF:** 4-12 GHz, SSB
- **Trx:** 28K (80%); 32 K @any frequency within RF band.
- **IF power variations :**peak-to-peak variation shall not exceed 5.0dB in any 2GHz portion. 7.0dB full band.
- **Cross talk :** less than -63dB
- **Image band suppression:** >10dB
- **Amplitude Stability:**less than 4.0×10^{-7} for timescales in the range of 0.05 s ≤ T ≤ 100 s and 3.0×10^{-6} for T = 300 seconds.
- **Optical:** Aperture Efficiency > 80%, Polarization Efficiency >99.5%, Focus Efficiency >98%

ALMA Band 1 Science Case: main goals

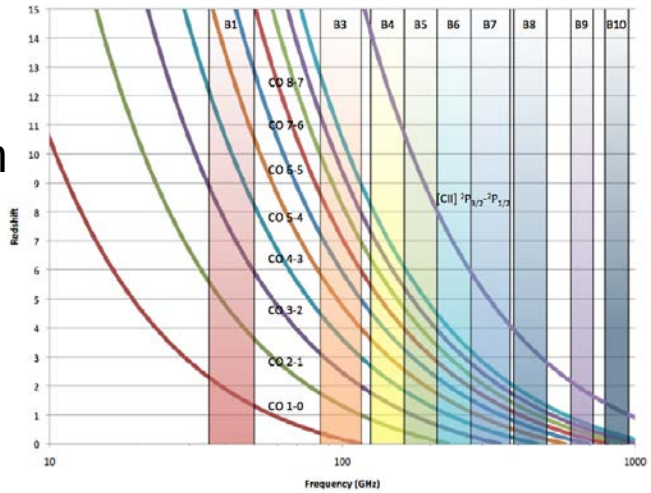
Two primary Level 0 goals with ALMA

- ***Evolution of grains in protoplanetary disks:***
  - following the evolution of dust grains from mm-size to cm-size pebbles in protoplanetary disks
- *ALMA 1.3 mm*



ALMA 7 mm
?
large grains

- ***Molecular gas in high-redshift galaxies***
  - detection of rotational transitions of CO from J=1-0 to J=6-5 .Detection of CO J=3-2 at epoch of reionization (z~6-9)
  - possibility of *blank-sky* surveys



Science case: many more cases

The ALMA Band 1 Science Case includes a very broad range of science goals:

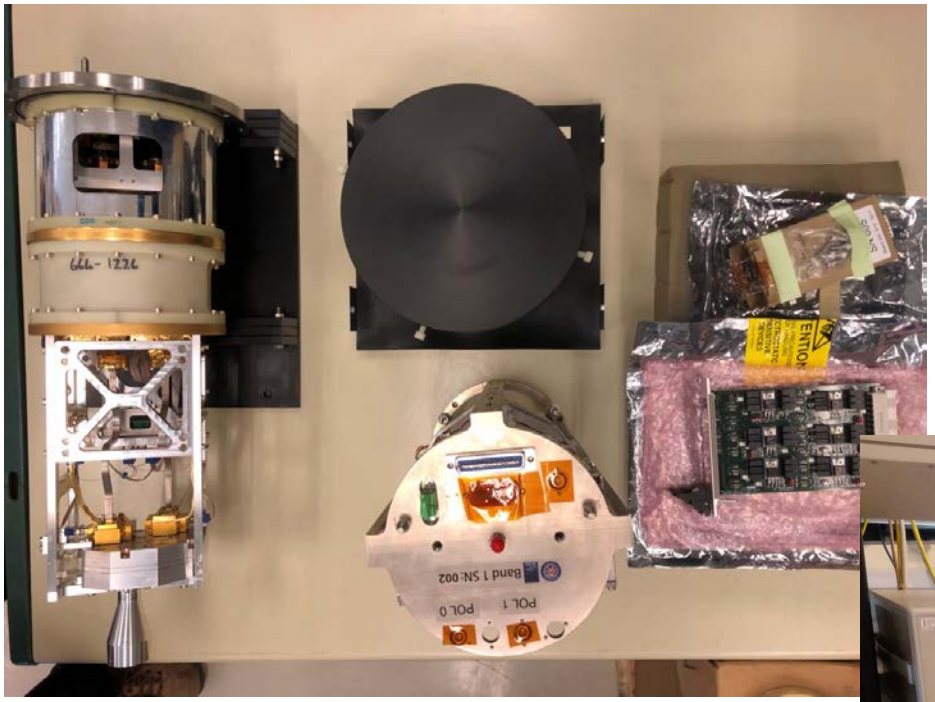
- observations of Sunyaev-Zel'dovich effect (SZE) clusters
- very small grains and spinning dust
- fine structure of chemical differentiation in molecular cloud dense cores
- complex carbon-chain molecules
- Zeeman effect
- ....

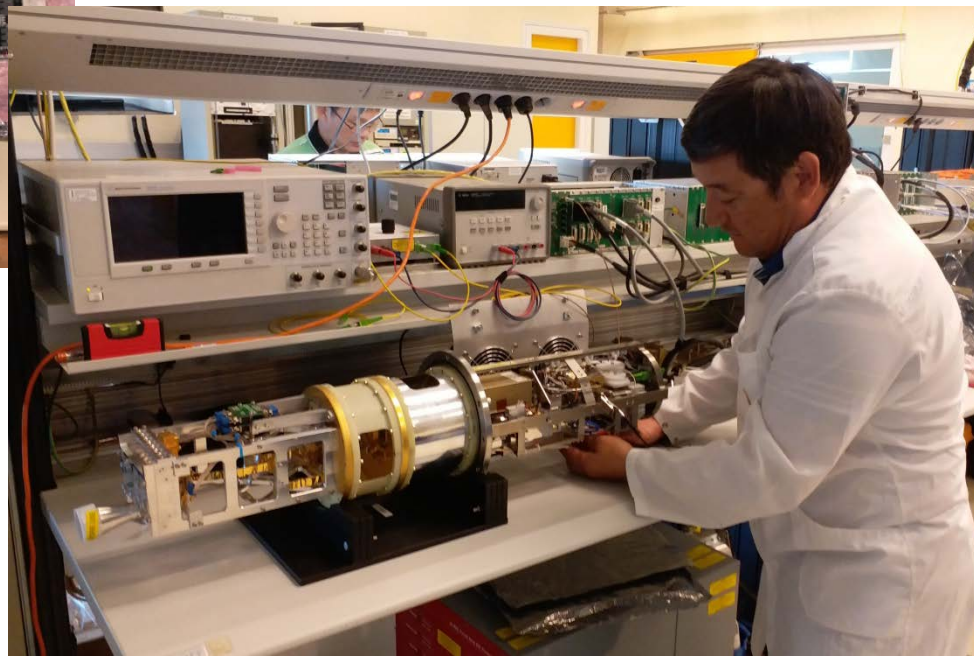
Full ALMA Band 1 Science Case: *http://arxiv.org/abs/1310.1604*

Band 1 Project

- Approved by ALMA Board for proto-typing in 2014.
- Approved by ALMA Board for Band-1 Production: May 2016
- Approved by ALMA Board for Manufacturing Readiness Review (MRR): 2019

- Band 1 Team responsible for:
  - CCA+WCA, CPDS, Bias modules and photomxiers.
  - Band 1 Prototype Development
  - Band 1 Cartridge Production
  - Maintenance;
  - Integration and testing at OSF
  - Test Line and its Maintenance

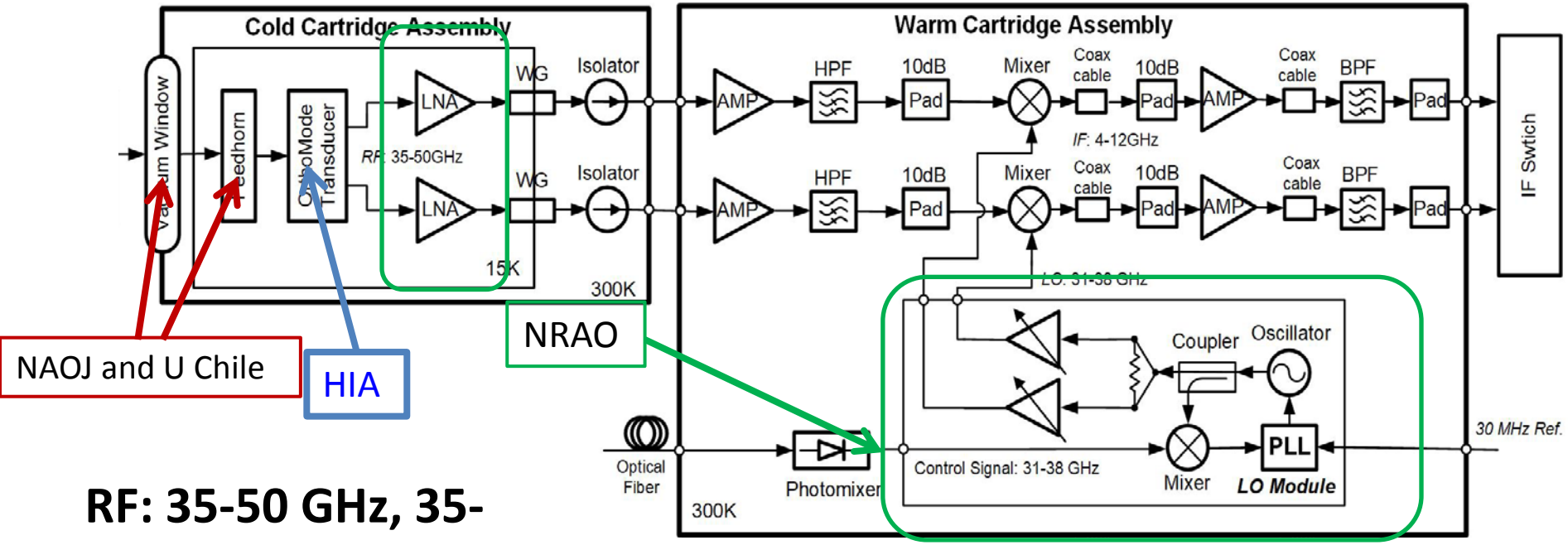

Band 1 SN: 002
POL 1
POL 0



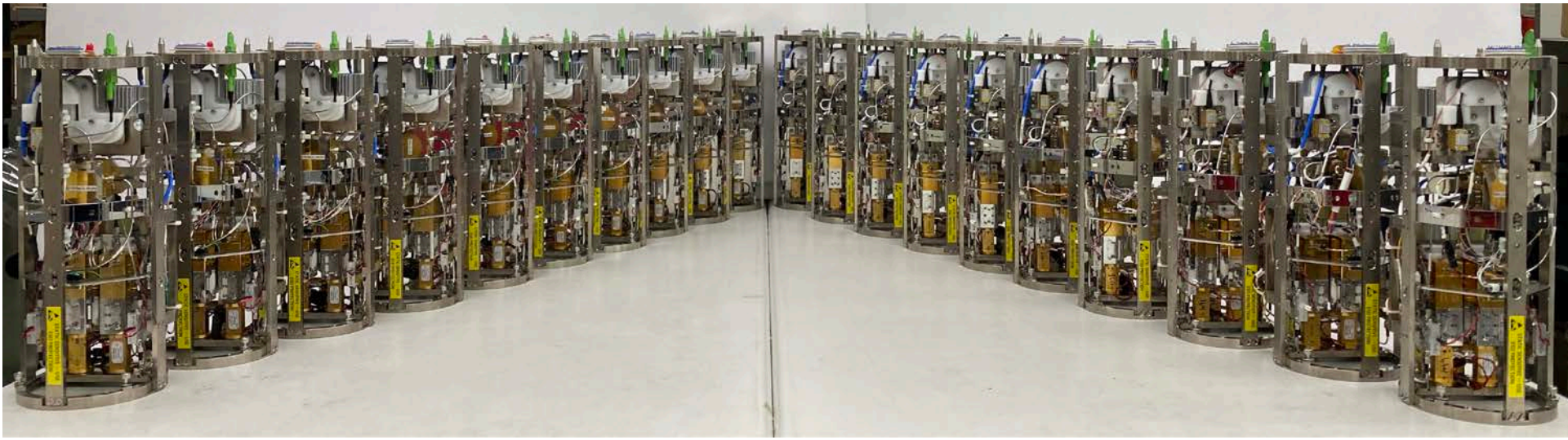
Timeline

- **2014 March:** Approved by ALMA Board for proto-typing.
- **2016 May:** Approved by ALMA Board for Band-1 Production Design: May 2016
- **2019** Approved by ALMA Board for Manufacturing Readiness Review (MRR)
- **2020 March** FETMS(Front-End Test and Measurement System) Verification at OSF
- **2021 August** Astronomical “first-light” with ALMA antennas in Chile
- **2023 March** Complete #73 cartridge delivery

Overview



RF: 35-50 GHz, 35-52GHz(Best effort)
LO: 31- 40 GHz,
IF: 4-12 GHz, SSB
Trx: 28-32 K

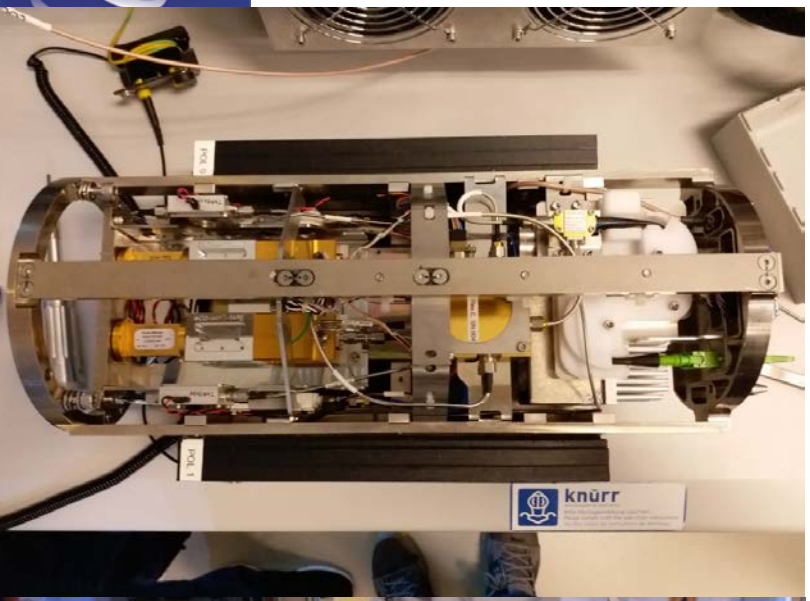


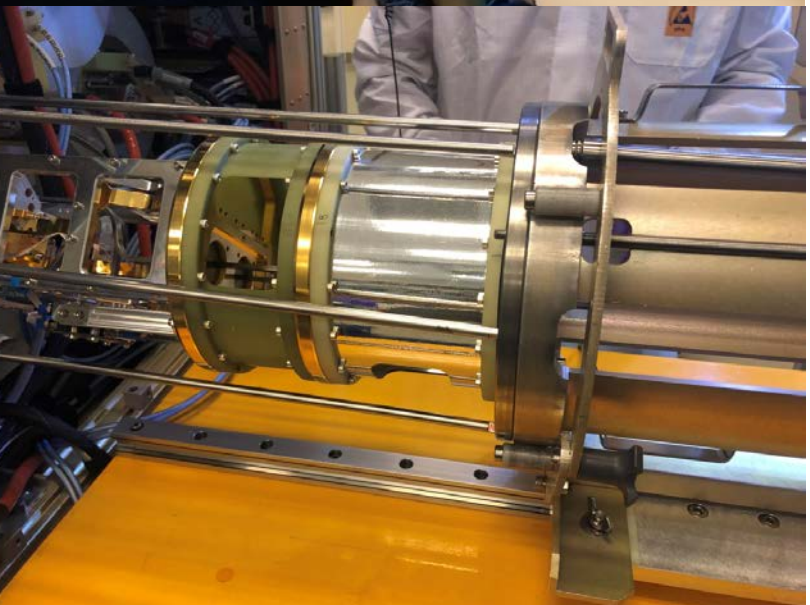
Band-1 Receiver Performance

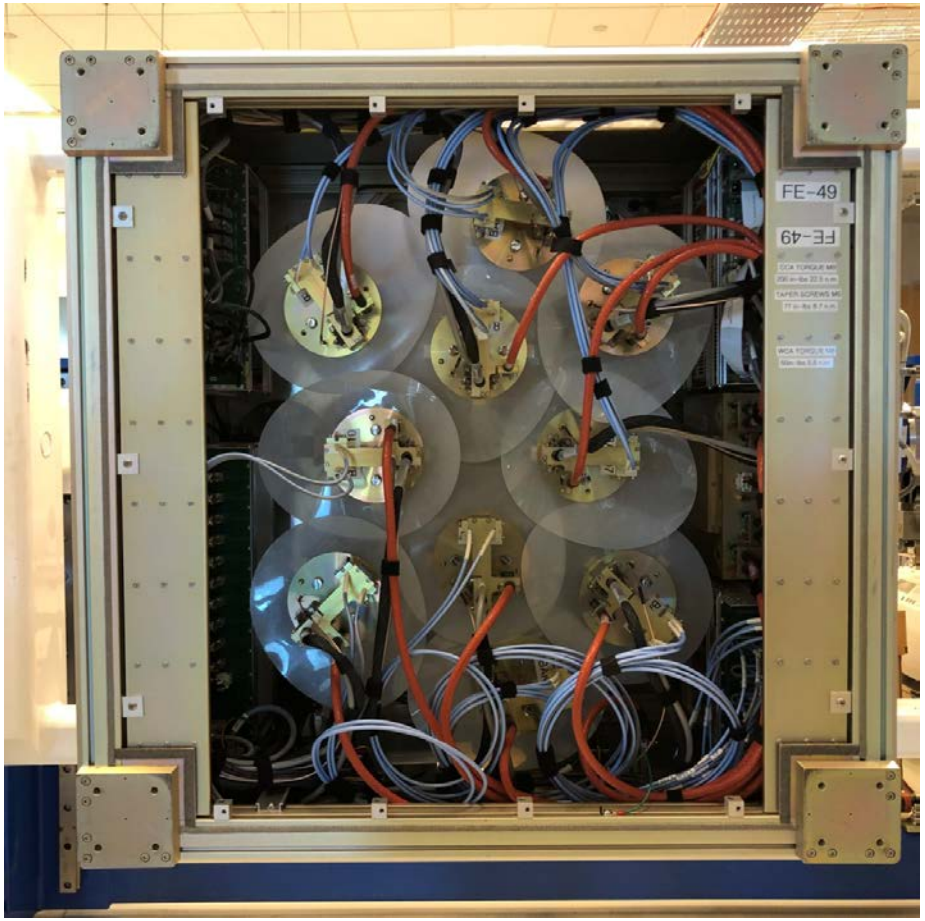
- Fully compliant with the ALMA Band-1 receiver specification

- Till November 15th 2023:
  - 73 units of Band 1 receivers compliant with the ALMA specification and delivered to ALMA OSF
  - 45 12-meter antenna equip with the Band 1 receiver
  - 6 7-meter antenna equip with the Band 1 receiver.
  - Ready for ALMA cycle 10 observation call.

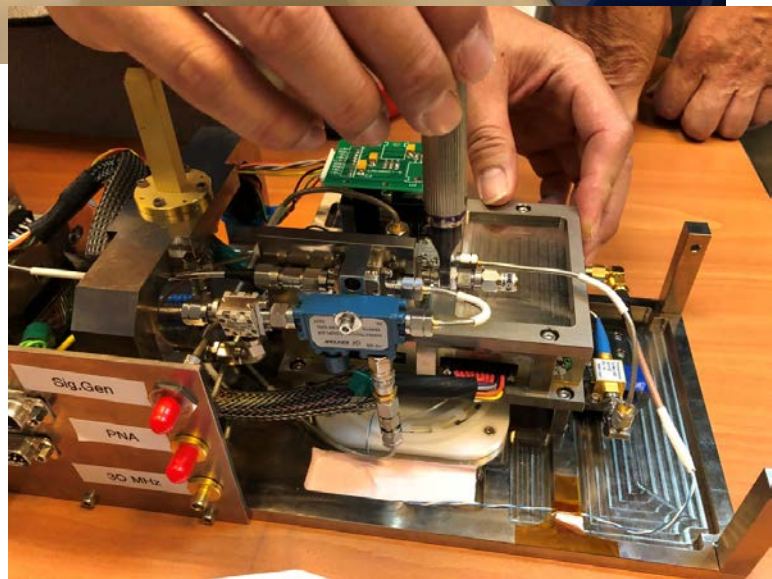
First Unit at ALMA

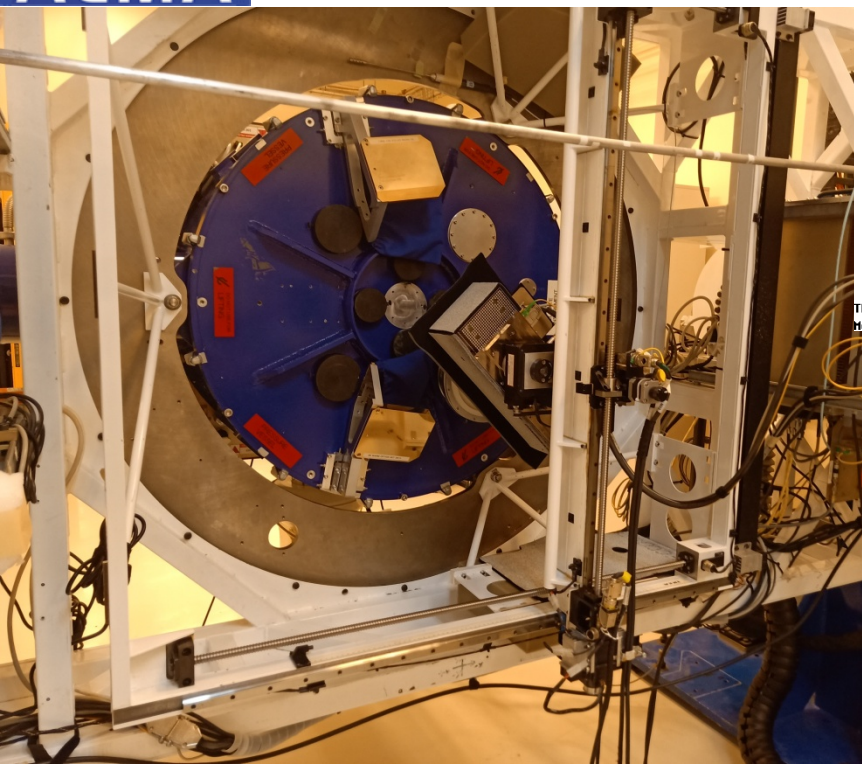


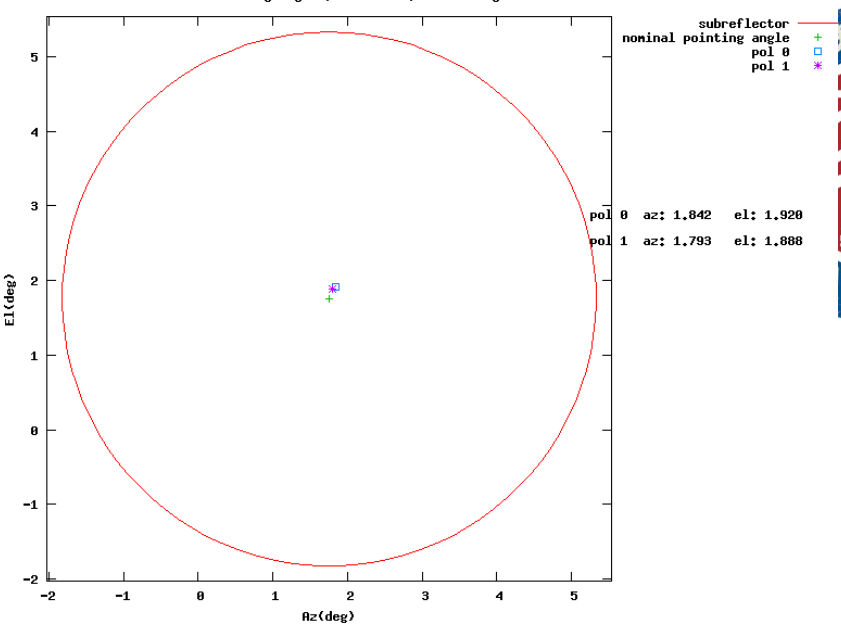


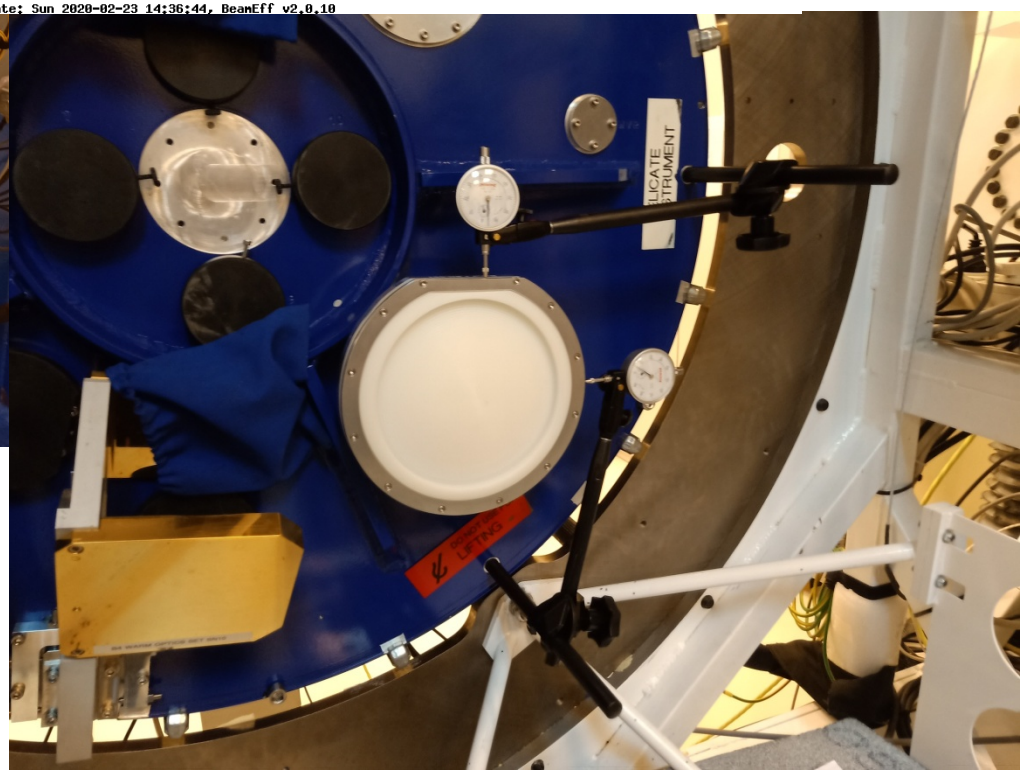


First Unit at ALMA






subreflector
nominal pointing angle
pol 0
pol 1
pol 0 az: 1.842 el: 1.920
pol 1 az: 1.793 el: 1.888
El(deg)
Az(deg)
TDH=71337, FEConfig=2153
MeasDate: Sun 2020-02-23 14:36:44, BeamEff v2.0.10



System Noise Temperature

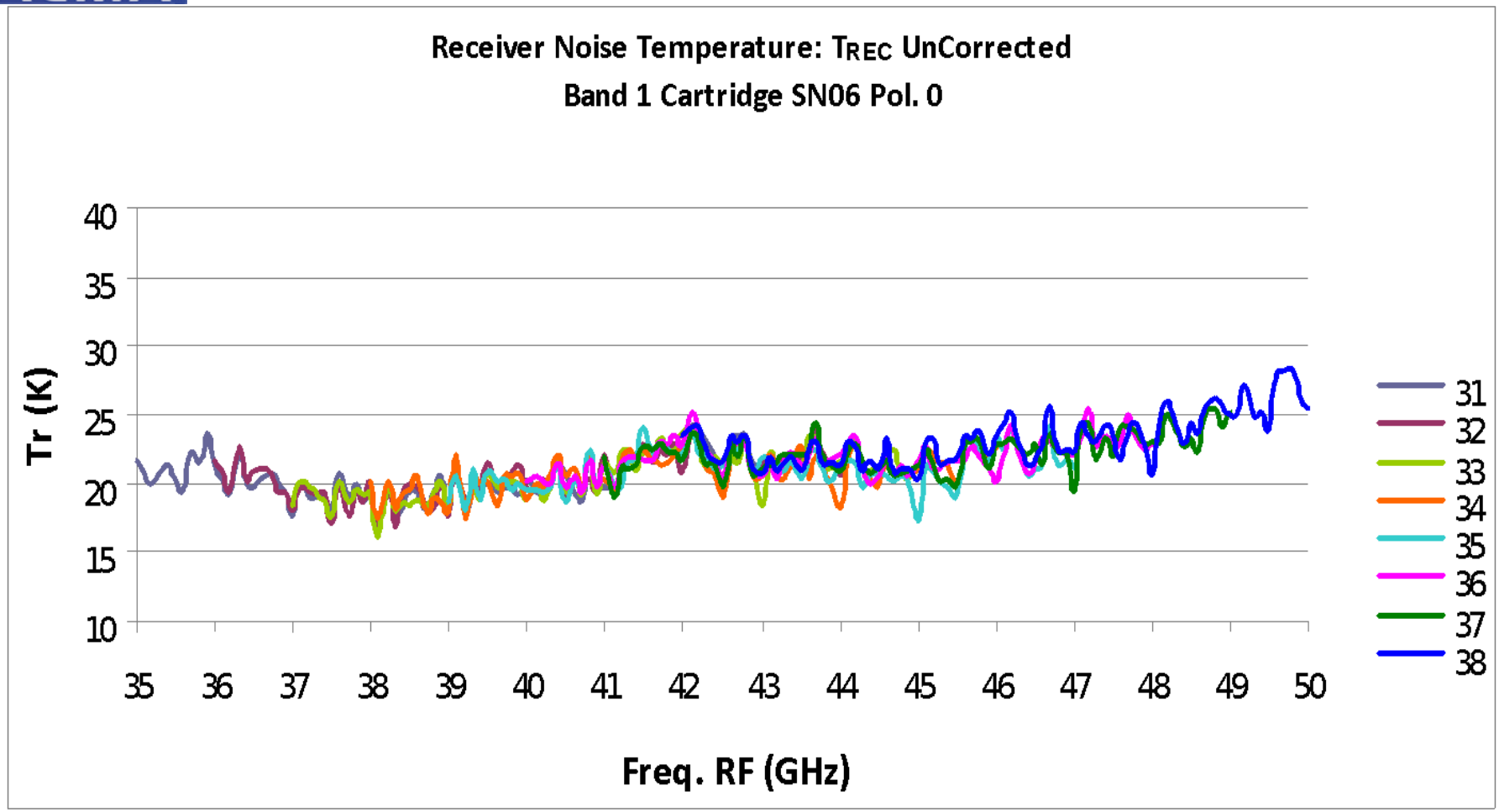
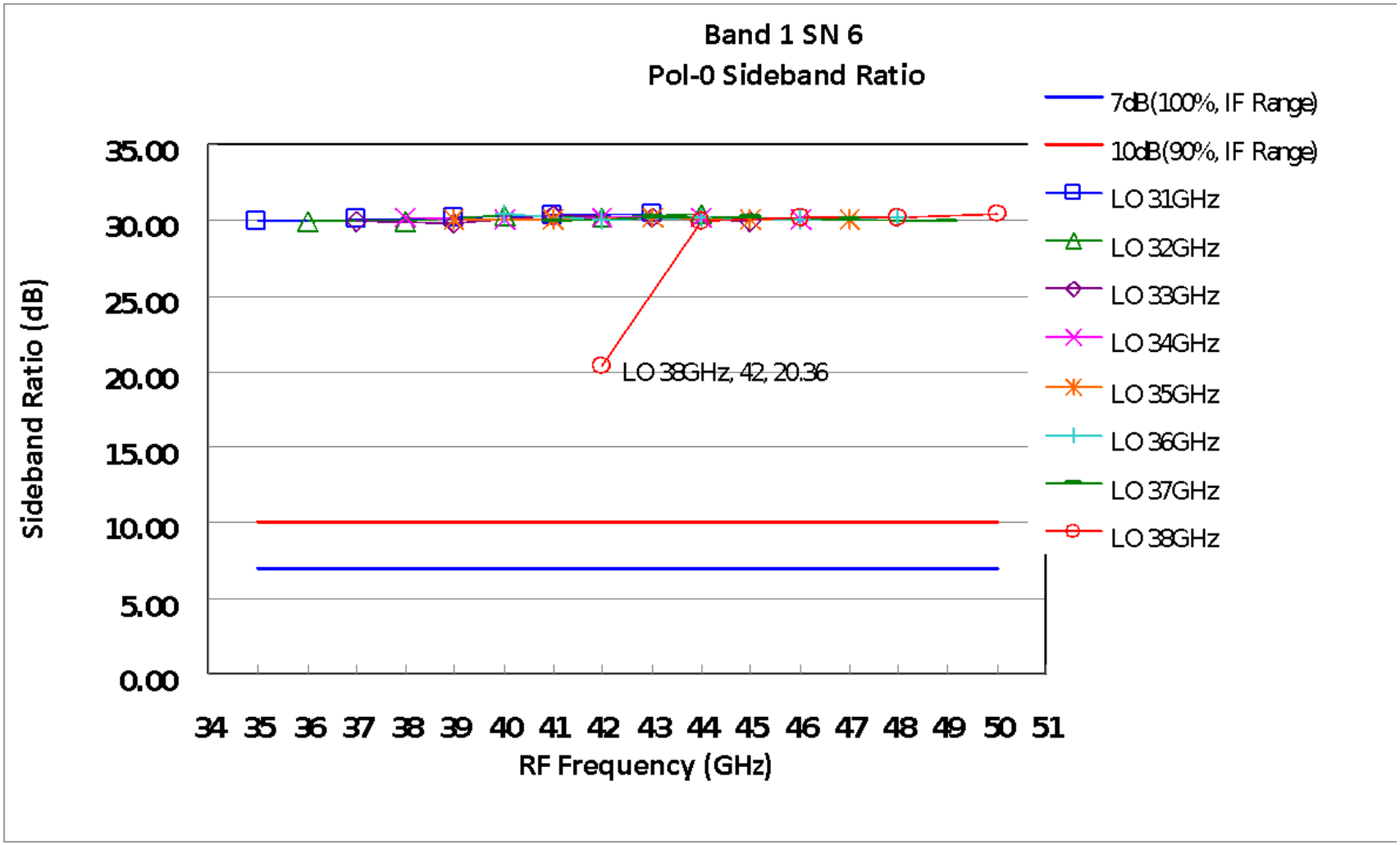
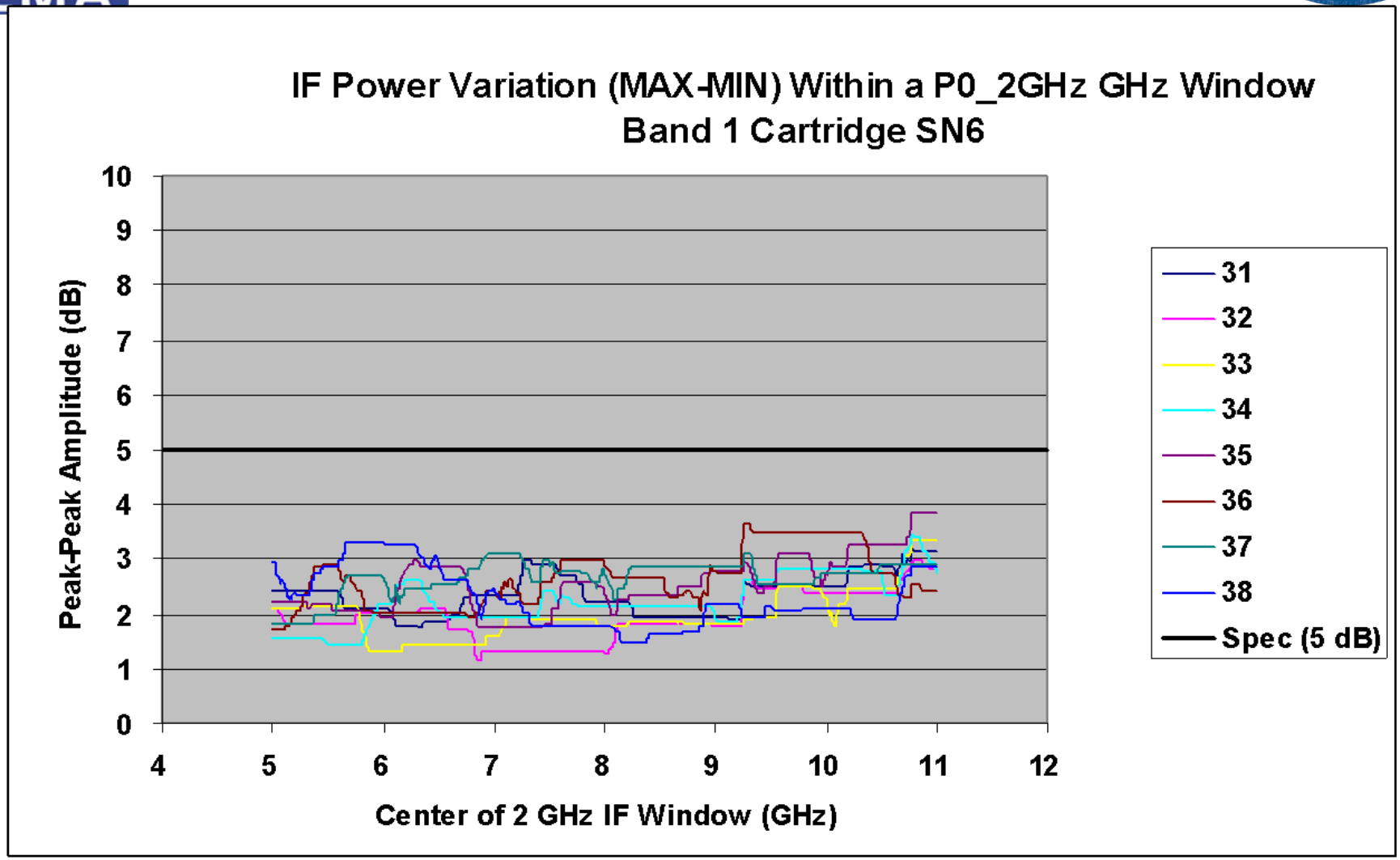


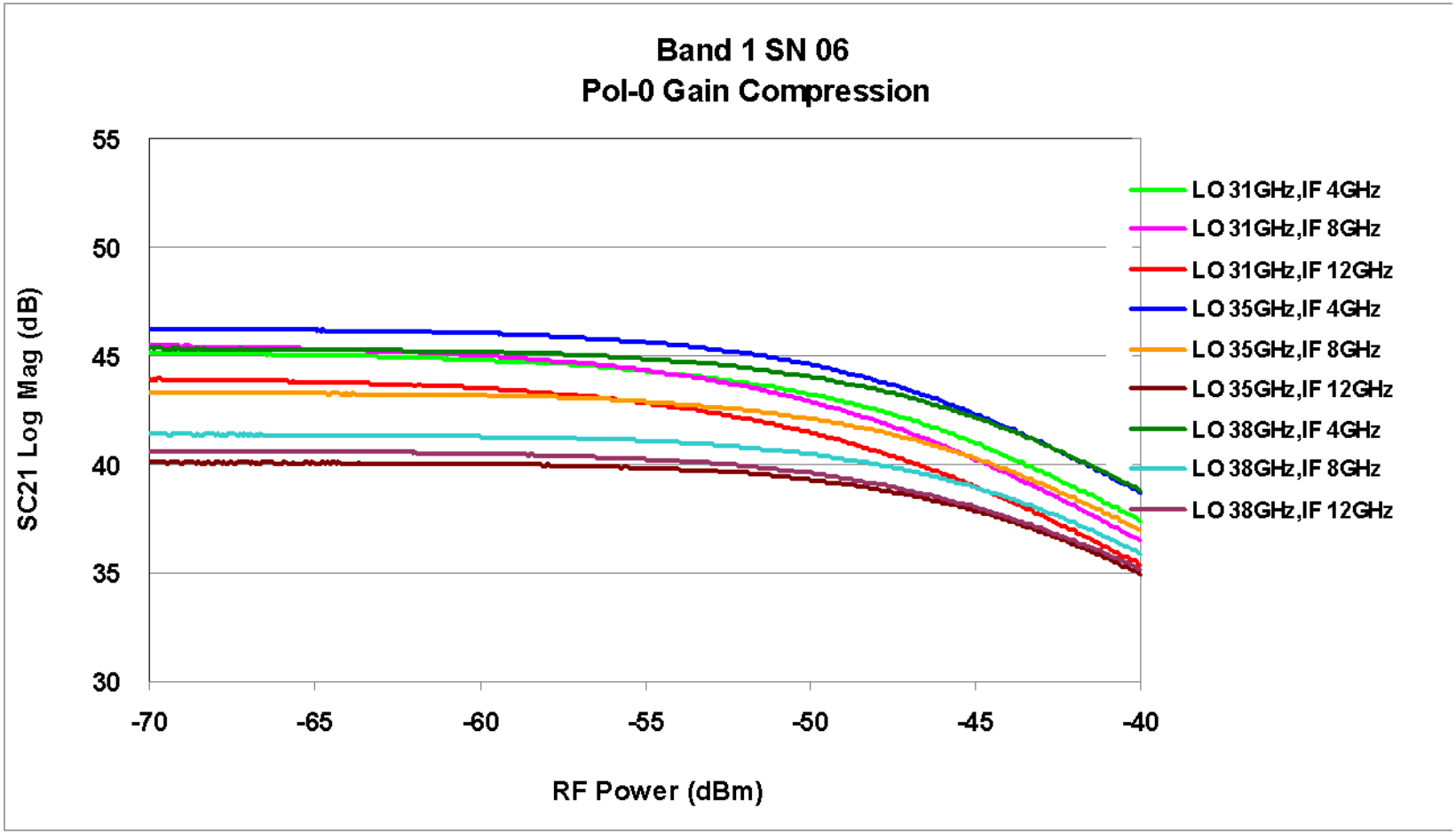
Image-band suppression



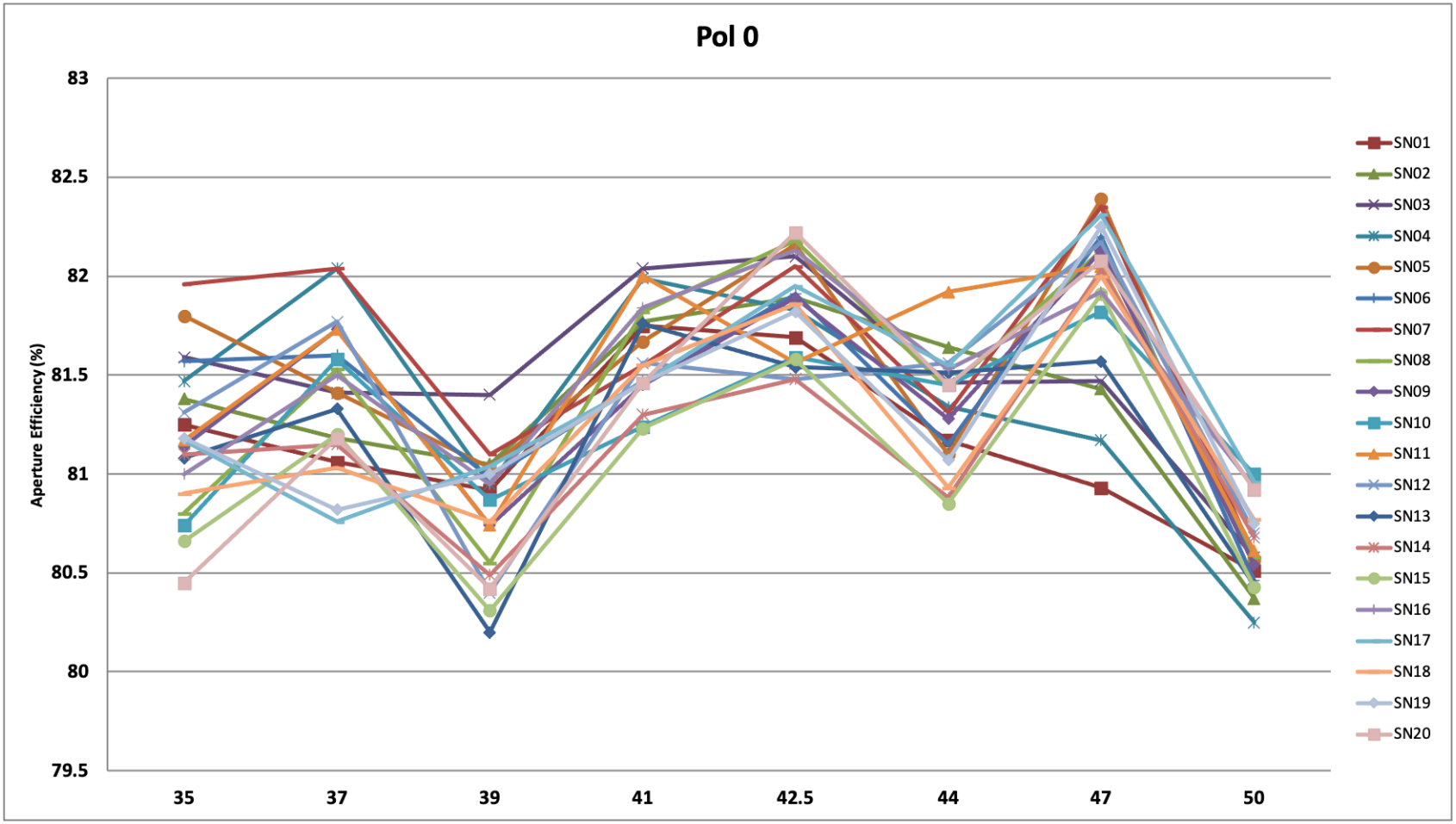
IF power variation within 2 GHz window



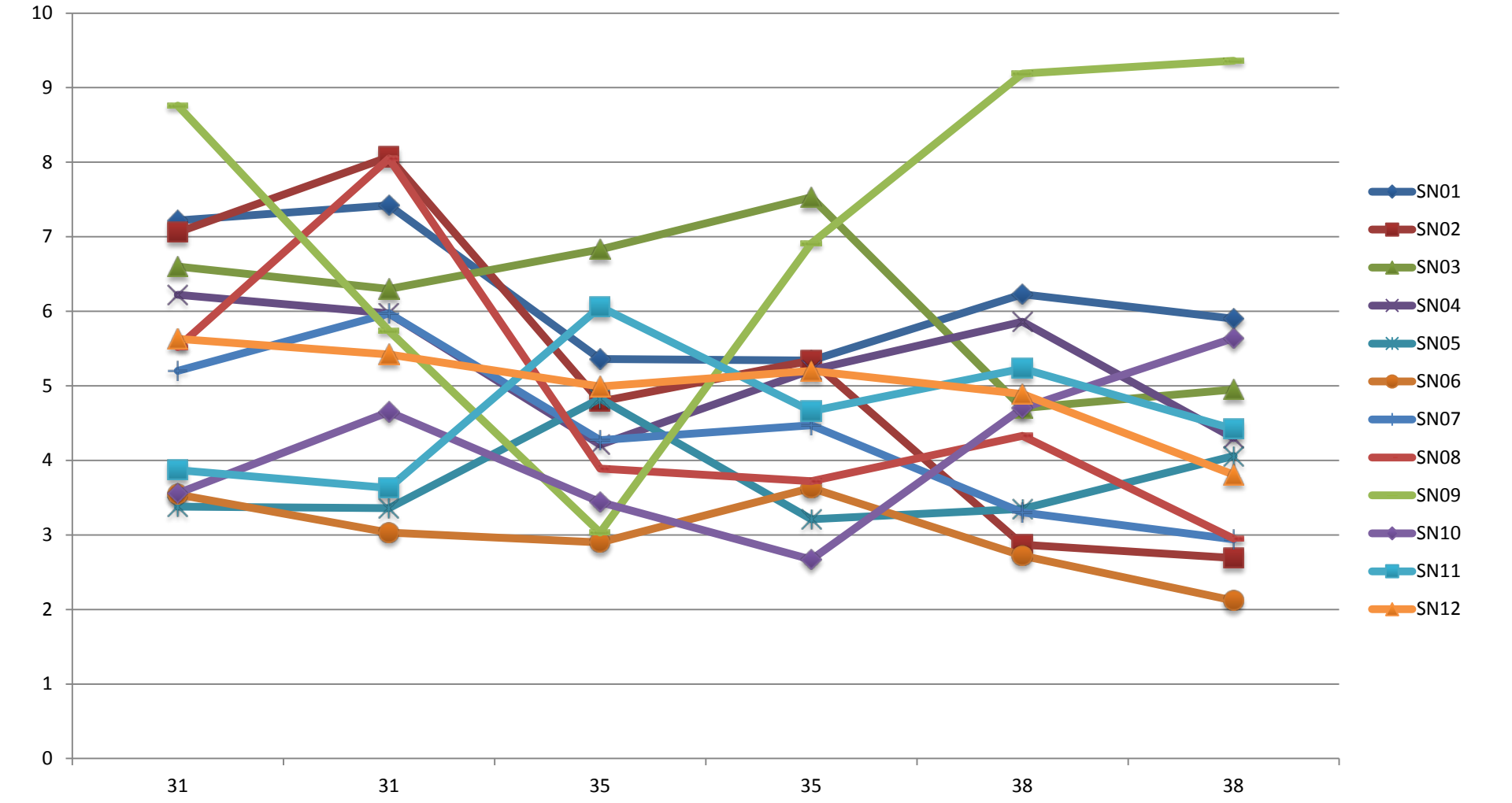
Gain Compression



Aperture efficiency for First 20 Band-1 receiver

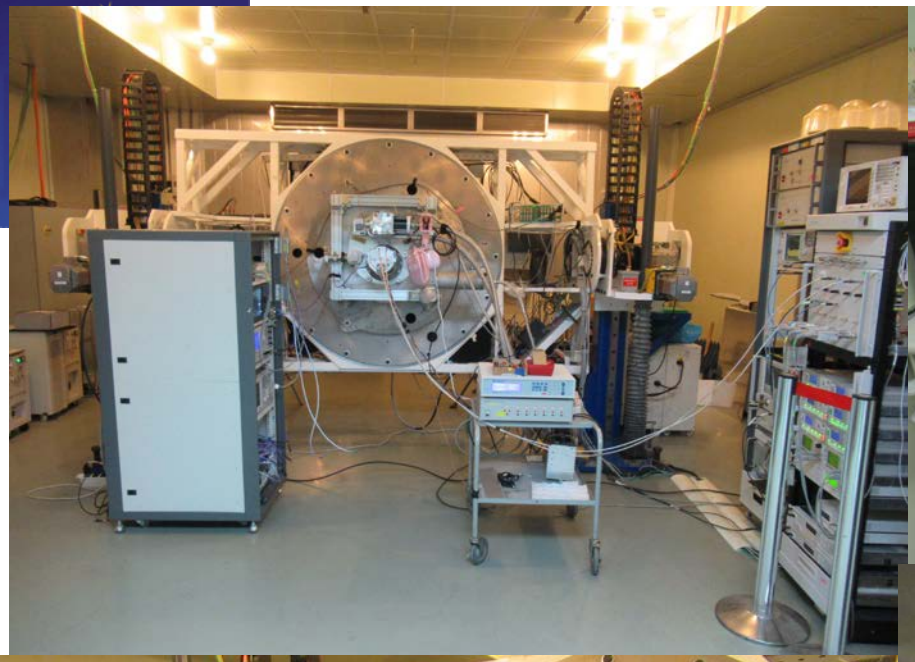


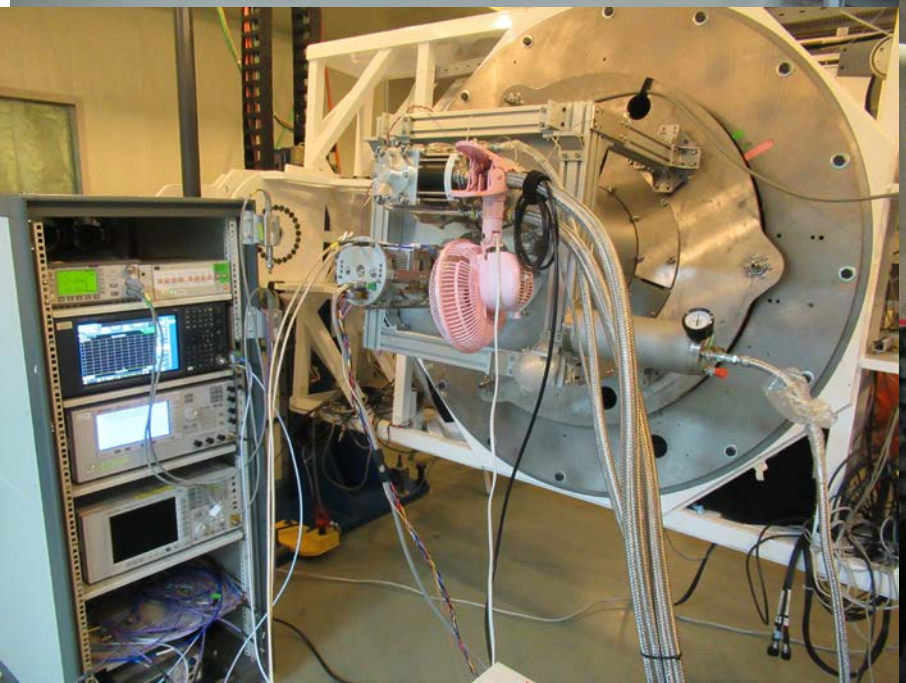
Phase Stability

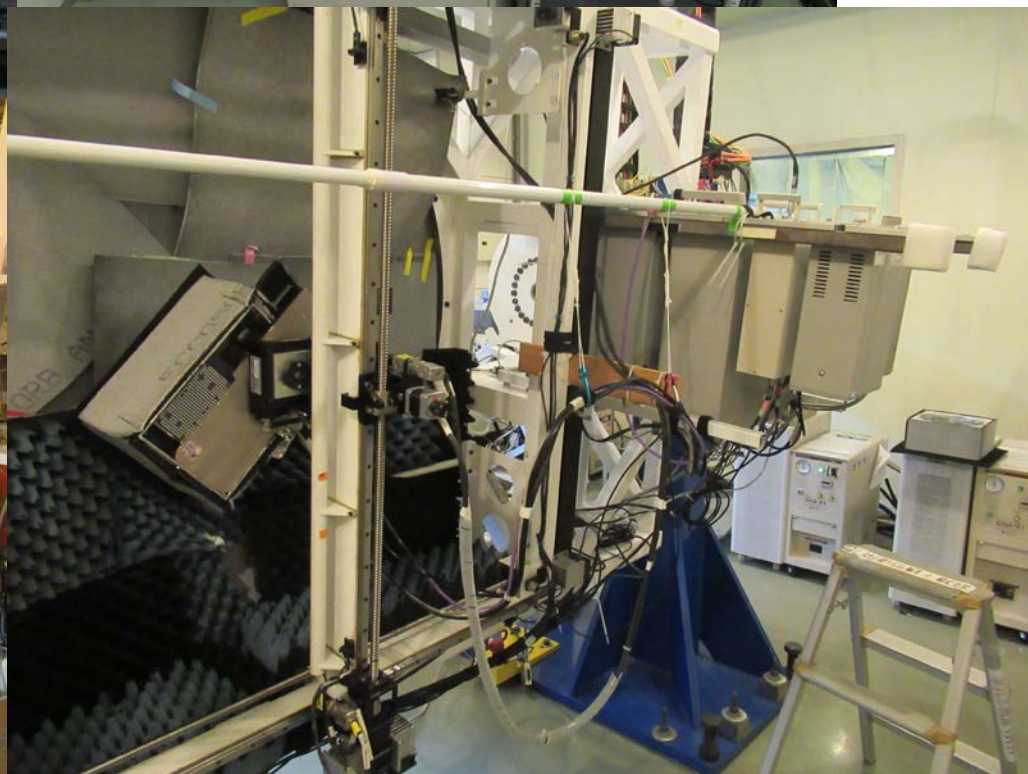


Band 1 production in Taiwan

- 2 technicians
- 2 engineers (includes Q.A. engineer)
- Administrative specialist
- 73 production Band-1 receivers were assembled and passed the production assurance test and fulfill the specifications.







Band 1 Integration and Verification at Telescope site

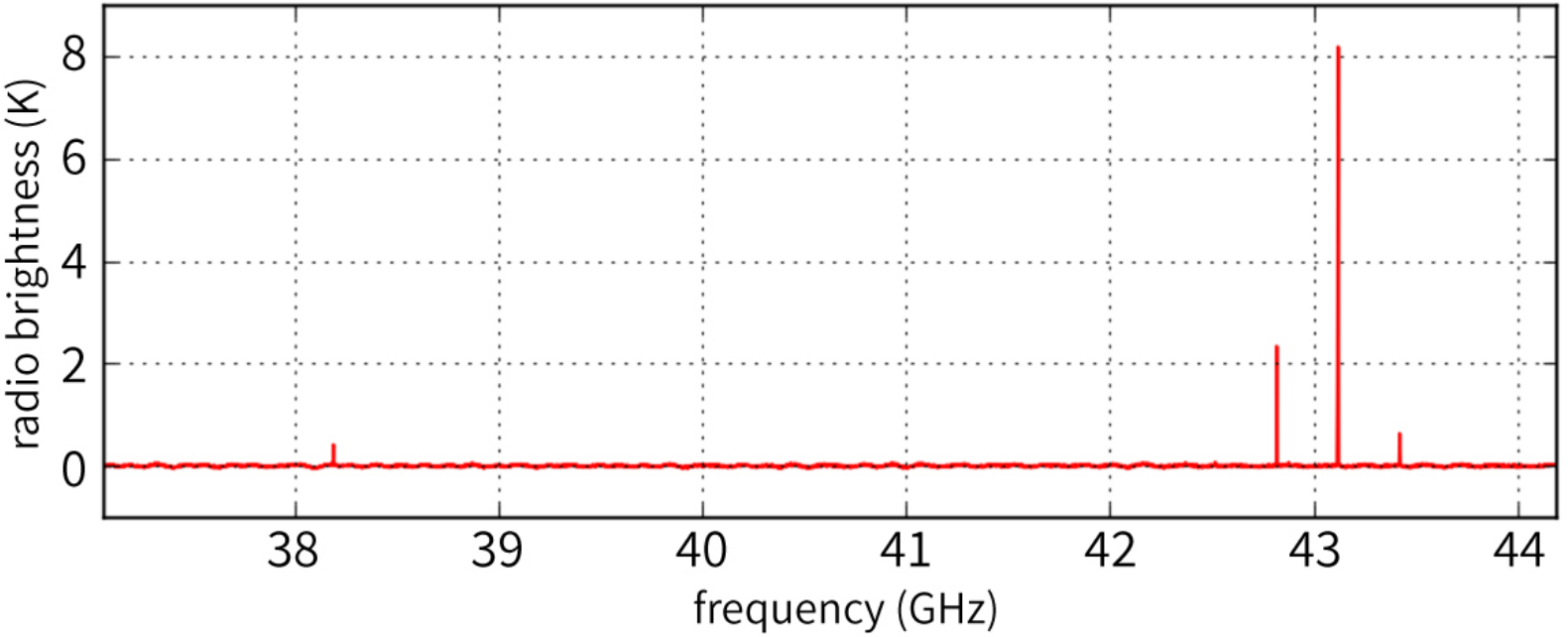
- August 14, 2021: The first light of the Band-1 receiver was achieved with the observation of the edge of the Moon at the ALMA site.

- August 27, 2021: Interferometric observations with the Band-1 receivers installed on three different antennas

Band 1 First light

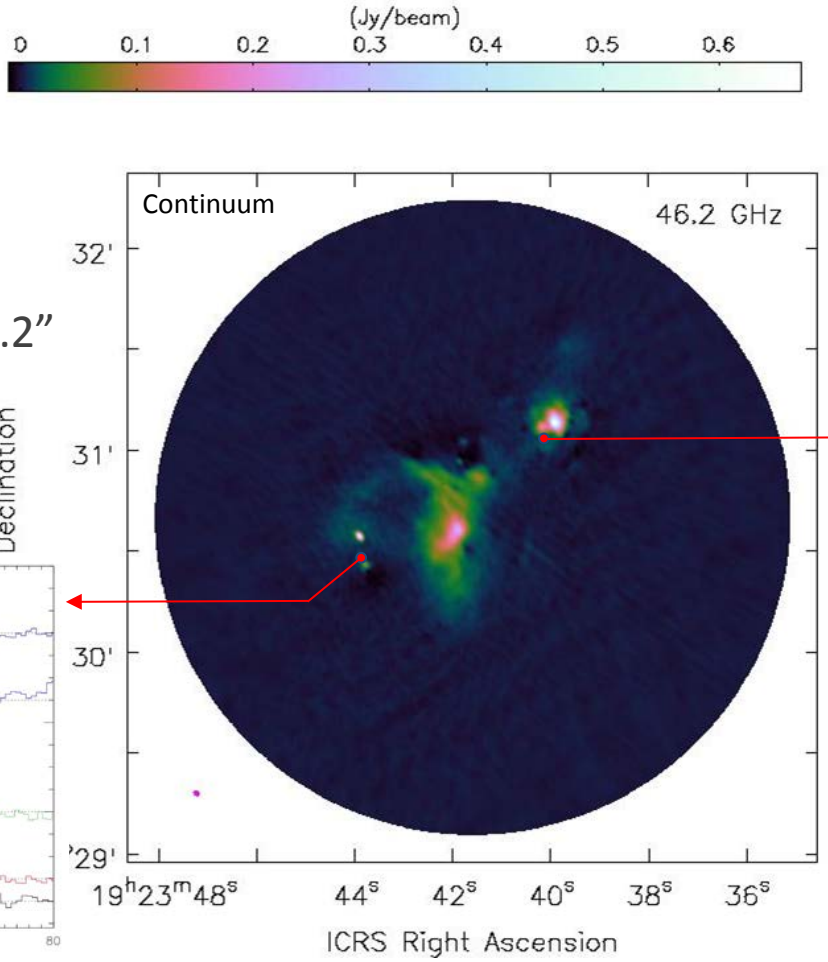
- First radio spectrum conducted towards the evolved star VY CMa.
  - The three different transitions of the SiO maser were detected,
  - V=0, J=1-0 at 43.423 GHz
  - V=1, J=1-0 at 43.122 GHz
  - V=2, J=1-0 at 42.820 GHz

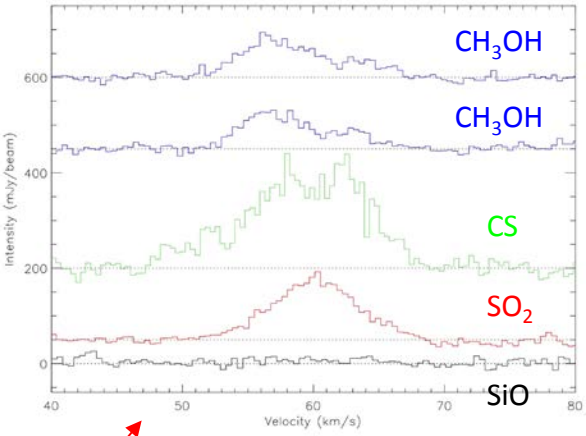
  An additional line is detected at a frequency around 38.2 GHz, and further studies are needed to confirm the species.

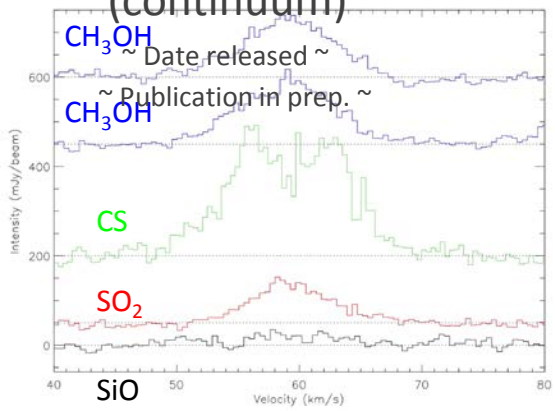


Science Verification - W51 line and continuum imaging

- Star-forming region
- With 20 antennas
- 70 mins on source
- Resolution: 1.8” x 1.2”
- FOV ~ 3 arcmins
- Max. S/N ~ 840 (continuum)







~ Date released ~

~ Publication in prep. ~

RMS in lines:

5-12 mJy per 0.4 km/s channel

Expected sen sensitivity is achieved.
Stability & Reliability are verified.

ASIAA & NAOJ ALMA Band 1 team

https://almascience.nrao.edu/alma-data/science-verification/w51_band1

SUMMARY

- 73 units of ALMA Band-1 receivers have been built and fully characterized at the Band-1 receiver laboratory in Taiwan
- Engineering verification: completed
- Commissioning-and-Science Verification: almost finished, working on the data/result

SUMMARY

- Commissioning-and-Science Verification:
  - the commissioning-and-science verification will be done with a limited number of Band-1 receivers on the sky confirm the readiness of the receiver system for science operation
  - Demonstrate and advertise this new capability of ALMA to the community and to test data reduction procedure and performance of science observations with ALMA Band 1.
  - Targeting be announced as a new observing capability in the cycle-10 proposal call.

SUMMARY

- Till November 15th 2023:
  - 73 units of Band 1 receivers compliant with the ALMA specification and delivered to ALMA OSF
  - 45 12-meter antenna equip with the Band 1 receiver
  - 6 7-meter antenna equip with the Band 1 receiver.
  - Ready for ALMA cycle 10 observation call.