GGAO Notch Filter at 20K and Other RFI Mitigation Work

D.F. Sullivan
L. Hilliard
D. Hudson
B. Bulcha
C. Turner
M. Deshpande
T. Stevenson
G. Rajagopalan

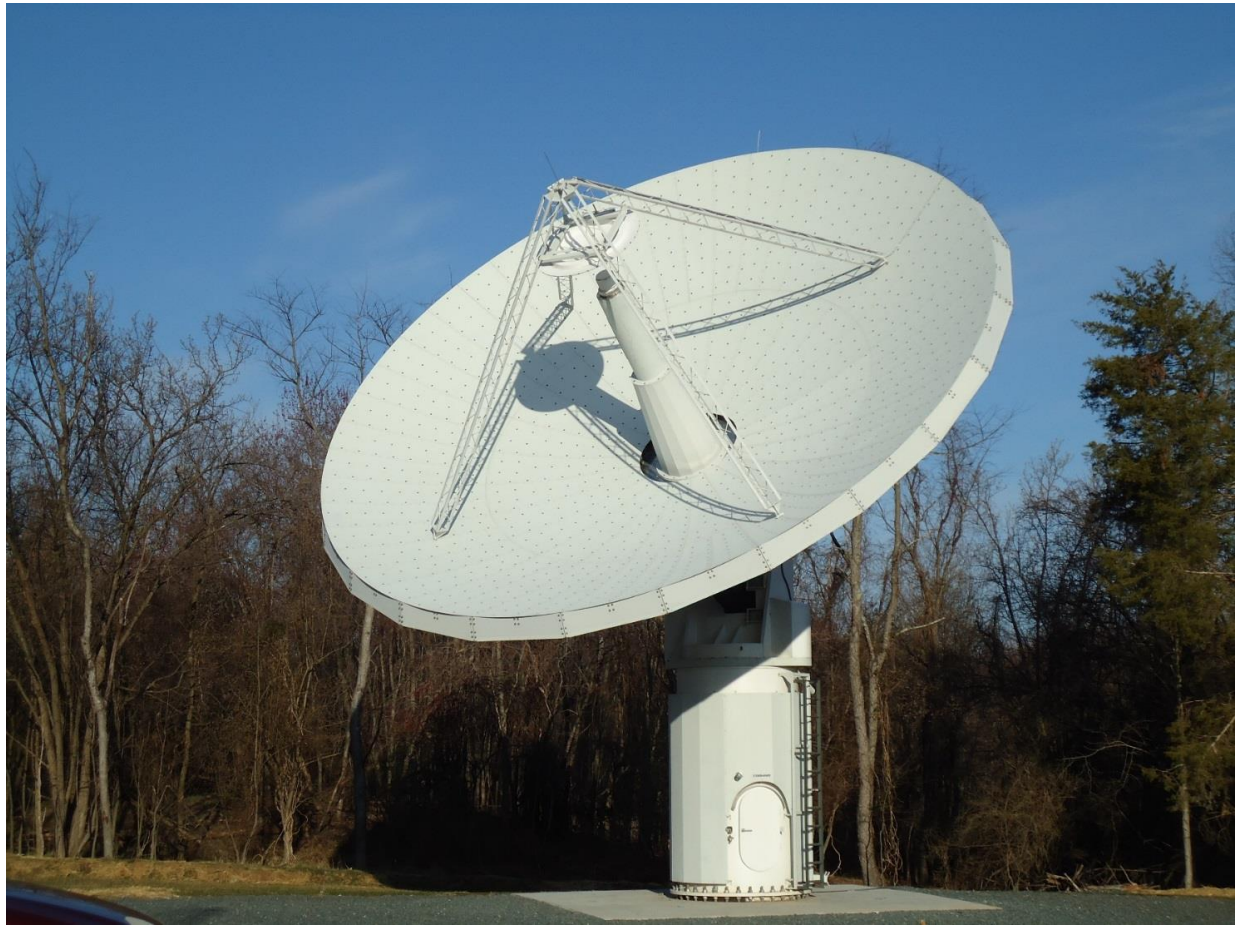
OUTLINE

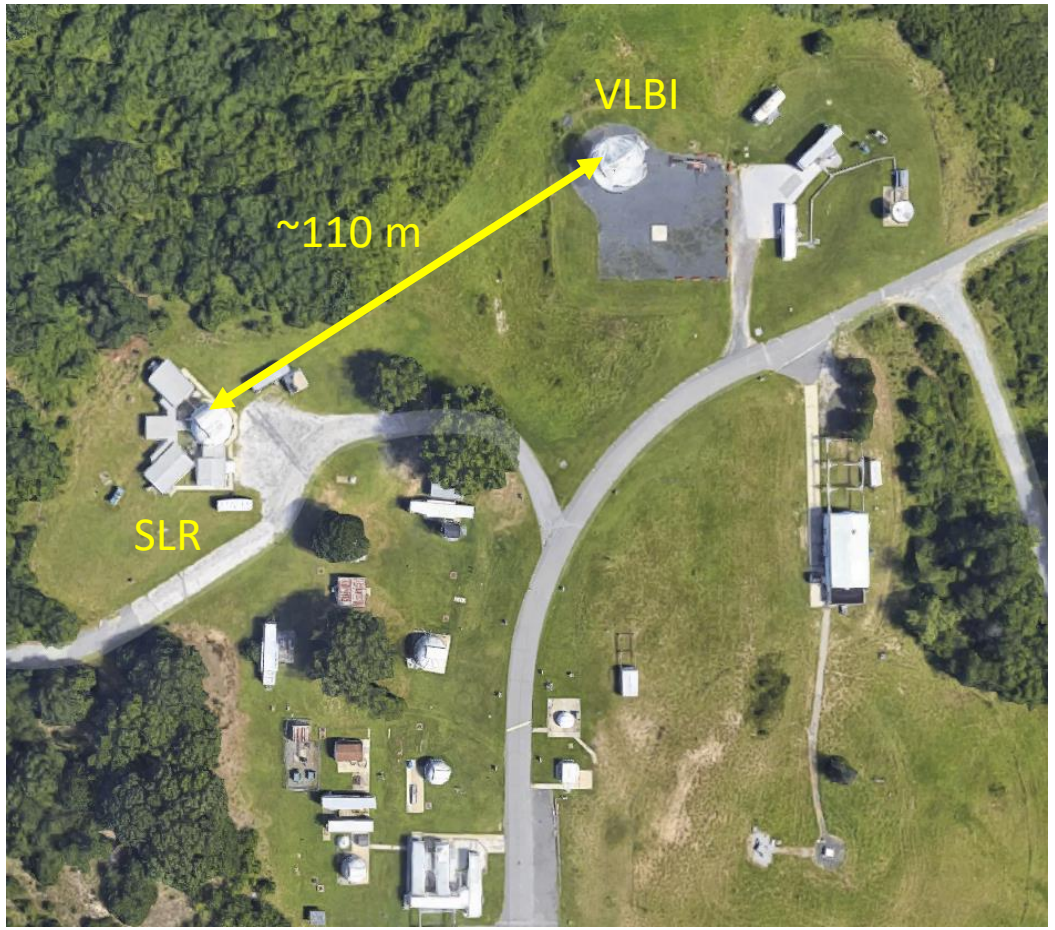
- Motivation: full sky observations in the presence of RFI
- Use high temperature superconductor (YBCO) for low loss filter material
- First steps: filter design and testing at 77 K
- Latest steps: Dedicated VLBI laboratory and test cryostat
- Next steps: complete filter characterization, integrate with VLBI receivers

*See L. Hilliard, “Detection and measurement of RFI in radio astronomy”, 2017 IVS General Meeting

GGAO antenna environment

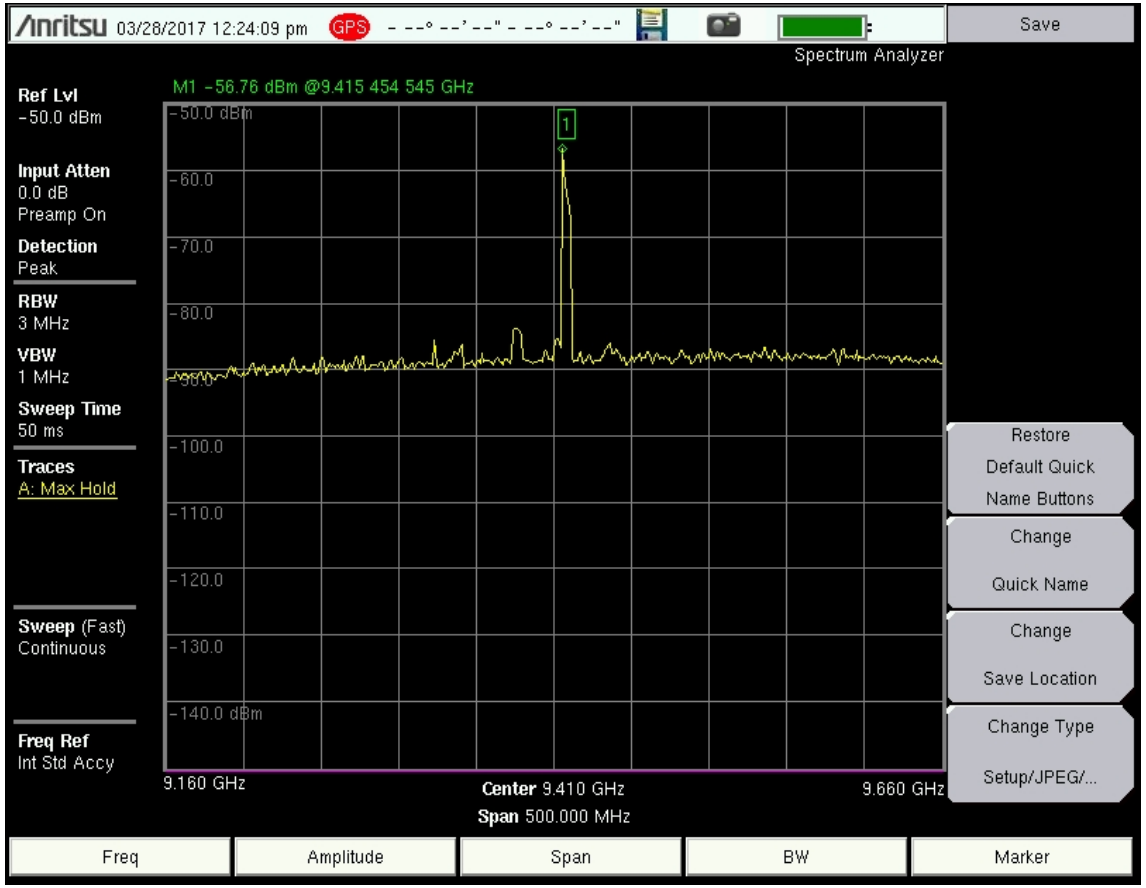
12 m VLBI antenna





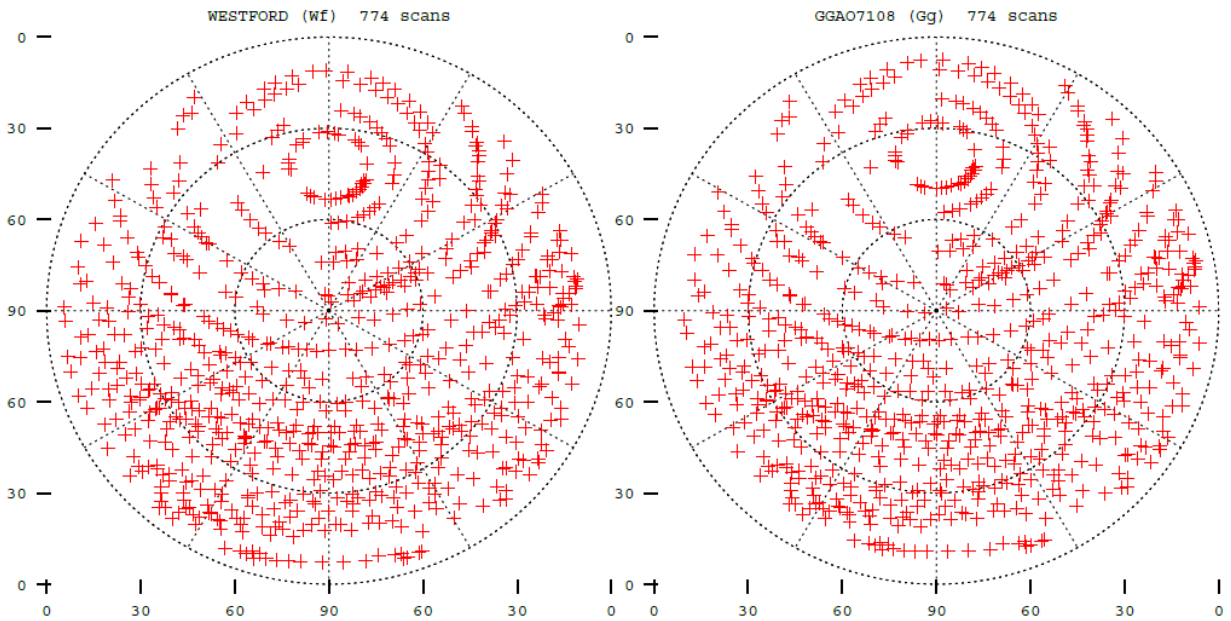
Satellite Laser Ranging (SLR) and Laser Hazard Reduction System (LHRS) are co-located with VLBI antenna

LHRS radar signal at ~ 9.4 GHz must be avoided by VLBI antenna to prevent damage to receiver LNAs

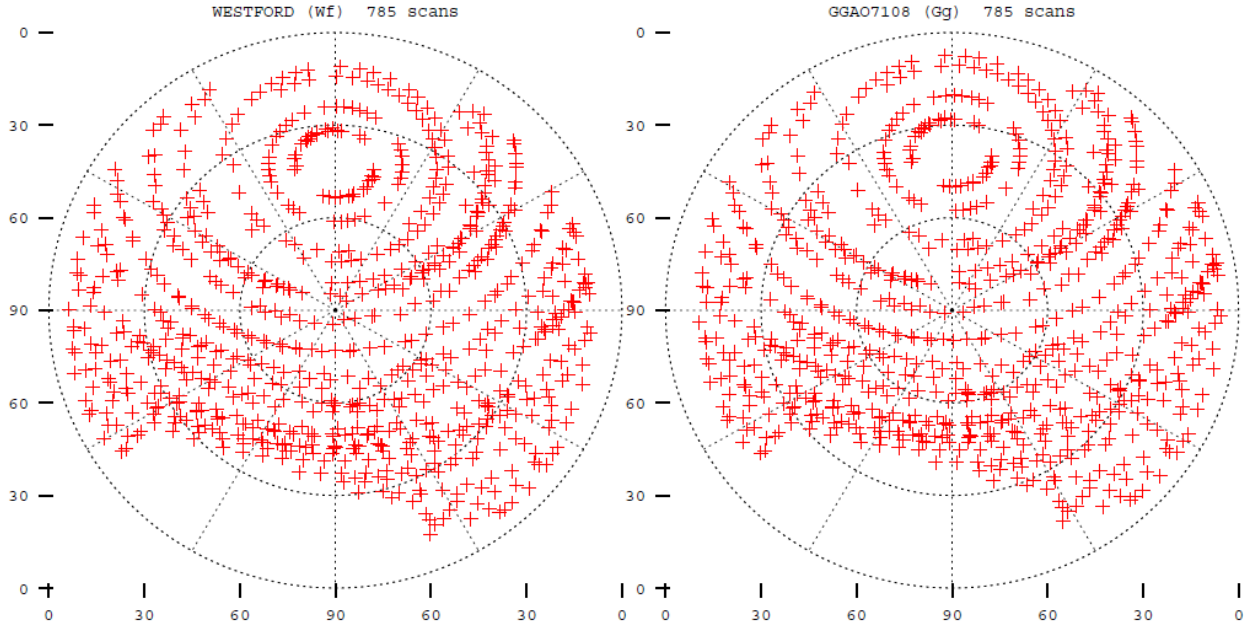


Loss of Southern sky due to GGAO radar mask must be accounted for in observation schedules

unmasked observing plan



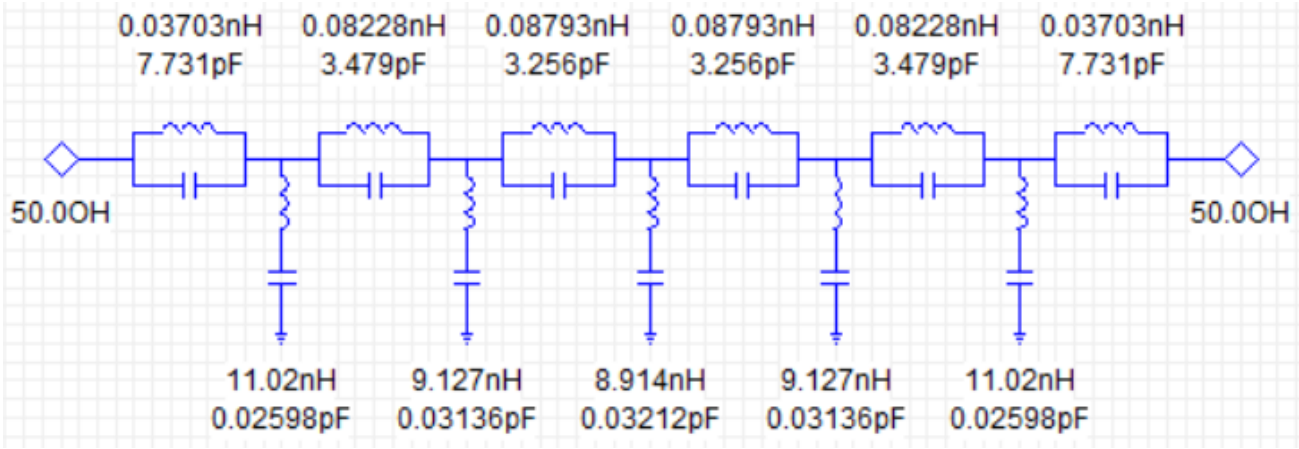
masked observing plan



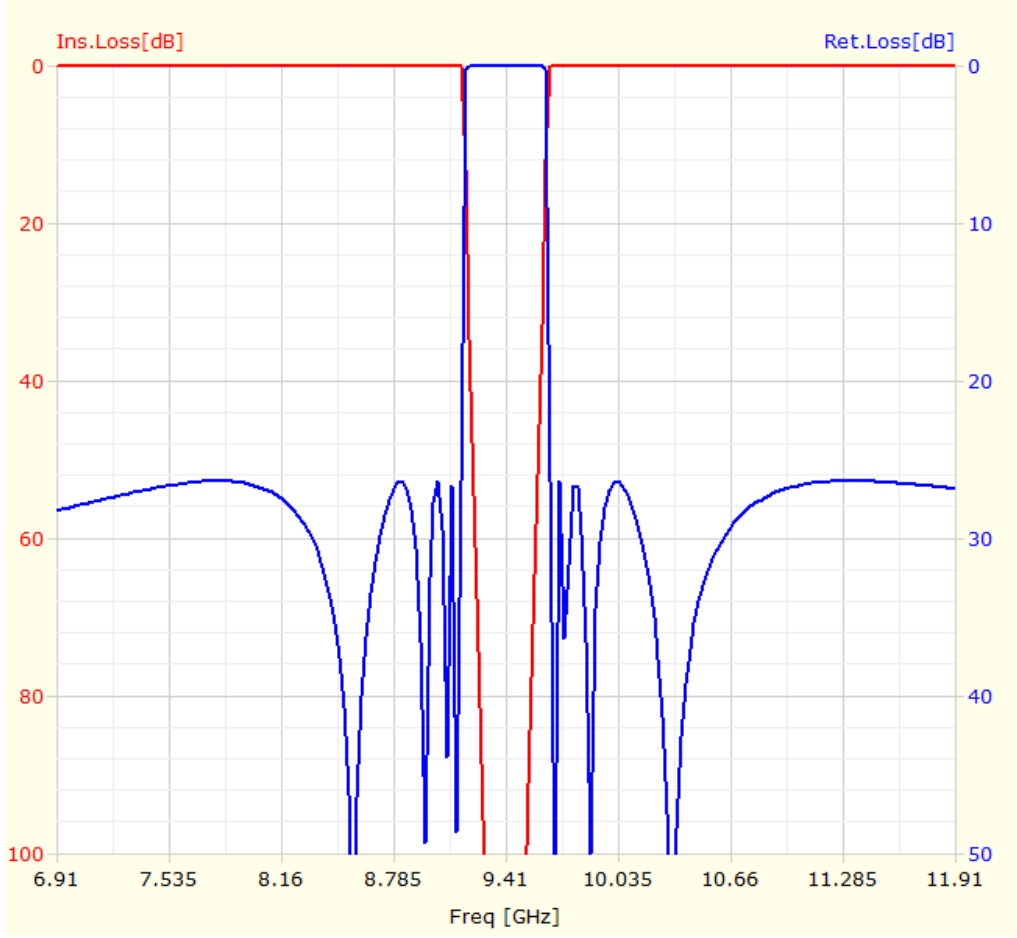
A radar frequency notch filter will enable nearly full sky observations at GGAO

Notch Filter Design

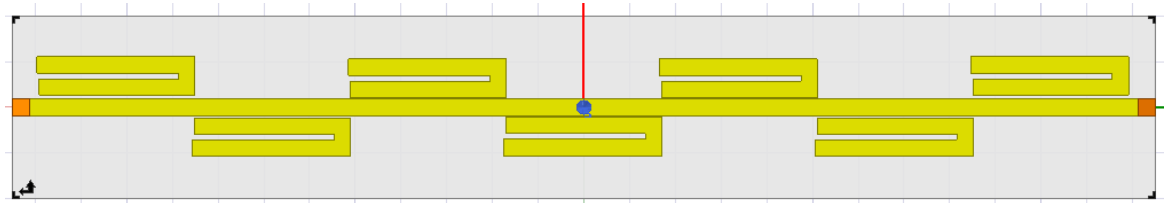
- -50 dB rejection at 9.41 GHz ± 150 MHz
- -3 dB rejection at 9.41 GHz ± 250 MHz
- Insertion loss less than 0.5 dB outside VGOS band (2-14 GHz)
- Fit inside a 40 x 20 x 10 mm^3 volume



Equivalent LC filter network

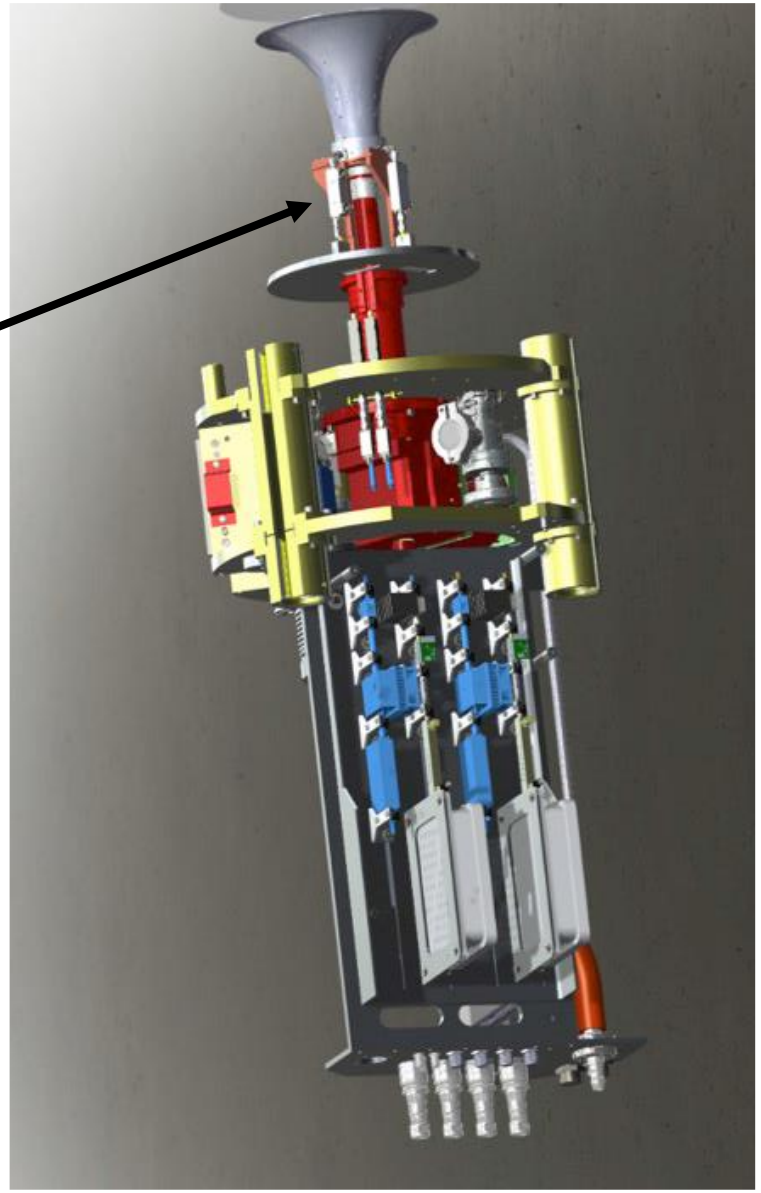


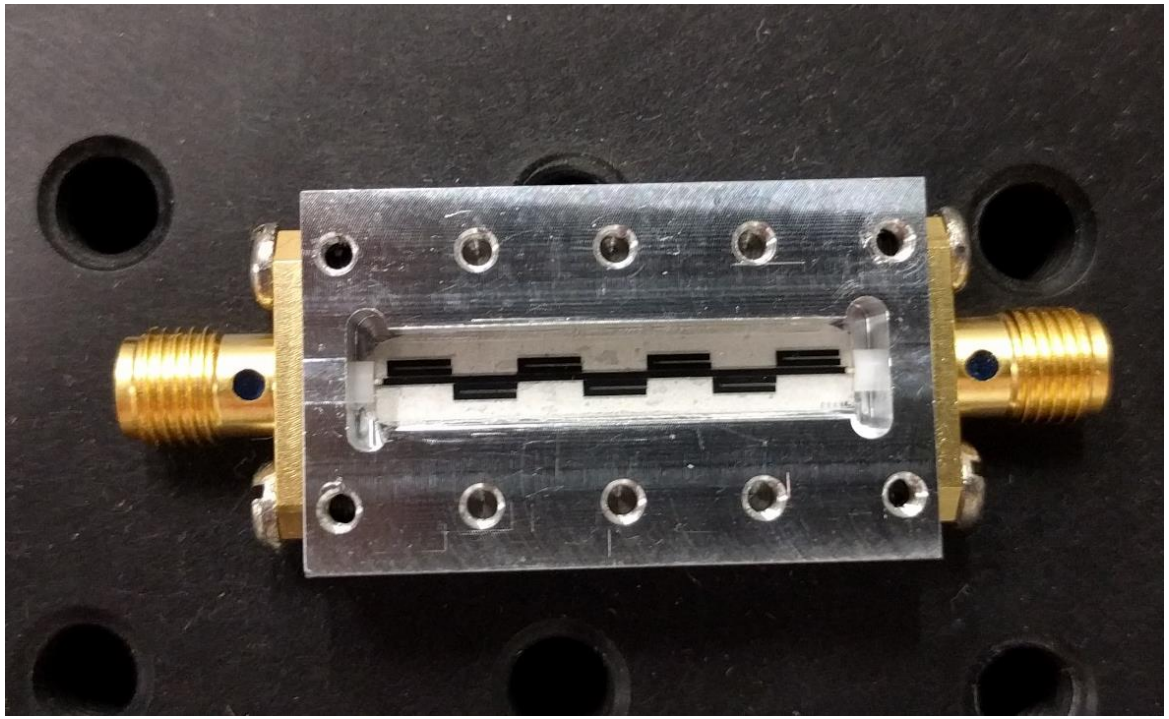
7th-order Chebyshev filter model



Filter CAD model

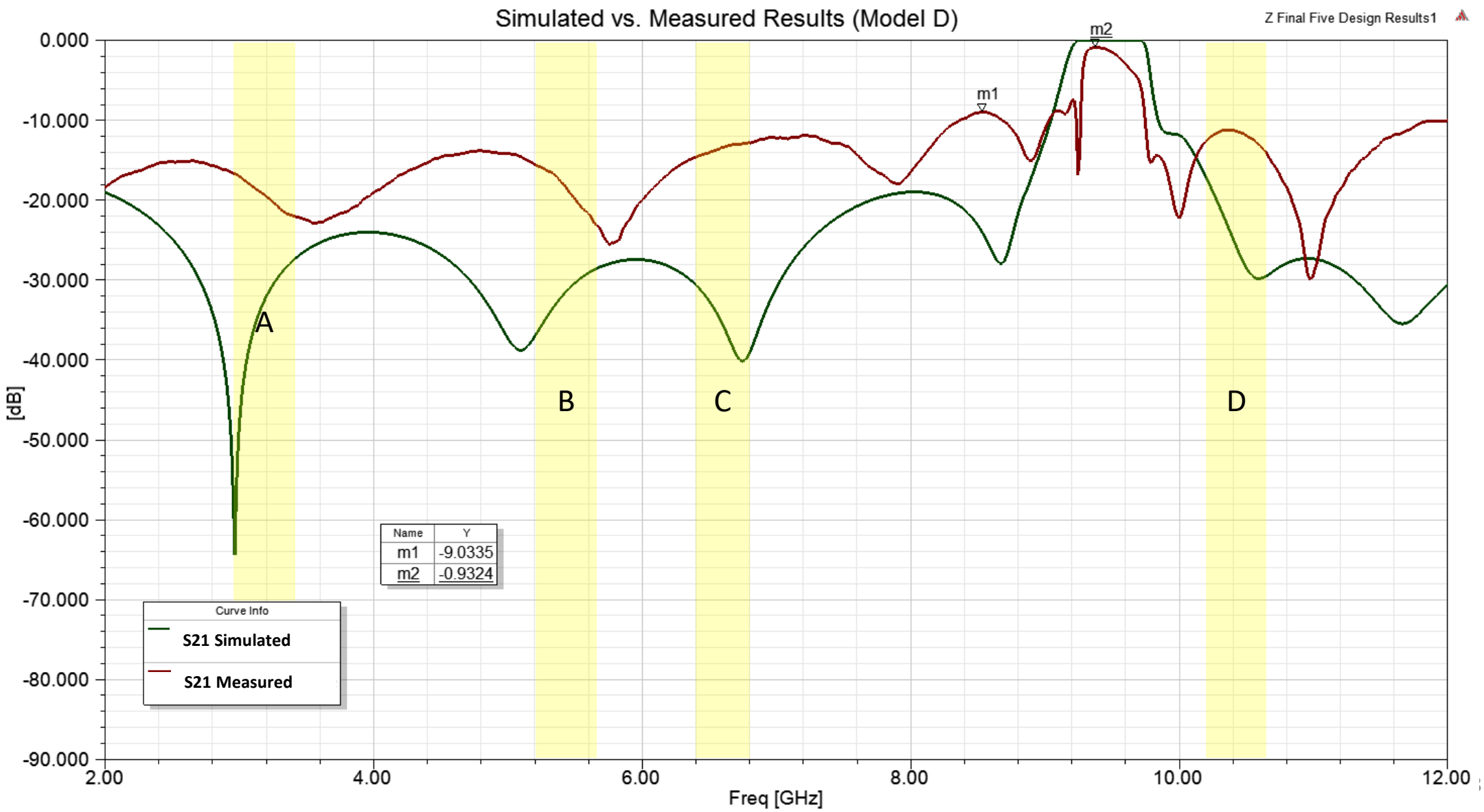
Filter location
in receiver



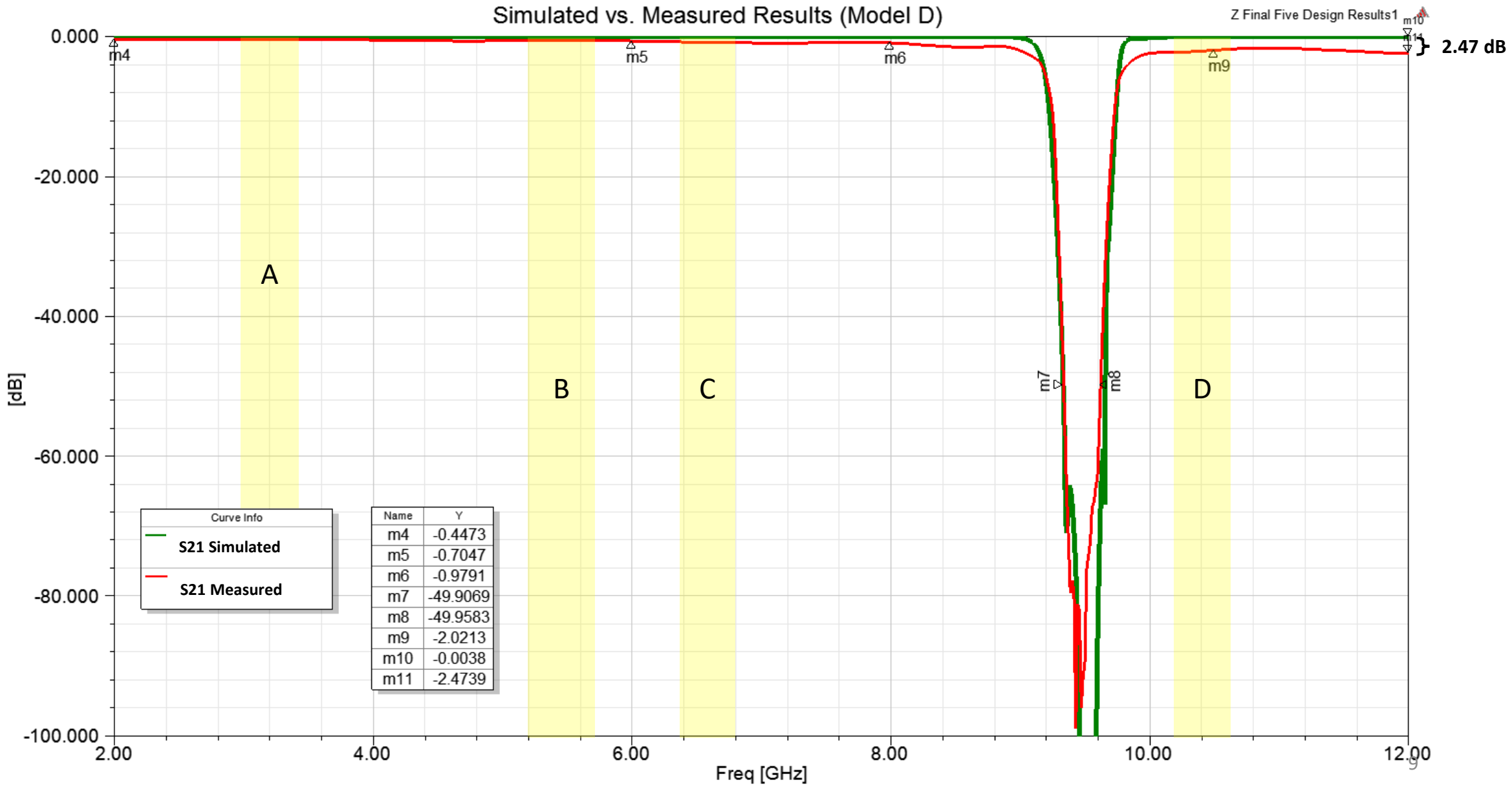


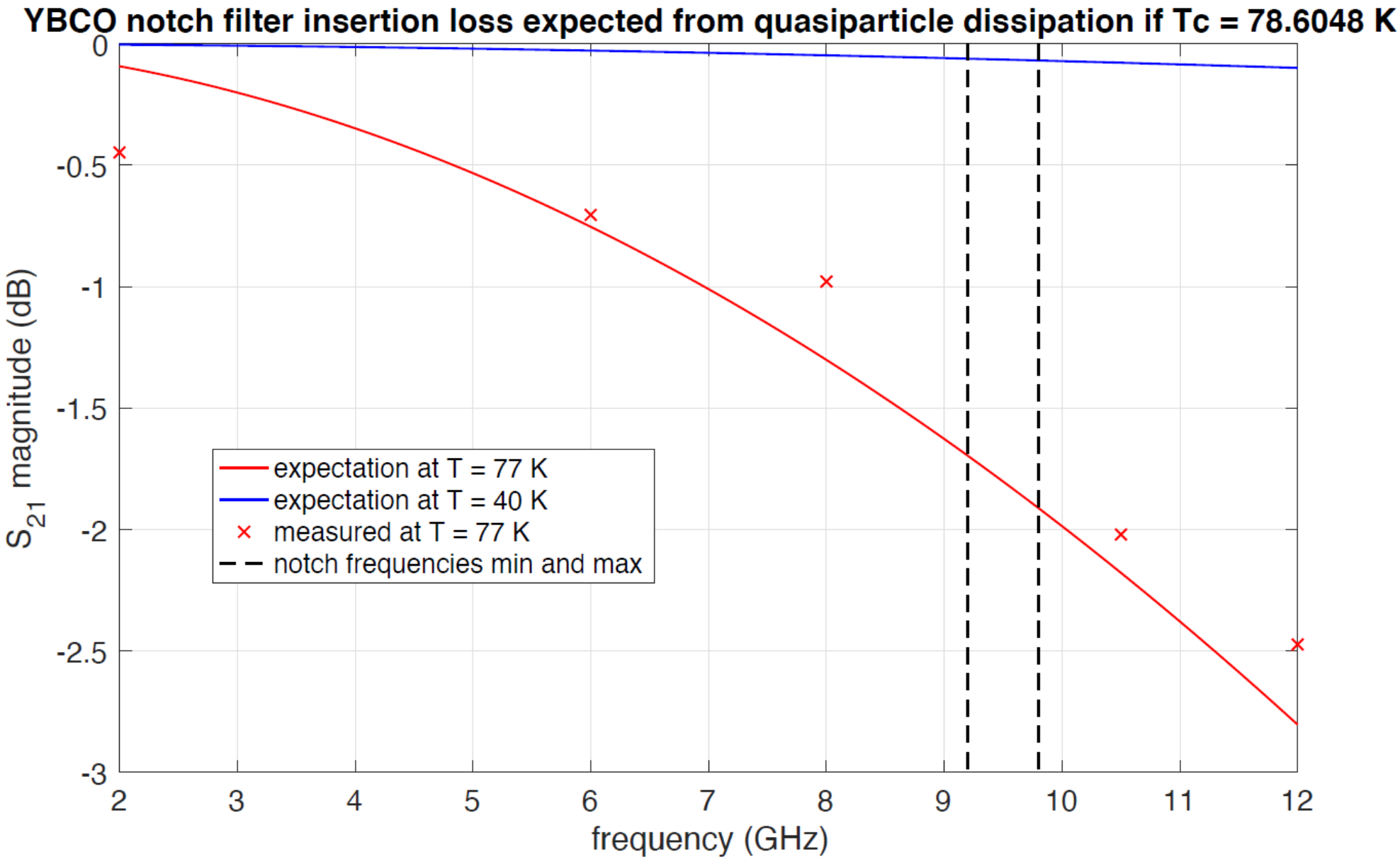
YBCO vendor: STAR Cryoelectronics

77 K Reflection



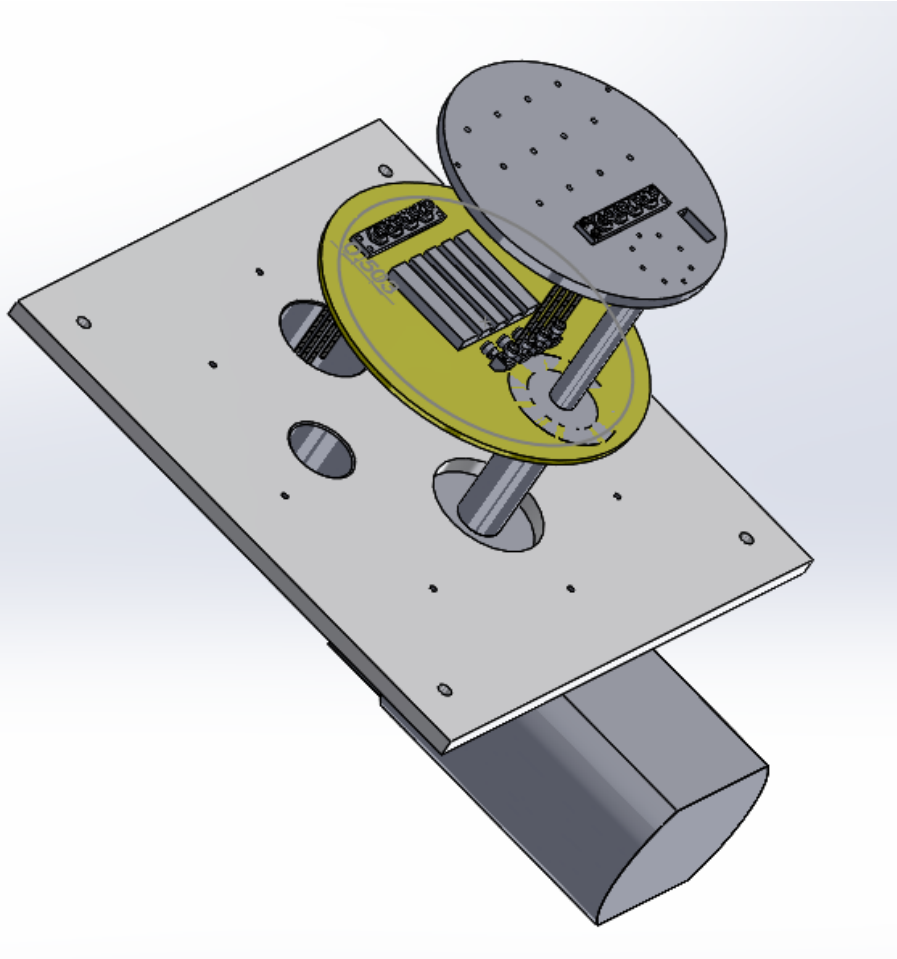
77 K Transmission

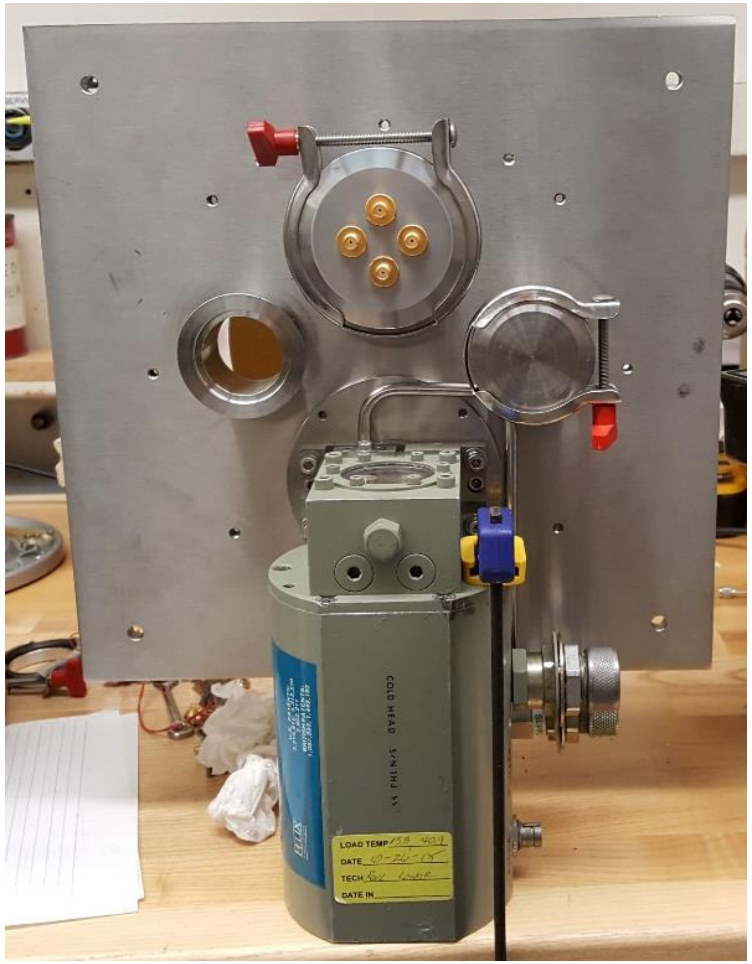




Filter is expected to perform much better at typical receiver temperatures (T ~ 20K)

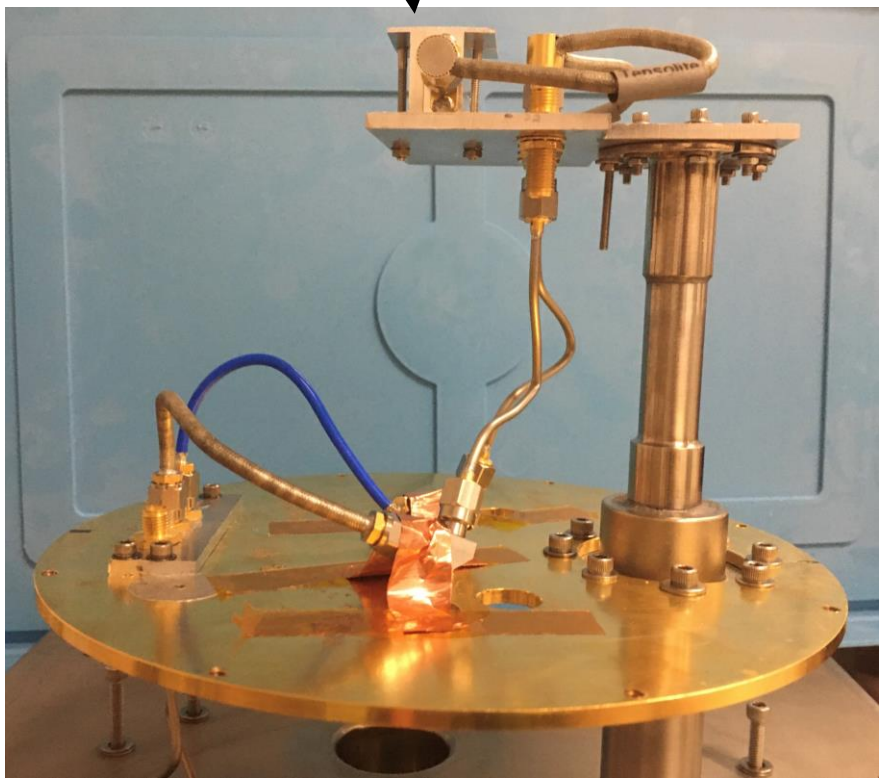
VLBI test cryostat



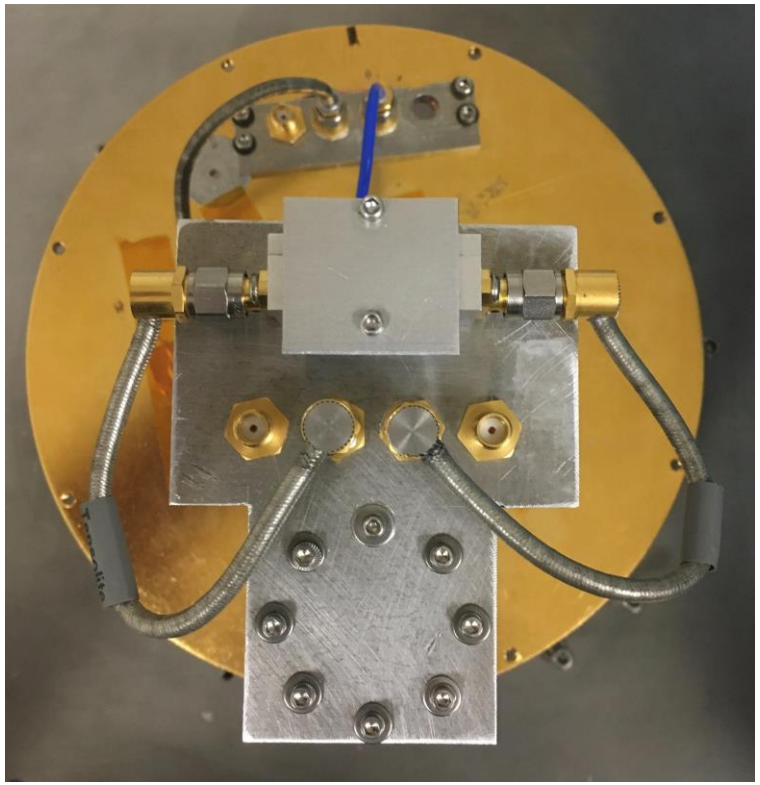


- Low thermal conductivity (SS BeCu) signal lines from 300 K to 50 K
- Cu signal lines heat sunk at 50 K
- SS BeCu signal lines from 50 K to 20 K

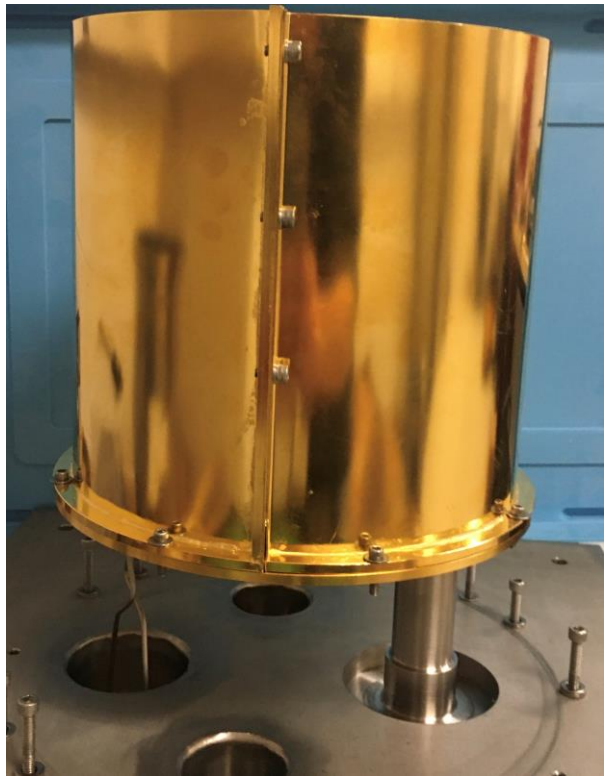
notch filter package



sample stage

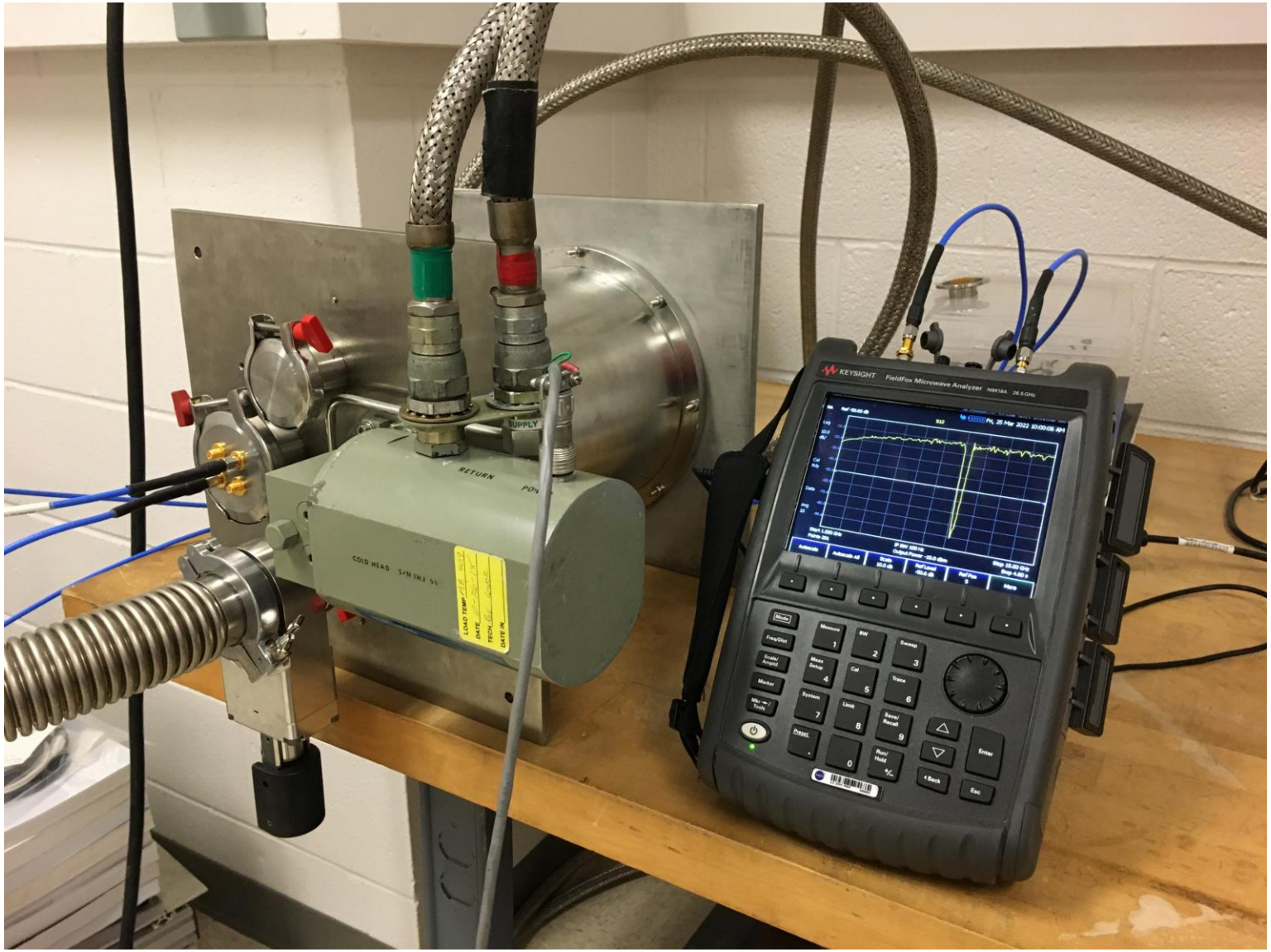


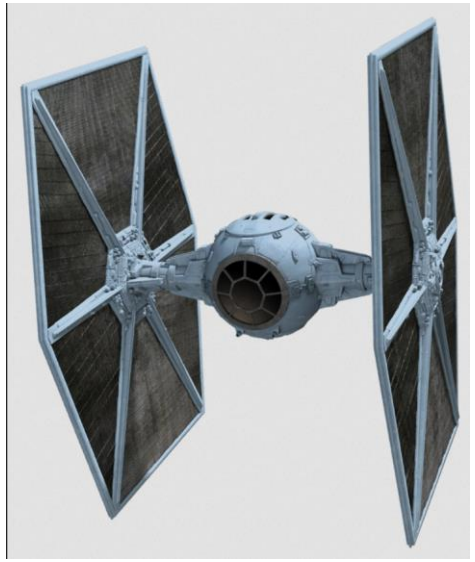
50 K shield



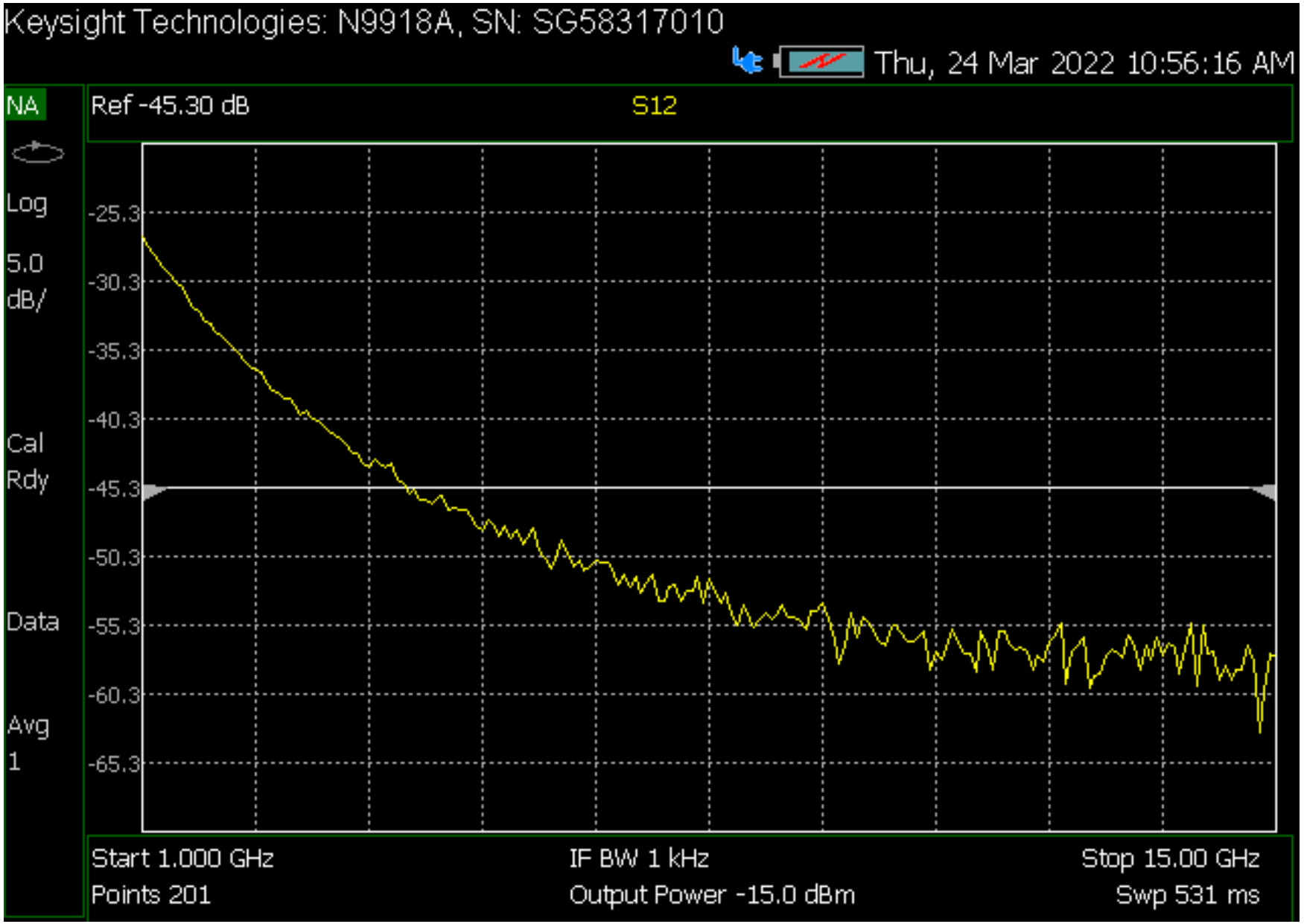
Multiple coaxial lines in cryostat enable a variety of future experiments

Operational VLBI cryostat



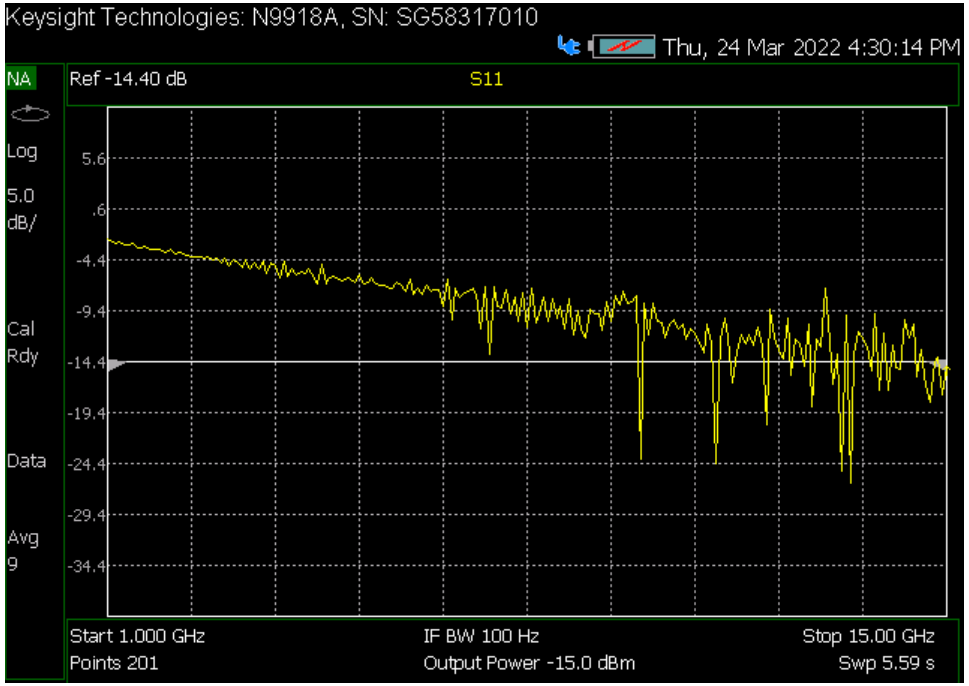


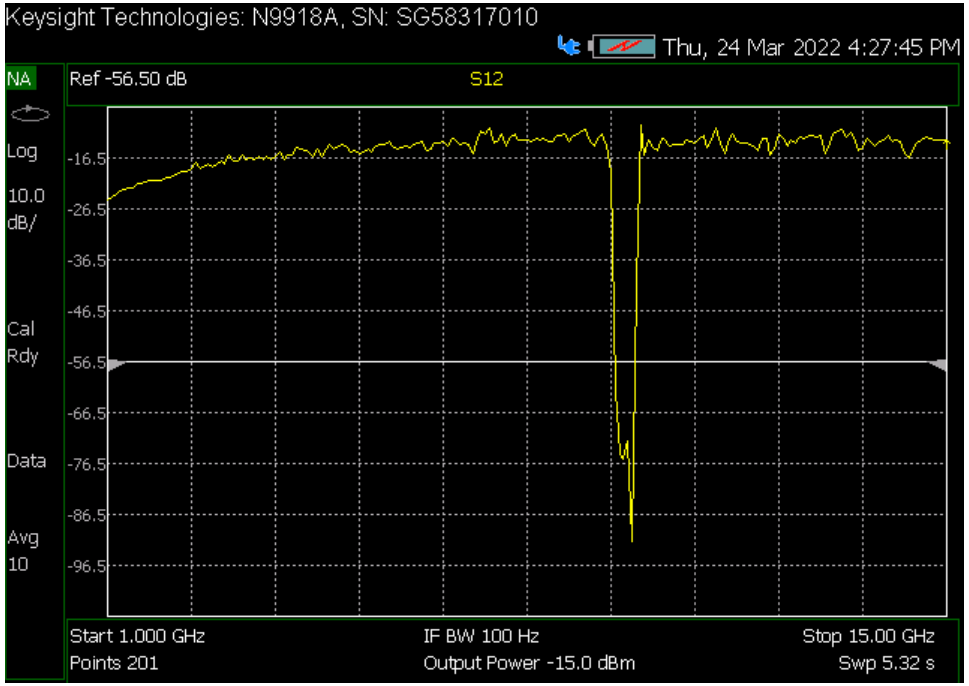
S12 for YBCO notch filter at T ~ 300 K (R ~ 550 Ω)

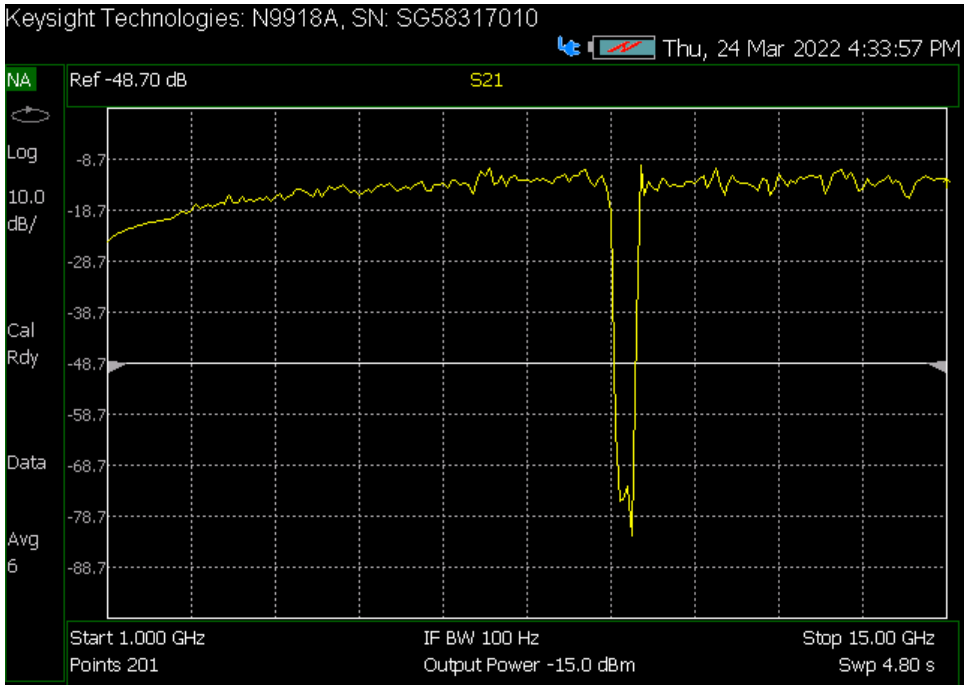


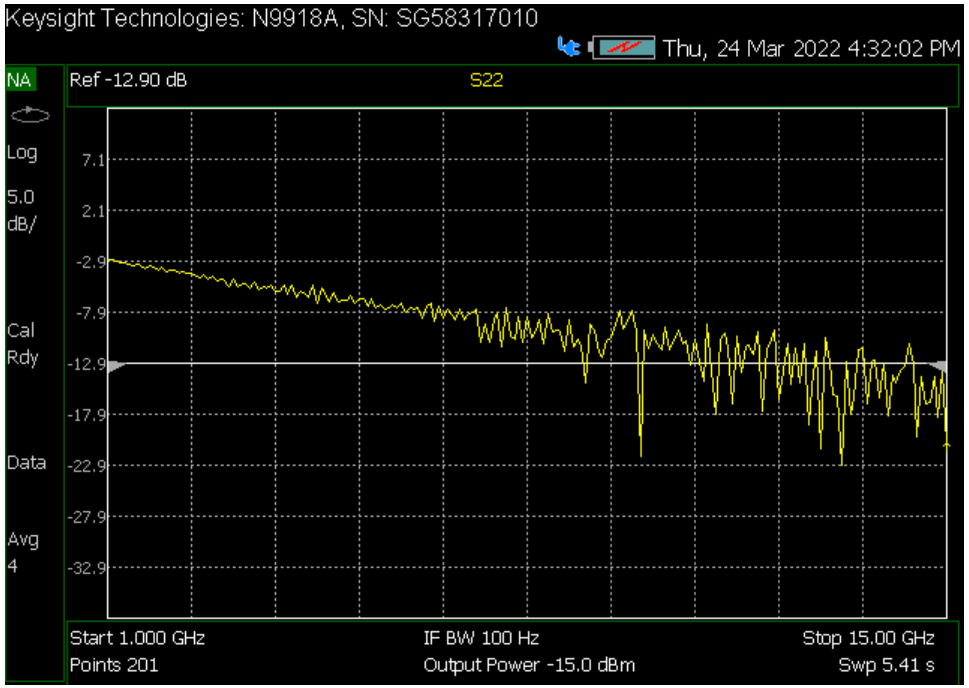
<u>Warm observations are not possible with a YBCO filter in the signal chain</u>

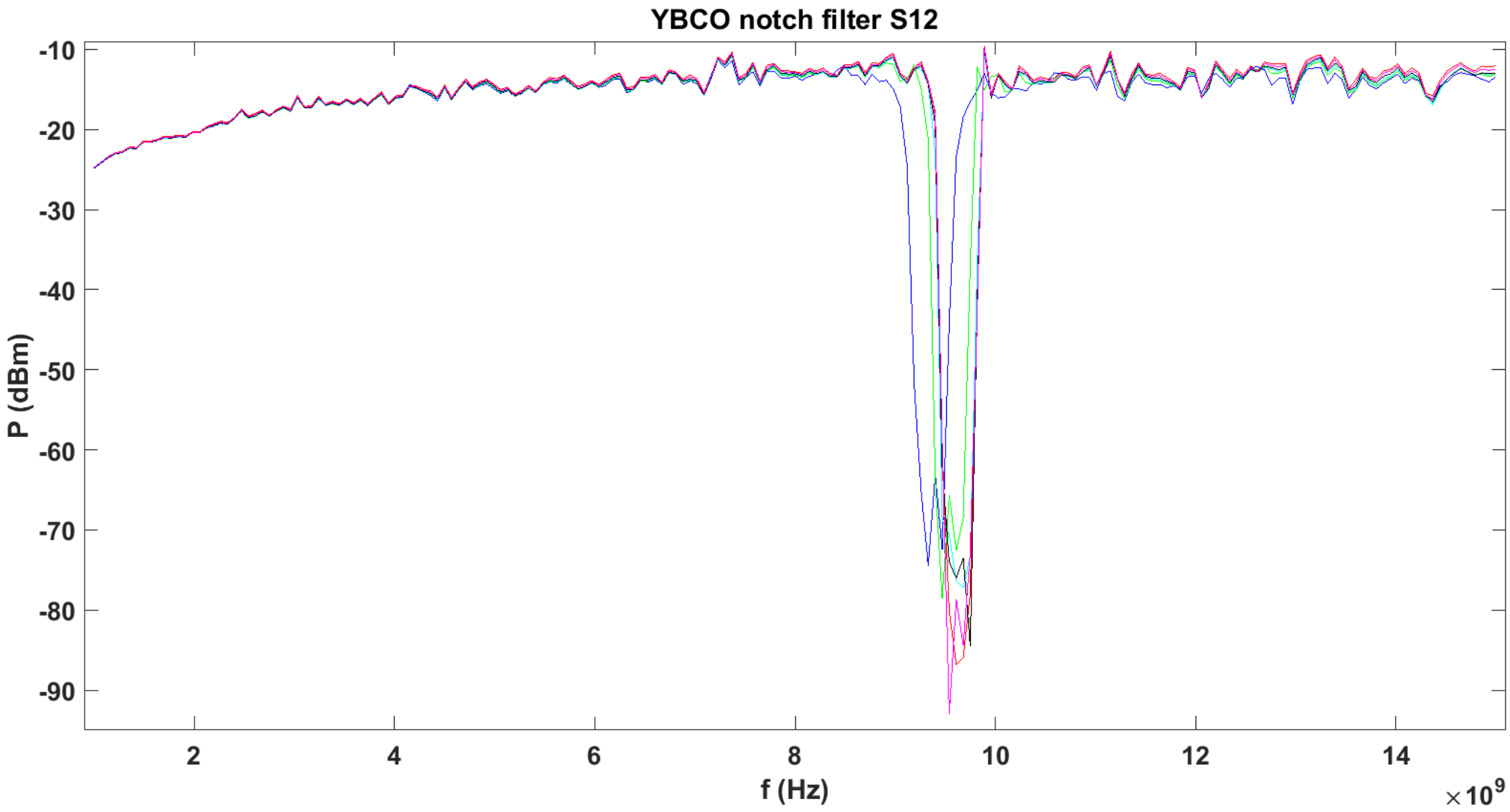
YBCO notch filter S-parameters near Tc



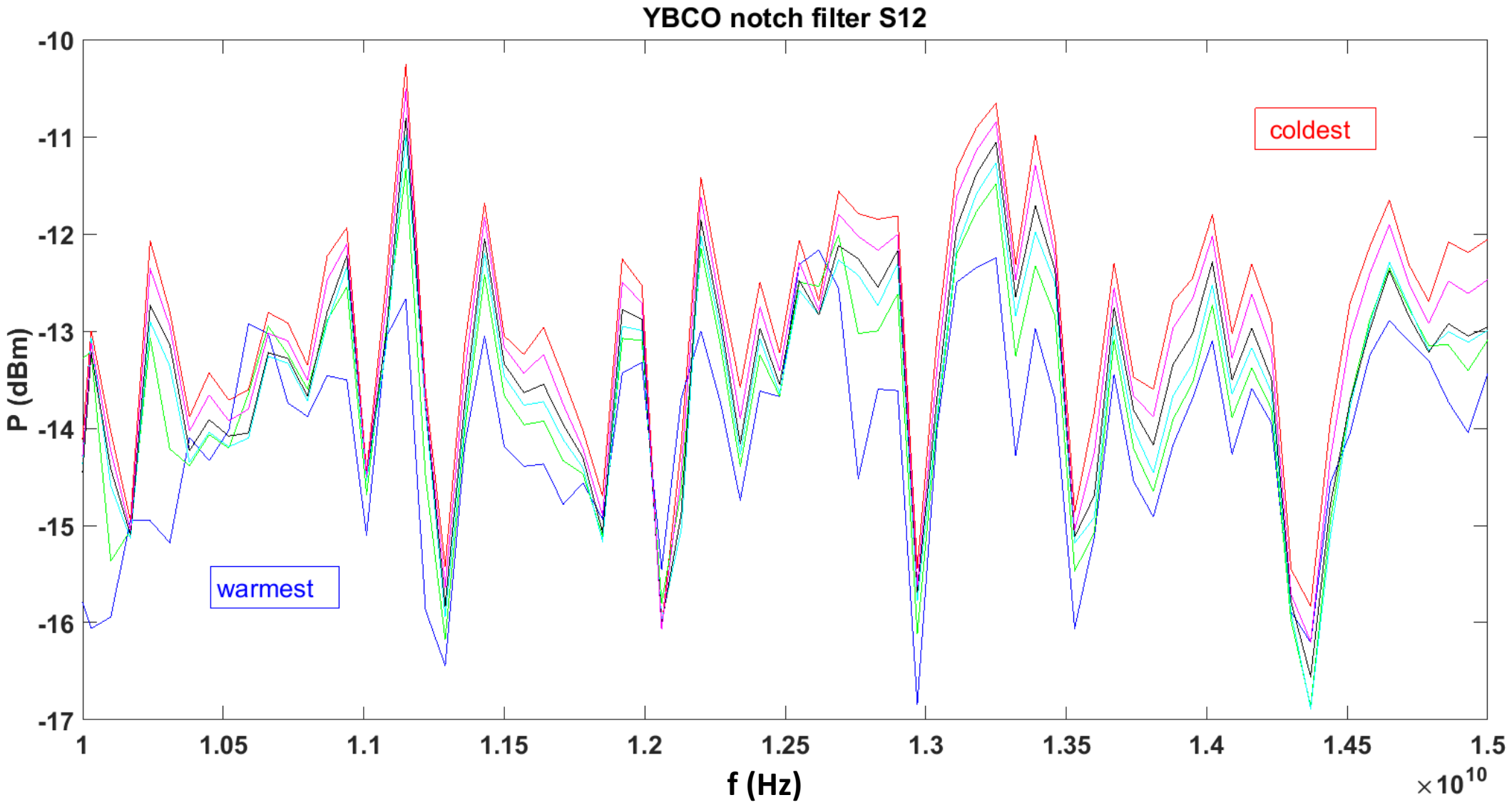








Note: data is uncalibrated



As filter is cooled, loss outside notch band is reduced

Conclusion

- First iteration of YBCO notch filter demonstrates successful design (stop-band achieves desired performance)
- YBCO notch filter is only viable for cold operations
- New test cryostat enables a wide range of component characterization (filters, directional couplers, LNAs, calibration systems, etc.)
- Modified case design should help improve performance (heat sinking, better connectors, etc.)
- Special thanks: A. Niell, J. Redmond, D. Khachadourian