GGAO Notch Filter at 20K and Other RFI Mitigation Work

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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
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

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 mm³ volume

Equivalent LC filter network

7th-order Chebyshev filter model
YBCO vendor: STAR Cryoelectronics
77 K Reflection

Simulated vs. Measured Results (Model D)

Freq [GHz]

<table>
<thead>
<tr>
<th>Name</th>
<th>Y</th>
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<tbody>
<tr>
<td>m1</td>
<td>-0.0335</td>
</tr>
<tr>
<td>m2</td>
<td>0.9324</td>
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QueIn Info
- S21 Simulated
- S21 Measured
77 K Transmission

Simulated vs. Measured Results (Model D)

FREQ [GHz]

Freq [GHz]

2.00 4.00 6.00 8.00 10.00 12.00

[dB]

-100,000 -80,000 -60,000 -40,000 -20,000 0,000

Curve Info

S21 Simulated
S21 Measured

Name | Y
---|---
m4 | -0.4473
m5 | -0.7047
m6 | -0.9791
m7 | -49.9069
m8 | -49.9583
m9 | -2.0213
m10 | -0.0038
m11 | -2.4739

2.47 dB
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
Multiple coaxial lines in cryostat enable a variety of future experiments
Operational VLBI cryostat
Warm observations are not possible with a YBCO filter in the signal chain for YBCO notch filter at $T \sim 300$ K ($R \sim 550$ Ω).
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.)

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