Performance of a Low-parasitic Frequency Domain Multiplexing Readout

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Introduction

- Frequency Domain Multiplexing (fMux) is a TES readout technique used on current CMB experiments
- Parasitic impedance in fMux is a dominant source of crosstalk and limits operation of lower-Rₙ bolometers
- We have designed and implemented a readout with the SQUID next to the LC
  - Reduced wiring length → reduced parasitics
- Here we show performance of the prototype system alongside SPT-3G readout hardware for comparison

Key Benefits

- Reduced Parasitics
  - Low Rn detectors
  - Reduced crosstalk
- Decreased NEPₚreadout
- Higher MUX-factor

- Decreased stray resistance enables operation of lower-Rₙ bolometers, to better optimize noise.
  - Reduces NEPₚreadout because the bolometers can be operated with lower Vₚbias. Optimal R for a typical fMux is ~0.5-1.0 Ohms.
- Reduced crosstalk enables denser packing of bolometers in frequency space
  - This allows for higher multiplexing factors and improved scalability.
- Leverages much of the existing DfMux architecture, which has proven on-sky performance
- Drop-in replacement for 3G-style LC boards

Design and Implementation

- Move the SQUID from the 4 K stage to the 250mK stage
- This reduces the wiring length between the SQUID and LC chip and hence reduces parasitic impedance
- Enables operation of low-resistance bolometers
- Improves scalability
- Retained as much of the existing DfMux design as possible.
- This reaps the benefits of reduced crosstalk, reduced parasitic resistance, and improved scalability, while retaining as much technological maturity as possible.
- Magnetic shielding for the SQUID: six layers of Metglas.
- Prototype boards are sized so they can be a drop-in replacement for SPT-3G-style LC boards in any of the SPT-3G testbeds or, in principle, the telescope itself.

Performance

- The T > Tc noise performance of the prototype system is comparable to the performance of the standard SPT-3G hardware.
- The median parasitic resistance of the prototype is half that of 3G DfMux hardware. Vertical lines indicate the medians.

Next Steps

- Noise and Crosstalk Characterization
- Low-R bolometer integration
- Testing with calibrated resistors, and eventually low-R bolometers
- Scaling
- Testing with a larger number of combs
- SQUID improvements
- Lower thermal dissipation required for operation at scale with a sorption refrigerator

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3G Hardware
Prototype Hardware

Resistance vs Power curves for three representative bolometers. These curves have been corrected to remove the parasitic resistance.

V-phi curve for a representative NIST SA13 SQUID at three temperatures. We see slight improvement in peak-to-peak and transimpedance at lower temps.

Schematic of the DfMux readout. The wires highlighted in red run between the LC resonators and the SQUID. Stray impedance in these wires create a voltage divider effect which is the dominant source of crosstalk in the existing DfMux system.