Front-end Design of the Read-Out System for Micromachined Sensors applied to CMB Observations

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Work Plan

CMB Foregrounds

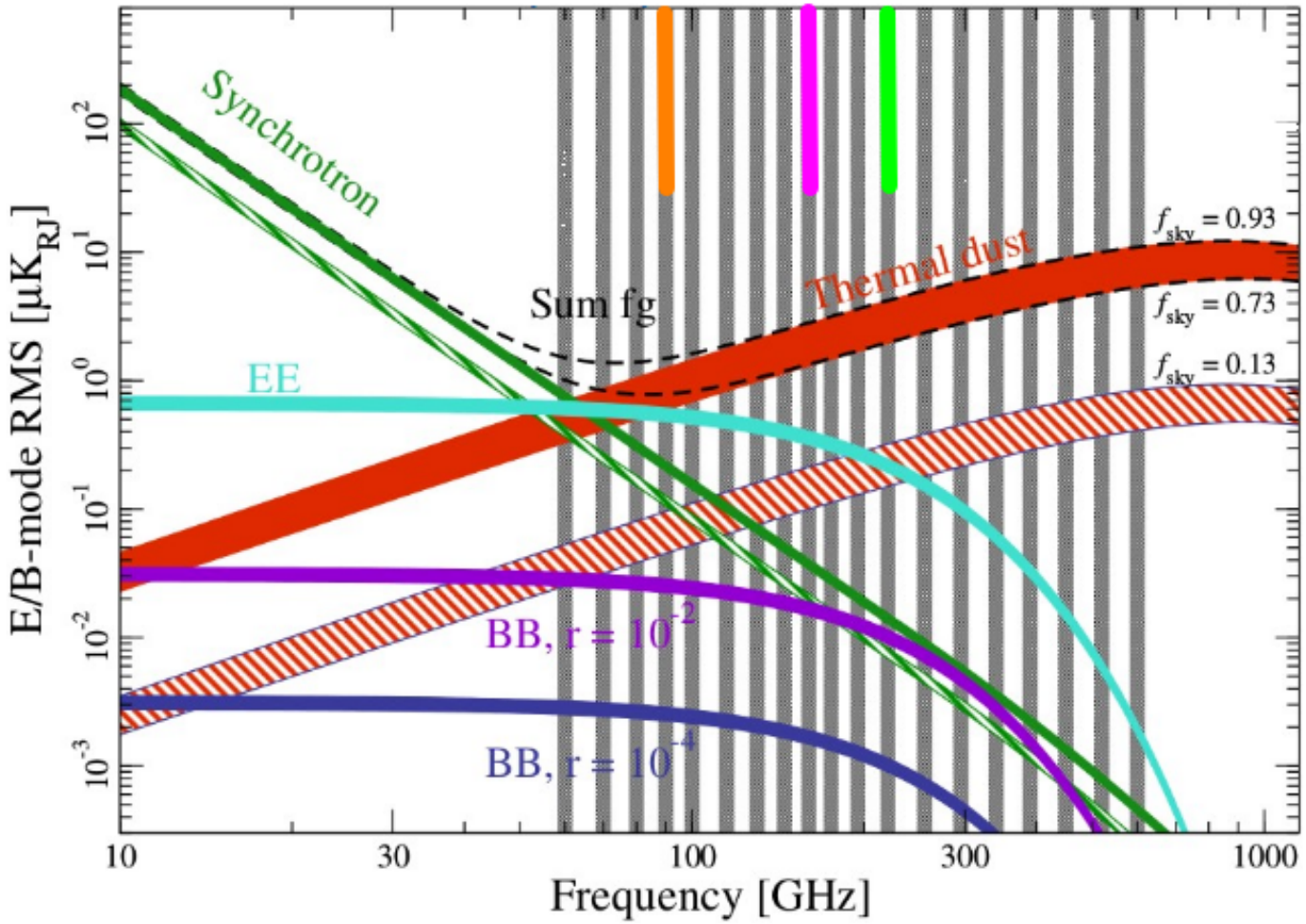


Figure: Brightness temperature spectra of polarized foregrounds[1]

1. Collaboration, T. C. (2017b). Exploring cosmic origins with core:b-mode component separation. *arXiv:1704.04501*

Background Limited Performance Detectors

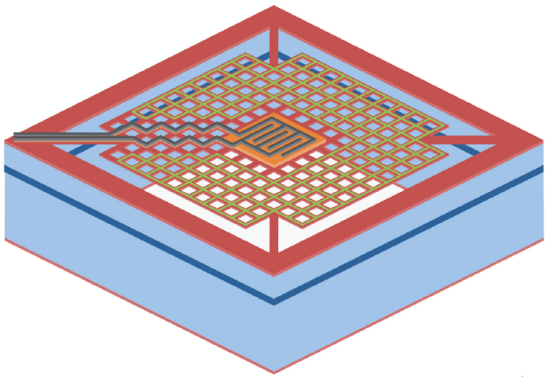
$$NEP^2_{h\nu} = 2h\nu P_{CMB} + \frac{P^2_{CMB}}{2\Delta\nu}$$

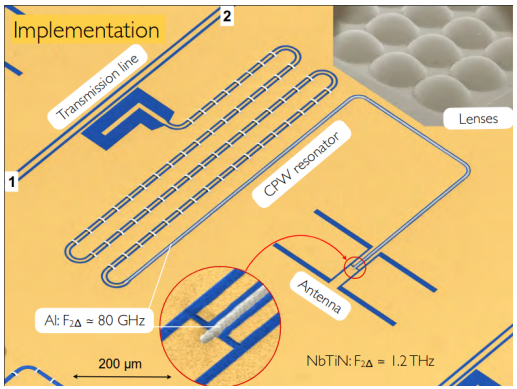
$$NEP^2_{Det} = [3-20] * 4kT_0 P_{Back}$$

$$NEP^2_{Det} \leqslant NEP^2_{h\nu} \rightarrow T_0 \leqslant 350mK * \frac{1mm}{\lambda}$$

$$\lambda_{CMB} \approx 1.5mm$$

(a) Noise Equivalent Power Budget





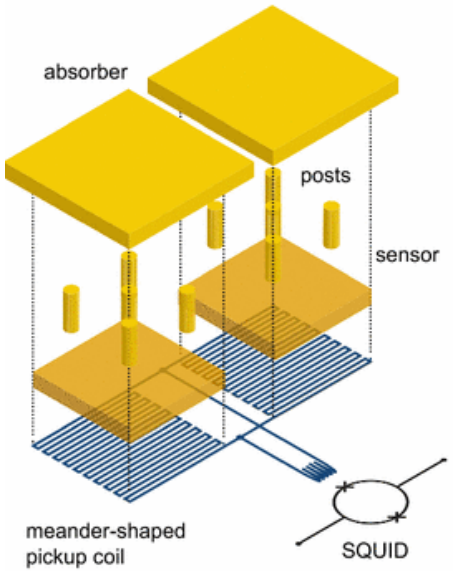


Figure: BLIP Cryogenic Detectors[2]

2. Piat, M. (2008). Review of detector rd for cmb polarisation observation. *Astroparticule et Cosmologie (APC), Universite*

CMB Stages

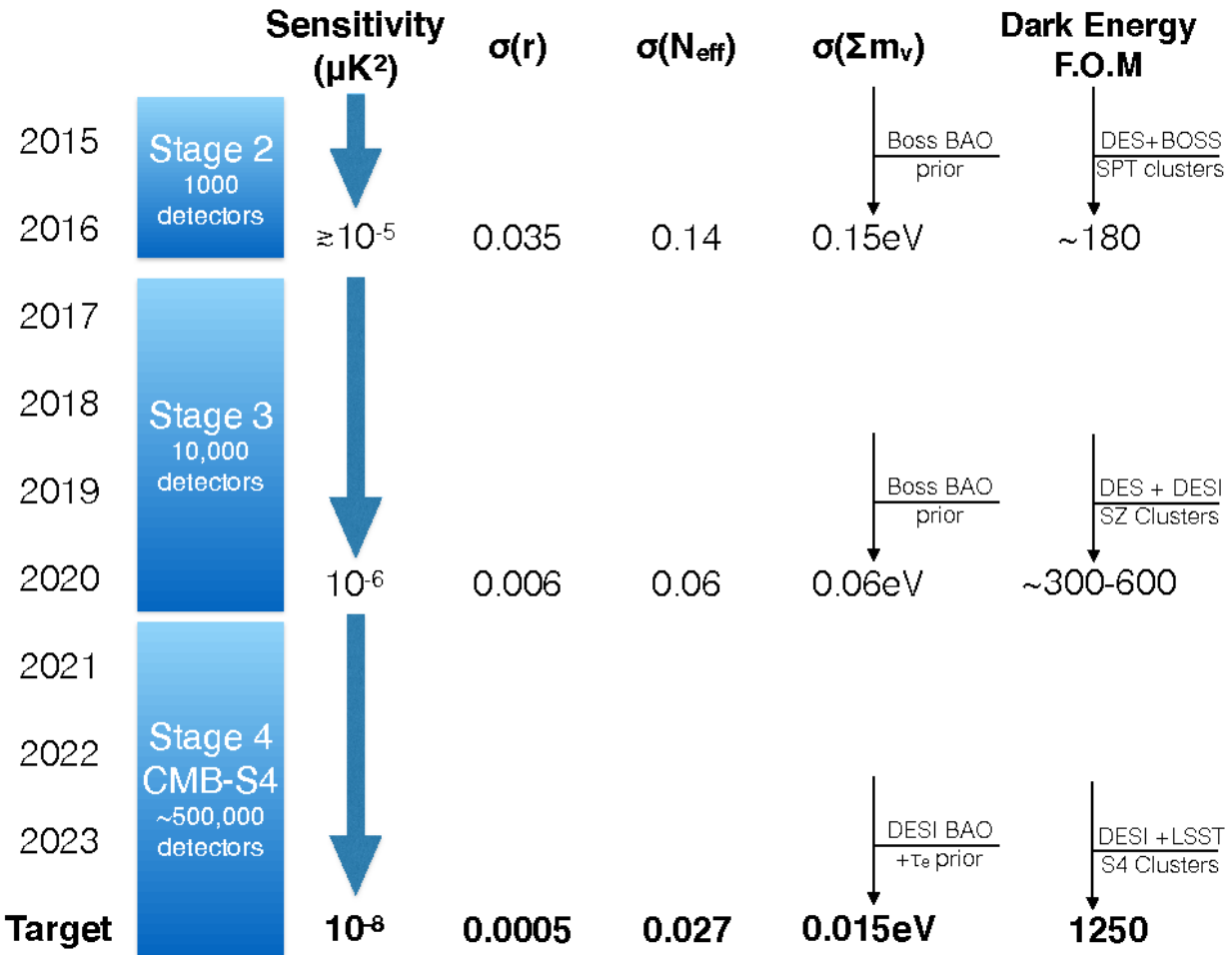


Figure: CMB Proposed Stages (CMB-S4 Collaboration[3])

3. Collaboration, C.-S. (2017a). Cmb-s4 technology book. *arXiv:1706.02464*

Cryogenic systems

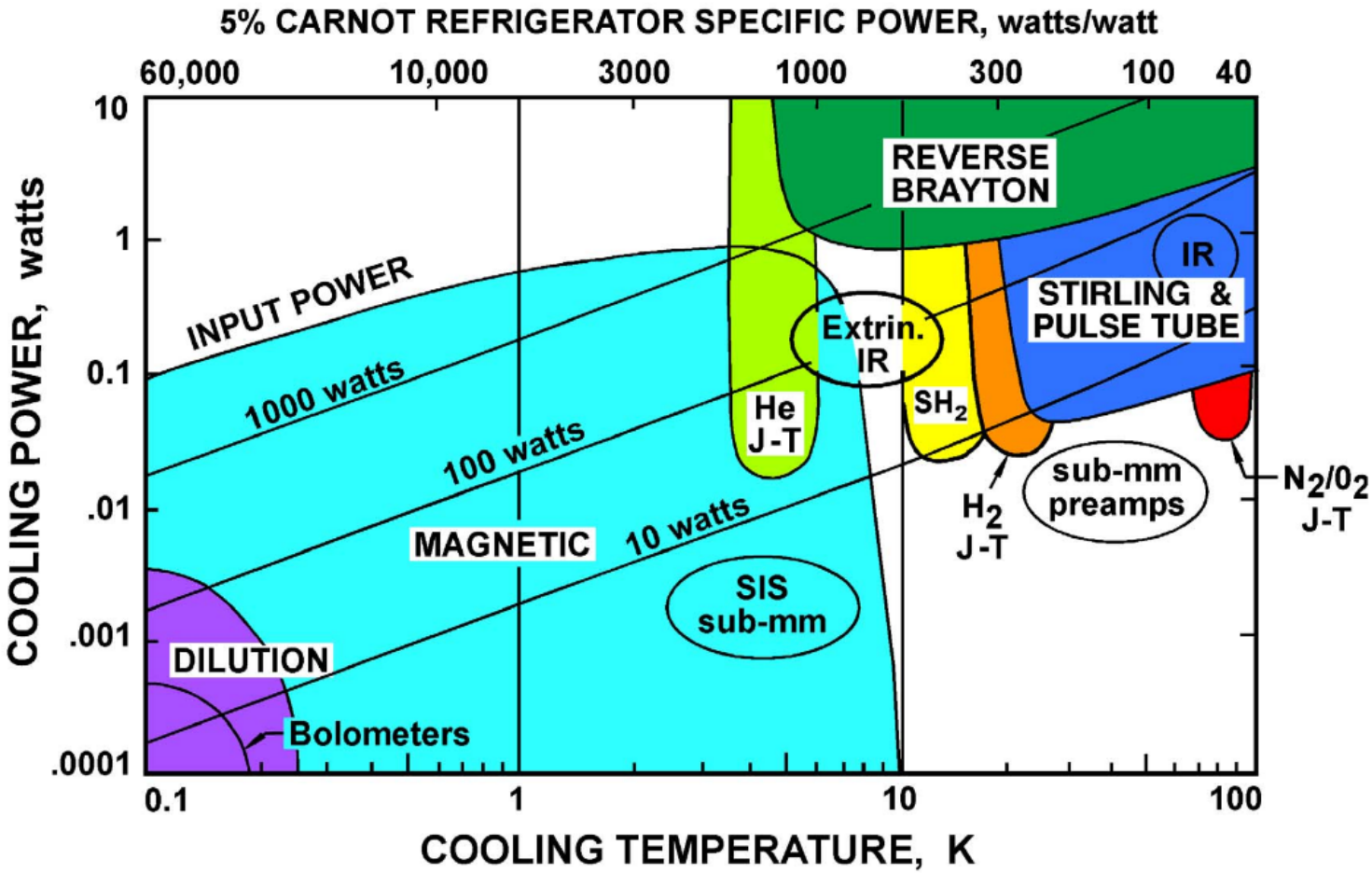
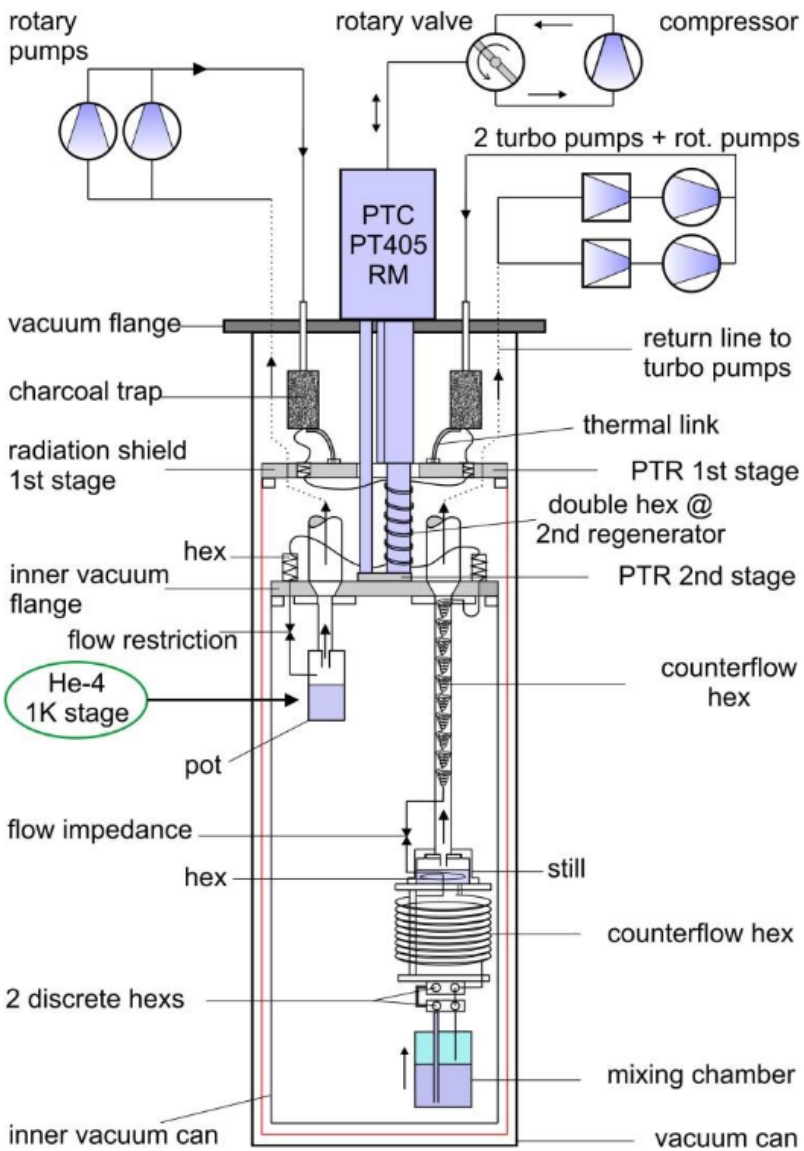
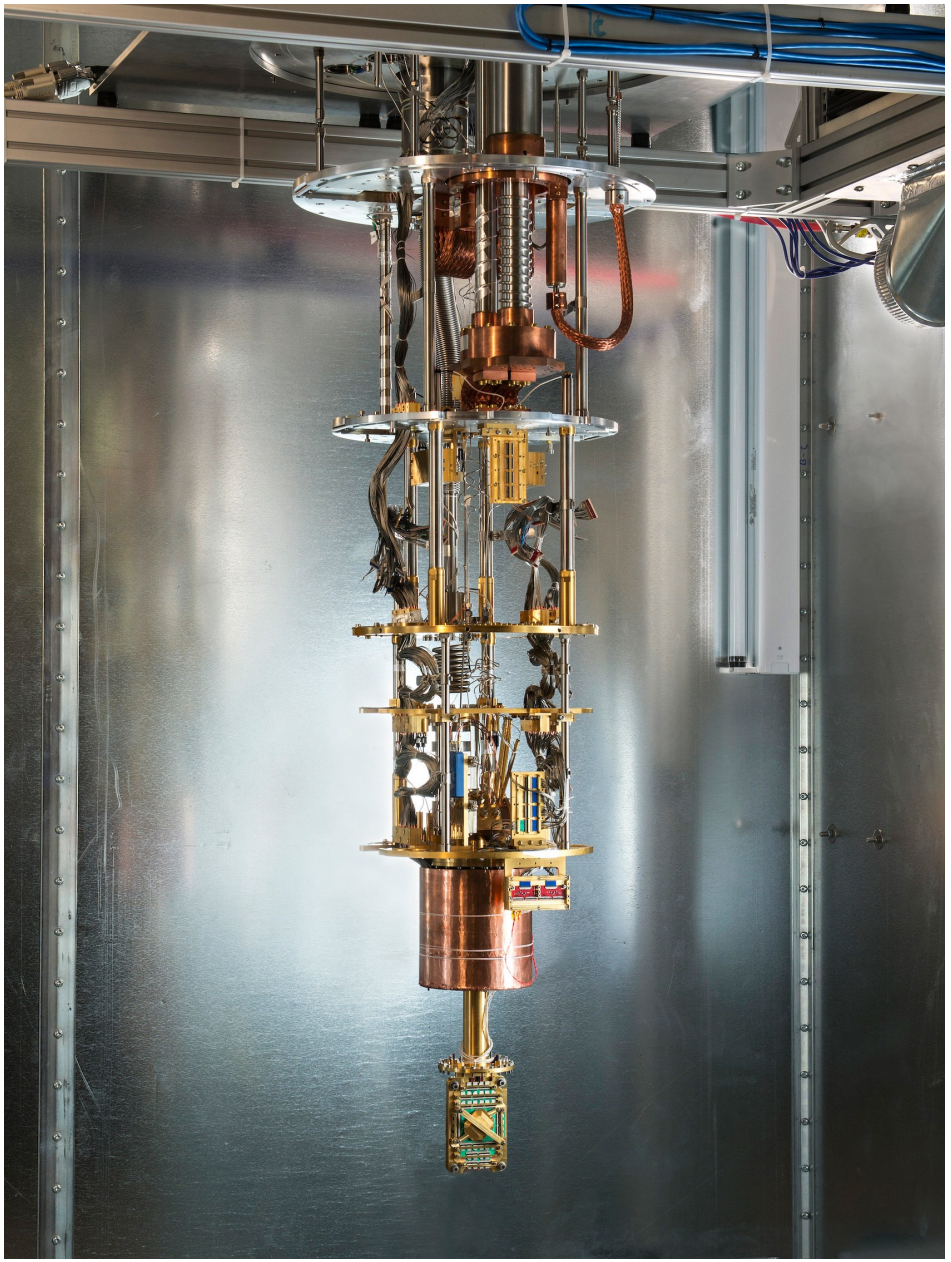


Figure: Attainable Cooling Power[4]

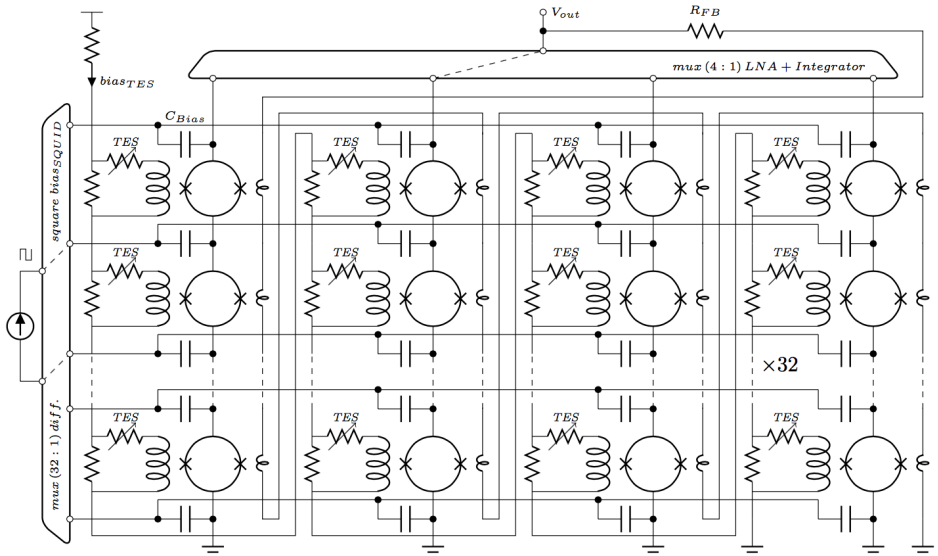
4. CR.G. Ross, J. (2015). Cryocoolers for space applications. *CL15-2287*

Dilution Fridge

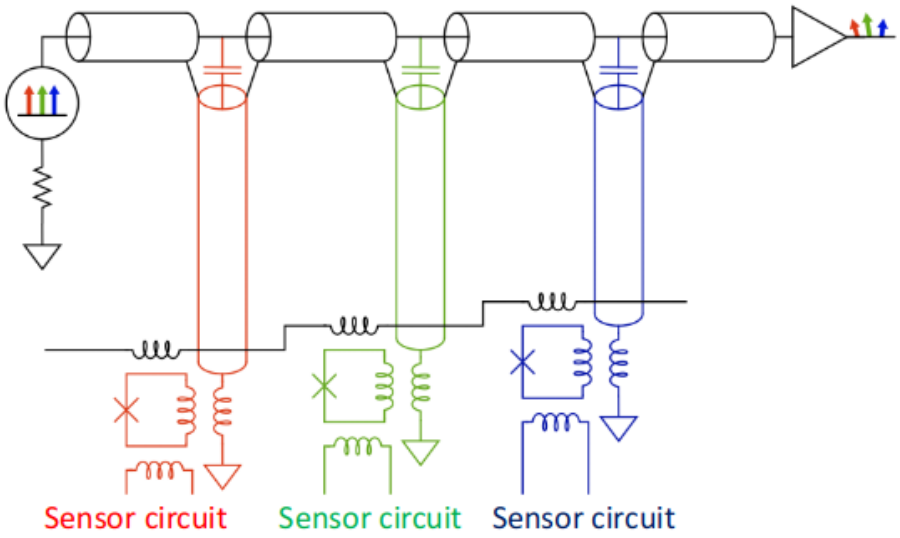




TDM Vs. FDM multiplexing Systems[5][6]



(a) TDM System



(b) FDM System

5. Collaboration, T. Q. (2017c). Qubic technical design report. *arXiv:1609.04372*
6. Mates, J. A. B. (2011). The microwave squid multiplexer. *PhD Thesis, B.A. Swarthmore College*

Read-Out System

Main Objective

Design a compact, scalable and universal RF Analog Front-End for the readout system of cryogenic detectors using frequency division multiplexing in the range of GHz.

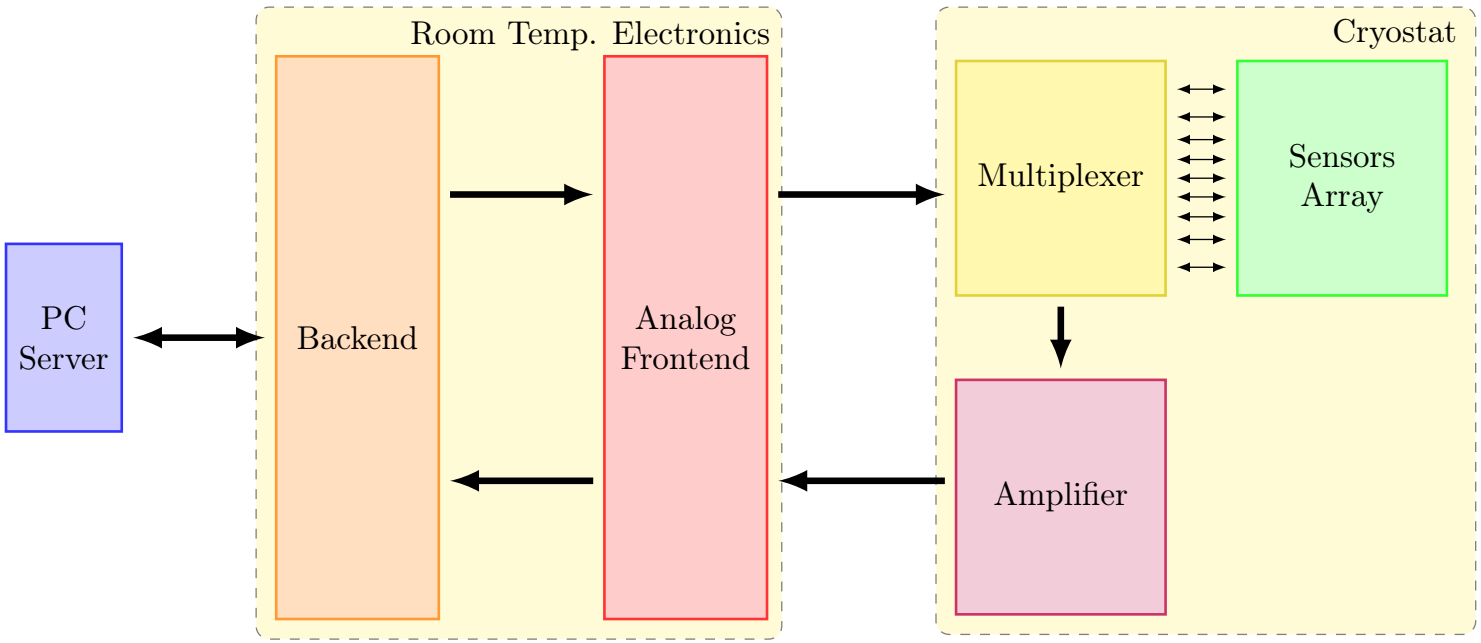
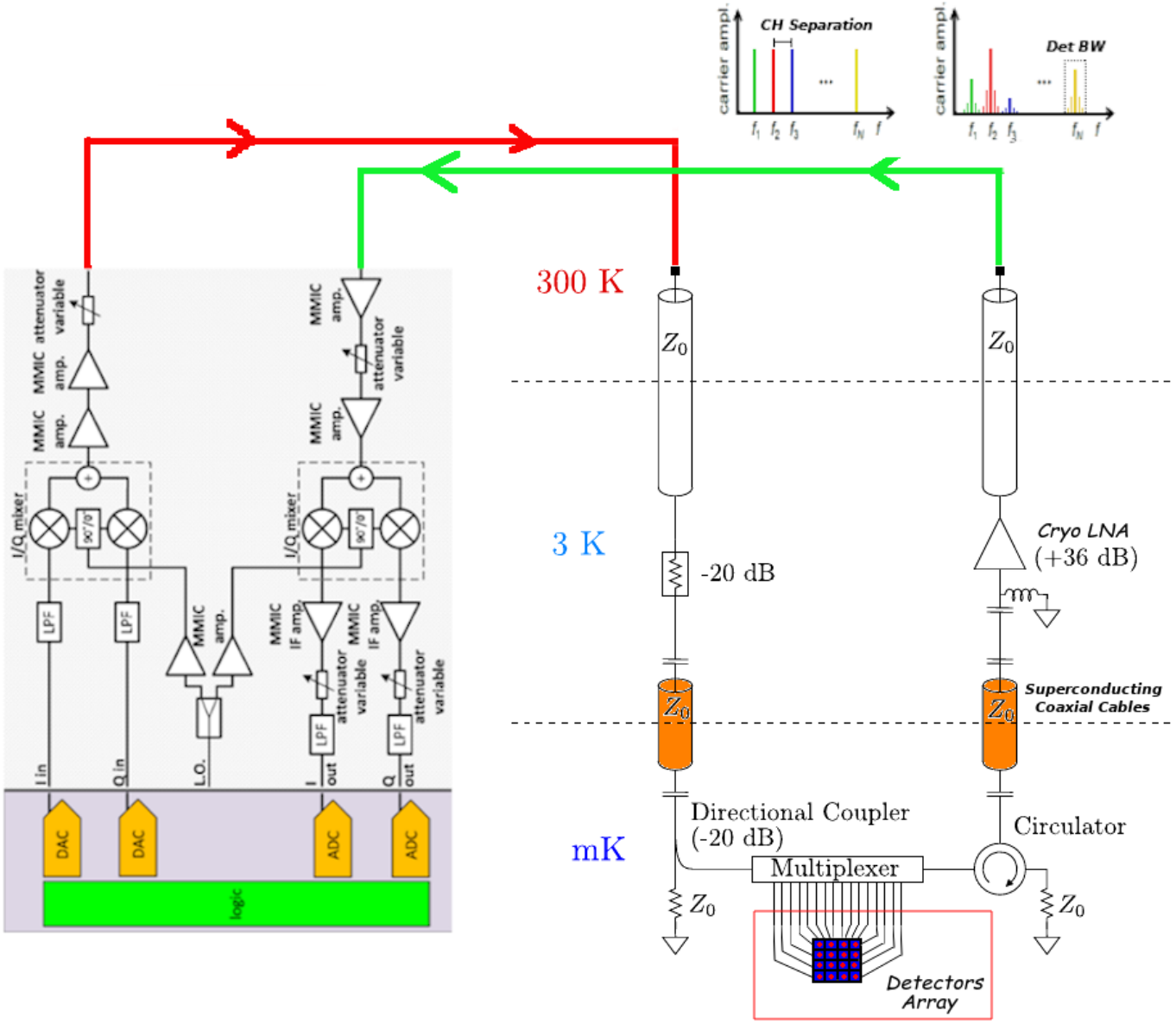


Figure: FDM multiplexing System.

Current Work

Cryogenic Circuit



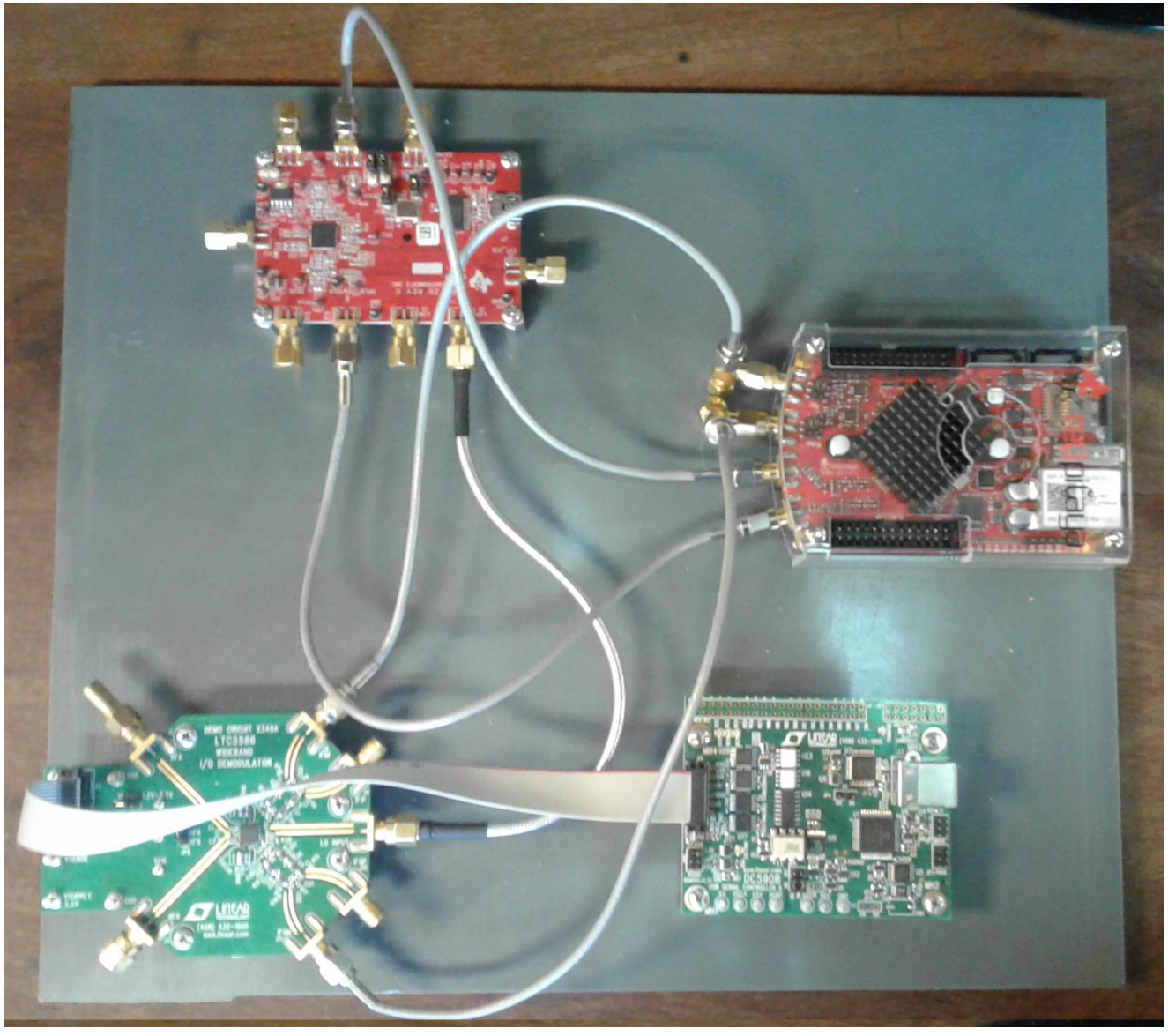
Front End Requirements

Table: Warm Front End Requirements.

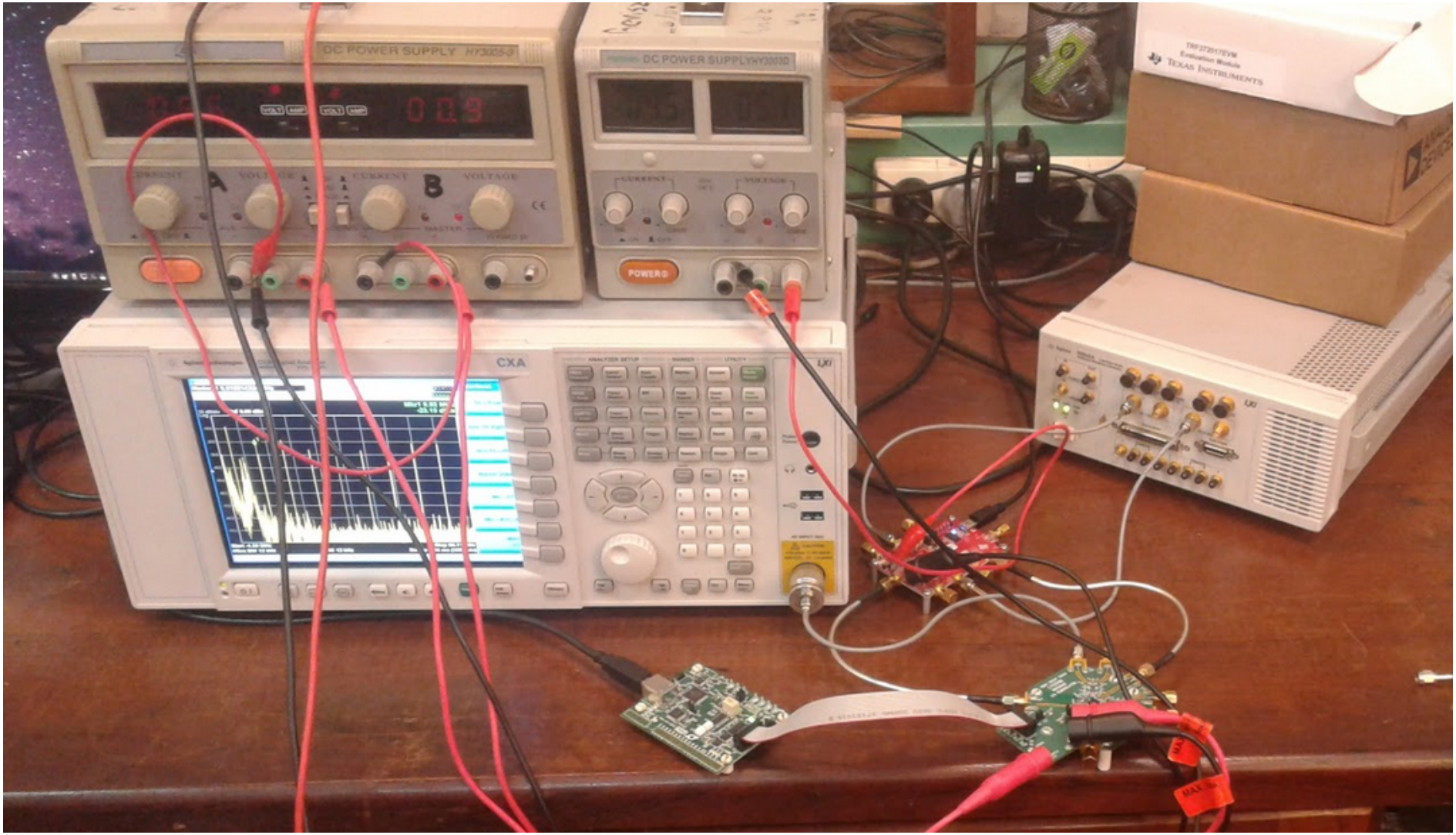
Requirements	Value	Description[7][8]
Total Bandwidth	4GHz to 8GHz	Limited by Cryogenic LNA and μSQUIDmux Bandwidth
Readout Powers	-90dBm to -60dBm	Readout power per pixel
Number of Channels	400	Limited by μSQUIDmux
Number of ADCs	5	80 channels per ADC
ADC SNR	$\geq$ 65dB	almost 10*log10(Number of tones) greater than LNA SNR
Number of Channels per ADC	80	
ADC sample frequency	800Msps	Limited by SNR
Number of DACs	5	to covers the LNA bandwidth
DAC SNR	$\geq$ 75dB	almost 10dB greater than ADC SNR
Total Power per tile	-30dBm to -0dBm	At cryostrat entry
Modulation Type	IQ	800 MHz of Complex Bandwidth, Limited by SNR
Number of IQ mixers	10	5 for up and 5 for down-conversion
Number of Local Oscillators	5	5 for up and down-conversion
LOs Frequency Range	4GHz to 8GHz	
Reference Clock Jitter	$\leq 150fs$	SNR due to jitter 10dB greater than intrinsic ADC SNR
LOs Phase Noise	$\leq -80dBc/Hz$	@1KHz offset

7. O. Sander, N. K. e. a. (2018). Software-defined radio readout system for the echo experiment. *arXiv:1806:10673v1*
8. Rantwijk, J. V. (2015). Multiplexed readout for 1000-pixel arrays of microwave kinetic inductance detectors. *arXiv:1507.04151*

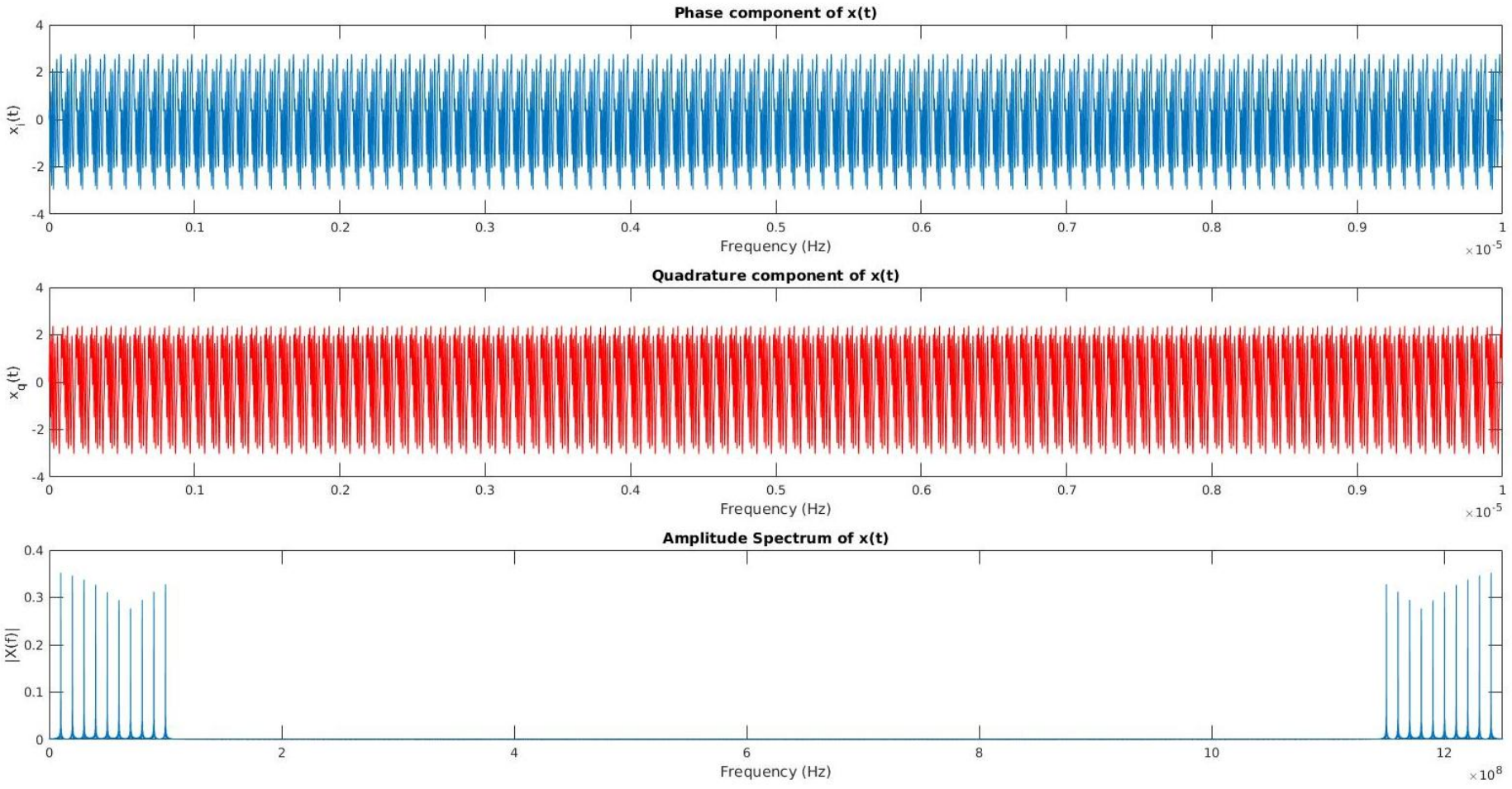
Prototype Front-End



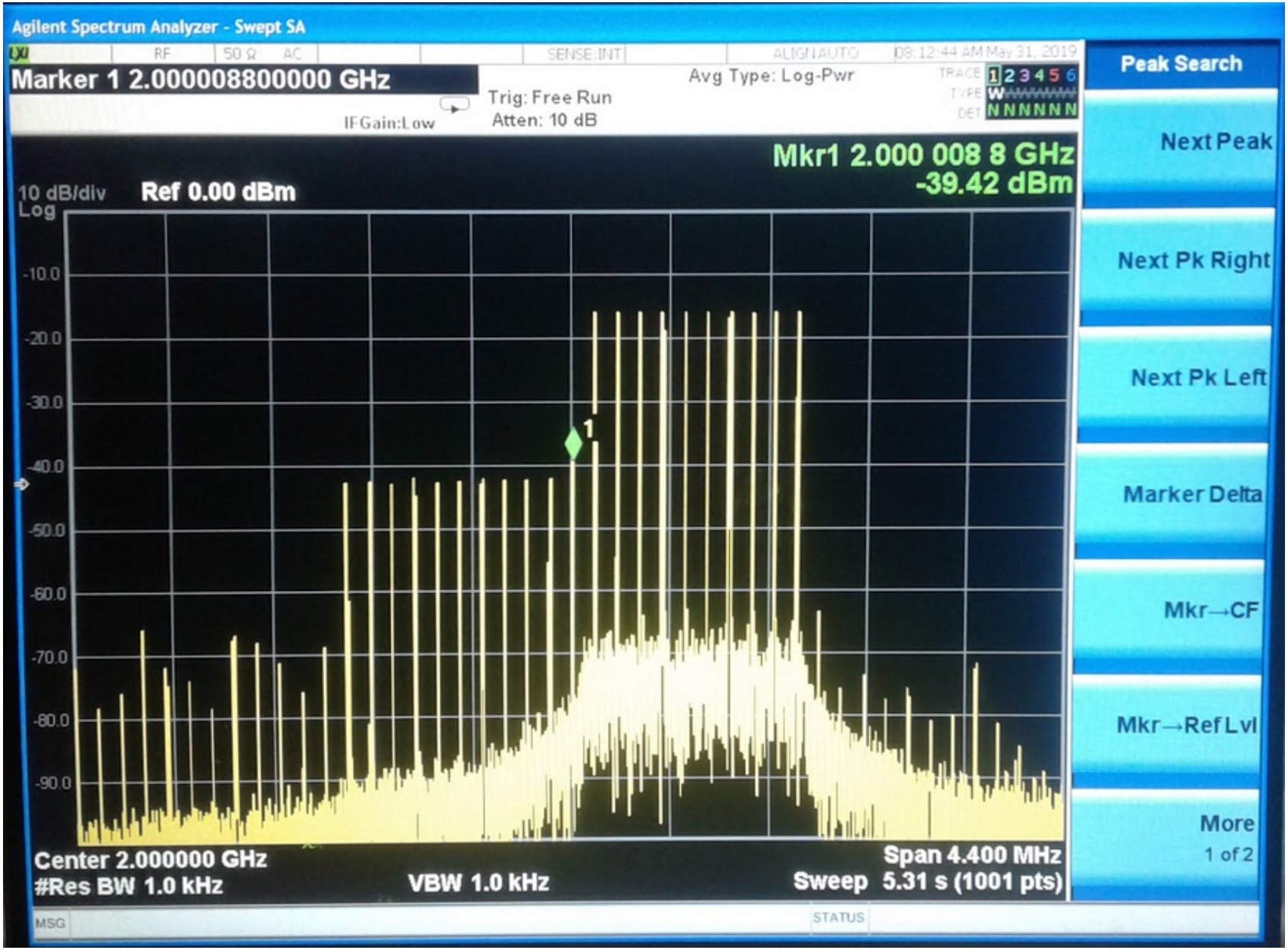
Behavior Analysis



Generated Signal



Transmitted Signal



Actual Efforts and Conclusions

- **CMB Instruments**
  - Scalability.
  - Different frequency bands.
  - Systematic effects control.
  - Preferential sites.
- **Detection Chain**
  - Increase the multiplexing factor.
  - Dissipated power reduction at low temperature stages.
  - Commercial components.
- **Conclusions**
  - Linearity and High SNR (Noise and Harmonics).
  - High Sample Rates and Bandwidths.
  - Frequency, Clock and RF Power High Stability.
  - Adequate Read-Out Powers.

Future Work

Stay at KIT

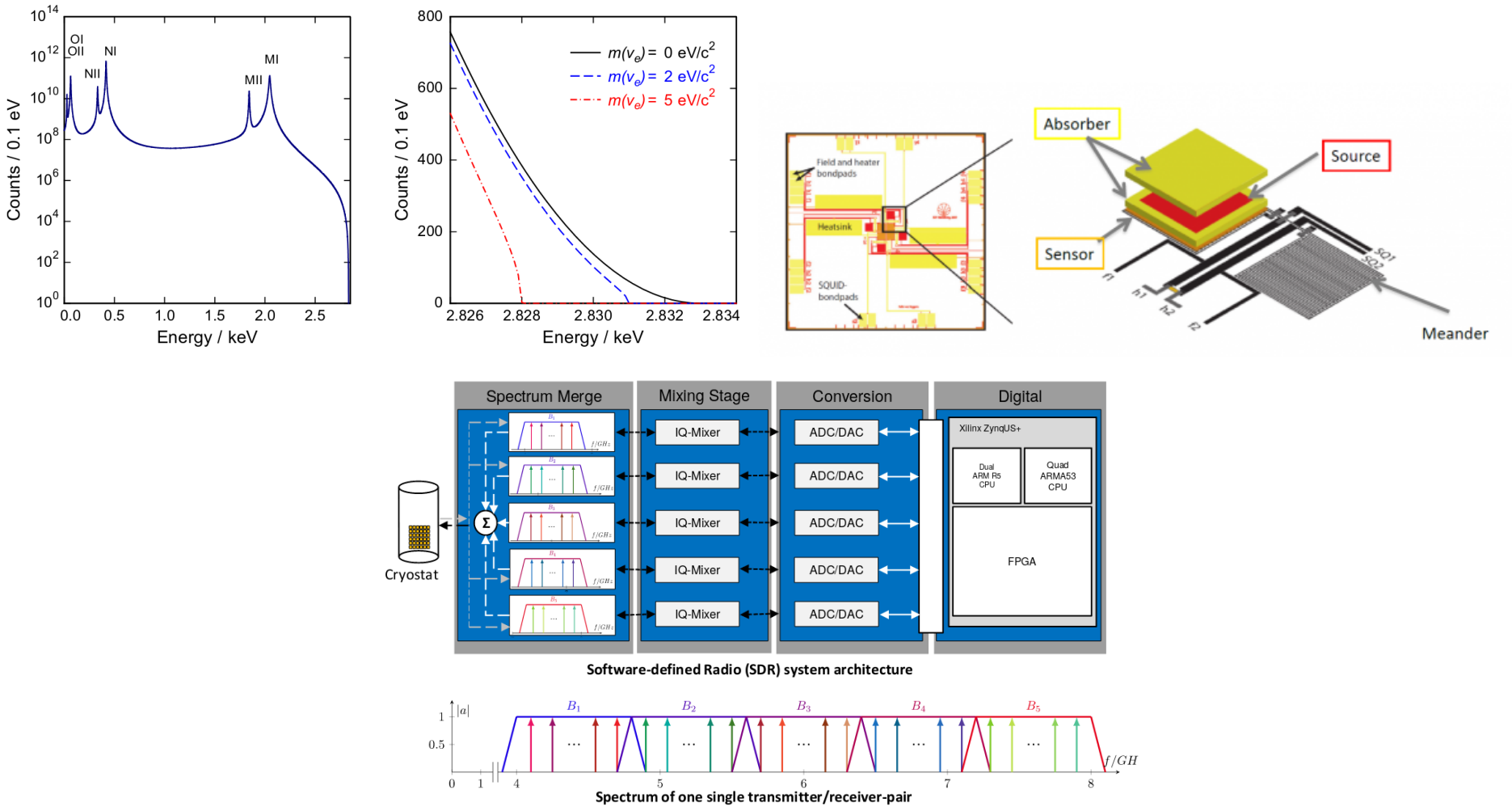
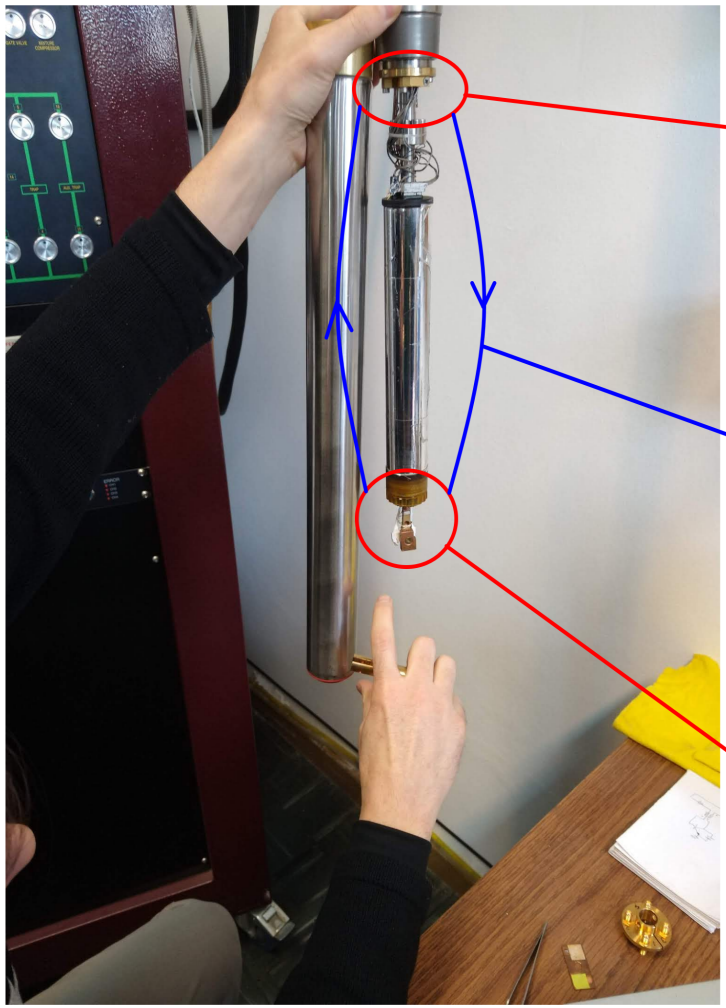
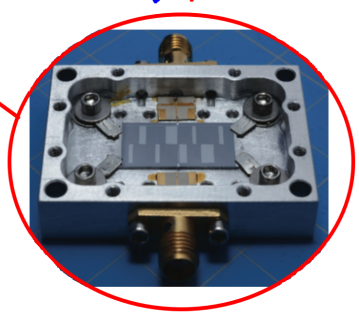


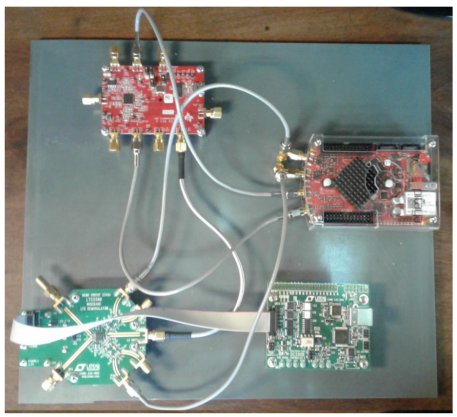
Figure: Readout System for ECHo Project[9]

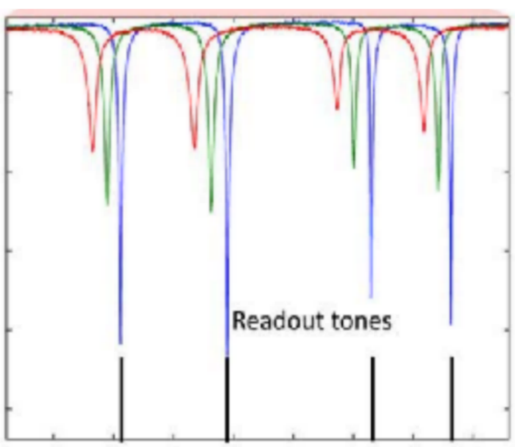
9. O. Sander, N. K. e. a. (2018). Software-defined radio readout system for the echo experiment. *arXiv:1806:10673v1*

MKID Readout at Low Temp. Labs









Thanks!

Questions?

References

References

Collaboration, C.-S. (2017a). Cmb-s4 technology book. *arXiv:1706.02464*.

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