Towards highly multiplexed SQUID based readout system

Eng. SALUM, Juan Manuel

Universidad Nacional de San Martin - Karlsruher Institut für Technologie

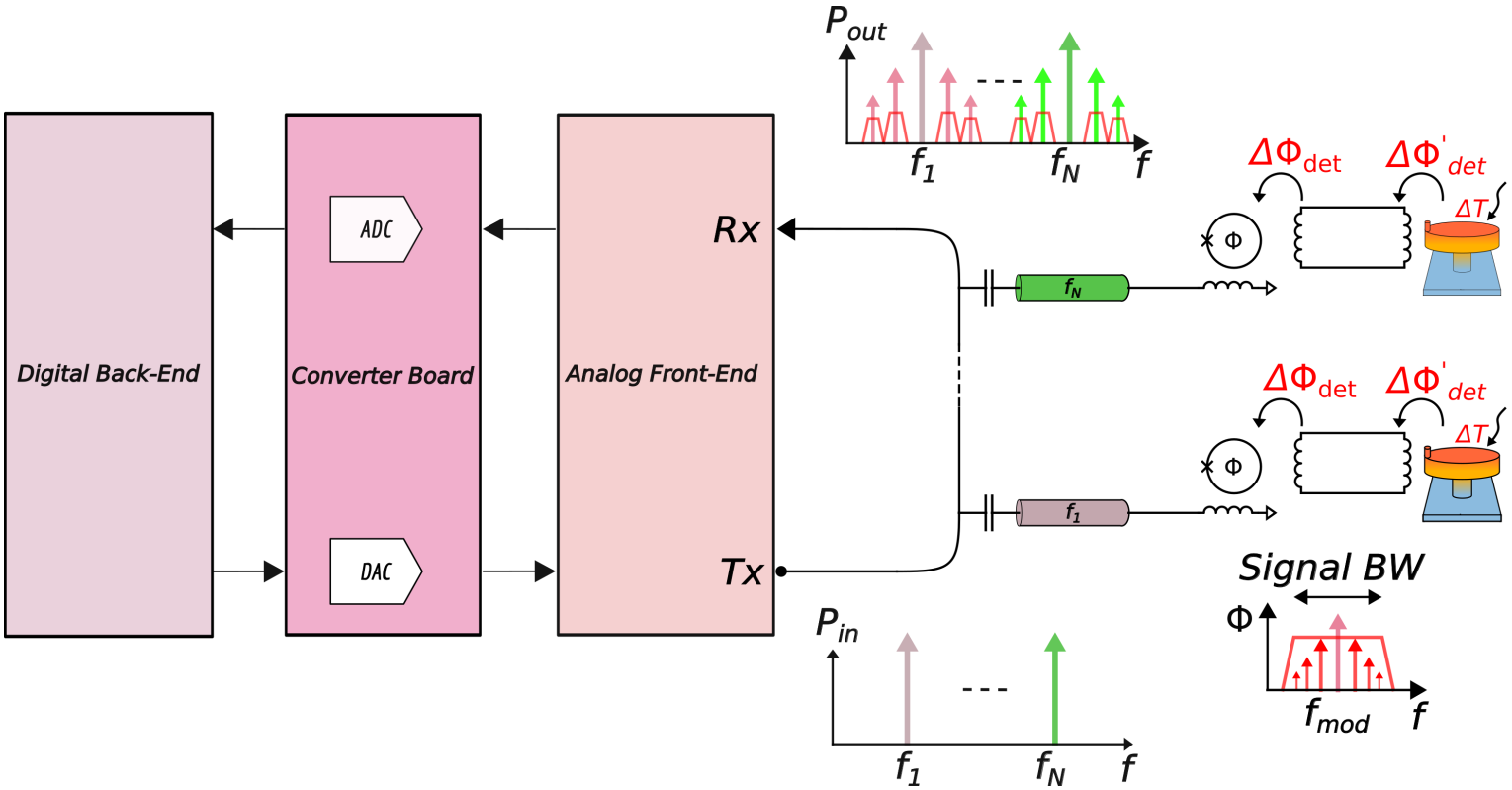
Directors: Prof. Dr. Platino, Manuel - Prof. Dr. Weber, Marc
juan.salum@iteda.cnea.gov.ar

21 de Noviembre del 2023

Índice

1. Readout system
2. Next generation experiments
3. SFDR and SNR trade-off
4. Spectral Engineering
5. Tone-tracking
6. Summary

Readout system



Flexibility: Generation algorithm, number of tones, amplitude and phase per tone, tones spacing, channelization, demodulation method, downsampling, amplification, filtering, etc.

Sensitivity: Detector noise dominant, high signal to noise ratio (SNR) and spurious free dynamic range (SFDR)

Next generation experiments

CMB S-4 Experiment

Data Acquisition & Control

The CMB-S4 data acquisition and control ('DAQ') software will need to control and acquire data from the 550,000 high-speed detectors, as well as a myriad of systems on each of the 21 telescope platforms and across the site (the telescope platforms themselves, as well as the 100mK cryogenics, pumps, cooling loops, warm thermometry, calibrators, weather data, instrument settings, and many more). DAQ will also be developing the live monitoring system to assess system performance in real time.

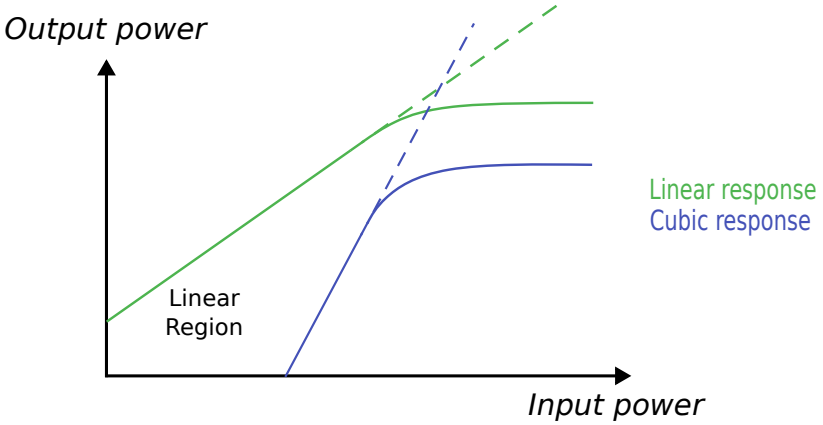
ECHo Experiment

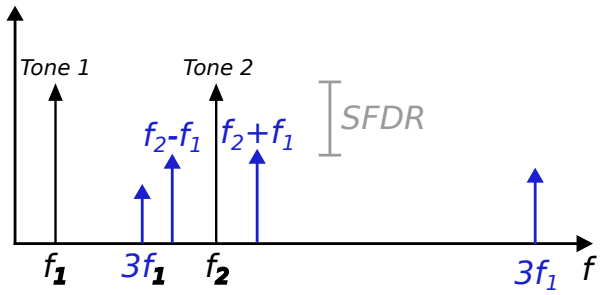
The first phase of the ECHo experiment, ECHo-1k, successfully demonstrated the feasibility of the microfabrication of MMC arrays implanted with ^{163}Ho [7]. The results of this phase have paved the way towards the next phase of the ECHo experiment, ECHo-100k. For the ECHo-100k phase, the requirements in terms of number of detector pixels, ^{163}Ho activity per pixel and energy resolution become substantially more stringent: from 60 pixels to 12000 pixels, from 1 Bq/pixel to $\sim$ 10 Bq/pixel and from 10 eV FWHM to 5 eV FWHM. In order to satisfy these challenging requirements, a new detector design has been developed and implemented for the ECHo-100k experimental phase. The key improvements

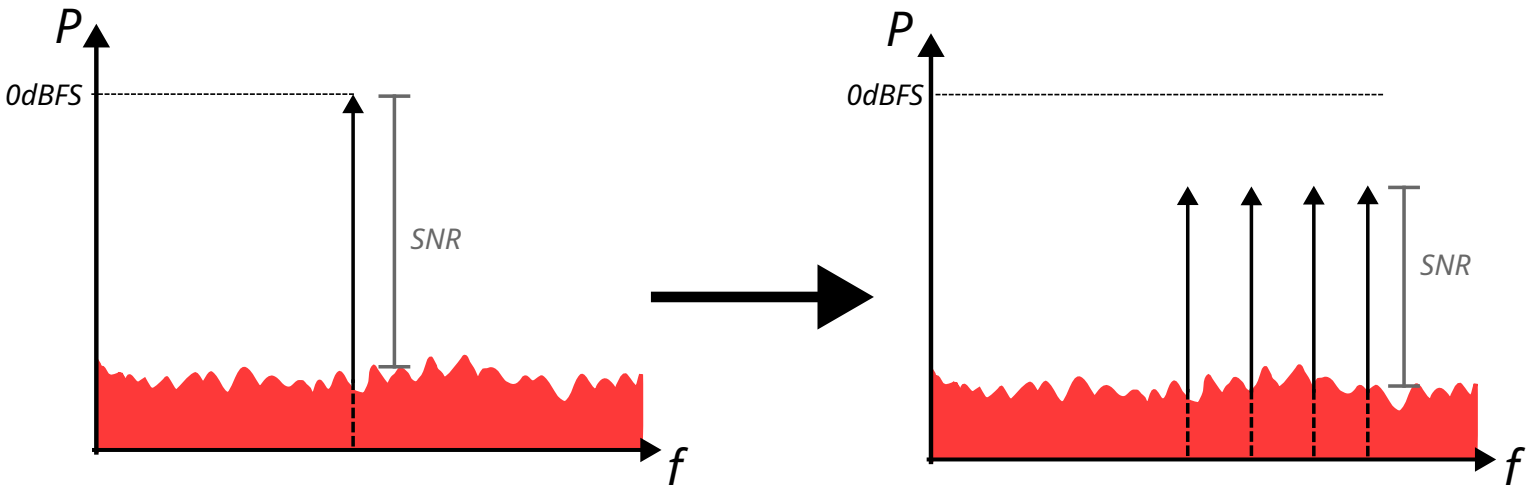
CMB-HD Experiment

The CMB-HD telescope cameras will hold about 400,000 pixels. Each pixel will have two frequency bands and two polarizations for a total of 1.6 million detectors. We assume in the base-

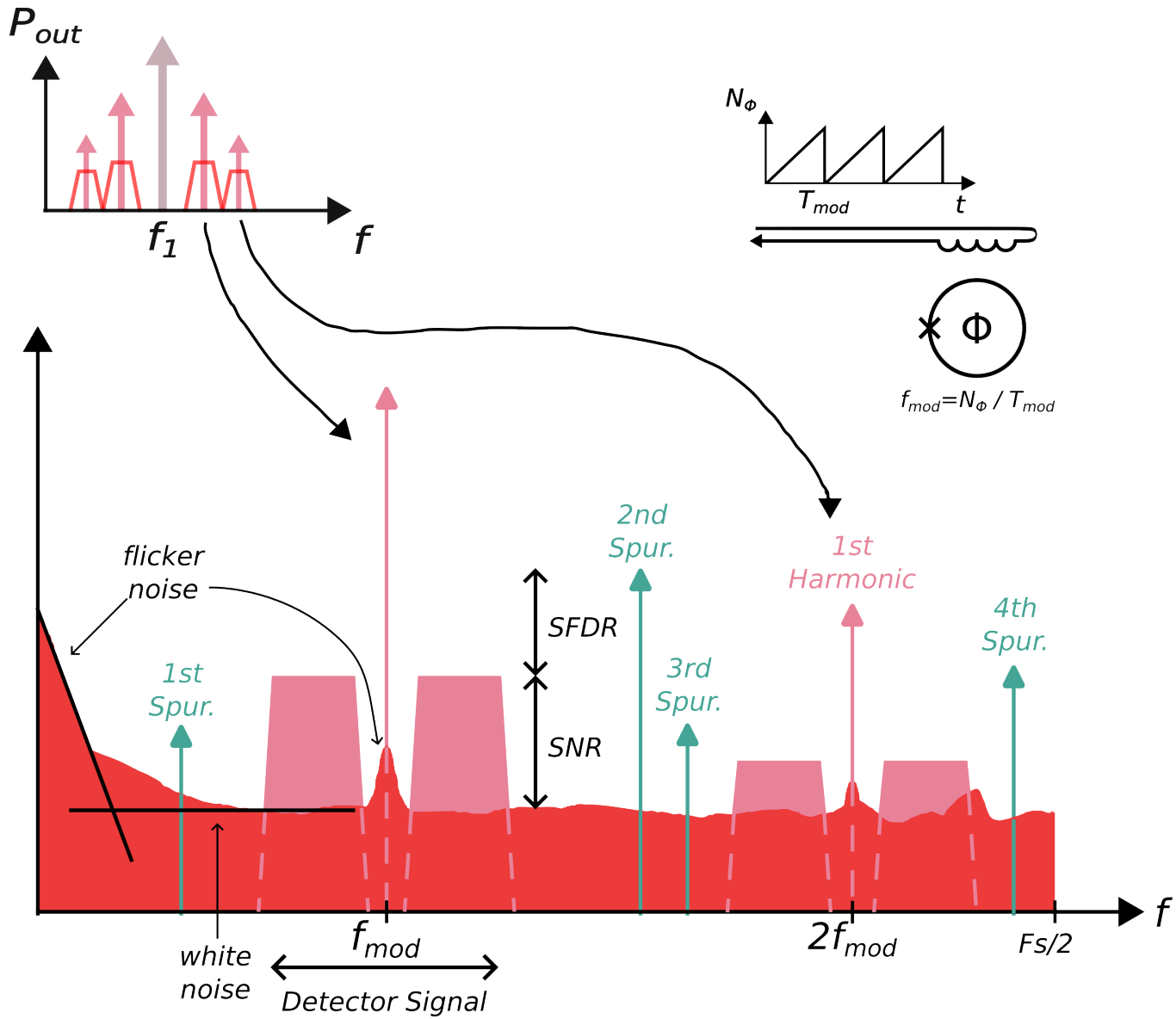
SFDR and SNR trade-off



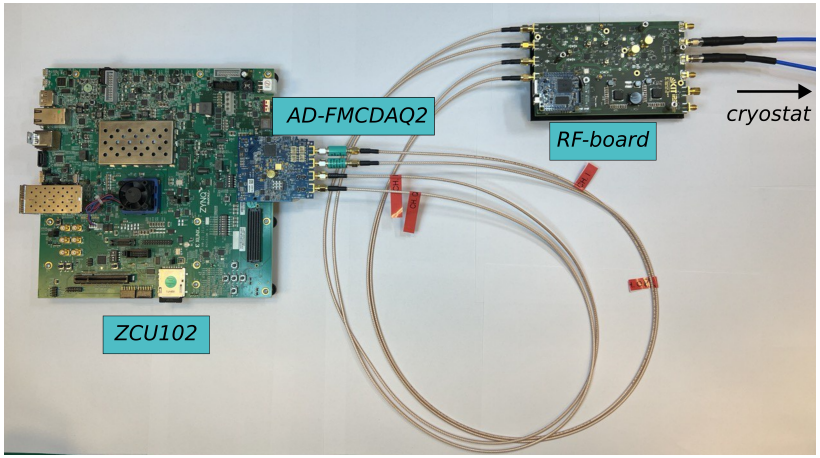


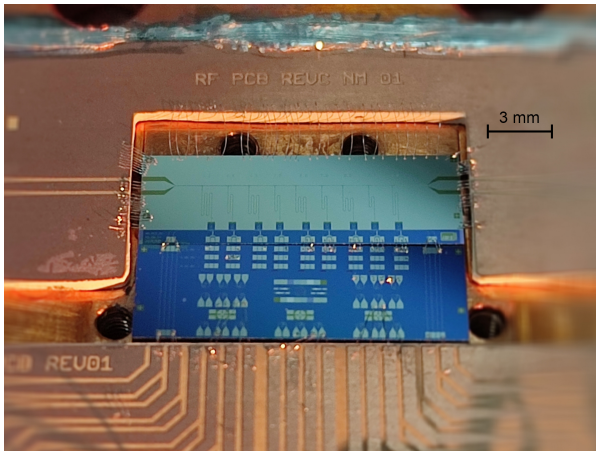


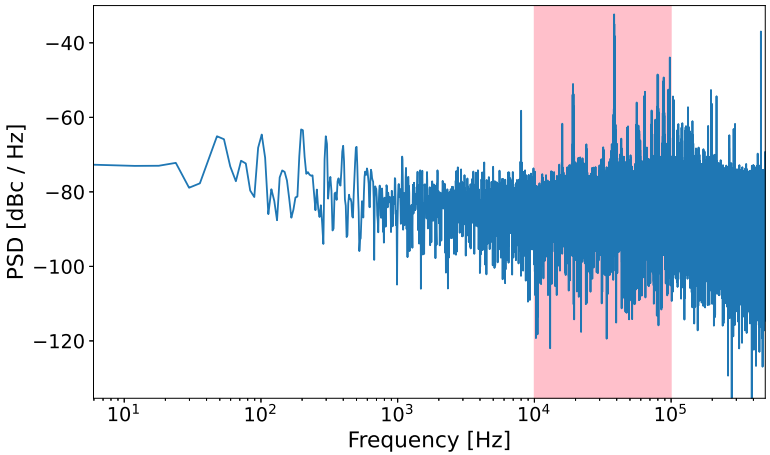
Spectral Engineering

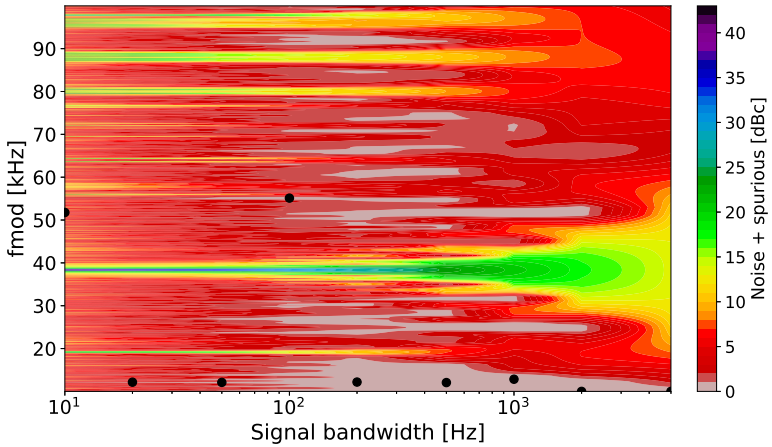


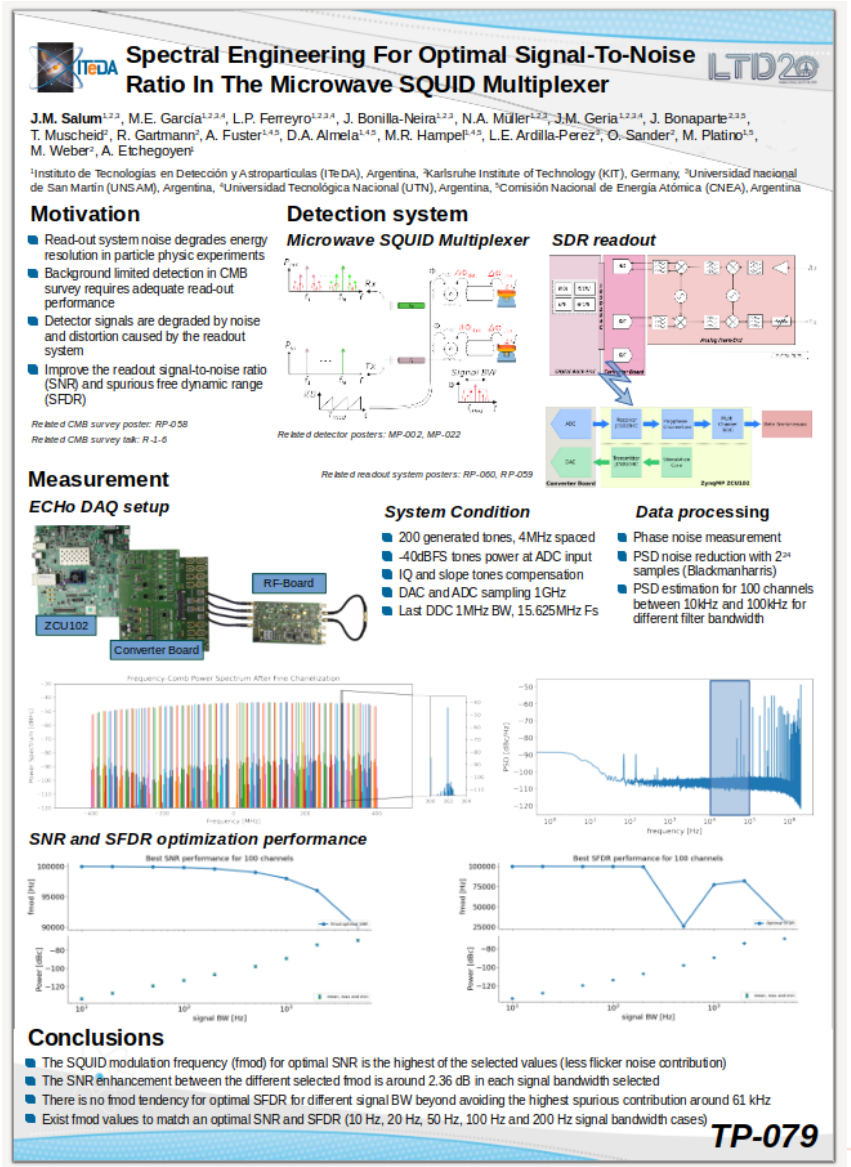
Spectral Engineering











Spectral Engineering For Optimal Signal-To-Noise Ratio In The Microwave SQUID Multiplexer

LTD20

J.M. Salum[1,2,3], M.E. García[1,2,3,4], L.P. Ferreyro[1,2,3,4], J. Bonilla-Neira[1,2,3], N.A. Müller[1,2,3], J.M. Geria[1,2,3,4], J. Bonaparte[2,3,5], T. Muscheid[2], R. Gartmann[2], A. Fuster[1,4,5], D.A. Almela[1,4,5], M.R. Hampel[1,4,5], L.E. Ardilla-Perez[2], O. Sander[2], M. Platino[1,5], M. Weber[2], A. Etchegoyen[2]

[1]Instituto de Tecnologías en Detección y Astropartículas (ITeDA), Argentina, [2]Karlsruhe Institute of Technology (KIT), Germany, [3]Universidad nacional de San Martín (UNSAM), Argentina, [4]Universidad Tecnológica Nacional (UTN), Argentina, [5]Comisión Nacional de Energía Atómica (CNEA), Argentina

Motivation

- Read-out system noise degrades energy resolution in particle physic experiments
- Background limited detection in CMB survey requires adequate read-out performance
- Detector signals are degraded by noise and distortion caused by the readout system
- Improve the readout signal-to-noise ratio (SNR) and spurious free dynamic range (SFDR)

Related CMB survey poster: RP-058
Related CMB survey talk: R-1-6

Detection system

Microwave SQUID Multiplexer

Related detector posters: MP-002, MP-022

SDR readout

Related readout system posters: RP-060, RP-059

Measurement

ECHo DAQ setup

RF-Board
ZCU102
Converter Board

System Condition

- 200 generated tones, 4MHz spaced
- -40dBFS tones power at ADC input
- IQ and slope tones compensation
- DAC and ADC sampling 1GHz
- Last DDC 1MHz BW, 15.625MHz Fs

Data processing

- Phase noise measurement
- PSD noise reduction with 2^{24} samples (Blackmanharris)
- PSD estimation for 100 channels between 10kHz and 100kHz for different filter bandwidth

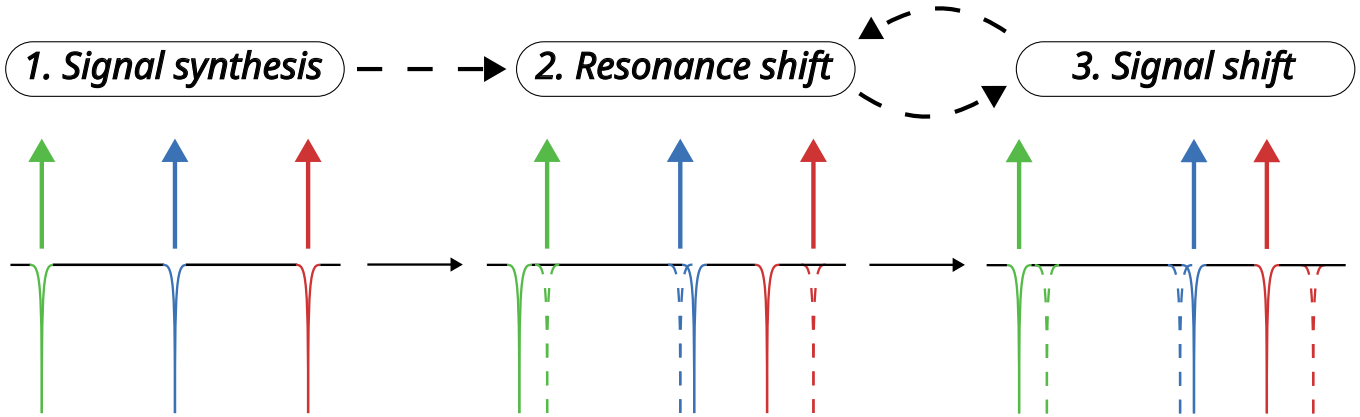
SNR and SFDR optimization performance

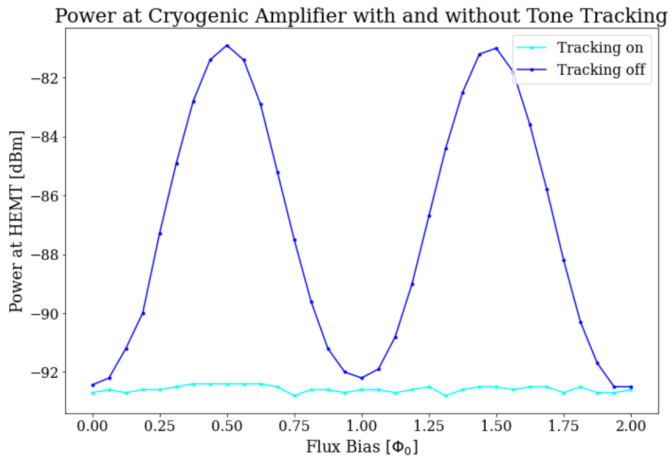
Conclusions

- The SQUID modulation frequency (fmod) for optimal SNR is the highest of the selected values (less flicker noise contribution)
- The SNR enhancement between the different selected fmod is around 2.36 dB in each signal bandwidth selected
- There is no fmod tendency for optimal SFDR for different signal BW beyond avoiding the highest spurious contribution around 61 kHz
- Exist fmod values to match an optimal SNR and SFDR (10 Hz, 20 Hz, 50 Hz, 100 Hz and 200 Hz signal bandwidth cases)

TP-079

Tone-tracking





DOI: 10.1063/5.0125084

Summary

- Readout systems for hundreds of thousands detectors are being demanding for future scientific experiments.
- To met this demand, new techniques are required.
- Spectral Engineering demonstrated to be a technique to optimizes the detector signal SNR and SFDR.
- Tone-tracking is a promising technique although it still have difficulties at high frequencies.

Thanks!

Questions?