DeepClean:
Software Injection Tests on KAGRA Data

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Introduction

- Generate the white Gaussian noise background.
- Apply the band pass filter on background channels.
- Inject the sine wave with 125 Hz.
- We will test the performance of:
  - Noise injected strain data before and after the subtraction
  - Cross Spectrum Density of Strain-PEM and PEM-PEM
  - Transfer function around injected frequency.
Background Data - White Gaussian Background

- Generate the white Gaussian noise background data.
- Apply Butterworth band-pass filter with 120 - 130 Hz.
- White Gaussian Strain amplitude: 2e-21
- White Gaussian PEM amplitude: 8e-8
Injection Dataset - Sine Wave Injection

- Inject sine wave with frequency: 125 Hz.
- Injection lasts for 240 seconds.
- Strain amplitude: 2e-20
- PEM amplitude: 8.3e-4 Pa
- No phase shift between Strain and PEM injection.
Background and Injected Sine Wave
Background: Before Injection
Background: After Injection

**Injected STRAIN**

**Injected PEM**
Strain/PEM ASD: Background and Injection
Test 1
Dataset Properties

GPS time to train: 1275891680 (duration: 240 seconds)

GPS time to clean: 1275891920 (duration: 240 seconds)

Strain channel: K1:CAL-CS_PROC_C00_STRAIN_DBL_DQ

PEM channel: K1:PEM-MIC_PSL_TABLE_PSL4_Z_OUT_DQ

Sampling rate: 4096 Hz

Bandpass filter:

filt_fl = 120

filt_fh = 130

Epochs: 12
Train Data ASD: Raw Strain and Cleaned Strain (125 Hz)
Test 2
Dataset Properties

- GPS time to train: 1275891680 (duration: 240 seconds)
- GPS time to clean: 1275891920 (duration: 240 seconds)
- Strain channel: K1:CAL-CS_PROC_C00_STRAIN_DBK_DQ
- PEM channel: K1:PEM-MIC_PSL_TABLE_PSL4_Z_OUT_DQ
- Sampling rate: 4096 Hz
- Bandpass filter:
  - filt_fl = 120
  - filt_fh = 130
- Epochs: 15
Loss with Epoch = 15
Train Data ASD: Raw Strain and Cleaned Strain (125 Hz)
CSD: Strain-PEM
Transfer Function

Transfer Function: Normalized Cross Spectrum (125Hz)
Dataset Properties

- GPS time to train: 1275891680 (duration: 240 seconds)
- GPS time to clean: 1275891920 (duration: 240 seconds)
- Strain channel: K1:CAL-CS_PROC_C00_STRAIN_DBL_DQ
- PEM channel: K1:PEM-MIC_PSL_TABLE_PSL4_Z_OUT_DQ
- Sampling rate: 4096 Hz
- Bandpass filter: 
  - $\text{filt}_\text{fl} = 120$
  - $\text{filt}_\text{fh} = 130$
- Epochs: 18
Loss with Epoch = 18
Raw and Cleaned Strain (125 Hz)
CSD: Strain-PEM

Strain-PEM CSD (125Hz)

- Injected Sine
- Background
- Injection
- Cleaned

Frequency (Hz)

[Graph showing signal levels across different frequencies.]
Transfer Function

Transfer Function: Normalized Cross Spectrum (125Hz)
Dataset Properties

- GPS time to train: 1275891680 (duration: 240 seconds)
- GPS time to clean: 1275891920 (duration: 240 seconds)
- Strain channel: K1:CAL-CS_PROC_C00_STRAIN_DBL_DQ
- PEM channel: K1:PEM-MIC_PSL_TABLE_PSL4_Z_OUT_DQ
- Sampling rate: 4096 Hz
- Bandpass filter:
  - filt_fl = 120
  - filt_fh = 130
- Epochs: 20
Loss with Epoch = 20
Raw and Cleaned Strain (125 Hz)
CSD: PEM-PEM

PEM CSD (125Hz)

- Injected Sine
- Background
- Injection
Transfer Function

Transfer Function: Normalized Cross Spectrum (125 Hz)
Summary

- We prepare the white Gaussian noise background and apply the band-pass filter with 120-130 Hz before the sine wave injection.

- **Software injection test**: We prepare the 480 seconds single-frequency sine wave injection to the strain and PEM background.

- We have shown the training and cleaning on the same segment of the 125 Hz injection with different epochs.

- 10 Hz-wide band-pass filter on DeepClean (i.e. 120-130 Hz) has been used and performs better on 125 Hz frequency of injection.