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 100 - 150 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

**STRAIN: Before Injection**

![Graph of STRAIN: Before Injection](chart1.png)

**PEM: Before Injection**

![Graph of PEM: Before Injection](chart2.png)
Sine Wave Injection: Strain and PEM

**Strain: Sine Waves Injection**

**PEM: Sine Waves Injection**

Time [minutes] from 2020-06-11 06:21:00 UTC (1275891678.0)
Background: After Injection
Strain/PEM ASD: Background and Injection

Strain ASD: Background and Injection (125 Hz)

PEM ASD: Background and Injection (125 Hz)
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:

\[ \text{filt}_{fl} = 120 \]

\[ \text{filt}_{fh} = 130 \]

Epochs: 12
Loss with Epoch = 12

The graph shows the loss over Iteration with different epochs. The blue line represents the Train data, and the green line represents the Test data.
CSD: Strain-PEM

Strain-PEM CSD (125Hz)

- Injected Sine
- Background
- Injection
- Cleaned

Frequency (Hz):

- 120
- 122
- 124
- 126
- 128
- 130

Amplitude (V^2/Hz):

- $10^{-22}$
- $10^{-20}$
- $10^{-18}$
- $10^{-16}$
- $10^{-14}$
- $10^{-12}$
- $10^{-10}$
- $10^{-8}$
- $10^{-6}$
- $10^{-4}$
- $10^{-2}$
- $10^{0}$
CSD: PEM-PEM
Transfer Function

Transfer Function: Normalized Cross Spectrum (125Hz)
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_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: 15
Loss with Epoch = 15

- **Train**
- **Test**
Raw and Cleaned Strain (125 Hz)
CSD: PEM-PEM

PEM CSD (125Hz)

- Injected Sine
- Background
- Injection

[Graph showing frequency response with labeled axes and curves]
Transfer Function

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

10^{-22} to 10^{22}

120 to 130
CSD: PEM-PEM
Transfer Function

Transfer Function: Normalized Cross Spectrum (125Hz)

Frequency (Hz):

[Graph showing normalized cross spectrum with different lines representing injected sine, background, injection, and cleaned signals.]
Test 4
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簋RAIN_DBL_DQ

PEM channel: K1:PEM-MIC_PSL_TABLE_PSL4簋Z簋OUT_DQ

Sampling rate: 4096 Hz

Bandpass filter:

- filt_fl = 120
- filt_fh = 130

Epochs: 20
Loss with Epoch = 20
Train Data ASD: Raw Strain and Cleaned Strain (125 Hz)
CSD: Strain-PEM

Strain-PEM CSD (125Hz)

- Injected Sine
- Background
- Injection
- Cleaned

Frequency (Hz)

[Graph showing frequency response with different categories]
Transfer Function

Transfer Function: Normalized Cross Spectrum (125Hz)
Summary

We prepare the white Gaussian noise background and apply the band-pass filter with 100-150 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.