Software Injection Tests on DeepClean

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Injection Dataset - White Gaussian Background

- Generate the white Gaussian noise background for training dataset.
- Apply Butterworth band pass filter: 100 - 150 Hz
- White Gaussian Strain amplitude: 2e-20
- White Gaussian PEM amplitude: 8e-3
Injection Dataset - Sine Wave Injection

- We prepare the injected sine wave for cleaning.
- Inject sine wave with frequency: 125 Hz.
- Injection lasts for 300 seconds.
- Strain amplitude: 2e-21
- PEM amplitude: 8e-3 Pa
- No phase shift between Strain and PEM injection.
Dataset Properties

- GPS time to train: 1275891680 (duration: 320 seconds)
- GPS time to clean: 1275800000 (duration: 320 seconds)
- Strain channel: K1:CAL-CS_PROC_C00_STRAIN_GAUSSIAN
- PEM channel: K1:PEM_Gaussian
- Sampling rate: 4096 Hz
- Bandpass filter: 10 Hz wide, centered at the injected frequency
- Epochs: 30

\[ J = 1 \times J_{asd} + 0 \times J_{mse} \]

\[ J = 0 \times J_{asd} + 1 \times J_{mse} \]

\[ J = 0.5 \times J_{asd} + 0.5 \times J_{mse} \]

\[ J = 0.7 \times J_{asd} + 0.3 \times J_{mse} \]

\[ J = 0.3 \times J_{asd} + 0.7 \times J_{mse} \]
Loss Function

- Loss function can be written as $J = \omega J_{asd} + (1 - \omega) J_{mse}$

  - $\omega$ is a weighting factor that goes from 0 to 1.

- Amplitude spectrum density (ASD) loss function: $J_{asd} = \frac{1}{M} \sum_{i=0}^{M-1} \sqrt{\frac{S[r, r][i]}{S[h, h][i]}}$

  - $M$ is the number of frequency bins.

- Residual $r(t) = h(t) - p(t)$

- Raw strain data $h(t)$

- Predicted noise in strain $p(t)$

- Mean Squared Error (MSE) loss function: $J_{mse} = \frac{1}{N} \sum_{i=0}^{N-1} r[i]^2$

  - $N$ is the number of time-series samples.
\[ J = 1 \times J_{\text{asd}} + 0 \times J_{\text{mse}} \]
Predicted Strain (125 Hz)
ASD: Predicted Strain (125 Hz)
Raw and Cleaned Strain (125 Hz)
CSD: Strain-PEM (125 Hz)
CSD: PEM-PEM (125 Hz)
Transfer Function (125 Hz)
\[ J = 0 \times J_{asd} + 1 \times J_{mse} \]
ASD: Predicted Strain (125 Hz)
Raw and Cleaned Strain (125 Hz)

Train Data ASD: Raw Strain and Cleaned Strain (125 Hz)
CSD: Strain-PEM (125 Hz)
CSD: PEM-PEM (125 Hz)
Transfer Function (125 Hz)
\[ J = 0.5 \times J_{asd} + 0.5 \times J_{mse} \]
Predicted Strain (125 Hz)
ASD: Predicted Strain (125 Hz)
Raw and Cleaned Strain (125 Hz)
CSD: Strain-PEM (125 Hz)
CSD: PEM-PEM (125 Hz)
\[ J = 0.7 \times J_{asd} + 0.3 \times J_{mse} \]
Predicted Strain (125 Hz)
ASD: Predicted Strain (125 Hz)
Raw and Cleaned Strain (125 Hz)
CSD: Strain-PEM (125 Hz)
CSD: PEM-PEM (125 Hz)
Transfer Function (125 Hz)
\[ J = 0.3 \times J_{asd} + 0.7 \times J_{mse} \]
Predicted Strain (125 Hz)
ASD: Predicted Strain (125 Hz)
Raw and Cleaned Strain (125 Hz)
CSD: Strain-PEM (125 Hz)
CSD: PEM-PEM (125 Hz)
Transfer Function (125 Hz)
Summary

- We prepare the **white Gaussian noise background data** for training.
- And the **injected sine wave data** for cleaning.
- We can see that the peak is subtracted and the other spectral lines are subtracted as well.