IDENTIFICATION OF THE MECHANICAL DYNAMICS OF THE SUPERCONDUCTING RADIO-FREQUENCY CAVITIES FOR THE European XFEL CW UPGRADE

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As per the authors' knowledge, for the first time, a multi-sine excitation signal is used to identify the mechanical model for the SRF cavity with an accuracy of 73.89%.

INTRO

- Research gap: For the first time, two different spectrally rich excitation signals, multi-sine, and stepped-sine are used to identify the mechanical dynamics of the SRF cavities.
- Multi-sine consists of a sum of multiple sinusoids. The amplitude, frequency, and phase of each sinusoid can be chosen freely. Mathematically a multi-sine can be defined as

$$u(t) = \sum_{n=1}^{N} A_n sin(2\pi f_n t + \phi_n)$$

- Stepped-sine only allows exciting a system with a single frequency at a time, and then this frequency is updated to the next desired frequency. Mathematically a stepped-sine can be defined as

$$u(t) = A sin(2\pi f_n t + \phi)$$

$$f_n = f_{n\_1} + \Delta f$$

- Motivation: The use of multi-sine as an excitation signal is motivated by its time efficiency compared to stepped-sine and higher identification accuracy compared to step signal.

METHODS

- The mechanical dynamics of SRF cavities are excited using piezo actuators.
- Both multi-sine and stepped-sine are applied in a closed loop as illustrated in Fig. 1.

- Both multi-sine and stepped-sine have a frequency range from 1 to 250 Hz.
- Detuning is not measurable so it is computed using the first principle method.
- The System Identification Toolbox of MATLAB was used to identify a 20-order model using the black-box approach for multi-sine signals.

RESULTS

- Both approaches (multi-sine and stepped-sine) give compatible results identifying the main mechanical eigenmodes of the system so there is a good qualitative agreement as shown in Fig.2.
- The model identified using multi-sine showed a mean prediction accuracy of 73.89%. Validation for one of the data set is shown in Fig.3.

DISCUSSION

- The model identified using multi-sine data will be used for control design for CW upgrade.
- Model order reduction is required, otherwise, it might not be possible to implement model-based control techniques on such a high order model.
- For future work, we could increase the amplitude of piezo actuation for the multi-sine approach to increase the SNR so we can better capture the mechanical dynamics of the SRF cavity.

FIGURES

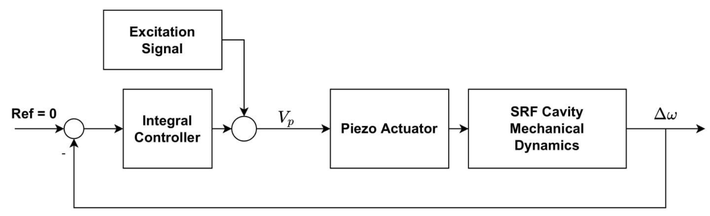

Figure 1: Experimental setup scheme.

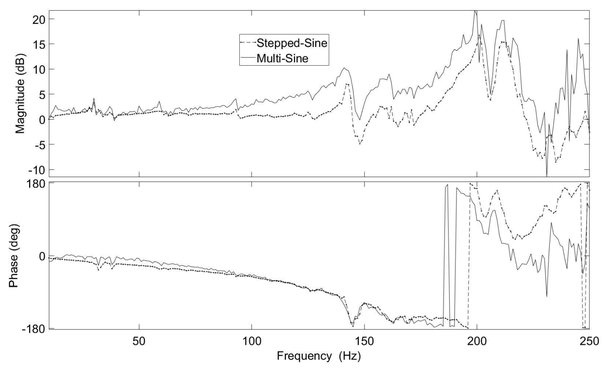

Figure 2: Comparison of transfer functions from piezo voltage to detuning for multi-sine and stepped-sine.

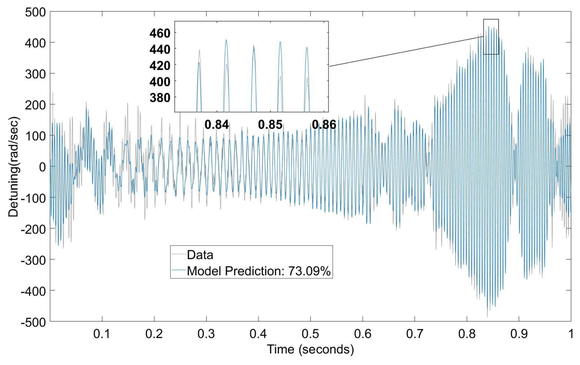

Figure 3: Time-domain validation of model identified using the multi-sine data set.

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