# A Multivariable Experiment Design Framework for Accurate FRF Identification of Complex Systems

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**Abstract**

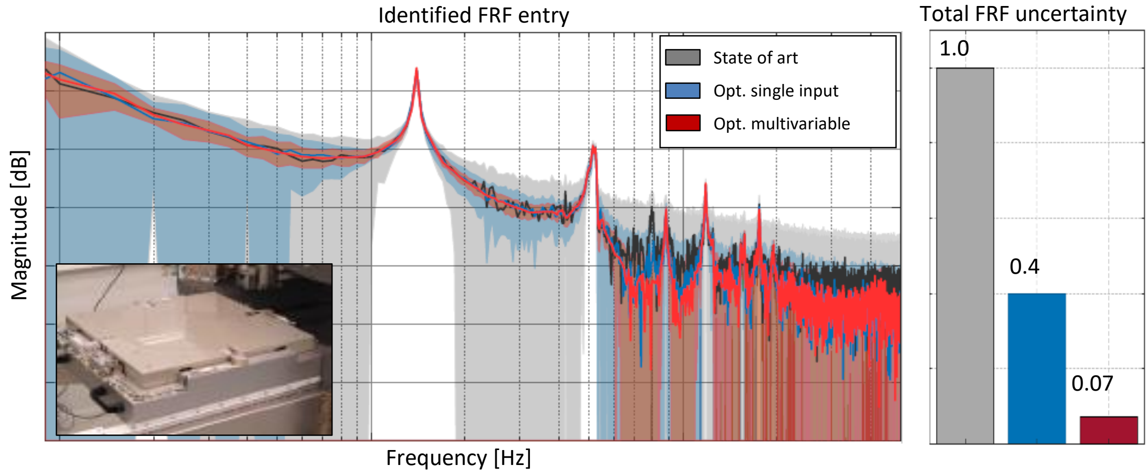
Accurate Frequency Response Function (FRF) identification is essential in high-precision mechatronics. To meet the ever-increasing performance requirements, there is a need to identify FRFs faster and more accurately. The quality of the identified FRF depends on the excitation signals used in the identification experiments, hence these must be designed carefully. Ideally, such design maximizes signal-to-noise ratio, while respecting the system limitations to guarantee safe operation. State of the art excitation methods in the industry address these items conservatively, since typically:

1) the spectrum is designed conservatively, e.g., uniform spectrum/ white noise,
2) physically relevant system input and output constraints are addressed implicitly,
3) only a single input is excited at a time, also for MIMO systems.

Consequently, the FRF quality is non-optimal.

In this research, a systematic framework is developed to optimally design multi-sine excitations for the FRF identification of mechatronic systems [1]. Herein, items 1) and 2) are addressed through a 2-step design approach: in step 1, a preliminary experiment is performed to acquire prior system knowledge. Step 2 involves an optimized-based synthesis of custom excitation signals that maximize the FRF quality within the system constraints. Particularly, for MIMO systems, item 3) is addressed through full multivariable and directional excitation design that exploits the plurality of the actuator inputs [2].

The techniques are applied to a 7 x 8 wafer stage and compared to the industrial state of art (uniform spectrum). The resulting FRFs and their total uncertainty are shown in the middle and right figure, respectively. The optimized single input design (blue) outperforms the state of art (grey) by a factor 2.5, while the optimal multivariable excitations (red) achieve an improvement factor of 14.2. This demonstrates the power of the developed techniques.




*Left:* Wafer stage and FRFs, incl. 95% uncertainty region (shades). *Right:* Total FRF uncertainty.

## *References*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[2] Dirkx N, Oomen T. Multivariable Experiment Design with Application to a Wafer Stage: a Sequential Relaxation Approach for Dealing with Element-Wise Constraints. Submitted. 2019.