

# Ultrasensitive Mass Sensing Through Coupled Microelectromechanical Resonator Arrays

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## Introduction:

- What is the optimal number of resonators? Which resonator should be perturbed? Which eigenmode should be examined?

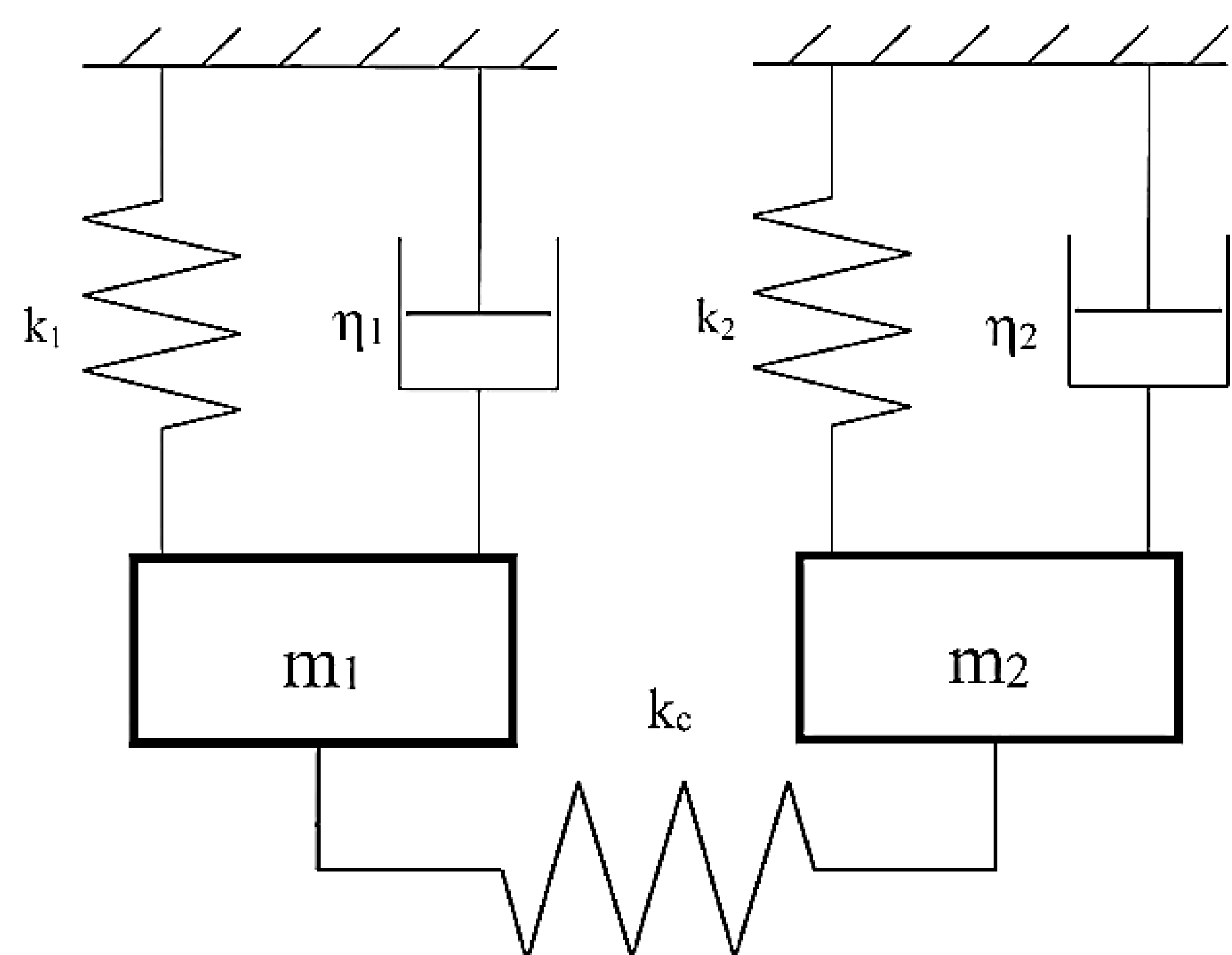


Figure 1. Mass-Spring-Damper Representation

## Computational Techniques:

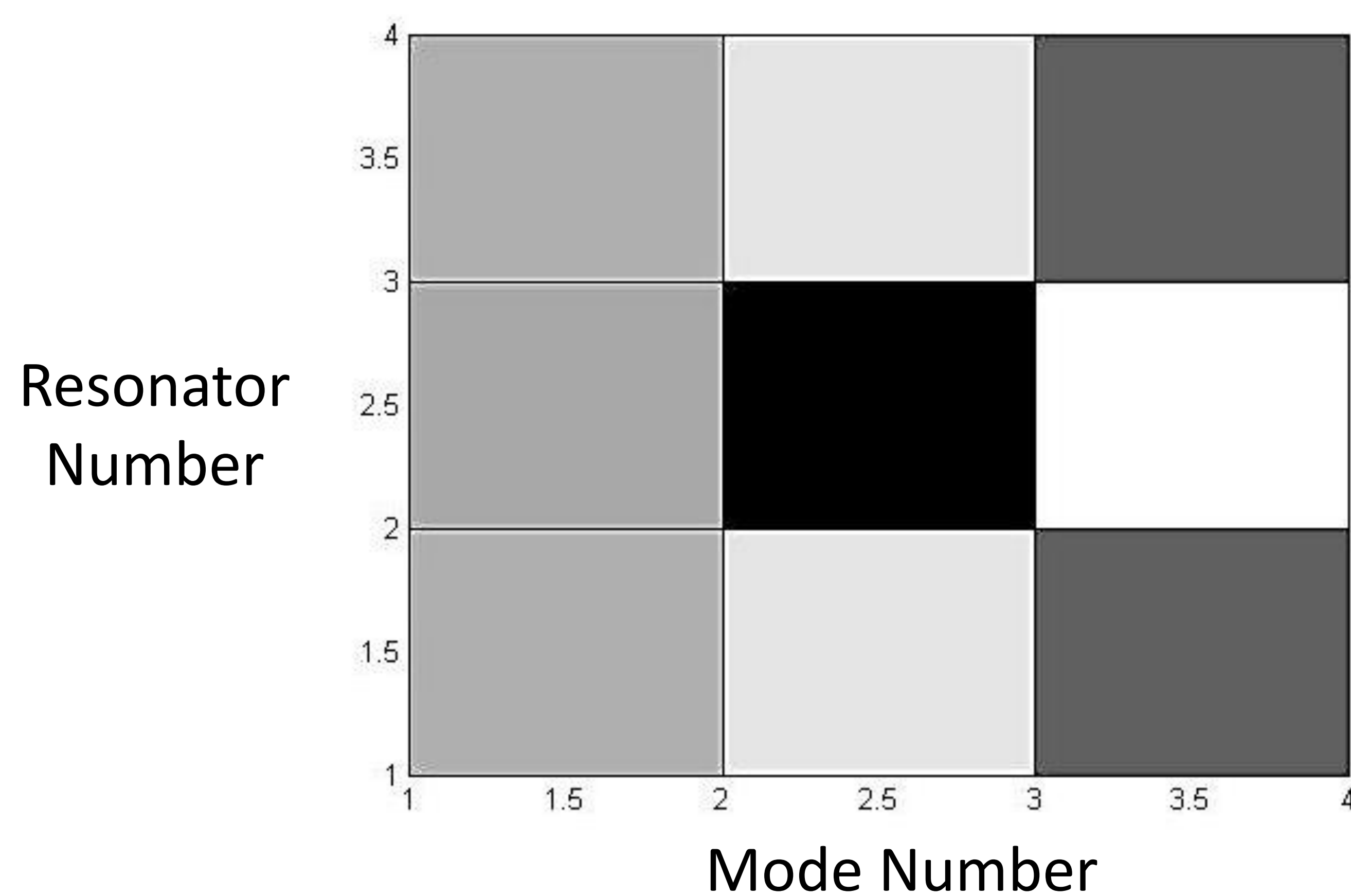


Figure 2: Eigenvalue Sensitivity Matrix

$$\frac{1}{\delta_k} \frac{|\bar{\lambda}_i - \lambda_i|}{\lambda_i} = s_{ki} = \phi_{ki}^2 \quad e \propto \frac{\delta}{\alpha}$$

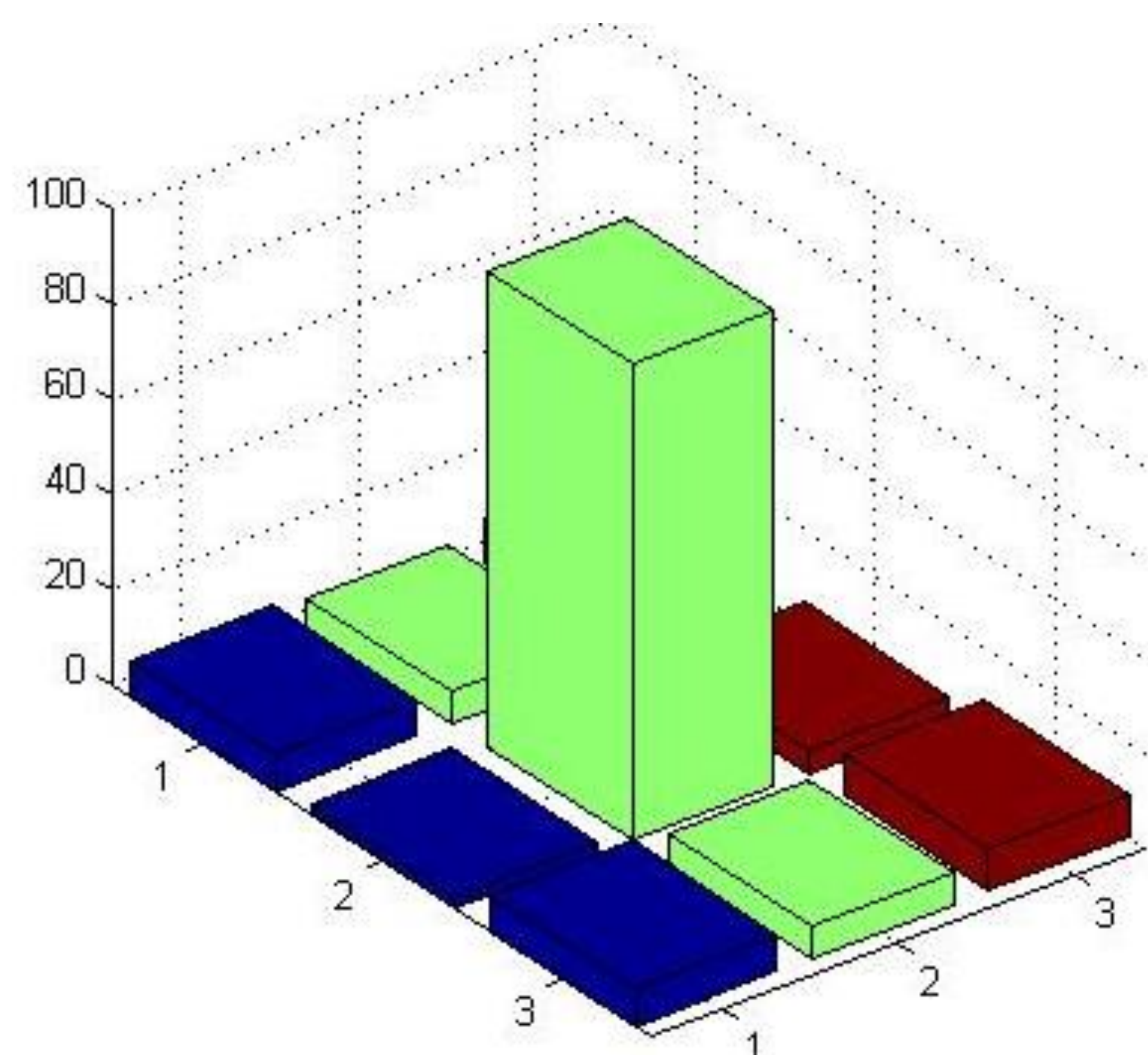


Figure 3. Error Matrix

**Results:** The highest sensitivity was achieved for a single DOF system. The next best sensitivity was achieved for a 3DOF system for the (2,3) configuration. Eigenmode sensitivities for a weakly coupled array were found to be three orders of magnitude higher than their eigenvalue counterparts. The MEMS module of COMSOL was used to perform FEM analysis of various types of CRAs such as coupled cantilever arrays, coupled disks of various degrees-of-freedom. Their FRF (Frequency Response Function) was analyzed, before and after mass perturbation. Thus, the mass responsivity was determined.

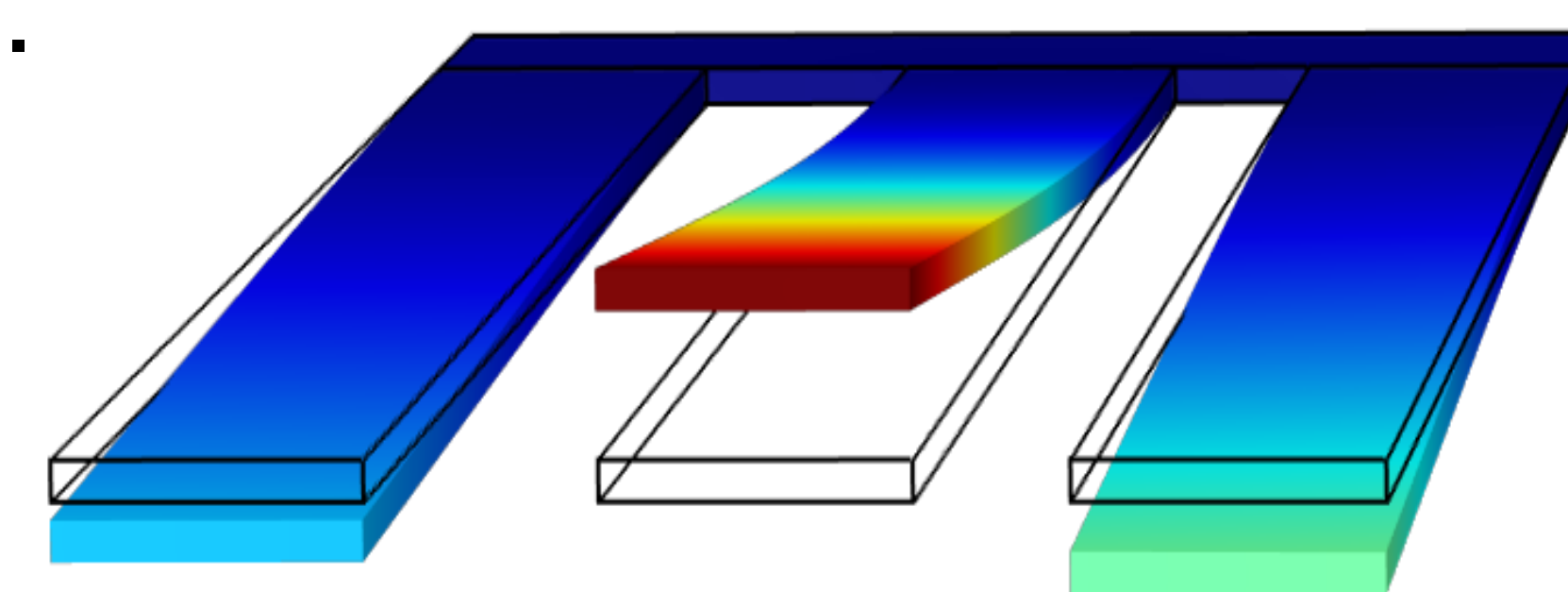


Figure 4. Third Eigenmode of 3DOF System (Out-of-Phase)

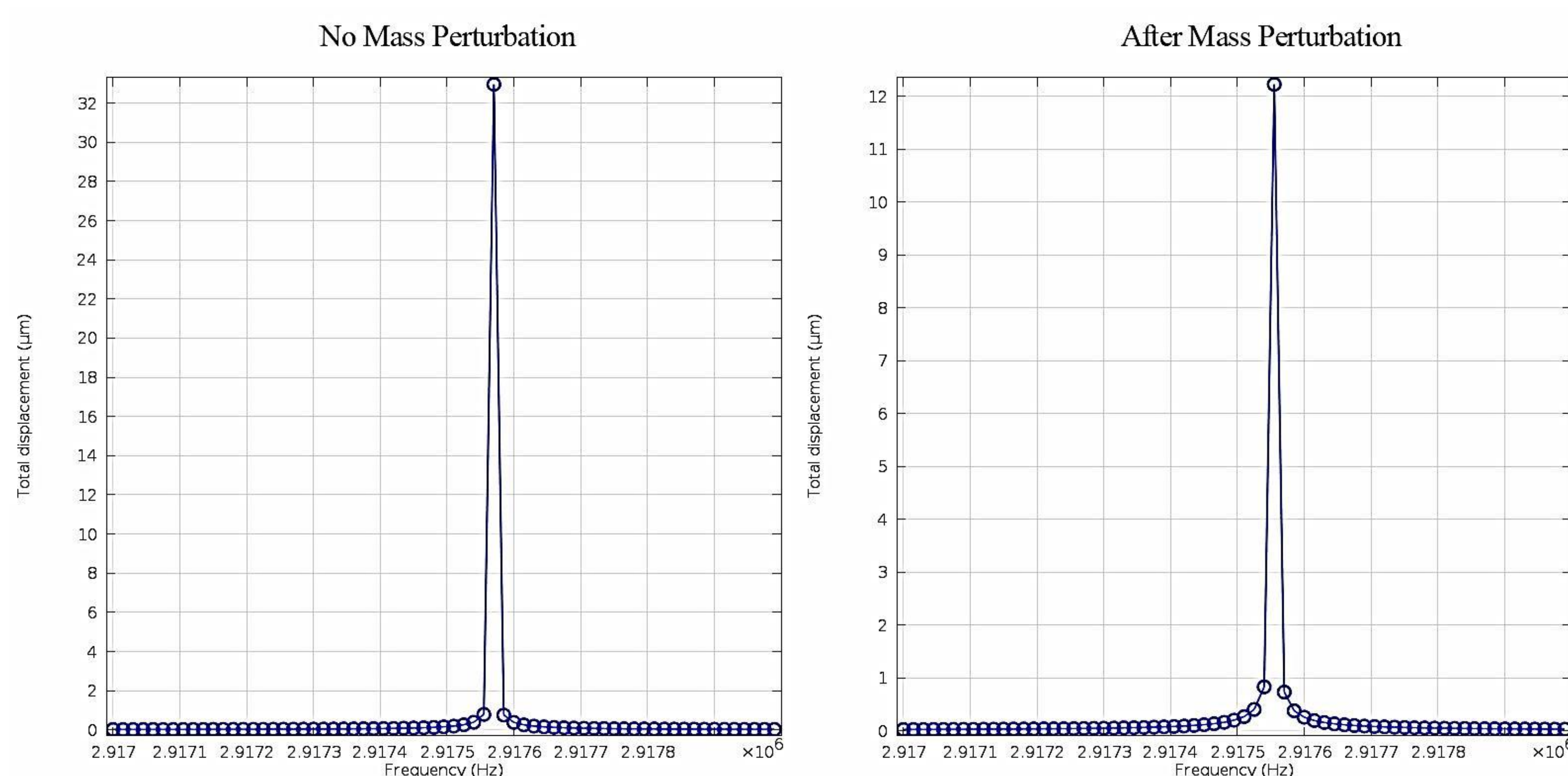


Figure 5. FRF of 3DOF System (Out-of-Phase)

**Conclusions:** If the system is strongly coupled, it is advantageous to examine eigenvalues. If the system is weakly coupled, it is better to examine eigenmodes. The configuration with the best value of sensitivity and the least value of measurement error should be selected.

## References:

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4. R. L. Fox, *et al.* "Rates of change of eigenvalues and eigenvectors." *AIAA journal* 6.12 (1968): 2426-2429.