Fairing Noise Reduction for Directive Acoustic Fields

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Launch Vehicle Acoustic Environments

Liftoff

Transonic

Max-q

Acoustic levels within the fairing are generally most severe shortly after liftoff.

Acoustic levels outside the faring are generally most severe at and near transonic conditions.

Acoustic Test Procedures

Reverberant Chamber

- Test levels can be set with high accuracy
- Test is repeatable
- Acoustic field is diffuse – sound waves are incident from all directions

Progressive Wave

- Higher levels can be achieved
- Sound waves incident from one direction - grazing

Acoustic Test Specifications

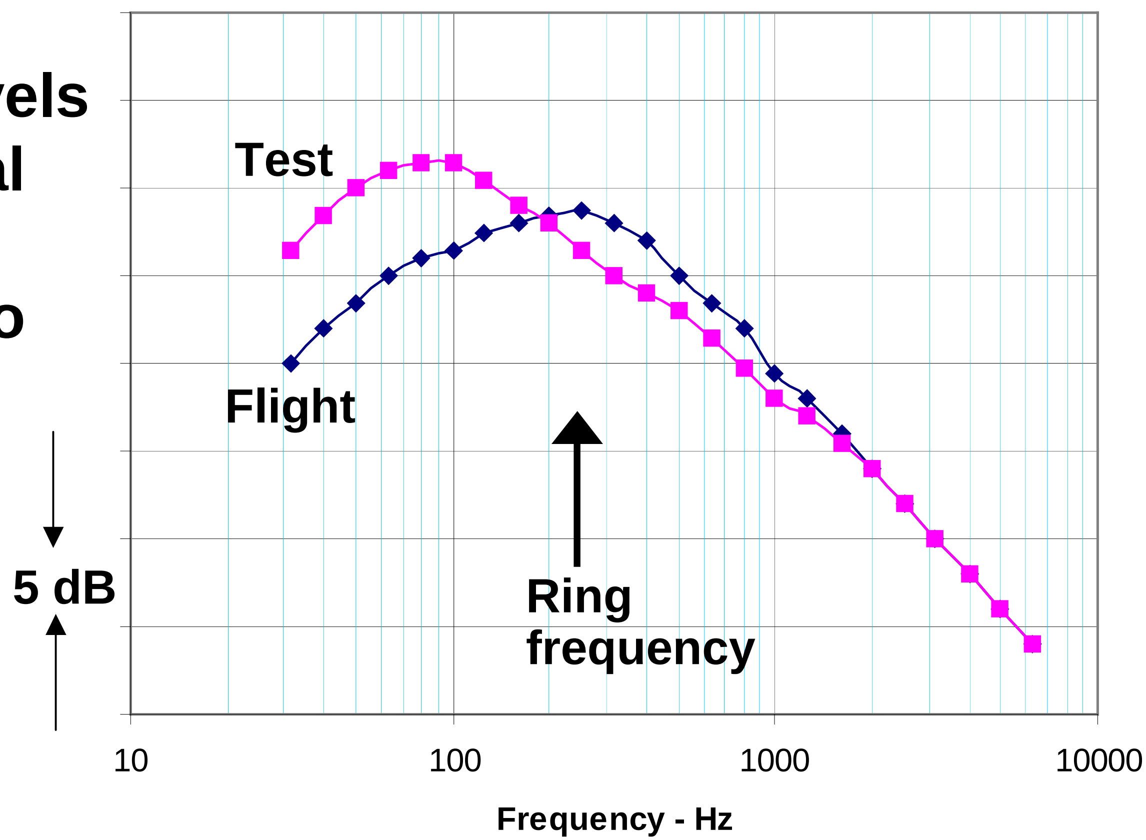
Specifications for acoustic spectra are meet with great accuracy using today’s test chambers.

Specifications for spatial cross-correlation (or wavenumber spectra) are given less attention – testing in a reverberant chamber may be required.

When testing is conducted to determine fairing noise reduction performance, the directivity of the liftoff acoustic field should be considered.

Payload Space Acoustic Levels

The chamber acoustic test levels were set to equal the liftoff flight levels external to the fairing.



Flight/Test Differences

Differences between the fairing noise reduction measured in a test chamber and measured in flight are attributed to the differences in the directivity of the acoustic field during liftoff.

Modal Response

The response of a single mode can be determined theoretically

$$W_n(f) = \underbrace{\left|H_n(f)\right|^2}_{\text{frequency response function for the mode}} \iint dx \iint dx' \, \underbrace{W_p(x, x', f)}_{\text{cross-spectrum of the acoustic field}} \psi_n(x) \underbrace{\psi_n(x')}_{\text{mode shape}}$$

Unfortunately, the cross-spectrum for the flight environment is not known so that engineering judgment must be used in evaluating the modal response.

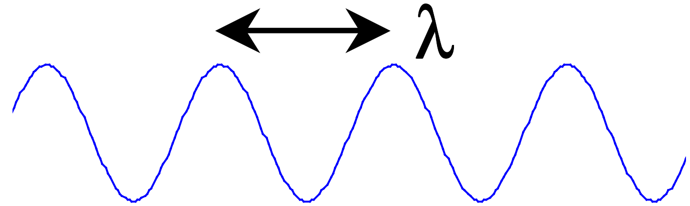
Modal Response - Wavenumber

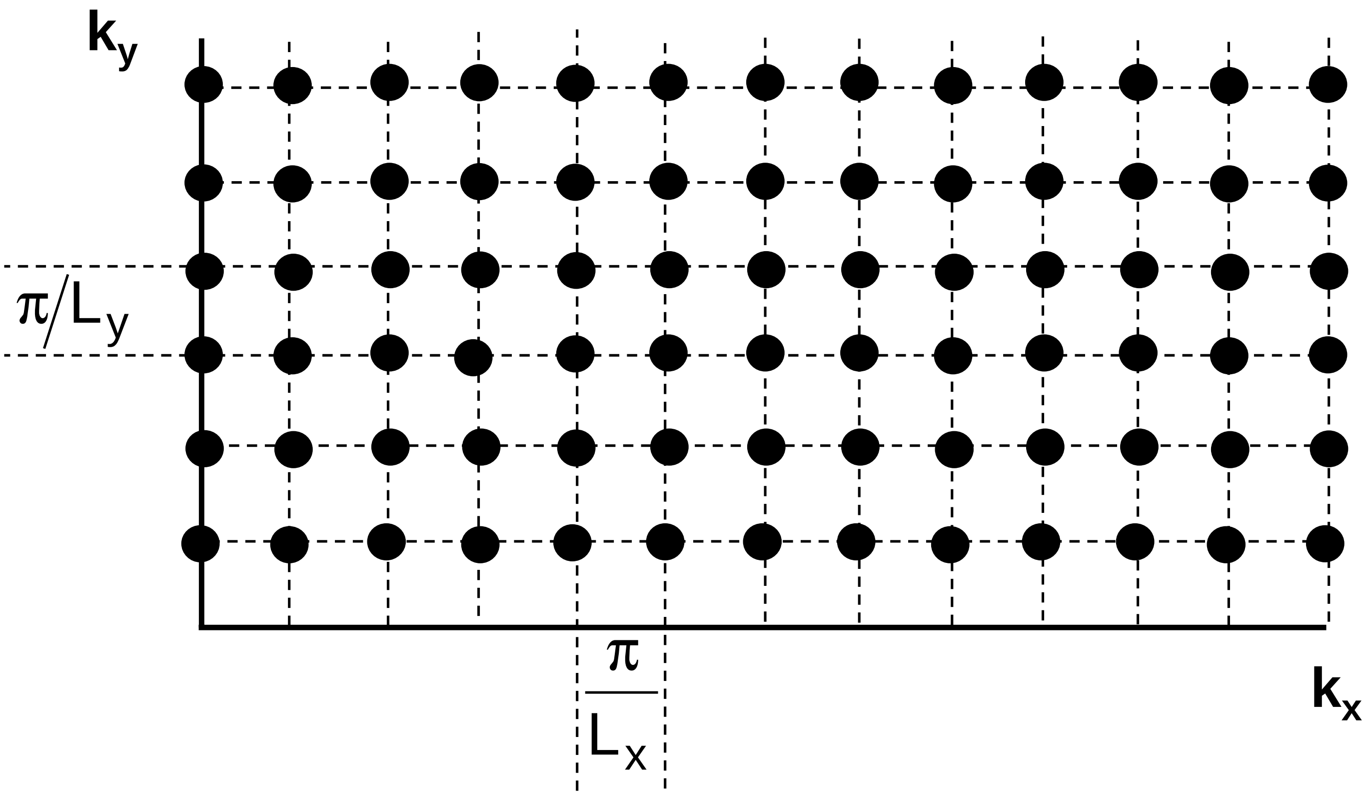
The response of a single mode can also be determined from the wavenumber spectrum

$$\underbrace{W_n(f)}_{\text{frequency response function for the mode}} = \left|H_n(f)\right|^2 \iint dk\; \underbrace{W_p(k,f)}_{\text{wavenumber spectrum of the acoustic field}} \underbrace{\left|\tilde{\psi}_n(k)\right|^2}_{\text{Fourier transform of the mode shape}}$$

Modes in Wavenumber Space

Each mode is a point in wavenumber space

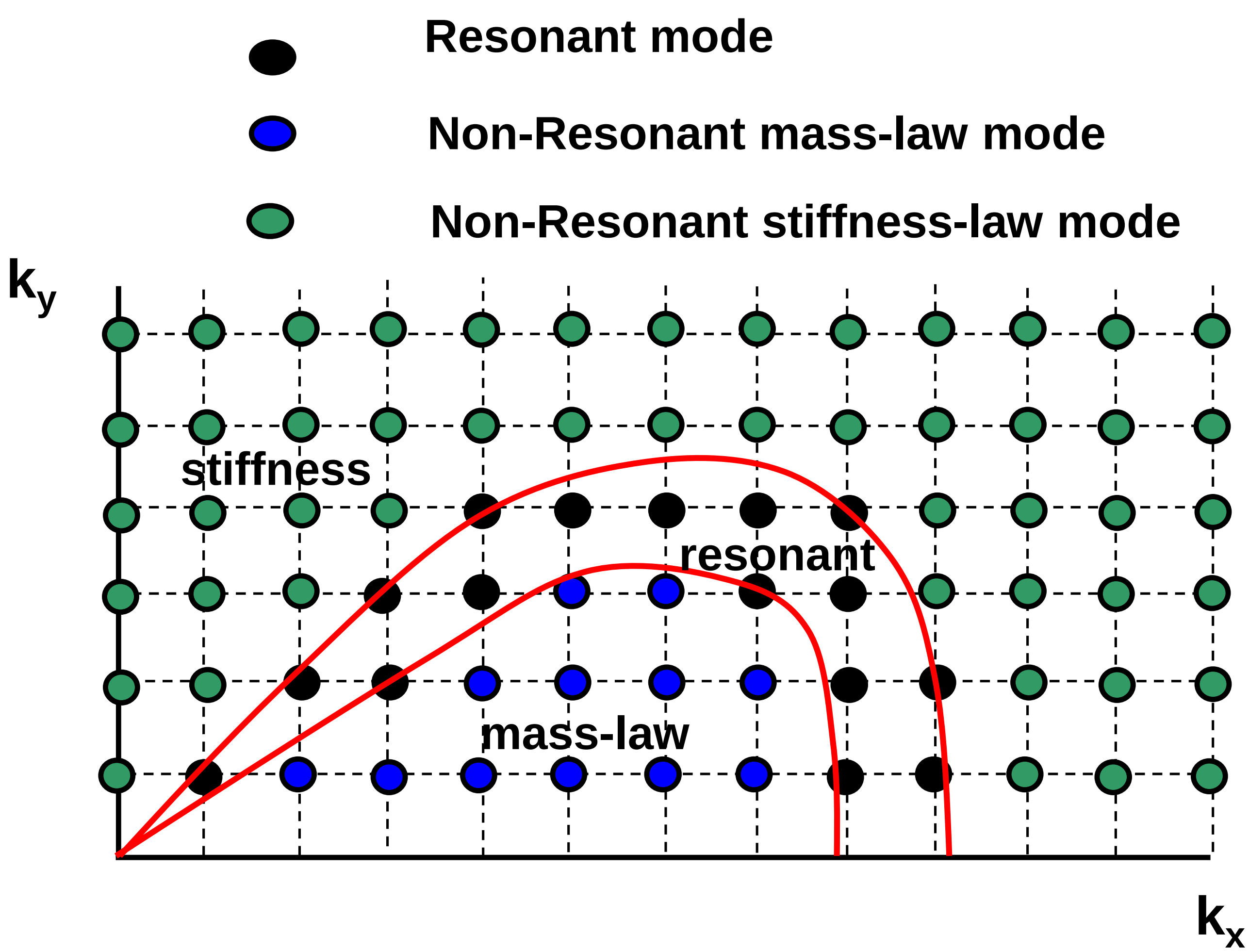




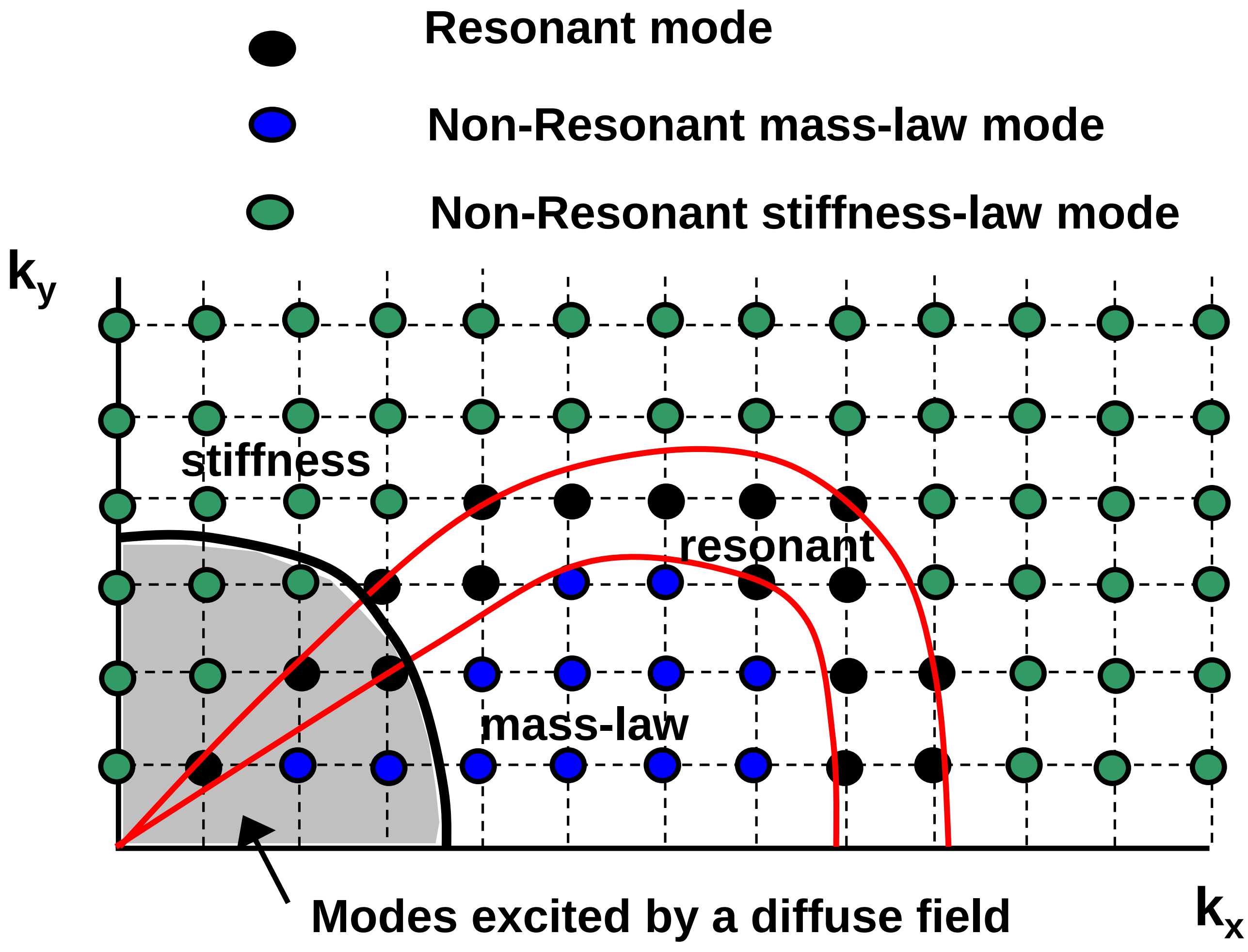
$$k_x = \frac{2\pi}{\lambda_x}$$

$$k_y = \frac{2\pi}{\lambda_y}$$

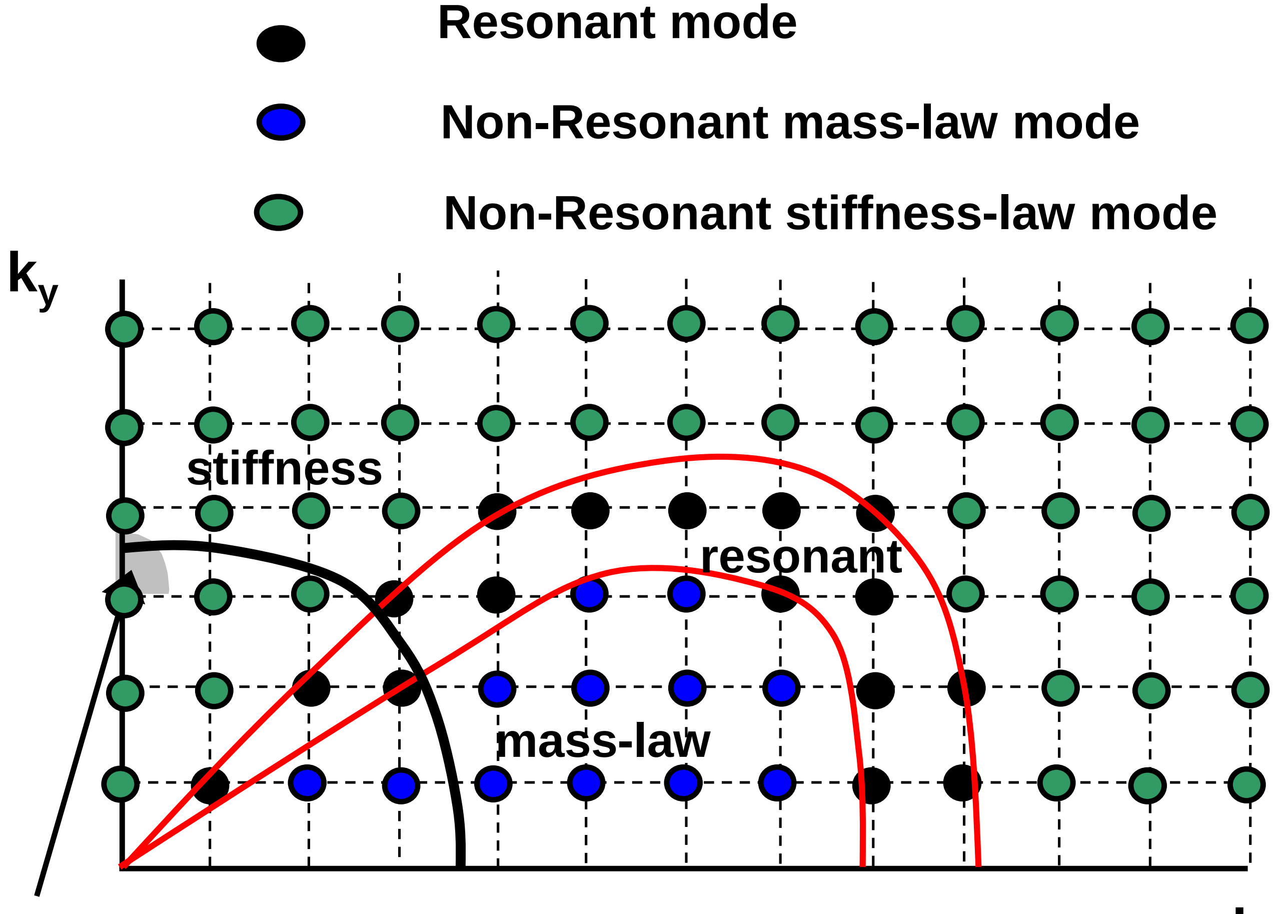
Classification of Resonant Modes



Excitation of Modes by a Diffuse Field

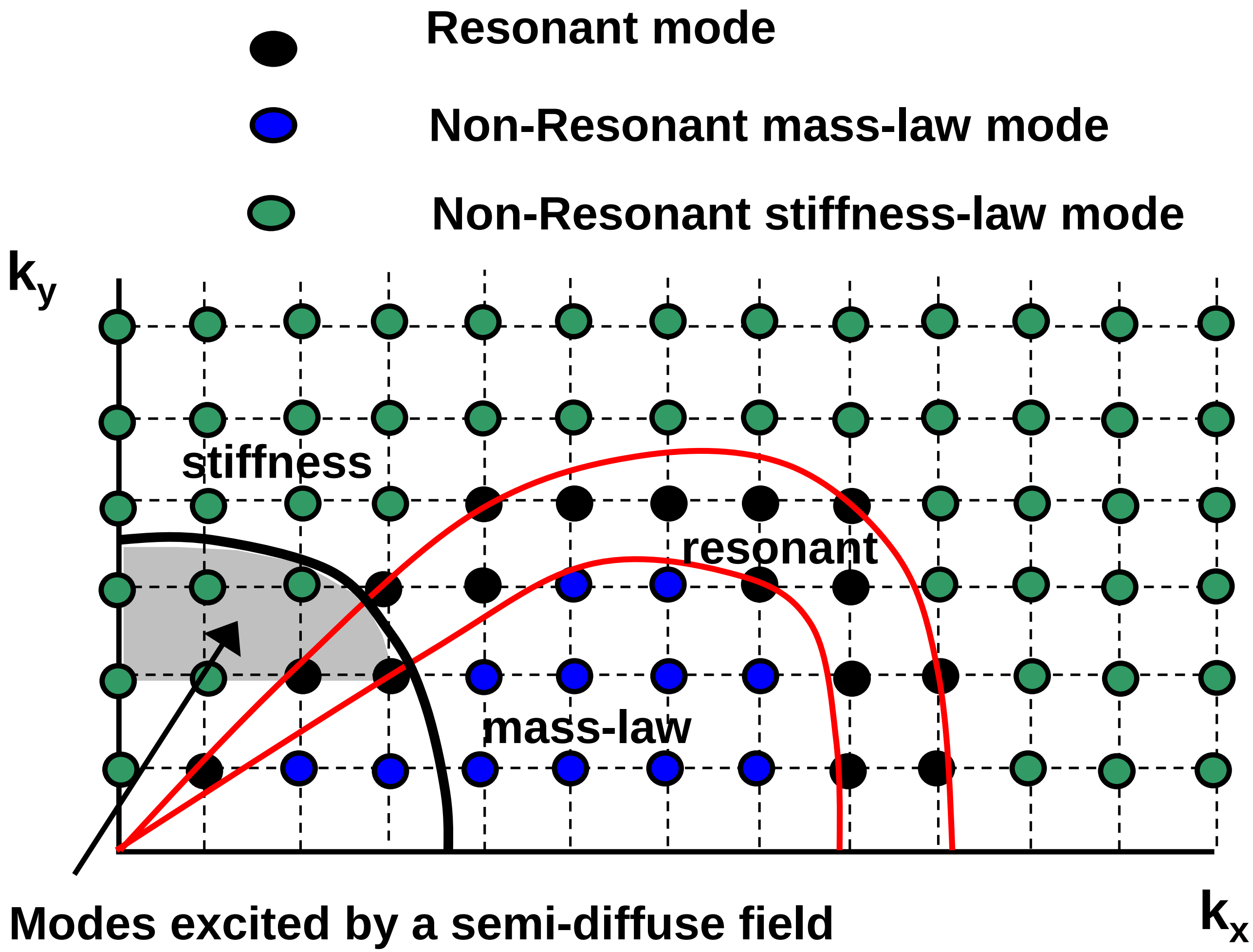


Excitation of Modes by a Progressive Wave



Modes excited by a progressive wave

Excitation of Modes by a Semi-Diffuse Field



Conclusions

Flight measurements of the cross-spectrum of the liftoff acoustic field are needed.

Measurements of fairing noise reduction obtained in a test chamber must be corrected to obtain flight predictions.

Noise mitigation methods should take into account the directivity of the excitation.