The “bridge hill” of the violin

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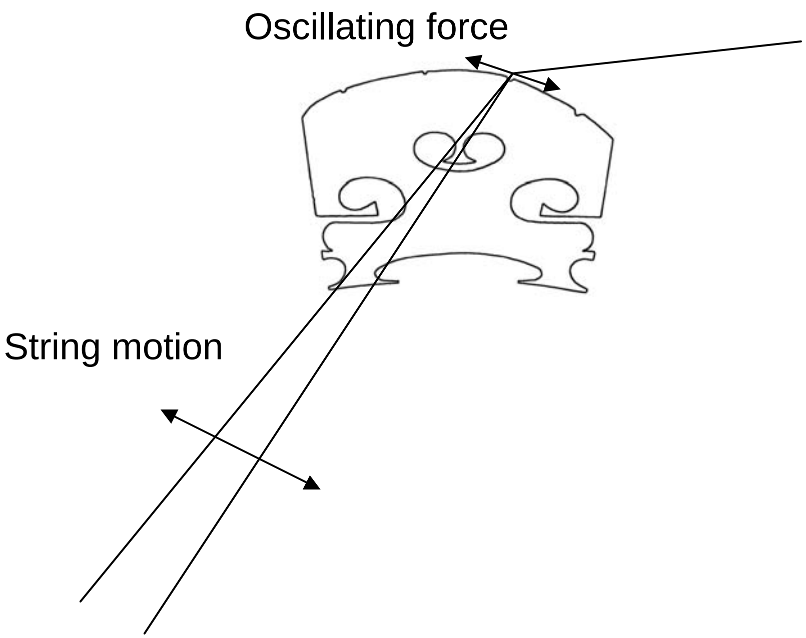
With thanks to Helen Burslem, Ian Cross, Jonathan Woolston and David Rubio

How the violin works — roughly



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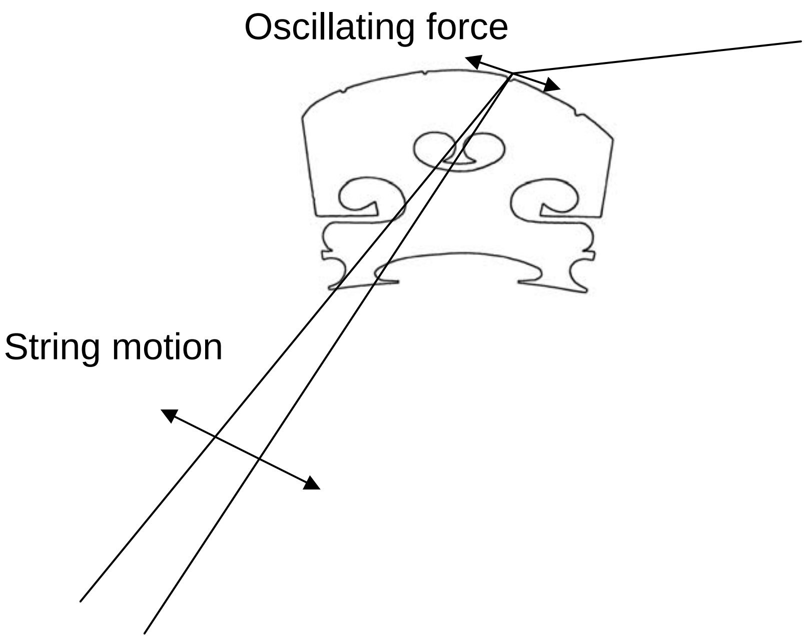
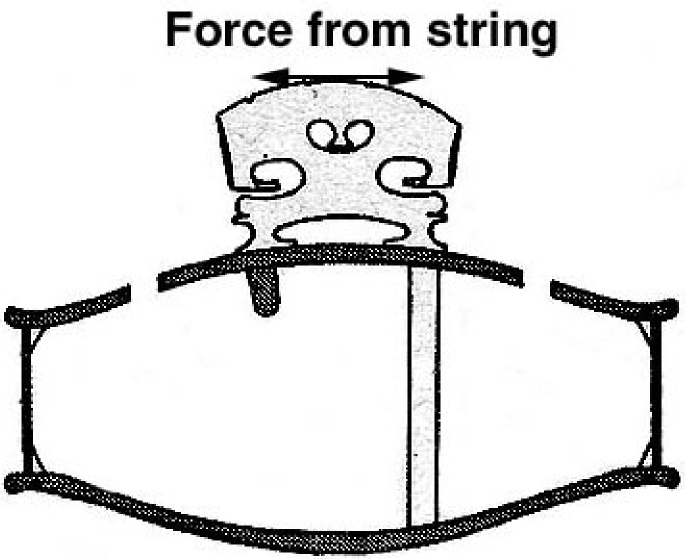
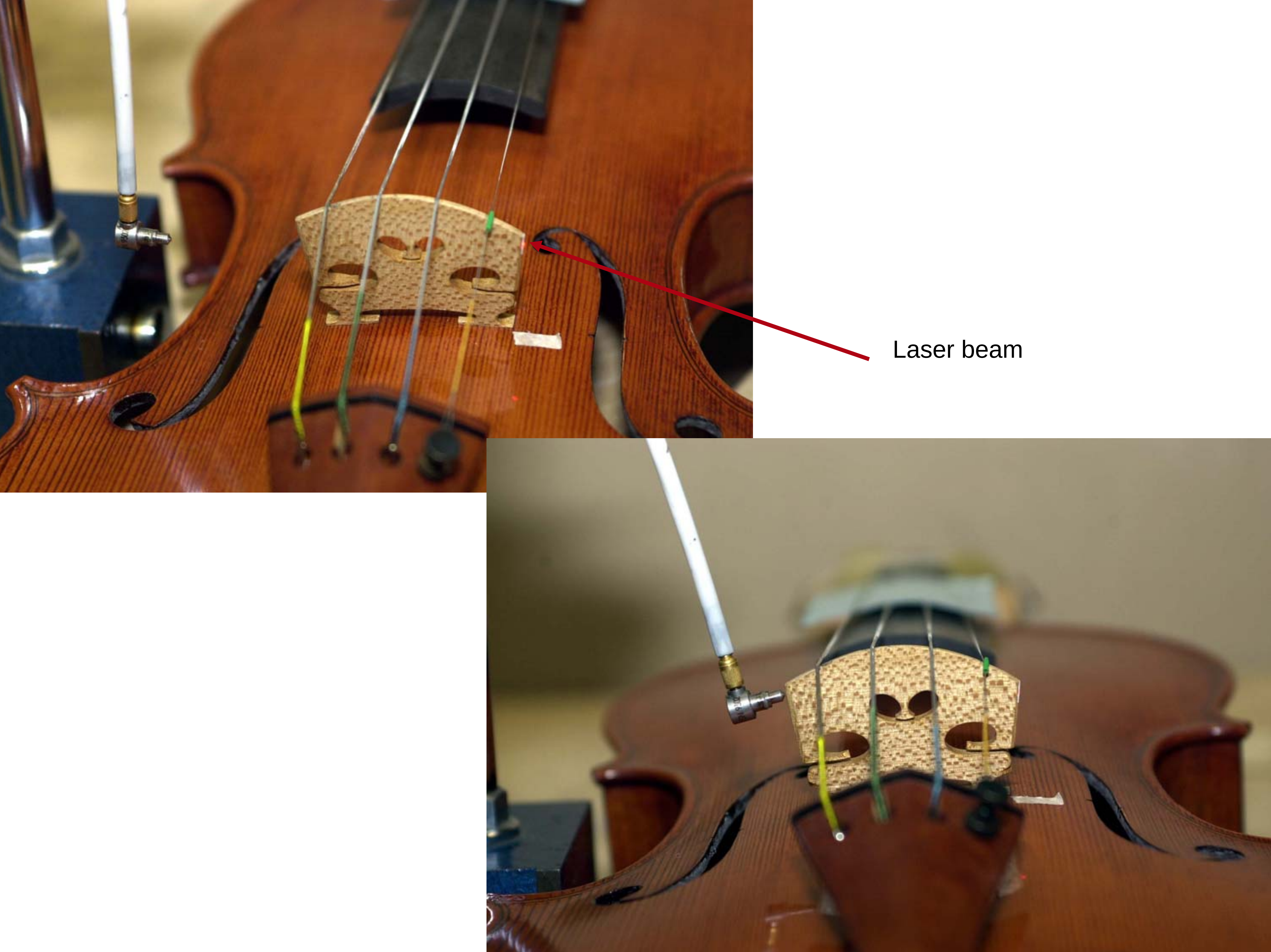
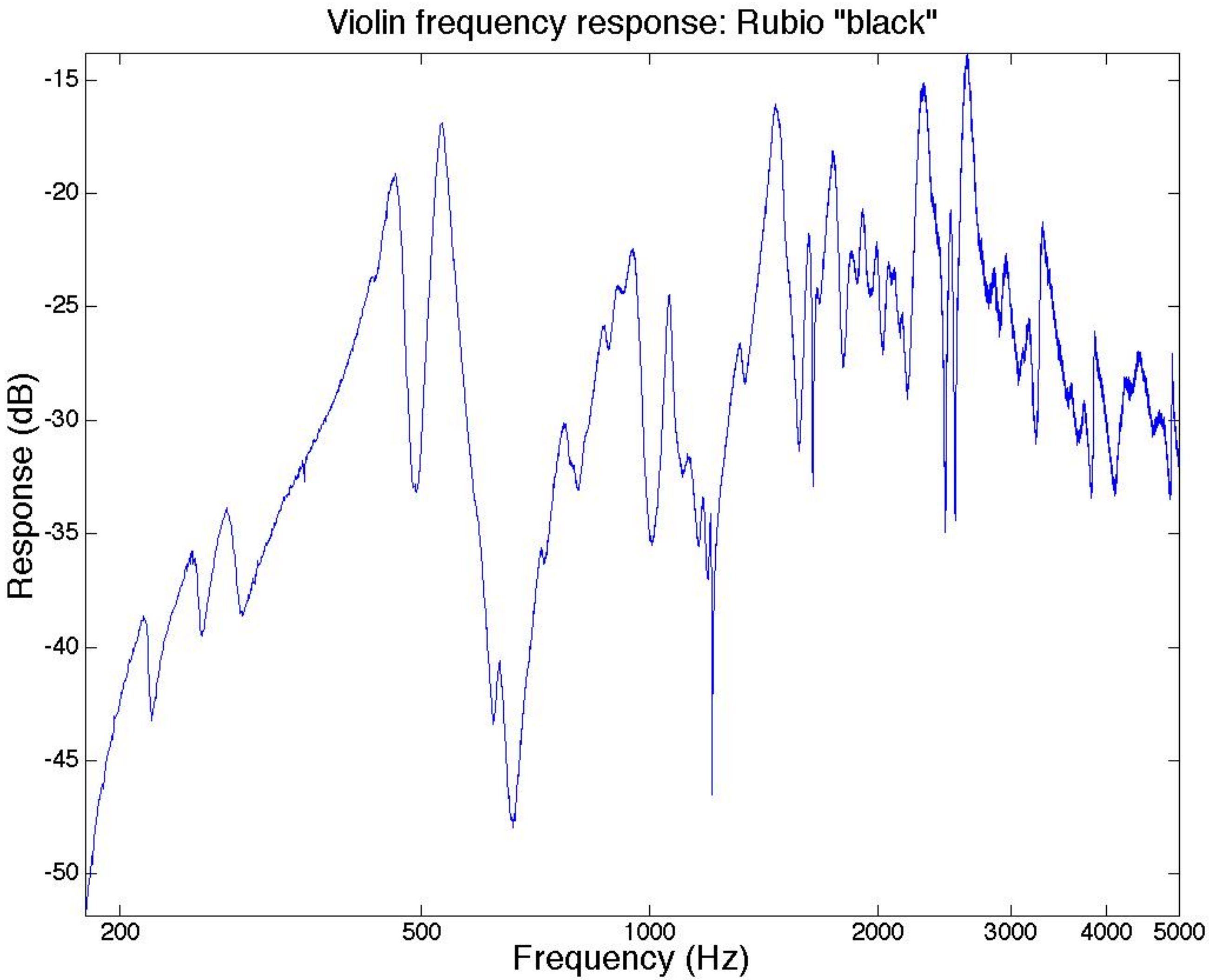


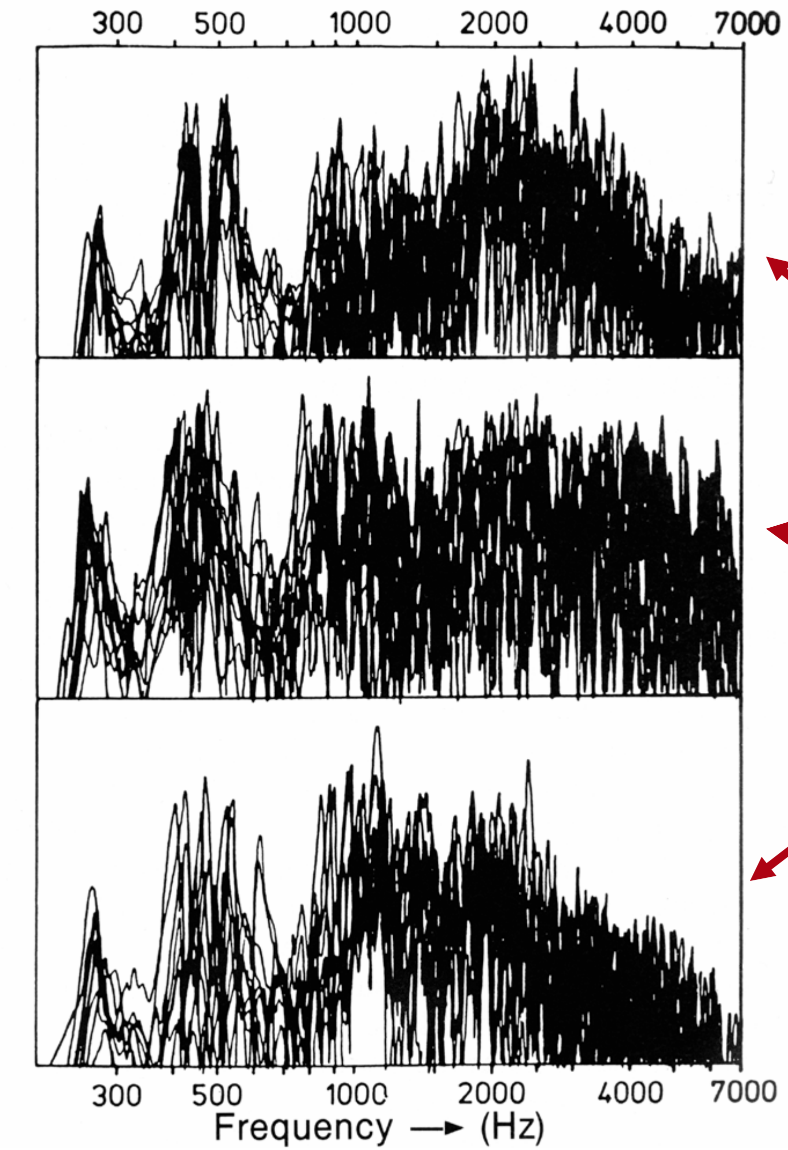



Laser beam

A typical measured input admittance



Some important measurements



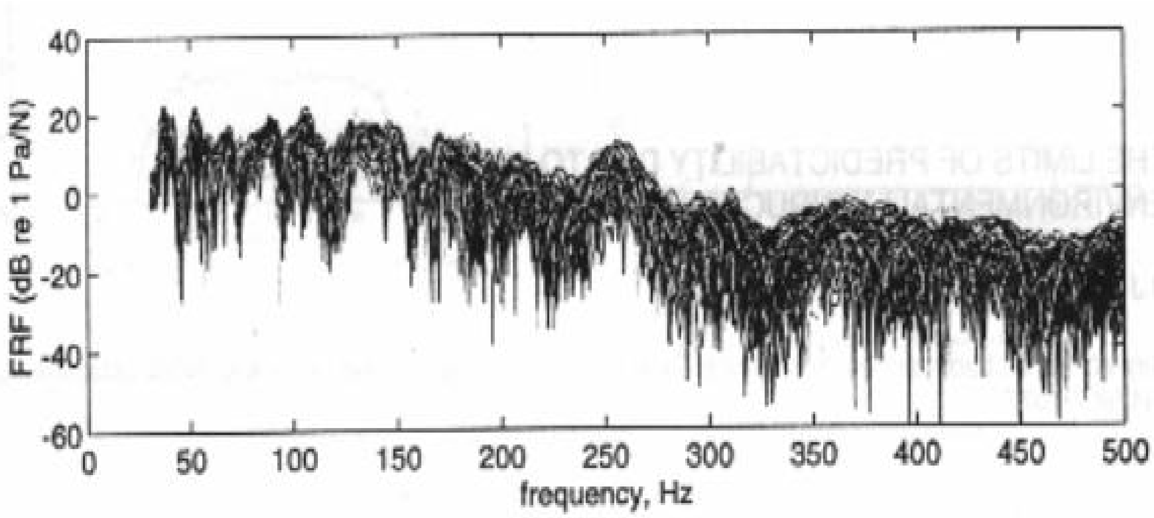
Two researchers, Heinrich Dünnwald and Erik Jansson, have measured the response of many violins, and they both noticed a similar feature. These are some of Dünnwald's results.

10 old Italian violins

10 modern "master violins"

10 factory violins

An aside: the violin is not so unusual...

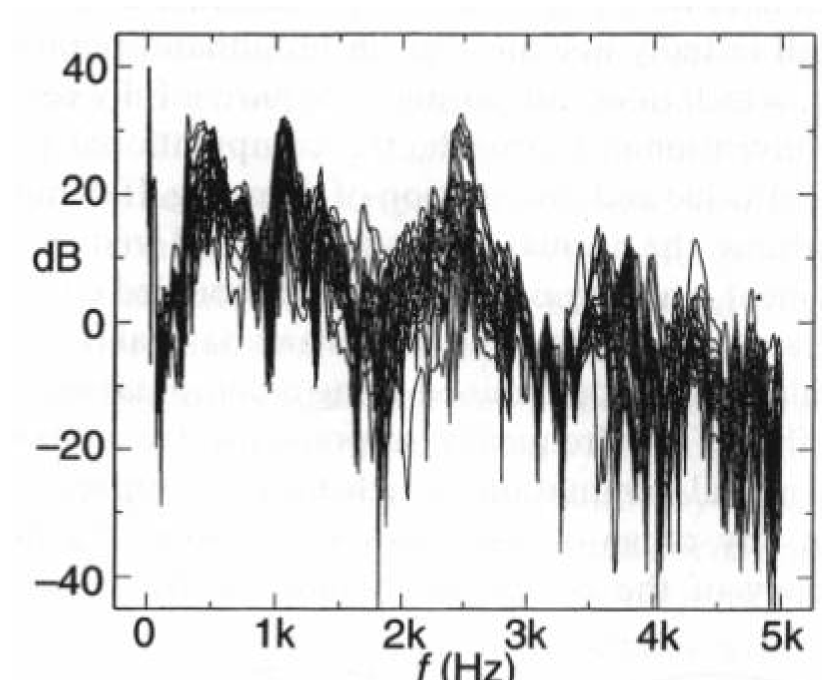


98 successive cars from a production line: structure-borne response

[Kompella & Bernhard, Measurement of the statistical variation of structural-acoustic characteristics of automotive vehicles, *In Proc. SAE Noise and Vibration Conf., Warrendale, USA: Soc. Auto. Eng.*, 1993]

41 nominally identical beer cans subjected to acoustic excitation

[Fahy, *Foundations of Engineering Acoustics, Academic Press*, 2001, p275]



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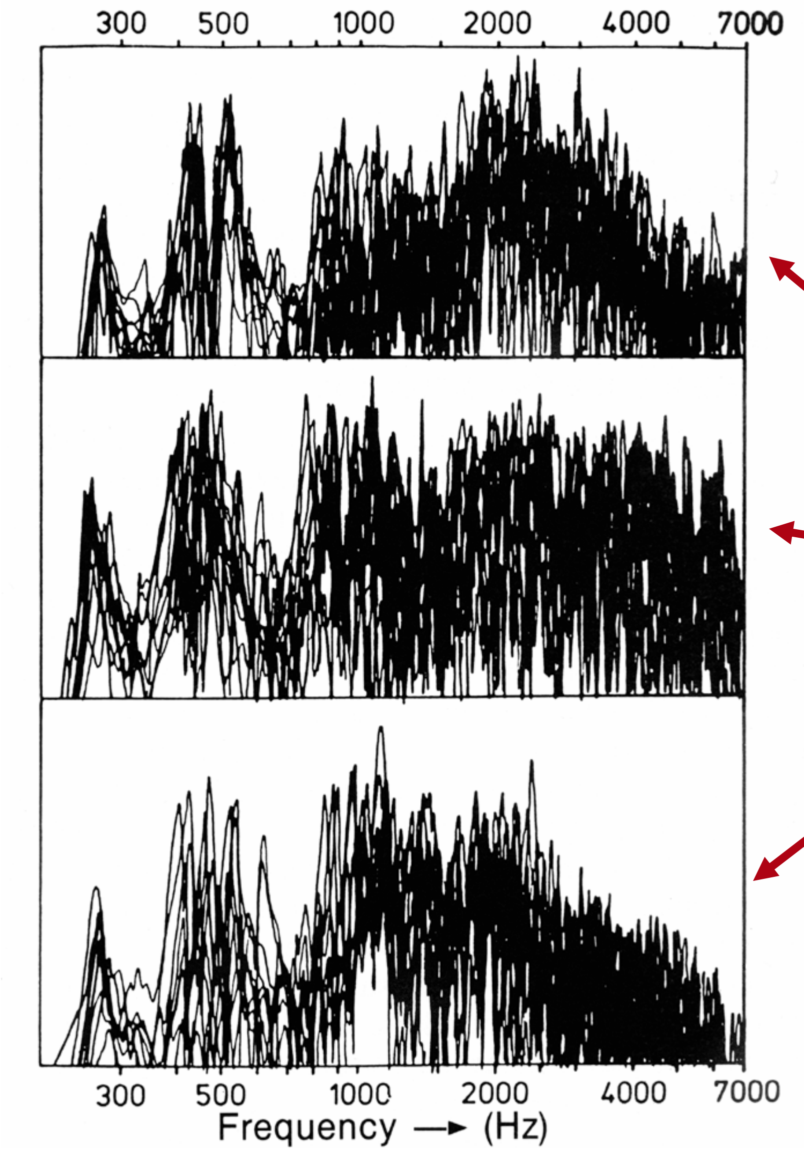

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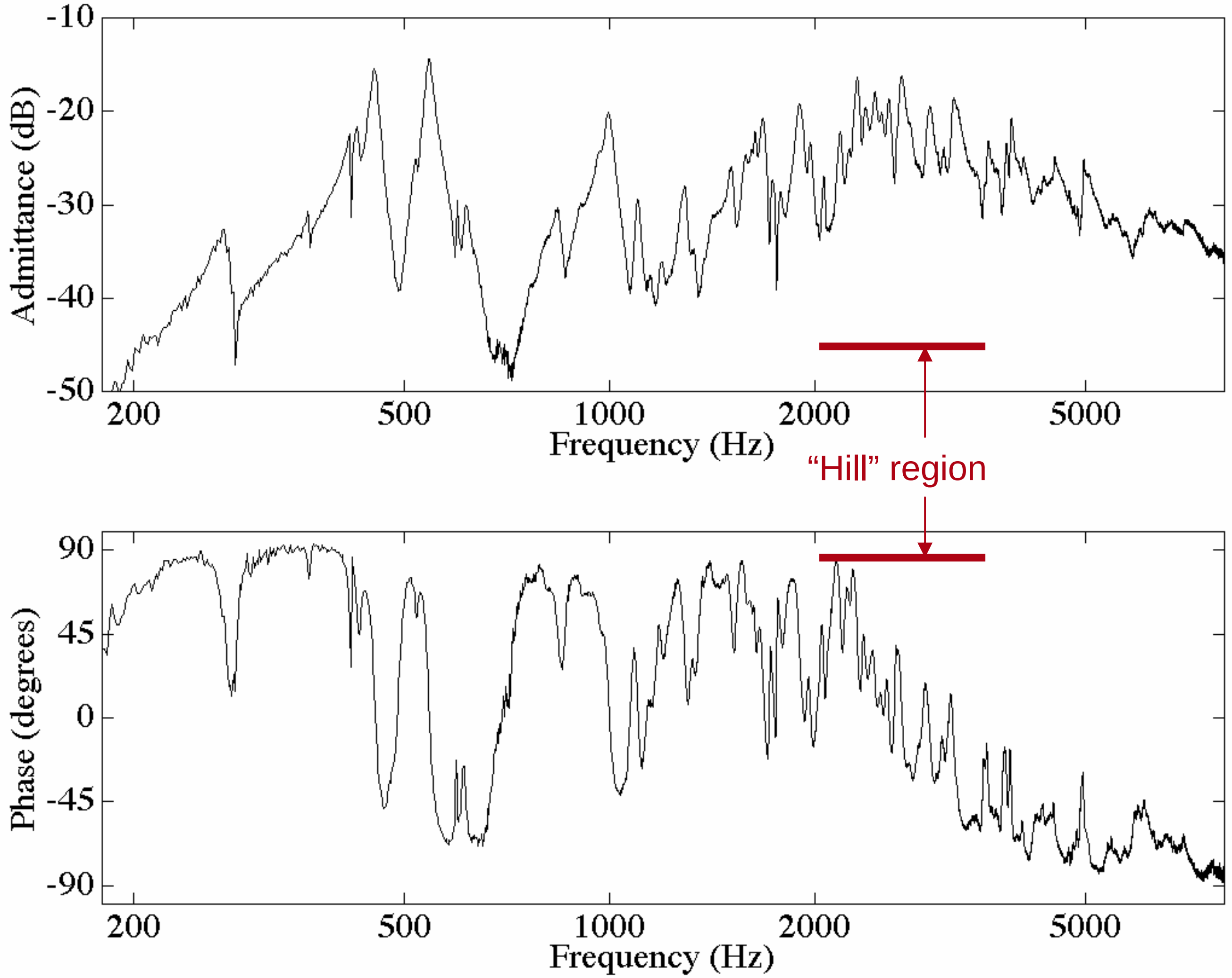
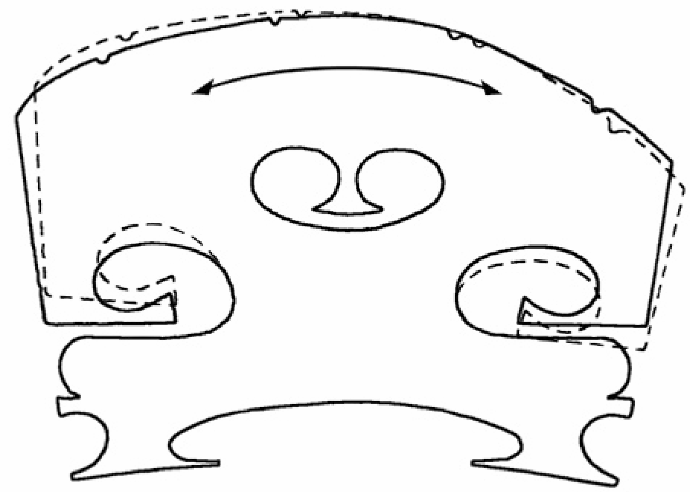
A typical “bridge hill”



Why a “bridge hill”?

One possible reason for this feature lies in the behaviour of the bridge.
A normal bridge has its first in-plane resonance around 3 kHz when the feet are clamped. The mode shape is roughly like this:



It seems a good guess that this bridge resonance is somehow implicated in the “hill”, as was suggested originally by Cremer and Jansson.

Other Jansson experiments

Erik Jansson has carried out a long series of experiments on this “bridge hill”, together with the violin maker Benedykt Niewczyk. He has concluded that the behaviour is more complicated than he initially thought.

(1) The “hill” is not determined solely by the bridge: it can also be influenced by changing the graduation of the top near the bridge feet, and to an extent by the position of the soundpost and the detailed cut of the f-holes.

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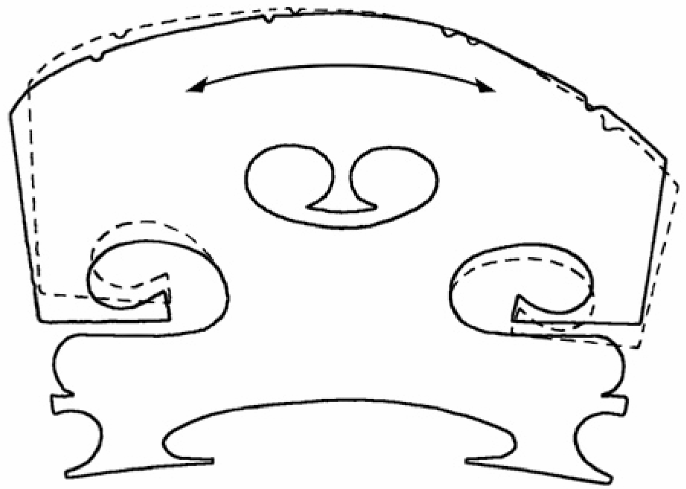
(2) The hill is very sensitive to the spacing of the bridge feet.

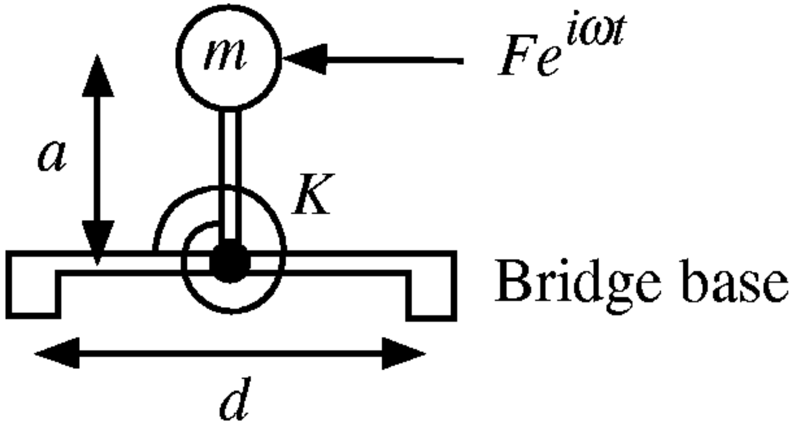
(3) Replacing a standard bridge with a "plate bridge" with no cutouts made remarkably little difference to the hill on his test instrument.

To explain these observations is the challenge for the work to be presented next.

Why a “bridge hill”?



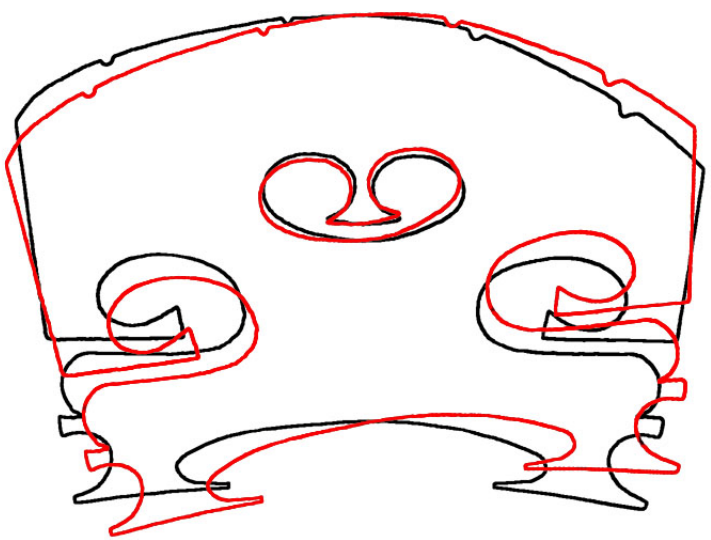
Idealised version:



What happens when the bridge is on the violin?

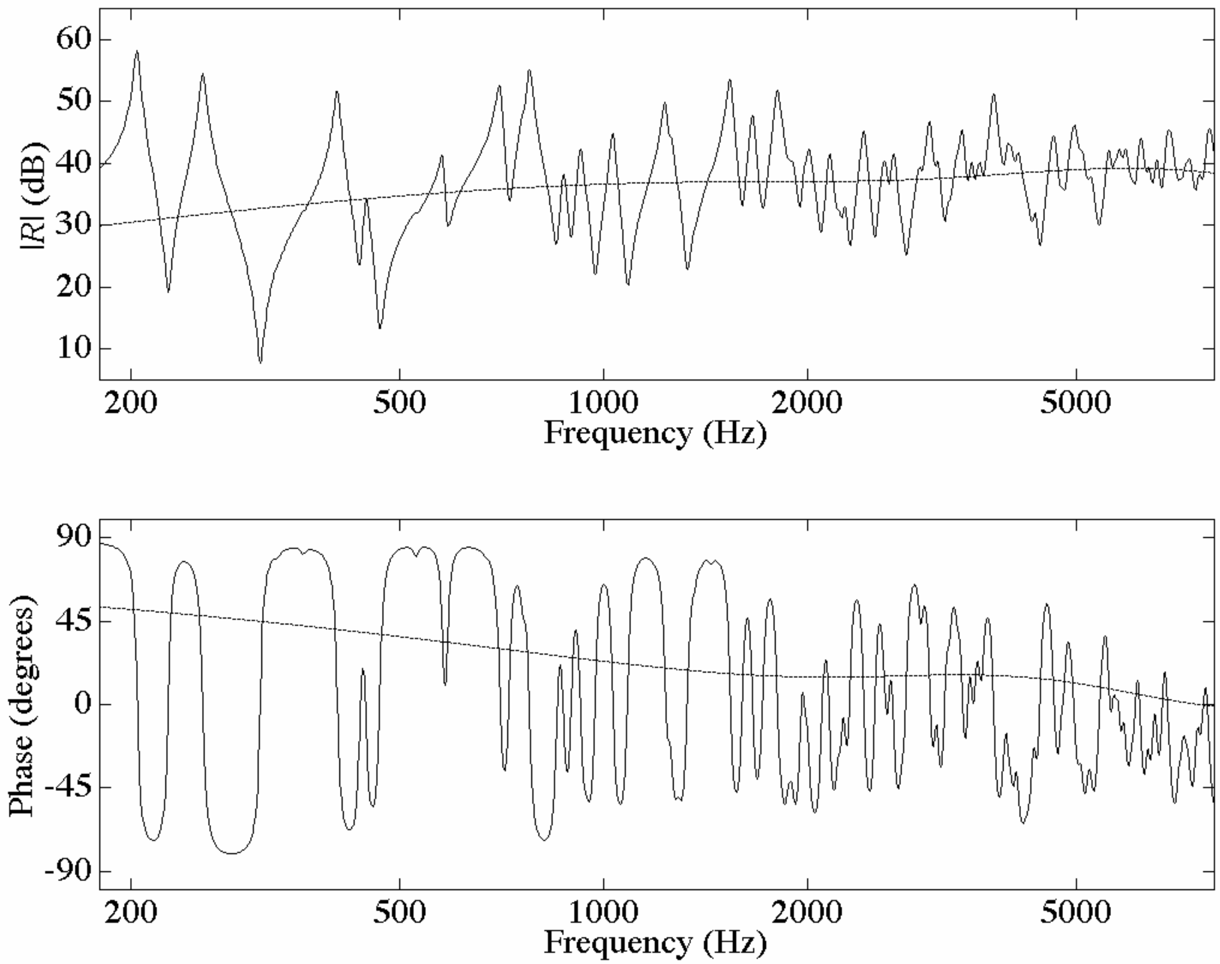
When mounted on the violin, the feet can move on the “springiness” of the top. There will still be a bridge resonance related to the previous picture, but its frequency will be lower.

In the extreme case, the bridge will not bend very much at all: the mass of the bridge will act against the stiffness of the top to produce the resonance. This is presumably what happened with Jansson’s “plate bridge” test.



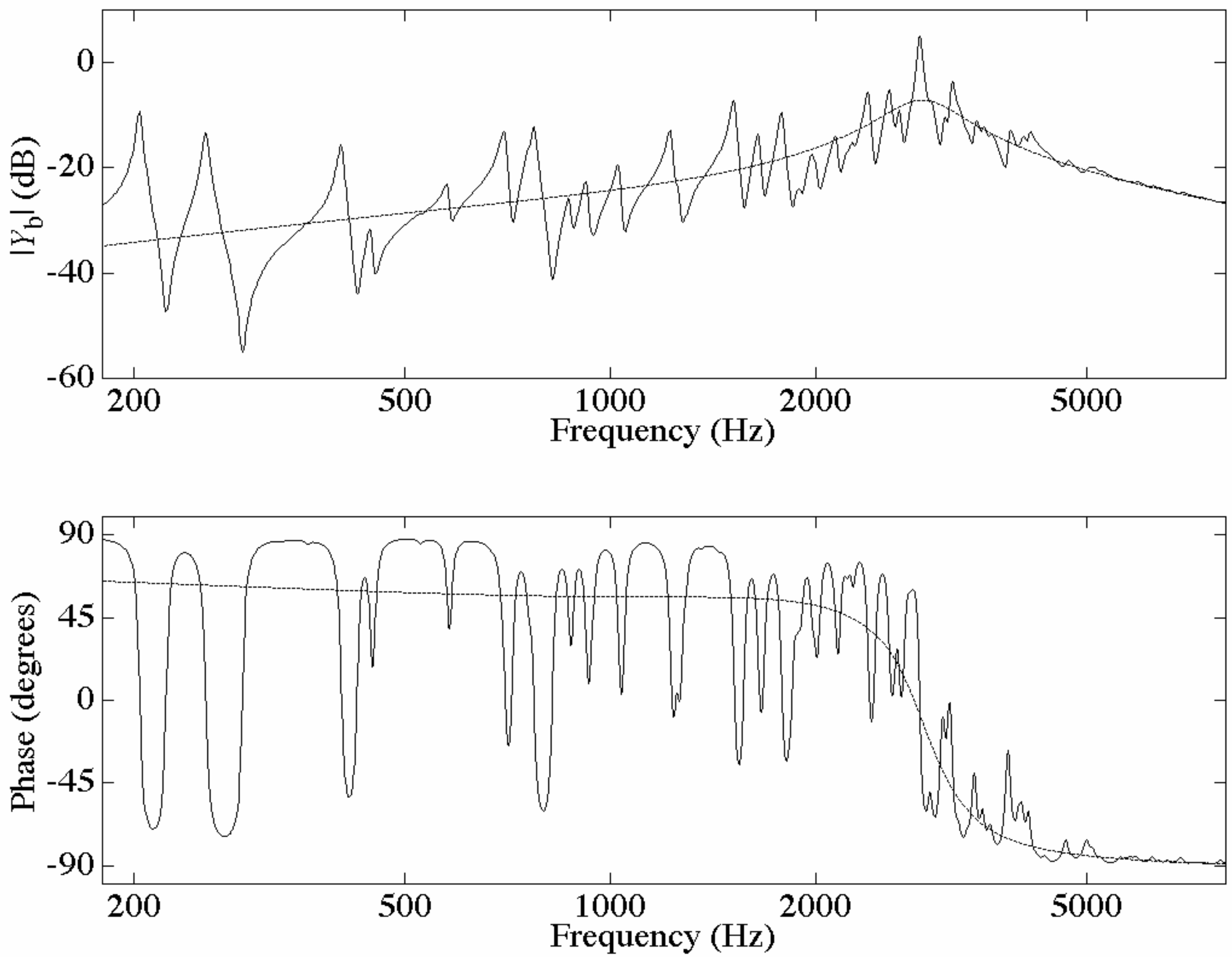
Why a “bridge hill”?

This single resonance is enough to have the right kind of effect on the input admittance. Here is the rotational admittance of an idealised “violin” body without bridge:



Why a “bridge hill”?

With the simple bridge model, it turns into this:



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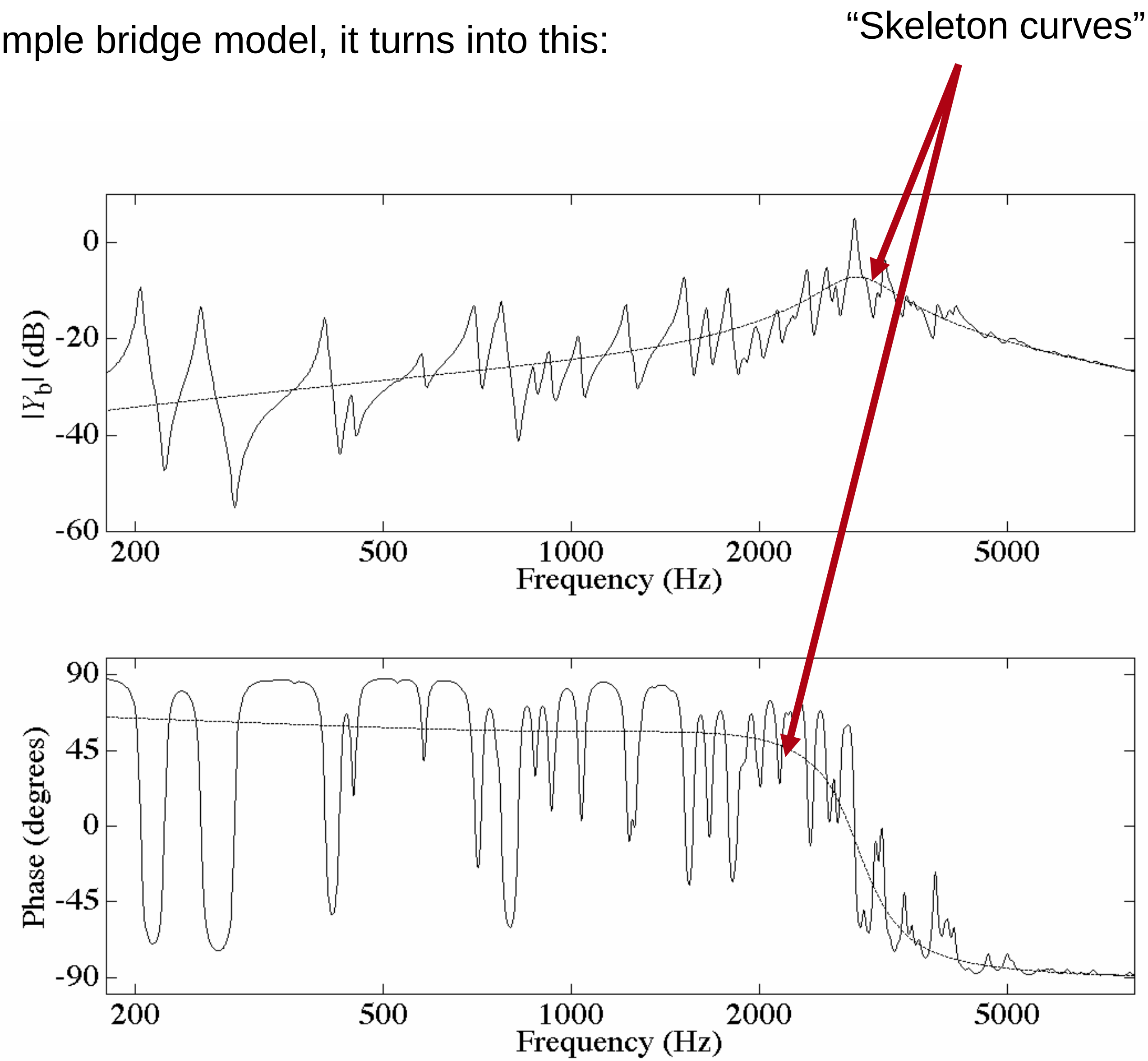

Shape of the skeleton curves

It is easier to trace the effect of adjustments to the bridge by looking at these skeleton curves, without the confusing detail of the individual body resonances.

The skeleton curves can be calculated, by adapting a method developed for vibration prediction in complex structures such as ships and aeroplanes.

QuickTime™ and a
TIFF (LZW) decompressor
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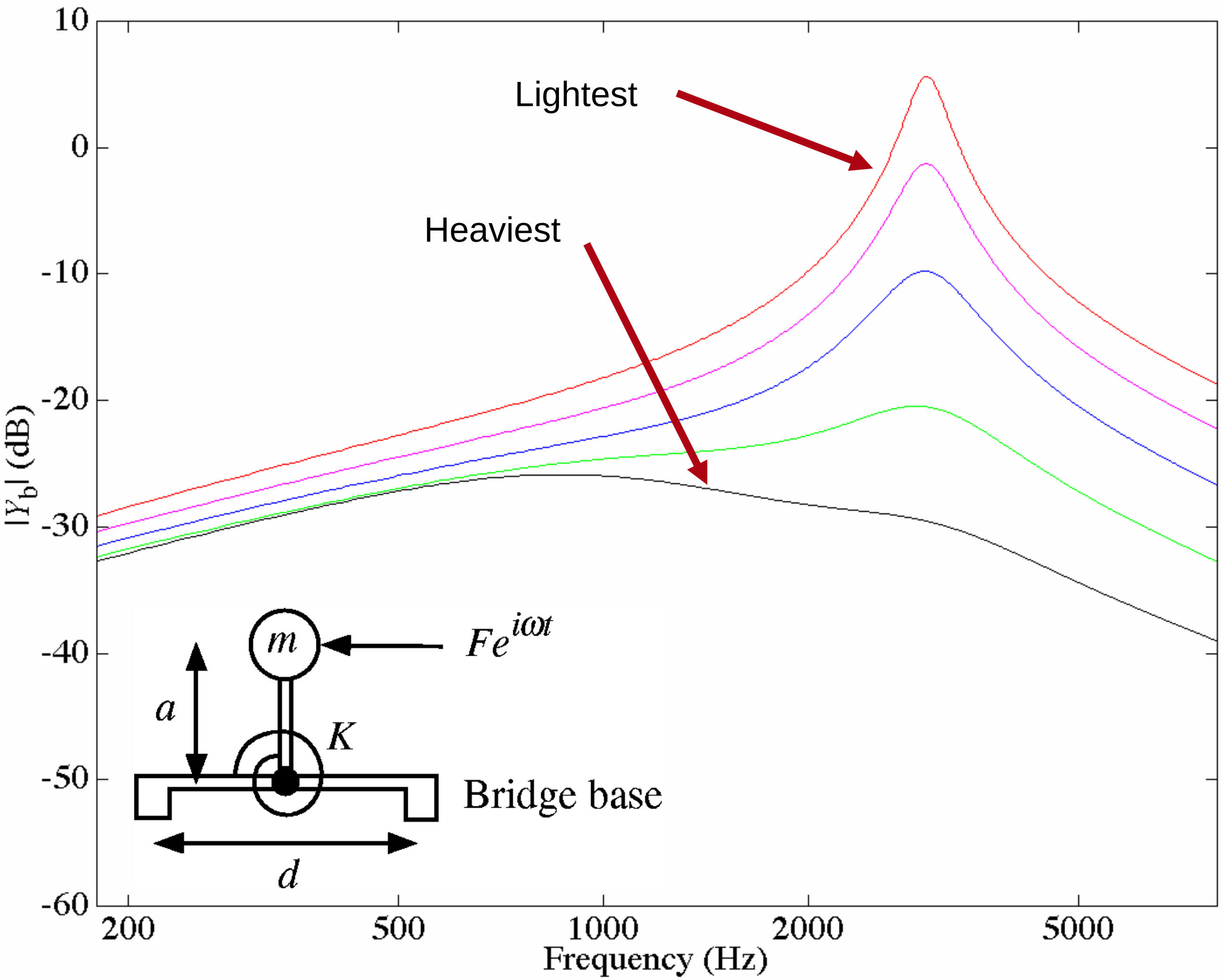
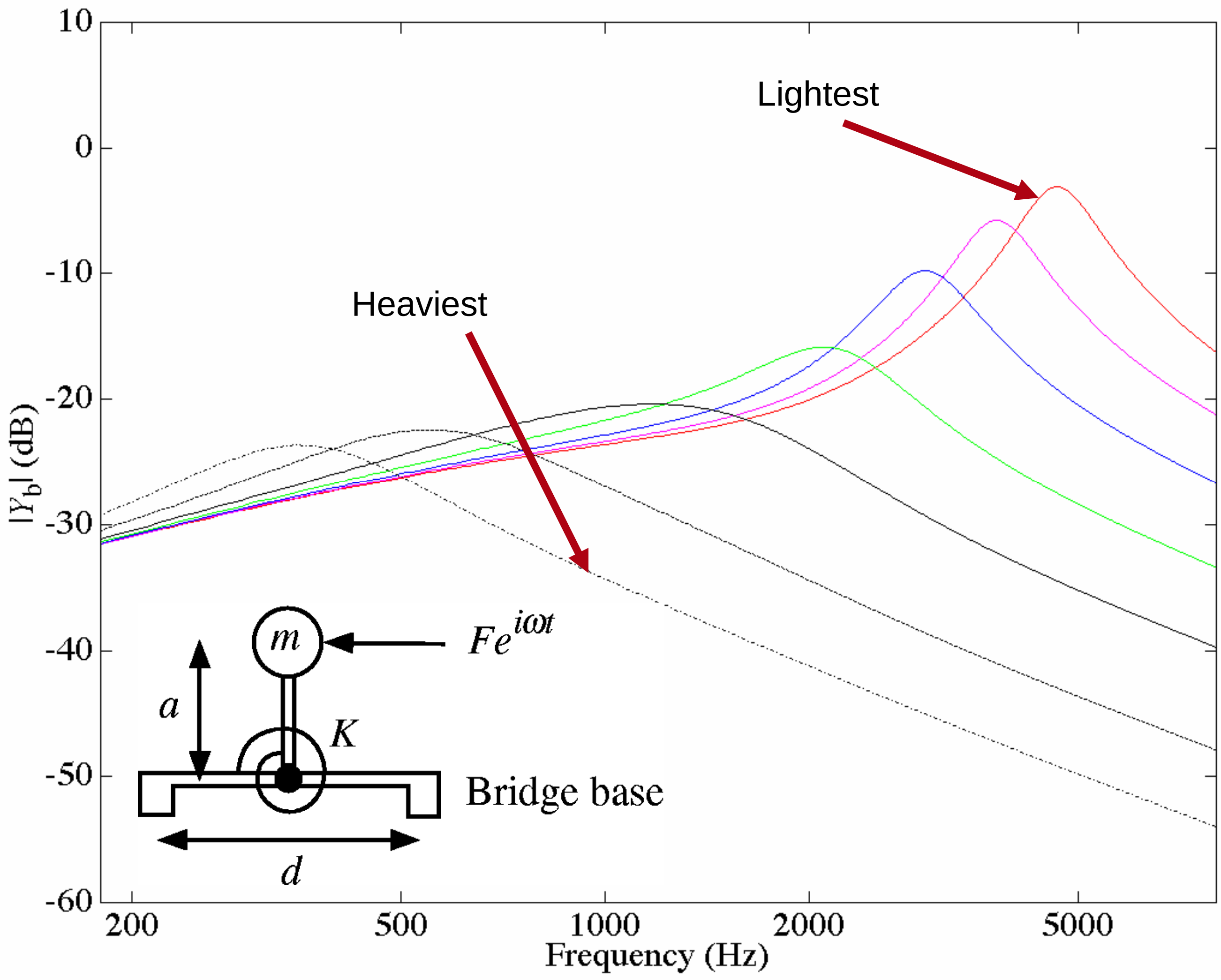
Skeleton curves and bridge adjustment

Vary the mass of the top of the bridge, keeping the resonance frequency fixed:



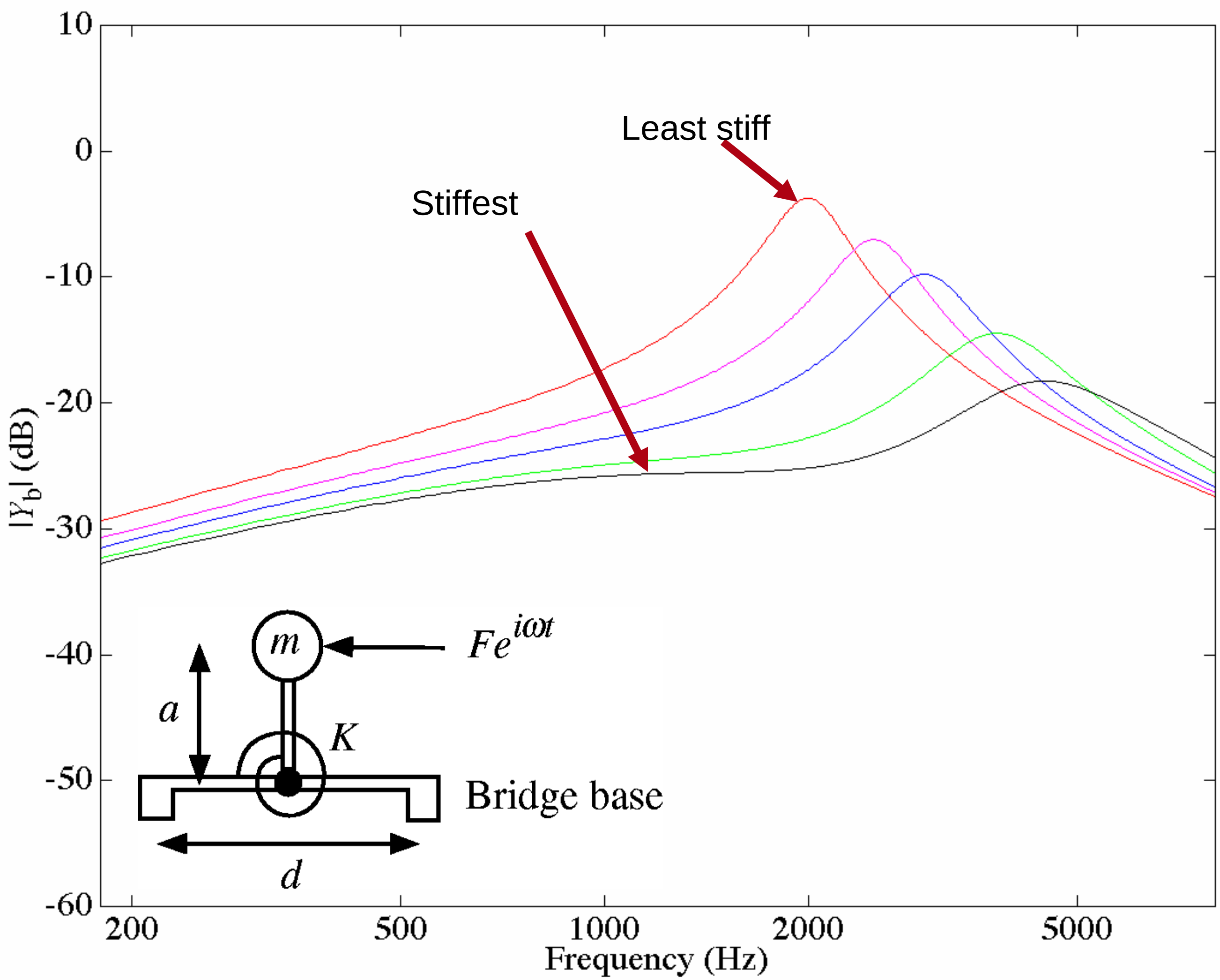
Skeleton curves and bridge adjustment

Vary the mass of the top of the bridge, keeping the stiffness fixed:



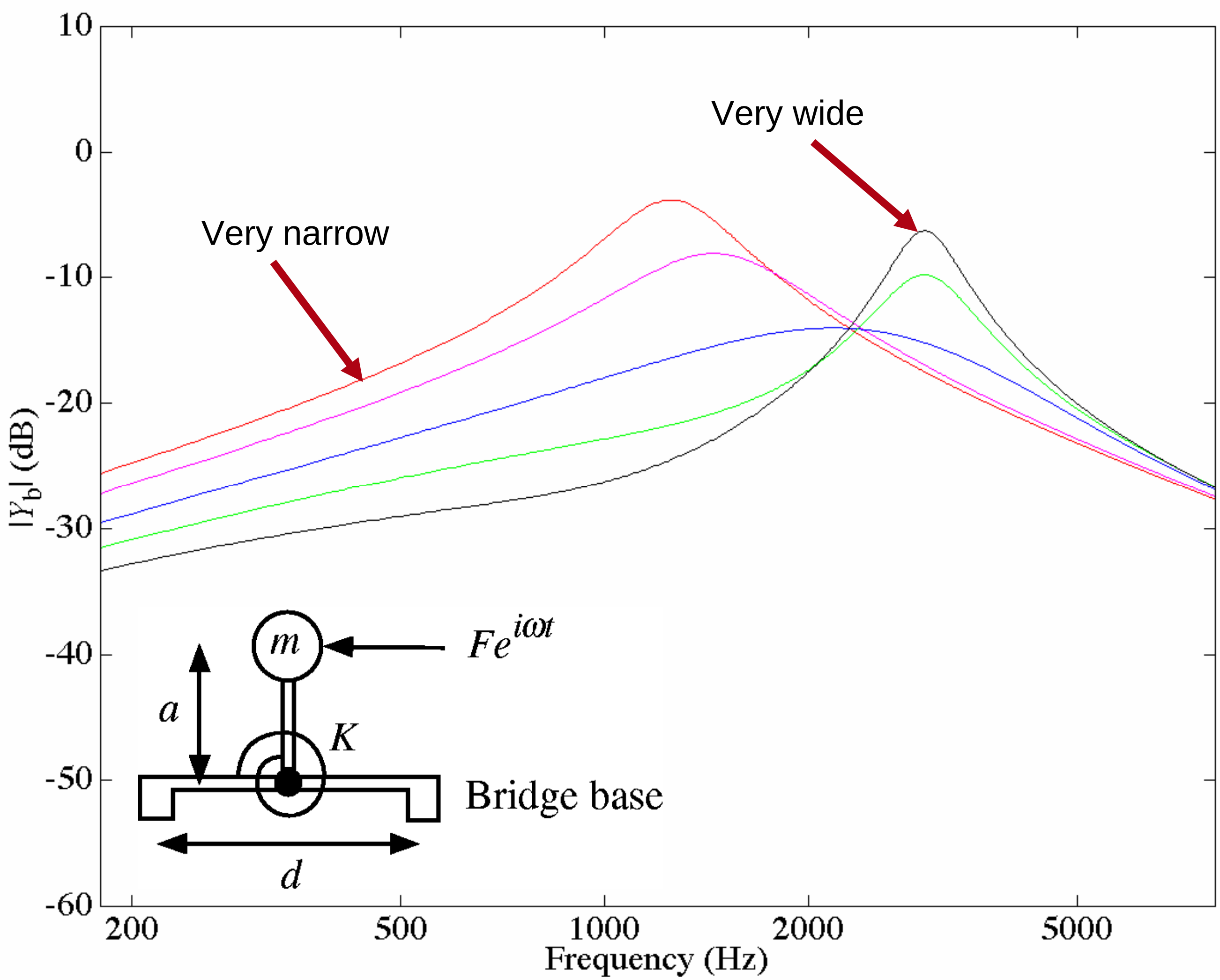
Skeleton curves and bridge adjustment

Vary the stiffness of the bridge, keeping the mass fixed:



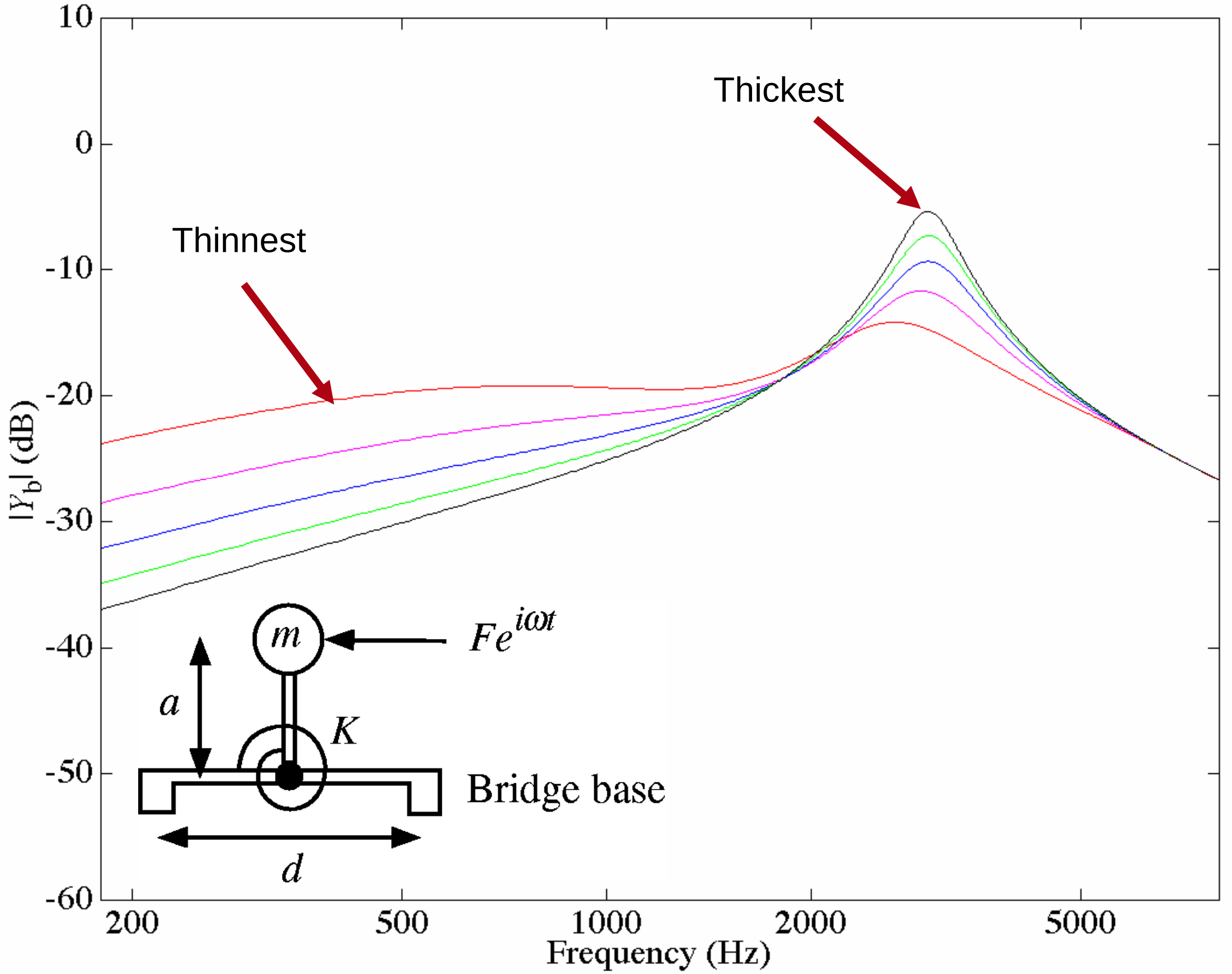
Skeleton curves and bridge adjustment

Vary the foot spacing of the bridge:



Skeleton curves and bridge adjustment

Vary the top thickness of the “violin”:



Does it really work?

Some important issues to address by tests with real instruments and bridges:

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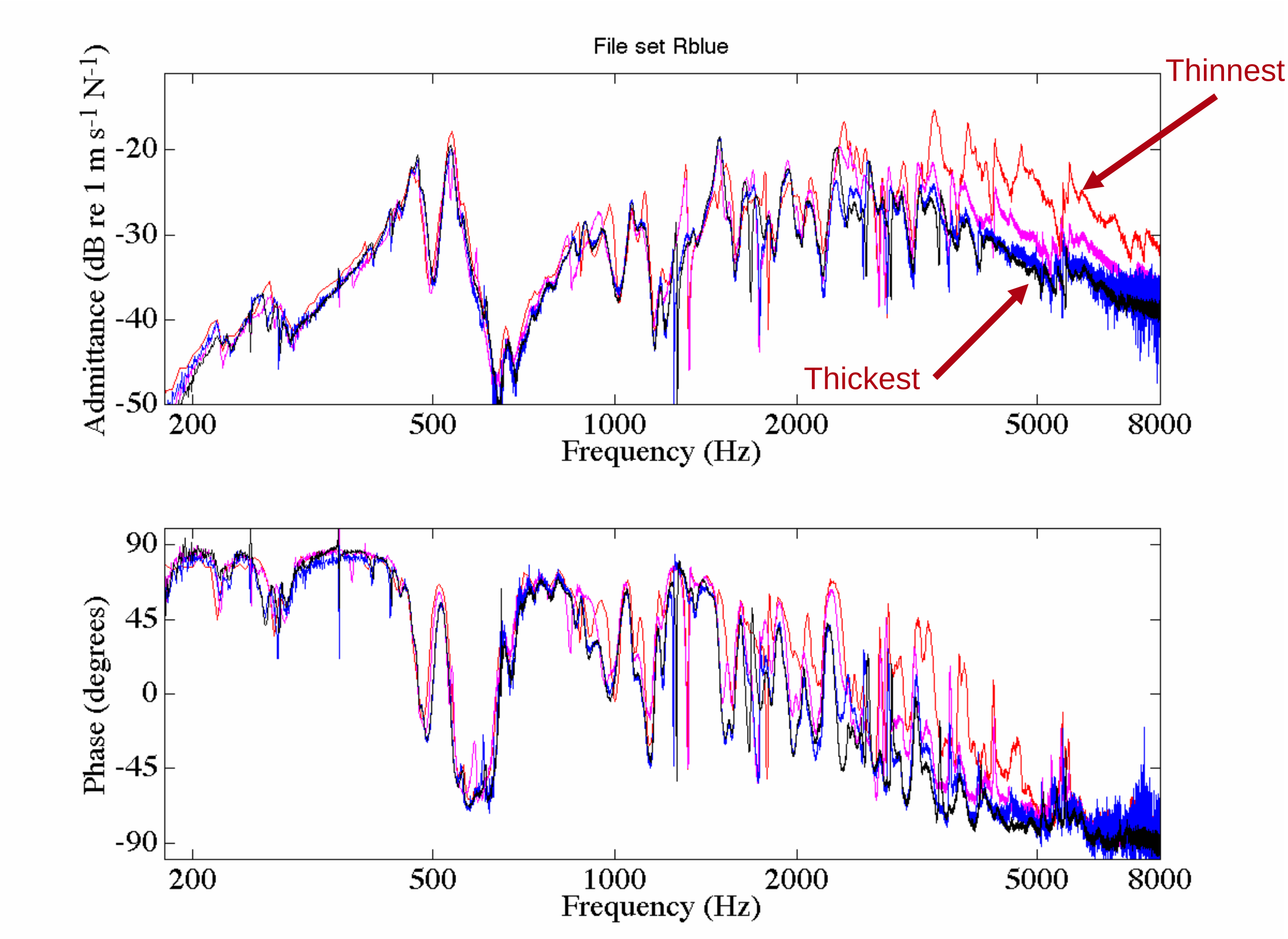
(2) What is the range of adjustment available in practice?

(3) Do violins differ from each other in their sensitivity to bridge adjustment?

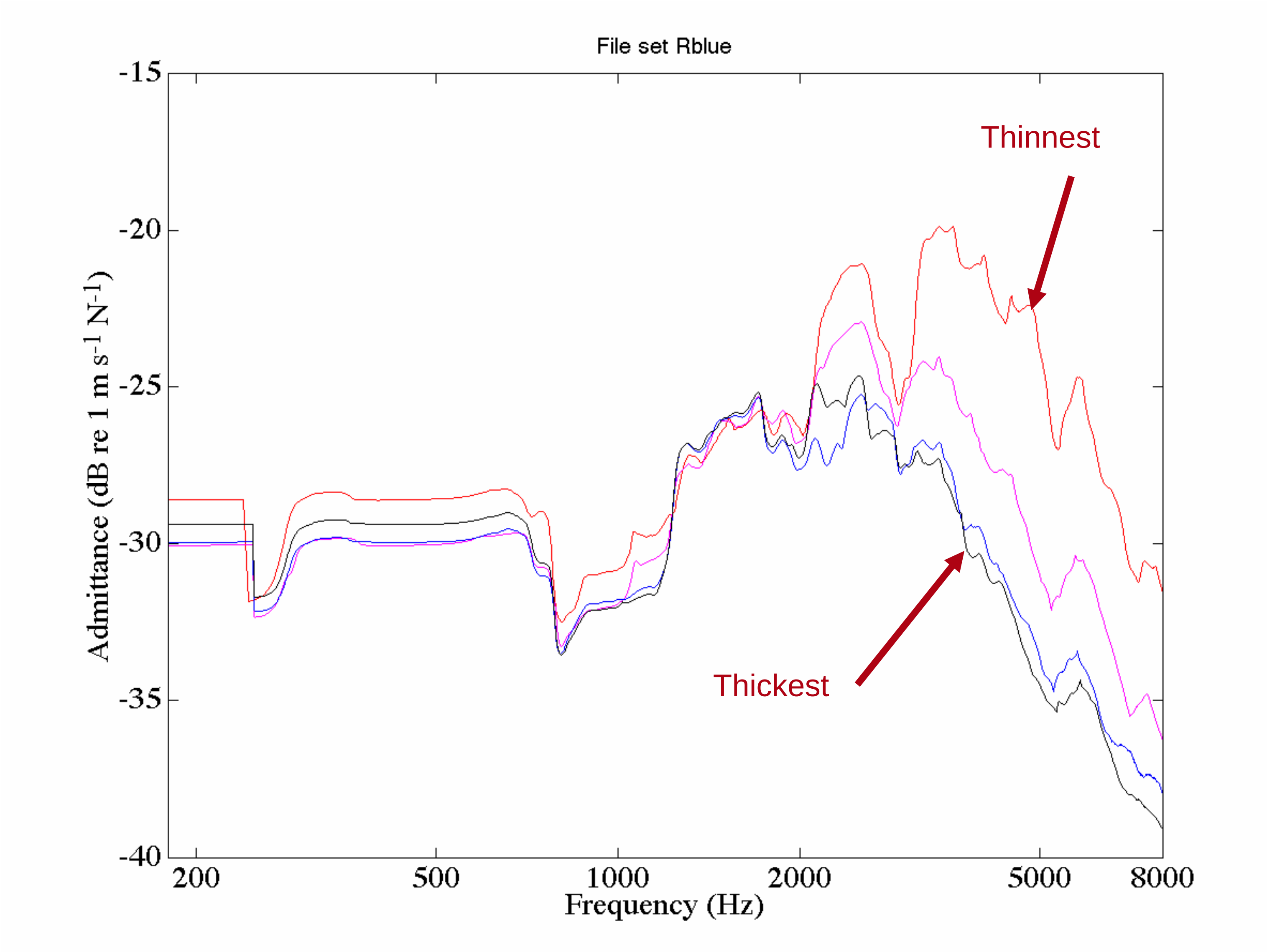
(4) Is it really the “bridge hill” that players and listeners are responding to when they judge quality? Or at least, is it definitely one of the things they respond to?

An experiment with 4 different bridges



An experiment with 4 different bridges

The same results for amplitude response, but smoothed with a 500 Hz RMS average.



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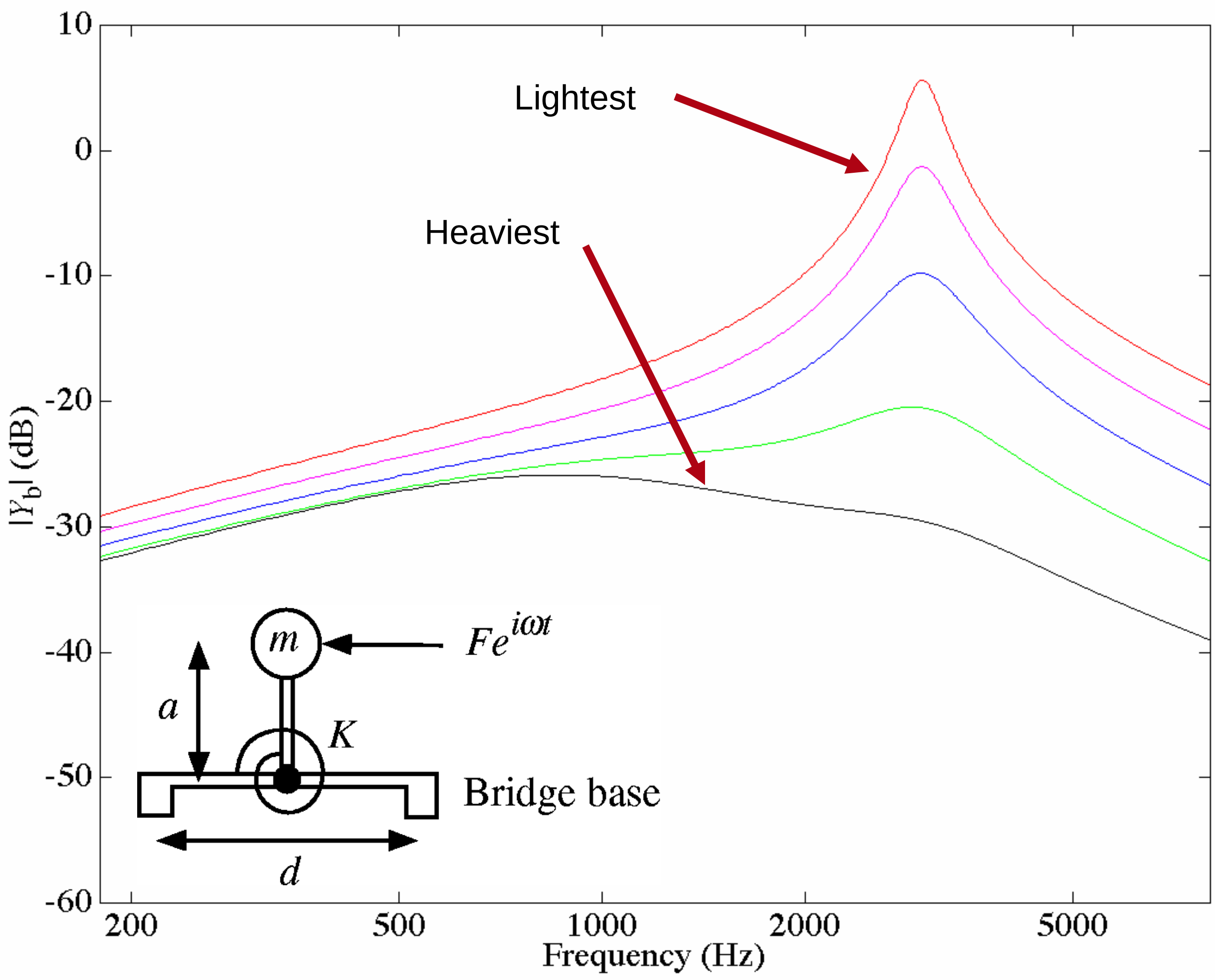

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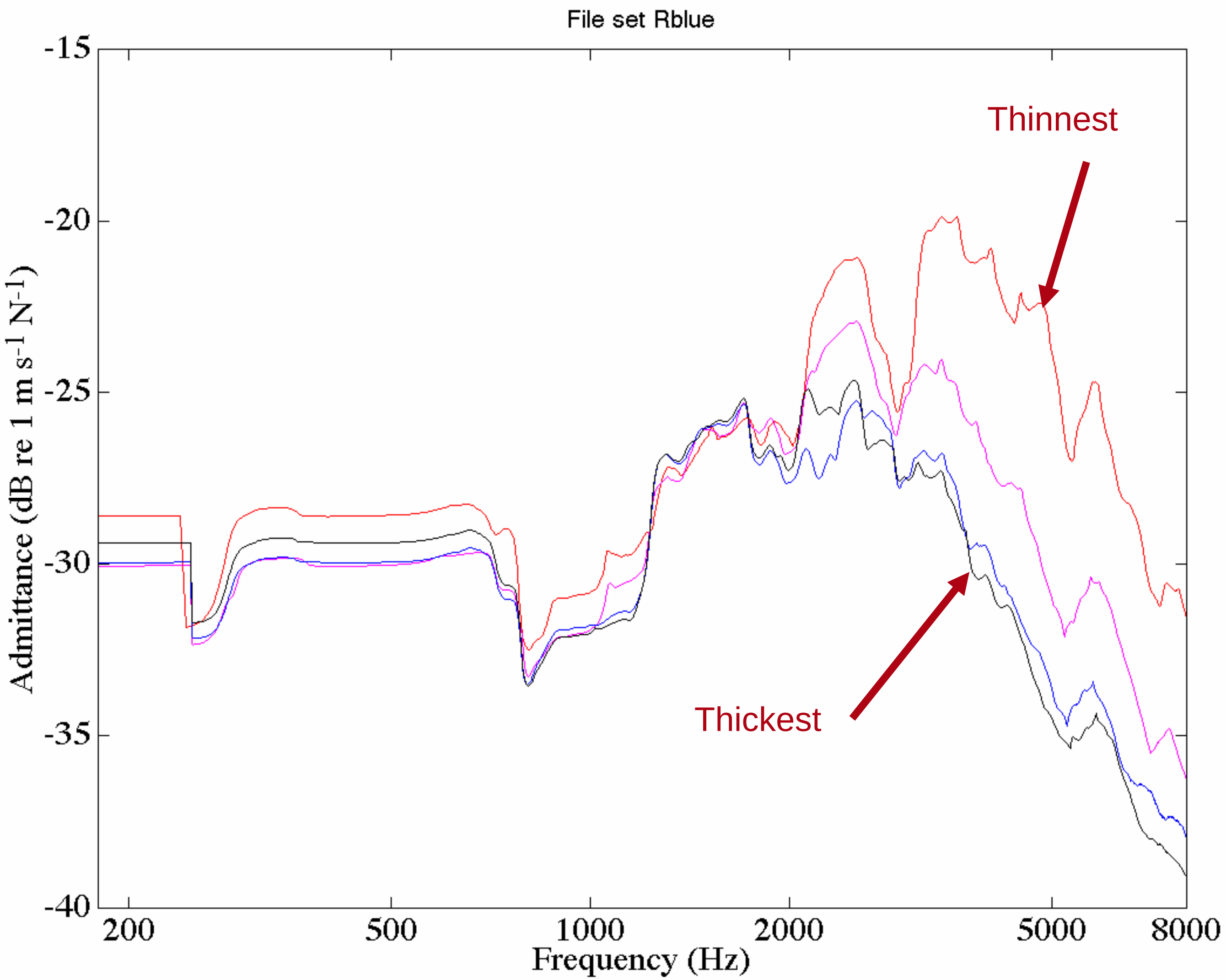
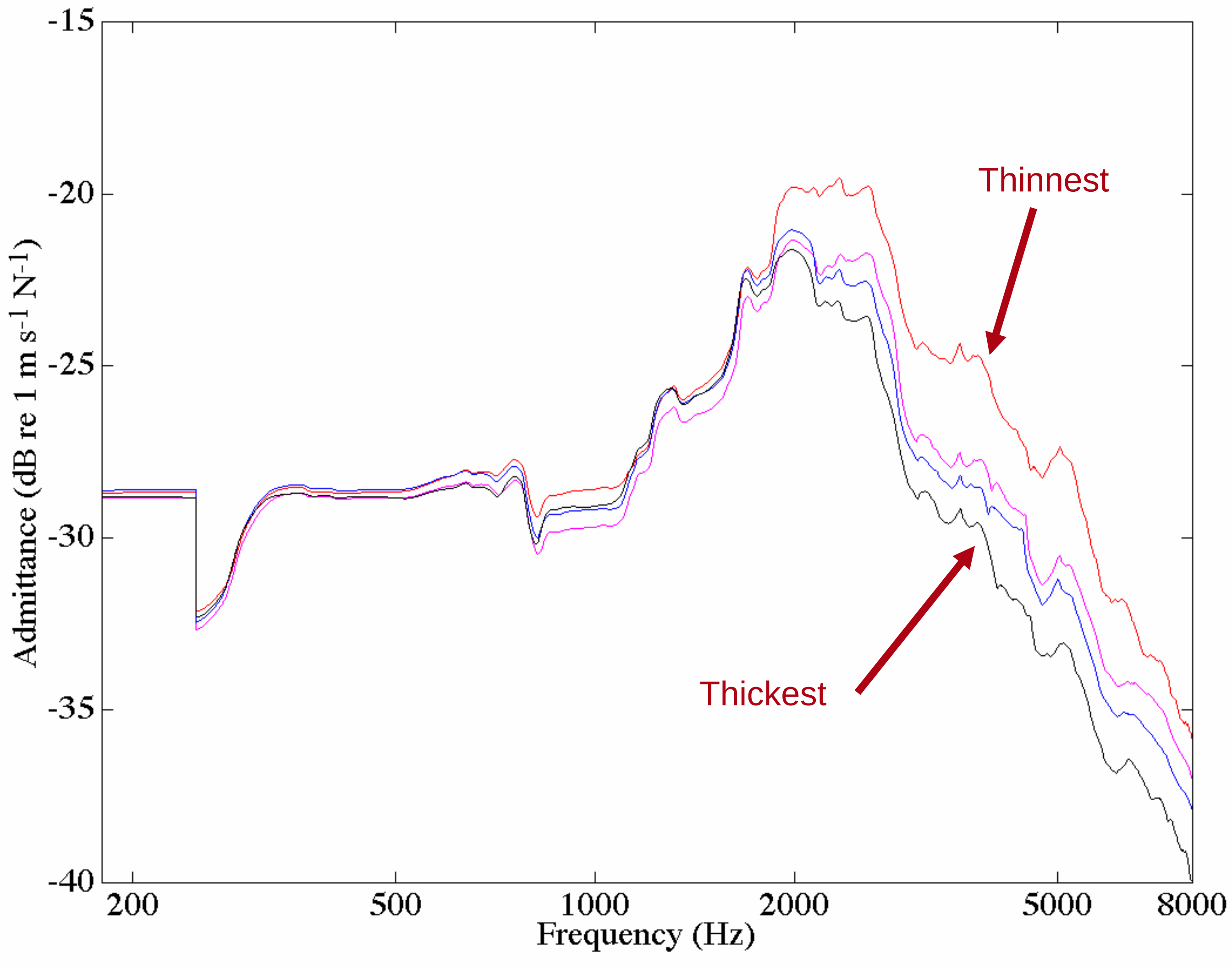


A different experiment with 4 different bridges

A similar set of smoothed results from a different experiment.



Can players tell the difference?

The four bridges from the previous slide have been used in an undergraduate project, in which players (all music students) were given the same violin to play after random swaps of the bridges. Each time, they had to rate the instrument on 7 descriptive scales:

bright/dull

mellow/harsh

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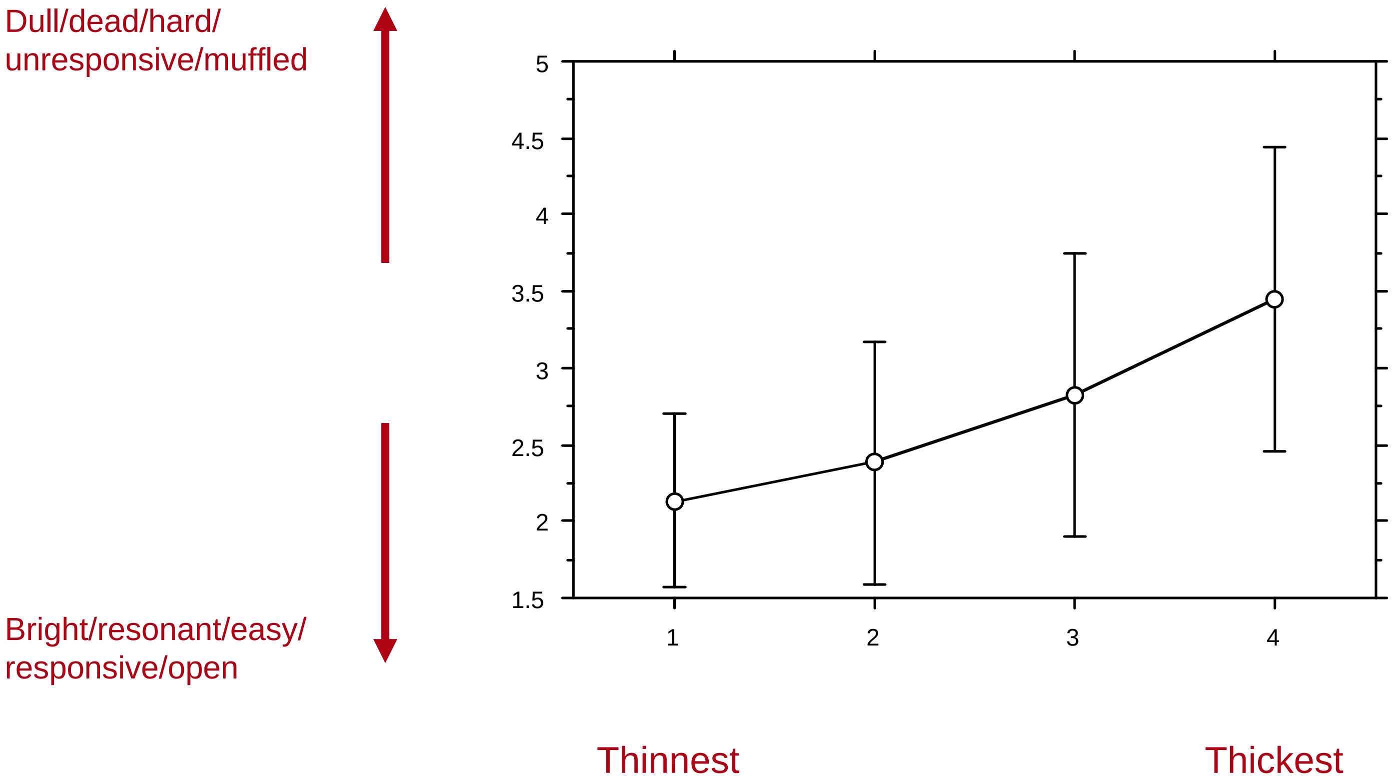
The encouraging outcome was that the players were, on the whole, able to tell the bridges apart.

Out of the 7 adjective pairs, 5 were strongly correlated.

Can players tell the difference?

The average result for these 5 pairs showed a clear trend across the 4 bridges:



What happens next?

The theory presented here seems to fit the main findings of Jansson's measurements. It is also reassuring that players readily notice the difference made by quite small changes to the bridge structure.

But there are still several important things to check:

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(2) Do other features contribute to what we have been calling the "bridge hill"? The soundpost? The damping behaviour of the wood and/or varnish?

(3) Is it really the "hill" to which players are responding in our experiment? This is a "graphic equaliser" effect: can you make a recorded instrument sound like an old Italian by adjusting the equaliser? We hope to address this directly with experiments with "virtual violins".