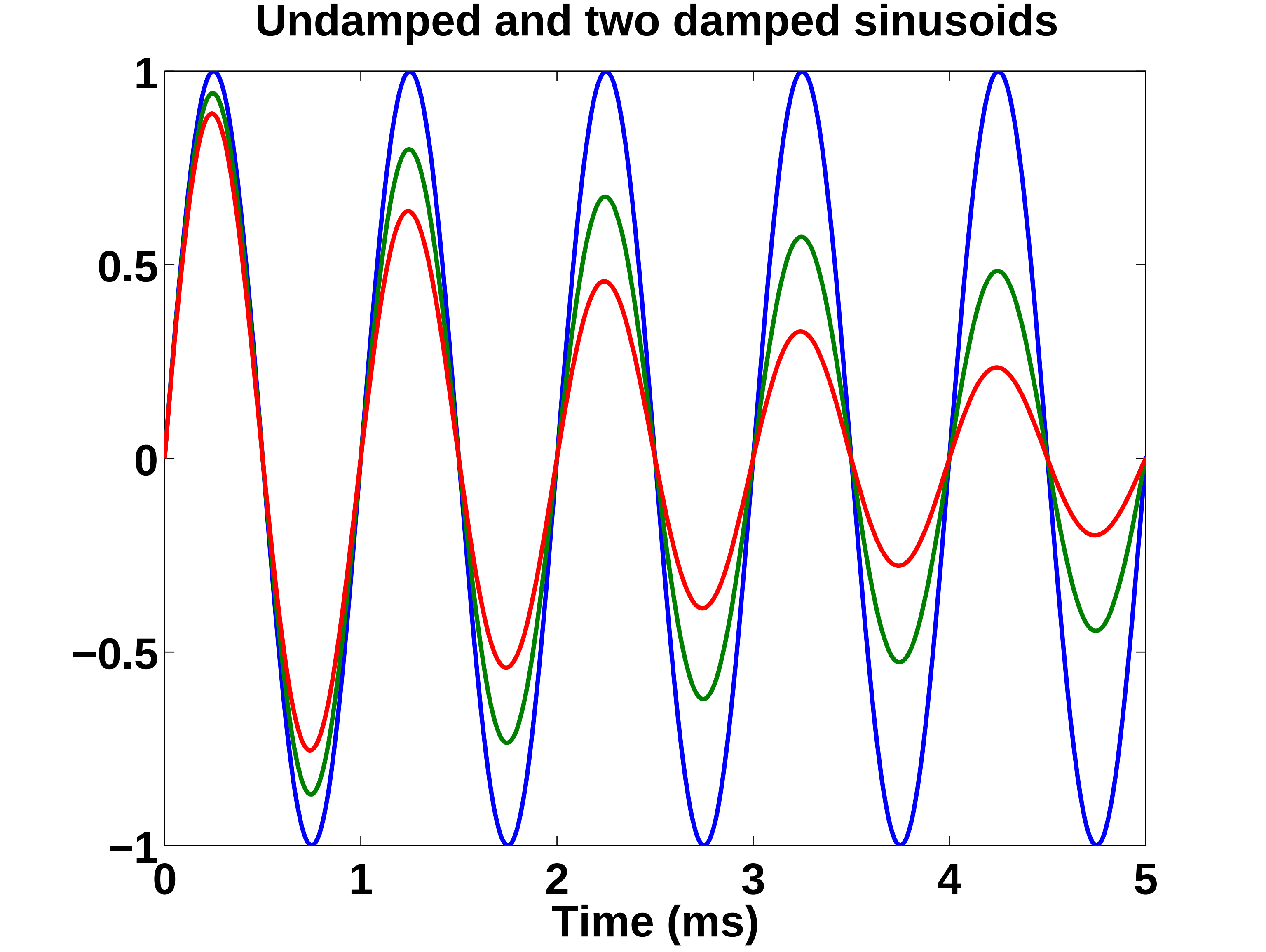
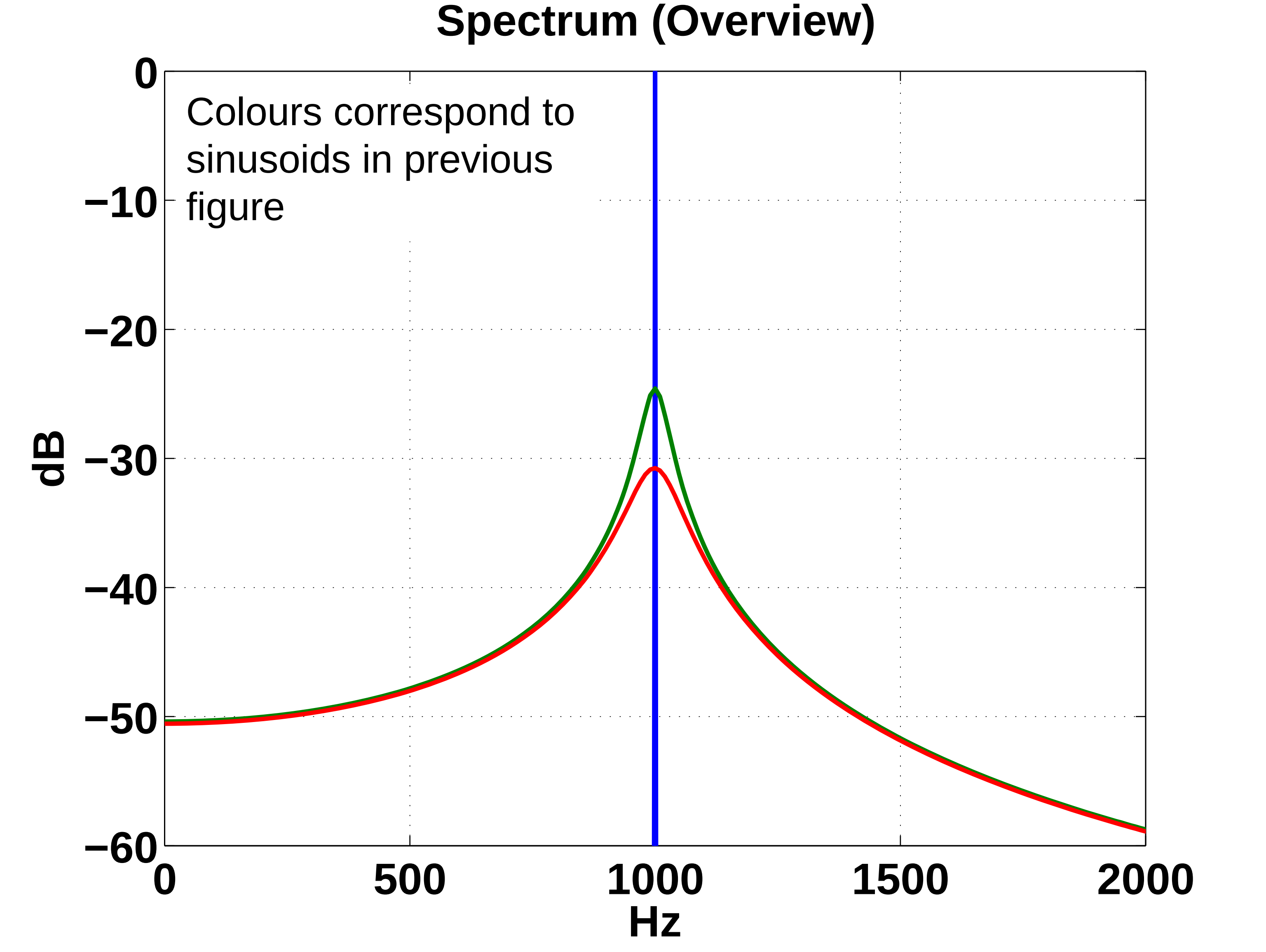
Damping and Bandwidth

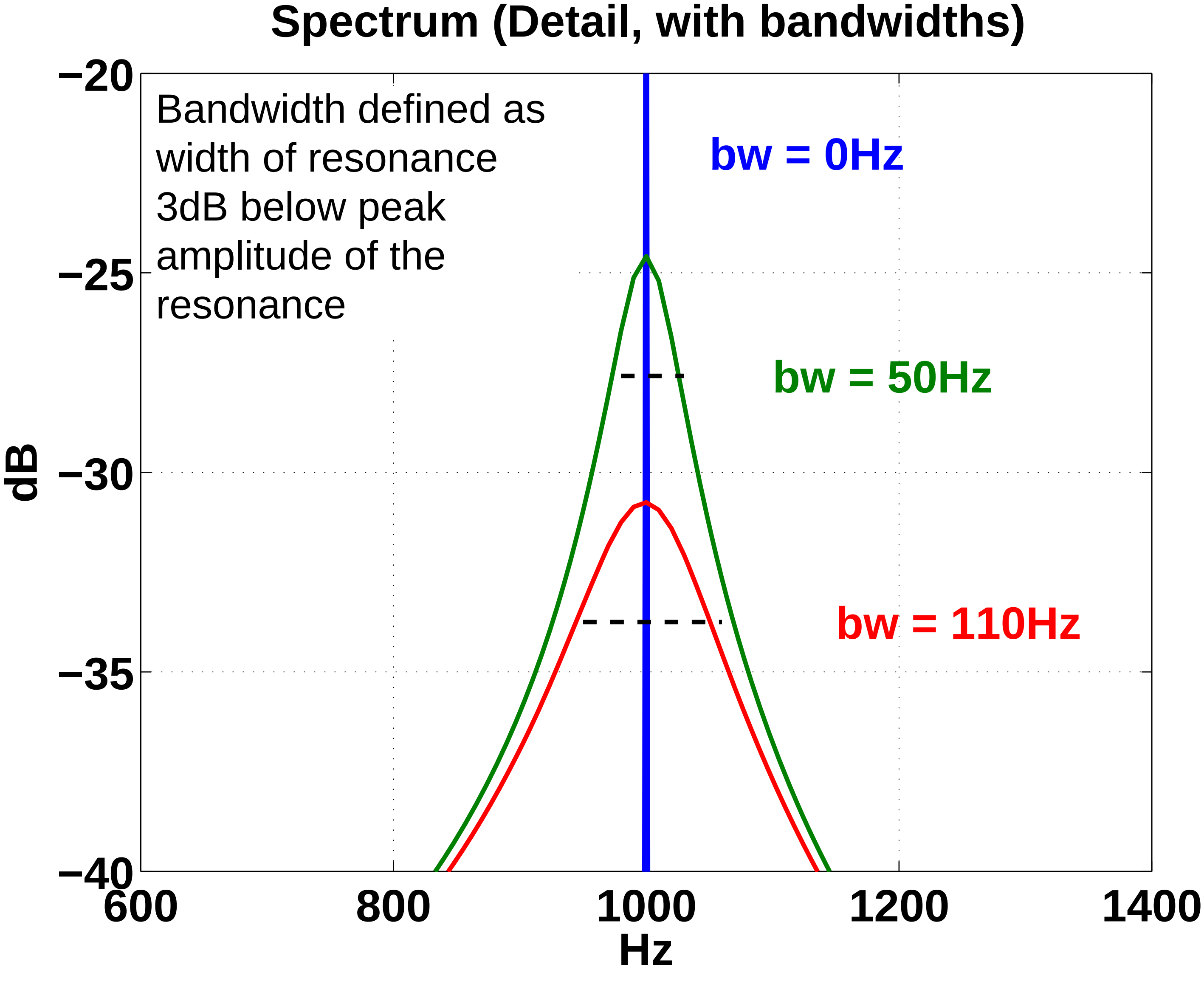
Colour illustrations.

Followed by further explanations from Johnson, "Acoustic and Auditory Phonetics", Chapter 8.


Undamped and two damped sinusoids
1
0.5
0
−0.5
−1
0
1
2
3
4
5
Time (ms)



Spectrum (Overview)
Colours correspond to sinusoids in previous figure
0
−10
−20
−30
−40
−50
−60
dB
0
500
1000
1500
2000
Hz



Spectrum (Detail, with bandwidths)
Bandwidth defined as width of resonance 3dB below peak amplitude of the resonance
bw = 0Hz
bw = 50Hz
bw = 110Hz
−20
−25
−30
−35
−40
dB
600
800
1000
1200
1400
Hz

8
Nasals and Laterals

In chapter 7 we saw that stops and affricates are more complicated than vowels and fricatives, because their productions have more than one stage and more than one type of sound source. Nasals and laterals are also more complicated than vowels or fricatives, but in a different way: it is their vocal tract filtering characteristics that are more complicated. As in the last chapter, we will start with a (relevant) digression.

8.1 Bandwidth

One way in which the vocal tract filtering function in nasals is different from that in oral vowels is that the width of the resonance peak (the bandwidth) of the first formant is larger in nasals. So, before discussing the acoustic properties of nasals, we will discuss formant bandwidths.

Figure 8.1 shows an undamped sine wave and two damped sine waves. Amplitude in the damped sine waves decreases over time. Like pushing a child on a swing: you give the swing a push, and before long it stops swinging, because the energy you put into the push is dissipated by a natural resistance to the swinging motion – the friction as the swing (and child) moves through the atmosphere. The damped sine wave labeled "heavy damping" loses amplitude more quickly than the one labeled "light damping." To follow our analogy, the more heavily damped wave corresponds to swinging on the earth, the lightly damped wave to swinging on the moon (where the atmosphere is less dense, and therefore the effect of friction is smaller).

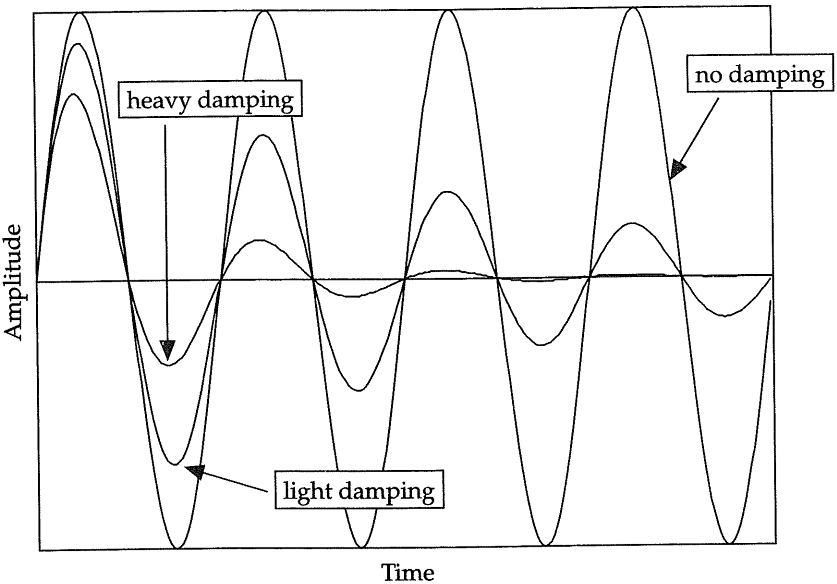


Figure 8.1 An undamped sine wave compared with two damped sine waves identical in frequency and phase.

Recall that the spectrum of a sine wave has a line showing the amplitude and frequency of the wave. As you might guess, given the fact that a damped sine wave does not have an exactly sinusoidal form, damped sine waves have more complex spectra than undamped sine waves. Figure 8.2 shows that the spectra of damped sine waves have peaks at the same frequencies as the undamped sine wave, but also have energy spread over other frequencies near the frequency of the peak. The spectral result of damping the sine wave is to broaden the peak around the sine wave's frequency. With an undamped sine wave the peak is infinitely narrow, but with more and more damping the peak gets wider and wider. Look again at the waveforms in figure 8.1. The one that corresponds to swinging on the moon (light damping) looks more like a pure sine wave than the other. Because the "light damping" waveform is more similar to a sine wave than the "heavy damping" waveform, the "light damping" spectrum looks more like a sine wave spectrum. That is, it has a narrower peak. The wave that decays more rapidly looks less like a sine wave in both the waveform display and the spectrum.

Because the walls of the vocal tract are soft, they absorb some of the

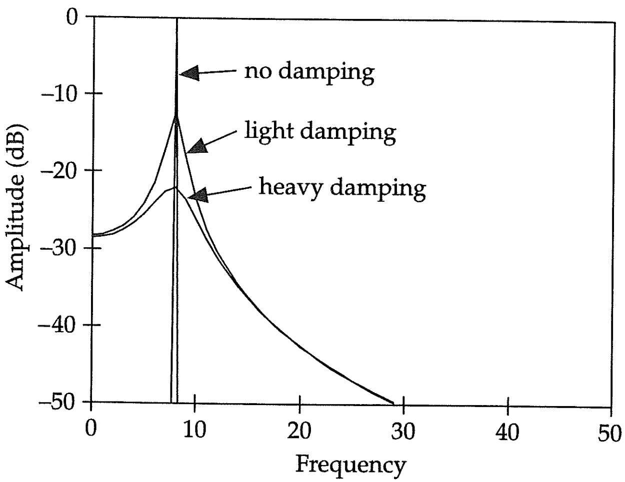


Figure 8.2 Power spectra of the waveforms shown in figure 8.1. Note that increased damping corresponds to wider bandwidth of the spectral peak.

sound energy produced by the vibrating glottis. (The inertia of air, in and out of the vocal tract, also absorbs some of the sound energy.) The sound pressure waves that resonate in the vocal tract might go on vibrating infinitely, but the sound energy is absorbed by the soft walls and the inertia of air, the way friction absorbs the energy in the push of the swing. Thus, when we look at vocal tract resonances (formants), they have certain bandwidths, because the resonant frequencies of the vocal tract are damped. If the walls of the vocal tract were hard (and hence could reflect sound energy without absorbing it), the formants would have much smaller bandwidths.

The formant bandwidths during nasal sounds are wider than those in nonnasal sounds, because the vocal tract with the nose open has greater surface area and greater volume. The greater surface area of the vocal tract means that the walls of the vocal tract absorb more sound than in nonnasal sounds, and the greater volume of air means that the inertia of air within the vocal tract absorbs more sound as well. However, as we will see, the apparent widening of the F_1 bandwidth in nasalized vowels is more complicated than this.