DSP4Linguists

Leonardo Araujo

July 30, 2021

Acoustic wave

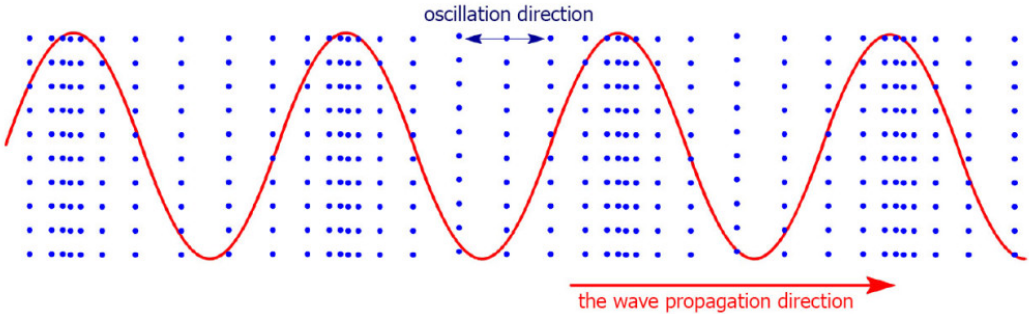


Figure 1: Acoustic wave.

Analog > Digital / Digital > Analog

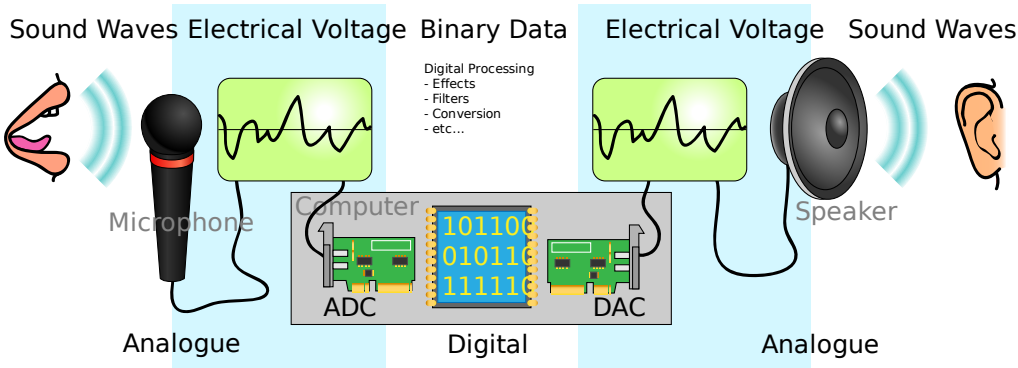


Figure 2: ADC and DAC.

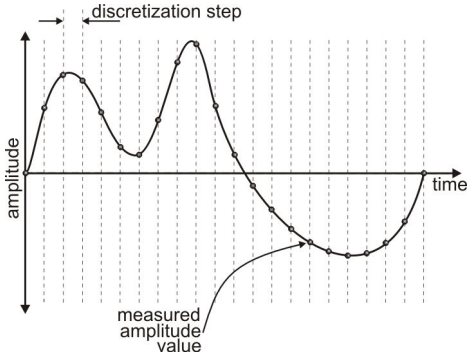


Figure 3: Sampling.

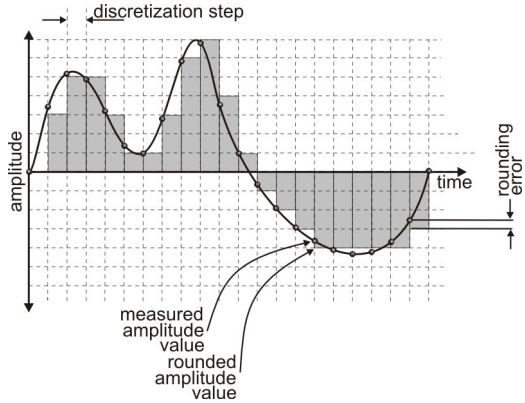


Figure 4: Quantization.

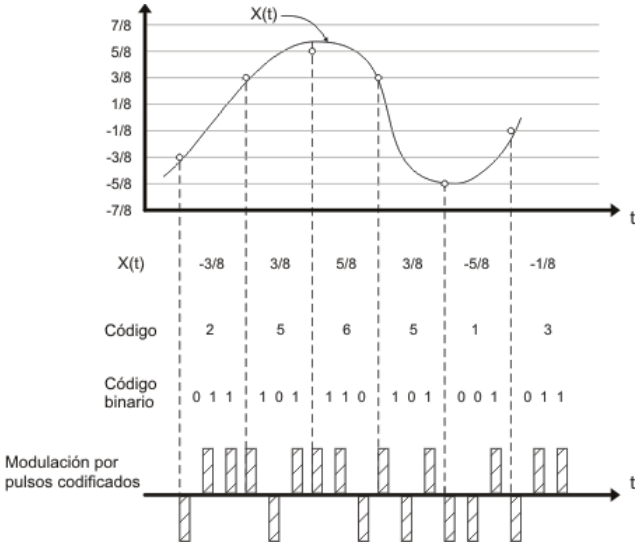


Figure 5: Coded pulses.

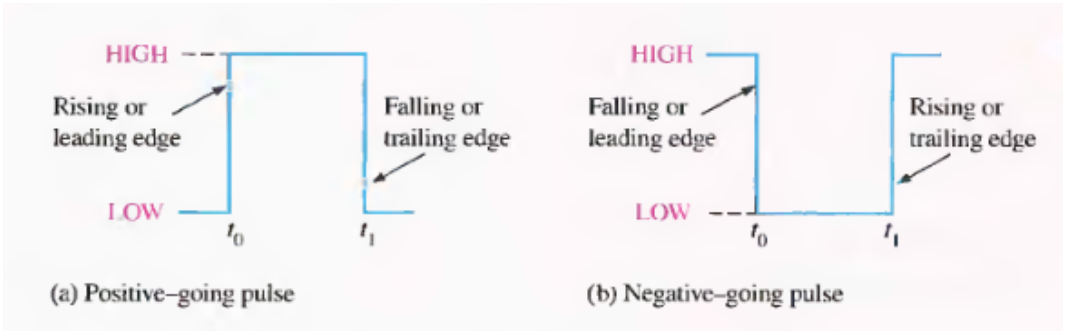


Figure 6: Digital pulse.

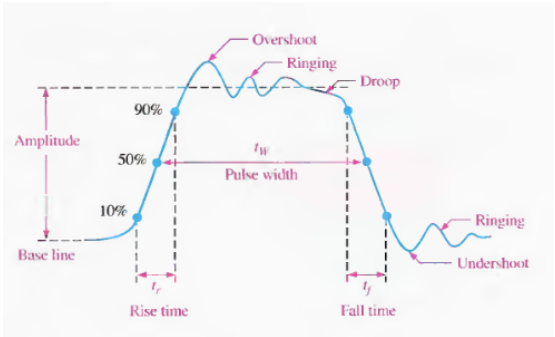


Figure 7: Non-ideal Pulse.

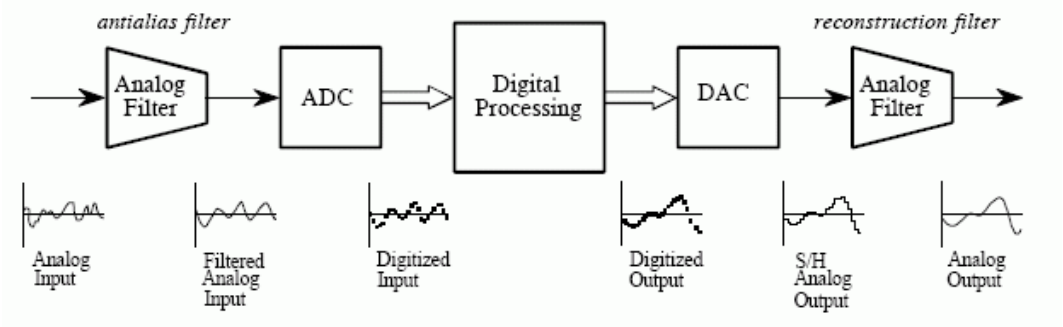


Figure 8: ADC and DAC

Quantizer

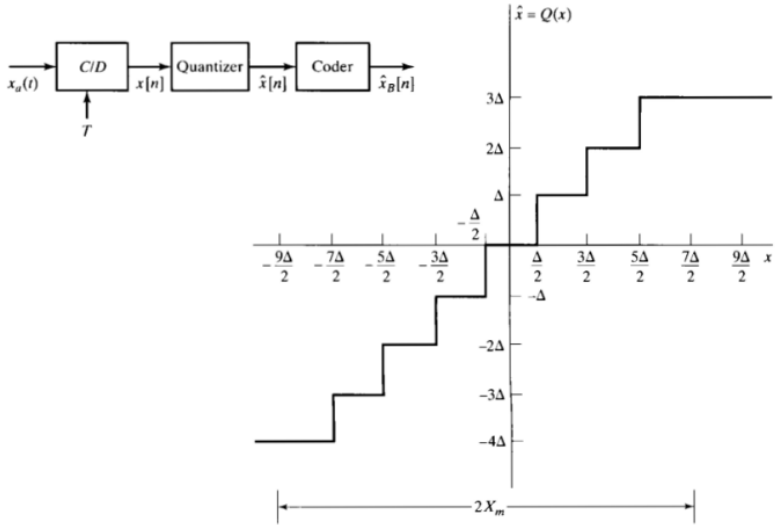


Figure 9: 3 bits uniform quantizer

Quantization examples

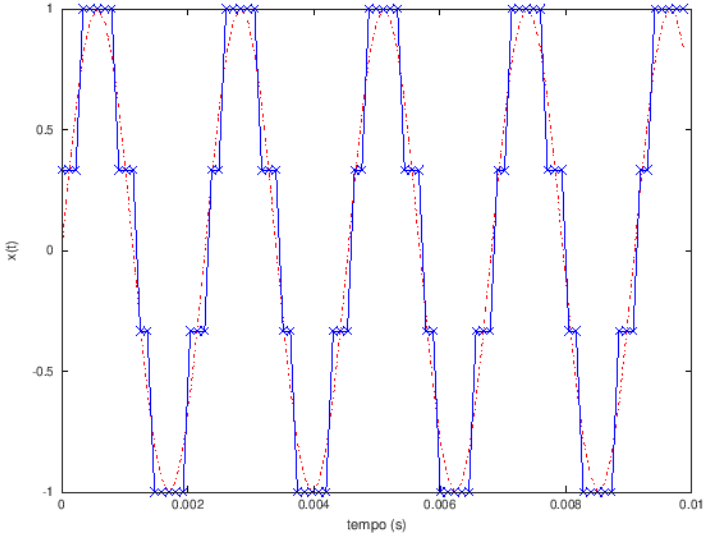


Figure 10: 440 Hz sin wave.

Clipping

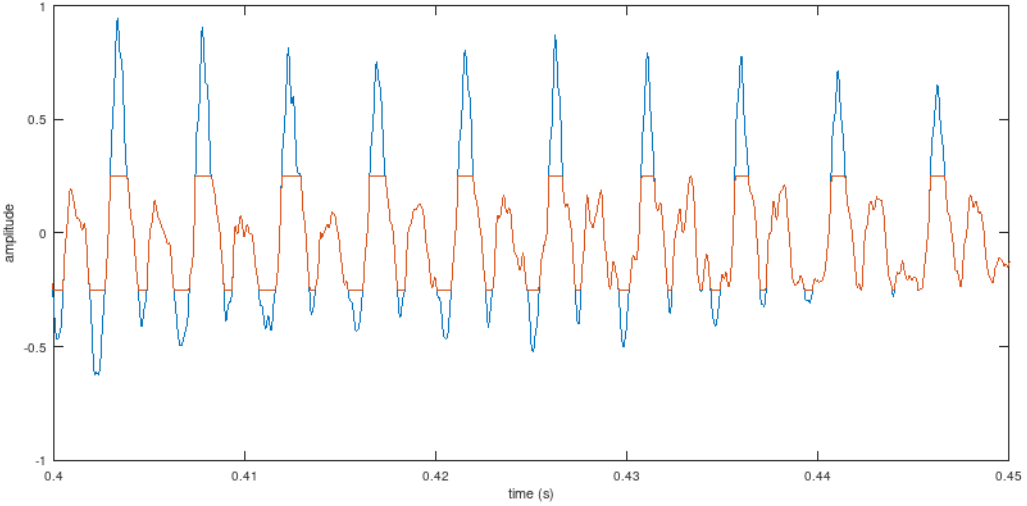
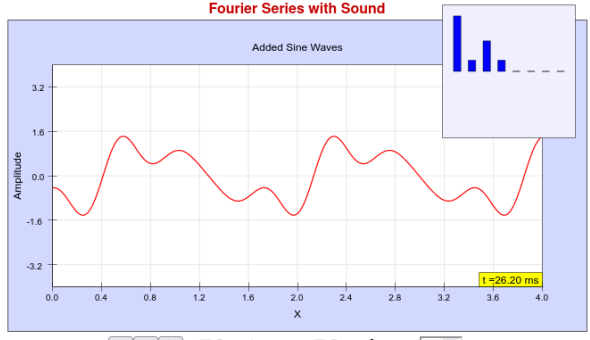


Figure 11: Signal clipping

Fourier Series

Simulation



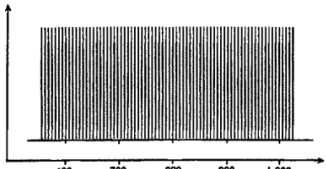


Fig. 5.3. The spectrum of a sound consisting of a large number of tones with the same amplitude.

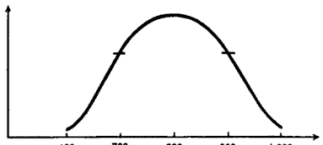


Fig. 5.4. A curve specifying a resonator.

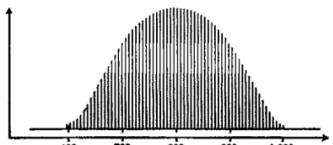
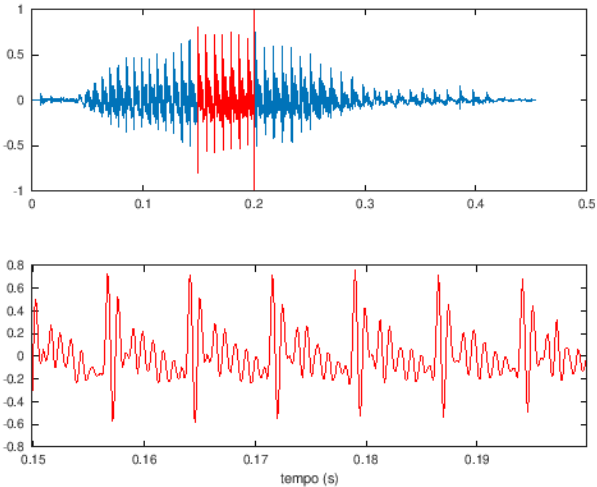


Fig. 5.5. The output of the resonator in fig. 5.4 when the input shown in fig. 5.3 is applied to it.

Figure 13: Resonator

Vowel

open_front_unrounded.mp3



Pitch

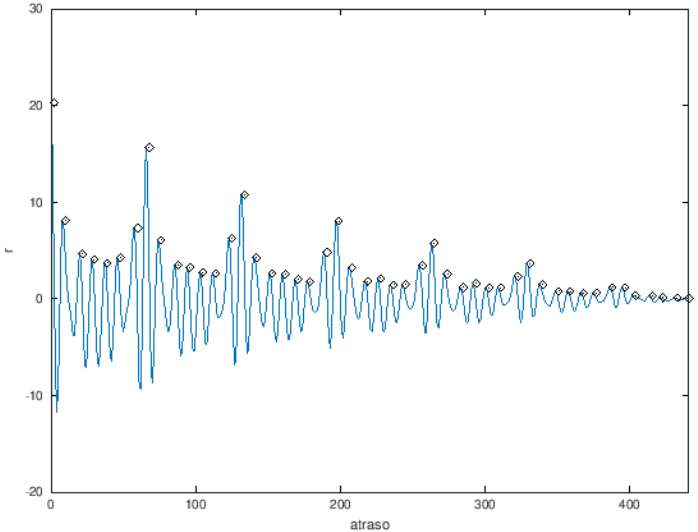


Figure 15: Autocorrelation

LPC model

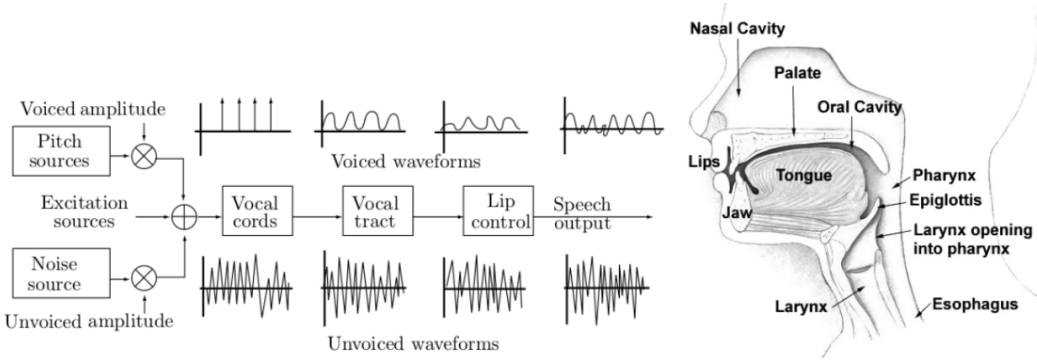


Figure 16: LPC model and vocal tract

Vocal apparatus

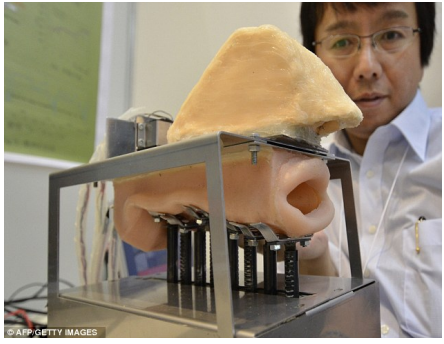


Figure 17: Hideyuki Sawada's KTR voice robot
https://www.youtube.com/watch?v=qobhDJ_vEOc

vocal cord stroboscopy examination

History of Speech Synthesis

four people sing Kyrie eleison during laryngoscopy

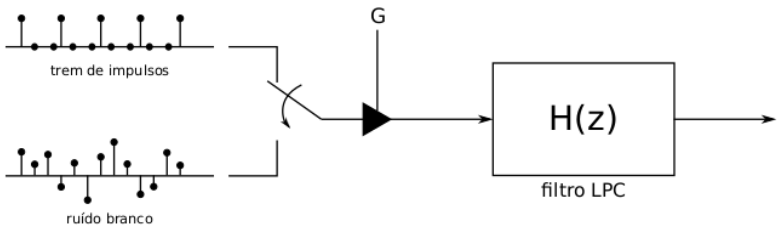


Figure 18: LPC model

synthesized example

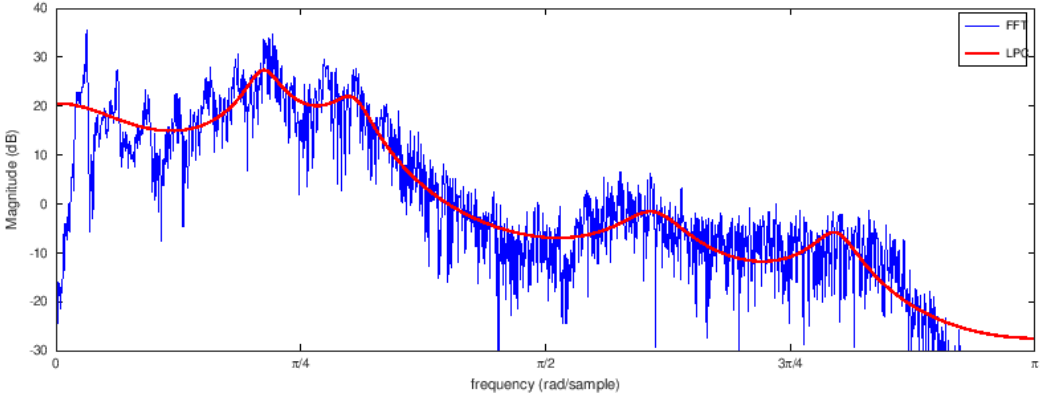


Figure 19: Spectrum and LPC.

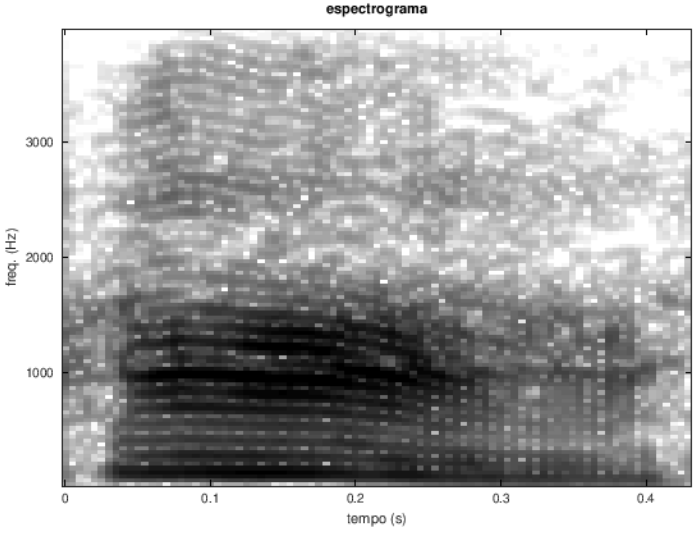


Figure 20: Spectrogram.

Spectrogram

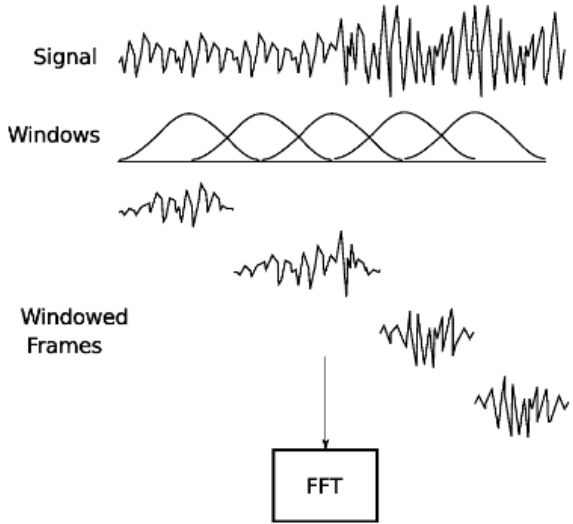


Figure 21: Schematics

Time vs Frequency

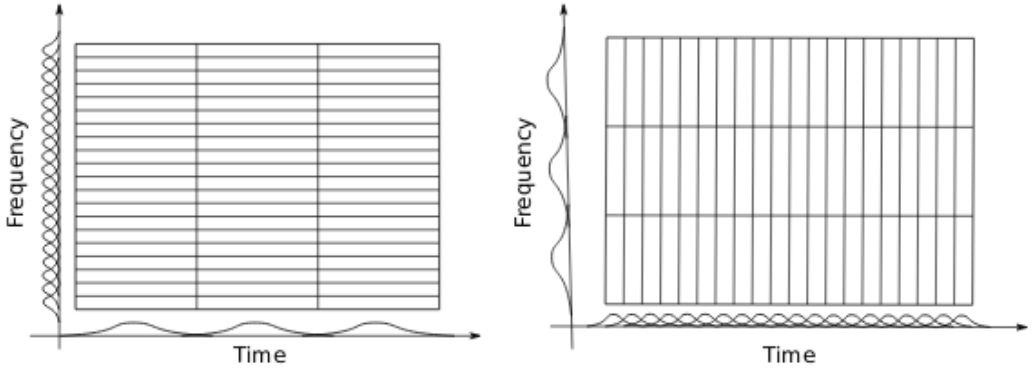


Figure 22: Uncertainty principle

The Uncertainty Principle

Figure 23: Heisenberg’s uncertainty principle

Spectrogram

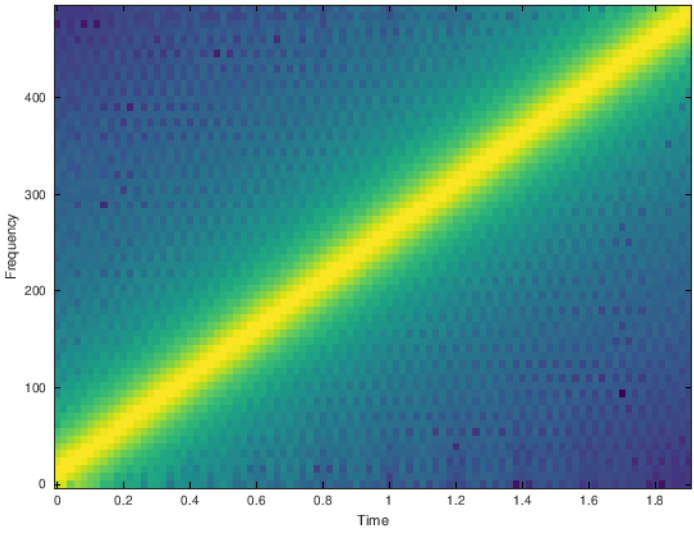


Figure 24: Chirp example, from 0 to 500Hz.

Shepard Tone

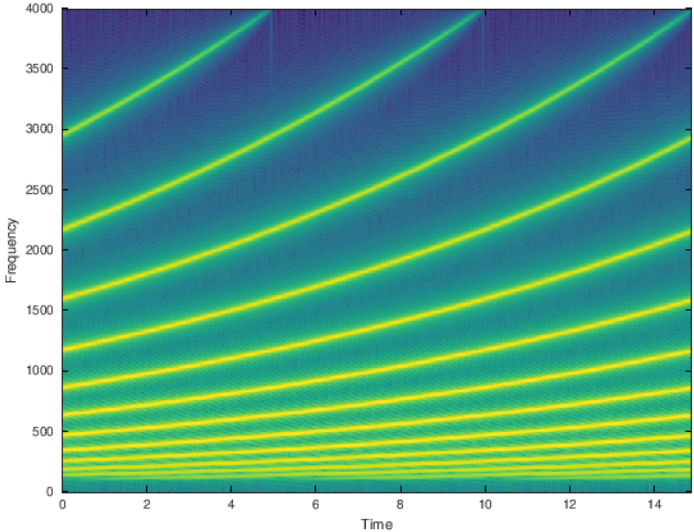


Figure 25: Shepard Tone

Downsampling

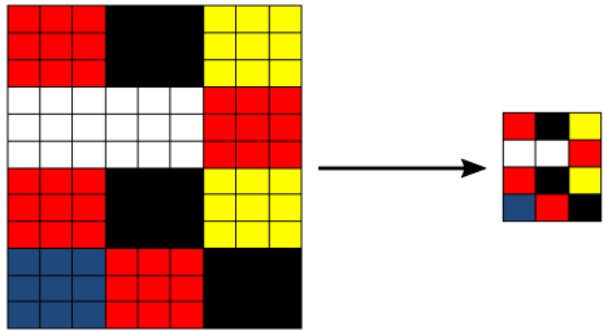
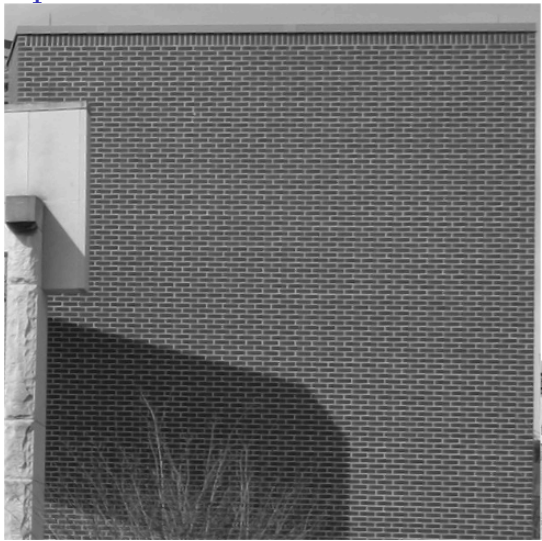
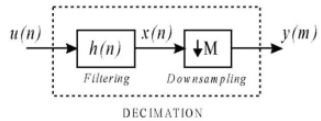


Figure 26: Downsampling example

Downsample / Decimate





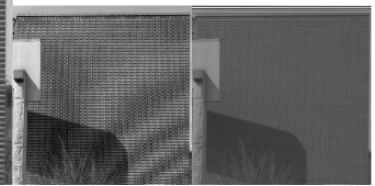


Figure 27: Downsample and Decimate

Downsample / Decimate (audio example)

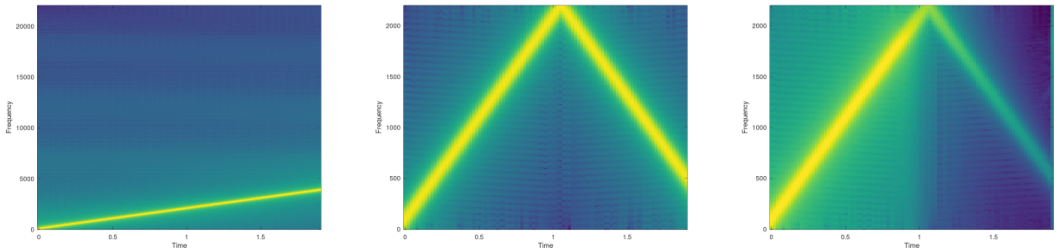


Figure 28: Downsample and Decimate

Hearing

- Intensity
- Pitch
- Duration
- Quality/timber

Pitch metamery

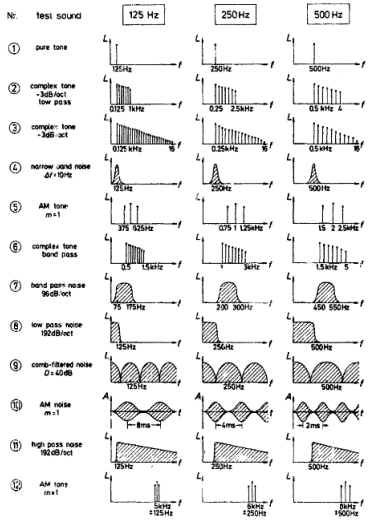


Fig. 1. Schematic representation of test sounds employed.

Figure 29: Fastl, H. & Stoll, G. Scaling of pitch strength, Hearing Research (1979): 293-301

Pitch JND

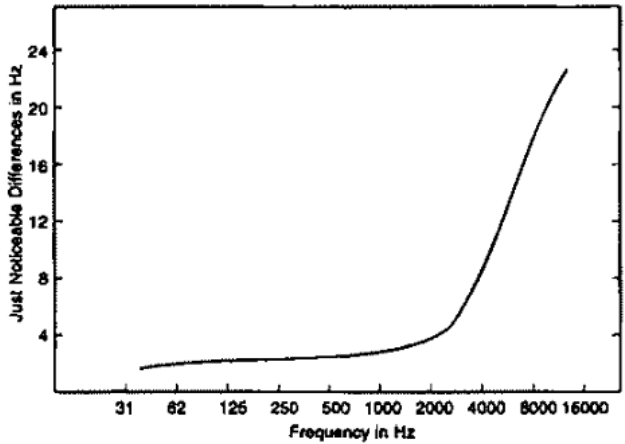


Fig. 6.3. A graph showing how much the frequency or a tone has to be altered in order to produce a change in pitch.

Figure 30: Elements of acoustic phonetics, Peter Ladefoged (1996)

Pitch scales

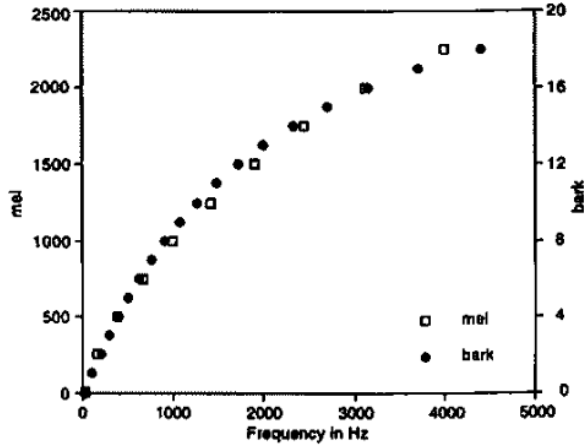


Fig. 6.4. Graph showing the relation between frequencies in Hz and the corresponding values on two different pitch scales, mel and bark.

Figure 31: Elements of acoustic phonetics, Peter Ladefoged (1996)

Duration

- Staat /ʃtaːt/ - country; state
- Stadt /ʃtat/ - city; town

Hearing range

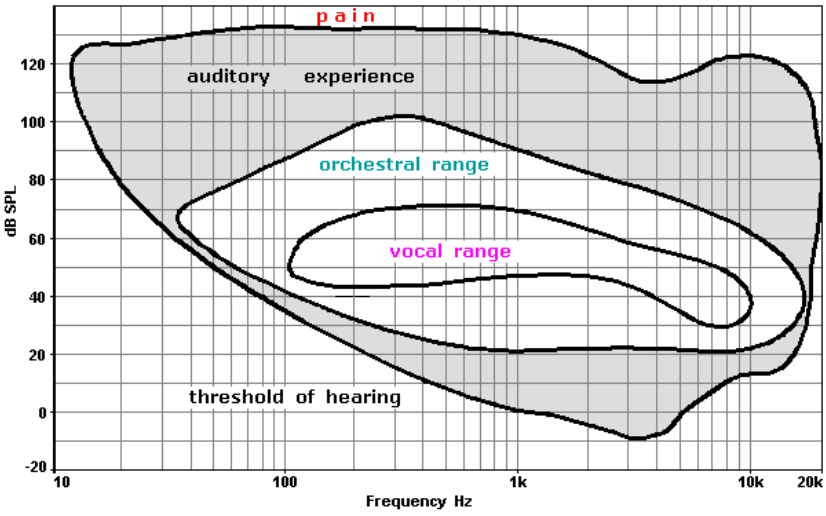


Figure 32: Hearing range

Fletcher-Munson curves

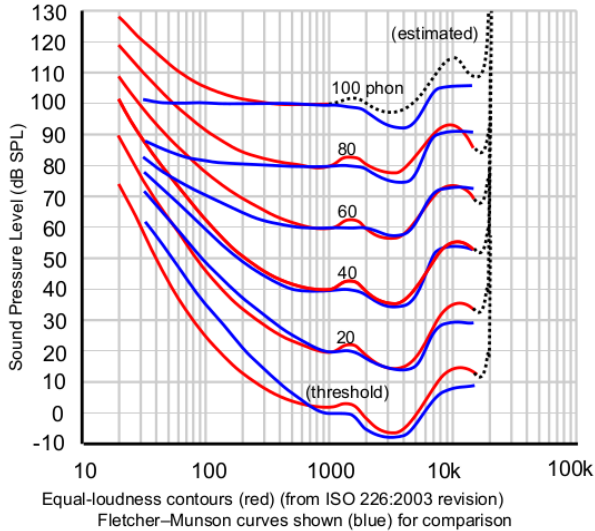


Figure 33: Equal-loudness contour

Masking

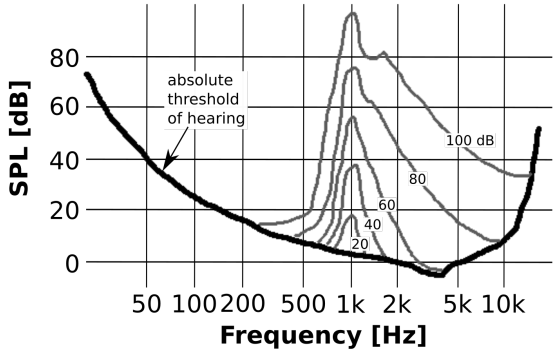


Figure 34: Frequency masking

Masking

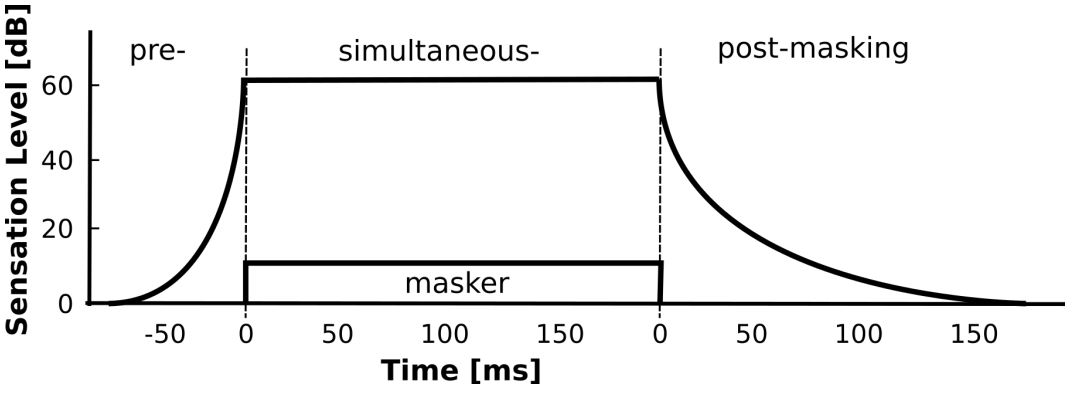


Figure 35: Time masking

Musical instruments

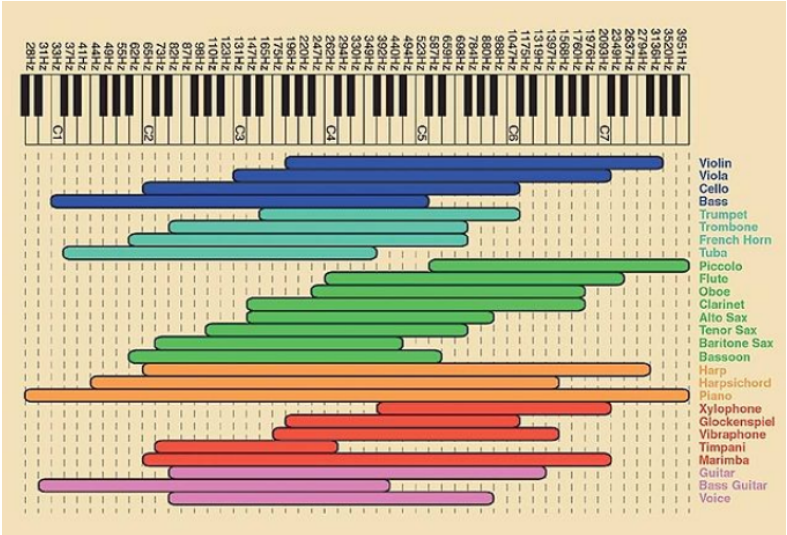


Figure 36: Frequency range of musical instruments

Ear

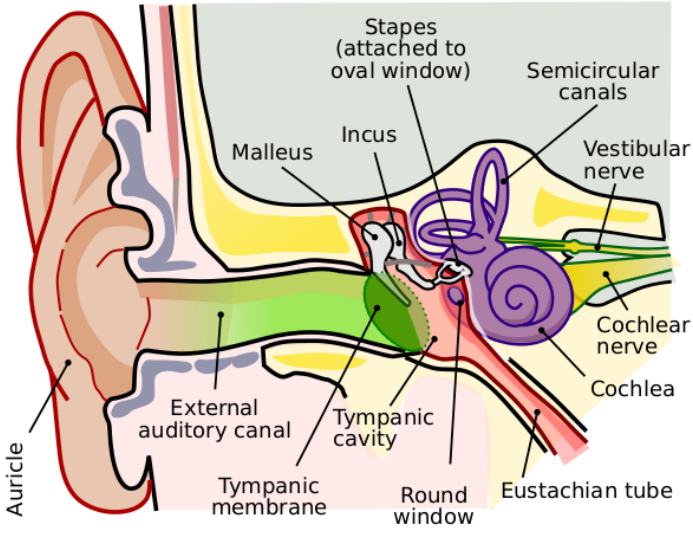


Figure 37: Ear

Middle ear

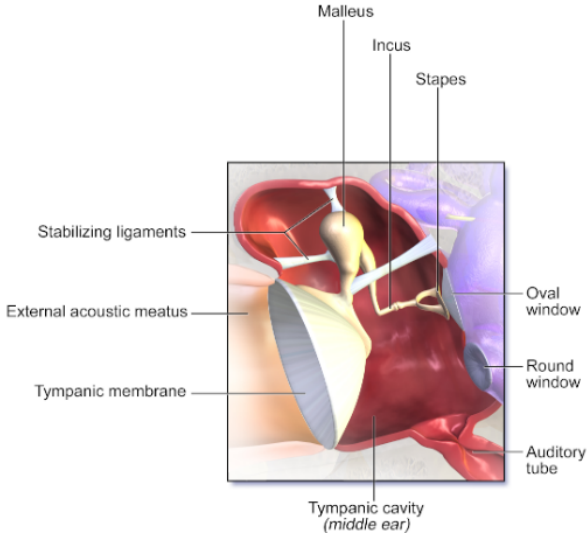


Figure 38: Middle ear

Cochlea

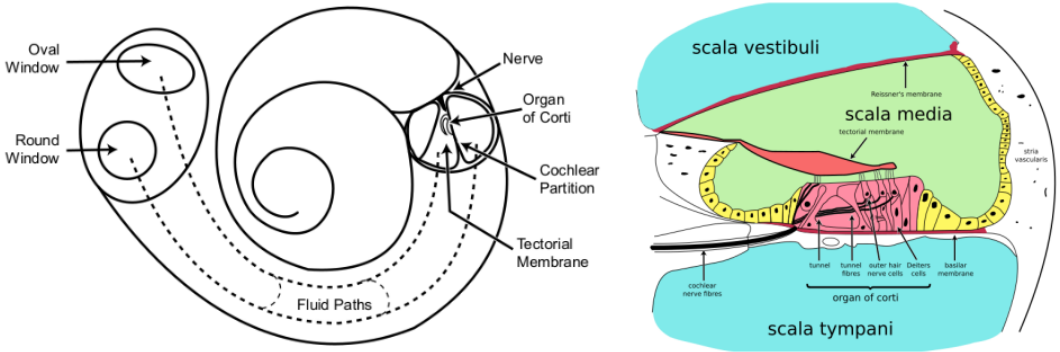


Figure 39: Cochlea and organ of Corti

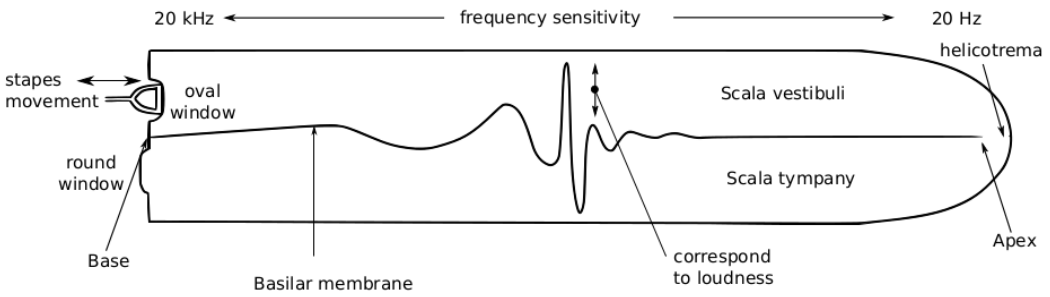


Figure 40: Travelling wave

Hair cells

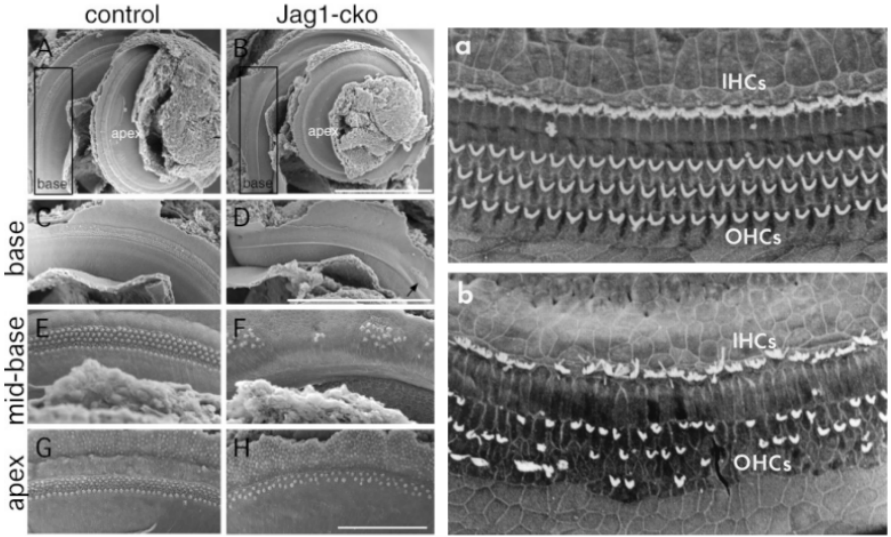


Figure 41: Inner (IHC) and outer hair cells (OHC)

Auditory Scene Analysis - Albert Bregman

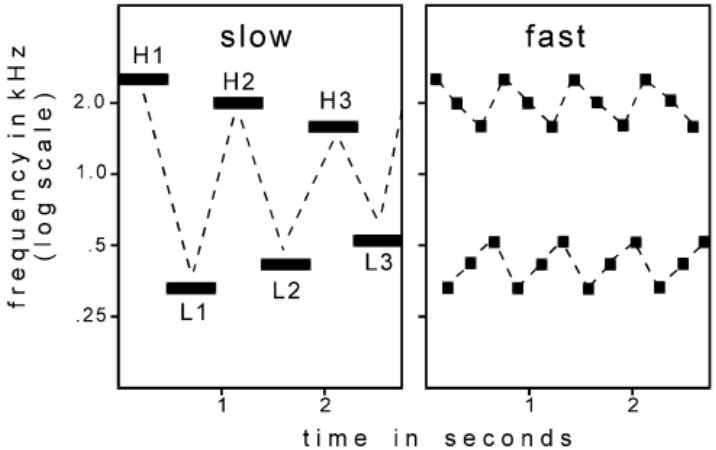


Figure 42: Stream segregation in a cycle of six tones

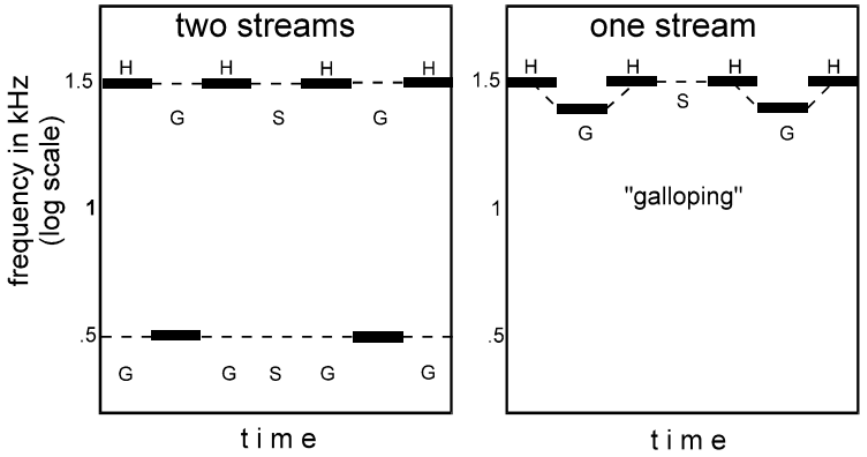


Figure 43: Loss of rhythmic information as a result of stream segregation

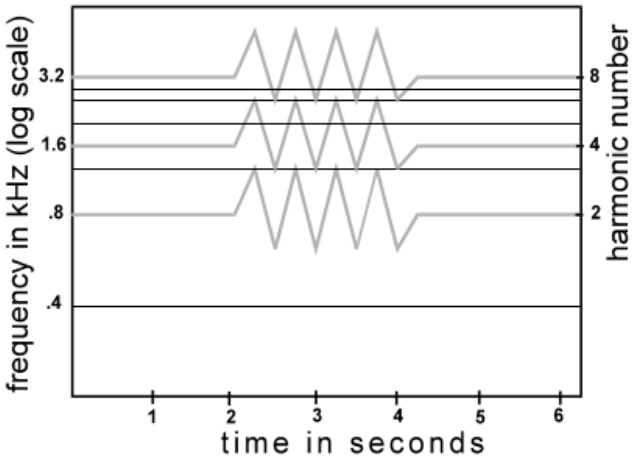


Figure 44: Fusion by common frequency change

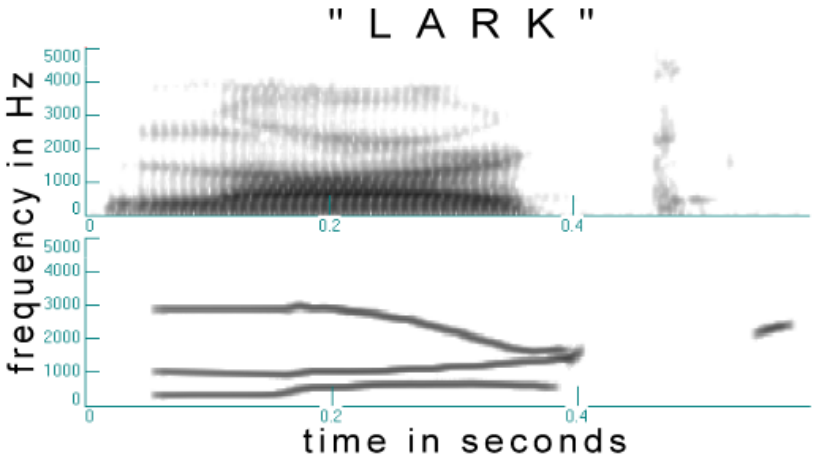


Figure 45: Sine-wave speech

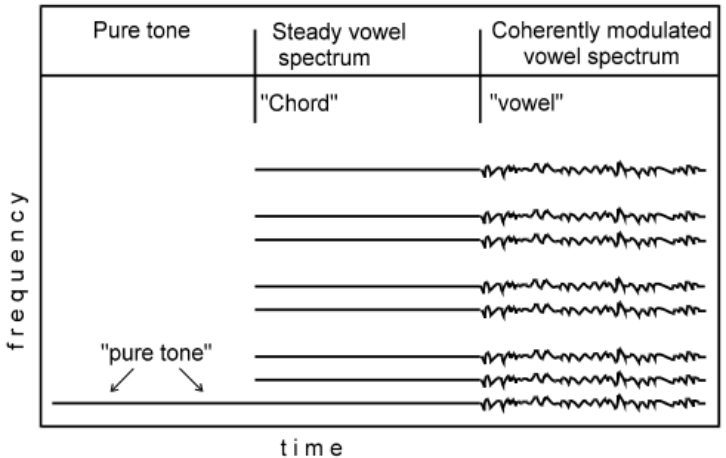


Figure 46: Role of frequency micro-modulation in voice perception

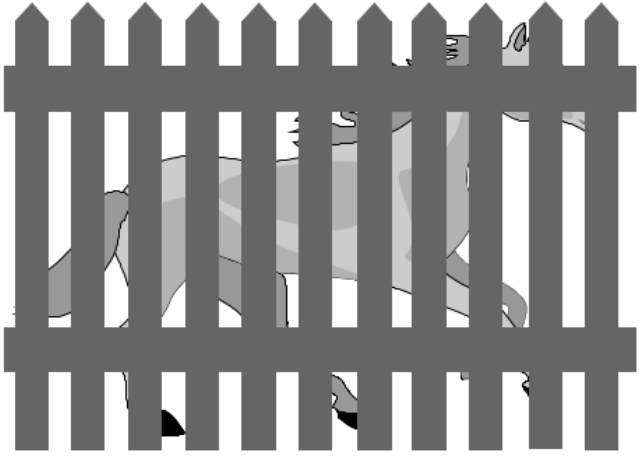


Figure 47: The picket-fence effect with speech

Audio file formats

Table 1 - Overview of selected Audio Codecs

Name	WAV	FLAC	MP3	Vorbis	AAC	Speex	Opus	WMA
Released	1991	2001	1993	2000	1997	2003	2012	1999
Compression	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Loss-less	–	Yes	No	No	No	No	No	No
Bit-rate (kbit/s)	1,411.2	935	16–320	48–500	16–320	2–24	8–128	32–448
Encoder	–	flac	lame	oggenc	ffmpeg	speexenc	opusenc	ffmpeg
Decoder	–	ffmpeg	lame	oggdec	ffmpeg	speexdec	opusdec	ffmpeg

Figure 48: I Siegert, AF Lotz, LL Duong, A Wendemuth, Measuring the impact of audio compression on the spectral quality of speech data, 2016

Compression ratio

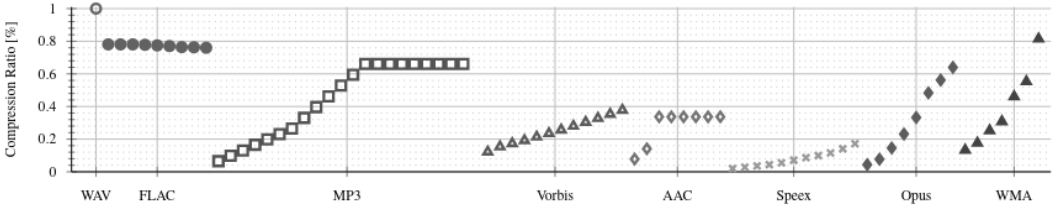


Figure 1 - Achieved average compression ratio for each codec and bit-rate. The bit-rate is increasing from left to right, see Table 2.

Figure 49: I Siegert, AF Lotz, LL Duong, A Wendemuth, Measuring the impact of audio compression on the spectral quality of speech data, 2016

Compresstion error

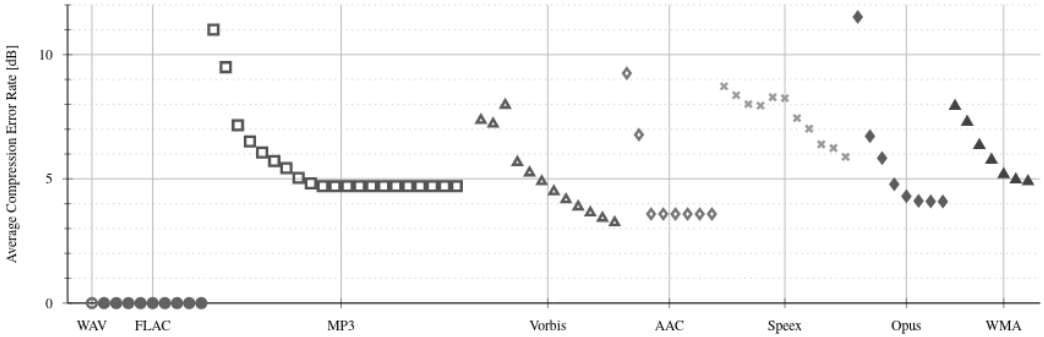


Figure 3 - Average compression error rate for each codec and bit-rate. The bit-rate is increasing from left to right, see Table 2.

Figure 50: I Siegert, AF Lotz, LL Duong, A Wendemuth, Measuring the impact of audio compression on the spectral quality of speech data, 2016

Compression ratio vs compression error

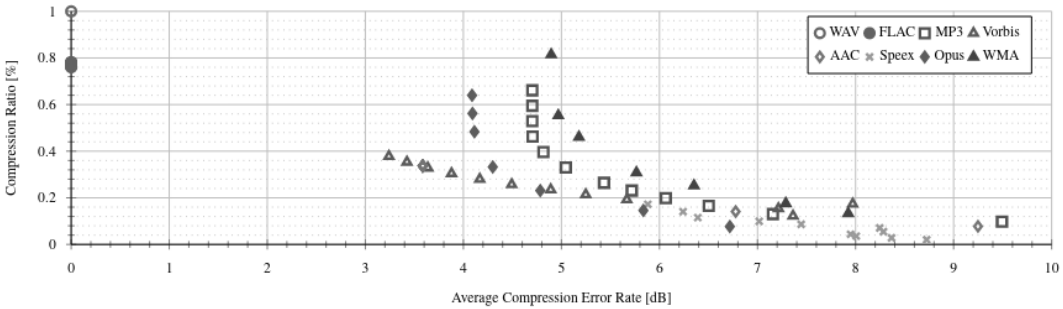


Figure 4 - Average compression ratio over average compression error rate for each codec and bit-rate.

Figure 51: I Siegert, AF Lotz, LL Duong, A Wendemuth, Measuring the impact of audio compression on the spectral quality of speech data, 2016

Conclusion

“we recommend to use FLAC for all cases where the accuracy matters. In cases where a slight error is acceptable, we recommend Vorbis at 500 kbit/s” (Siegert et al 2016)

Praat

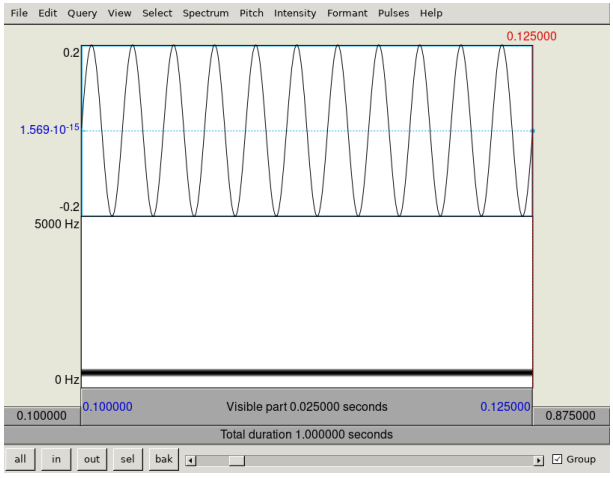


Figure 52: 440Hz sin wave

Praat

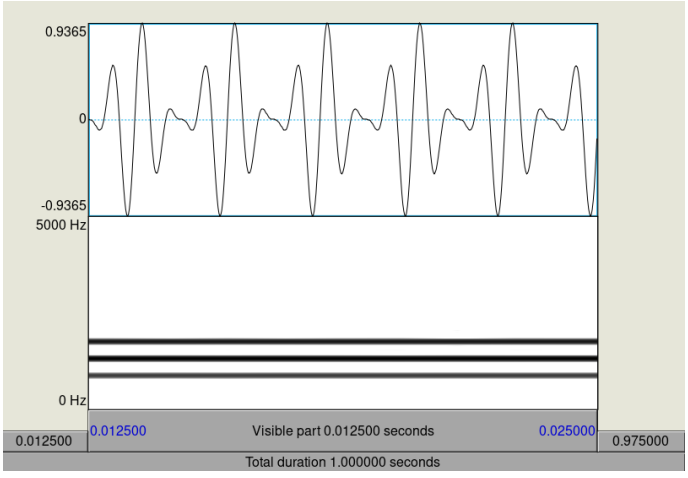


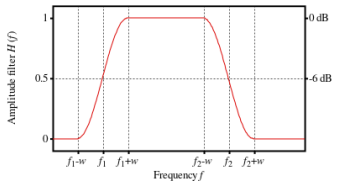
Figure 53: 1/4 sin(2 pi 880x) + 1/2 sin(2 pi 1320x) + 1/4 sin(2 pi 1760x)

Praat

Spectrum: Filter (pass Hann band)...

A command to modify every selected **Spectrum** object.

The complex values in the **Spectrum** are multiplied by real-valued sine shapes and straight lines, according to the following figure:



Settings

From frequency (Hz) (standard value: 500 Hz)
the lower edge of the pass band (f_1 in the figure). The value zero is special: the filter then acts as a low-pass filter.

To frequency (Hz) (standard value: 1000 Hz)
the upper edge of the pass band (f_2 in the figure). The value zero is special: the filter then acts as a high-pass filter.

Smoothing (Hz) (standard value: 100 Hz)
the width of the region between pass and stop (w in the figure).

Usage

Because of its symmetric Hann-like shape, the filter is especially useful for decomposing the Spectrum into consecutive bands. For instance, we can decompose the spectrum into the bands 0-500 Hz, 500-1000 Hz, 1000-2000 Hz, and 2000-"0" Hz:

Figure 54: Filter pass Hann band

Praat

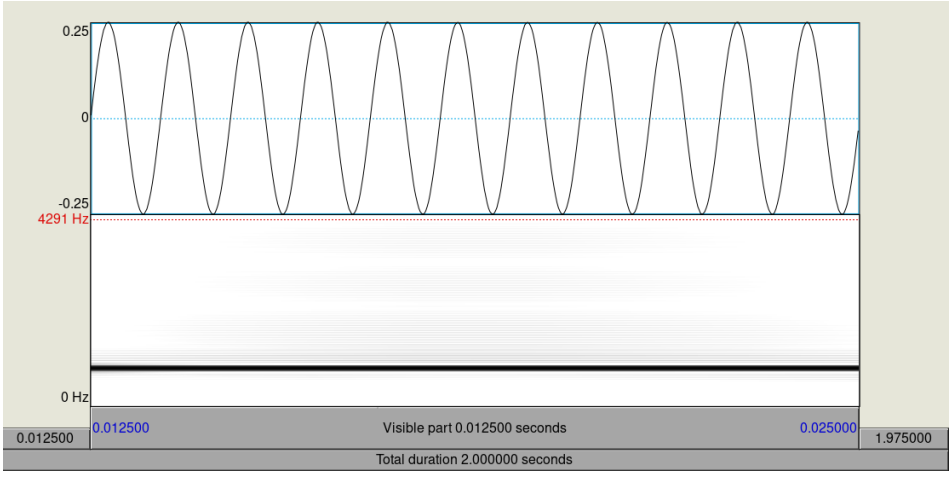


Figure 55: f1=780, f2=980, w=100

Praat

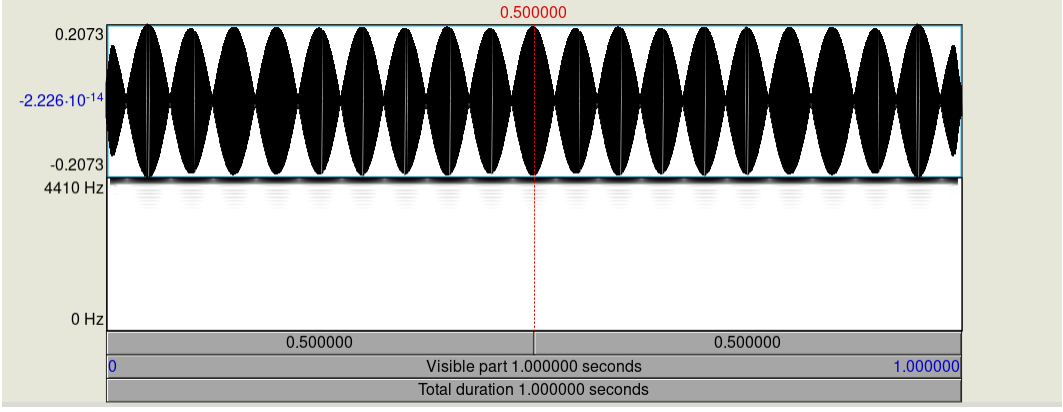


Figure 56: 4400Hz sin wave

Praat

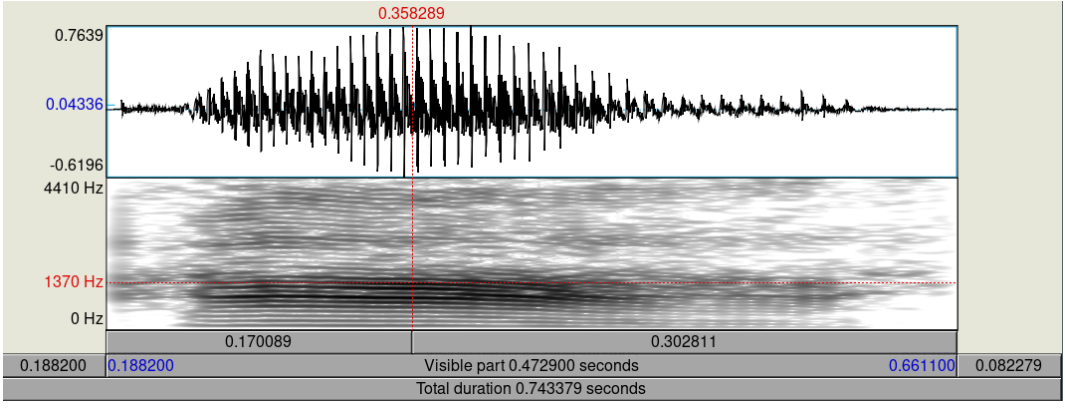


Figure 57: ah

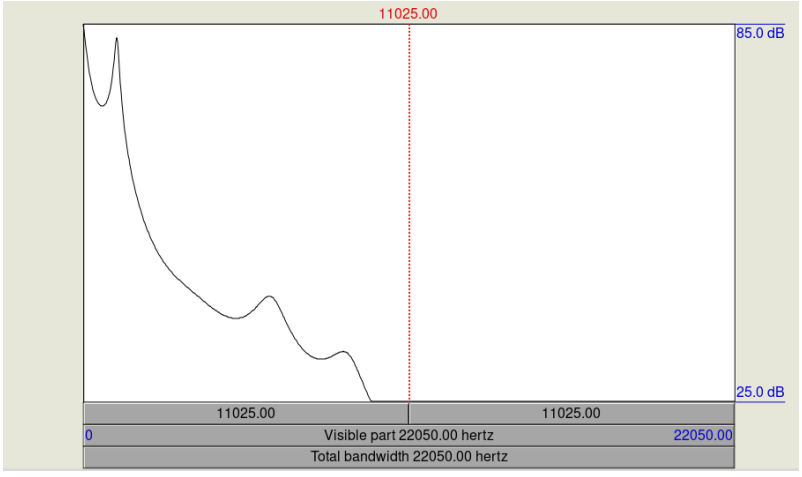

11025.00
85.0 dB
25.0 dB
11025.00
11025.00
0
Visible part 22050.00 hertz
22050.00
Total bandwidth 22050.00 hertz

Figure 58: ah

Praat

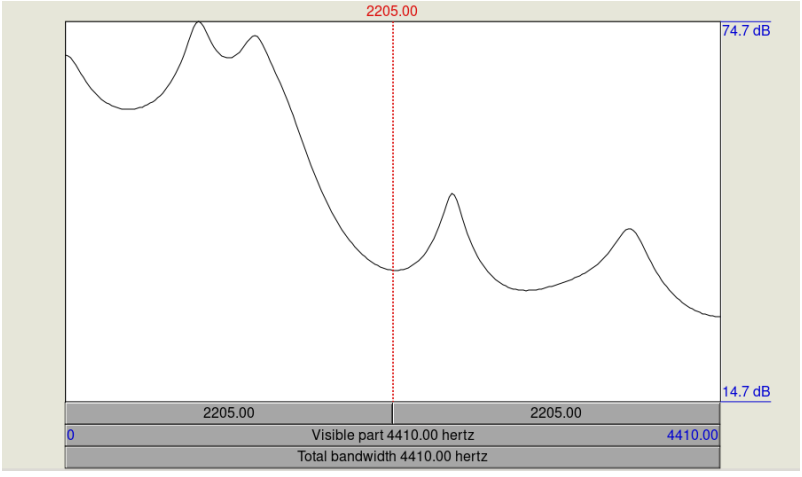


Figure 59: ah

THE END