Neuroprothetik Exercise 7
Cochlear Implant Filter Banks

Nico Hertel

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1 Electrode Corner Frequencies

A very simple cochlear implant can be modeled by a set of bandpass filters, where each filter corresponds to a certain region on the basal membrane of the cochlear. Each electrode of the implant then corresponds to one filter. One way of describing a bandpass filter is by calculating its cutoff frequencies, the frequencies where the amplitude of an incoming signal is damped by 3 dB. For this cochlear implant model we will look a the frequency range from 200 Hz to 8 kHz. As the frequency-place transformation of the cochlear happens on a logarithmic- rather than a linear scale, the filters should also be equidistant on the logarithmic scale. Figure 1 shows the corresponding cutoff frequencies for a model with 22 electrodes.

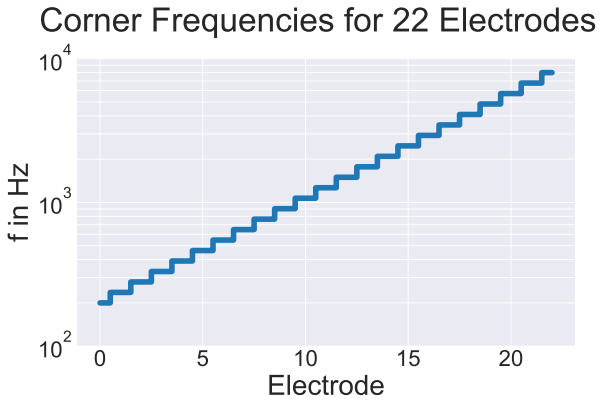

Figure 1: The cutoff or corner frequencies for the bandpass filters of the electrodes in a simple cochlear model.

2 Create a Filter Bank

Now the corresponding filters to the electrodes are created. For this, a third order butterworth-bandpass-filter is used for every electrode. Figures 2 and 3 show the frequency response of those bandpass-filters for a cochlear implant with three and 22 electrodes respectively. As the lower cutoff-frequency of one filter is the same as the higher cutoff-frequency of the prior filter, the filters intersect at the cutoff frequencies.

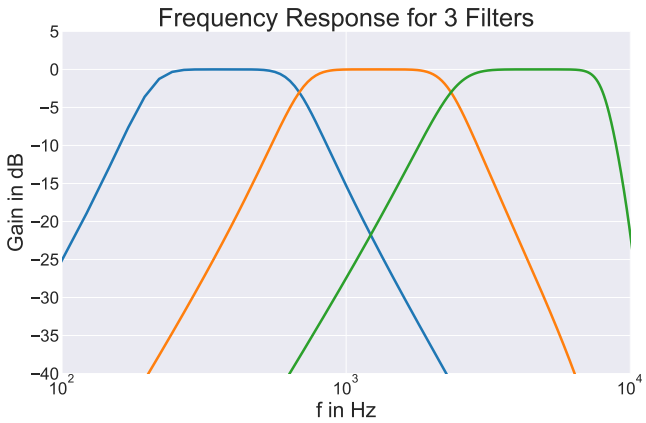

Figure 2: The frequency response of a three CI with three electrodes.

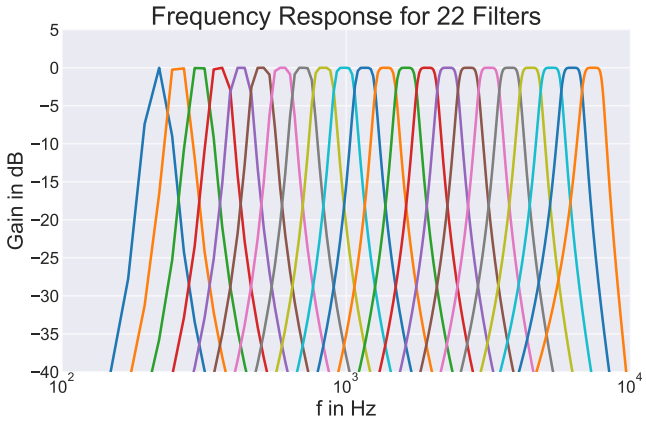

Figure 3: The frequency response of a three CI with 22 electrodes.

Now, a sample sound file, shown in figure 4, should be analyzed. For this, the sound file is then filtered by each bandpass filter in a 12-electrode cochlear

implant model. Figure 6 shows the time-signal of the single channels (Channel 1 corresponds to the first electrode, channel 2 to the second and so on). If we compare those with the spectrum of the original sound file (figure 5) we see that there are four peaks in original spectrum, one at about 10 Hz, another at approximately 100 Hz and 1000 Hz and the last peak between 3 kHz and 6 kHz. This corresponds to the shape of the sound in each channel. While the first peak at 10 Hz is not covered by the CI and the second peak only partial, the more sensible region of the ear (2 kHz - 5 kHz) is indeed following the observed pattern.

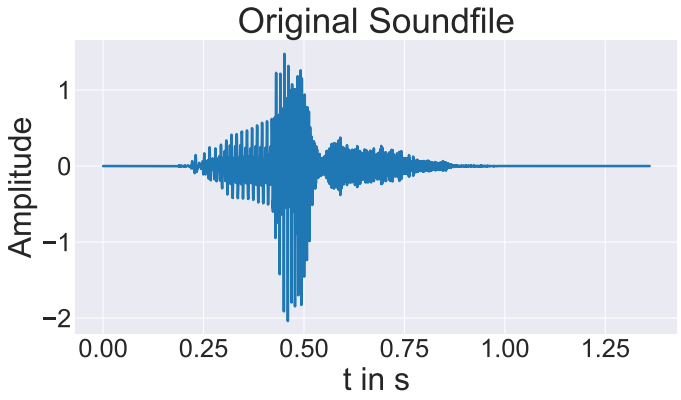

Figure 4: The analyzed sound file

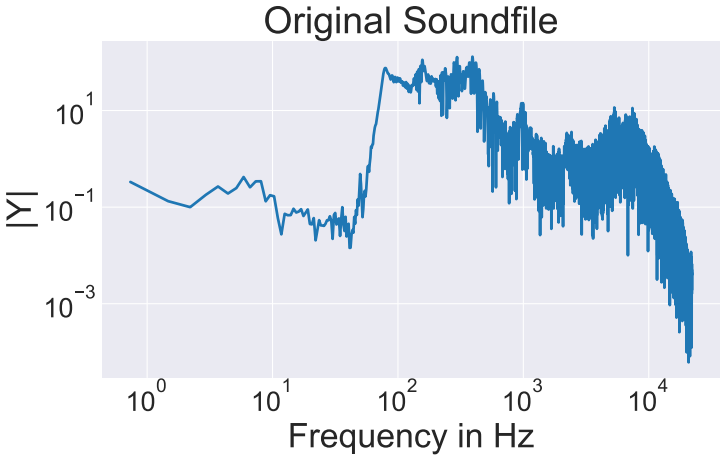

Figure 5: The spectrum of the original sound file

3 Join the channels

In a last step, the individual channels of the CI are joined to model the output of the CI as a whole. Figure 7 shows the spectrum of four cochlear implants with 3, 6, 12 ad 22 electrodes, while figure 8 shows the corresponding spectrograms. The spectrograms are trimmed at the start and end to ignore the silence of the re cored sound file.

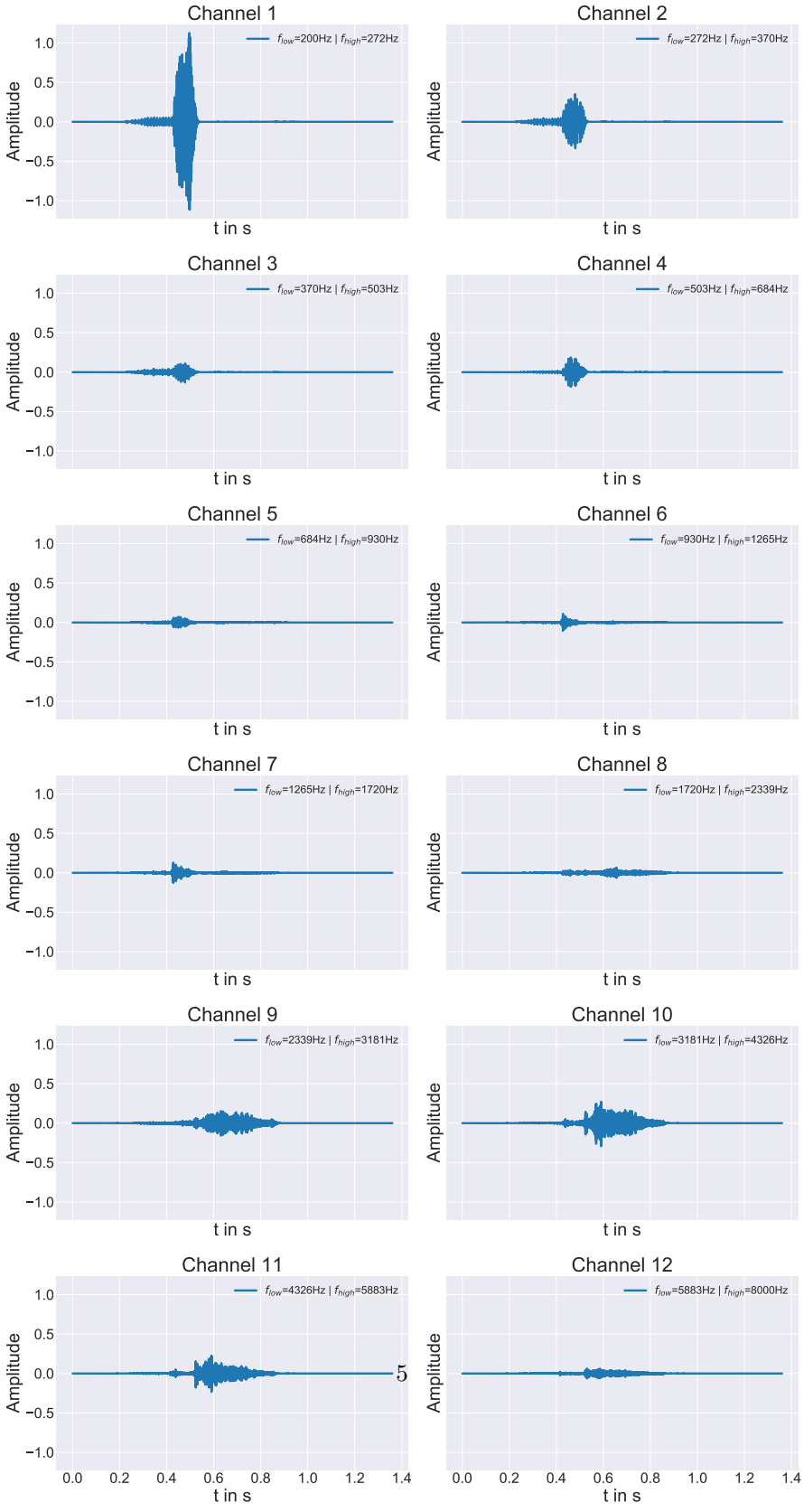

Figure 6: The analyzed sound file

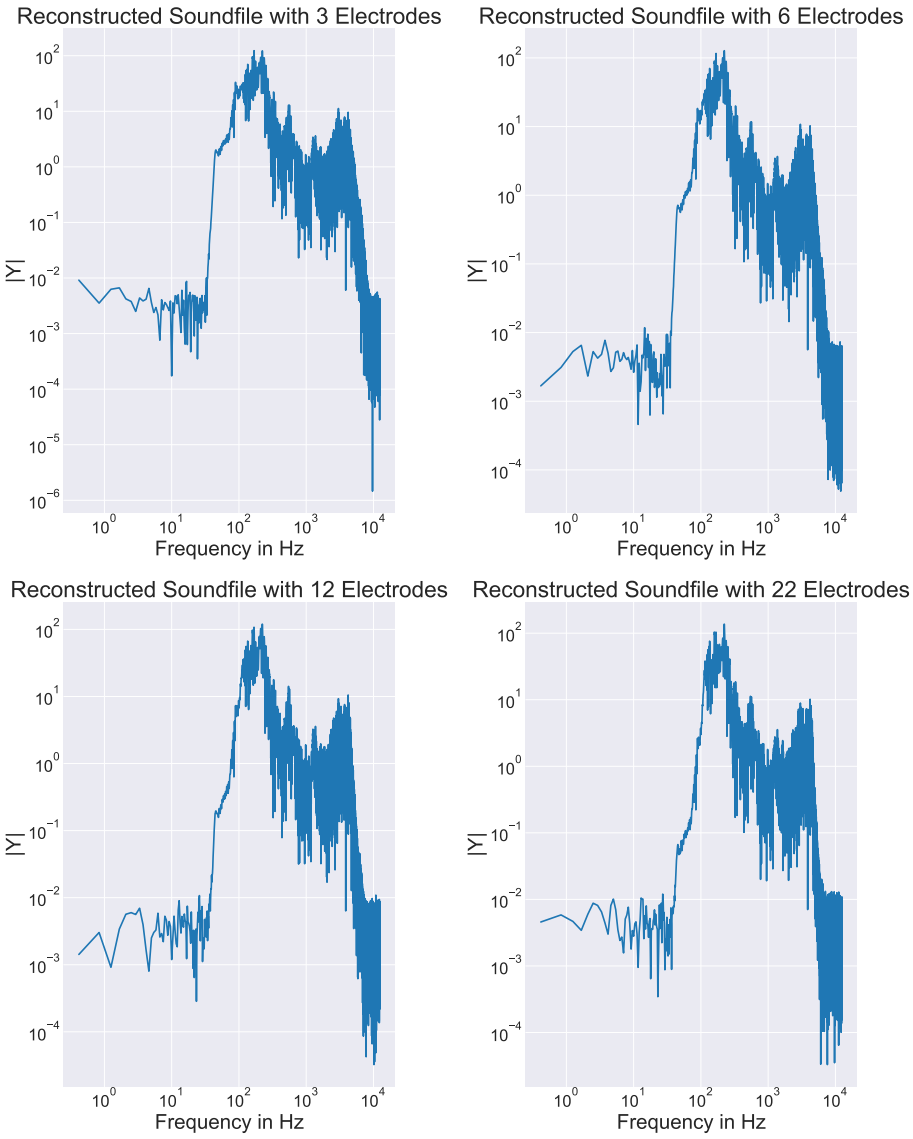

Figure 7: The spectrum of the output of a CI with different amount of electrodes

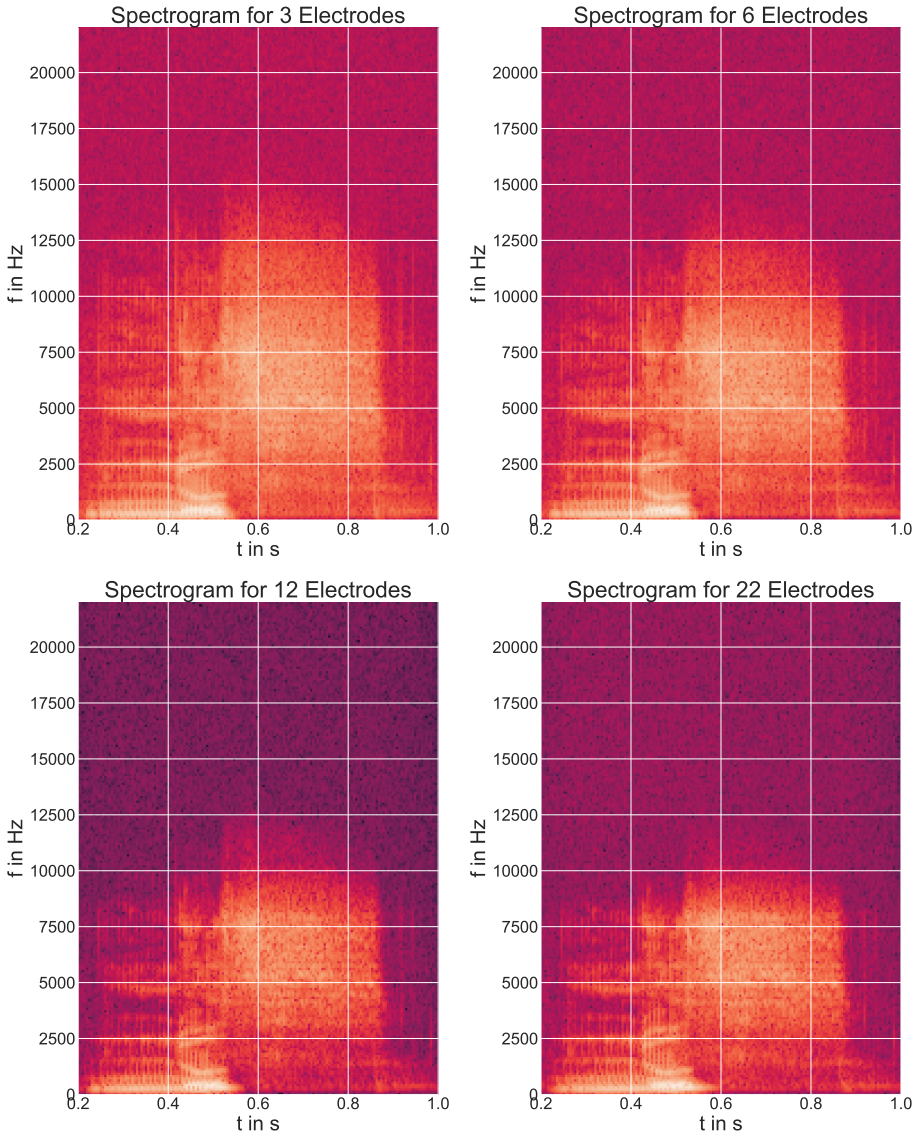

Figure 8: The spectrogram of the output of a CI with different amount of electrodes. A brighter color corresponds to a higher intensity for that frequency at that time point.