

Big Idea (Week 5): Receiver Model for Human Psychoacoustics

Human sound perception involves both mechanical (anatomical) transduction apparatus and electro-chemical (neural) processing. The mechanical sensing apparatus, the linkage of bones connecting the eardrum to the cochlea, is directly stimulated by vibrational frequencies arising from acoustic pressure waves. As a result, it effectively passes a frequency domain representation (as discussed in Week 4) of the sound wave into the neural inputs to the cognitive stages of auditory processing.

Understanding the mechanics of this receiver helps us derive a model of human psychoacoustics. This model can be used to explain and understand the limits of our audible perception. From experimentation and consistent with this model, we see:

- Vibrational sensitivity of the cochlea gives rise to the range of frequencies we can hear. Humans perceive frequencies roughly between 20Hz and 20,000Hz.
- Human auditory perception reduces continuous acoustic waveforms to a representation based around roughly two dozen frequency bands. These are termed *critical bands*.
- Within a critical band, certain patterns of sound can render others imperceptible (*i.e., masked*) when played simultaneously or in sufficiently close sequence. Such auditory processing is, to a significant extent, decoupled between critical bands, so that masking effects in one band are largely independent of the others.
- Our sensitivity to sounds varies across the bands, with the highest sensitivity in the 2–4KHz range. Sensitivity diminishes toward both the high and low frequency ends of the audible spectrum.

This receiver model is valuable in engineering and compressing sound waves. It allows us to distinguish the aspects of the sound wave that are actually important to reproduce from the aspects that are unimportant and can be discarded without perceptual distortion. That is, it tells us which information in an audio signal cannot be sensed by humans such that omission in a lossy encoding does not noticeably affect the perceived sound.