Description for a problem studied at the UK Mathematics-in-Medicine Study Group Nottingham 2006
< http://www.maths-in-medicine.org/uk/2006/auditory-representation/ >

Representation of spectrum in the auditory system

Dr Chris Sumner, MRC Institute of Hearing Research, University of Nottingham

---

The auditory system has to represent sound across 12 orders of magnitude of intensity (120dB). At present we only partly understand how the system is able to function so well across this range. One mechanism to deal with this is compression in the cochlea. The passive mechanical filtering properties of the basilar membrane are modified by an active process which amplifies very quiet sounds. Gain decreases very rapidly with sound pressure level such that a doubling in level might only lead to a 10% increase in the amplitude of vibration on the basilar membrane. Thus at the level of the cochlear there exists a mechanism which increases the dynamic range of the cochlea by at least 60dB at some frequencies. A common source of hearing deficit is damage to this active mechanism, which produces a raise in thresholds but also a reduction in the dynamic range of the system such that whilst quiet sounds are much quieter, loud sounds are just as loud. In the brain, problems of representation remain in the representation of broadband spectra. The majority (70%) of auditory nerve (AN) fibres are highly sensitive and have a dynamic range which only changes in firing rate at very low levels. The dynamic range of the firing rate of these neurons can be as little as 15dB. Thus at normal signal levels (>60dB SPL) almost all auditory nerve fibres are firing at their saturated rate. Recordings of the auditory nerve fibre responses to steady state vowels confirm that the representation of spectrum in auditory nerve fibres varies with level and is highly degraded at high sound levels.

This being the case, how is it that we can recognise sounds and understand speech across the majority of our dynamic range? A computational model of the auditory periphery coupled to a model of the ventral cochlear nucleus (and in particular so-called chopper cells) would be ideally suited to address this problem.