Relationships between cochlear tuning and delay probed with a nonlinear transmission-line model

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Otoacoustic emissions have provided both a powerful scientific and clinical tool into cochlear function, though their utility has generally been confined to assaying sensitivity. However, evidence has been emerging that stimulus-frequency emissions (SFOAEs) can also be used as a means to estimate frequency selectivity in populations (Shera et al., 2002 PNAS 99:3318-3323). The basic idea is that delays associated with emission generation reflect build-up times of the cochlear filters: The sharper the tuning, the longer the delay. SFOAE delays vary with frequency, in a fashion consistent with changes in tuning along the length of the cochlea (i.e., broadening from base to apex). Additionally, delays vary considerably across species and appear longest in humans, an observation that has broad comparative ramifications. Understanding the full implications of these types of variations in SFOAE delay requires answering basic questions about the relationship between tuning and delay in the cochlea. For example, is it possible to disentangle delays associated with propagation as opposed to filter build-up? Can SFOAE delays be used to estimate tuning in individuals? And a question stemming from the pioneering studies of von Bekesy: How do differences in the tonotopic map (e.g., number of octaves spanned from base to apex) or morphological properties (e.g., cochlear length) affect tuning and delay estimates? To address these questions, we use a time-domain implementation of a nonlinear computational transmission-line model recently developed for examining connections between cochlear mechanics, OAEs, and psychophysics (Epp et al., 2010, JASA 128:1870-1883). Specifically, we investigate how changes in mechanical and morphological properties affect relationships between delay and tuning.