AN EXAMINATION OF COCHLEAR FILTER RESPONSE PROPERTIES USING F_1- AND F_2-SWEEP DPOAE PHASE DELAY ESTIMATES IN HUMAN ADULTS

Denise M. Bowman, Jos J. Eggermont, & David K. Brown
Department of Psychology, University of Calgary, Calgary, Alberta T2N1N4

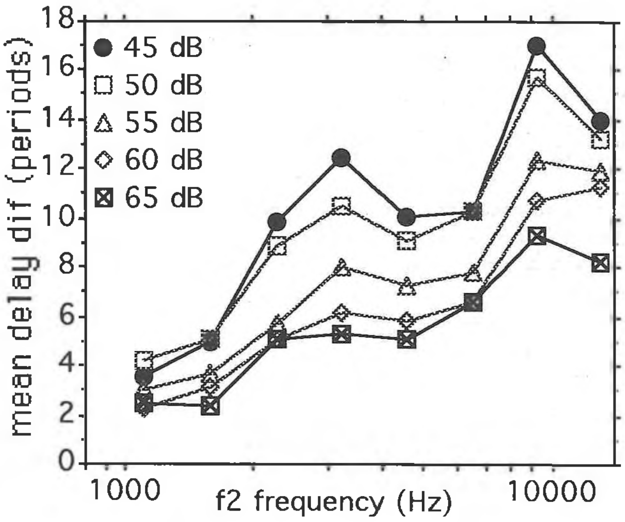
Distortion product otoacoustic emissions (DPOAEs) are recorded in the ear canal when two continuous pure tones (or primaries) of different frequency are presented simultaneously, and energy is emitted at a third frequency. Distortion is generated by the nonlinear interaction of the primaries, where the traveling-waves of the lower frequency (f_1) and higher primary (f_2) overlap along the basilar membrane. The distortion provides an indication of the degree to which the vibration of a particular region of the cochlea can be influenced by tones at other frequencies. Thus, DPOAEs reflect the mechanical tuning of the cochlea.

The slope of the unwrapped DPOAE phase response is used to determine DPOAE latency. The f_1-sweep DPOAE phase delay is composed of an anterograde and retrograde traveling-wave delay plus an intensity dependent filter build-up time at the site of OAE generation (Kimberley et al., 1993). DPOAE delay estimates in a f_2-sweep paradigm are longer than delay estimates in a f_1-sweep stimulation paradigm at the same frequency and intensity (O'Mahoney & Kemp, 1995; Bowman et al., 1996). The f_2-sweep and f_1-sweep phase delay difference is intensity and frequency dependent. On the basis of these observations it has been suggested that the f_2-sweep DPOAE phase delay is composed of a greater proportion of the filter build-up time at the site of DPOAE generation than the f_1-sweep delay. Bowman et al. (1996) have posited that a proportion of the DPOAE filter response can be isolated by subtracting f_1-sweep DPOAE delays from f_2-sweep delays at similar f_2 frequencies in normal adult ears.

A number of investigators have shown that the cochlear filter can be described by the impulse response of the basilar membrane when the impulse response is defined as the product of an nth order gamma function and a cosine (Goldstein et al., 1971; Eggermont, 1979). The shape of the cochlear filter is determined by the order of the gamma function under the assumption of minimum phase delay. The order of the gamma function can be calculated from the number of periods of delay to the peak of the impulse response.

This study examined DPOAE filter response properties obtained from f_2- and f_1-sweep DPOAE phase delay estimates at eight different f_2 frequencies (1.1-13.0 kHz) and five intensities in 60 normal hearing adult human ears. f_2- and f_1-sweep phase delay differences were calculated by subtracting the f_1-sweep delays from f_2-sweep delays for each subject. The basilar membrane impulse response was calculated from the mean DPOAE phase delay difference at each f_2 frequency and intensity.

In the present study, the mean phase delay difference ranges from 2.0 periods at 1.1 kHz (65 dB) to 17 periods at 9.2 kHz (45 dB). Delay increases as f_2 frequency increases and intensity decreases.



The long delays observed at low primary intensity levels and high frequencies are consistent with the findings Ruggero (1992a) which indicated that the build-up time of the impulse response of the basilar membrane reflects filter tuning properties. Sharply tuned responses at low intensities had longer build-up times than broadly tuned responses at high intensities. Eggermont (1979) has similarly shown that sharp cochlear filters have long impulse responses with several cycles of delay to the response maximum when filters are derived from narrow band AP latency in humans.. The CF normalized tuning curve bandwidth of single auditory nerve fibers decreases as CF increases (Ruggero 1992b). The long filter build-up times observed in this study at high f_2 frequencies may therefore reflect frequency dependent differences in the tuning of higher frequencies responses.

Bowman, D.M., Eggermont, J.J., Brown, D.K., & Kimberley, B.P. (1996). 19th Midwinter Research Meeting of the Assoc. for Res. in Otolaryngol., 718.

Eggermont, J.J., (1979). JASA, 65, 463-470.

Goldstein, J.L., Baer, T. & Kiang, N.Y.S. (1971). In: M.B. Sachs (Ed.) Physiology of the Auditory System.

Kimberley, B., Brown, D., & Eggermont, J. (1993). JASA, 94, 1343-1350.

O'Mahoney, C.F. & Kemp, D.T. (1995). JASA, 97, 3721-3735.

Ruggero, M. A. (1992a). Cur. Opin. in Neurobiol., 2, 449-456.

Ruggero, M. A. (1992b). In: R. Fay & A. Popper (eds.) The Mammalian Auditory Pathway: Neurophysiology.