A. N. Cheeran, Speech processing with dichotic presentation for binaural hearing aids for moderate bilateral sensorineural loss, Ph. D. Thesis, Biomedical Engineering Group, School of Biosciences and Bioengineering, IIT Bombay, 2005.

Supervisor: Prof. P. C. Pandey.

Abstract - Sensorineural hearing impairment is characterized by frequency dependent shifts in hearing threshold, loudness recruitment, and increased spectral and temporal masking. Increased masking causes smearing of spectral peaks and suppression of cues like voice-onset-time, formant transitions, and burst durations, resulting in degraded consonantal identification. Masking takes place primarily at the peripheral level, while integration of information takes place at higher levels in the auditory system. For persons with moderate bilateral sensorineural impairment, the effect of increased masking may be reduced by splitting speech into two complementary signals, so that the signal components likely to mask or get masked are presented to different ears. The objective of the research is to investigate the use of dichotic presentation, with spectral, temporal, and combined splitting schemes, for improving speech perception by hearing impaired persons using binaural aids and by normal hearing persons under adverse listening conditions, in order to find the optimal splitting scheme and associated processing parameters.

For spectral splitting, perceptually balanced comb filters based on auditory critical bandwidths were designed as 256-coefficients linear phase FIR filters and had 1 dB passband ripple, 30 dB stop-band attenuation, and inter-band crossovers within 4 – 6 dB. Listening tests involving closed set identification of VCV syllables were conducted on five normal hearing subjects with simulated loss and on five hearing impaired subjects. On the basis of response time, recognition scores, and relative information transmission, the perceptually balanced comb filters were found to be superior to the comb filters with sharp inter-band transitions. Further investigations involved implementation and evaluation of the three speech processing schemes: (i) spectral splitting with perceptually balanced comb filters, (ii) temporal splitting with trapezoidal fading, 70% duty cycle, 3 ms transition duration, and inter-aural switching period Tc = 20 – 80ms, and (iii) combined splitting with time-varying comb filters, realized with a set of m (4 – 16) perceptually balanced comb filters swept over a cycle time Tc = 20 – 180ms. The objective was to find the optimal value of Tc for temporal splitting, optimal value of Tc and m for combined splitting and to compare three schemes. Listening test were carried out, with phonetically balanced monosyllables, on 7 normal hearing subjects with simulated loss and 13 subjects with bilateral sensorineural hearing loss.

Test results showed that all the presentation schemes reduced the load on perception process and improved speech perception. The optimal processing conditions were Tc = 20 – 40 ms for temporal splitting, and Tc = 40 – 80 ms with m = 8 and 16 for combined splitting. The highest improvements in response as well as recognition score were generally provided by spectral splitting, closely followed by combined splitting. On normal hearing subjects the SNR advantage at 60 % recognition score with best processing parameters was 5 dB for spectral splitting, 1.5 dB for temporal splitting, and 4 – 4.5 dB for combined splitting. For hearing impaired subjects the effectiveness of the schemes varied across subjects, which can be related to the extent and nature of loss. The relative improvements, for the optimal scheme and parameters for individual subject, ranged 6 – 138 % with an average of 35 %. It may be concluded that dichotic processing schemes can improve speech perception for persons using binaural hearing aids. The implementation should permit selection of the dichotic splitting scheme and fine-tuning of processing parameters.