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Review on Improving Speech Perception to Sensorineural Hearing Impairment Using Filters

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Abstract— Sensorineural hearing impairment causes widening of auditory filters. Widening of auditory filter leads to spectral masking. Spectral masking leads to degraded speech perception as there is masking of frequency components by adjacent frequency components. Earlier studies have revealed, frequency masking can be reduced by binaural dichotic presentation, using critical band filter bank. In this scheme speech signal from odd numbered critical band filters is presented to one ear and even numbered to other ear. Studies have shown that this scheme helps in reducing the effect of spectral masking for persons having moderate bilateral sensorineural hearing impairment. This paper presents the study of various techniques used for the improvement of sensorineural hearing impairment.

Keywords— Auditory filters, binaural, critical band filters, dichotic, frequency masking, sensorineural.

I. INTRODUCTION

The peripheral auditory system of the human ear behaves like a bank of bandpass filters called auditory filters or critical bands. One of the hearing impairment in humans is sensorineural hearing loss due to defects in the cochlea and auditory nerve. The characteristics of this loss are elevated hearing threshold, abnormal growth in loudness perception with increase in intensity, reduced frequency and temporal resolution and increased spectral and temporal masking. Reduction in spectral contrasts, results in broadening of auditory filters. The peaks and valleys of the speech spectrum are broadened affecting the perception of speech because of masking. Increased temporal masking results in the increase of forward and backward masking of weak acoustic segments by strong ones, which also affects speech intelligibility. Speech perception at higher auditory levels involves the integration of information received from both the ears.

In general, sensorineural loss is difficult to cure and it becomes progressively worse with time. Sensorineural hearing loss is associated with widening of the auditory filter bandwidths thus the filter slope becomes shallower and results in overlap of adjacent spectral bands called spectral masking. This leads to a decrease in frequency resolving capacity of the auditory system of the ears. From different investigations it was noticed that splitting the speech into different bands and presenting the alternate bands to each ear as shown in figure was advantageous for people with moderate bilateral sensorineural hearing impairment, with residual hearing in both ears. Splitting of speech into two signals, such that the frequency components that are likely to get masked are separated and presented to different ears has helped in reducing the effect of spectral masking. The information from the signals presented to the two ears gets integrated at higher levels in the auditory process.

II. BASILAR MEMBRANE MODELLING

The cochlea is an opened spiral tube lying in the middle ear. The opening in its base makes possible the penetration of the sound signals. The closed end is called the apex. The sound is detected and coded according to its frequency but it is place coding on the basilar membrane. High frequency sounds are detected at the base, whereas low frequencies are detected at the apex. The frequencies are precisely distributed along the basilar membrane and are as represented in figure 2.

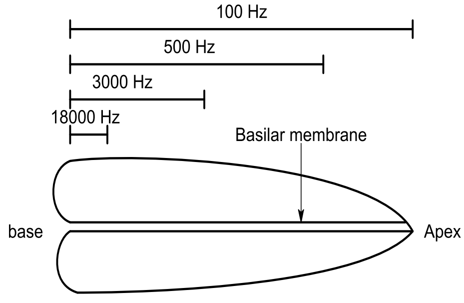

Fig. 2 Schematic of the basilar membrane, showing the change in characteristic frequency from base to apex.

The filters within cochlea are distributed in bands along the basilar membrane and are responsible of the selectivity of sound frequency in air. These filters can be modelled in pseudo logarithmic way. The bands are linear upto 500 Hz and logarithmic beyond. Each bandwidth can be determined using formula,

Bandwidth $(\Delta f) = 25 + 75\left[1 + 1.4\left(\frac{f}{1000}\right)^2\right]^{0.69}$ where f is central frequency of band [9].

III. PROCESSING SCHEMES

Several schemes are employed in literature to split the speech signals for binaural dichotic presentation. Lunner *et al*. (1993) evaluated a scheme using synthesized vowels in which the first formant was presented to left ear and the second formant to the right ear. The scheme used comb filters with constant bandwidth of 700Hz and 40dB stopband attenuation. The listening tests were conducted on male and female subjects in age group of 39-69 years with bilateral and moderate sensorineural hearing loss. The gain of the filters was adjusted depending on the hearing loss of individual subject. The scheme was able to improve speech recognition even in noisy environment. The results indicated an overall improvement in speech perception for dichotic conditions [1].

Chaudhari (1998) *et al.* investigated a scheme for splitting the speech into two complementary spectra each with nine bands for binaural dichotic presentation using Zwicker (1961) psychophysical tuning curves. The FIR comb filters were designed by frequency sampling method using linear optimization techniques. The proposed design was able to improve speech quality, response time, recognition scores and transmission of consonantal features as observed in the listening tests. Nonsense syllables using twelve English consonants /p, b, t, d, k, g, m, n, s, z, f, v/ in vowel-consonant-vowel (VCV) and consonant-vowel (CV) context with the vowel /*a*/ were used as test material and acquired using antialiasing filter with cut-off frequency 4.8 kHz and 16-bit ADC at a rate of 10 k Samples/s. The process of filtering speech was done offline and real time. The input and processed speech signal with the said scheme was presented to two ears through DAC, smoothing filter and power amplifier. Ten hearing impaired subjects in the age group of 18 to 58 years participated in the experiments. The subject had mild-to-very severe bilateral sensorineural hearing loss. The test material was presented binaurally at the individual subject’s most comfortable listening level. Implemented scheme has reduced the effect of spectral masking [2].

Chaudhari *et al*. in 2008 proposed a scheme in which critical bands corresponding to auditory filters based on psychophysical tuning curves were used. In binaural dichotic presentation scheme, splitting of speech signal in real time into two signals with complementary short time spectra using filters with magnitude based response on two auditory filter banks with linear phase was implemented and evaluated. Filter banks corresponding to eighteen critical bands over 5kHz frequency range were used. Listening tests were performed on subjects with ‘mild’ to severe ‘very severe’ bilateral sensorineural hearing loss. The usefulness of the scheme for better reception of spectral characteristics was evident as the results indicated improvement in speech quality, response time decrease, enhancement in recognition scores [3].

Comb filters were designed having adjustable magnitude response at transition crossovers for minimizing any change in perception intensity. Also reduction in pass band and increase in stop band was considered. Listening tests were performed on normal subjects with simulated hearing loss. The designed filter gave better speech recognition scores and relative information transmission than the earlier filter. Therefore the designed comb filter can be used for binaural aids for persons with bilateral sensorineural hearing impairment, for reducing the effect of spectral masking [4].

The speech perception gets degraded due to increased spectral and temporal masking in persons with sensorineural hearing loss. A scheme of binaural dichotic presentation was used to reduce the effect of both spectral and temporal masking simultaneously for persons with bilateral sensorineural hearing loss. Pair of time varying comb filters was used to split the speech signal into two for binaural dichotic presentation. Magnitude responses of filters were selected by cyclic sweeping. The spectral components in the neighbouring critical bands that are likely to mask each other were presented to different ears. Listening tests were conducted on normal hearing subjects with simulated hearing loss by adding broad band noise at different signal-to-noise ratios. The result showed significant improvement in recognition score, response time and reception of place and duration feature especially in adverse listening condition. The improvement in the perception of place and duration features showed that the scheme helped in reducing the effect of spectral and temporal masking. Also there was reduction in response time indicating a reduced load on the speech perception [5].

Work was carried out on filters with constant, critical and 1/3 octave bandwidth. Binaural dichotic scheme was performed using each type of filters for comparative study. Results indicated that constant bandwidth filters help in speech intelligibility. Speech perception was significantly improved for critical band based filter and 1/3 octave filters [6]. Some efforts are being made in implementing filters on FPGA for hearing impaired. The decimation filter used for hearing aid applications were implemented on FPGA. The implementation was carried out using the canonical signed digit representation. Each digital filter structure was simulated using MatLab, and its complete architecture was captured using DSP blockset and Simulink.

The filter was implemented on Xilinx FPGA using Virtex-II technology. Comb-half-band FIR-FIR structure and conventional comb-FIR-FIR decimation filter for same specifications were implemented for comparative study. The designed decimation filter of half-comb-band architecture contributed to a hardware saving of 69% as compared to the comb-FIR-FIR architecture; in addition, it reduced the power dissipation by 83%, respectively. The resulting architecture was hardware efficient and consumed less power compared to conventional decimation filters [7].

A low-power 8-band filter bank design was proposed for a digital hearing aid on an FPGA. The input sound was decomposed into eight frequency bands. Then, each band was multiplied by the corresponding prescribed gain. Finally, all bands were compressed to the output sound fitting to the hearing impaired. The low power consumption operation was observed using the local clock when required [8].

IV. CONCLUSIONS

Various techniques used for the improvement of sensorineural hearing impairment are discussed. The previous attempts which used constant bandwidth filter improved speech intelligibility to some extent. Binaural dichotic presentation using bank of critical band filters resulted in significant improvement in speech perception. Especially reception of consonantal place feature was significantly improved showing the advantage of scheme for reducing the spectral masking. The temporal splitting scheme with time varying comb filters resulted in increased recognition scores, response time, and reception of place features indicating reduced effect of spectral and temporal masking. Significant reduction in response time showed reduced load on speech perception. Also attempts were carried out by implementing filters using FPGA for hearing impaired; the hardware efficiency and low power consumption were observed in the implemented filters.

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