Binaural Dichotic Presentation to Reduce the Effect of Increased Temporal and Spectral Masking in Sensorineural Hearing Impairment
ABSTRACT -- Sensorineural hearing loss is characterized by increased temporal and spectral masking, resulting in degraded speech perception. Earlier investigations have shown that binaural dichotic presentation using comb filters with complementary magnitude responses improved speech perception, particularly the place feature. Further, inter-aural switching with periodic trapezoidal fading functions improved the perception of duration feature. For simultaneously reducing the effect of the two types of masking, a scheme has been devised with a pair of time varying comb filters, with bands corresponding to auditory critical bands. Thus the spectral components in neighboring critical bands do not mask each other, and the sensory cells on the basilar membrane get a relaxation time due to sweeping of the filter pass bands. The scheme was implemented using linear phase 256-coefficient FIR filters. Magnitude responses were cyclically swept with 20 ms period, in steps by selecting the filter coefficients for each step from a pre-calculated set. Listening tests involved closed set identification of 12 vowel-consonant-vowel syllables. The processing scheme resulted in the improvement of recognition scores, response time, and transmission of features, particularly place and duration, indicating reduction in the effect of spectral and temporal masking.
Causes of Sensorineural Loss
• Damage to hair cells in the cochlea
• Degeneration of auditory nerve fibers

Characteristics of Sensorineural Loss
• Frequency dependant shifts in hearing thresholds
• Reduced dynamic range, loudness recruitment
• Poor frequency selectivity, & increased spectral masking
• Reduced time resolution, & increased temporal masking
Effects of Increased Spectral Masking

Smearing of spectral peaks and valleys due to broader auditory filters.

↓

Reduction in internal spectral contrast.

↓

Reduction in discrimination of consonantal place feature.
**Effects of Increased Temporal Masking**

Forward and backward masking of weak segments by strong ones.

\[ \downarrow \]

Reduced ability to discriminate sub-phonemic segments like noise bursts, voice-on-set time, and formant transitions.
Spectral Splitting for Binaural Dichotic Presentation with Comb Filters

**Lunner et al. [1993]:** Filters with constant bandwidth (700 Hz). *Improvement of 2 dB in SNR.*

**Chaudhari & Pandey [1998]:** Filters with bandwidths corresponding to auditory critical bands. *Improvement in the perception of consonantal place feature.*

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Temporal Splitting for
Binaural Dichotic Presentation

Lunner et al., [1993]. Combined spectral & temporal splitting (at 50 Hz), by symmetrical switching of filter outputs of a pair of comb filters. *No further improvement over spectral splitting. Poor sound quality due to switching.*

Jangamashetti & Pandey [2000]. Temporal splitting (at 50 Hz), with overlapping trapezoidal fading functions. *Improved perception of consonantal duration feature.*
Objective

Reduction in the effects of temporal & spectral masking by using a pair of time-varying comb filters for splitting the speech signal spectrally and temporally for binaural dichotic presentation.
SPECTRAL SPLITTING: Sensory cells corresponding to alternate bands of the basilar membrane are always stimulated.

TEMPORAL SPLITTING: All the sensory cells of a ear get relaxed alternately for some time.

COMBINED SPLITTING: All the sensory cells of the basilar membrane get periodic relaxation from stimulation.
Schematic representation of the scheme of splitting using time varying comb filters
Representation of magnitude response of one time varying comb filter
Implementation of Time Varying Comb Filters

Set of linear phase FIR filters with pre-calculated coefficients

- No of coefficients: 256
- Pass band ripple: < 1 dB
- Stop band attenuation: > 30 dB
- Gain at inter-band crossovers: -4 to -6 dB
- Sweep cycle duration: 20 ms
- Number of shiftings: 2, 4, 8, or 16
An idealized representation of magnitude response of the pair of time varying comb filters using 4 shiftings for the (a) left ear and (b) right ear
Listening Tests for Evaluation of the Scheme

*Test material:* 12 English consonants /p, t, k, b, d, g, m, n, s, z, f, v/ in VCV context with vowel /a/.  

*Subjects:* Normal hearing subjects (5 Ss, 20-40 yrs age, 3 M, 2F).  

*Listening condition:* Sensorineural loss simulated by adding gaussian noise with short-time SNRs of $\infty$, 6, 3, 0, -3, -6, -9, -12, -15 dB. Comfortable listening level (70–75 dB SPL).
Performance Measurement

- Response Time Statistics
- Stimulus-Response Confusion Matrix
  - Recognition Scores
  - Relative Information Transmission of Consonantal Features (overall, voicing, place, manner, duration)
Average response times (ms).

Relative improvements in response times (ms).
Average of percentage recognition score.

% Relative improvement in recognition score.
Average of percentage overall information transmitted.
Relative information transmitted (%) for place feature.
**Summary of Results**

*More improvement at higher simulated loss (lower SNR).*

*Max improvement for 4 and 8 shftings.*

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>Rel. improv. (%)</th>
<th>SNR: -15 dB</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4 shifts</td>
<td>8 shifts</td>
</tr>
<tr>
<td>Response Time</td>
<td>17</td>
<td>14</td>
</tr>
<tr>
<td>Recognition Scores</td>
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<td>29</td>
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<tr>
<td>Rel. Informn. Tr.</td>
<td>Overall</td>
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<td>17</td>
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<tr>
<td>Duration Feature</td>
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<td>318</td>
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<tr>
<td>Place Feature</td>
<td>177</td>
<td>149</td>
</tr>
</tbody>
</table>
Further Work

• *Optimal Parameters*: No of Shiftings & Cycle Duration.

• Listening Tests with Subjects with Bilateral Sensorineural Loss.

• Incorporation of Frequency Dependant Gain and Multi-Band Amplitude Compression in the implementation.