Objective Assessment of Envelope Enhancement Algorithms for Assistive Hearing Devices

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November 2017

Outline

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Background and Introduction

- Speech understanding in noisy environments with poor signal-to-noise ratio (SNR) is a significant challenge for hearing impaired listeners

- The poor speech perception for hearing impaired listeners arises from deficits in
  - Spectral processing
  - Temporal processing
  - Binaural processing
  - Cognitive processing

Background and Introduction Cont'd

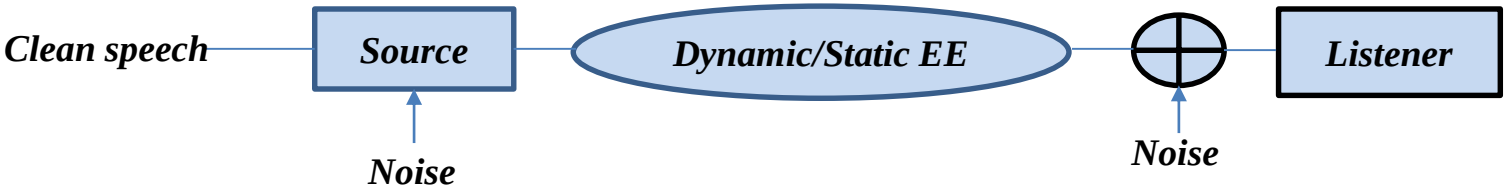
- This research focuses on enhancing speech for hearing impaired listeners with poor temporal processing

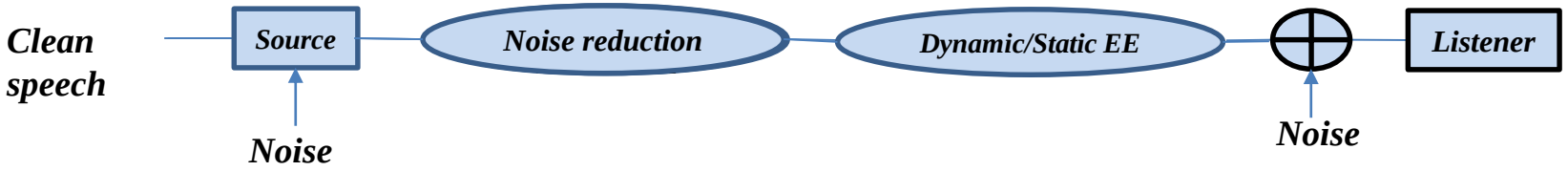
- Recent evidence:
  - Research by Narne *et al.*[3, 4, 5] showed that a dynamic envelope enhancement (EE) algorithm improves word recognition by listeners with auditory neuropathy spectrum disorder (ANSD)

  - More recently, Shetty & Kooknoor [6] showed that a static envelope enhancement algorithm improved consonant recognition scores by older hearing impaired listeners at different Signal-to-Noise Ratios (SNRs)

Problem Statement

- Previous research considered only subjective evaluation of envelope enhancement algorithms by applying them to short speech segments (consonants, vowels, and words)
- They assumed that there is no background noise at the source location of the speech (e.g. remote microphone)
- Background noise is only added after the speech signal is enhanced and ready to be transferred to a listener



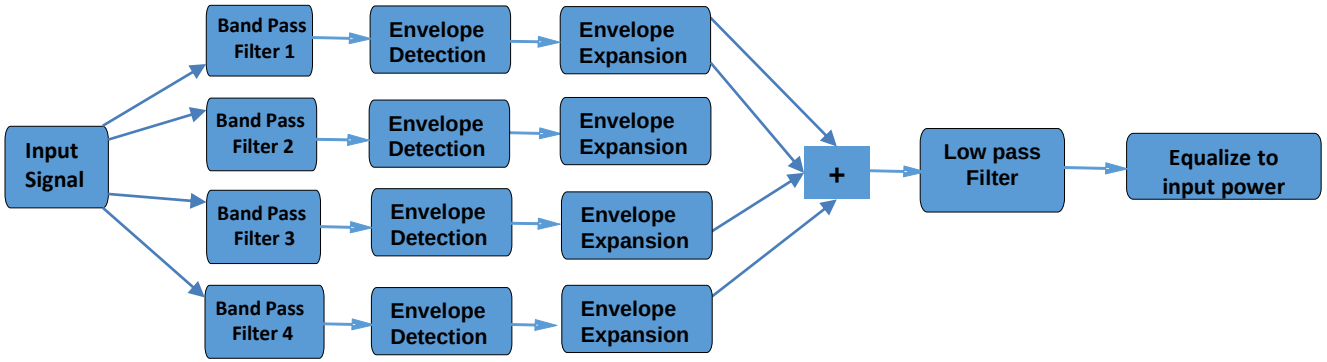


Our Contribution

- Speech perception (at the sentence level) evaluation of the dynamic/static EE algorithms
- Investigation of objective speech intelligibility metrics in predicting the speech intelligibility
- Using the objective intelligibility metric (HASPI) to benchmark the performance of envelope enhancement algorithms in different noisy/processing conditions

Dynamic EE Implementation

- The algorithm first divides the speech signal into a specified number of bands
- Next, the envelope of the signal is extracted through full-wave rectification followed by low pass filtering
- Then, the extracted envelope is either left intact or raised to the power *k* with respect to its instantaneous value
- A correction factor is obtained by (expanded envelope/original envelope)
- The obtained correction factor is multiplied with the original band pass signal at each band
- The resulting bands are added to get the enhanced signal



Enhancing the Envelope by Exponential Law

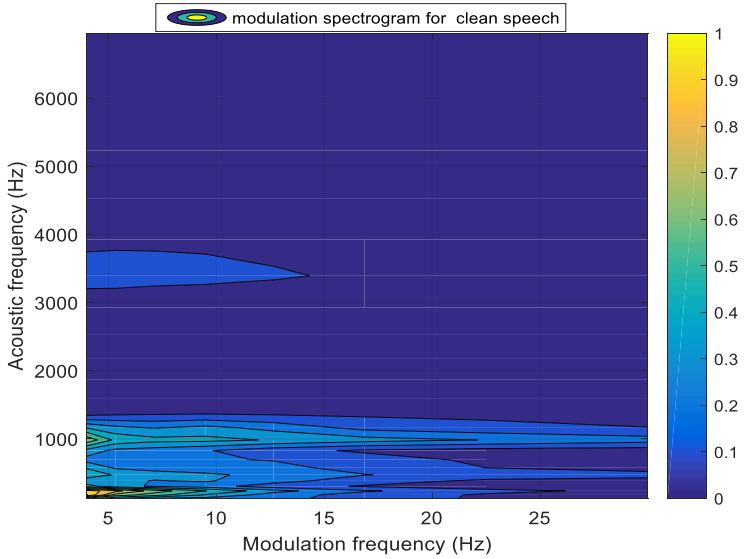
- k_{min}=0.3
- k_{max}=4
- E_{bmin}=minimum amplitude of the envelope
- Eb_i=instantaneous amplitude of the envelope
- τ (time constant for the exponential) = 0.0001
- Maximum expansion is applied to the lowest envelope amplitude
- Maximum compression is applied to the highest envelope amplitude

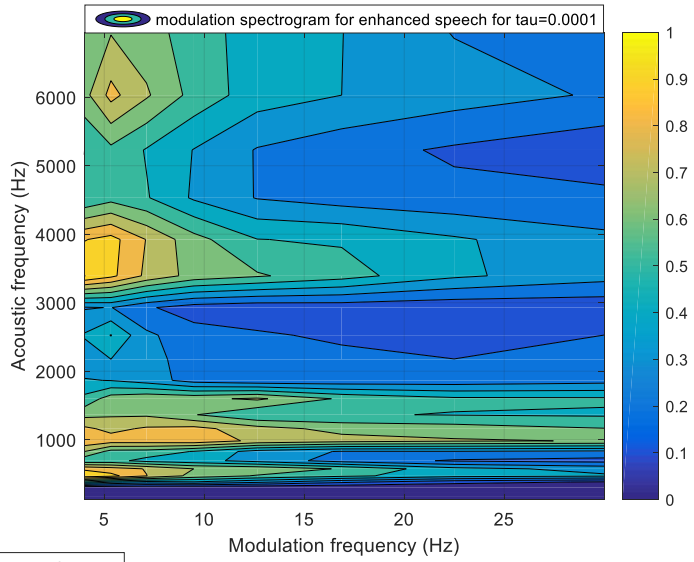
$$k_{bi} = e^{\frac{(E_{bmin} - E_{bi})}{\tau}}(k_{max} - k_{min}) + k_{min}$$

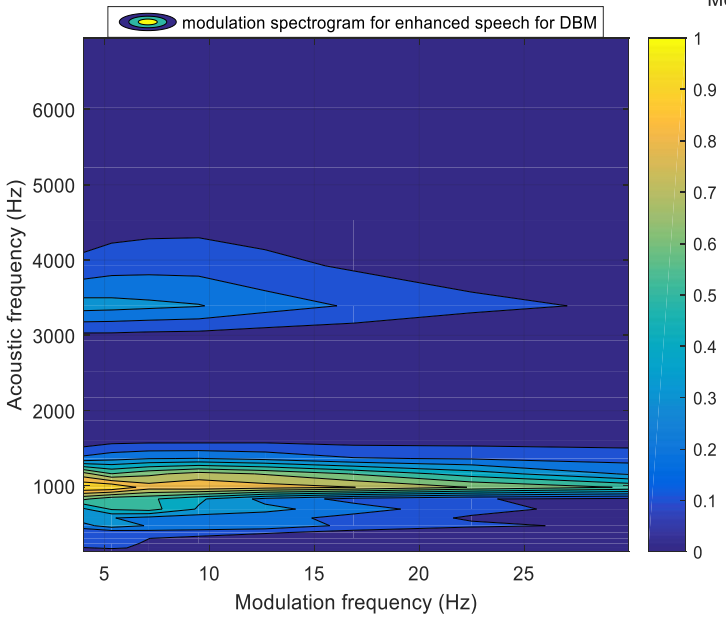
Deepen Band Modulation Algorithm (Static EE)

- This technique was recently evaluated by Shetty and Kooknoor [6]
- The algorithm first divides the input speech into 20 bands
- The temporal envelope is extracted
- The envelope in each band is passed through a band pass filter
- Before summing the individuals bands together, a gain of 20 dB was provided to the envelope in channels

Modulation Spectral Energy







Assessment of Envelope Enhancement

- Subjective methods require individuals to judge the quality and intelligibility of the processed speech signal
  - Costly
  - Time consuming
- Computer-based objective measurement have been proposed to estimate speech intelligibility and quality in the presence or absence of background noise
- Objective measurement methods can be divided into two categories
  - Intrusive
  - Non-intrusive

Hearing Aid Speech Perception Index (HASPI)

- Hearing Aid Speech Perception Index (HASPI) [7] is an intrusive measure of speech intelligibility

- The computed HASPI has value between 0 and 1
  - Zero means no intelligibility
  - One means perfect intelligibility

Experimental Methodology

- The dynamic EE algorithm was implemented in MATLAB
- The static EE is available in Praat
- The clean speech sentences used in the present study were taken from the hearing in noise test (HINT) database [2]
  - This test contains 25 lists with each list consisting of 10 sentences
- In the present research study, the Minimum-Mean-Square-Erroe (MMSE) noise reduction algorithm was investigated as front-end
  - This algorithm was chosen as it generates fewer artifacts (musical noise)

- Objective results are shown as the HASPI scores, averaged over the ten sentences in that randomly selected list
- In conditions involving background noise, the HINT speech-shaped-noise was mixed with the clean speech at different SNRs before applying the noise reduction and/or envelope enhancement algorithms

Experimental Results

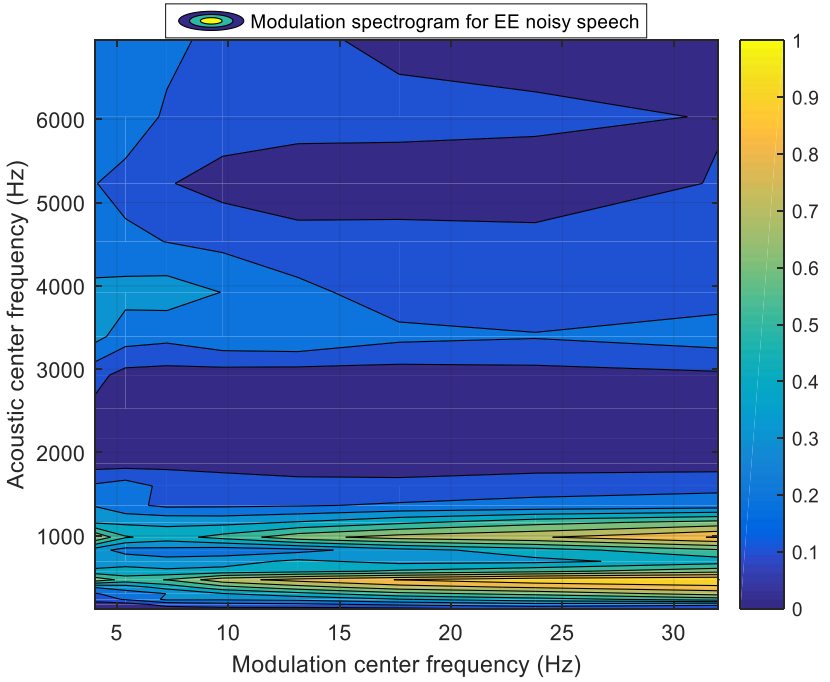
without noise reduction

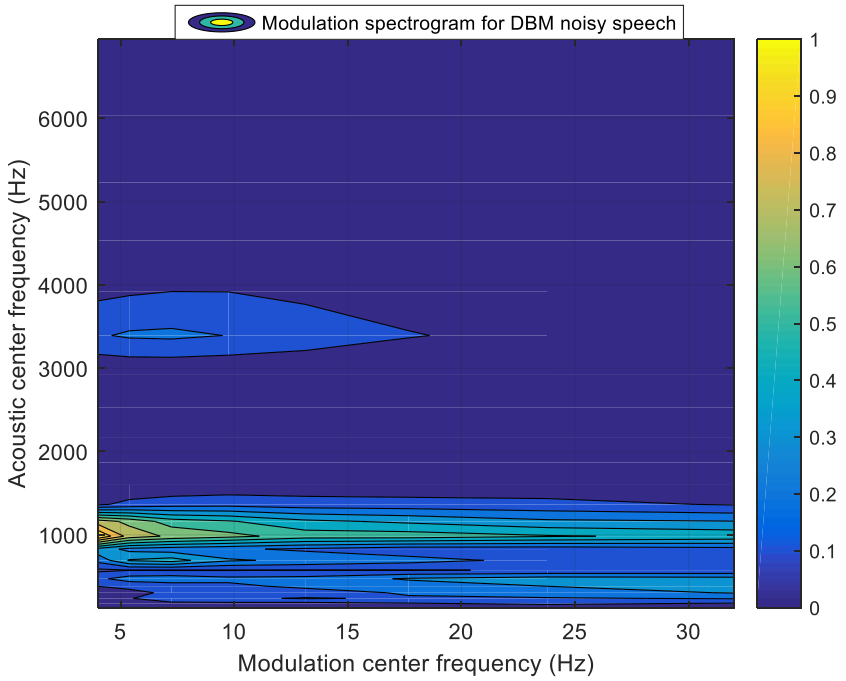
LSNR (dB) \ SSNR (dB)	0	5	10	15	20
3					EE
0				EE	EE
-3			EE	EE	EE
-6	EE	EE	EE	EE	EE

with noise reduction

LSNR (dB) \ SSNR (dB)	0	5	10	15	20
3	DBM			EE	EE
0	DBM		EE	EE	EE
-3	DBM	EE	EE	EE	EE
-6	EE	EE	EE	EE	EE

Experimental Results Cont'd (Modulation Spectrogram for (SSNR=0 and LSNR=3 dB)





Conclusion and Future Work

- Individuals with temporal processing deficits have difficulties in understanding speech in the presence of noise
  - Envelope enhancement algorithms have the potential to improve speech perception for these individuals
- Experiments were conducted to investigate the performance of envelope enhancement algorithms objectively using the HASPI metric
- EE algorithms are effective only in certain combinations of source and listener SNRs
- Performance differences exist among different implementations of EE algorithms

Conclusion and Future Work Cont'd

- The incorporation of a noise reduction algorithm can expand the range of effectiveness of EE algorithms
- Results can potentially guide the choice and activation of EE algorithms in assistive hearing devices
- Benchmarking the performance of EE algorithms with different type of background noise
- Implementing EE algorithms in real time using open source Master Hearing Aid framework

References

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