W13a

The "Temporal Limits Encoder" for Cochlear Implants: Its Potential Advantages and An FFT-based Algorithm

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Background:

Most CI strategies preserve only temporal envelopes from a small number of frequency channels (e.g., 12/MED-EL, 16/AB, 22/Cochlear, 24/Nurotron). Because:

1) there is a upper temporal pitch limits (~300 pps) for CI's electric hearing;
2) the interleaved sampling among channels was acknowledged as a proper way to reduce inter-electrode current field interaction, and this sampling operation should be done on a slowly varying signal, according to the Nyquist Sampling Theorem and a CI Psychophysical sampling theorem (Mckay, et al., 1990s)

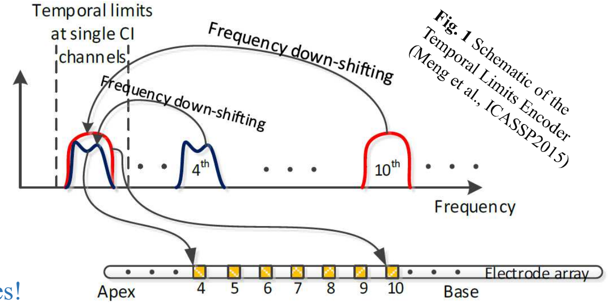

Fig. 1 Schematic of the Temporal Limits Encoder (Meng et al., ICASSP2015)

New Idea: TLE

Do not extract envelope as the continuous interleaved sampling (CIS) strategy does!

Do frequency downshifting on the band signal to a range where the frequency varying is slow enough (lower than the upper temporal pitch limit) to be detectable and fast enough (higher than the lower temporal pitch limit) to be perceived as a pitch varying but not a loudness varying (See Fig.1). So, it is named as a temporal pitch limits encoder (TLE) strategy.

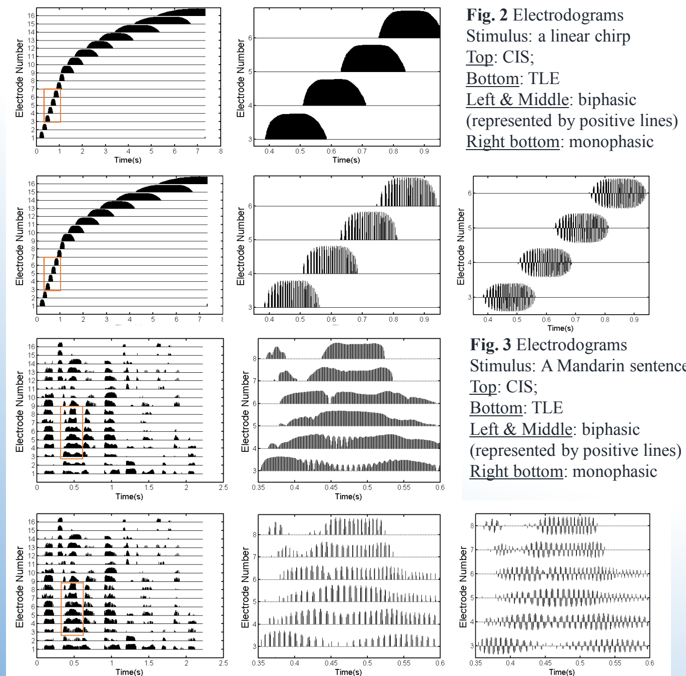

Fig. 2 Electrodograms
Stimulus: a linear chirp
Top: CIS;
Bottom: TLE
Left & Middle: biphasic (represented by positive lines)
Right bottom: monophasic

Fig. 3 Electrodograms
Stimulus: A Mandarin sentence
Top: CIS;
Bottom: TLE
Left & Middle: biphasic (represented by positive lines)
Right bottom: monophasic

Electrodogram generation method details:

The stimulation rate is 1000 pulse-per-second.
The temporal limit range was set as [100,300] (Hz).
An identical power-law function (p = 0.2) was used in both strategies.
The stimulus in Fig.2 is a linear chirp; the stimulus in Fig.3 is a Mandarin sentence: tā chī wǎn fàn jīng cháng qù sàn bù (他吃完晚饭经常去散步)

Advantages of TLE: See Fig. 2 & 3

1. Preserve the same overall temporal envelopes as CIS; (Left column)
2. Frequency variation within each band is preserved; (Middle column)
3. Monophasic pulses can also be used; (Right column)

Potential benefits of TLE on sound perception with CIs

In Meng et al., (2016), we introduced TLE from the perspective of temporal fine structure (TFS) enhancement. However, the TFS enhancement in TLE is achieved very implicitly and not intended actually: a frequency downshifting operation produced a slowly-varying duplicate of the original band signal and coincidently the duplicate can be seen as a combination of the original temporal envelope and a slowly-varying TFS.

Whatever, in TLE, more temporal variation information originated from incoming sound can be represented in a slowly varying manner which is presumed to be feasible to the auditory nerves according to existing electric psychophysical datum. So, TLE potentially benefits CI users':
1. Pitch related tasks; 2. Speech-in-noise recognition;
3. Spatial hearing, including localization and spatial unmasking.

Current status:

1. An FFT based TLE algorithm with low computational complexity, which is comparable to that of ACE-like ones, has been developed.
2. Looking for collaborations on CI experiments:
   a) CI companies provide us research processors; or
   b) Scientists do the strategy evaluation in their own lab on CI Users.

References

Meng, Zheng, and Li. "A temporal limits encoder for cochlear implants." *ICASSP 2015*.
Meng, Zheng, and Li. "Mandarin speech-in-noise and tone recognition using vocoder simulations of the temporal limits encoder for cochlear implants." *JASA*. 139.1 (2016): 301-310.