W04b

Measuring the ability of clinical processors to encode binaural cues in the signal envelope

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INTRODUCTION

- Poor sound localization abilities in bilateral cochlear implant users have been attributed to the lack of sensitivity to interaural time differences (ITDs) when listening with clinical processors[1,2].
- While fine structure ITDs are discarded by the signal processing, envelope ITD cues should still be encoded by the sound processor. However, the independent operations of the sound processors in each ear may still affect the fidelity of the ITD cues available[3,4,5].
- In this work, we measure the abilities of Advanced Bionics HiRes-S and Cochlear Advanced Combination Encoder (ACE) strategies to encode a simple acoustic signal to estimate how well envelope ITD cues can be encoded.

METHOD

Stimuli

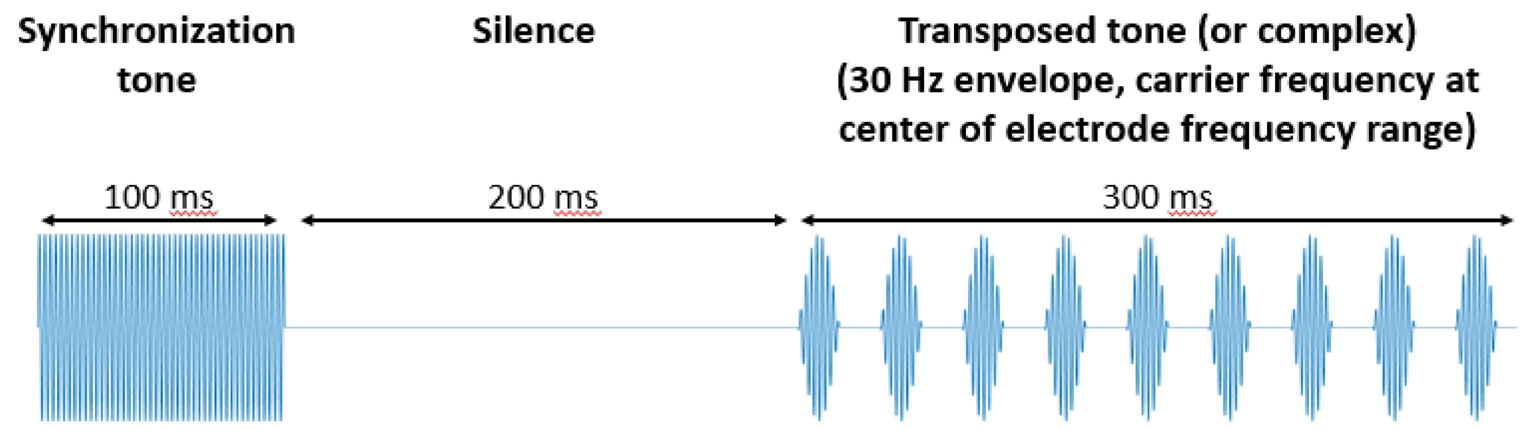

Figure 1 shows an example of a single channel stimulus. For multi-channel measurements, multiple transposed tones were added together. All channels had 30 Hz amplitude modulation.

Table 1. Measurement configurations

Electrode numbers and center frequencies are shown.

Configuration	AB Naida Q70	Cochlear Nucleus 5 (N5)
Single-Apical	2 (455 Hz)	19 (626 Hz)
Single-Mid	9 (1518 Hz)	12 (1688 Hz)
Single-Basal	15 (4251 Hz)	4 (5000 Hz)
Multi-Apical	1-8 (333,455,541,642, 763,906,1076,1278 Hz)	22-15 (251,376,501,626, 751,876,1001,1126 Hz)
Multi-Basal	9-16 (1518,1803,2142,2544, 3022,3590,4251,6652 Hz)	8-1 (2876,3313,3813,4376, 5001,5688,6501,7438 Hz)
Multi-Interleaved	2,4,6,8,10,12,14,16 (455,642,906,1278, 1803,2544,3590,6652 Hz)	22,19,16,13,10,7,4,1 (251,626,1001,1438, 2188,3313,5001,7438 Hz)

Measurement Setup

- Electrical stimulation patterns were measured using a National Instruments USB-6343 data acquisition card (NIDAQ). The NIDAQ has 32 channels of input and a maximum sampling rate of 500 kHz, though actual sampling rate of measurements depends on the number of channels recorded.
- Stimuli presented to processor via auxiliary input port

Naida Direct Connect Setup

N5 Direct Connect Setup

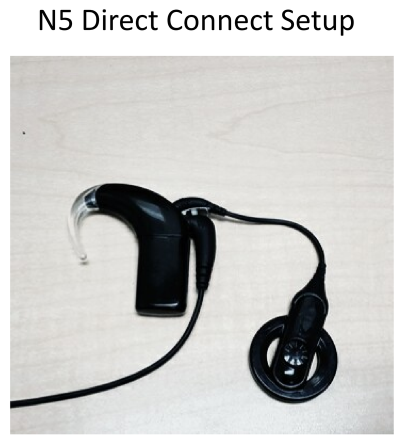

Figure 2 shows direct connect setup.

(Naida setup details courtesy of Amy Stein)

Table 2. Processor settings

Parameters	AB Naida Q70	Cochlear Nucleus 5
Strategy	HiRes-S	ACE (8 maxima)
Pulse Width	25.1 µs	25
Channel Rate	1243	900

RESULTS

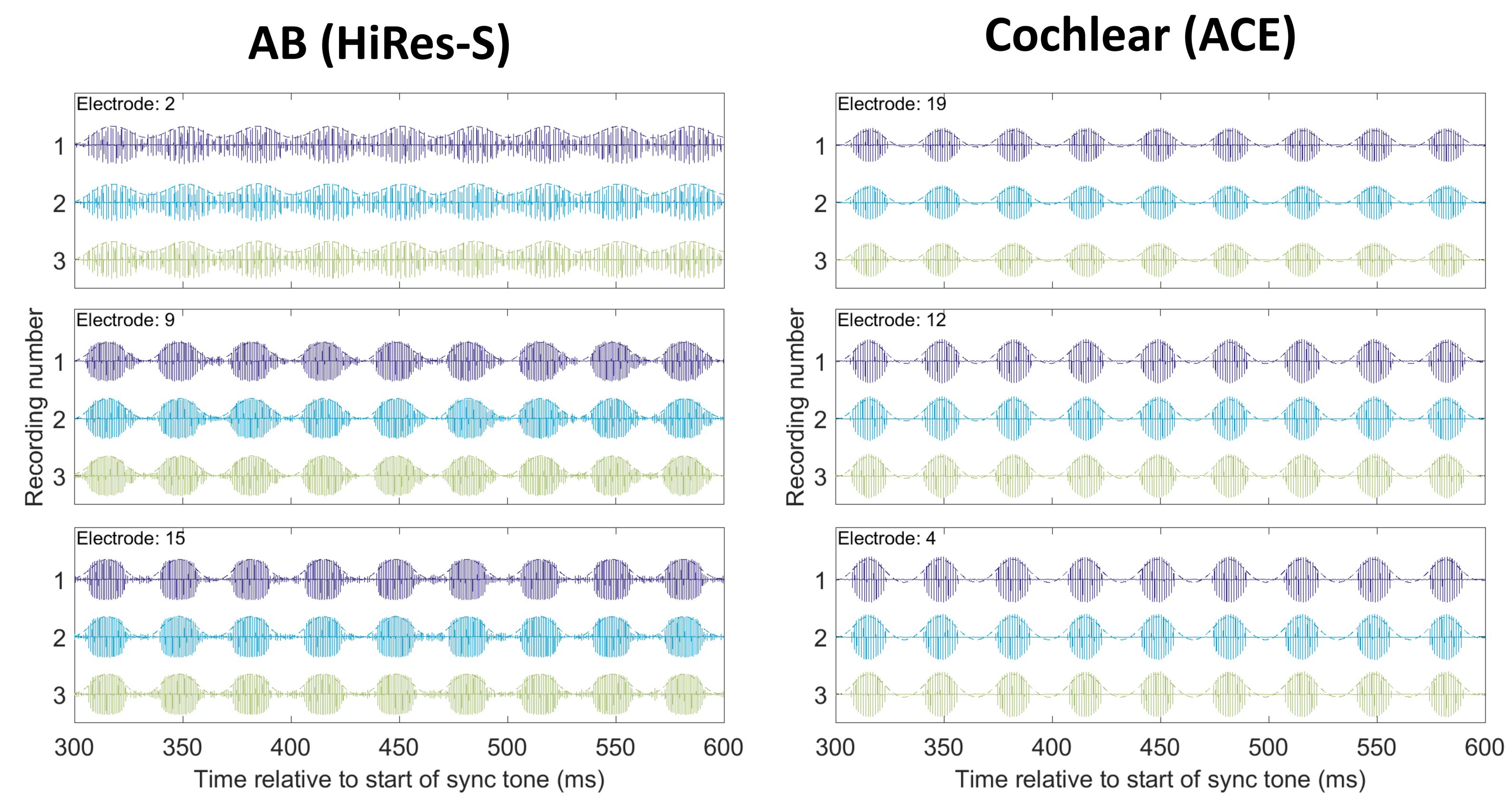

Figure 3 shows example recordings using the auxillary port for input for single channel stimuli at each target electrode. The Hilbert envelope low passed filter at 50 Hz is shown (dashed line). Each recording is sampled at 500 kHz.

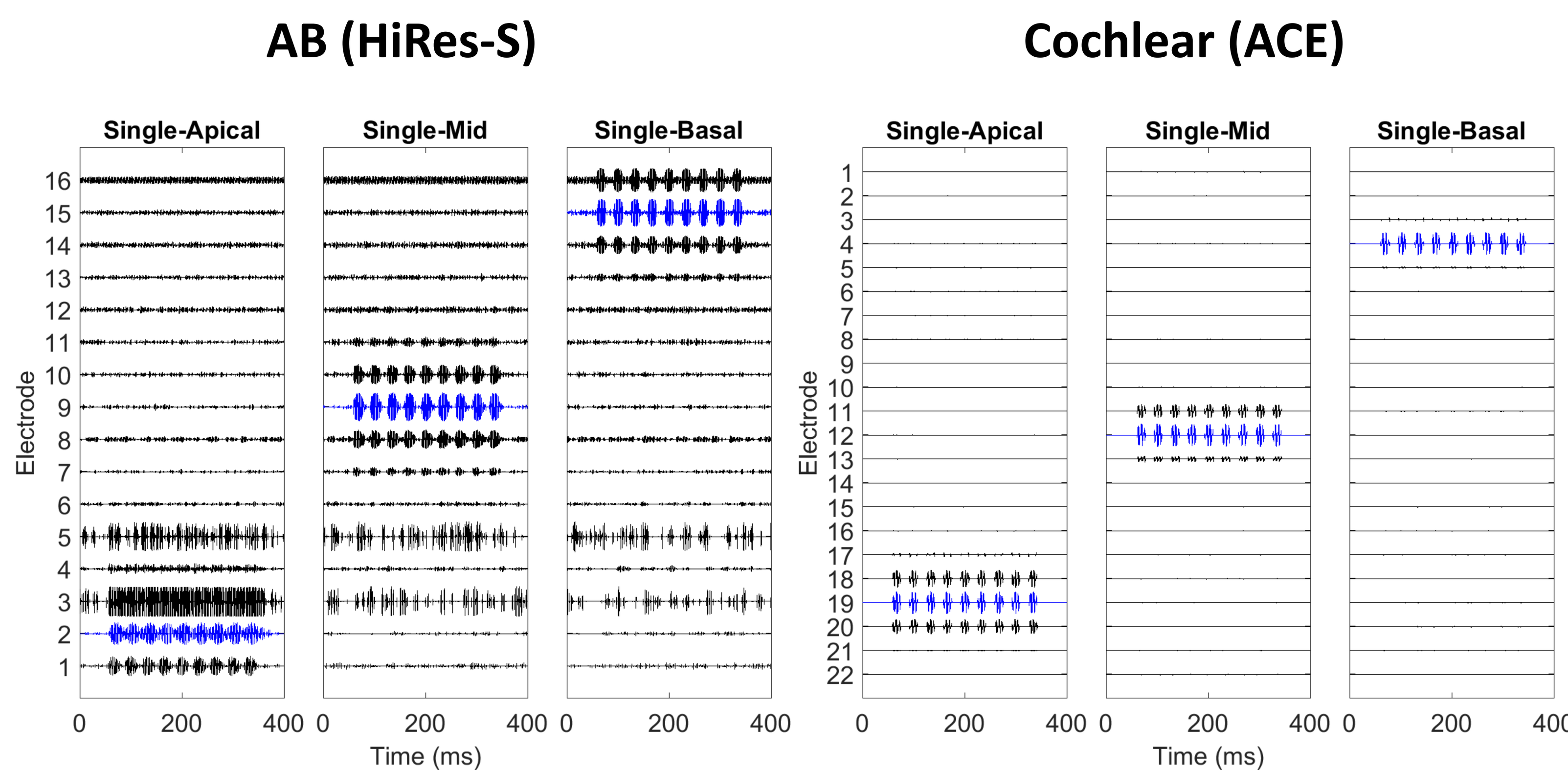

Figure 4 shows multi-channel recordings for a single channel stimuli. The target electrode is shown in blue. Activation on channels that were not stimulated are shown in black. Channel sampling is at 31250 Hz and 22727 Hz for the AB and Cochlear processors, respectively.

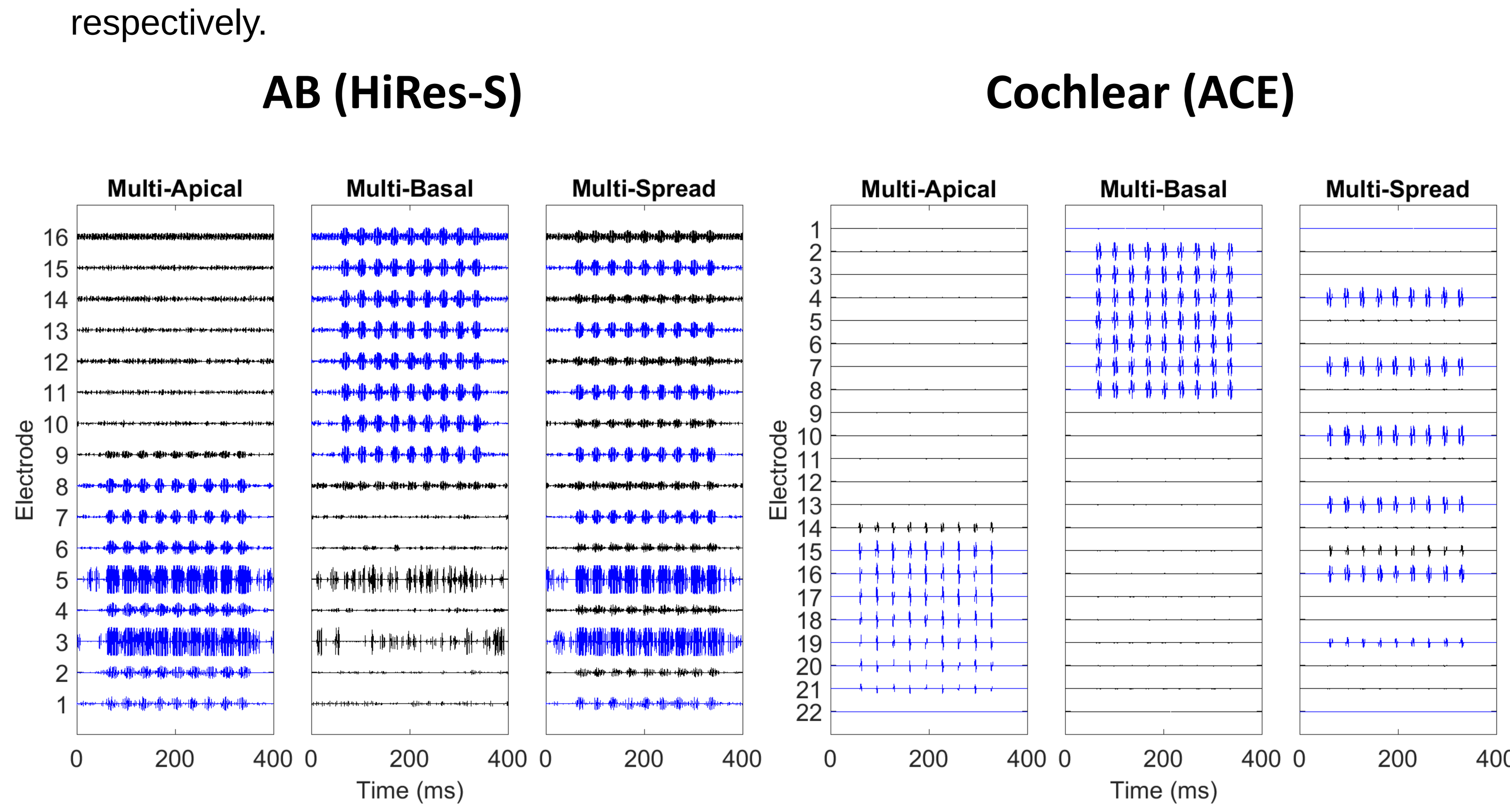

Figure 5 shows multi-channel recordings for different multi-channel stimuli. The targeted electrodes are shown in blue. Channel sampling is at 31250 Hz and 22727 Hz for the AB and Cochlear processors, respectively.

- The acoustic signal's envelope is highly reproducible across different recordings (**Fig. 3**).
- The acoustic envelope is encoded well by HiRes-S at the electrode allocated for high frequency (Electrode 15), but is temporally smeared at the low frequency electrode (Electrode 2). In contrast, ACE maintains the fidelity of the signal envelope at the three target electrodes (**Fig. 3**).
- Estimated variance in the onset of the electrical signal envelopes from 50 recordings show a small amount of jitter (**Table 3**).
- Recording on the entire electrode array shows other electrodes being activated even though only one electrode was targeted. The spread of activation on neighboring electrodes was more prevalent with HiRes-S* than ACE (**Fig. 4**).
- With multi-electrode stimulation, ACE appears to be able to reproduce the spectrum of the acoustic signal better than HiRes-S. However, the N of M channel selection of ACE appears to miss some of the targeted electrodes in favor of others (**Fig. 5**).

Table 3. Estimated Onset Jitter

Mean and standard deviation (in parenthesis) of onset jitter was estimated from 50 recordings of the single channel stimulus sampled at 500 kHz (2 µs resolution). Jitter is estimated by finding the difference between the onset of the synchronization tone and onset of the transposed tone in each recording (see Fig. 1).

Configuration	AB HiRes-S (µs)	Cochlear ACE (µs)
Single-Apical	73.8 (23.0)	9.6 (4.8)
Single-Mid	54.5 (92.5)	13.4 (4.2)
Single-Basal	45.3 (9.2)	10.7 (5.2)
Mean	57.9 (55.3)	11.2 (4.8)

*Note: the activity on electrodes 3 and 5 of the Naida Q70 is likely due to electrical interference, and not due to the signal processing.

DISCUSSION

- The relatively good envelope encoding and small onset jitter suggests that independent processors on the two ears are capable of presenting envelope ITDs with good temporal precision for simple stimuli.
- However, these processors activate channels beyond that of the spectral content of the acoustic signal. This poor spectral encoding may degrade location cues of real-world sounds by introducing random interaural time and level differences within channels that should not be active.
- The different outcomes between the HiRes-S and ACE strategies may reflect the difference between using band pass filters and Fast Fourier Transform based signal analysis.

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