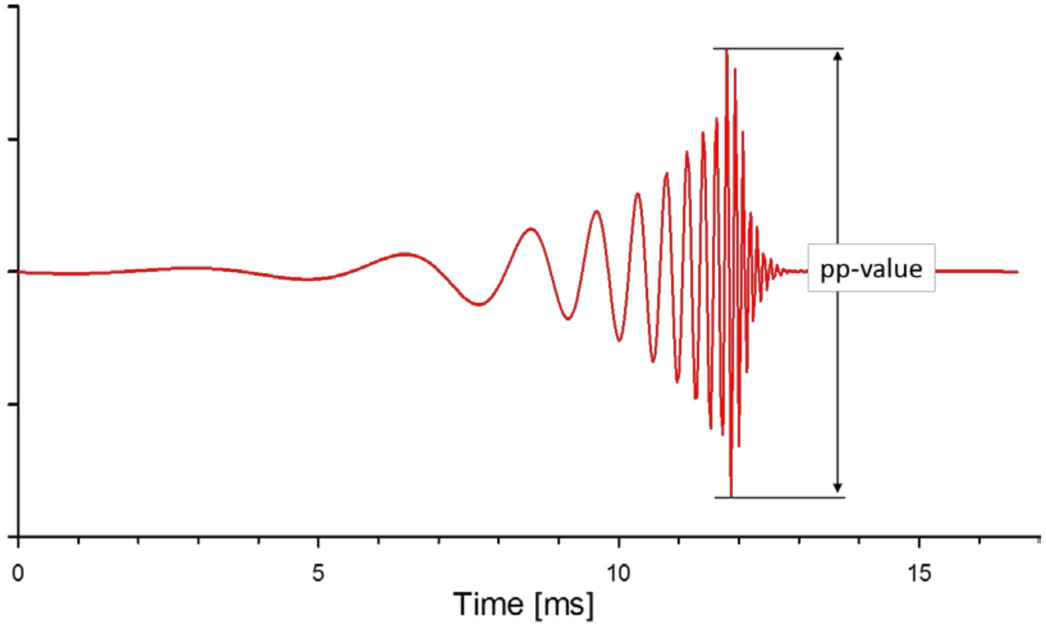
Technology Advances to Meet the Needs of Pediatric Electrophysiologic Assessments: The Use of CE-Chirp Stimuli for Pediatric Electrophysiology

A Sound Foundation Through Early Amplification 2016

7th International Pediatric Audiology



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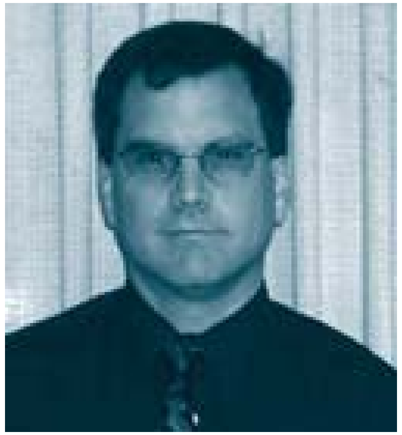
Introduction

Manny Don

Claus Elberling



Curtis Ponton

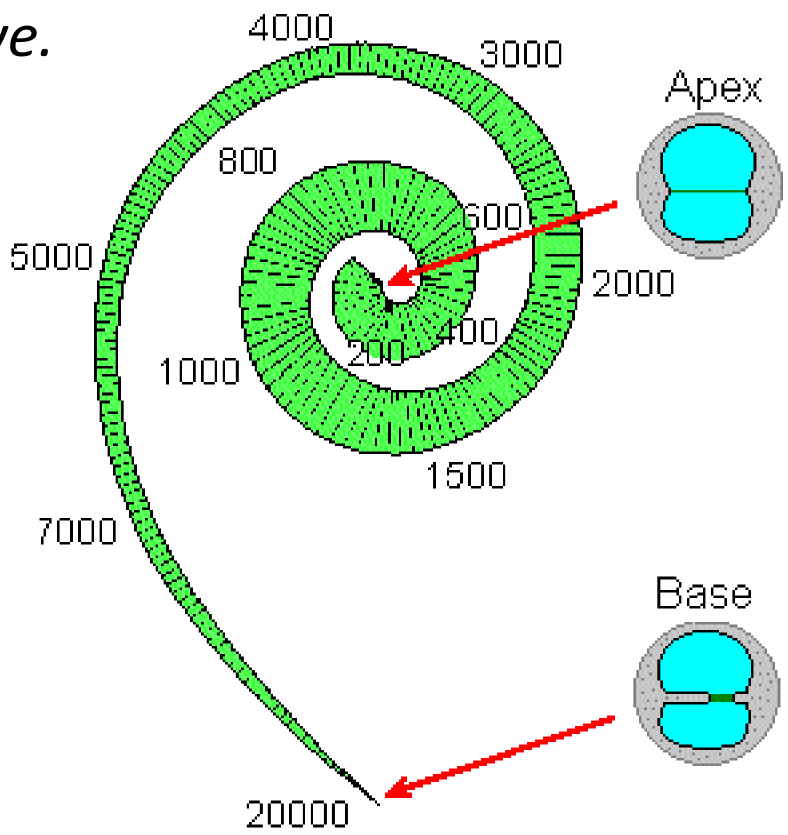
Jos Eggermont

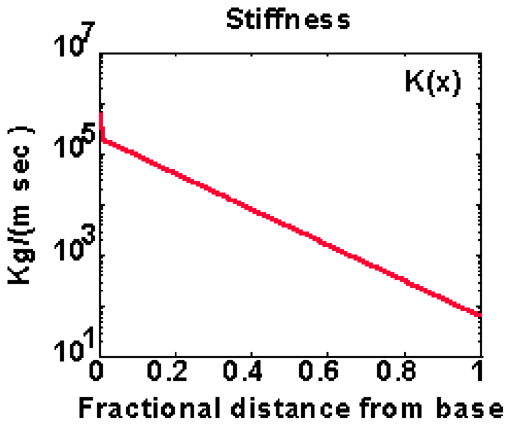
The Miracle CE-Chirp

- Stimulus that reorganizes timing of spectral stimulation to synchronize cochlear response.
- Produces response (ABR, ASSR,…) with up to 2X amplitude of traditional stimuli of same level
- Enhances response detection
- Reduces time to automated detection (Huge need)
- Lowers threshold of response detection

REVIEW OF COCHLEAR FUNCTION

Basilar Membrane
View from above.

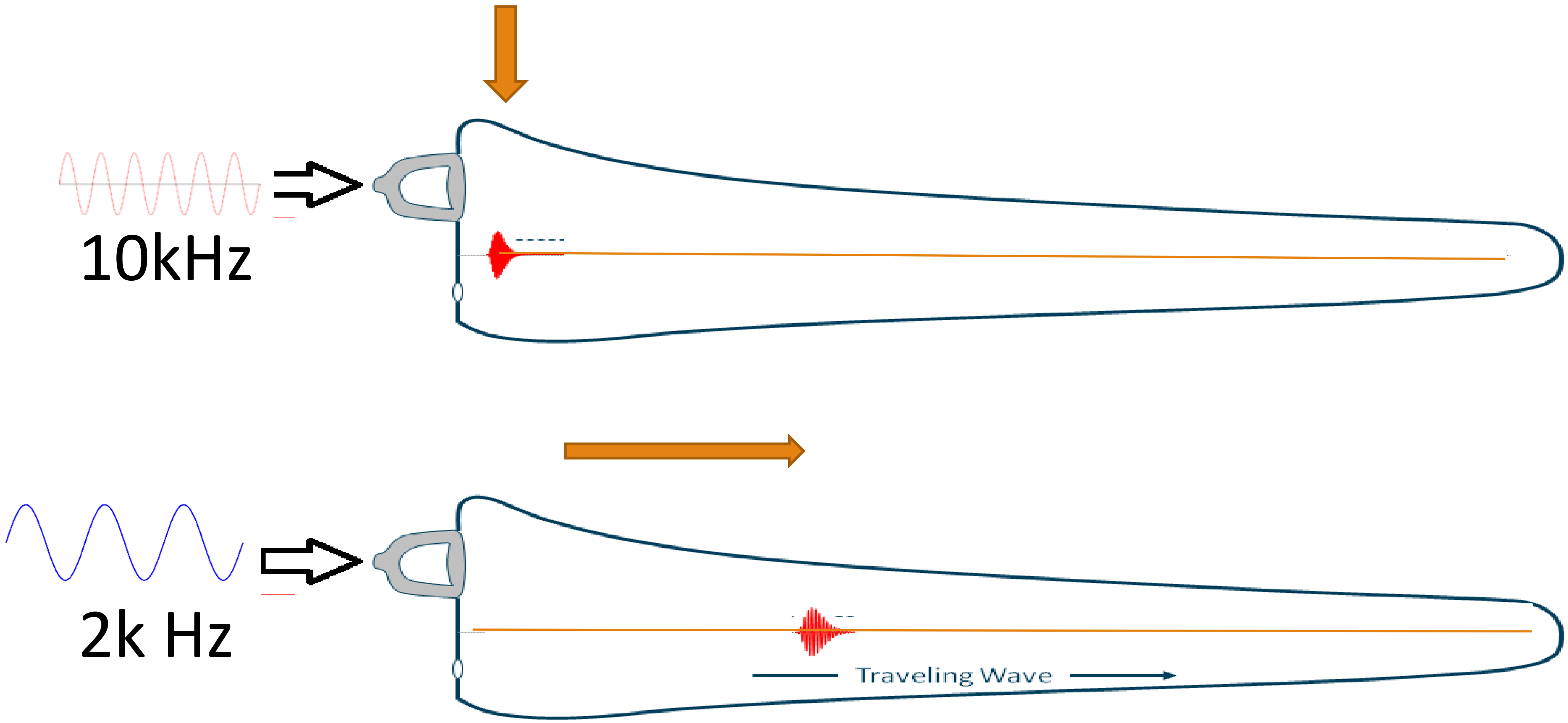




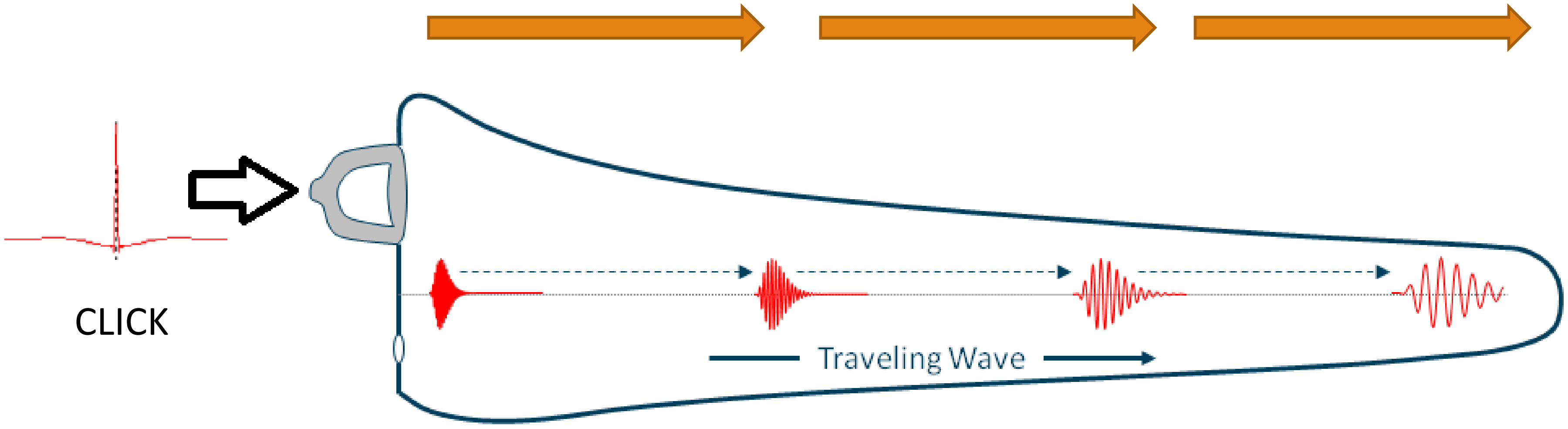
- Sound (vibration) enters the cochlea through the oval window at the base.
- The energy must travel through the fluids from base to apex until the region registering the sound frequency is reached.
- This is the traveling wave and it slows the activation of the lower frequency regions.

http://www.youtube.com/watch?v=dyenMluFaUw

TONAL STIMULUI WILL *ACTIVATE* THE BASILAR MEMBRANE *AT THEIR POINT OF RESONANCE.*

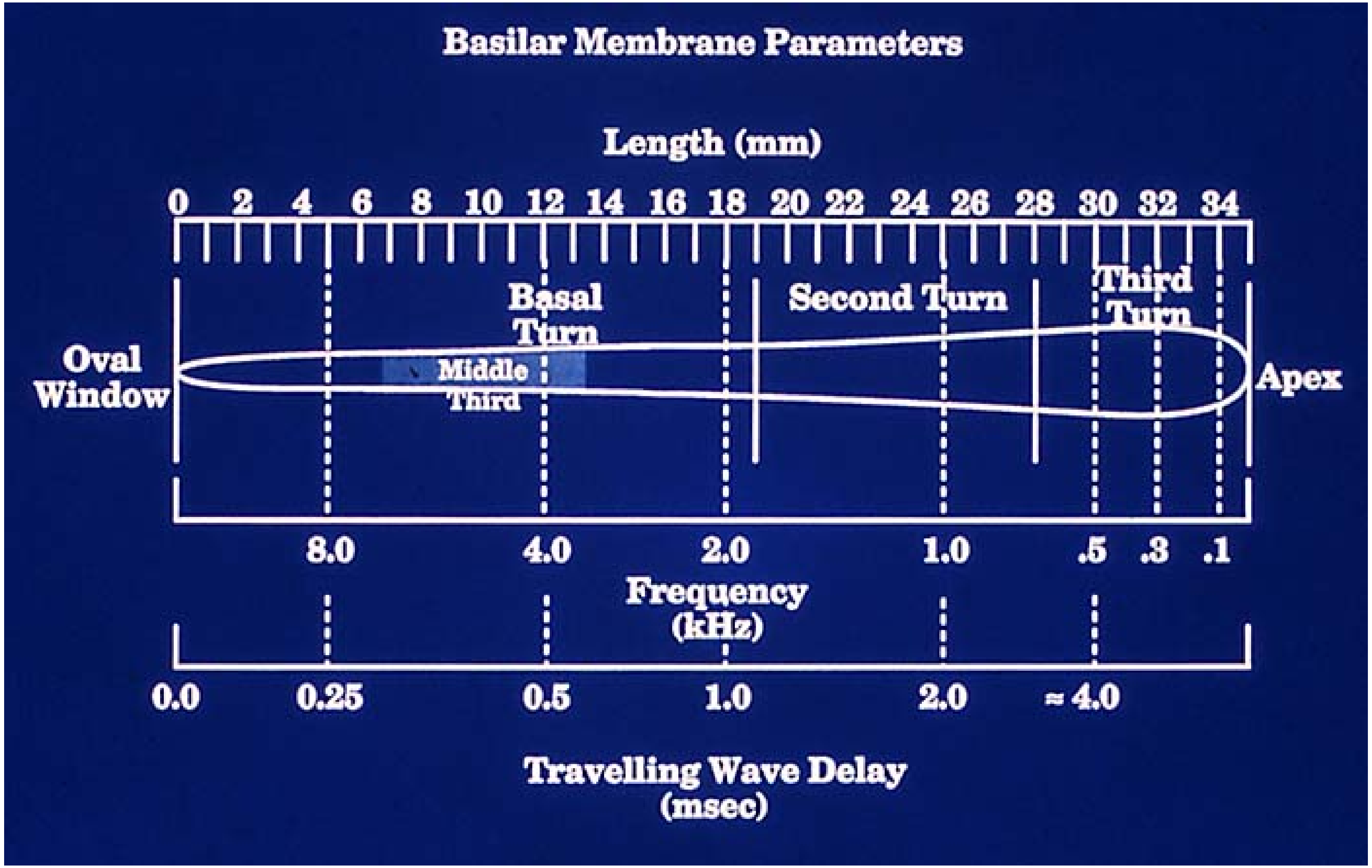


A CLICK WILL *PROGRESSIVELY* ACTIVATE THE ENTIRE LENGTH OF THE BASILAR MEMBRANE



Transient, broad band stimuli

Curtis Ponton estimates delay to 500 Hz as 4 ms

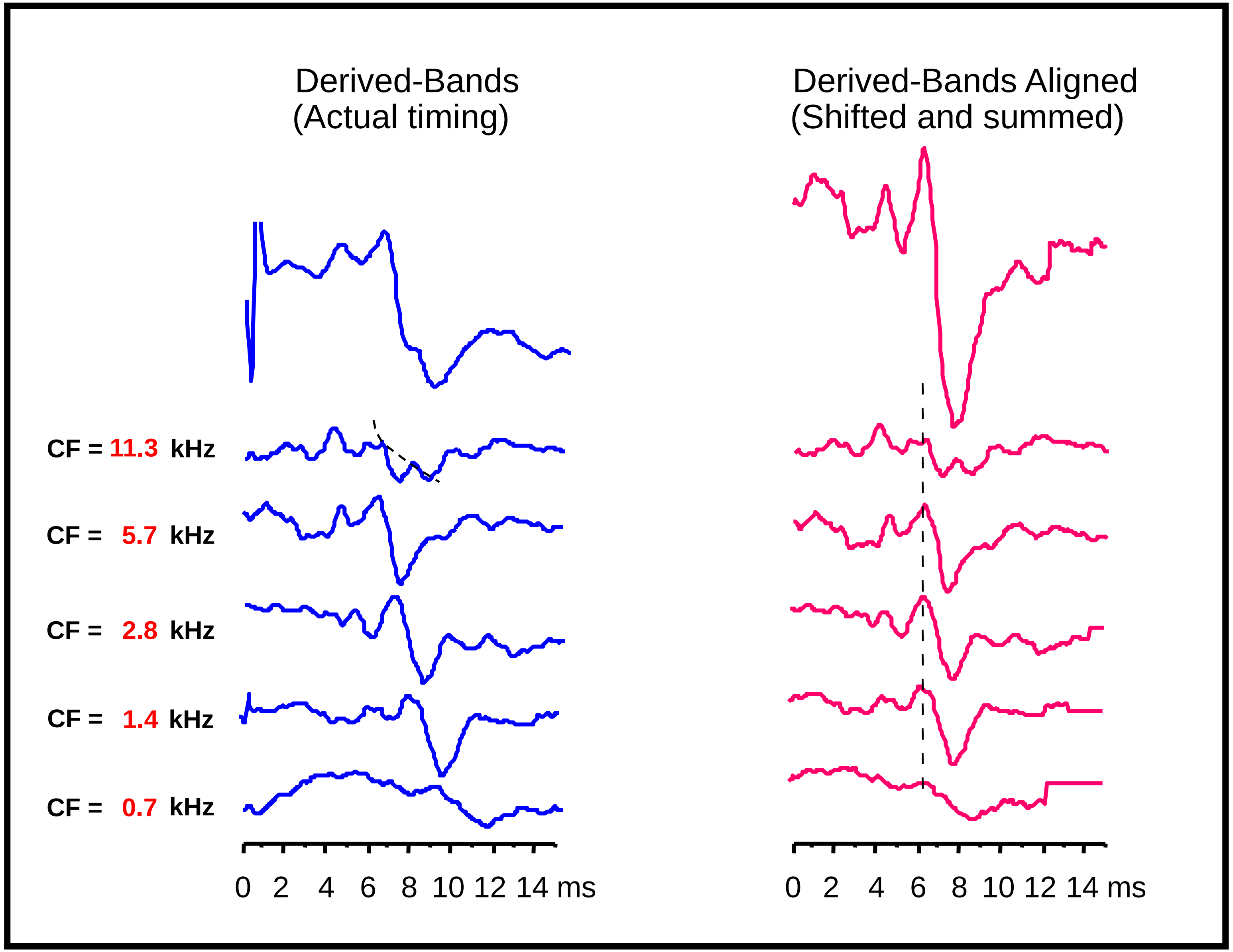


From Curtis Ponton

Stacked ABR:

Removing the Wave V delay from Frequency change- produces a much bigger component response!

M. Don – House Ear Institute, 2002



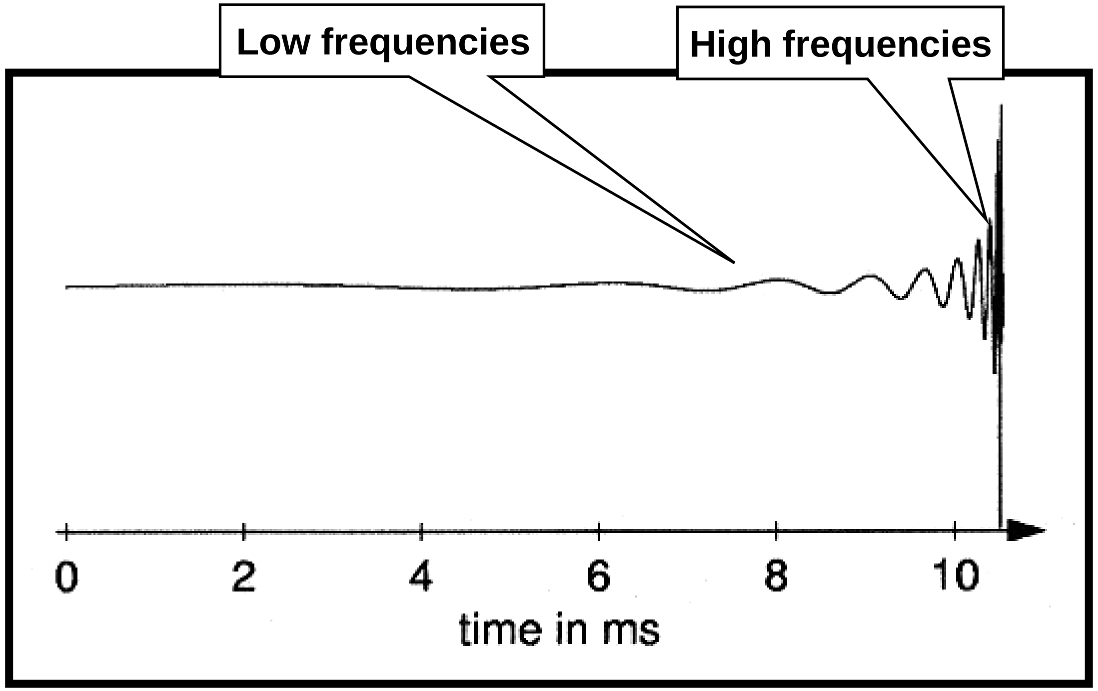
Chirps are stimuli created using “input” compensation for traveling wave delay.

Instead of compensating at the response level a chirp compensates at the stimulus.

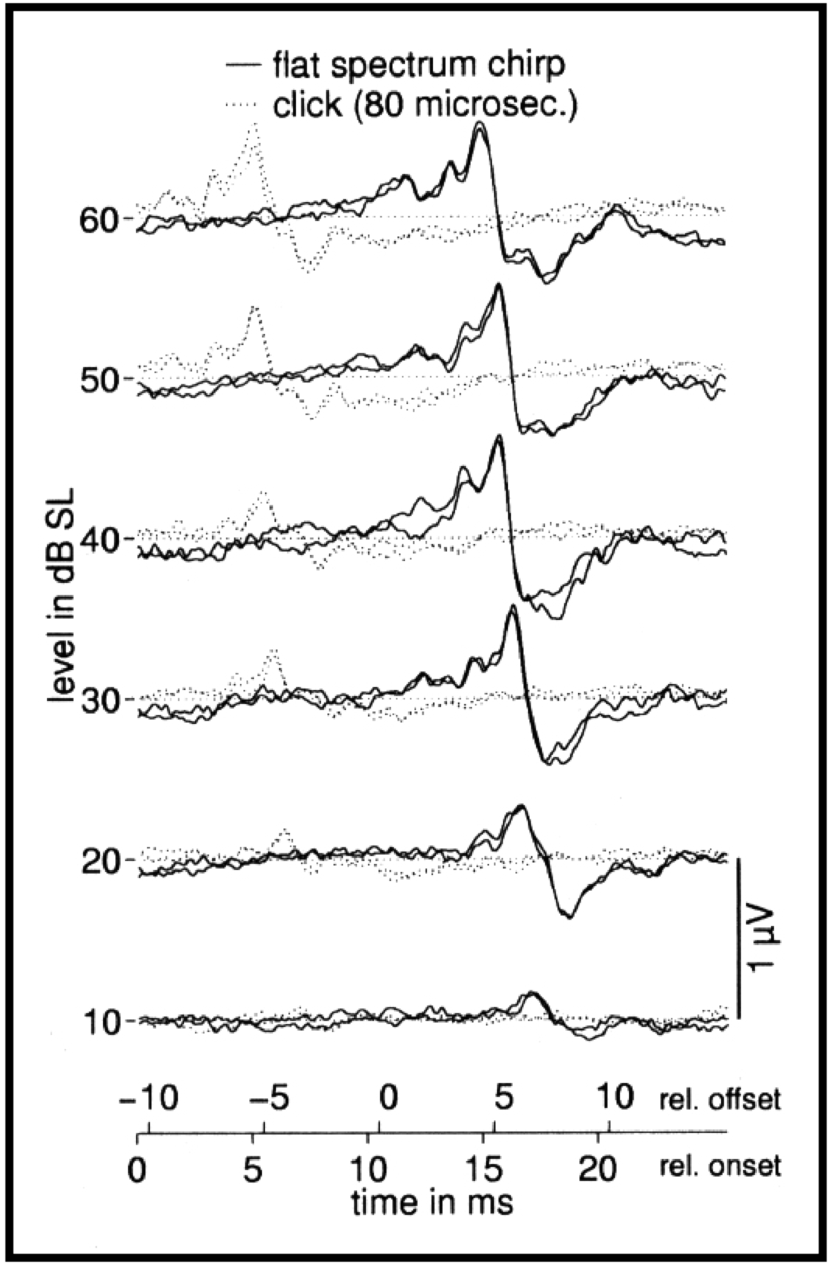
The click is broken into component frequencies. The low-frequencies are presented before the high-frequencies in a progressive manner. (Like starting the slow runners in a race first, staggering the runners by speed so they all cross the finish line together.)

A *chirp-evoked ABR* is significantly larger than a click ABR (even though they have the same spectral energy) for the same reason that the stacked ABR is bigger.

Chirp vs Click-Evoked ABR

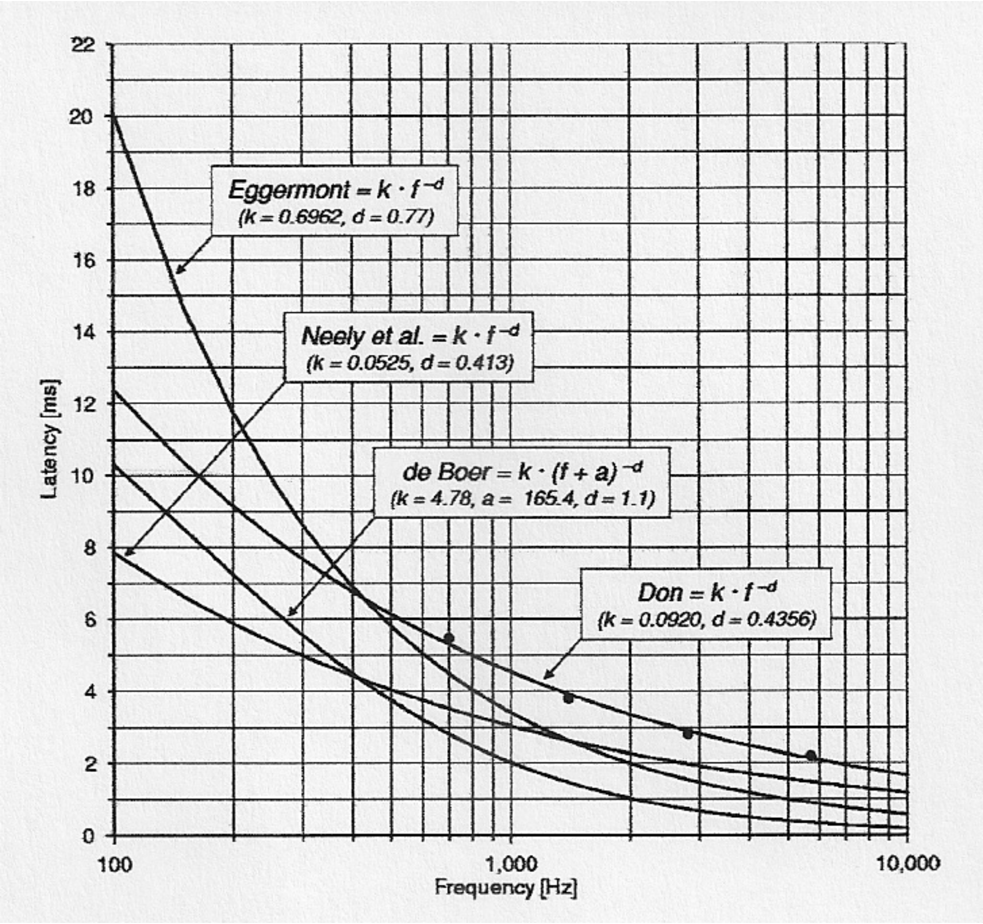


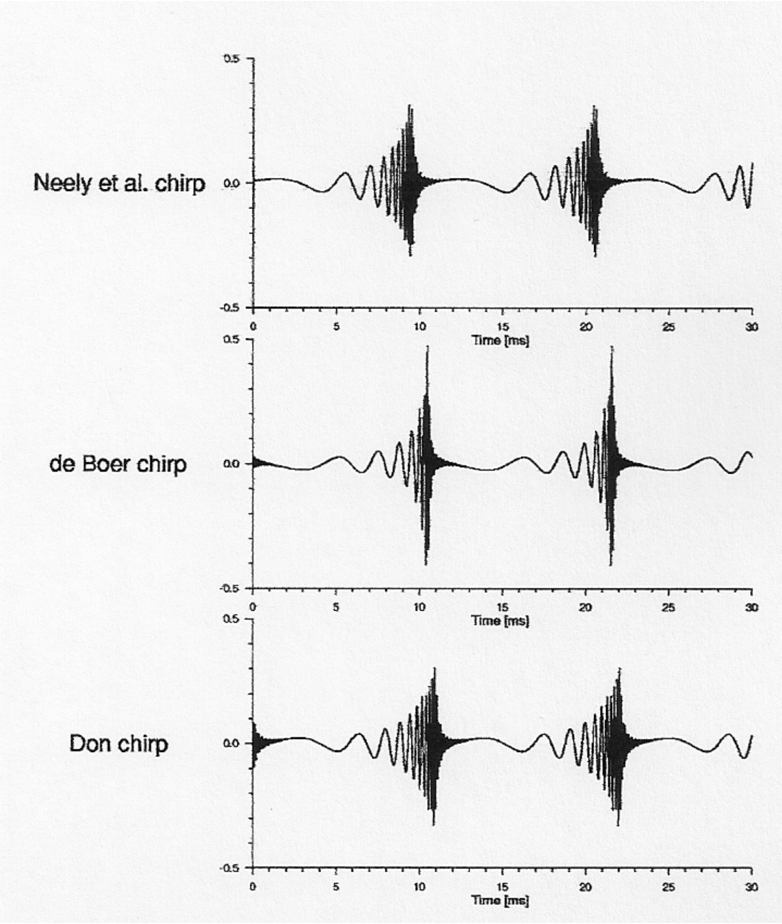
Chirp stimulus



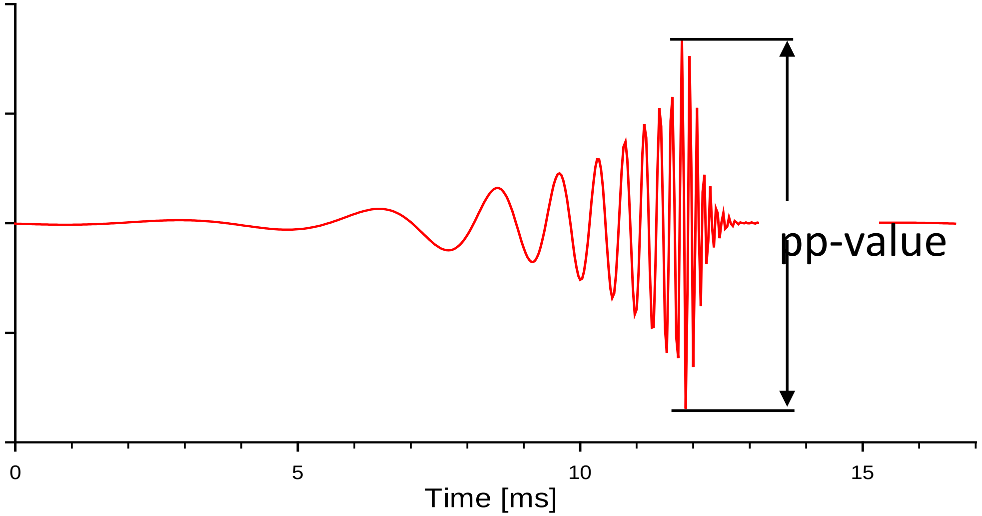
Dau et al. 2000

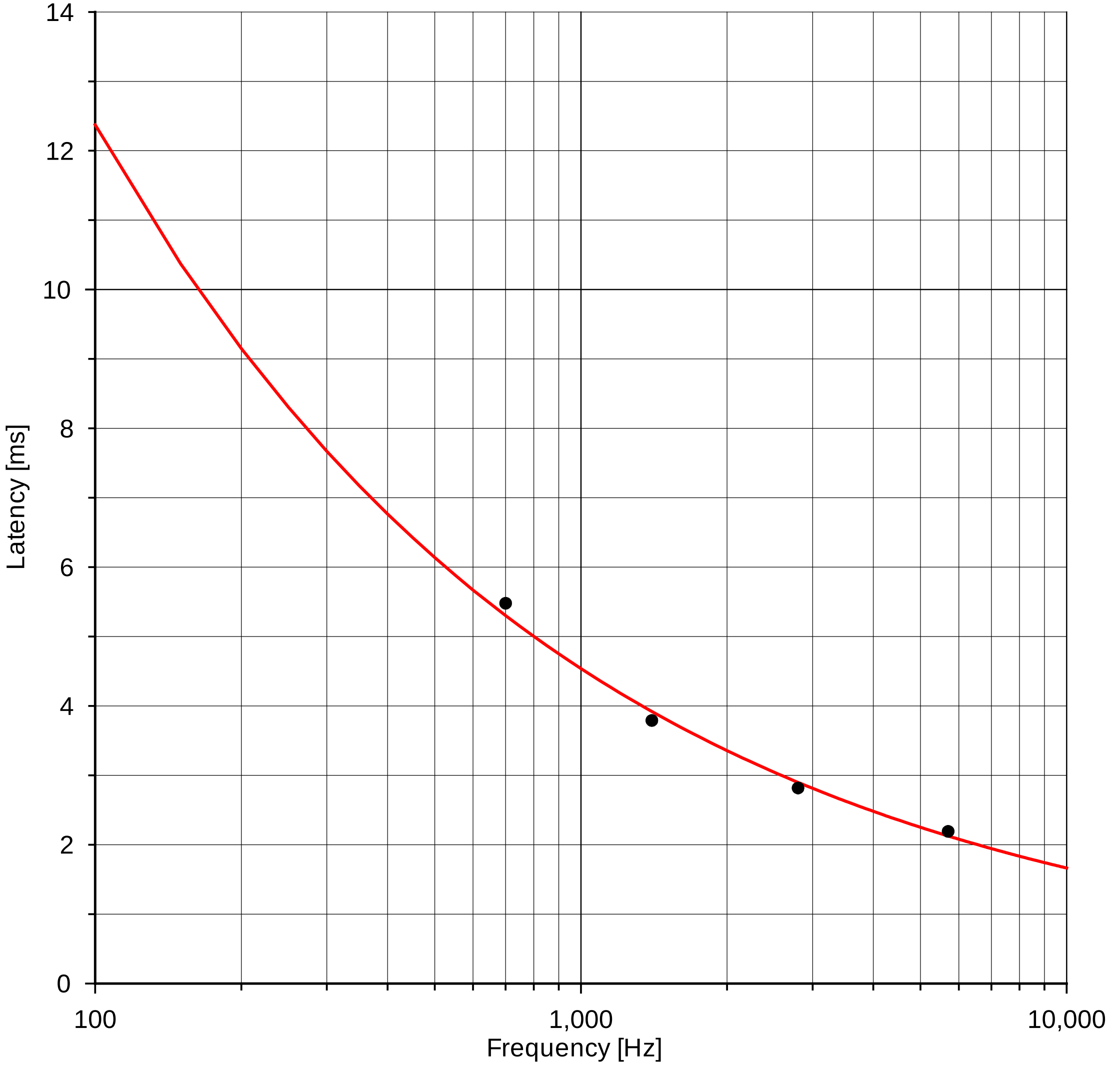
Many models of cochlear travel time have been used to develop different Chirps





CE-Chirp delay functions derived from narrow-band ABR latencies based on data from M. Don





CE=Claus Elberling

Why Use the *CE*-Chirp?

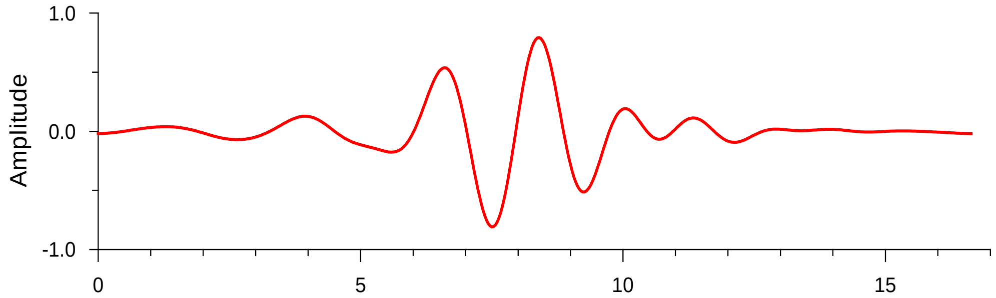
Studied most extensively

Narrow Band CE-Chirps

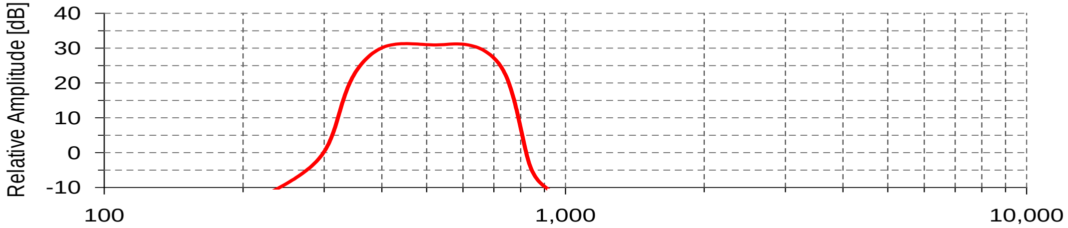
Developed Level-Specific Chirps

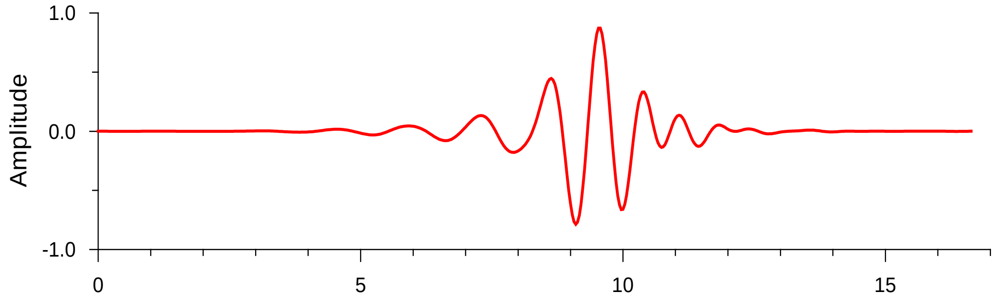
Onset timing adjusted to maximize clinical use

Narrow band CE-Chirps for Clinical Audiology

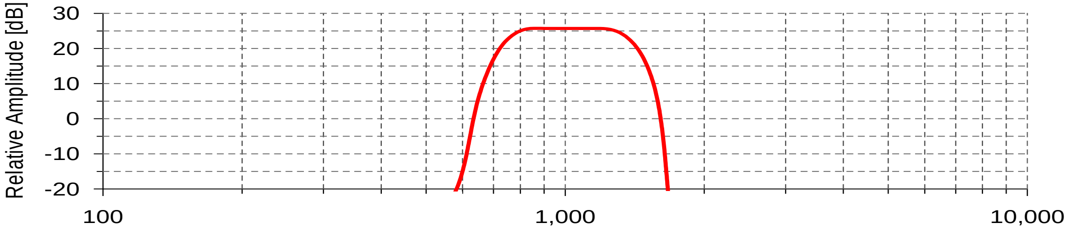


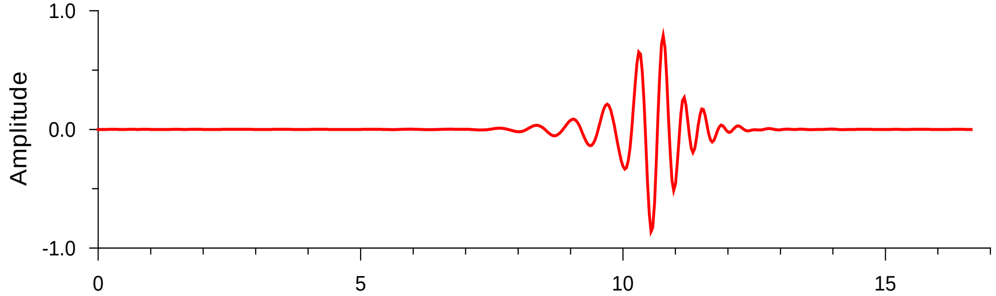
500 Hz



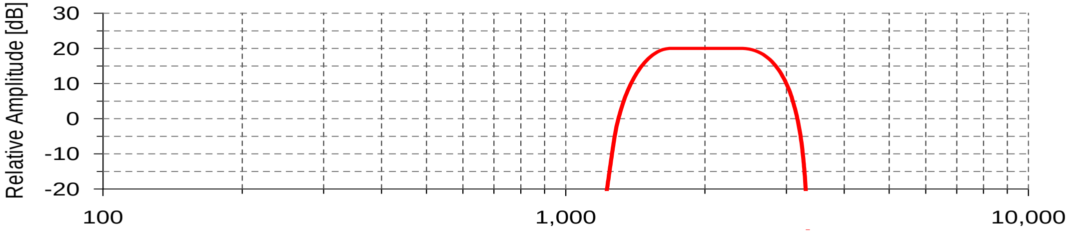


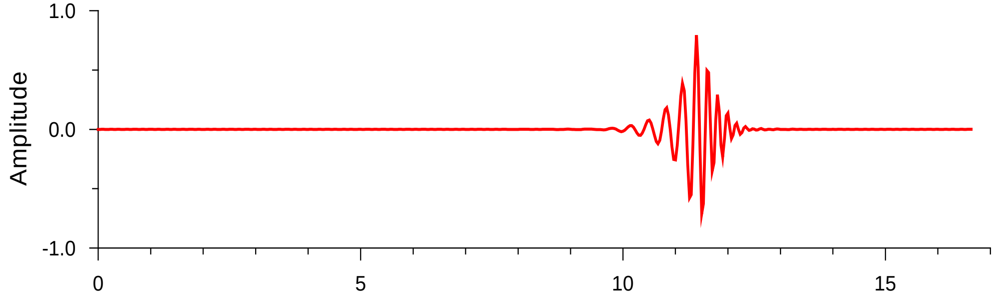
1000 Hz



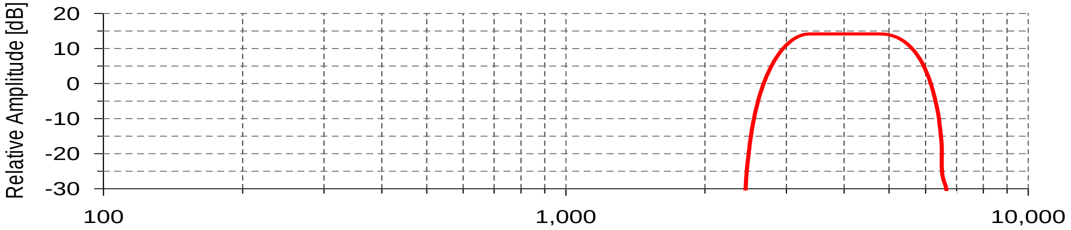


2000 Hz

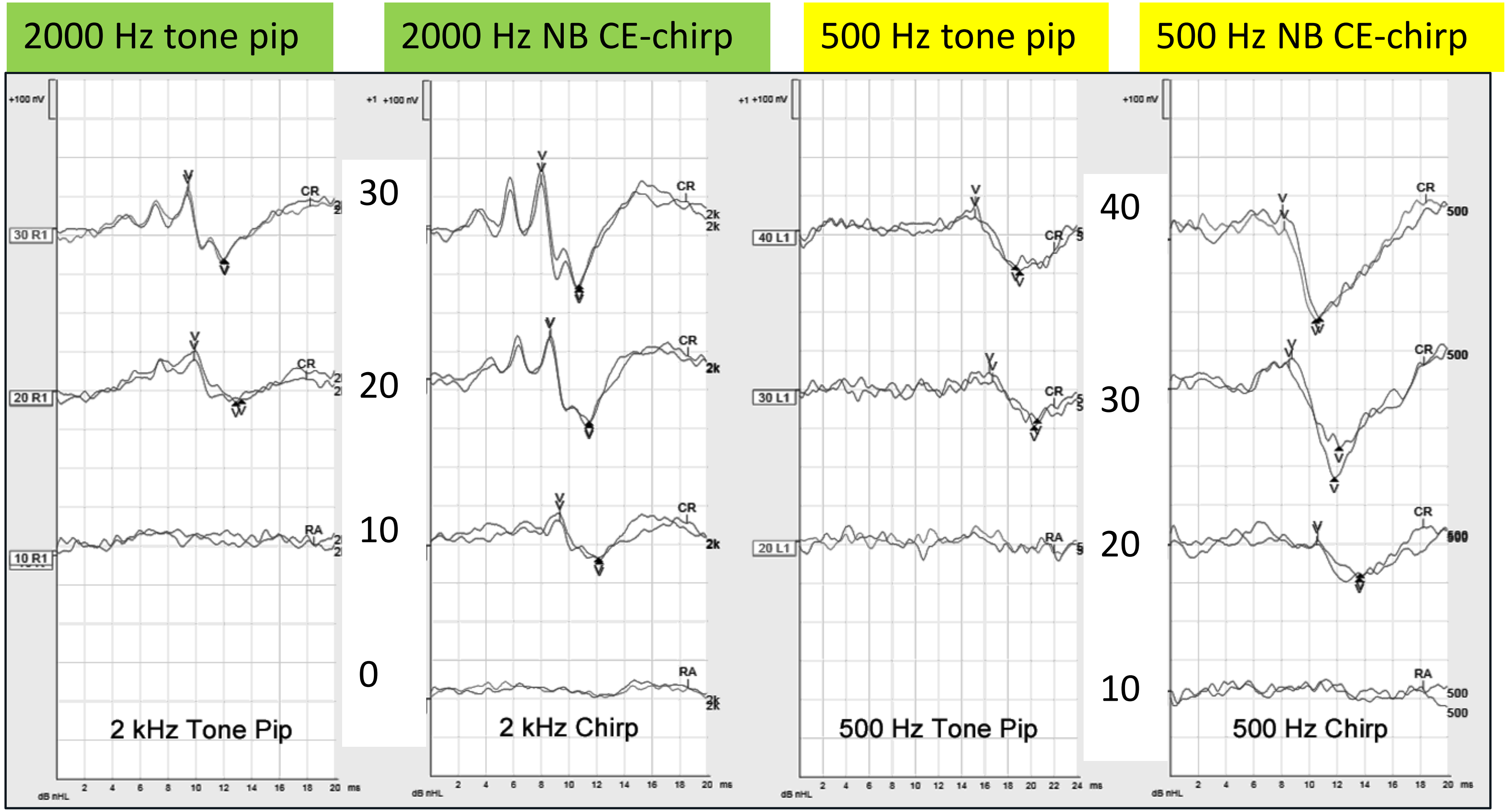




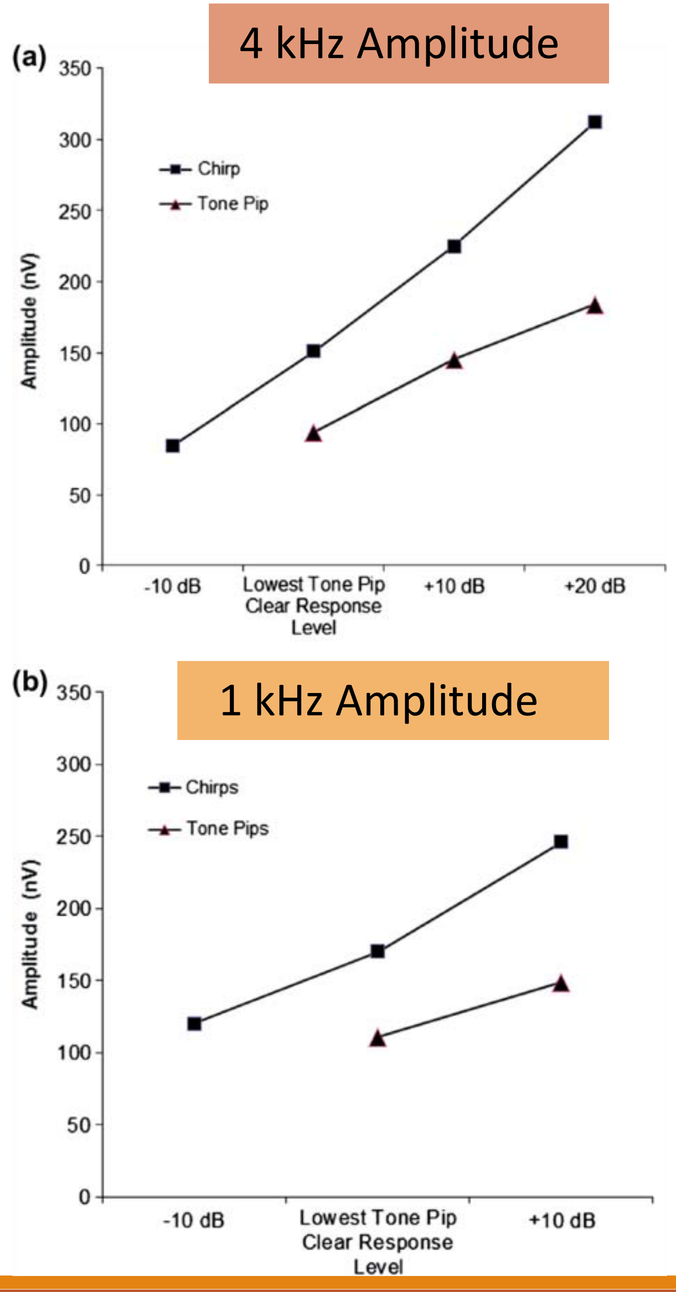
4000 Hz



Lake Como Poster filled in .5 and 2k Hz Results



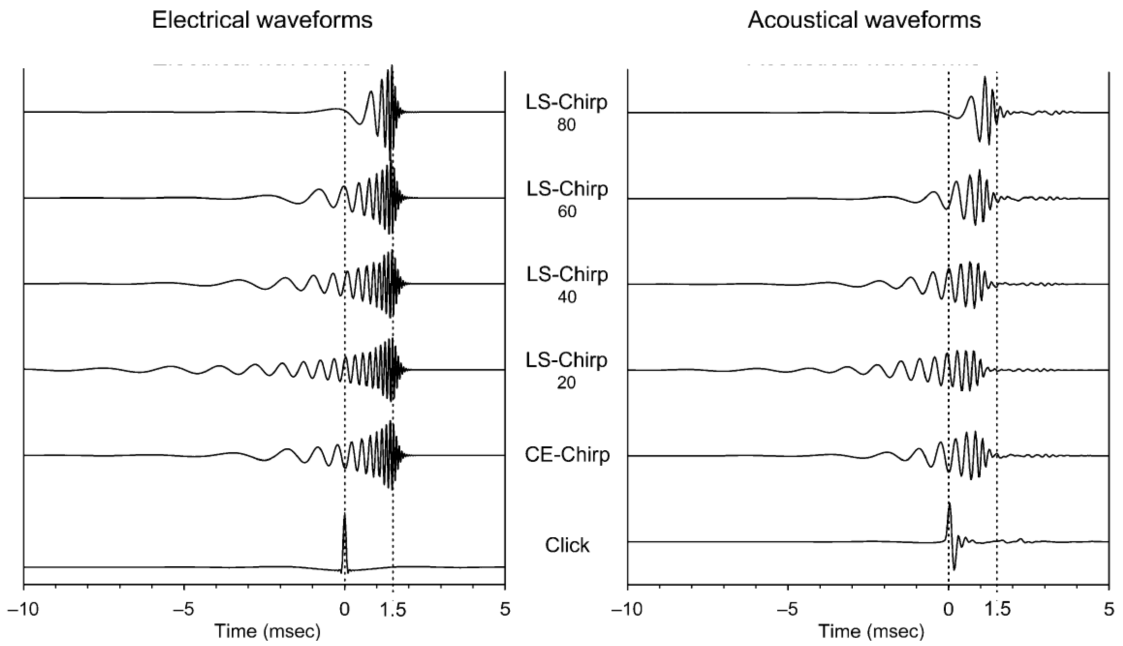
Inga Ferm* and Guy Lightfoot **Amplitudes, test time and estimation of hearing threshold using frequency specific chirp and tone pip stimuli in newborns**. HEAL 2014, Lake Como, Italy

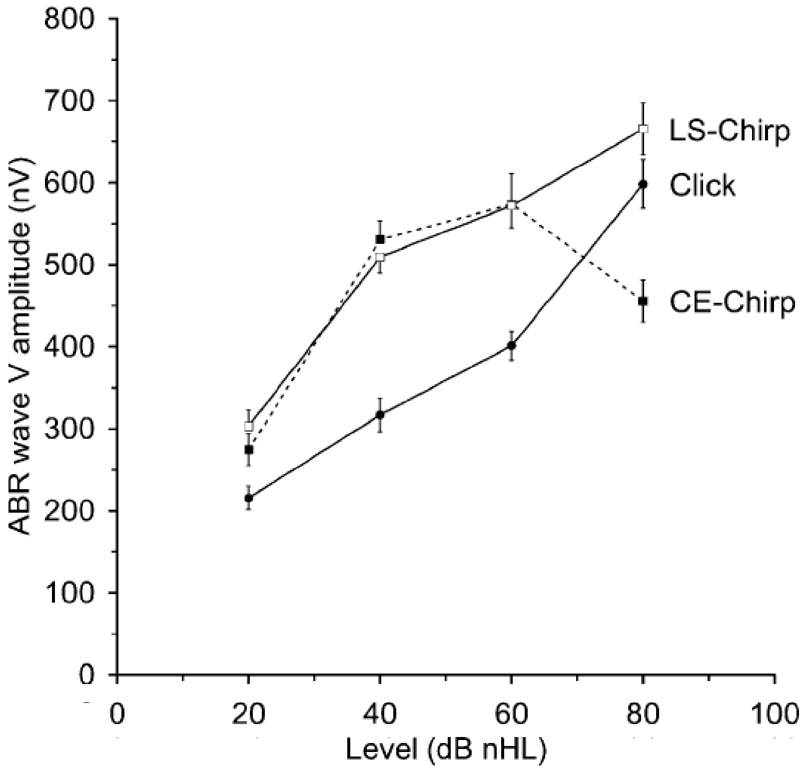


"4 kHz difference equates to an average chirp threshold advantage of 5.2 dB, whilst at 1 kHz the chirp advantage is 6.2 dB"

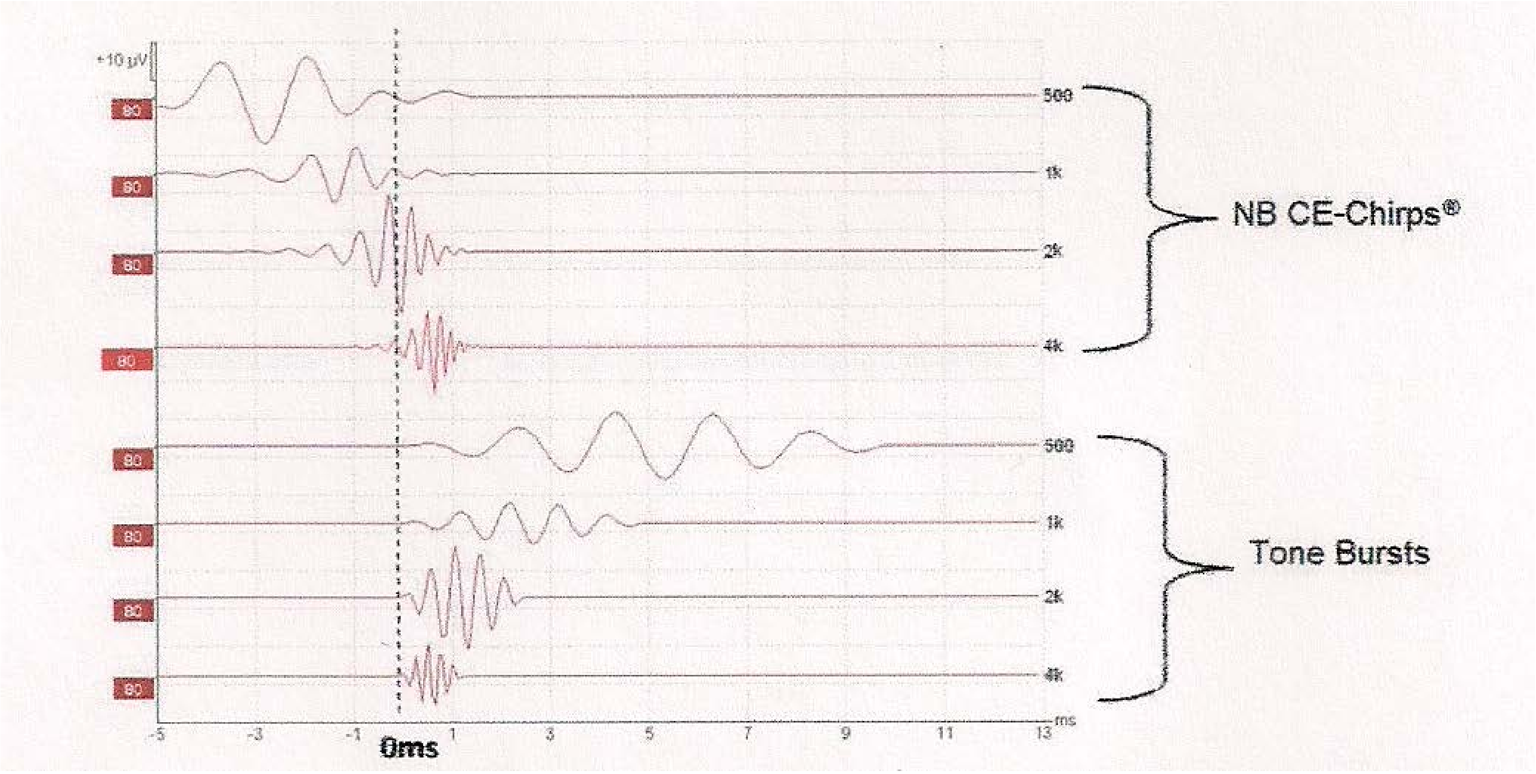
"***The mean NB CE-chirp response amplitude was approximately 50% larger than that of a pip at 2 kHz and approximately 30% larger at 500 Hz. Fmp values were typically double for NB CE-chirps***."

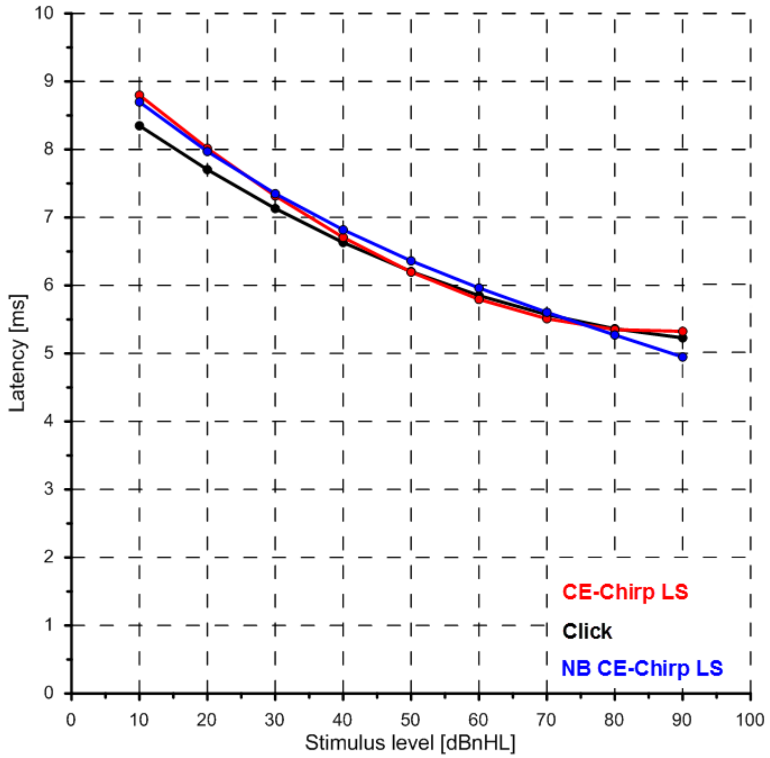
Level Specific CE-Chirps Maintain Amplitude Advantage at High Levels





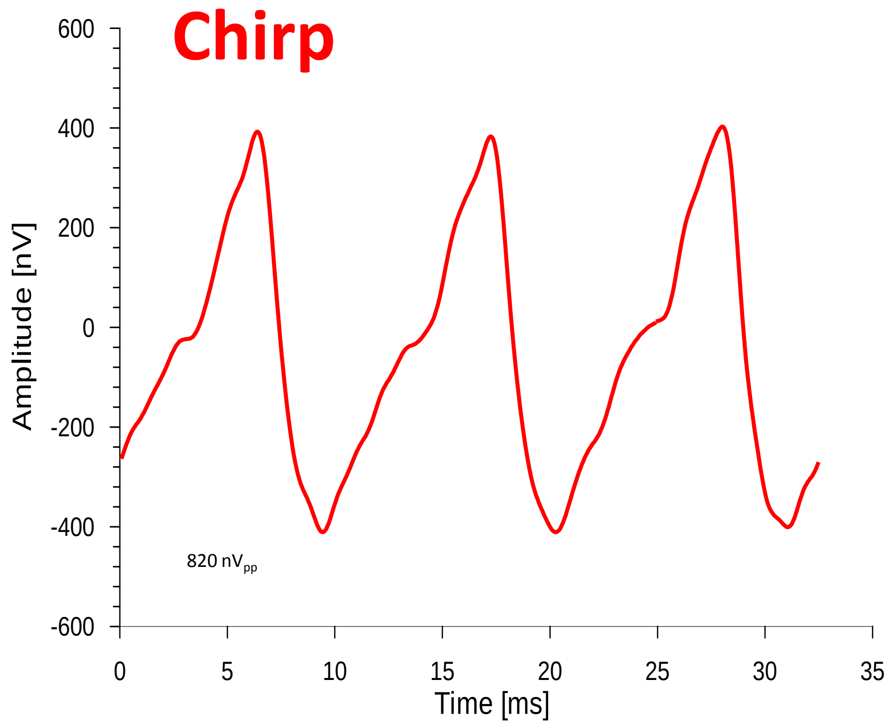
After EP4.4 Latency Norms for WB and NB CE-Chirps are as expected for Clicks

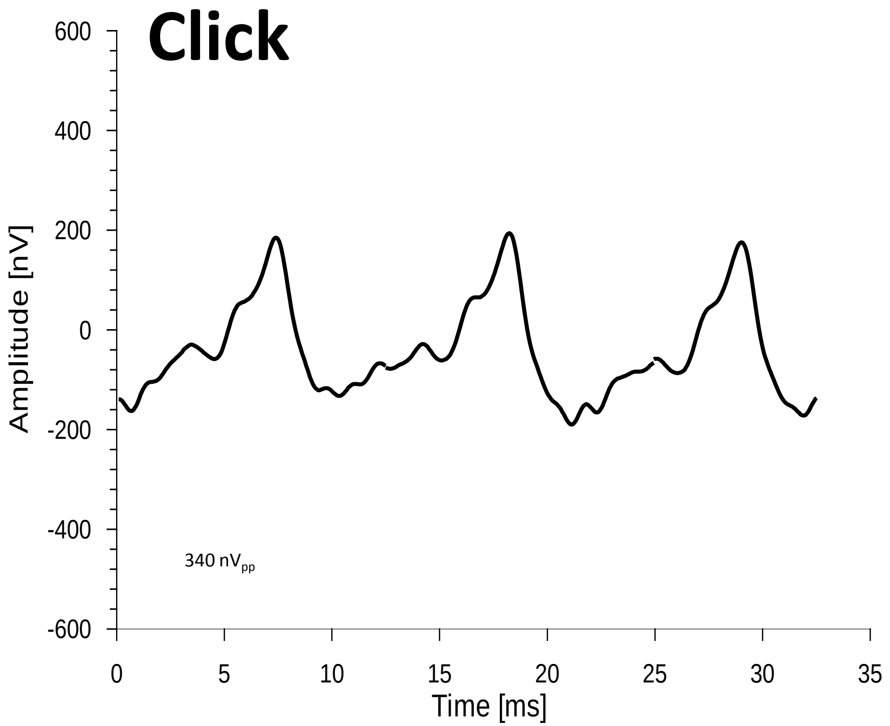




CE-Chirps also enhance ASSR amplitude!

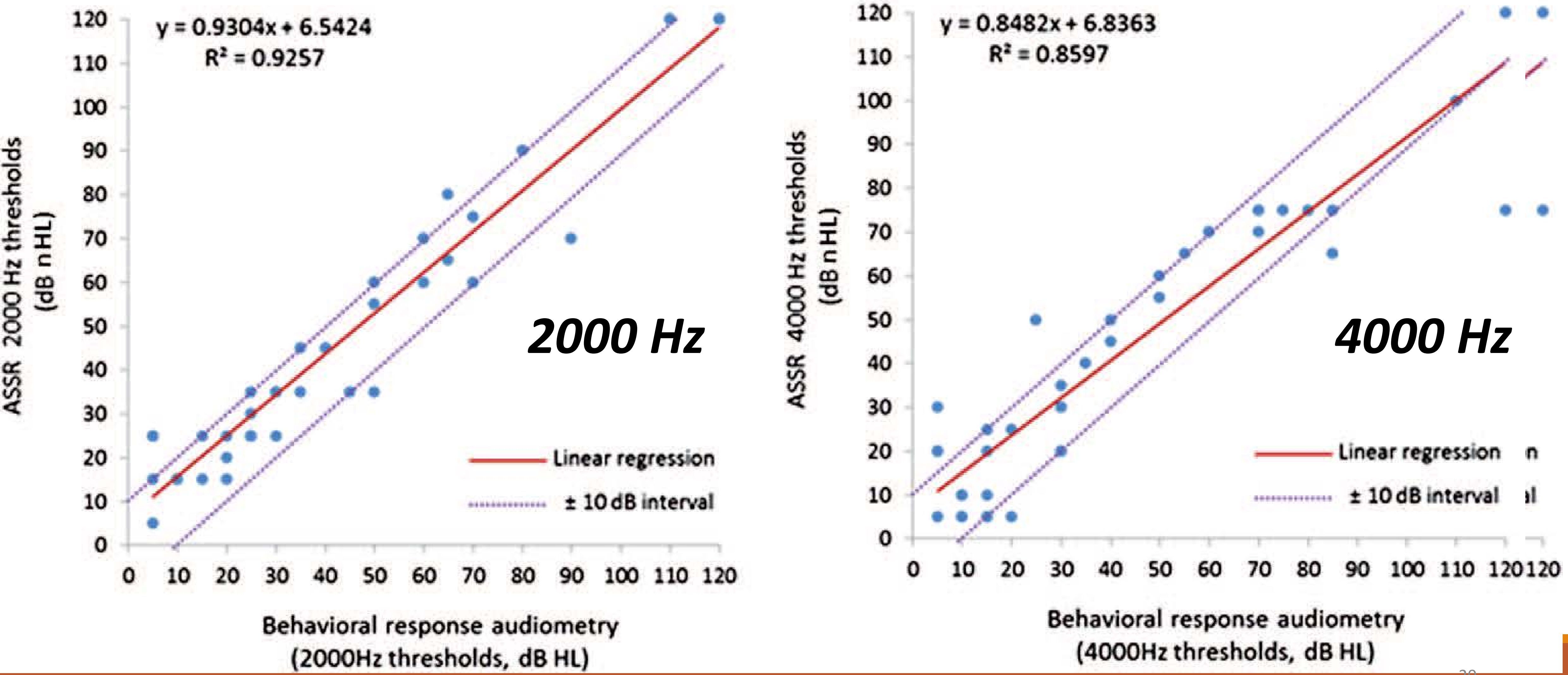
50 dBnHL

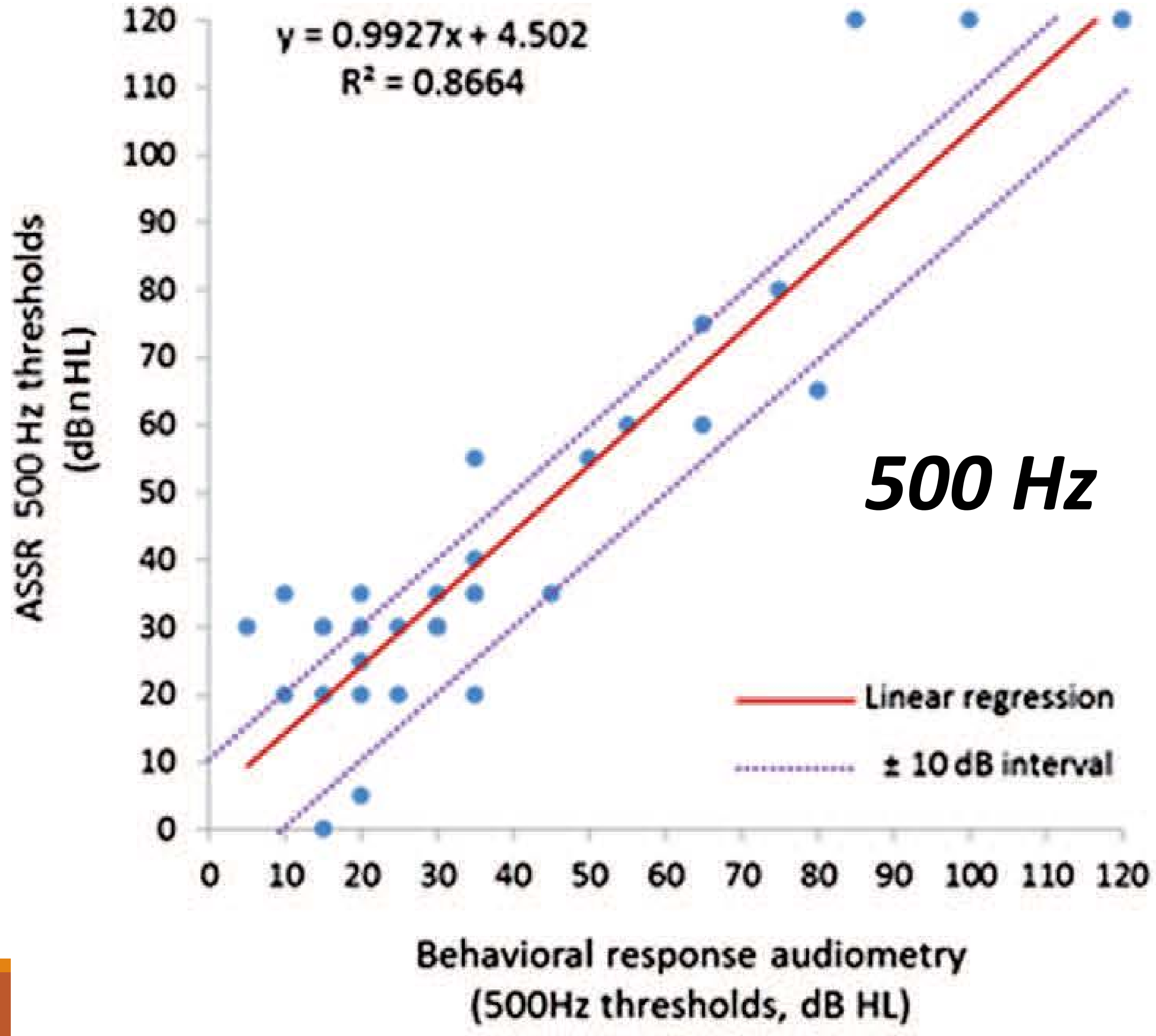


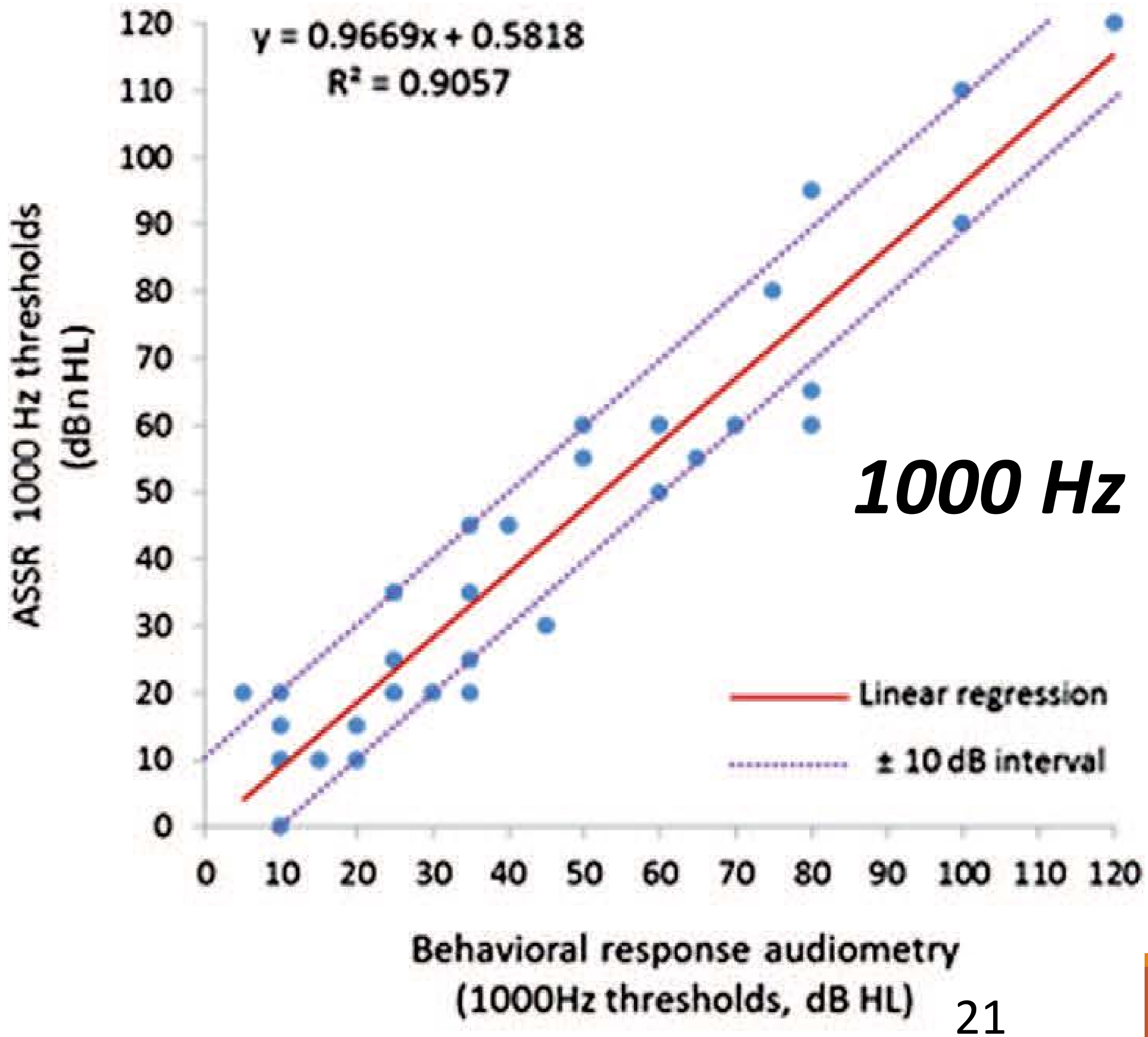


F. Venail et al. Narrow band CE-Chirps evoked ASSR in Children

International Journal of Audiology 2014; Early Online: 1–8

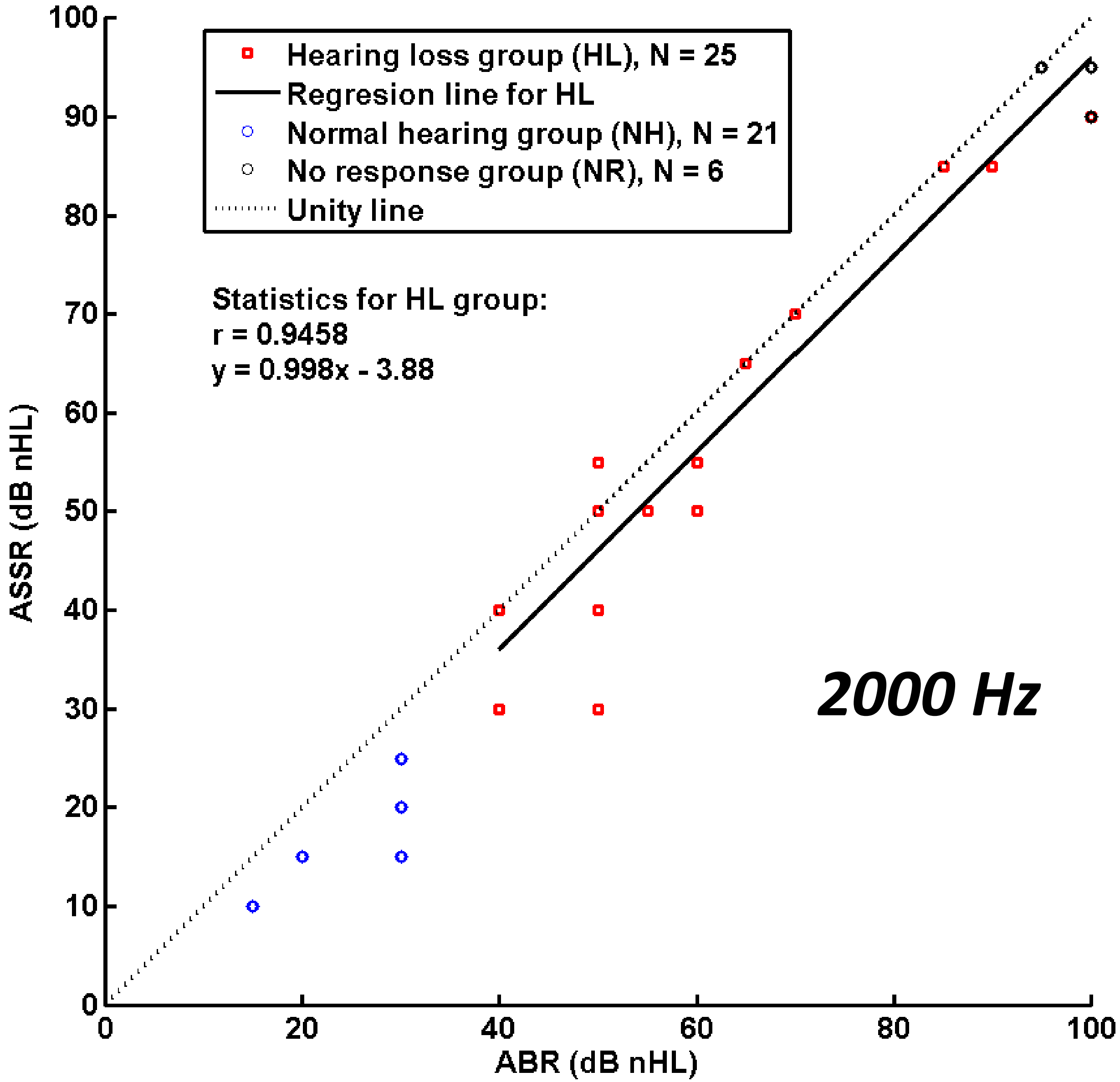



y = 0.9927x + 4.502
R² = 0.8664
500 Hz
Linear regression
± 10 dB interval
ASSR 500 Hz thresholds (dBnHL)
Behavioral response audiometry (500Hz thresholds, dB HL)

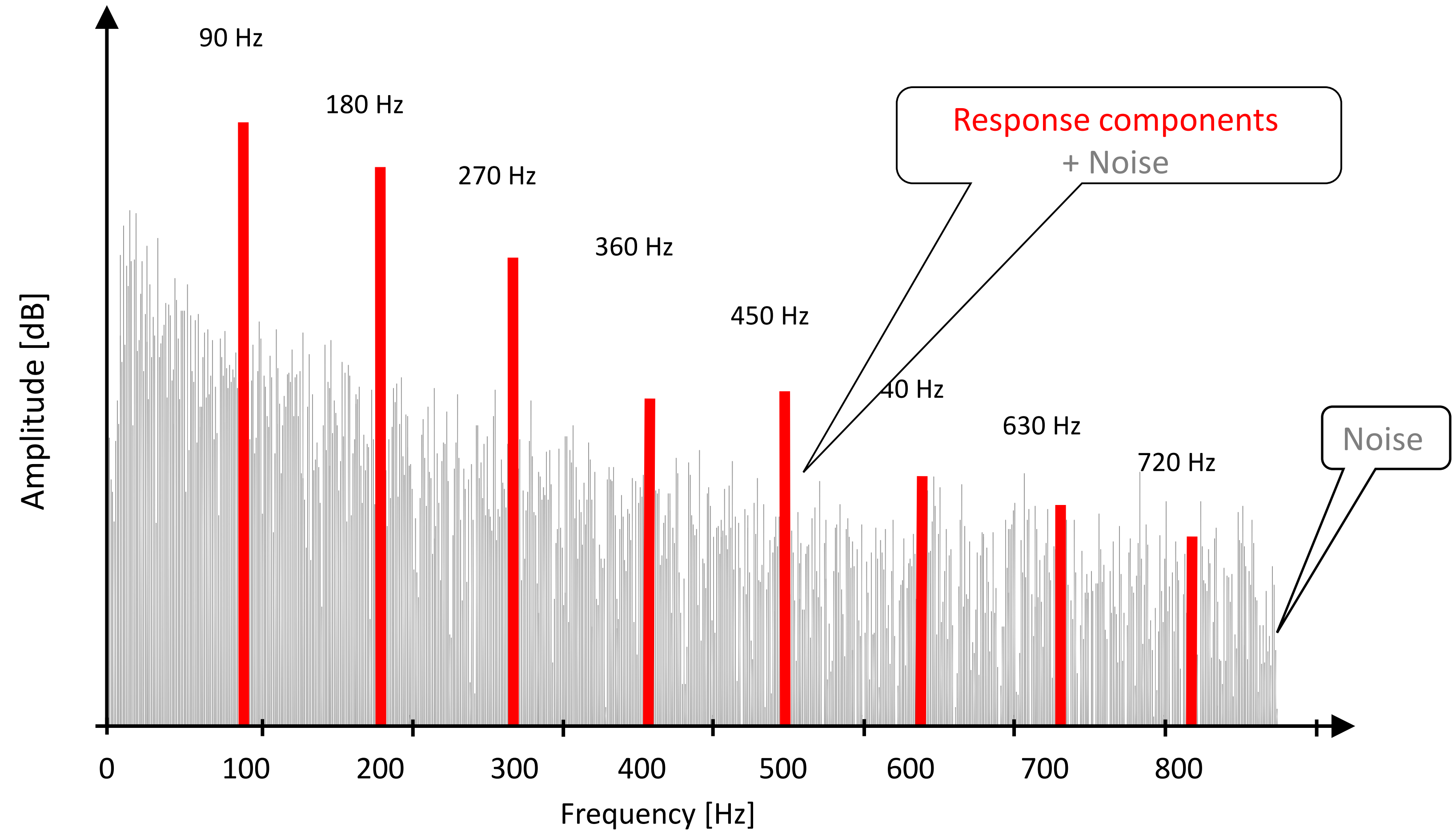

y = 0.9669x + 0.5818
R² = 0.9057
1000 Hz
Linear regression
± 10 dB interval
ASSR 1000 Hz thresholds (dBnHL)
Behavioral response audiometry (1000Hz thresholds, dB HL)

Comparison of threshold estimation in infants with hearing loss or normal hearing using Auditory Steady-State Response evoked by narrow band CE-chirp and ABR evoked by tone pips: results for 2000 Hz

Franck Michel, Audiology Clinic, Department of Otorhinolaryngology, Aarhus University Hospital, Denmark



In Addition to use of CE-NB Chirps- New ASSR uses Enhanced Detection Algorithm



Amplitude Advantage = Test Time Reduction

When response amplitude is doubled, it will take ¼ of the averaging time to achieve the same signal to noise ratio!

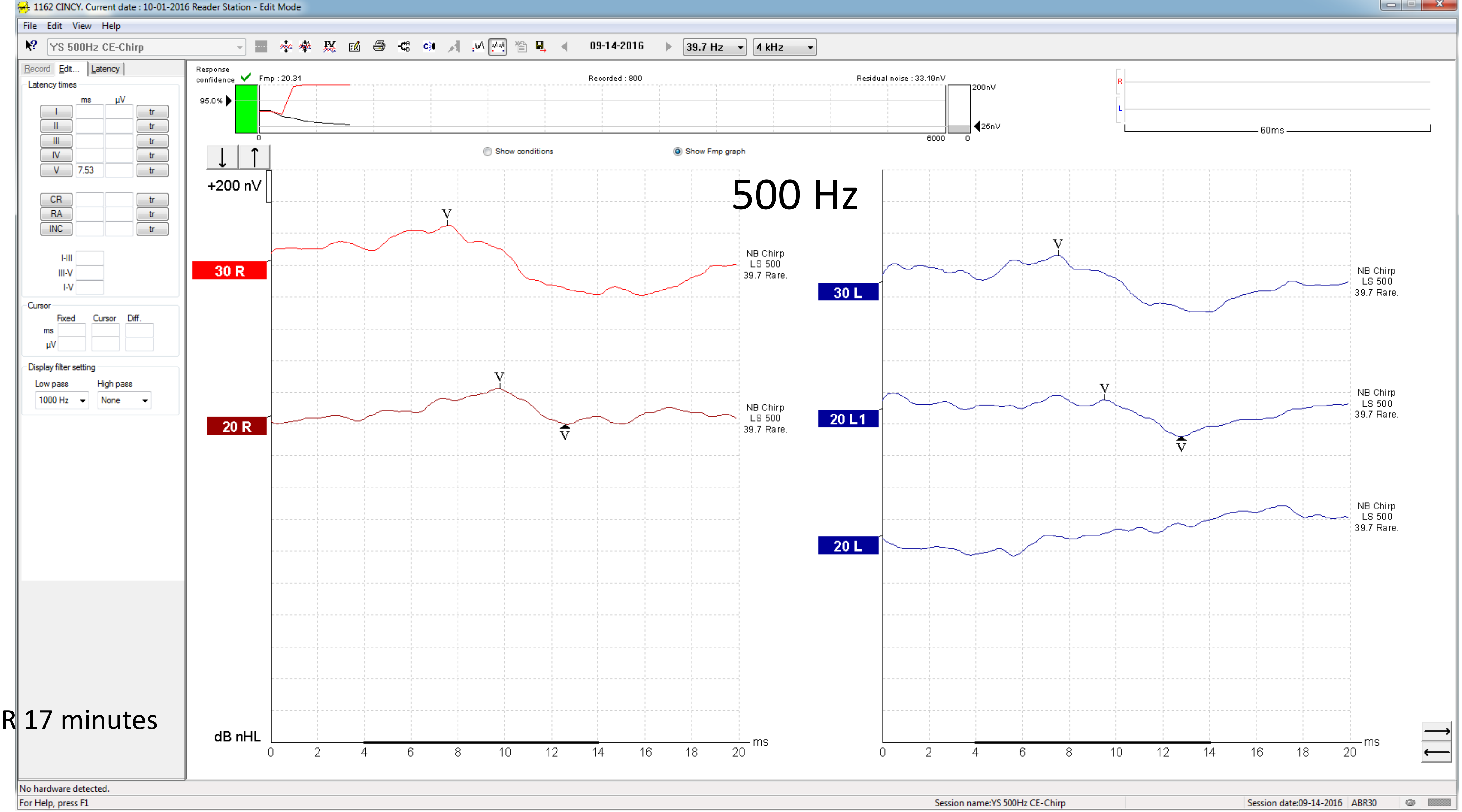
When using a SNR-based stopping rule for determining response presence/absence, such as Fmp for ABR or automated detection in ASSR, one can see dramatic decreases in test time when using CE NB Chirps .

Test Time Using Chirps:
Time to Achieve 8 Thresholds

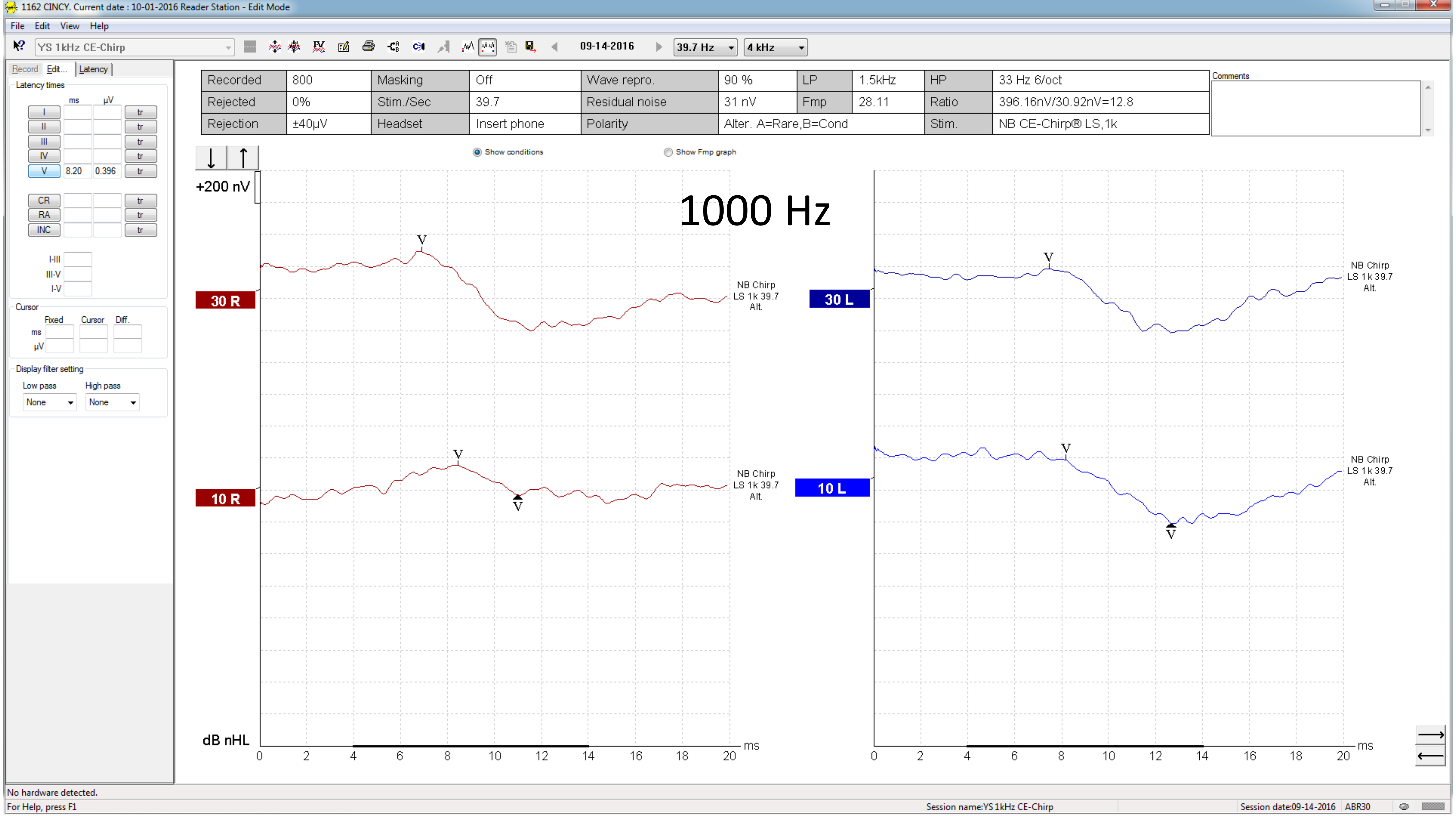
	Mean Minutes	Median Minutes	10th Percentile	90th Percentile
ABR	24.76	25.00	13.00	41.00
	P=0.002			
ASSR	18.20	14.80	8.25	32.79

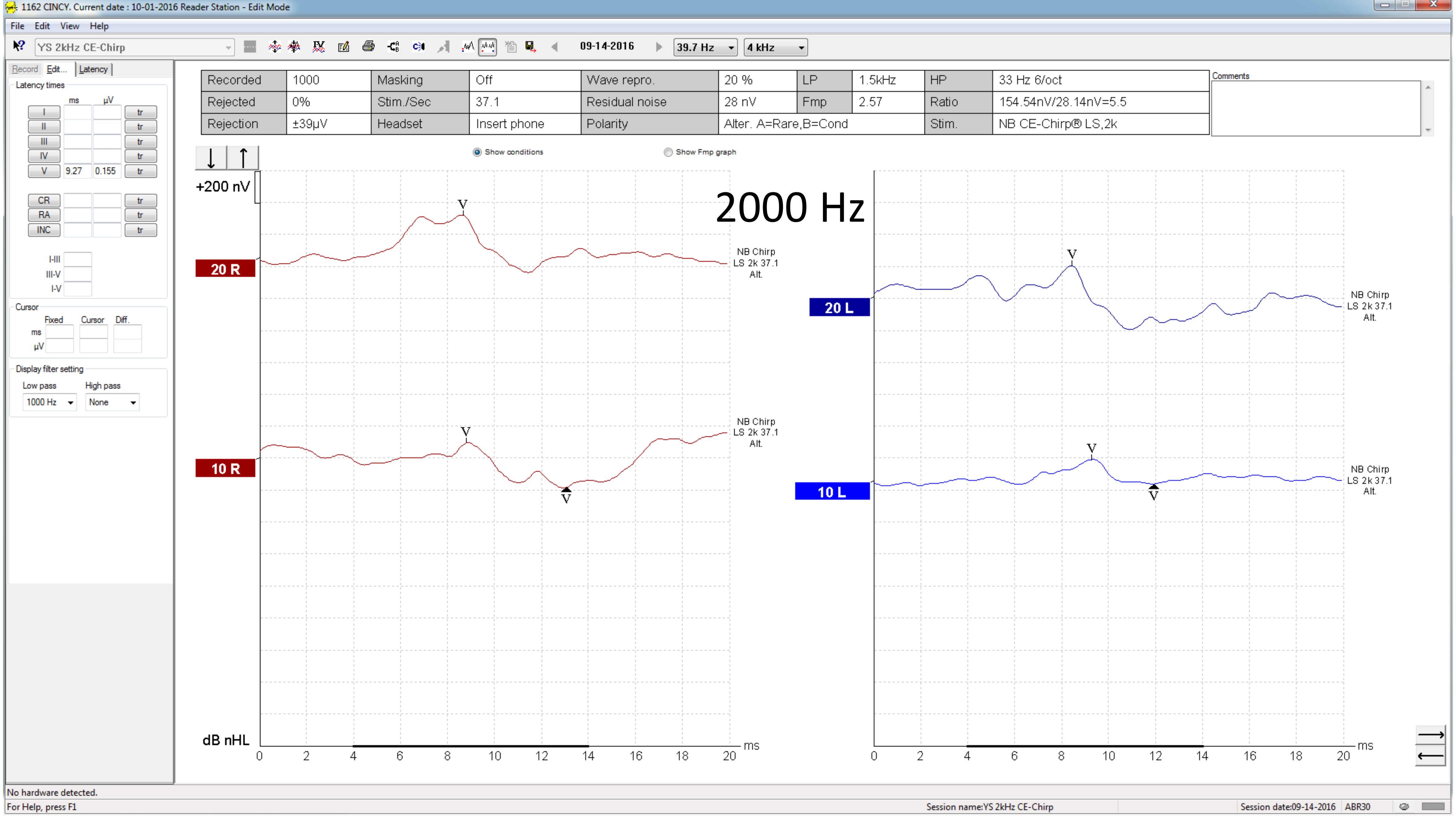
Preliminary Data from 29 Cases of Infants & Toddlers, mostly natural sleep; many with normal hearing.
Air conduction 500, 1k, 2k & 4k Hz in both ears.

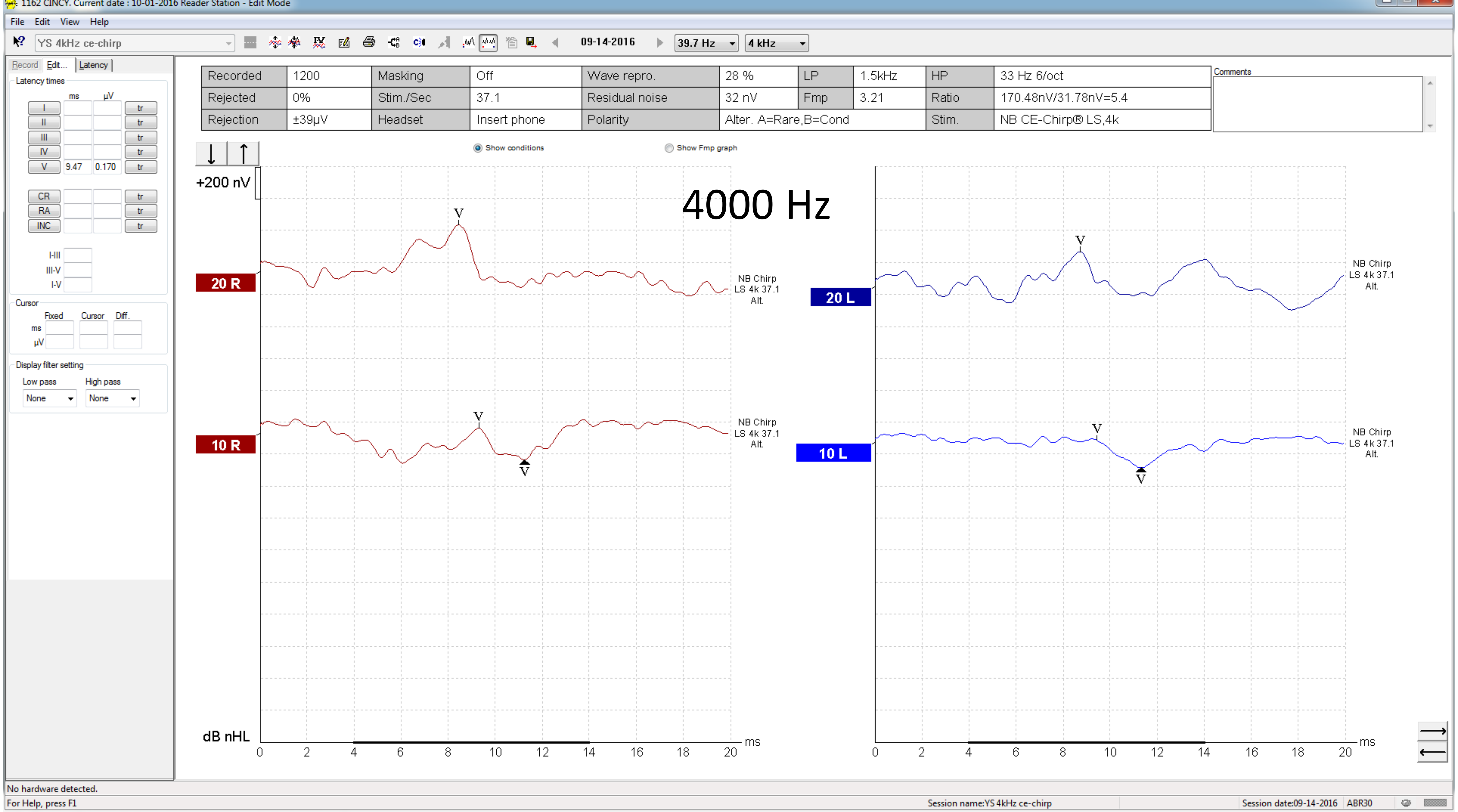
Case Example: 3-month old Natural Sleep, Normal Hearing



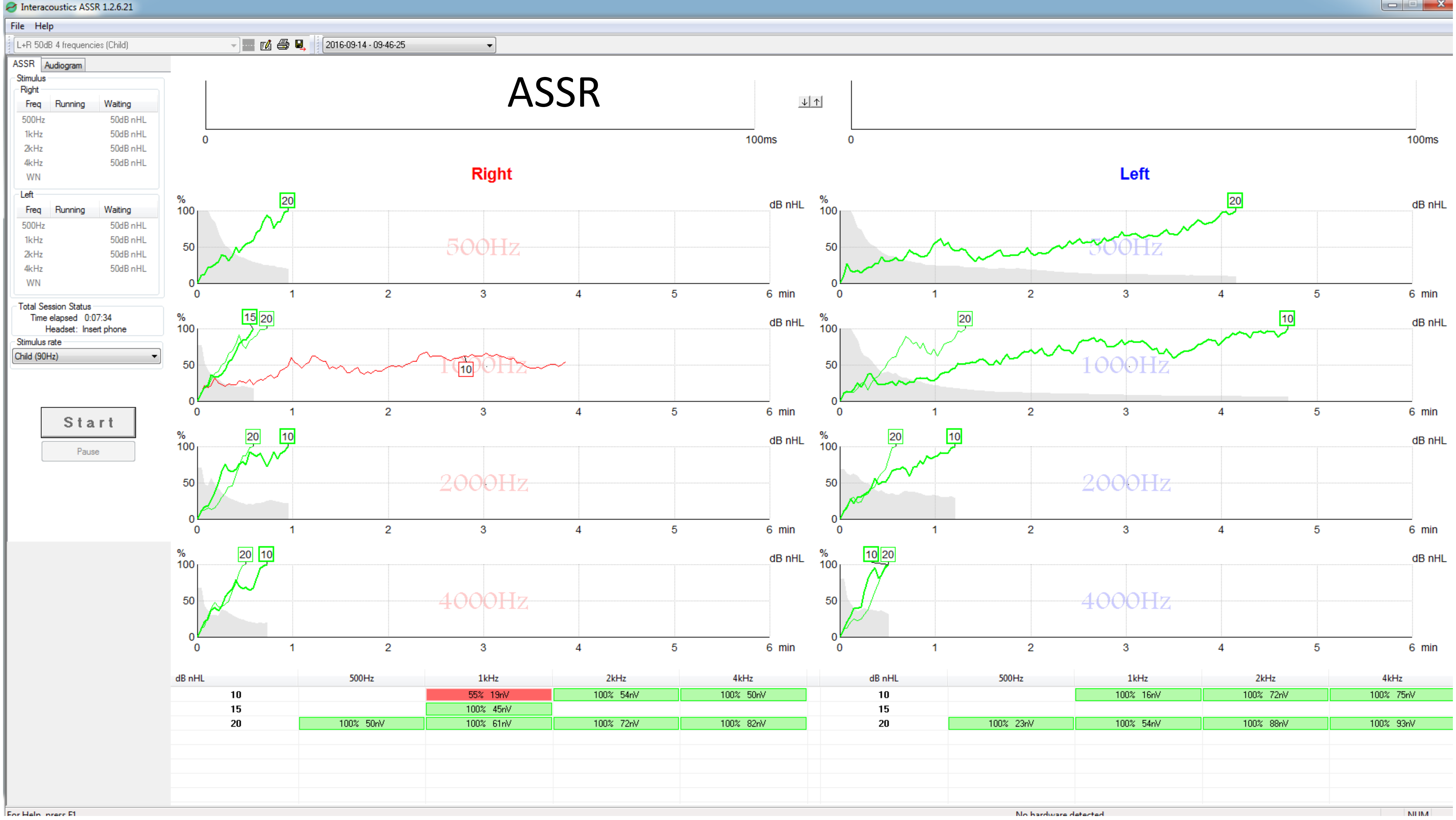
ABR 17 minutes

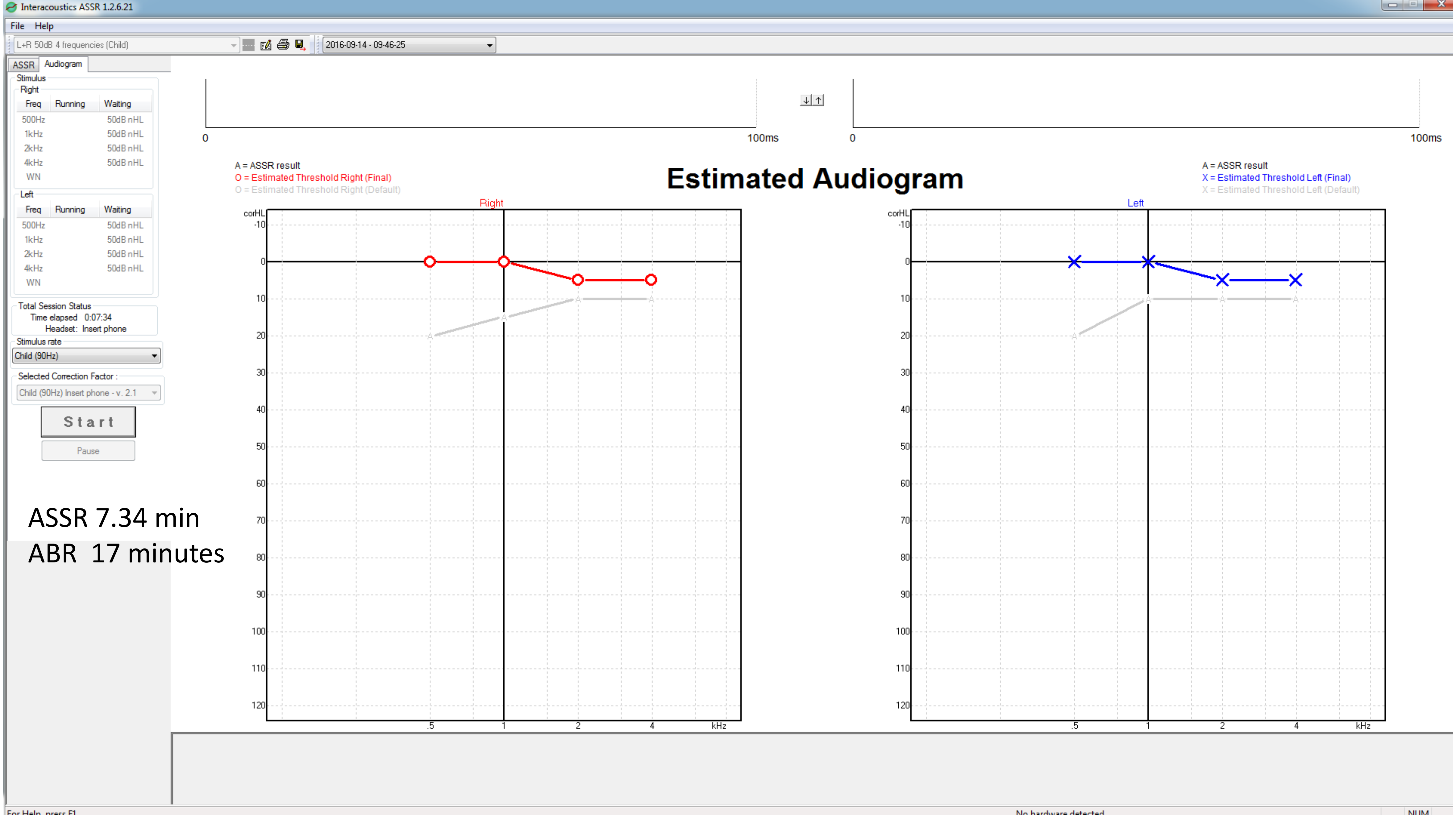

1162 CINCY. Current date : 10-01-2016 Reader Station - Edit Mode
File Edit View Help
YS 1kHz CE-Chirp
09-14-2016
39.7 Hz
4 kHz
Record Edit... Latency
Latency times
ms µV
I II III IV V
8.20 0.396
tr
CR RA INC
I-III III-V I-V
Cursor
Fixed Cursor Diff.
ms µV
Display filter setting
Low pass High pass
None None
Recorded 800 Masking Off Wave repro. 90 % LP 1.5kHz HP 33 Hz 6/oct
Rejected 0% Stim./Sec 39.7 Residual noise 31 nV Fmp 28.11 Ratio 396.16nV/30.92nV=12.8
Rejection ±40µV Headset Insert phone Polarity Alter. A=Rare,B=Cond Stim. NB CE-Chirp® LS,1k
Comments
Show conditions
Show Fmp graph
+200 nV
1000 Hz
30 R
10 R
30 L
10 L
V
NB Chirp LS 1k 39.7 Alt.
dB nHL
0 2 4 6 8 10 12 14 16 18 20 ms
No hardware detected.
For Help, press F1
Session name:YS 1kHz CE-Chirp
Session date:09-14-2016 ABR30


1162 CINCY. Current date : 10-01-2016 Reader Station - Edit Mode
File Edit View Help
YS 2kHz CE-Chirp
09-14-2016
39.7 Hz
4 kHz
Record Edit... Latency
Latency times
ms µV
I tr
II tr
III tr
IV tr
V 9.27 0.155 tr
CR tr
RA tr
INC tr
I-III
III-V
I-V
Cursor
Fixed Cursor Diff.
ms
µV
Display filter setting
Low pass High pass
1000 Hz None
Recorded 1000 Masking Off Wave repro. 20 % LP 1.5kHz HP 33 Hz 6/oct
Rejected 0% Stim./Sec 37.1 Residual noise 28 nV Fmp 2.57 Ratio 154.54nV/28.14nV=5.5
Rejection ±39µV Headset Insert phone Polarity Alter. A=Rare,B=Cond Stim. NB CE-Chirp® LS,2k
Comments
Show conditions
Show Fmp graph
+200 nV
2000 Hz
20 R
NB Chirp LS 2k 37.1 Alt.
10 R
NB Chirp LS 2k 37.1 Alt.
20 L
NB Chirp LS 2k 37.1 Alt.
10 L
NB Chirp LS 2k 37.1 Alt.
V
dB nHL
0 2 4 6 8 10 12 14 16 18 20 ms
No hardware detected.
For Help, press F1
Session name:YS 2kHz CE-Chirp
Session date:09-14-2016 ABR30


1162 CINCY. Current date : 10-01-2016 Reader Station - Edit Mode
File Edit View Help
YS 4kHz ce-chirp
09-14-2016
39.7 Hz
4 kHz
Record Edit... Latency
Latency times
ms µV
I II III IV V
9.47 0.170
CR RA INC
I-III III-V I-V
Cursor
Fixed Cursor Diff.
Display filter setting
Low pass High pass
None None
Recorded 1200 Masking Off Wave repro. 28 % LP 1.5kHz HP 33 Hz 6/oct
Rejected 0% Stim./Sec 37.1 Residual noise 32 nV Fmp 3.21 Ratio 170.48nV/31.78nV=5.4
Rejection ±39µV Headset Insert phone Polarity Alter. A=Rare,B=Cond Stim. NB CE-Chirp® LS,4k
Comments
Show conditions
Show Fmp graph
+200 nV
4000 Hz
20 R
10 R
20 L
10 L
NB Chirp LS 4k 37.1 Alt.
V
dB nHL
ms
0 2 4 6 8 10 12 14 16 18 20
No hardware detected.
For Help, press F1
Session name:YS 4kHz ce-chirp
Session date:09-14-2016 ABR30

ASSR


Interacoustics ASSR 1.2.6.21
File Help
L+R 50dB 4 frequencies (Child)
2016-09-14 - 09-46-25
ASSR Audiogram
Stimulus
Right
Freq Running Waiting
500Hz 50dB nHL
1kHz 50dB nHL
2kHz 50dB nHL
4kHz 50dB nHL
WN
Left
Freq Running Waiting
500Hz 50dB nHL
1kHz 50dB nHL
2kHz 50dB nHL
4kHz 50dB nHL
WN
Total Session Status
Time elapsed 0:07:34
Headset: Insert phone
Stimulus rate
Child (90Hz)
Start
Pause
Right
Left
500Hz
1000Hz
2000Hz
4000Hz
dB nHL
% 100 50 0
0 1 2 3 4 5 6 min
0 100ms
dB nHL 500Hz 1kHz 2kHz 4kHz
10 55% 19nV 100% 54nV 100% 50nV
15 100% 45nV
20 100% 50nV 100% 61nV 100% 72nV 100% 82nV
dB nHL 500Hz 1kHz 2kHz 4kHz
10 100% 16nV 100% 72nV 100% 75nV
15
20 100% 23nV 100% 54nV 100% 88nV 100% 93nV
For Help, press F1
No hardware detected
NUM



ASSR 7.34 min

ABR 17 minutes

CE- Chirps

Try em- You will like em!

We've Come a Long Way in Hearing Evaluation

"HEY, LOOK UP HERE!"

Amplitude Adv ABR FS Amplitude/Accuracy using ASSR Amplitude -> Time Advantage

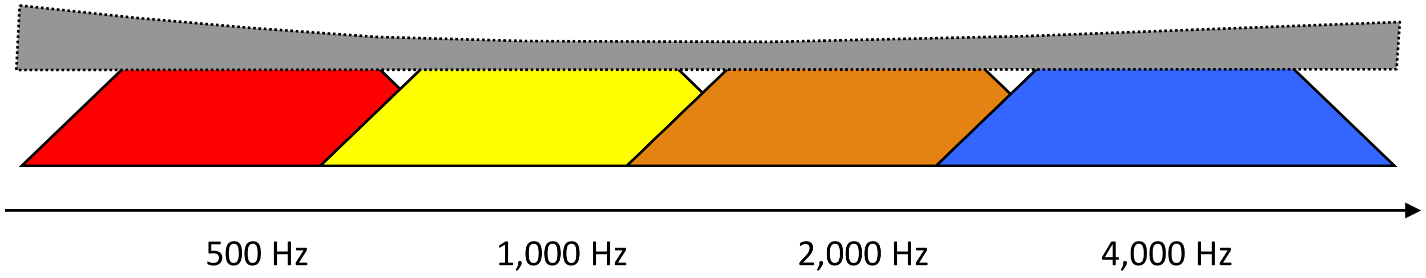
CE-NB Chirps Achieve Lower Thresholds than Traditional Tone Bursts.

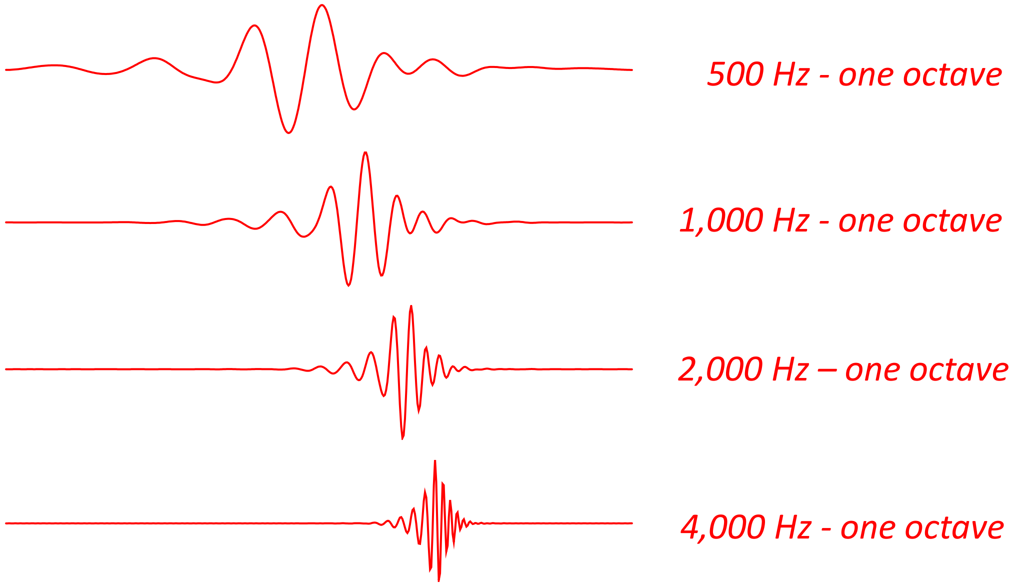
Using linear extrapolation the ***4 kHz difference equates to an average chirp threshold advantage of 5.2 dB, whilst at 1 kHz the chirp advantage is 6.2 dB.***

We propose that the ABR nHL threshold to eHL correction for NB CE-Chirps should be approximately 5 dB less than the corrections for tone pips at 2 kHz and 500 Hz, in line with NHSP guidance at 4 & 1 kHz.

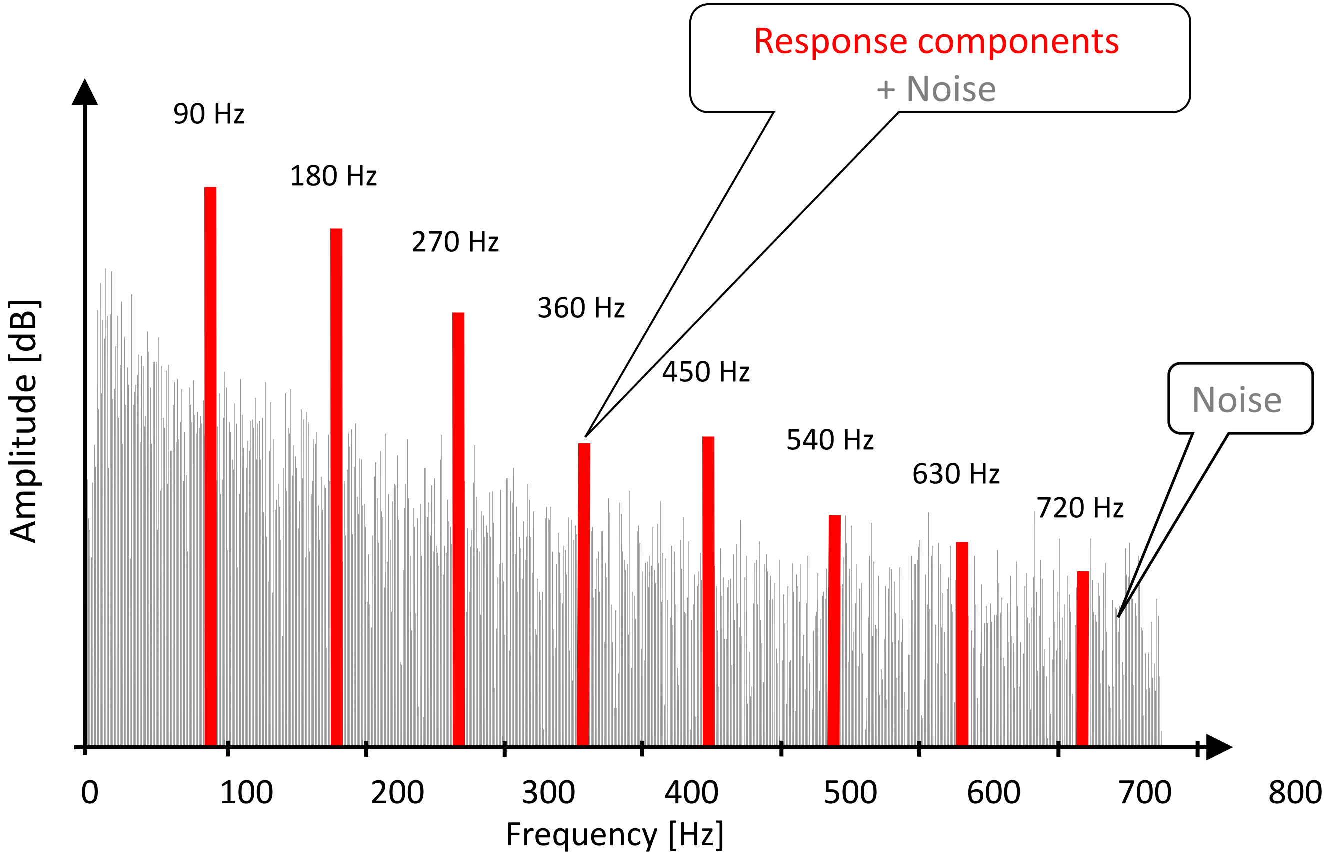
Simultaneous multi-frequency ASSR-testing

Band-limited Chirps

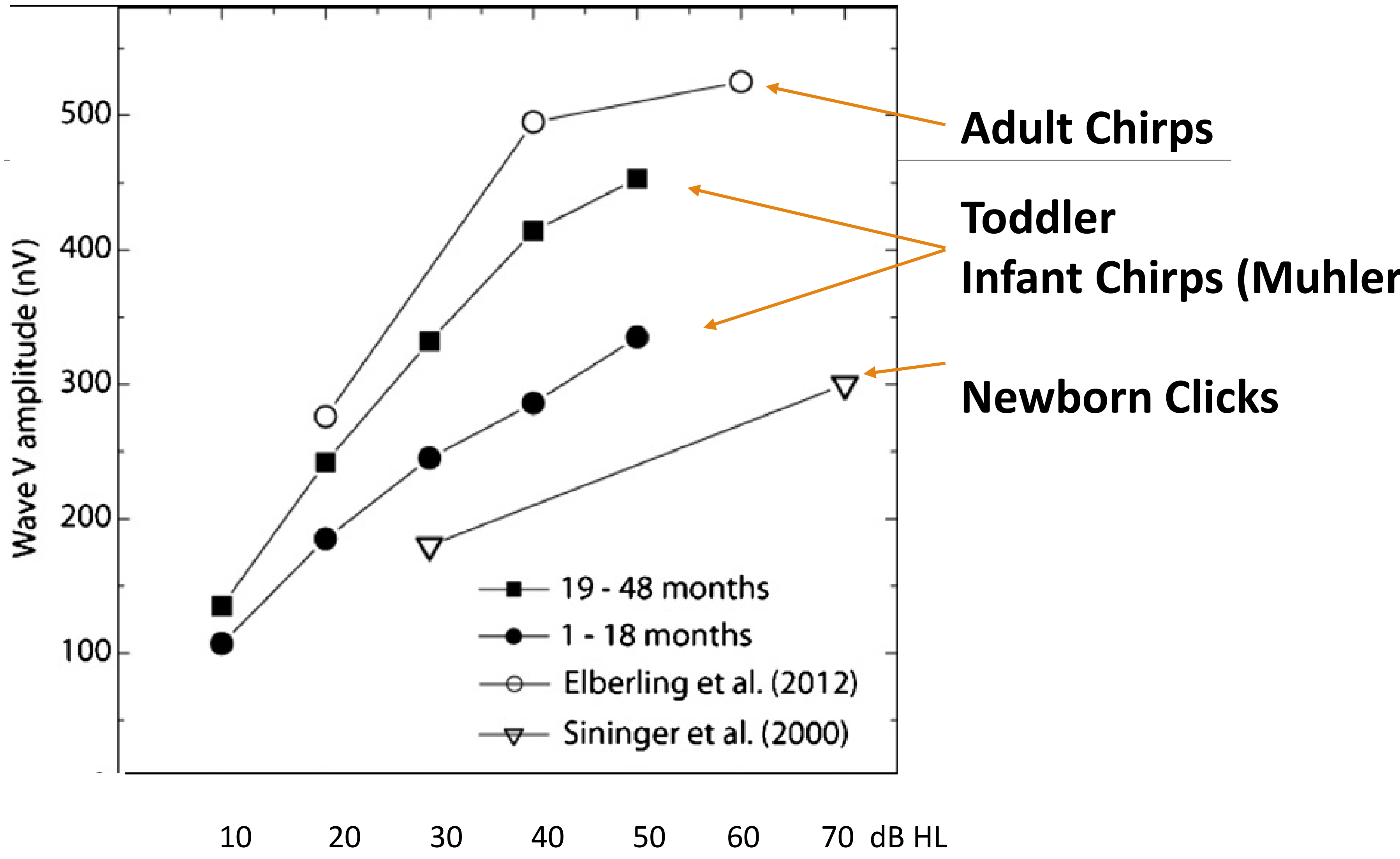




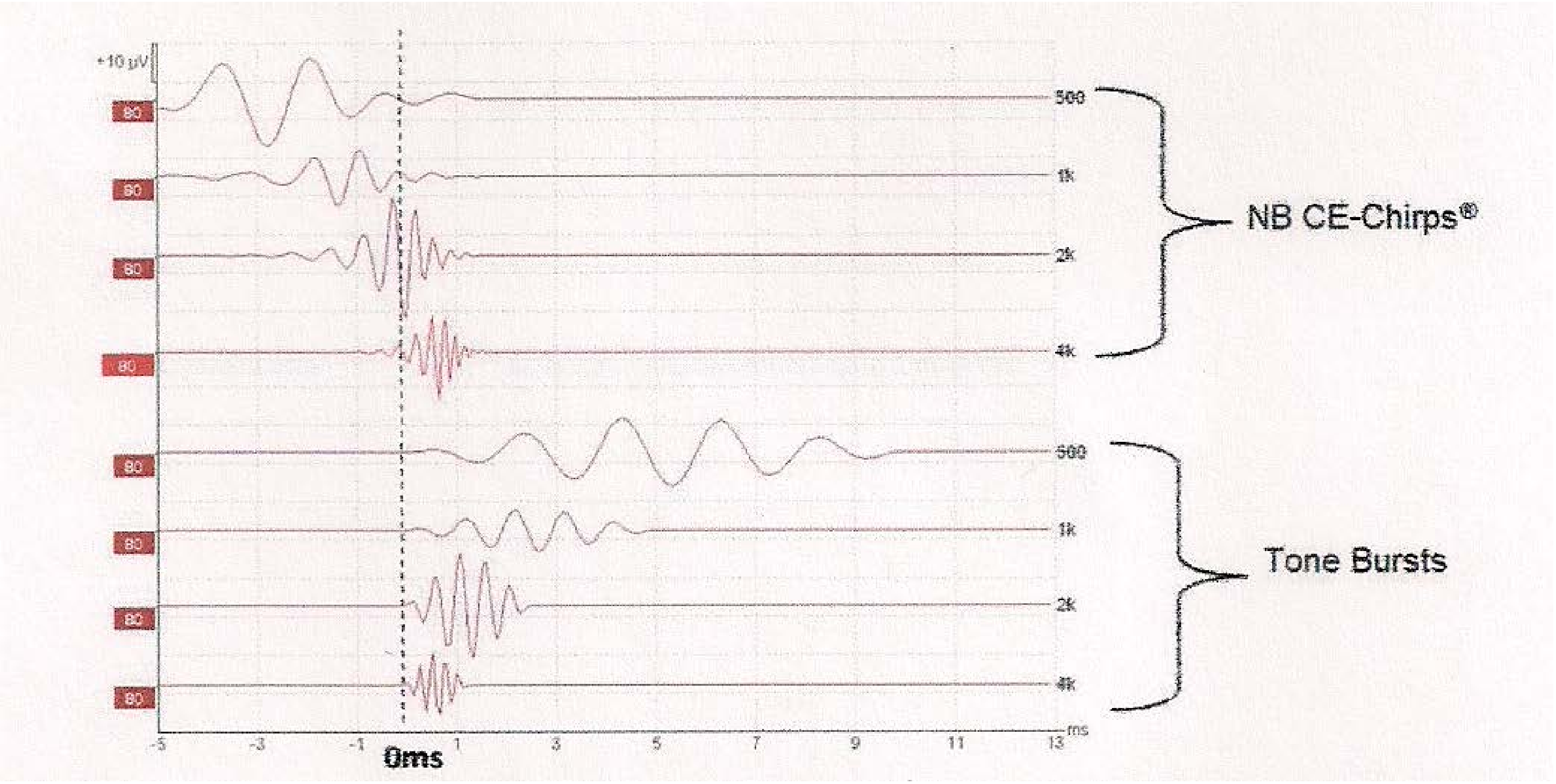
Amplitude spectrum of the ASSR



Amplitude Comparisons WB Chirps and Clicks



Adjustment of start of recording time re stimulus onset is implemented.



- The NB CE-Chirp response is less likely to have interference from stimulus artifact.
- Important to use alternating TB stimuli to avoid artifact and CM.
- Response window will be consistent across stimuli for the NB CE-Chirps which is convenient for setting the response detection window.

Calibration Standards for CE-Chirps are Published

Specifications

The *EPx5 version 4.3* by Interacoustics contains a novel series of brief stimuli:

- Click (wave-click)
- CE-Chirp® (also referred to as broadband CE-Chirp®)
- Narrow Band CE-Chirp® (also referred to as NB CE-Chirp®)

Calibration nHL

- Click stimuli are presented in nHL following the ISO standard 389-6 for peRETSPL to nHL[2].
- NB & CE-Chirp® family stimuli are not specified in the current international standard and are calibrated to nHL on the basis of two studies, PTB in Germany 2008 and DTU (Gøtsche-Rasmussen et al., 2012).[3]

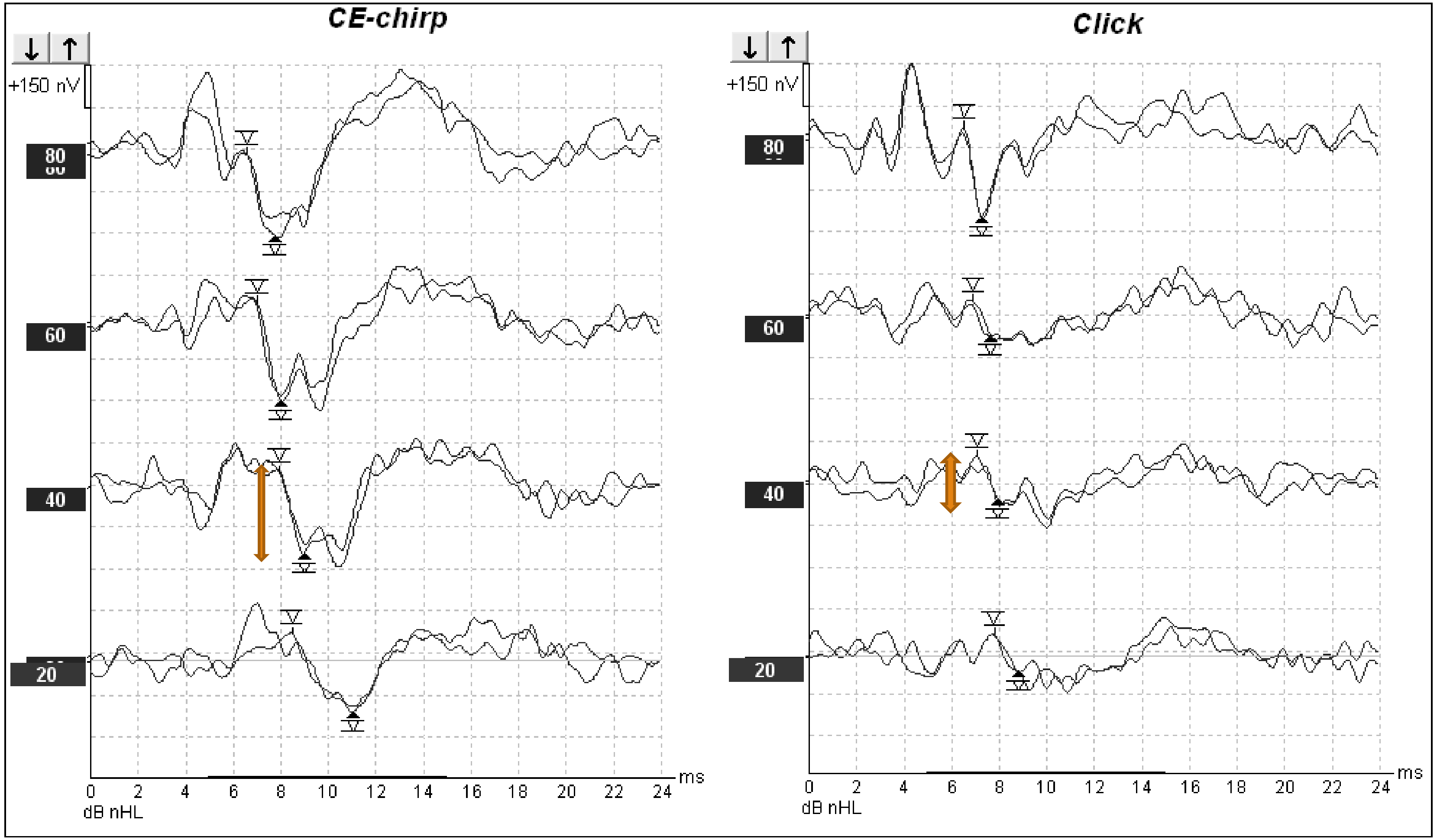
Please refer to section **Calibration** in the Eclipse ABR operational manual for more details.

Free Lunch

Using a chirp is no more work that using a click or a tone burst. There is no change in procedures otherwise.

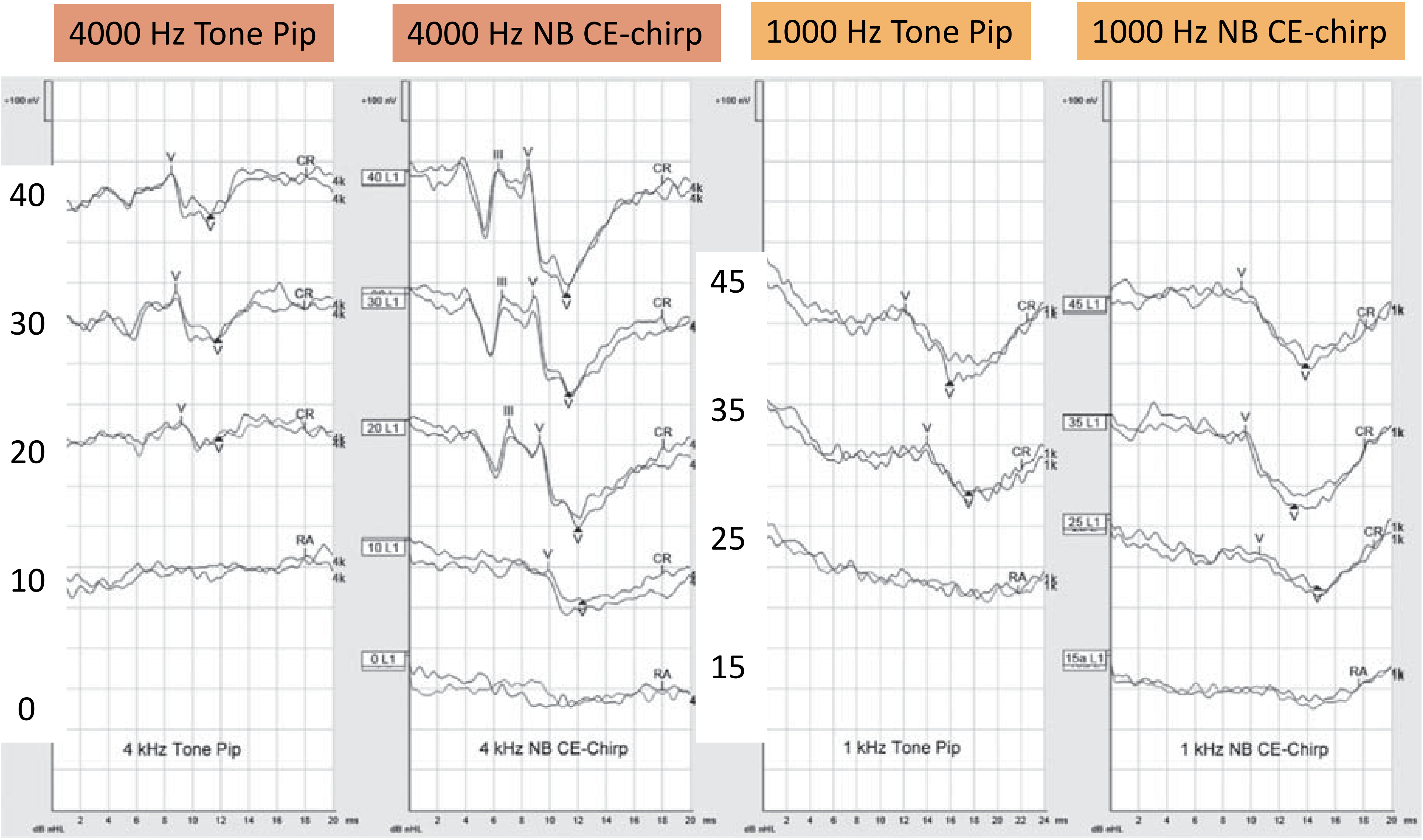
ABRs from RE of Full Term Newborn

Gabriela Ribeiro Ivo Rodrigues *, Nata´ lia Ramos, Doris Ruthi Lewis Comparing auditory brainstem responses (ABRs) to toneburst and narrow band CE-chirp1 in young infants International Journal of Pediatric Otorhinolaryngology 77 (2013) 1555–1560



Amplitudes from Chirps are significantly larger at low stimulus levels (did not use LS)!

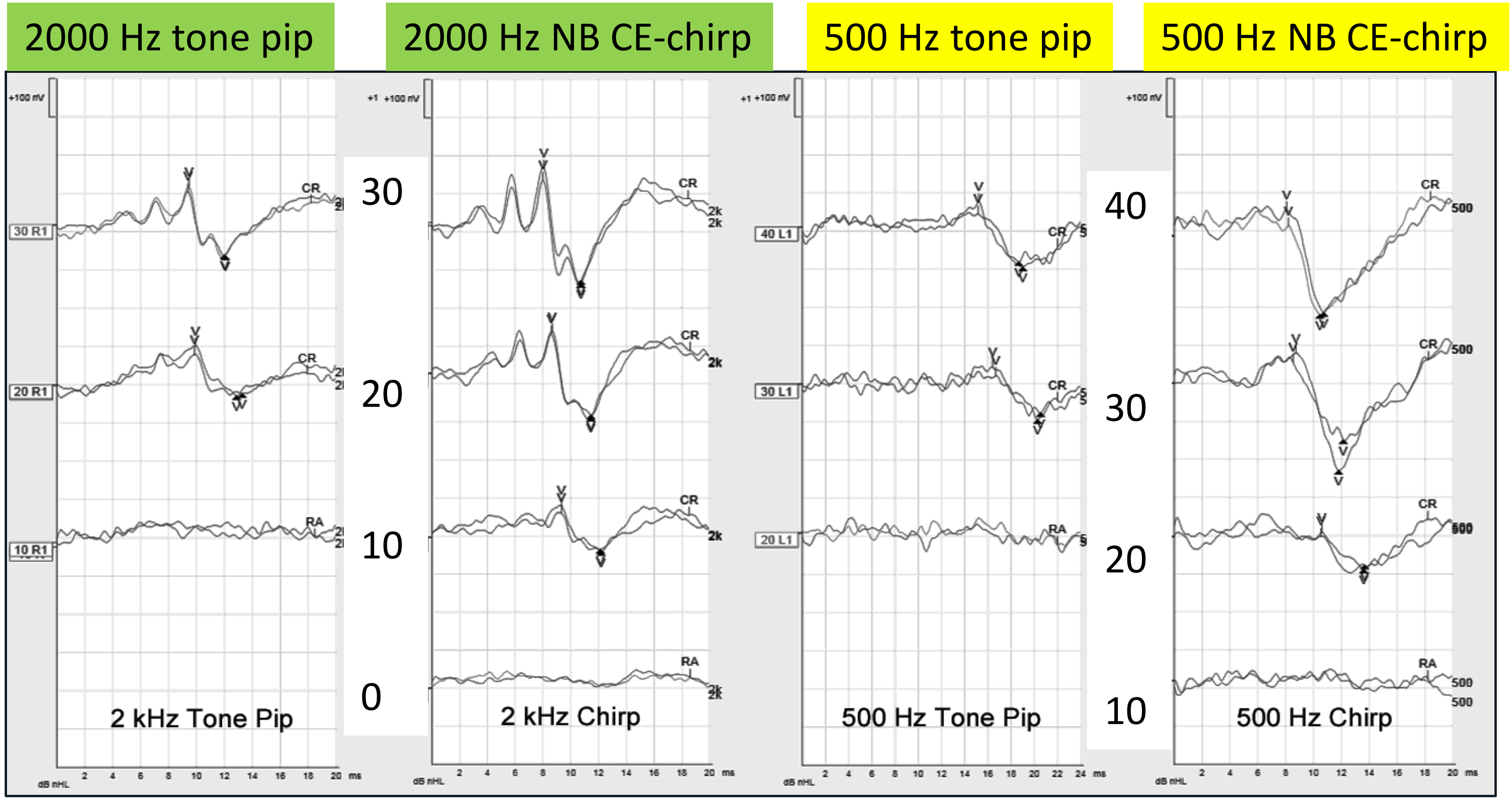
"4 kHz difference equates to an average chirp threshold advantage of 5.2 dB, whilst at 1 kHz the chirp advantage is 6.2 dB ".



Ferm, Lightfoot & Stevens International Journal of Audiology 2013;

Lake Como Poster filled in .5 and 2k Hz Results

The mean NB CE-chirp response amplitude was approximately 50% larger than that of a pip at 2 kHz and approximately 30% larger at 500 Hz. Fmp values were typically double for NB CE-chirps.

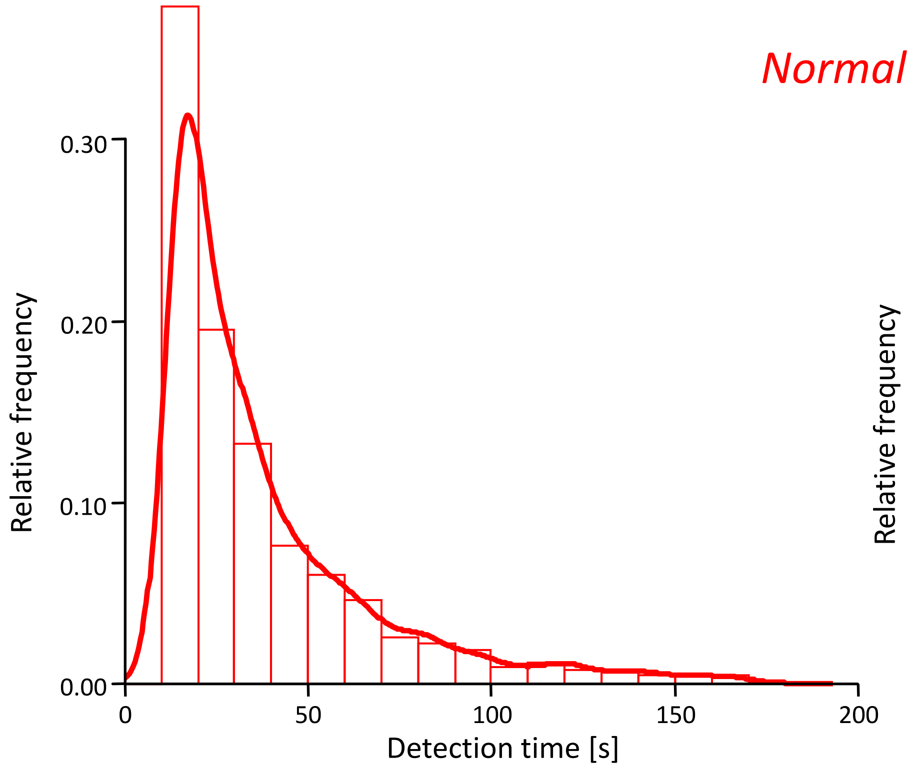


Inga Ferm* and Guy Lightfoot **Amplitudes, test time and estimation of hearing threshold using frequency specific chirp and tone pip stimuli in newborns**. HEAL 2014, Lake Como, Italy

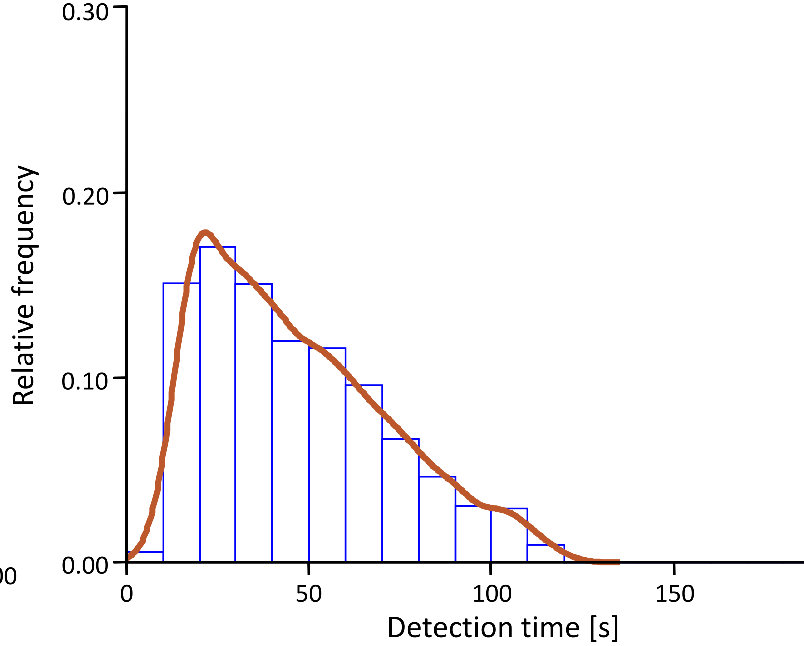
- Screening:
  - Click (40 dBnHL) and Chirp (35 dBnHL)
  - two groups of newborns (each of about N = 1,800)

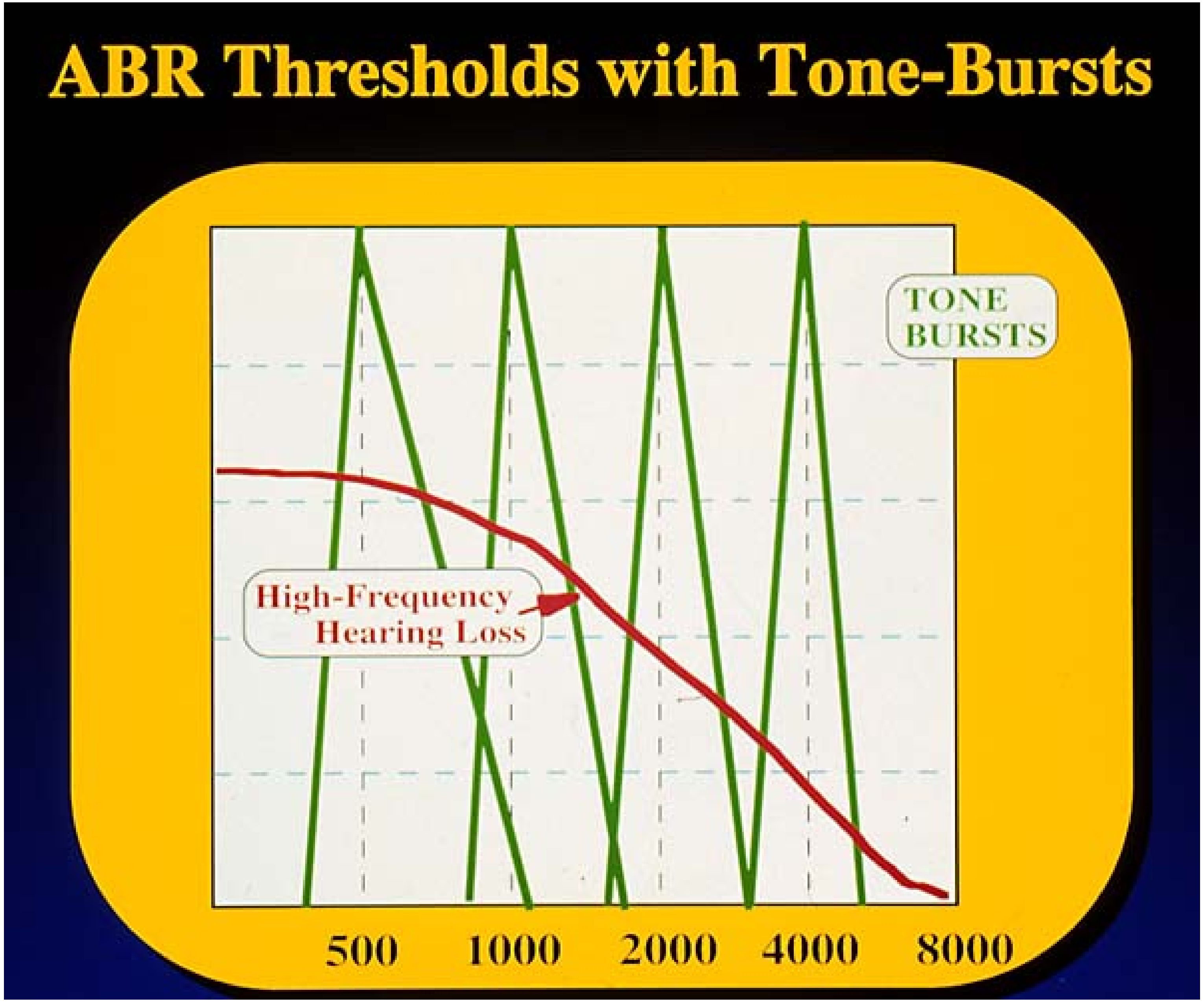
- Chirp - 35 dBnHL
  - maximum test time: 180 s
  - detection criterion: 0.1 %
  - number of ears: 1833
  - detection rate: 96.3 %
  - detection time: 28 s (median)
    38 s (mean)

- Click - 40 dBnHL
  - maximum test time: 120 s
  - detection criterion: 0.1 %
  - number of ears: 1744
  - detection rate: 95.4 %
  - detection time: 42 s (median)
    47 s (mean)



Normal Infants



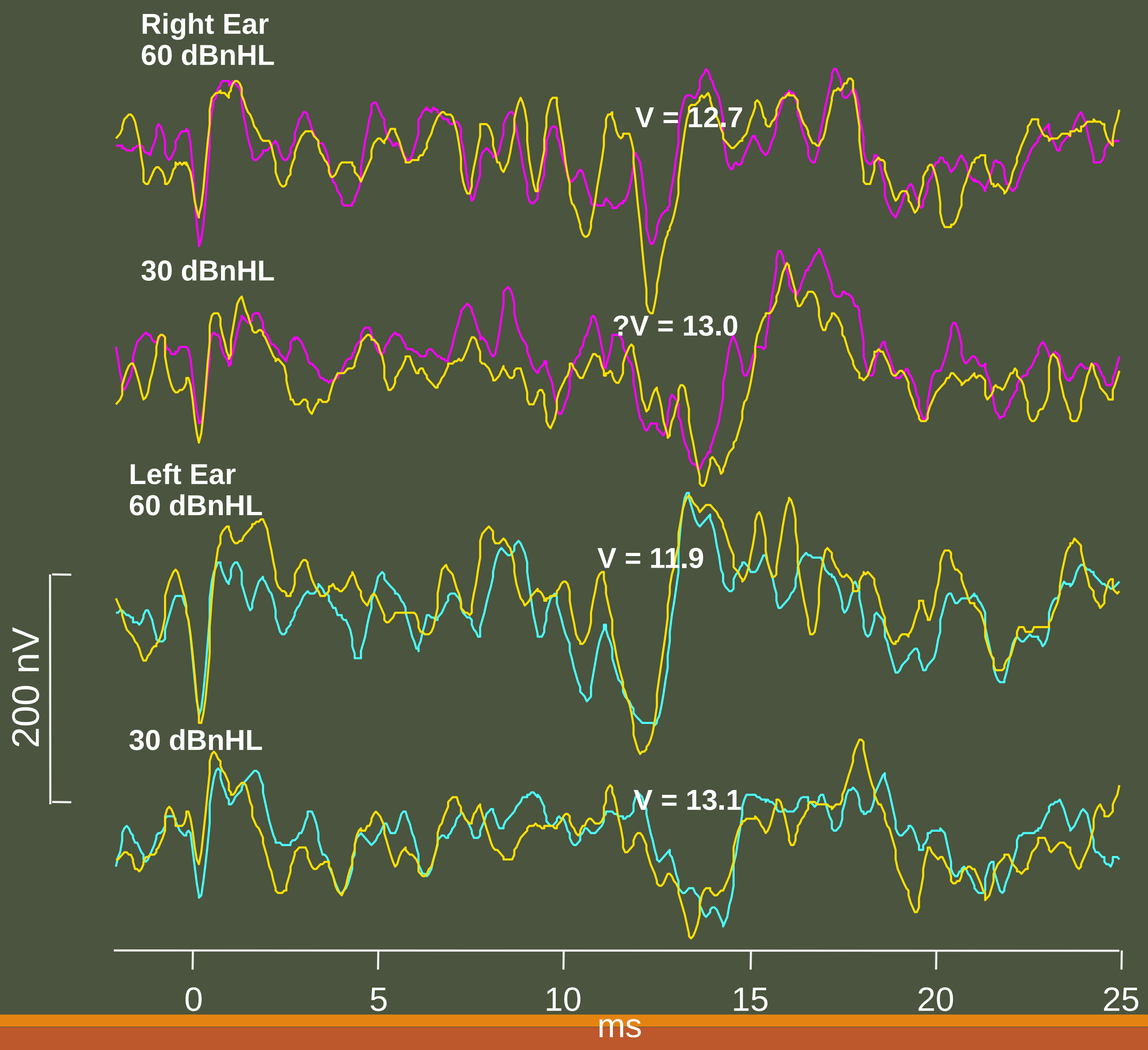

ABR Thresholds with Tone-Bursts
TONE
BURSTS
High-Frequency
Hearing Loss
500
1000
2000
4000
8000

Auditory Brainstem Response
Stimulus: Click, 25/s, Insert Earphones
Right Ear

Age at Test: 2 years, 9 months

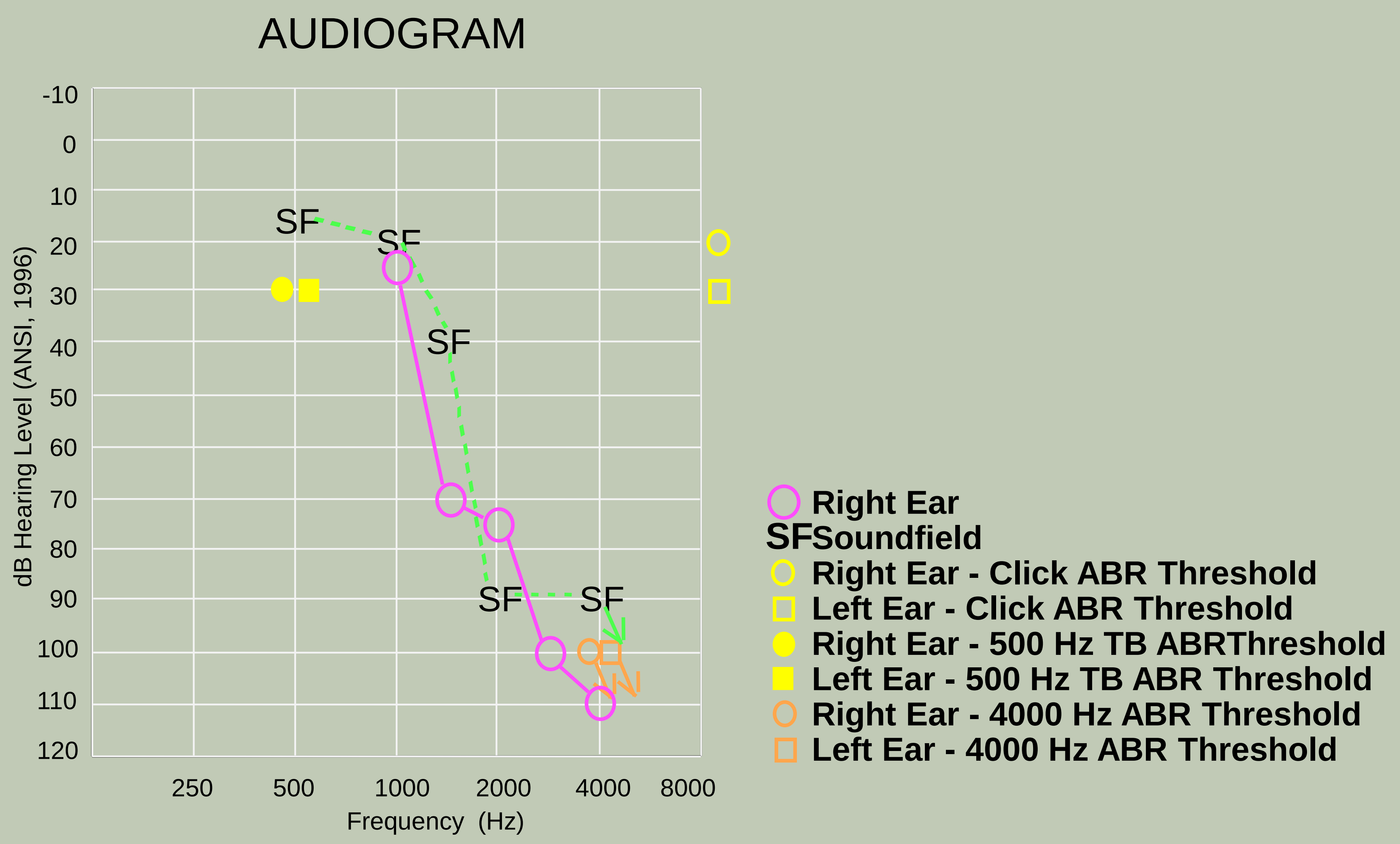
Auditory Brainstem Response
Stimulus: 500 Hz Tone Burst, Insert Earphones

Age at Test: 2 years, 9 months



Patient: ES
Age at Test: 2 years, 9 months

Auditory Brainstem Response
Stimulus: 4000 Hz Tone Burst, Insert Earphones


AUDIOGRAM
dB Hearing Level (ANSI, 1996)
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
250
500
1000
2000
4000
8000
Frequency (Hz)
SF
SF
SF
SF
SF
Right Ear
SF Soundfield
Right Ear - Click ABR Threshold
Left Ear - Click ABR Threshold
Right Ear - 500 Hz TB ABRThreshold
Left Ear - 500 Hz TB ABR Threshold
Right Ear - 4000 Hz ABR Threshold
Left Ear - 4000 Hz ABR Threshold