Evoked Potentials – Part 3
Auditory Steady State Response

Wendy Crumley MS CCC-A – Product Manager

otometrics
MADSEN · AURICAL · ICS

CHARTR EP 200

ASSR

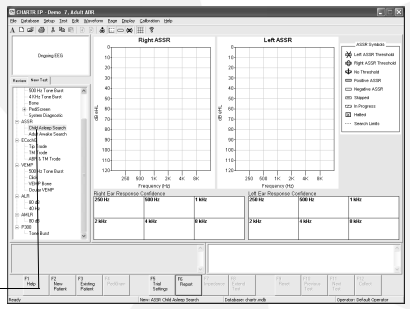
otometrics
MADSEN · AURICAL · ICS

ICS CHARTR ASSR Main Window

ASSR Procedure available to those who purchase this option

Collect button will be grayed out if do not have ASSR initialized.

For the tower if you do not have an ASSR Preamp or ASSR board or if something is not functioning properly.



Hearing Assessment · Fitting Systems · Balance Assessment

3

otometrics
MADSEN · AURICAL · ICS

Understanding ASSR

Clinical Applicability

- Assess the hearing of any patient of any age who cannot respond reliably to puretone audiometry
  - Infants
  - Patients with pseudohypacusis

Obtain Frequency Specific Information

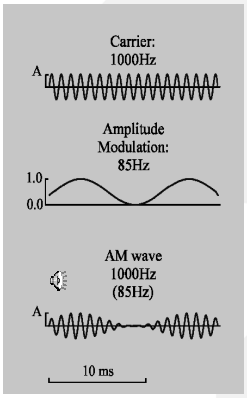
- Rule out hearing loss not identified by click ABR
- Determine the degree and configuration of the hearing loss
- Determine the type of the hearing loss (sensorineural or conductive)

ASSR Advantages

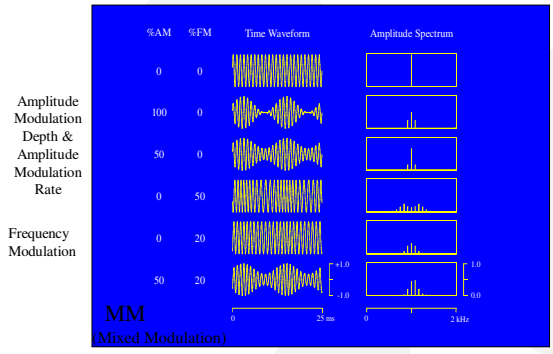
- Frequency specific stimuli
- Multiple tones presented simultaneously, binaurally
- Higher intensities
- Objective

Understanding the stimulus

- Carrier frequency
  - Pure tone frequency
  - 250, 500, 1000, 2000, 4000, 8000 Hz
- Amplitude modulation depth
  - Depth of signal envelope
  - Use 100%
- Frequency modulation
  - Percentage of modulation around the carrier frequency
  - Usually 20%
    - For 1000 Hz, 20% warbles between 900-1100 Hz
- Modulation rate
  - Number of times per second the frequency is modulated
  - Usually between 60-100 Hz



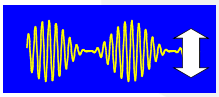
Slide courtesy of Dr. Terry Picton



Slide courtesy of Dr. Terry Picton

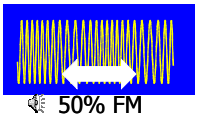
Stimulus

Amplitude



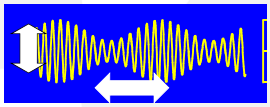
100% AM

Frequency



50% FM

MM



50% AM 20% FM

Slide courtesy of Dr. Terry Picton

otometrics
MADSEN · AURICAL · ICS

Hearing Assessment · Fitting Systems · Balance Assessment

10

- Mixed Modulation stimuli have less spectral splatter; therefore, more **Frequency Specific**.

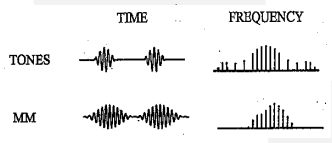


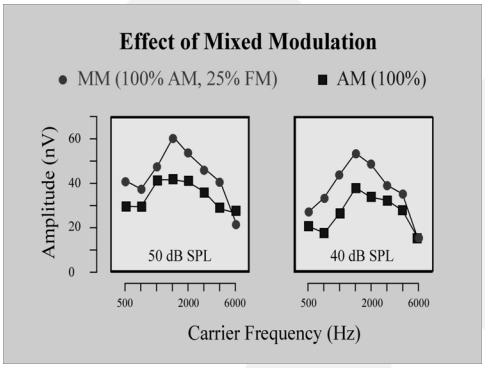
Image courtesy of Dr. Terry Picton

•**Higher Intensities** allow for increased information with patients with severe and profound losses.

otometrics
MADSEN · AURICAL · ICS

Hearing Assessment · Fitting Systems · Balance Assessment

11



John M.S., et al (2001) Multiple auditory steady-state responses to AM and FM stimuli Audiology and Neurotology Vol 6: 12-27

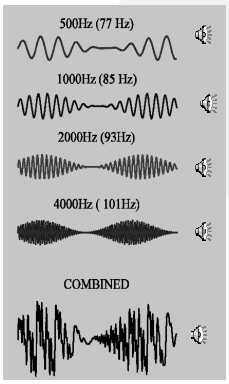
otometrics
MADSEN · AURICAL · ICS

Hearing Assessment · Fitting Systems · Balance Assessment

12

ASSR: Comparison with tone burst ABR

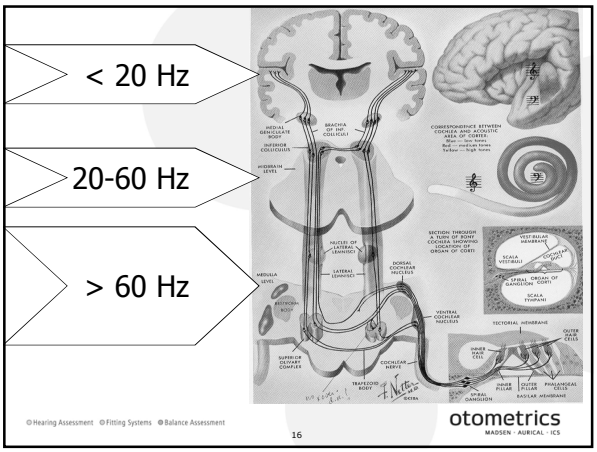
- Both are frequency-specific
- Neither require active patient participation
- ASSR stimuli are frequency-specific to higher levels than tone burst ABR
  - ASSR stimuli have less spectral splatter
- ASSR stimuli can have multiple tones presented simultaneously, binaurally
  - Response detection is different from ABR
- Tone burst ABR thresholds may be closer to behavioral thresholds for mild and moderate hearing losses
  - Johnson and Brown, 2005, *Ear & Hearing*



Slide courtesy of Dr. Terry Picton

The Modulation Rate determines the Neural Generators

- <20Hz Response dominated by the Primary Auditory Cortex similar to the Late Cortical Evoked Potentials
- >20Hz, but <60Hz – Response dominated by Auditory Midbrain, Thalamus, Primary Auditory similar to Middle Latency Evoked Responses
- >60Hz – Brainstem sites, cochlear nucleus, superior olivary complex, similar to ABR waveforms III-V



Hearing Assessment · Fitting Systems · Balance Assessment

16

otometrics
MADSEN · AURICAL · ICS

ASSR Response

- The cochlea is stimulated at the frequency of the carrier tone.
- The brain perceives the modulation of the tone.
- It is assumed that the part of the cochlea that is being stimulated by the carrier frequency (i.e. 1000 Hz) must be intact for the brain to respond to the modulation rate (i.e. 80 Hz) producing an ASSR response.

Hearing Assessment · Fitting Systems · Balance Assessment

17

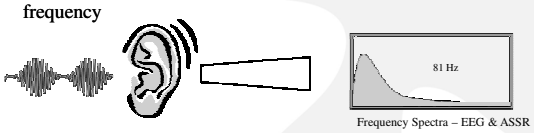
otometrics
MADSEN · AURICAL · ICS

Modulated Stimuli Produce Steady-State Responses at the Modulation Frequency

Carrier at 1 kHz
100% AM
81Hz modulation frequency

Activation at 1 kHz region of basilar membrane

Steady-State response at the modulation frequency



Frequency Spectra – EEG & ASSR

Sound

Cochlea

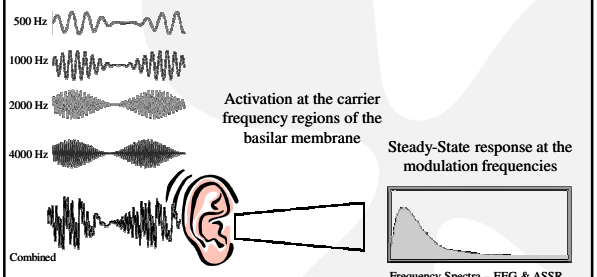
Brain

Hearing Assessment · Fitting Systems · Balance Assessment

18

otometrics
MADSEN · AURICAL · ICS

Four Stimuli Presented Simultaneously to One Ear



Activation at the carrier frequency regions of the basilar membrane

Steady-State response at the modulation frequencies

Frequency Spectra – EEG & ASSR

Sound Cochlea Brain

otometrics
MADSEN · AURICAL · ICS

Hearing Assessment · Fitting Systems · Balance Assessment

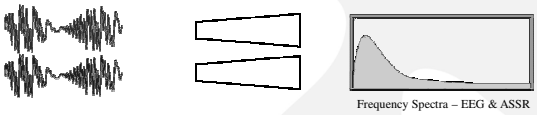
19

Four stimuli to the Right ear
Four stimuli to the Left ear

Carrier Hz	Mod Hz Right	Mod Hz Left
500	77	81
1000	85	89
2000	93	97
4000	101	105

Activation at the carrier frequency regions of the basilar membrane

Steady-State response at the modulation frequencies



Frequency Spectra – EEG & ASSR

Sound Cochlea Brain

otometrics
MADSEN · AURICAL · ICS

Hearing Assessment · Fitting Systems · Balance Assessment

20

CHARTR EP 200

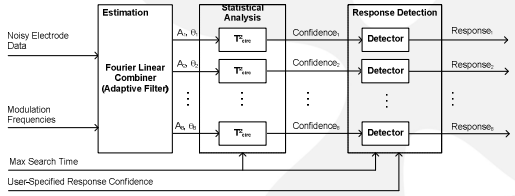
ICS ASSR Algorithm

RapidASSR™ Detection

otometrics
MADSEN · AURICAL · ICS

RapidASSR™ Detection

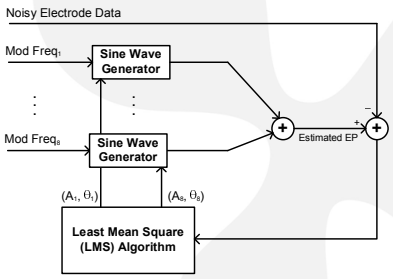
- There are 3 stages in the RapidASSR™ Detection
  - Estimation
  - Statistical Analysis
  - Response Detection



Estimation of the Response RapidASSR ™ Detection

- Fourier Linear Combiner (Adaptive Filter)
- Model for each test frequency – estimates the amplitude and phase of what it thinks the response for each frequency should look like (this is a starting point)
- Model adapts –the model compares its response estimate(s) to the patient data received (each sweep). The data that is not similar to the model is determined to be noise and is eliminated. The real data assists the model in adjusting its estimates the of amplitude and phase. This continues for several sweeps, updating the model and subtracting out error in the model.
- Determination of Amplitude and Phase for each test frequency – the model after several samples determines the amplitude and phase and this data is entered into the statistical analysis.

Fourier Linear Combiner



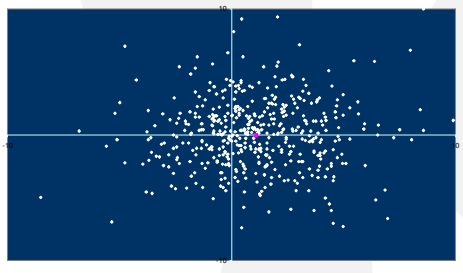
Fourier Linear Combiner published research

- Research studies involving evoked potentials:
  - Vaz CA and Thakor NV (1989) "Adaptive Fourier Estimation of Time-Varying Evoked Potentials," IEEE Trans. Biomed. Eng. 36(4), 448-455.
  - Tang Y and Norcia AM (1995) "An adaptive filter for steady-state evoked responses," Electroenceph. Clin. Neurophysiol. 96, 268-277.

Statistical Analysis

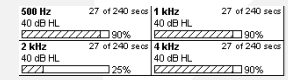
- Circular T squared - T^2_{circ} Statistic
- Each amplitude and phase the model determines present based on the patient data is plotted onto a polar plot (represented as white dot)
- Created specifically for detection of steady-state evoked potentials
  - Victor, J. D., and Mast, J. (1991) "A new statistic for steady-state evoked potentials," Electroenceph. Clin. Neurophys. 78, 378-388.

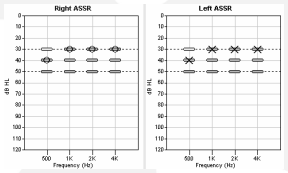
T^2_{circ} Statistic



Response Detection

- As the data points cluster around each other, the T^2_{circ} statistic determines if the response has reached for each test frequency. As the data is collected the statistical analysis is constantly updating response confidence level
- Once the response confidence level reaches 95%, a positive ASSR response is determined.





Comparison of FFT versus FLC

- Vander Werff K. (2009) Accuracy and time efficiency of two ASSR analysis methods using clinical test protocols. JAAA 20:433-452.
- Highlights:
  - There was not a significant difference between ASSR-behavioral threshold difference scores for the normal hearing and hearing impaired groups for either FFT or FLC methods at any frequency for independent or simultaneous recordings.
  - Total test time was not significantly different between FFT and FLC methods.
  - Test time was longer for hearing impaired subjects than for normal hearing subjects.
  - No significant difference in detection rate for an ASSR response was found between FLC and FFT methods.

CHARTR EP 200

Myths about ASSR

Myths about ASSR

ASSR is only good for detecting severe to profound hearing losses and does not function well for normal hearing or mild to moderate hearing losses. INCORRECT!!

Understanding Recruitment

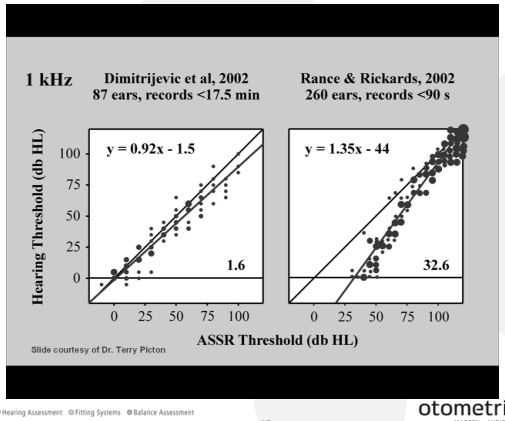
- Recruitment is the abnormal growth of loudness in the ear.
- Standard Audiometry – we see recruitment when the range between threshold and UCL is reduced.
- Electrophysiological Recruitment
  - Amplitude of the response at threshold for a person with "normal" hearing is very small.
  - Amplitude of the response at threshold for a person with "profound" hearing loss is large.

Understanding Signal Averaging

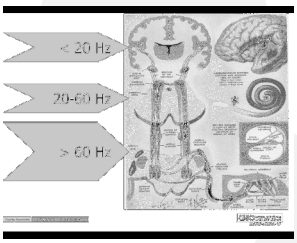
- Noise is always the enemy
- Noise has the greatest effect when measuring responses that are close to threshold
- The response MUST be larger than the noise in order to record it
- Averaging reduces the amount of noise and helps extract the response that is buried in the noise.
- Adaptive filter modeling can also eliminate noise by estimating the response and adjusting the estimates of the amplitude and phase over a series of sweeps

Short Averaging Times

- Some systems only average for 90 seconds
- You will be more likely to obtain responses for profound hearing loss than for normal hearing patients
- Because severe or profound hearing impaired patient's response at threshold is larger in amplitude (due to electrophysiological recruitment), it is easier to extract out the response from the noise. Therefore, you do not have to average as long.
- Short averaging times do not work well for normal hearing, mild or moderate hearing losses. You must average longer or use an adaptive filter to get the response out of the noise.

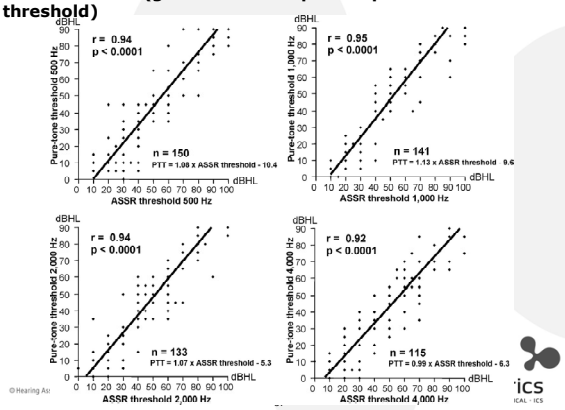


Impact of Modulation Rates



- Adult protocol uses rates close to 40Hz. Modulation rates below 60Hz, the patient must stay awake. Could have more noise – longer test times.
- Infant/Child protocol uses rates 60Hz or greater. You can use this protocol on any age.

Ahn et al 2007 (good relationship btwn puretone and ASSR threshold)

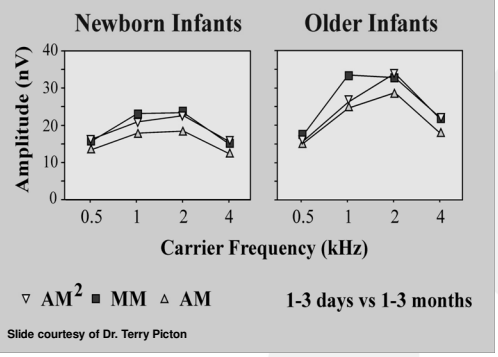


Myths about ASSR

ASSR is better for babies than adults.
INCORRECT!!

Obtaining normative data

- To have normative data that allows us to compare ASSR to puretone thresholds, we have to be able to obtain both sets of data to do the comparison.
- Normative data was obtained from Adults, because you cannot obtain accurate/reliable pure tone thresholds with infants.
- Newborns actually have much smaller response amplitudes than older children and adults.



Slide courtesy of Dr. Terry Picton

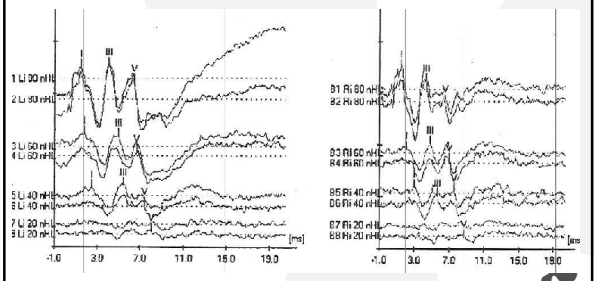
John M.S., et al (2004) Recording auditory steady state responses in young infants. Ear Hear 25: 539-553.

Always Use a Battery of Tests

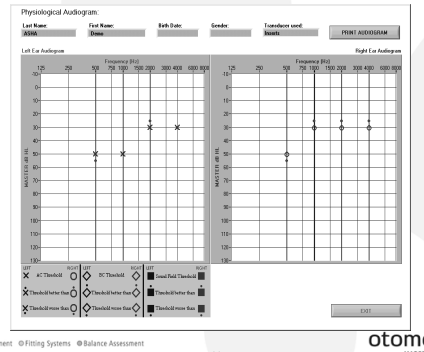
Case Study

- 7 month old infant
- Tested in OR to obtain baseline for ototoxic monitoring.
- Surgeon had difficulty inserting port for cisplatin, limited time to test.
- Obtained Click ABR (air conduction)
- Obtained partial ASSR results
- When patient returned to PICU obtained DPOAEs

Click ABR

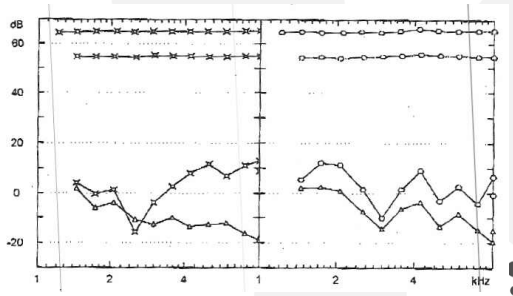


ASSR



DPOAEs – Ototoxicity Protocol

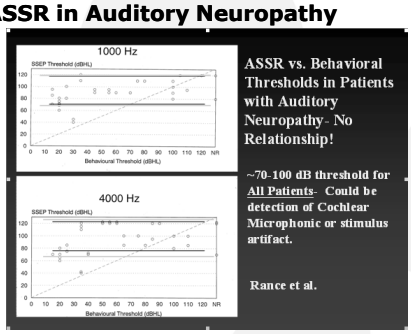
1500 to 10,000 Hz



ASSR and Auditory Neuropathy

- In patients with auditory neuropathy or neural dys-synchrony….
  - We might expect absent, sporadic, or elevated response pattern
  - The response may actually be the cochlear microphonic

ASSR in Auditory Neuropathy



ASSR vs. Behavioral Thresholds in Patients with Auditory Neuropathy- No Relationship!

~70-100 dB threshold for <u>All Patients</u>- Could be detection of Cochlear Microphonic or stimulus artifact.

Rance et al.

From *Optimized Recording and Detection of Frequency-Specific ABR*, presented by Sininger and Dworsack at AAA 2007

Rance G, Beer DE, Cone-Wesson B et al (1999) Clinical findings for a group of infants and young children with auditory neuropathy. Ear Hear 20(3);238-252.

Recommended Test Battery

- Otoacoustic Emissions and Auditory Reflexes
  - Assist in ruling out or confirming AN/AD or conductive component
- Click ABR (air conduction)
  - Neurological Assessment (I-V latencies, interaural latencies, cochlear microphonic) – Rule out or confirm AN/AD
  - Threshold Search (unless limited by time)
- Click ABR or ASSR (bone conduction)
  - Rule out conductive component
  - Other option high frequency tympanometry
- ASSR
  - Frequency Specific information – assist in HA fitting
- Behavioral/ Visual Reinforcement Audiometry
  - Always confirm with behavioral ASAP

CHARTR EP 200

ASSR – performing a test

otometrics
MADSEN · AURICAL · ICS

Patient Preparation

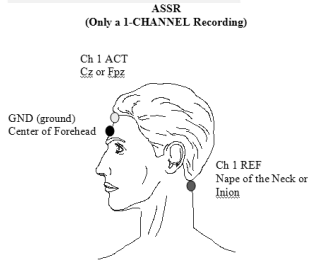
otometrics
MADSEN · AURICAL · ICS

CHARTR EP 200 Preamp

- Chartr EP 200 preamp connects to the Chartr EP 200 box via a 6 foot cable to allow ample distance between the patient and computer.
- The electrodes and transducers plug directly into the preamp.

otometrics
MADSEN · AURICAL · ICS

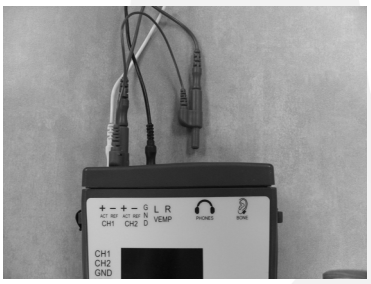
ASSR Electrode Placement – only Channel 1



ASSR Electrode Locations

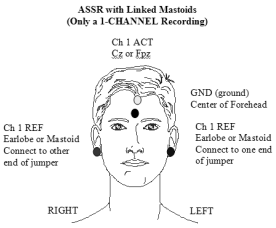
- Fz/Cz to posterior neck gives largest response.
- Inion reference may give less noise.
- Neck electrode may be difficult in babies with fatty pad on the neck. In these cases, move to the inion. Do not move down the back which can result in EKG noise.
- Linked mastoids may be an option.

Linked Mastoids

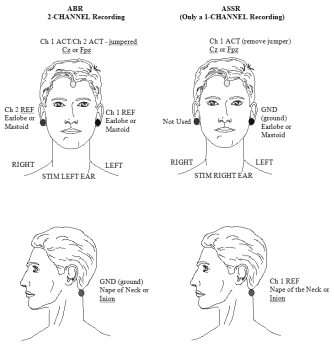


Ch 1 Act – Cz or FPZ
Ch 1 Ref – jumper with left and right mastoids connected
Ch2 Act – empty
Ch 2 Ref – empty
GND – high forehead

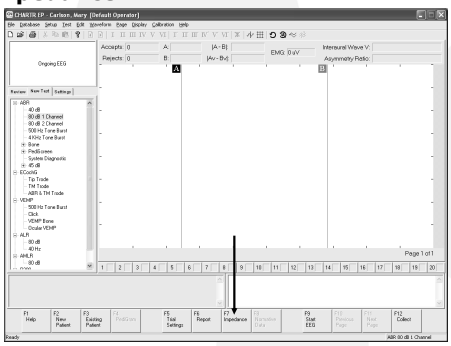
ASSR Electrode Placement – Linked Mastoids



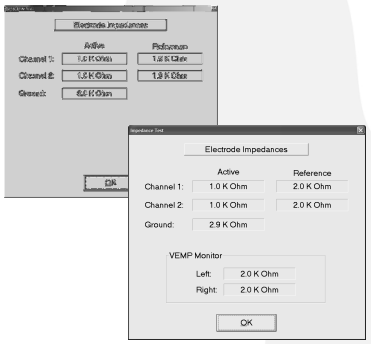
ASSR & ABR Electrode Placement



Impedance



Checking Electrode Impedance



Goal: Low electrode readings of **<5K** Ohms each balanced with no more than **<2K** Ohms difference between electrodes

Inter-electrode impedance is the most important (common mode rejection does not work well if inter-electrode impedance varies)

Patient State

- ASSR responses are much smaller in amplitude than ABR responses.
- Patient State is critical to shorter test time and accurate results.
- Patient should be very quiet or preferably asleep.
- Patient should be lying supine or in their most comfortable resting position.

Bone Conduction Responses

- Bone Oscillator should be placed on the mastoid. (using forehead can reduce output as much as 15dB ANSI S3.6 1996)
- Masking is available with ASSR for bone conduction testing and for unilateral hearing losses.
- Maximum intensity allowable is 60 dB because of artifacts.

Bone Conduction Responses

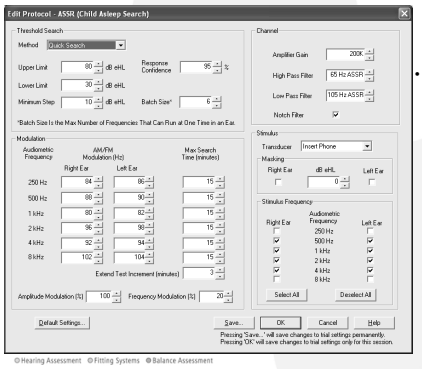
- Jeng FC, Brown C, Johnson T, & Vander Werff K (2004) Estimating Air-Bone Gaps Using Auditory Steady State Responses. *J AM Acad Audiol, 15, 67-78.*
- Small SA & Stapells DR (2004) Artifactual Responses when Recording Auditory Steady-State Responses. Ear Hear 25(6), 611-623.

Data Collection

ASSR Highlights

- Simultaneous testing of **both ears, up to 6 frequencies** and variable intensities.
- **User-adjustable parameters** for criterion limits, maximum step search time, modulation frequencies, test frequencies, intensities and ears tested.
- **Choice** of two search methods:
  - **Quick search** – starts search between the upper & lower limit. Will go back up to a higher intensity if missed a response
  - **Straight descent** – starts search at upper limit, does all frequencies then descends. Only descends, won't go up in intensity to find a threshold

ASSR Trial Settings dialog

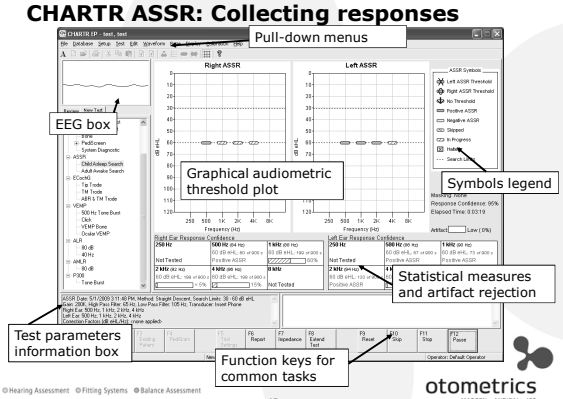


- User adjustable features:
  - Search method, limits and response confidence
  - Modulation parameters
  - Channel filters
  - Search time
  - Test frequencies

otometrics
MADSEN · AURICAL · ICS

64

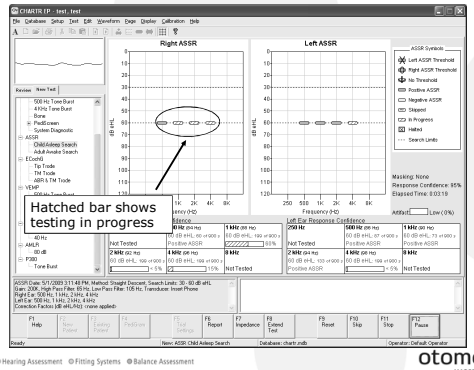
CHARTR ASSR: Collecting responses



otometrics
MADSEN · AURICAL · ICS

65

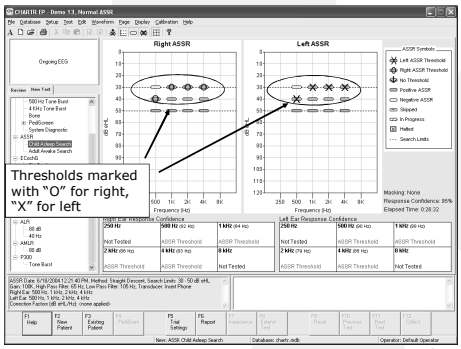
CHARTR ASSR: Collecting responses



otometrics
MADSEN · AURICAL · ICS

66

CHARTR ASSR: Collecting responses

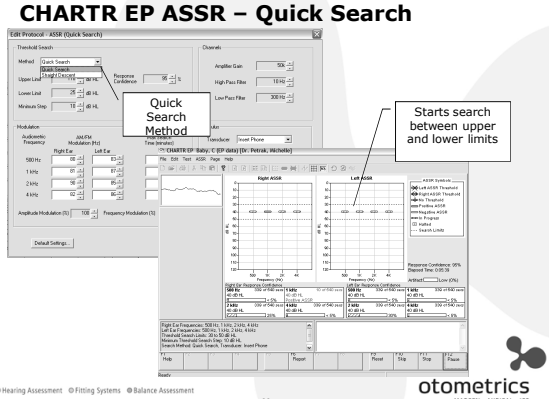


Hearing Assessment · Fitting Systems · Balance Assessment

otometrics
MADSEN · AURICAL · ICS

67

CHARTR EP ASSR – Quick Search

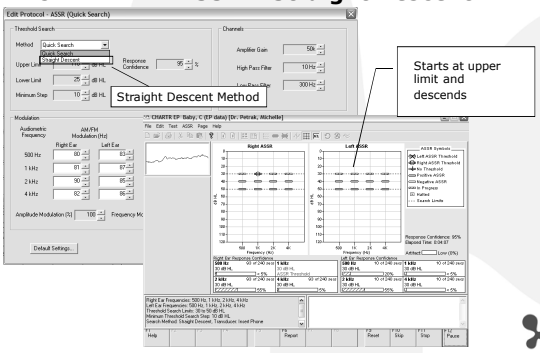


Hearing Assessment · Fitting Systems · Balance Assessment

otometrics
MADSEN · AURICAL · ICS

68

CHARTR EP ASSR – Straight Descent

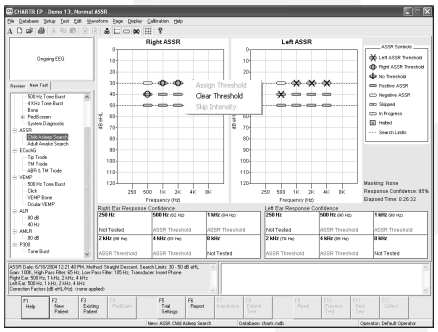


Hearing Assessment · Fitting Systems · Balance Assessment

otometrics
MADSEN · AURICAL · ICS

69

Data collection



Right Click on Response:

Skip Intensity – stops data collection for that particular frequency **(Collection Only)**

F10 Skip – skips that intensity for all frequencies (choose left, right or both) **(Collection Only)**

Assign Threshold – marks that intensity/frequency as being threshold. **(REVIEW only)**

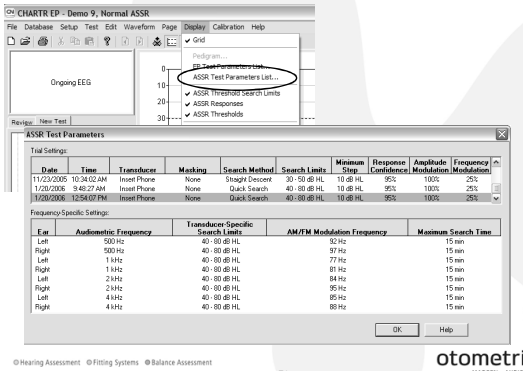
•**Clear Threshold** – clears that intensity/frequency as being determined as threshold. **(REVIEW only)**

Hearing Assessment · Fitting Systems · Balance Assessment

70

otometrics
MADSEN · AURICAL · ICS

Displaying Test Parameters



Hearing Assessment · Fitting Systems · Balance Assessment

71

otometrics
MADSEN · AURICAL · ICS

CHARTR EP 200

ASSR – determining threshold

otometrics
MADSEN · AURICAL · ICS

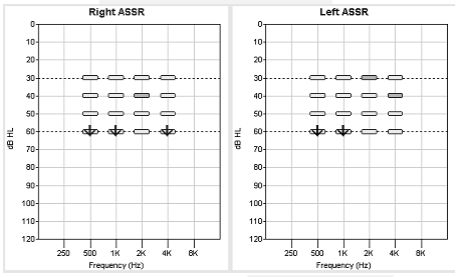
Determining Threshold Response with ASSR

- A threshold response is the lowest intensity at which a response is obtained.
- However, for that intensity to be determined a threshold, there should be responses present at higher intensities.
- Always the consider the pattern of the response

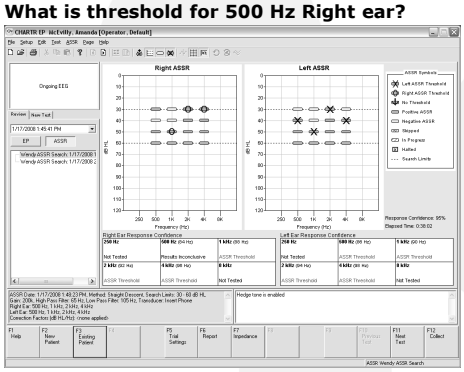
Response at Lower Intensity, No response at Higher Intensity

- The presence of a positive response can occur at a lower intensity even when it did not occur 10 dB higher. This phenomenon often occurs if the noise level (patient state) varies during the test. However, if you get a response at one level without seeing a significant response at 10 dB **and** 20 dB above this intensity, then you should be suspicious of the result at the lower intensity.

Response at Lower Intensity, No response at Higher Intensity



What is threshold for 500 Hz Right ear?

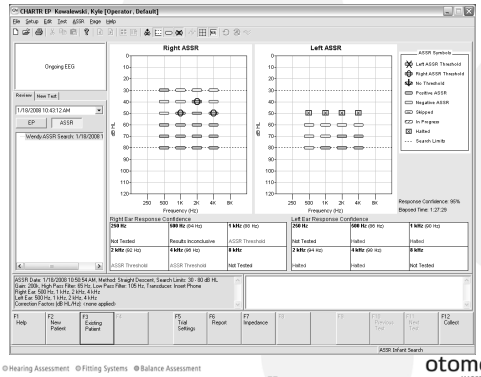


Hearing Assessment ⊙ Fitting Systems ⊙ Balance Assessment

otometrics
MADSEN · AURICAL · ICS

76

What is threshold for 500 Hz Right ear?



Hearing Assessment ⊙ Fitting Systems ⊙ Balance Assessment

otometrics
MADSEN · AURICAL · ICS

77

Determining Threshold Response with ASSR

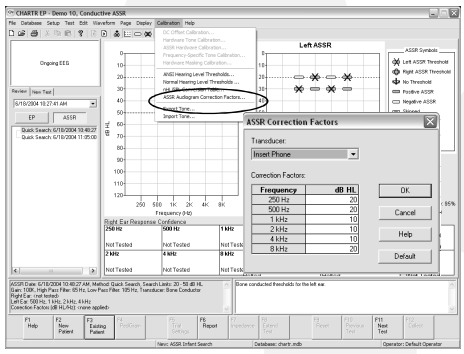
- Statistics are not perfect and all commercially available ASSR systems can report responses caused by artifact. The key is to know that such artifactual responses will be spurious and a child with significant hearing loss will not be identified as having normal hearing. Clinical judgment must always be used to determine the validity of responses. If in doubt, the cross-check principle applies, as always.

Hearing Assessment ⊙ Fitting Systems ⊙ Balance Assessment

otometrics
MADSEN · AURICAL · ICS

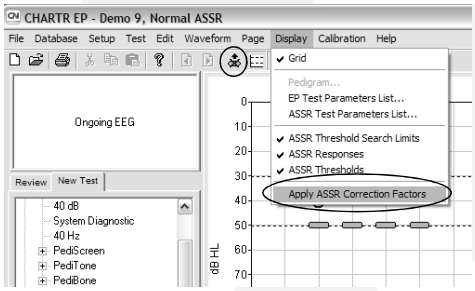
78

ASSR Correction Factors

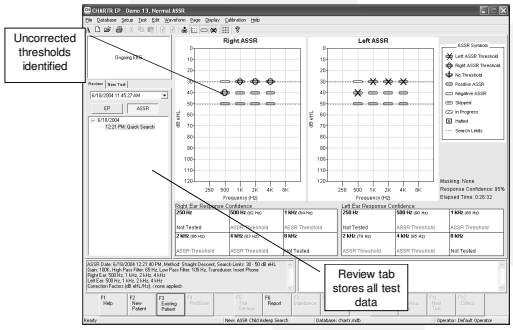


Can be applied during review

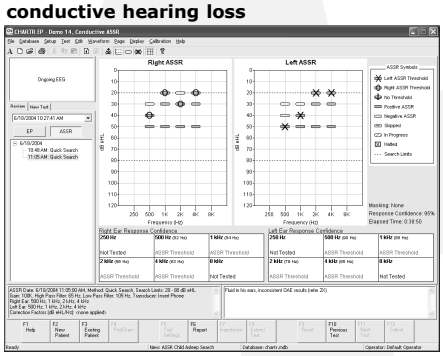
Applying Correction Factors



CHARTR EP ASSR – Completed Test



Air Conduction ASSR data – infant with conductive hearing loss

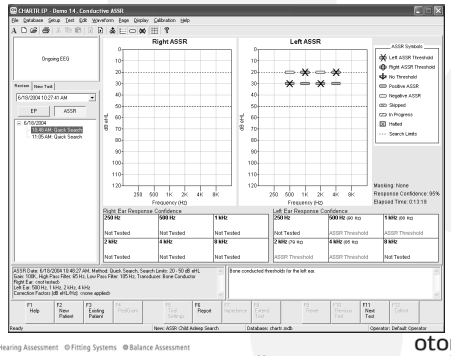


Hearing Assessment · Fitting Systems · Balance Assessment

otometrics
MADSEN · AURICAL · ICS

82

Bone Conduction ASSR data – infant with conductive hearing loss



Hearing Assessment · Fitting Systems · Balance Assessment

otometrics
MADSEN · AURICAL · ICS

83

Reporting

Hearing Assessment · Fitting Systems · Balance Assessment

otometrics
MADSEN · AURICAL · ICS

84

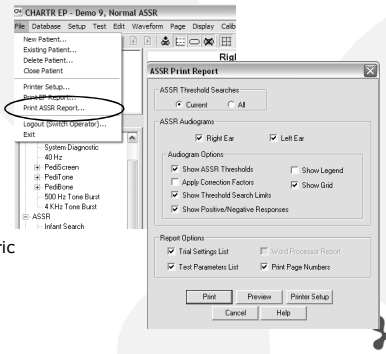
Printing ASSR report

Print Report Menu

- Select what you want printed

- Select optional test parameters to Print

- Optionally apply corrections to estimate audiometric thresholds or print blank audiogram

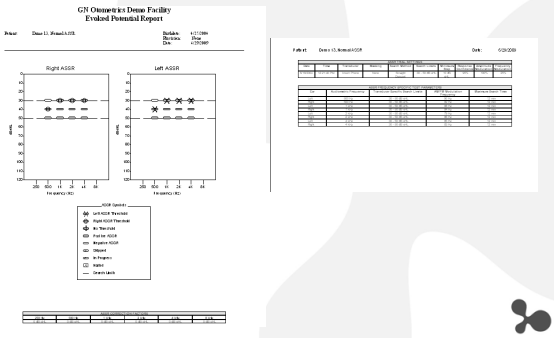


Hearing Assessment · Fitting Systems · Balance Assessment

85

otometrics
MADSEN · AURICAL · ICS

Report Preview



Hearing Assessment · Fitting Systems · Balance Assessment

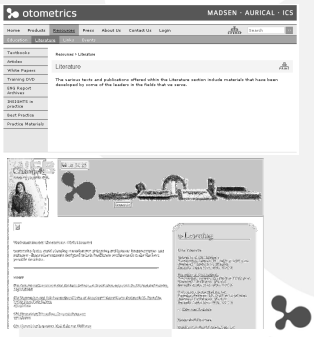
86

otometrics
MADSEN · AURICAL · ICS

Web-sites: Otometrics & Audiology Online

www.otometrics.com/resources

www.audiologyonline.com/channels/gn_otometrics.asp



Hearing Assessment · Fitting Systems · Balance Assessment

87

otometrics
MADSEN · AURICAL · ICS

Any Questions?