Objective Audiometry

- Otoacoustic Emissions
- Auditory evoked potentials

Remarks on Otoacoustic Emissions OAE

Sommerschule, 26.08.2016, P.O., KSL

- History
- Physiology
- Terminology
- Specialities and clinical relevance of OAE

History

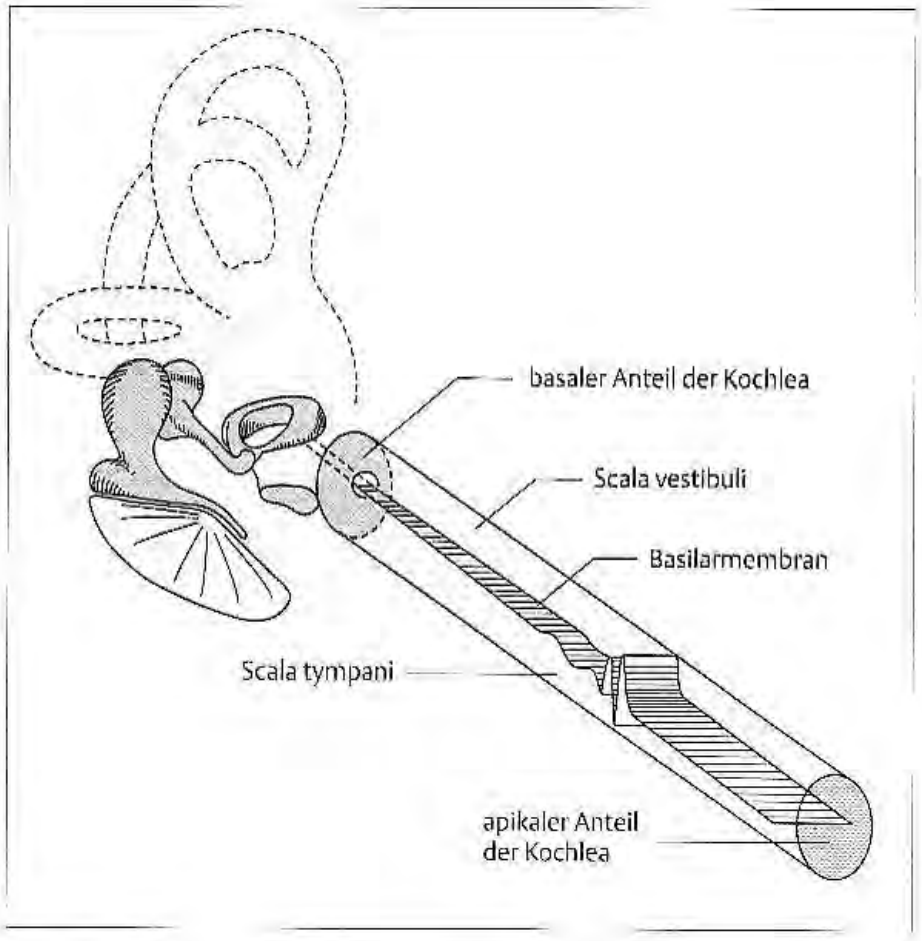


Abb. 2.3 Die Kochlea ist in dieser Schemazeichnung als ausgestreckte Röhre dargestellt. Die mit Perilymphe gefüllten Räume, Scala vestibuli und Scala tympani, sind durch die kochleäre Trennwand, hier vereinfacht als Basilarmembran bezeichnet, getrennt. Das idealisierte Bild einer Wanderwelle, hervorgerufen durch einen Sinuston, ist als Auslenkung der Basilarmembran gezeichnet. Die dargestellte Amplitude der Wanderwelle ist deutlich vergrößert wiedergegeben

- Who discovered them?
  - Georg Bekesy, 1961 nobel price

History

- In 1948 Thomas Gold, was able to show, that the travelling wave in the cochlea, described by Bekesy, could not explain the measurable sensitivity and frequency selectivity of the cochlea. He postulated the presence of measurable acoustic emissions in the outer ear canal due to mechanical cochlear amplification processes.
- Who measured it first?
  - In 1978, David Kemp, developed the first commercially available measuring system for OAE, the ILO 88

Destinies

- Georg Bekesy enjoyed the glory and the honor of a nobel prize winner up to his death in Honolulu in 1972

- David Kemp became probably more wealthy than most famous physicists, since he had his OAE-measuring system patented up to 1999.

- Thomas Gold who, in 1948, has presumably been misunderstood and unacknowledged at least by physicians, turned his interest to bigger objects already in 1949: The Steady-State Theory of the Expanding Universe

- P.O. , after 28 years of clinical practice, is still measuring OAE using the ILO 88 system with a lot of fun.

Physiology: cochlear amplifier

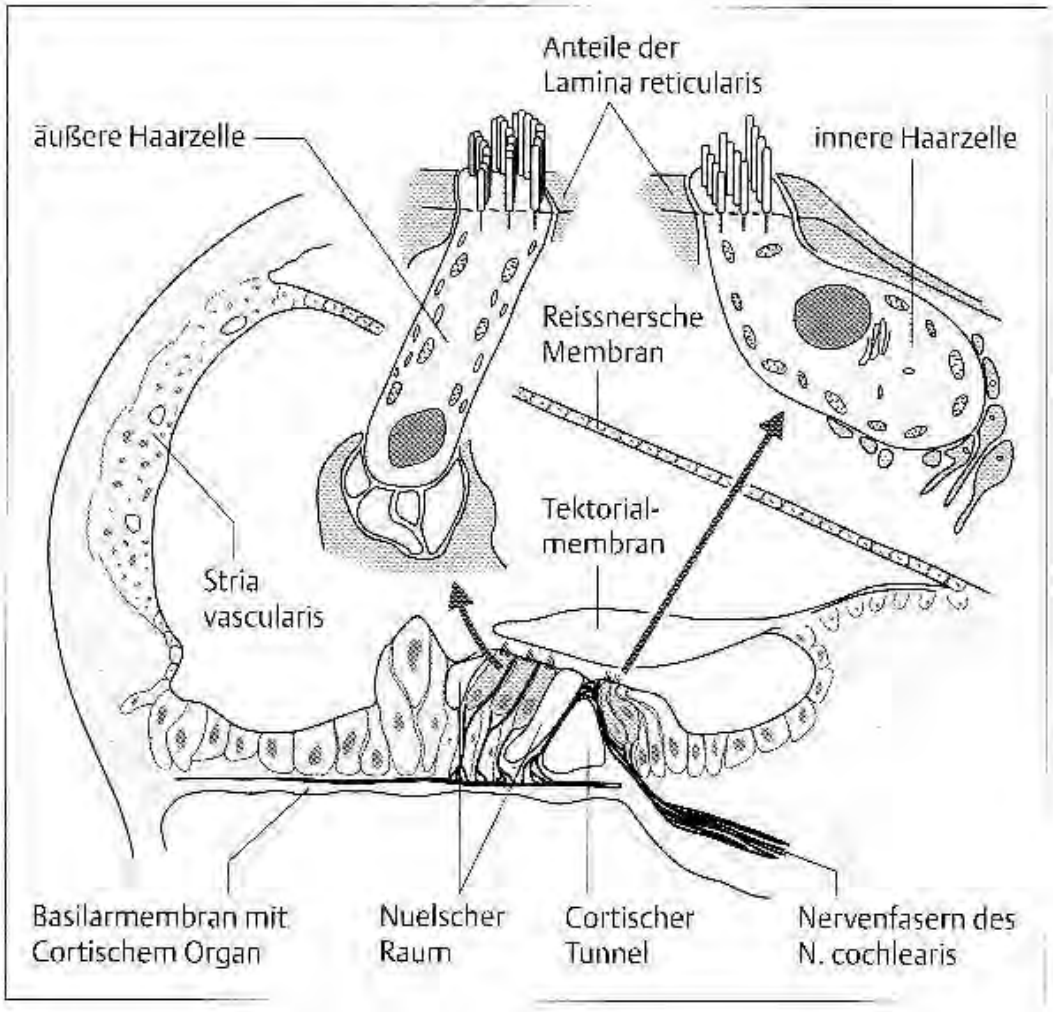


Abb. 2.2 Schematischer Querschnitt durch das Cortische Organ von Säugetieren und vom Menschen

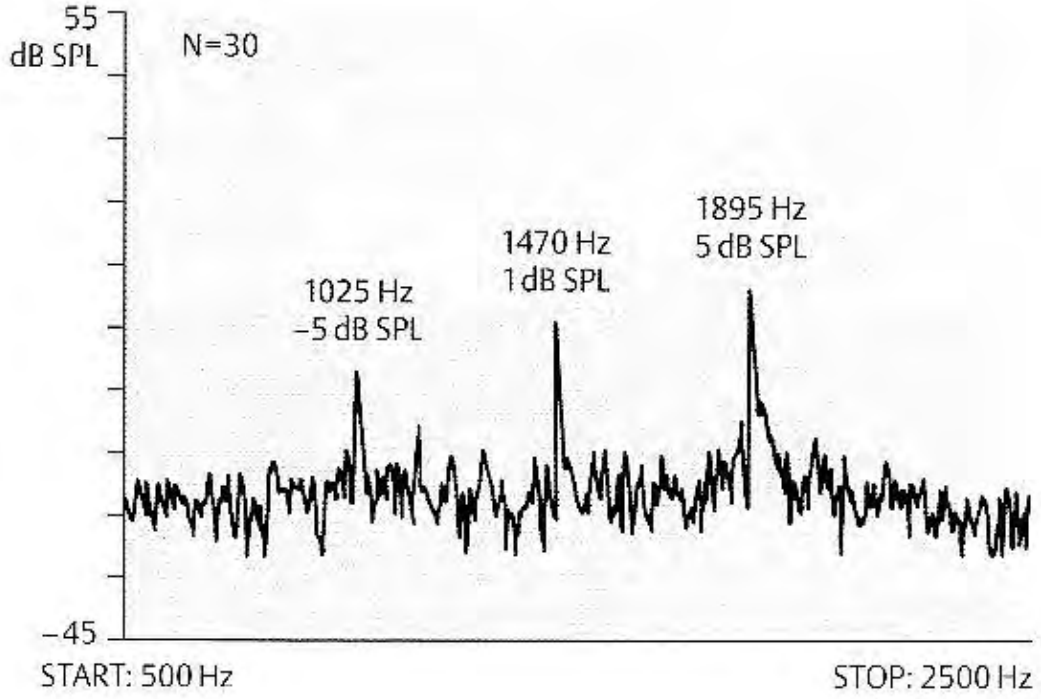
The outer hair cells are unquestioned as organs of the cochlear amplifier nowadays

Terminology

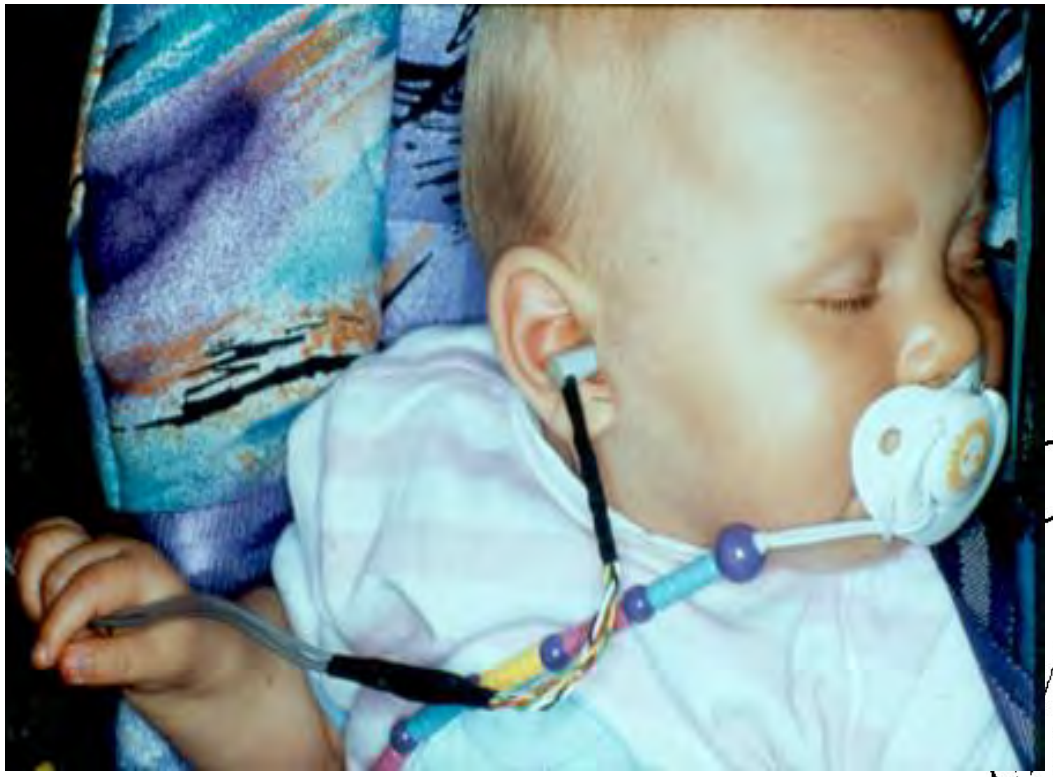
- Spontaneous OAE
- Evoked OAE = OAE needing a stimulus
  - Transitory evoked OAE : click stimulus
  - Distorsion product OAE: 2 sinus tones generate in the non linear amplifier of the outer hair cells additional tones
  - Stimulus-frequency dependent OAE: gliding sinus tone stimulus

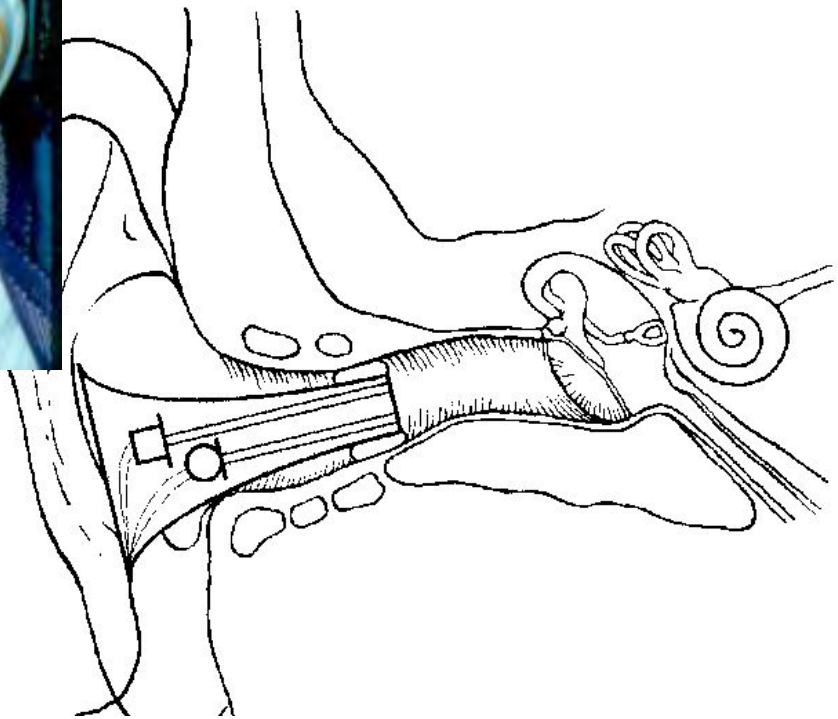
Spontaneous OAE

- fairly steep spectral lines, > 20 dB SPL
- Present in 50 % of normal hearing ears
- Absent in hearing loss > 20 dB HL
- no clinical relevance

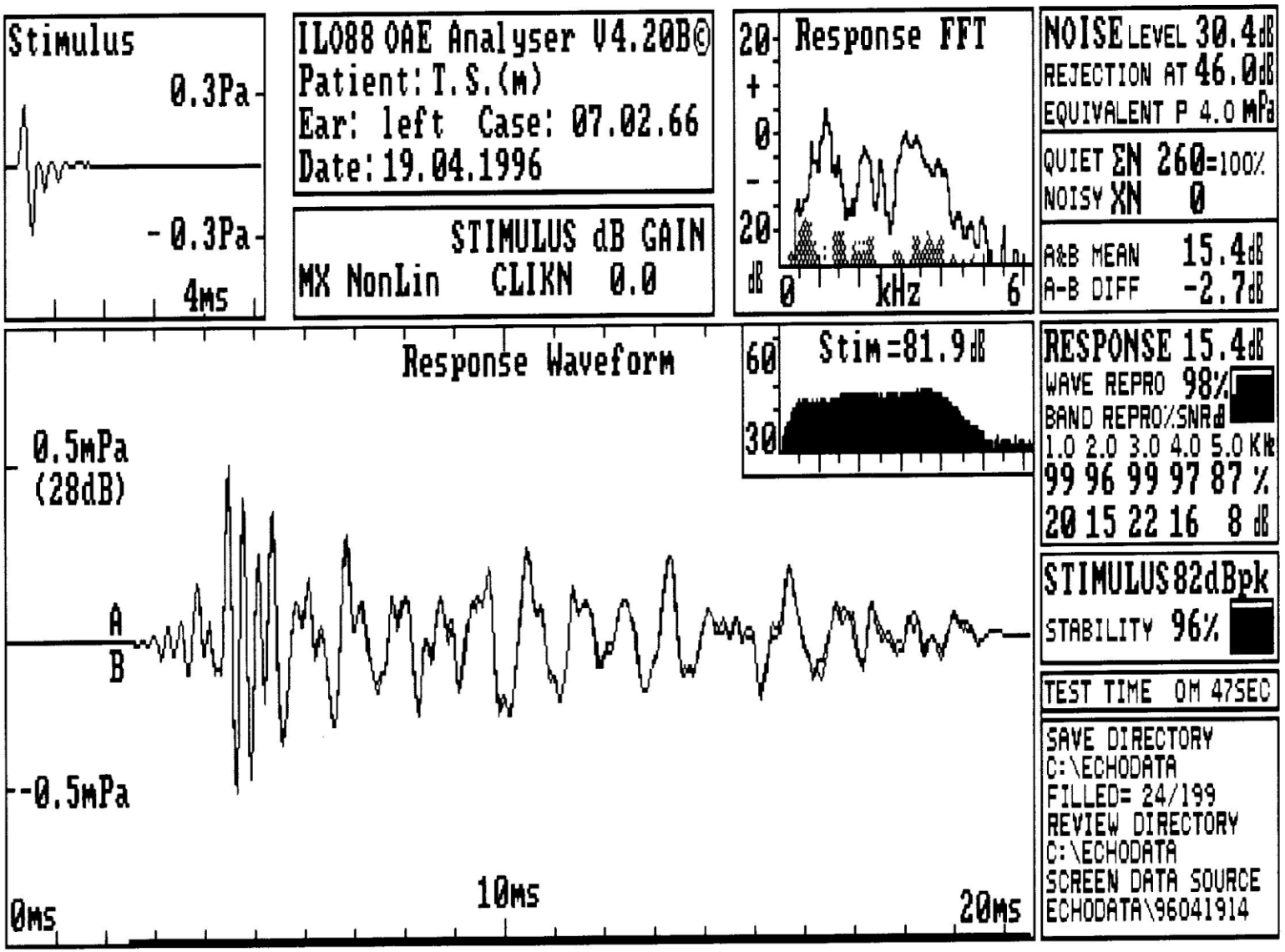


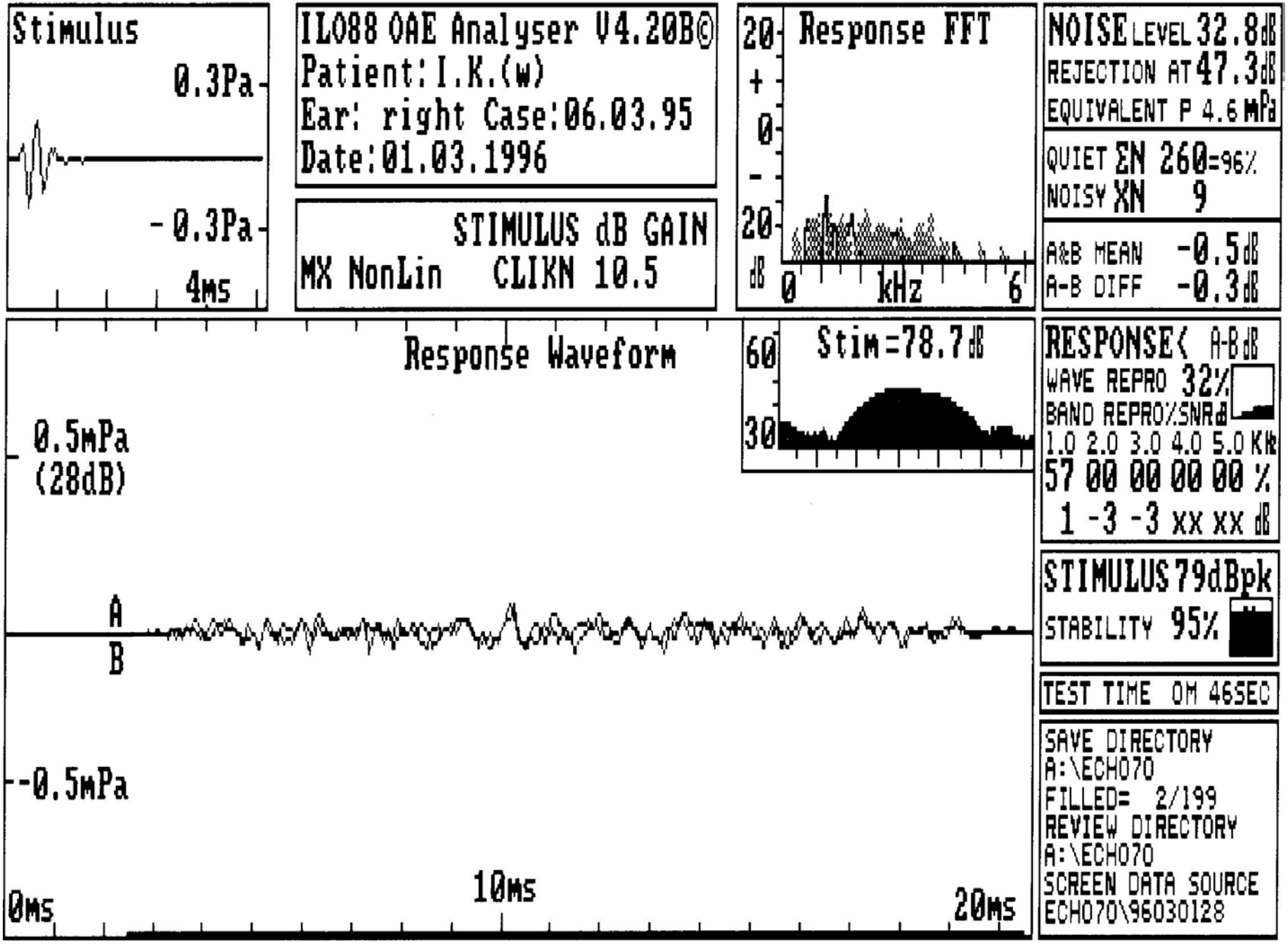
Transitory Evoked Otoacoustic Emissions
TEOAE



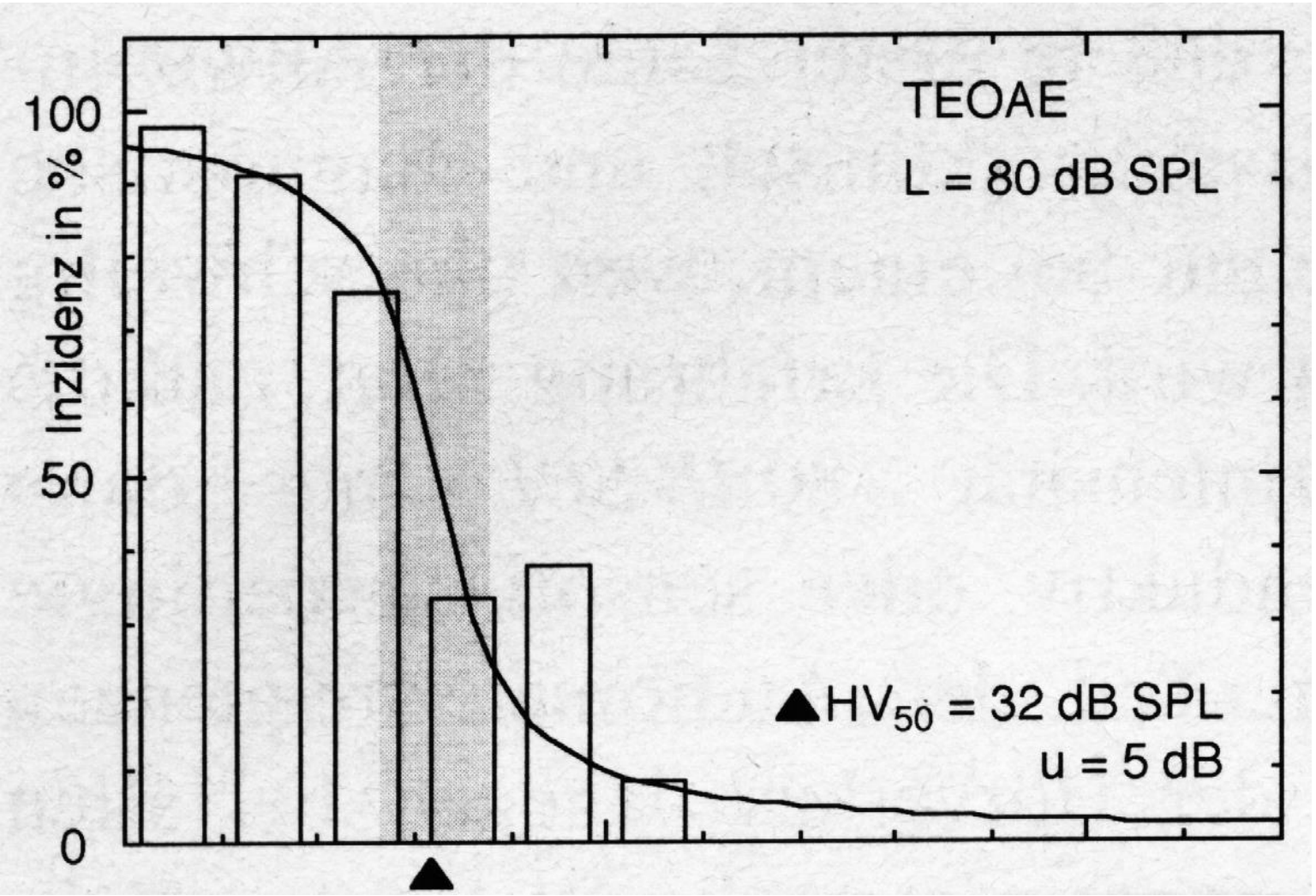


Transitory Evoked OAE




Stimulus
0.3Pa
-0.3Pa
4ms
ILO88 OAE Analyser V4.20B©
Patient: I.K.(w)
Ear: right Case:06.03.95
Date:01.03.1996
STIMULUS dB GAIN
MX NonLin CLIKN 10.5
Response FFT
20
+
0
-
20
dB
0
kHz
6
NOISE LEVEL 32.8dB
REJECTION AT 47.3dB
EQUIVALENT P 4.6 mPa
QUIET EN 260=96%
NOISY XN 9
A&B MEAN -0.5dB
A-B DIFF -0.3dB
Response Waveform
0.5mPa
(28dB)
A
B
-0.5mPa
0ms
10ms
20ms
Stim=78.7dB
60
30
RESPONSE(A-B dB
WAVE REPRO 32%
BAND REPRO%SNRdB
1.0 2.0 3.0 4.0 5.0 KHz
57 00 00 00 00 %
1 -3 -3 xx xx dB
STIMULUS 79dBpk
STABILITY 95%
TEST TIME 0M 46SEC
SAVE DIRECTORY
A:\ECHO70
FILLED= 2/199
REVIEW DIRECTORY
A:\ECHO70
SCREEN DATA SOURCE
ECHO70\96030128

When can OAE be measured, and when not?



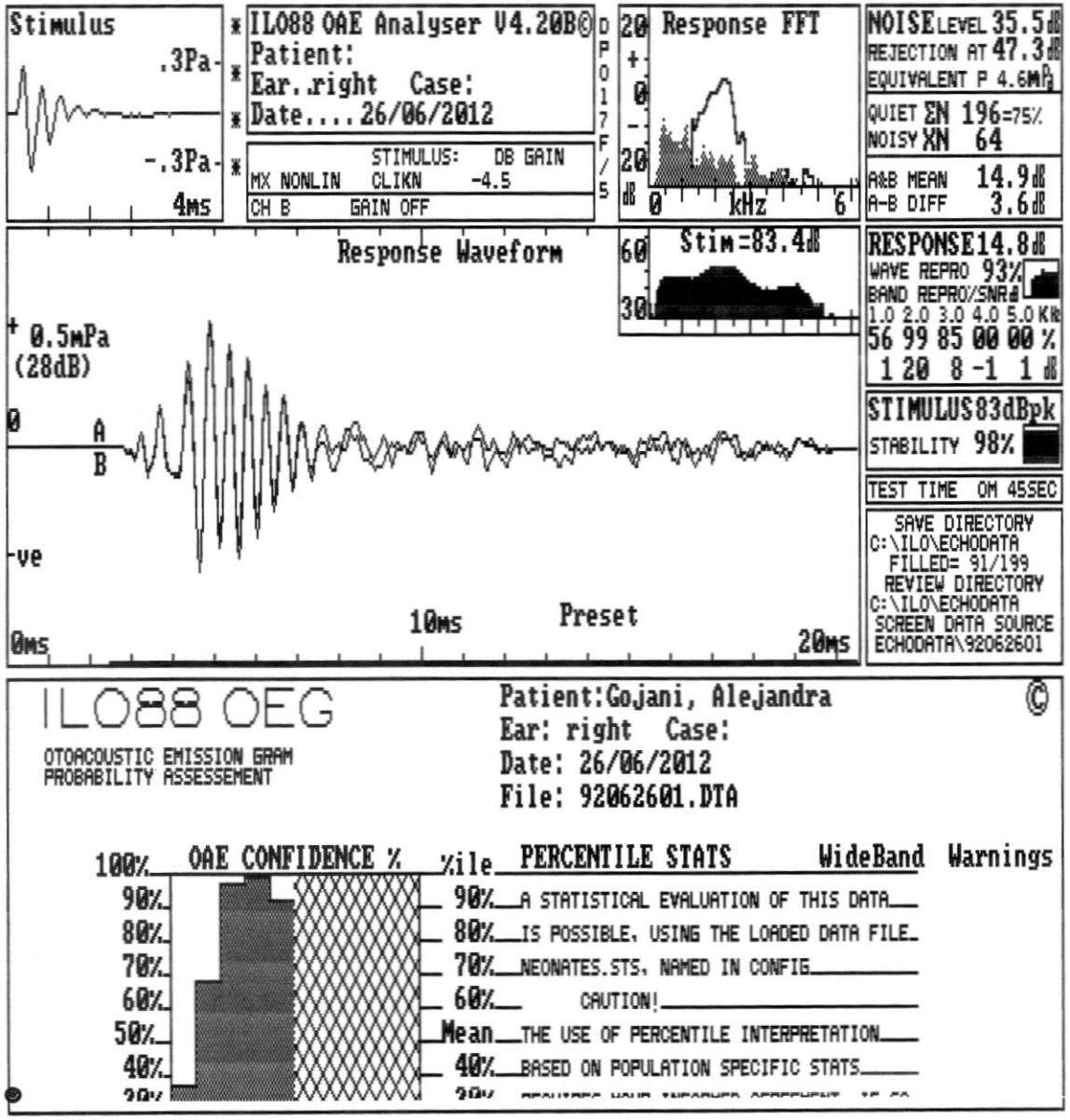
Clinical relevance

- Primarily, very useful **screening** instrument
  - objektive, not invasive
  - simple measurement technique, mainly due to temporal separation of signal and response
  - detectable in almost all normal hearing ears

Clinical relevance

- shortcomings
  - Low frequency-selectivity , 0,4 – 6 kHz
  - Vulnerable to noise (patient – related)
  - Low discrimination around 30 dB
  - errors due to artefacts
  - Susceptible to conductive hearing loss, double attenuation, for stimulus and response signal

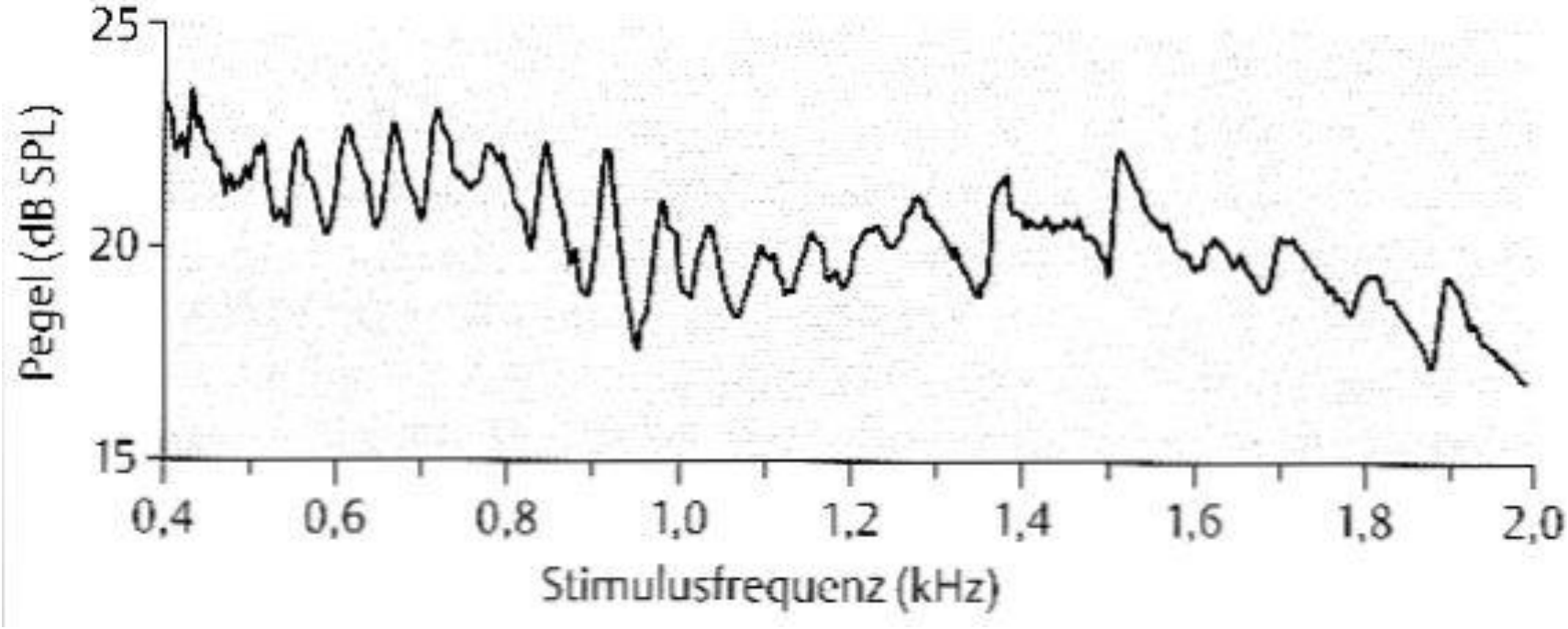
Errors due to artefacts



Stimulus-frequency-dependant OAE

- Gliding sinus tone as stimulus, response of same frequency at lower scale
- Difficult measurement!
- solution: changing interference in the outer ear canal, due to gliding tone, changing distance to response generator
- No clinical use

Stimulus-frequency-dependant OAE

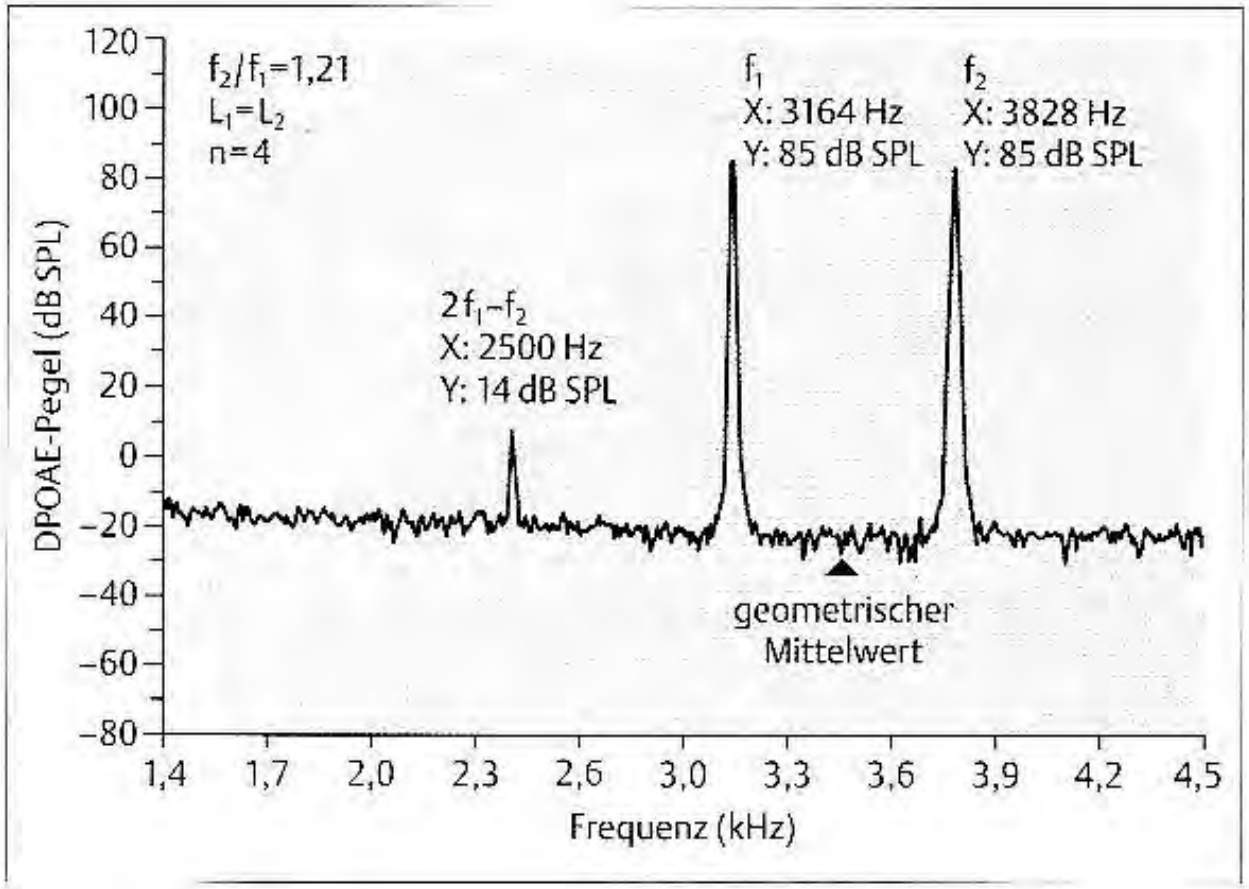


Distorsionsprodukt OAE

- All non linear amplifiers as the outer hair cells generate frequencies, that are not present in the input signal
- In the ear mainly the so-called cubic difference tone $2f1 – f2$, $f1<f2$
- Stimulation level around 65 dB SPL
- Response plotted as DP-gramm

Distorsionproduct OAE

Abb. 2.8 Darstellung eines typischen Distorsionsproduktes $2f_1 - f_2$, hier bei 2,5 kHz und aufgezeichnet von einem normalhörenden Ohr. Die Stimulusparameter sind in der Abbildung genannt. Die Lage des geometrischen Mittelwertes der Primärtöne $(f_1 \times f_2)^{0,5}$ ist mit einem Dreieck gekennzeichnet



Praxis der Neuroaudiologie, Höhmann, Dieler, Shehata-Dieler, Thieme

DP-gramm

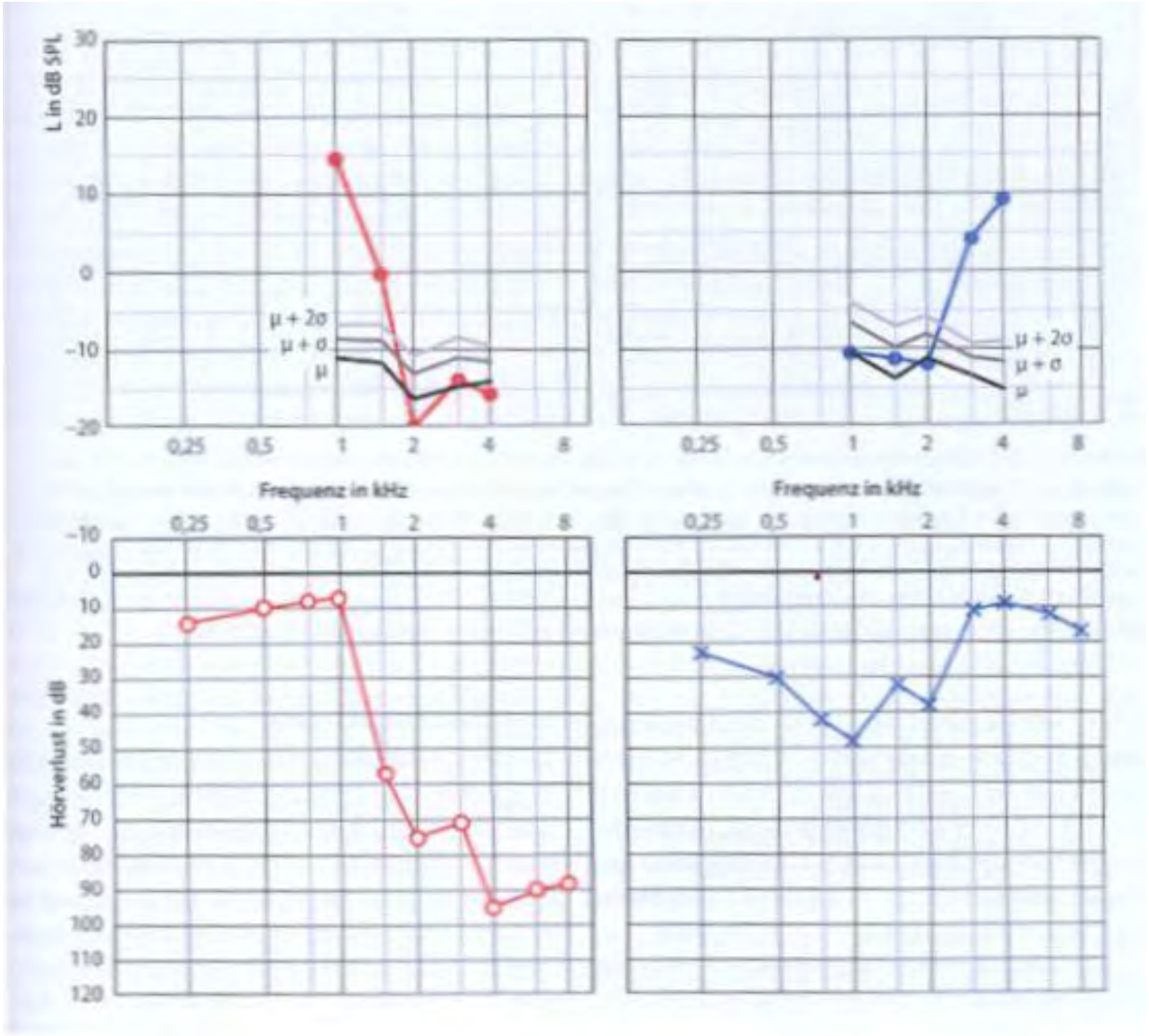


Abb. 4.18 DP-Gramme und Audiogramme in einem Fall von Hochtonhörverlust (linkes Bild) und Tieftonhörverlust (rechts). Die Korrelation zwischen DP-Gramm und Audiogramm beträgt im linken Bild 93 % und im rechten Bild 92 %. Es handelt sich um dieselben Ohren, deren TEOAE-Spektren in Abb. 4.10 gezeigt sind.

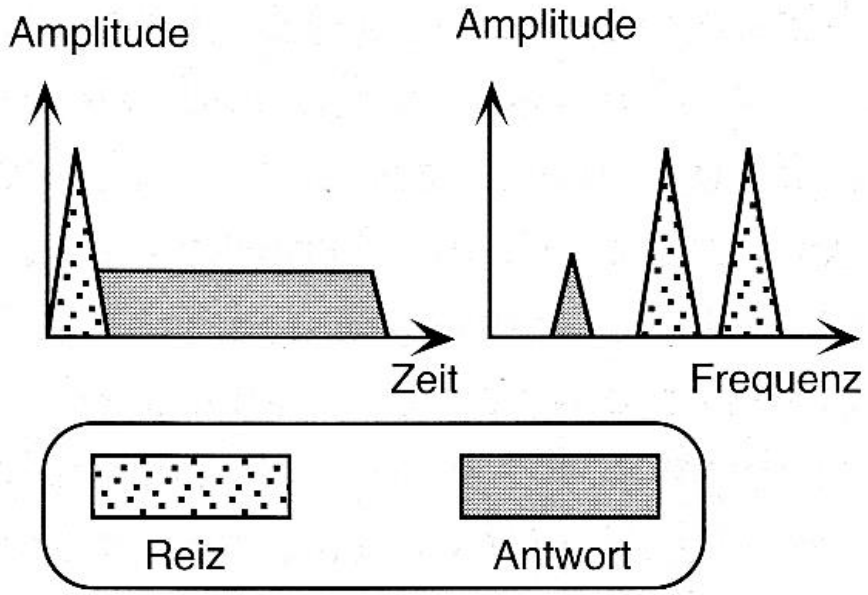
aus Objektive Audiometrie im Kindesalter, Hoth , Mühler, Neumann, Walger

Clinical relevance

- Objective non invasive audiometric method, applicable also in hearing loss from 30 dB to 55 dB HL.
- High frequency selectivity 1 – 6 kHz
- Helpful in the follow up after failure of Newborn Hearing Screeening using TEOAE and/or AAEP to determine and define the pattern of hearing loss

Separation of stimulus and response

Abb. 3.**14** Die Trennung zwischen Reiz und Antwort geschieht bei der Messung von TEOAE im Zeitbereich (links), bei der Messung von DPOAE dagegen im Frequenzbereich (rechts)



Remarks on auditory evoked potentials

Sommerschule, 26.08.2016, P.O., KSL

Auditory evoked potentials – Brain stem audiometry (BERA)

- Presentation of the EEG parts , representing the activity of the peripheric auditory pathway from the cochlear nerve to the brain stem, 1 to 10 % of the EEG signal!!
- Only possible if the patient is very quiet, f.ex. during the sleep or in general anasthesia

ERA/AEP

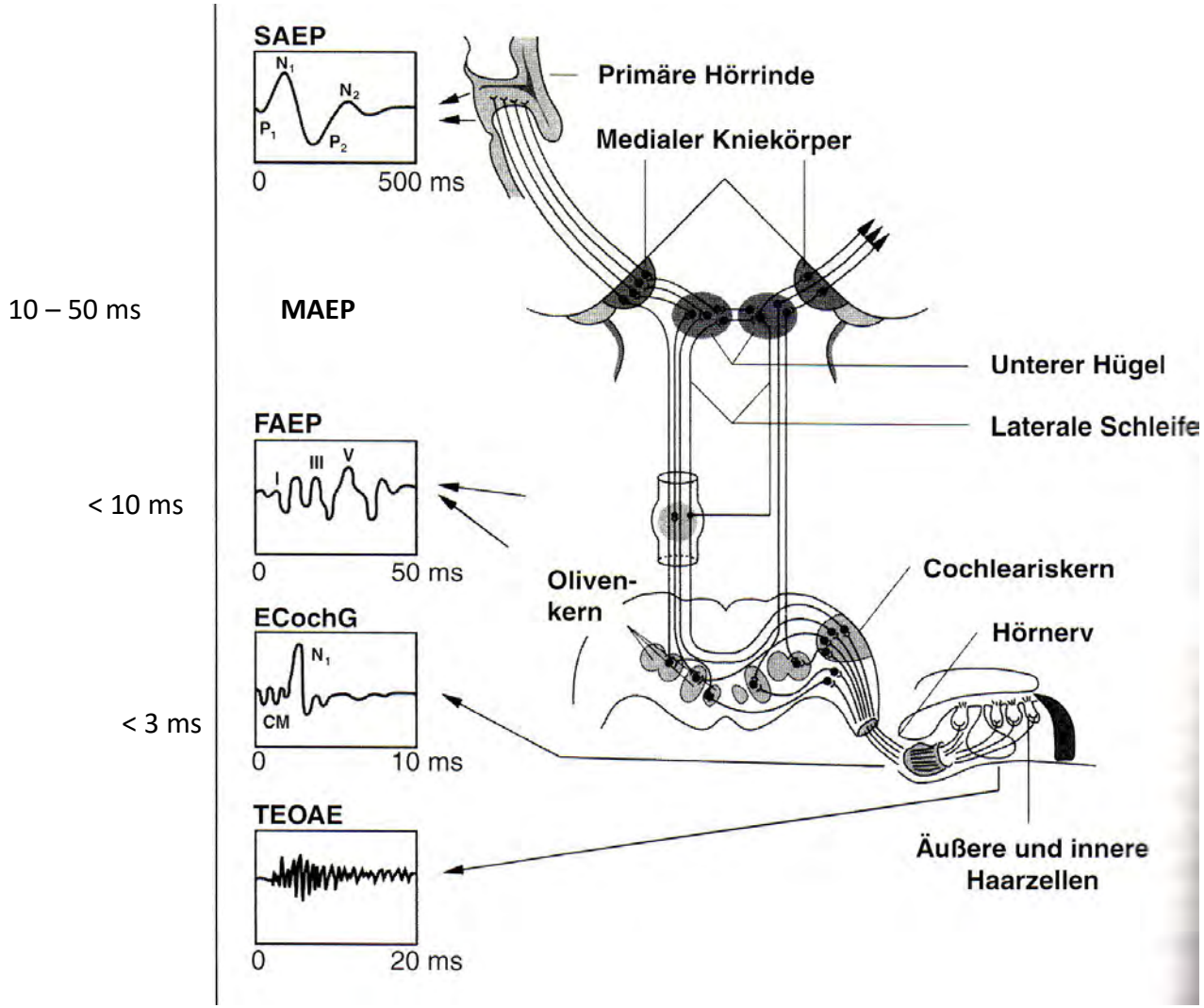
- ERA
  - **e**lectric **r**esponse **a**udiometry
  - **e**lektrische **R**eaktions**a**udiometrie

- AEP
  - **a**kustisch **e**vozierte **P**otentiale
  - **a**uditory **e**voked **p**otentials

AEP

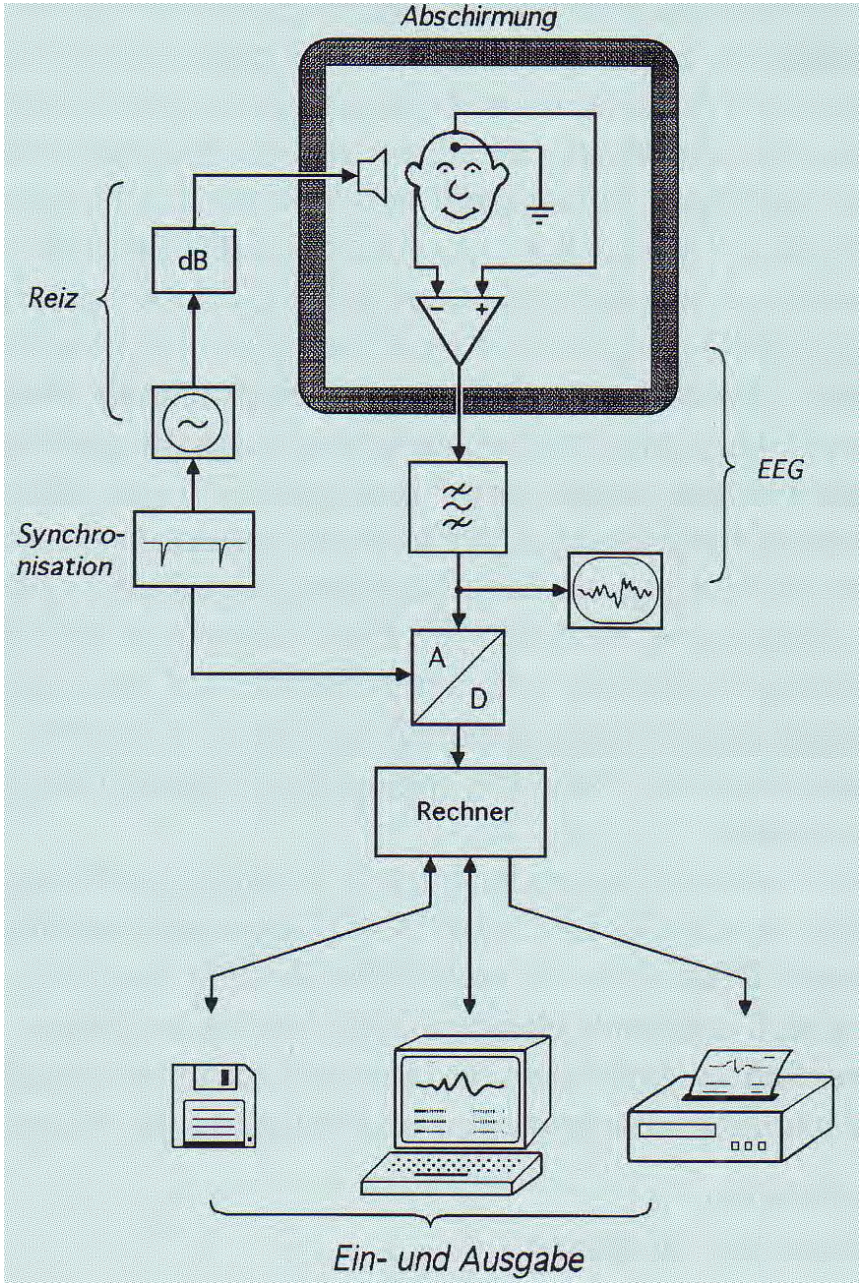
- SFAEP
    - sehr frühe auditorisch evozierte Potentiale (ECochG)
- FAEP
    - frühe auditorisch evozierte Potentiale (BERA)
- MAEP
    - mittlere auditorisch evozierte Potentiale (MLRA)
- SAEP
    - späte auditorisch evozierte Potentiale (CERA)

„Connectivity“ in the hearing pathway



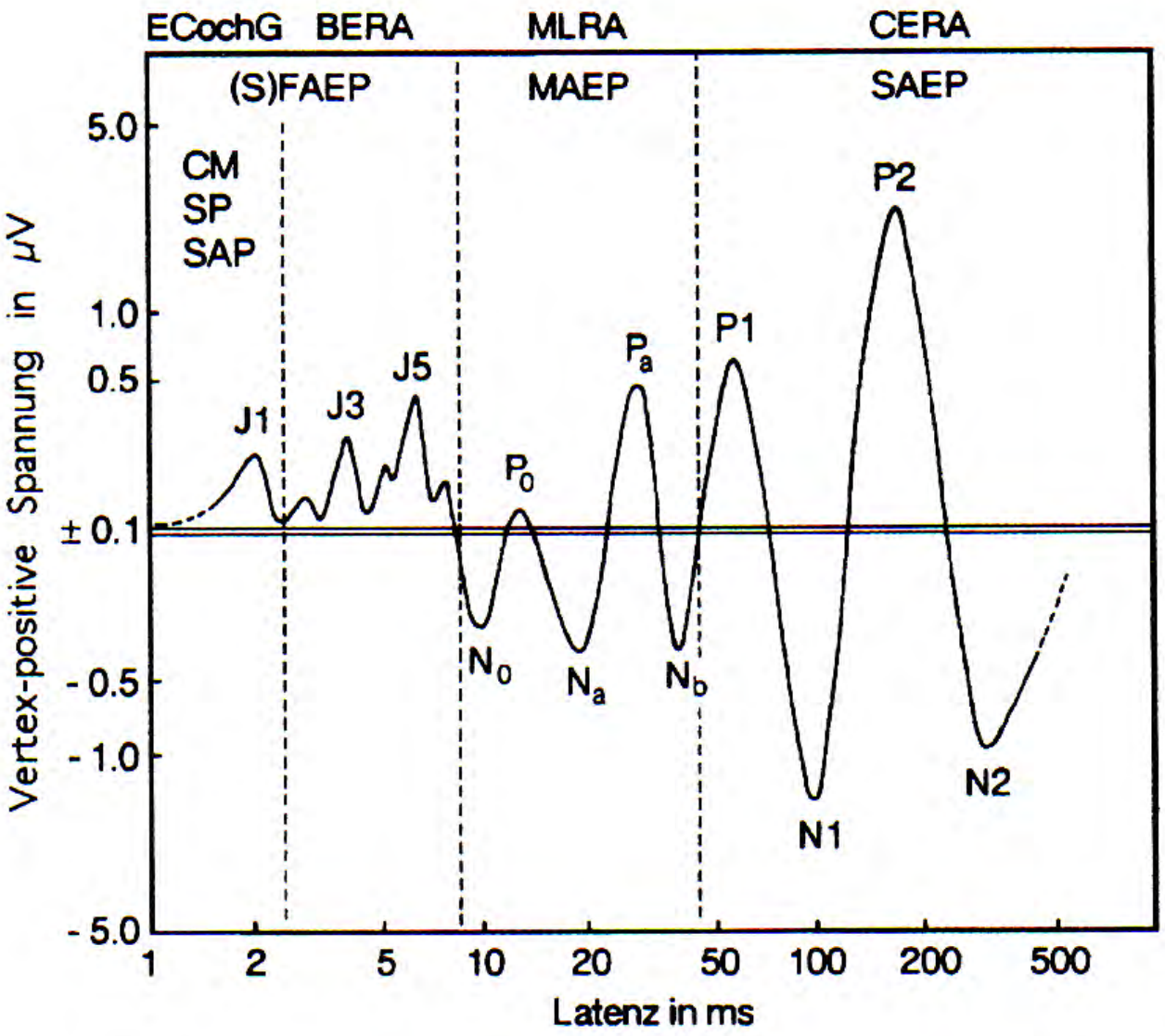
Aus FRIEDRICH, BIGENZAHN, ZOROWKA, „Phoniatrie u. Pädaudiologie“

Set up of measurements



Aus HOTH, LENARZ
„Elektrische
Reaktionsaudiometrie“

AEP



Aus

ERNST, BATTMER „Audiometrie und Funktionsdiagnostik in der HNO“

Electrocochleography (ECochG)

- Up to 3 ms 3 „Peaks“, cochlea microphonics (CM), Summating potentials (SP), compound action potential (CAP), are independant of the vigilance and can be enregistered directly after birth
- registration
  - transtympanal (Promotorium)
  - extratympanal (Electrode in the outer ear canal)
- stimulation
  - Burst or Click

FAEP

- Brainstem potentials up to a latency of 10 ms
- Registration with surface electrodes
  - vertex and mastoid
- Click stimulus, repetition of 1000-4000 x

FAEP, supposed signal generators

- I: initial segment of cochlear nerve (corresponds to CAP)
- II: cochlear nerve (entry into brain stem)
- III: nucleus cochlearis
- IV: superior olivary complex
- V: lemniscus lateralis
- VI: colliculus inferior
- VII: thalamo-corticale projections to hearing cortex

FAEP

- Waves I, III, V are of clinical relevance
- Wave II und IV, VI und VII are inconsistently present
- FAEP are not influenced by natural sleep, sedation and narcosis
- Measurable immediately after birth (prolonged latency up to age of 2)
- Amplitude and latency are dependant on stimulus intensity

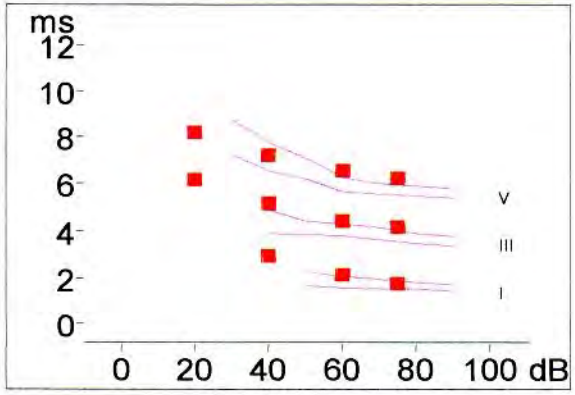
Indications

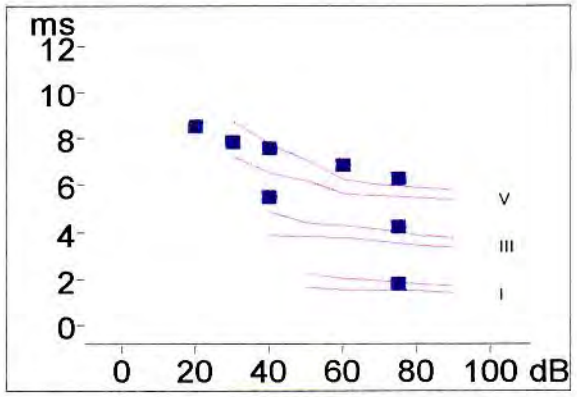
Diagnostics of Hearing Threshold

- Objective measure of hearing threshold
  - Wave V present up to subjectiv hearing threshold in optimal measuring conditions!

Diagnostics of hearing pathway

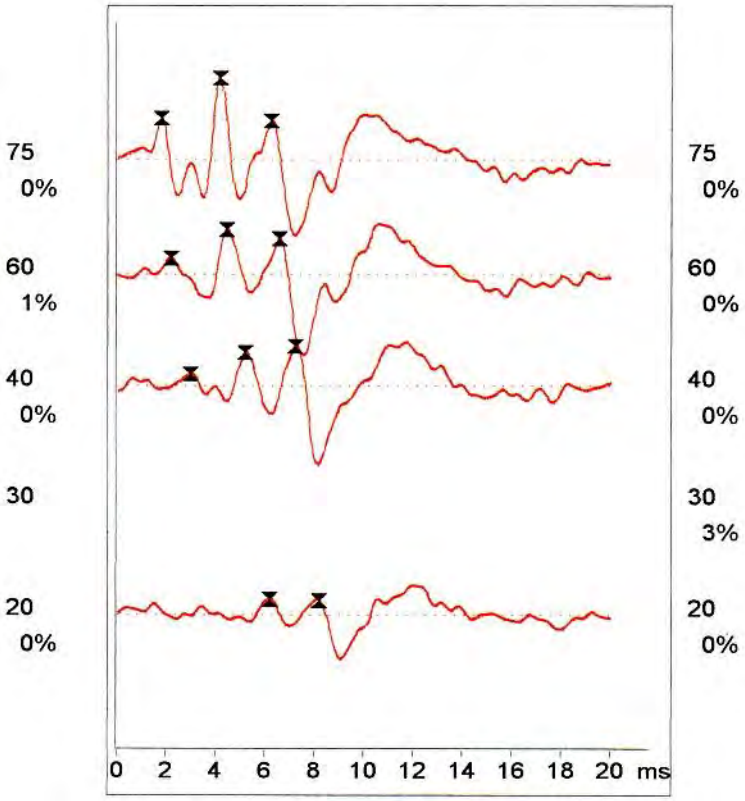
- Differenciation between cochlear and retrocochlear
  - Interpeaklatency (I-V, I-III, III-V)
  - intensity –latency function

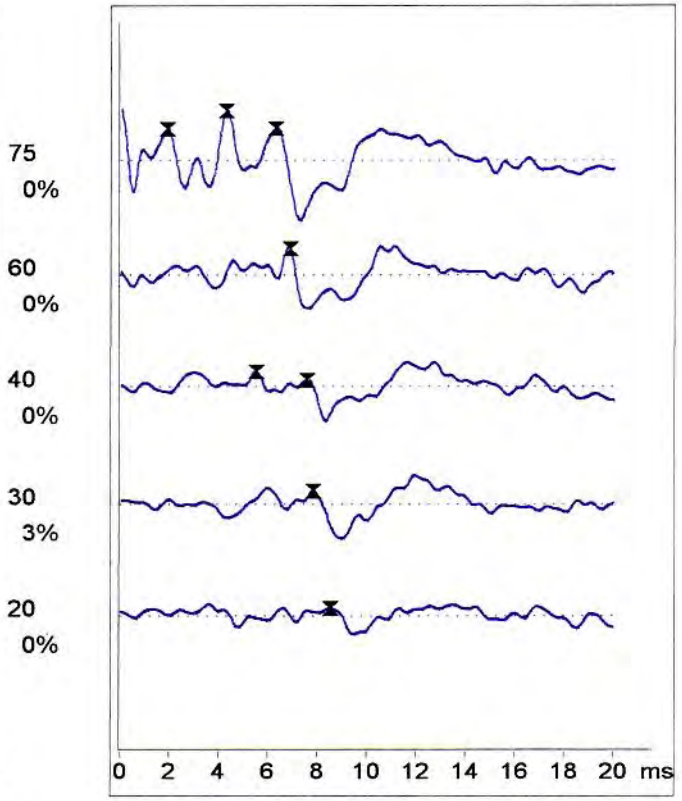




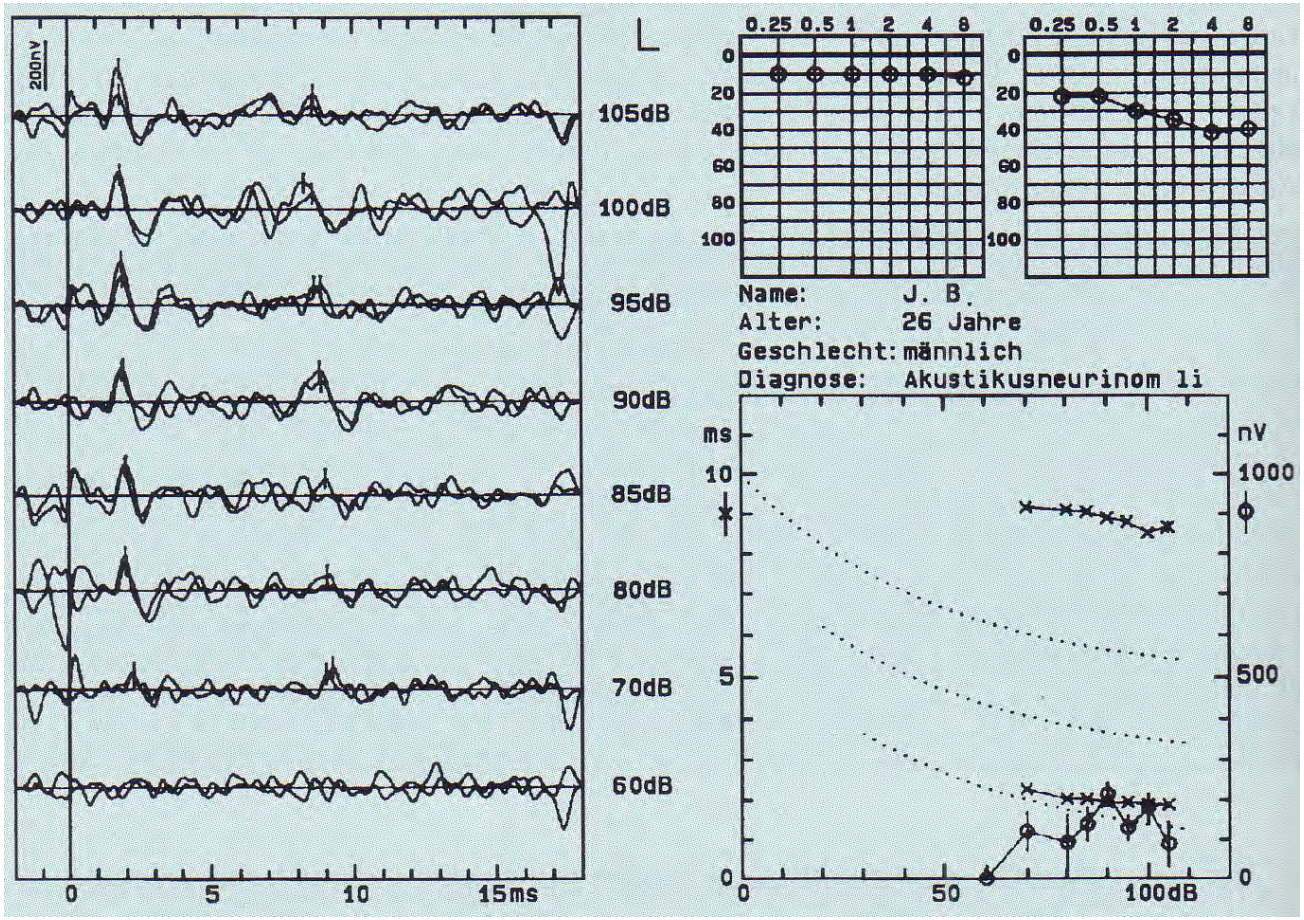
Rechts

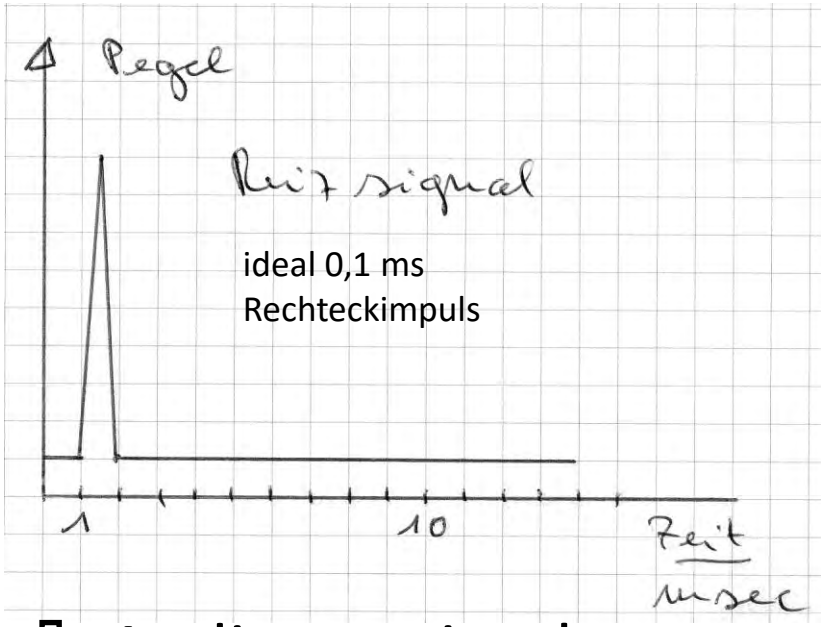
Links





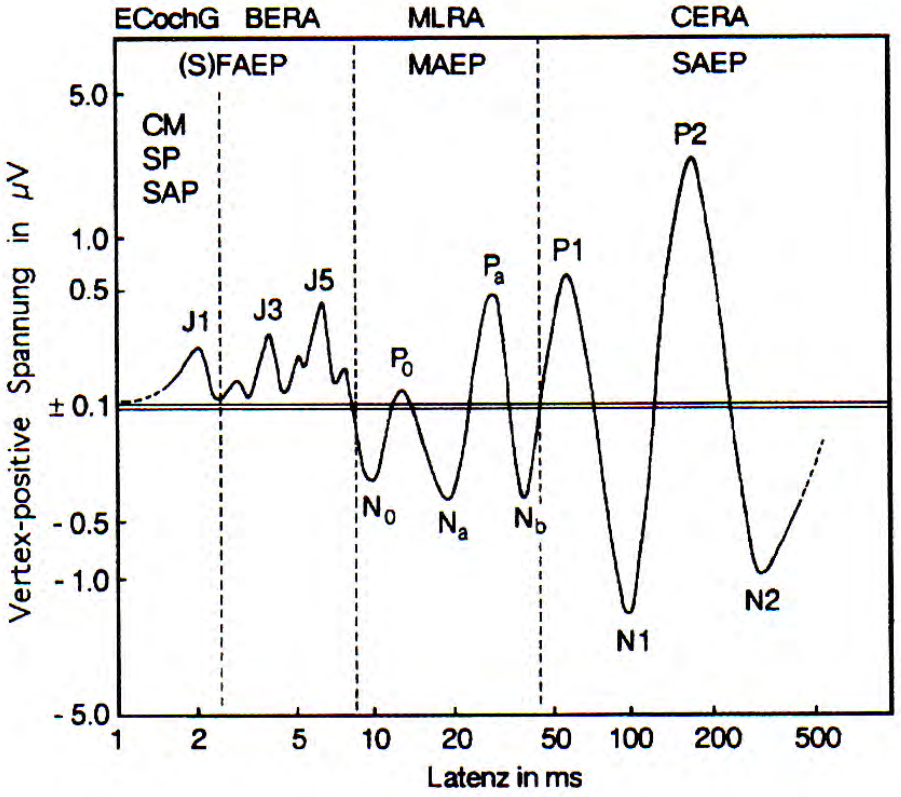
Example of acoustic neuroma





Auditory stimulus

Biological response



The clou of AEP measurement

- One has to get rid of signal parts not related to hearing processing! F.ex. Muscle action potentials of the mimic muscles of the face
- Many identical response signals and variable noise signals are added (f.ex. 3600)
- The sum of response signals is 3600 times as big.
- The sum of noise signals grows stochastically only with a factor $\sqrt{3600} = 60$!
- One has to measure long enough , to let the response signal grow bigger than the noise signal

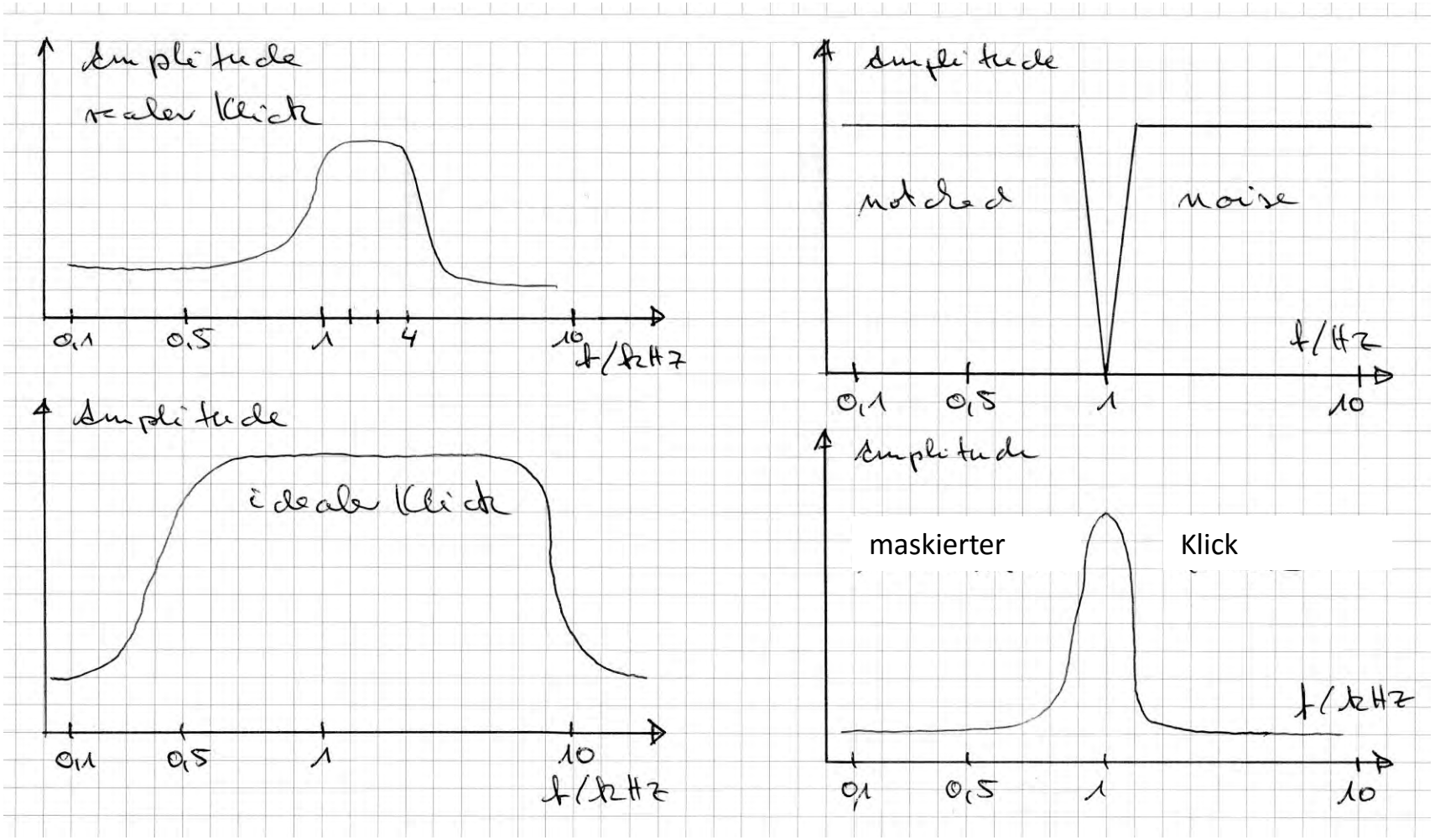
Requirements for stimulus

- It has to be very short, for as the structure of the response signal is sharp and easily identifiable, f.ex. click
- A click has a broad frequency spectrum, which is why the classic AEP is not frequency-specific
- There is also a sufficent number of short stimuli with narrow frequency spectrum available

Frequency-specific BERA

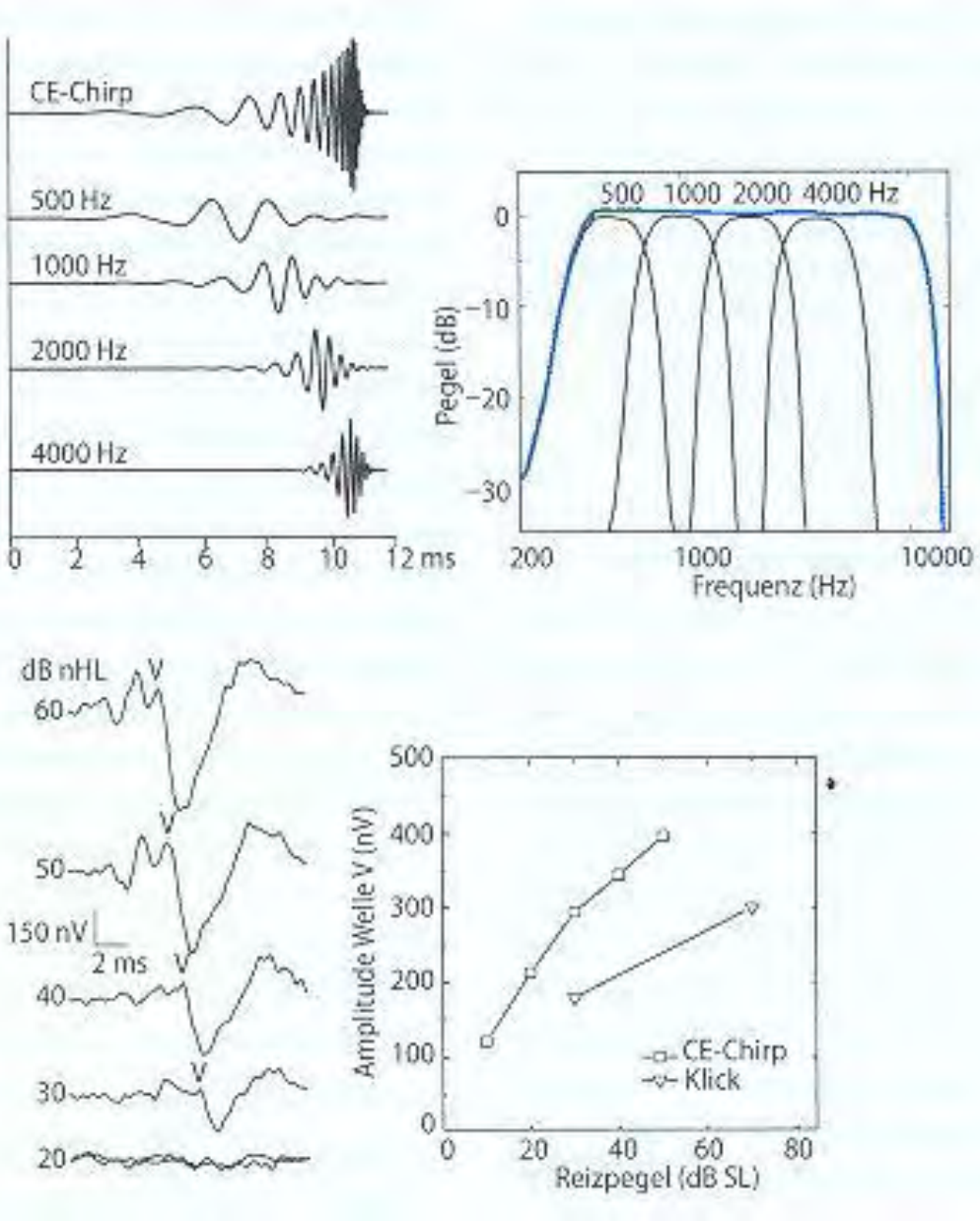
- Notched noise technique
- Chirp stimuli

The classic notched noise masked click

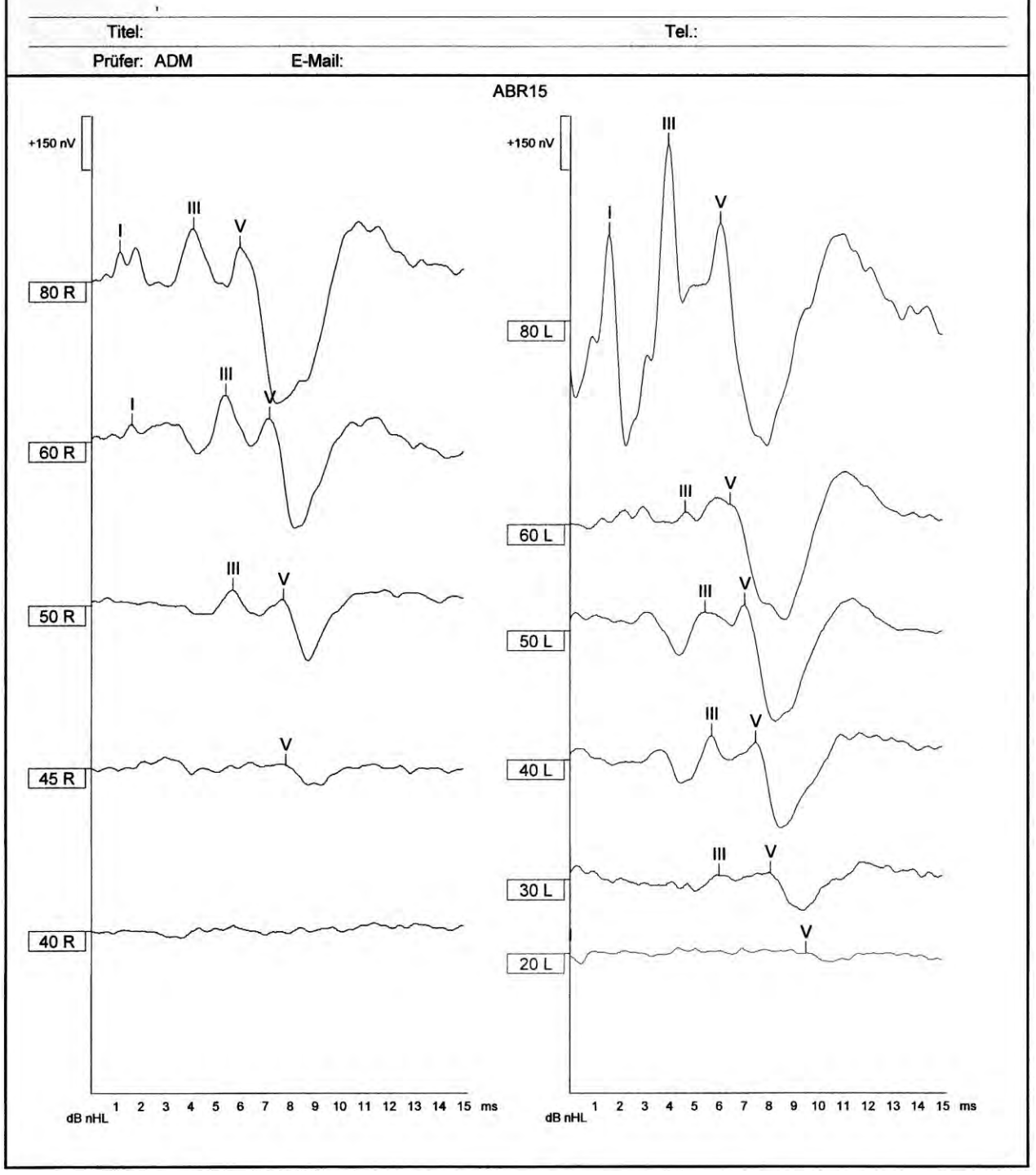


The new-age CE-Chirp

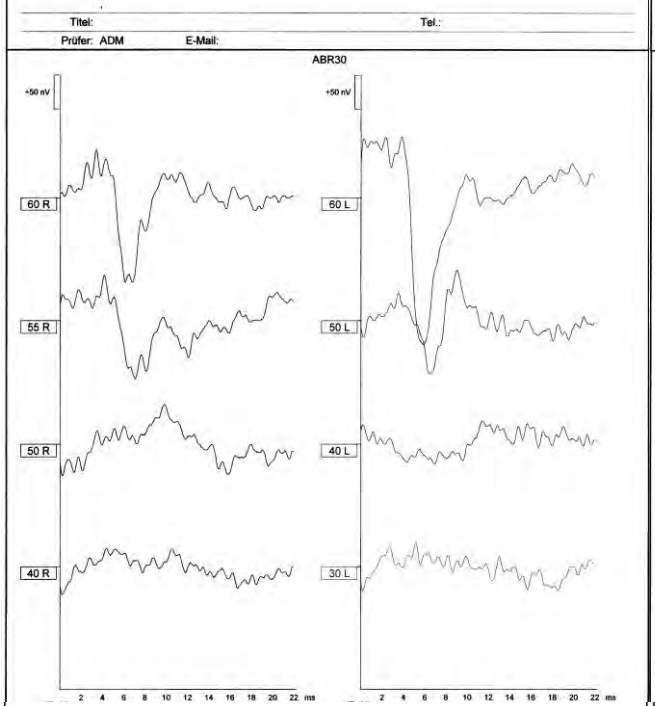
- Several sinus tones of a narrow frequency spectrum are added and the sum is temporaly limited.
- Then these partial tones are displaced towards one another in such a way, that the differences in signal progation time of the high and low frequency tones to the base and apex of the cochlea are accounted for.
- The result is a simultaneous pancochlear stimulation with synchronized sharp and intense potentials


CE-Chirp
500 Hz
1000 Hz
2000 Hz
4000 Hz
0 2 4 6 8 10 12 ms
500 1000 2000 4000 Hz
0
−10
−20
−30
Pegel (dB)
200
1000
10000
Frequenz (Hz)
dB nHL
60
50
40
30
20
V
150 nV
2 ms
500
400
300
200
100
0
Amplitude Welle V (nV)
CE-Chirp
Klick
0 20 40 60 80
Reizpegel (dB SL)

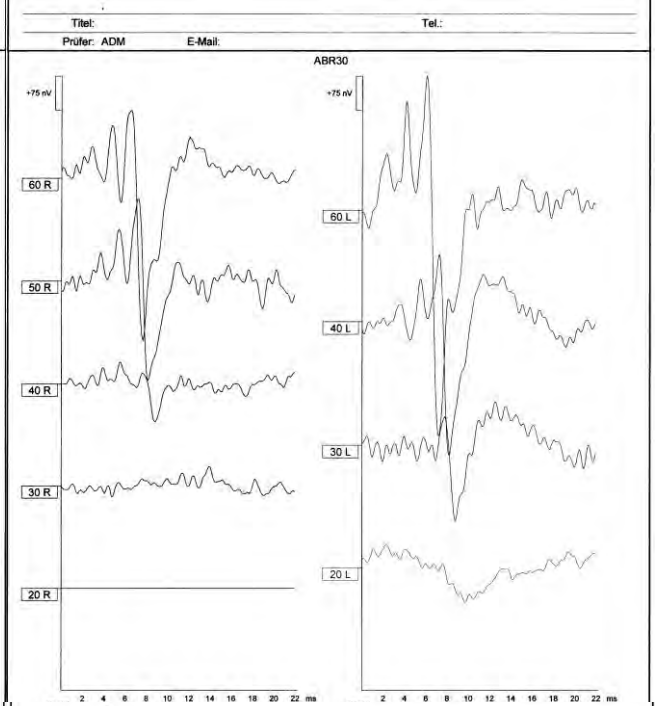
click


Titel:
Tel.:
Prüfer: ADM
E-Mail:
ABR15
+150 nV
80 R
60 R
50 R
45 R
40 R
+150 nV
80 L
60 L
50 L
40 L
30 L
20 L
I
III
V
dB nHL
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 ms

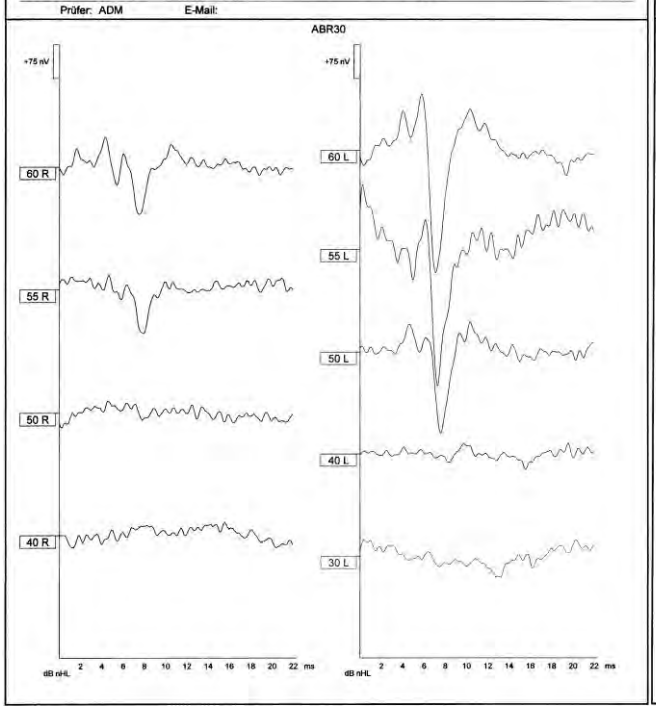
500 Hz Chirp



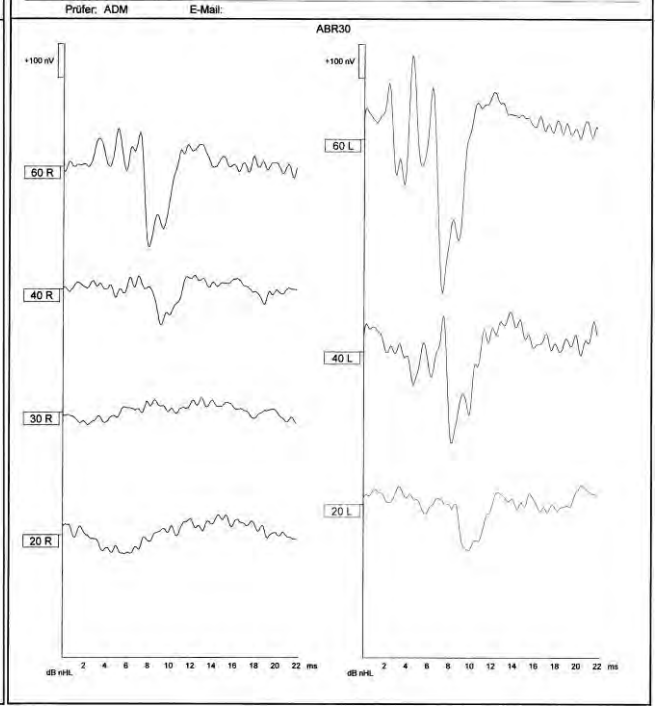
2000 Hz Chirp



1000 Hz Chirp

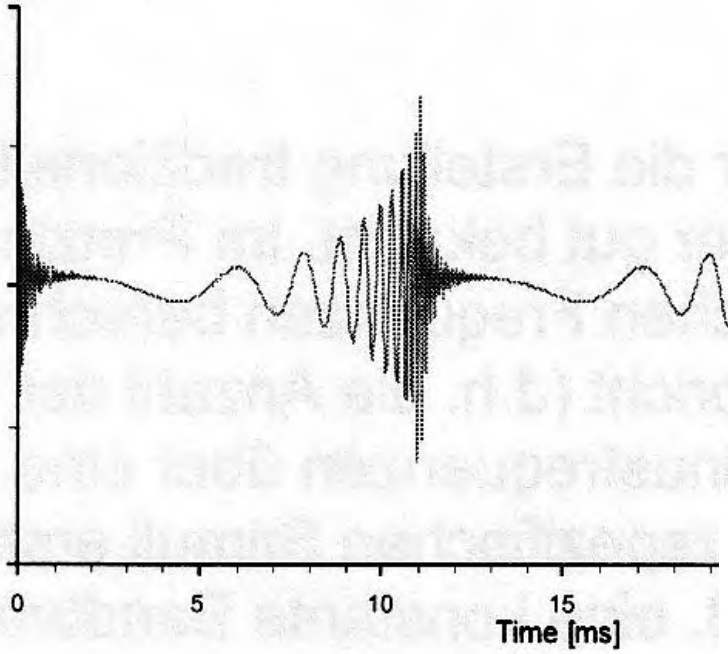


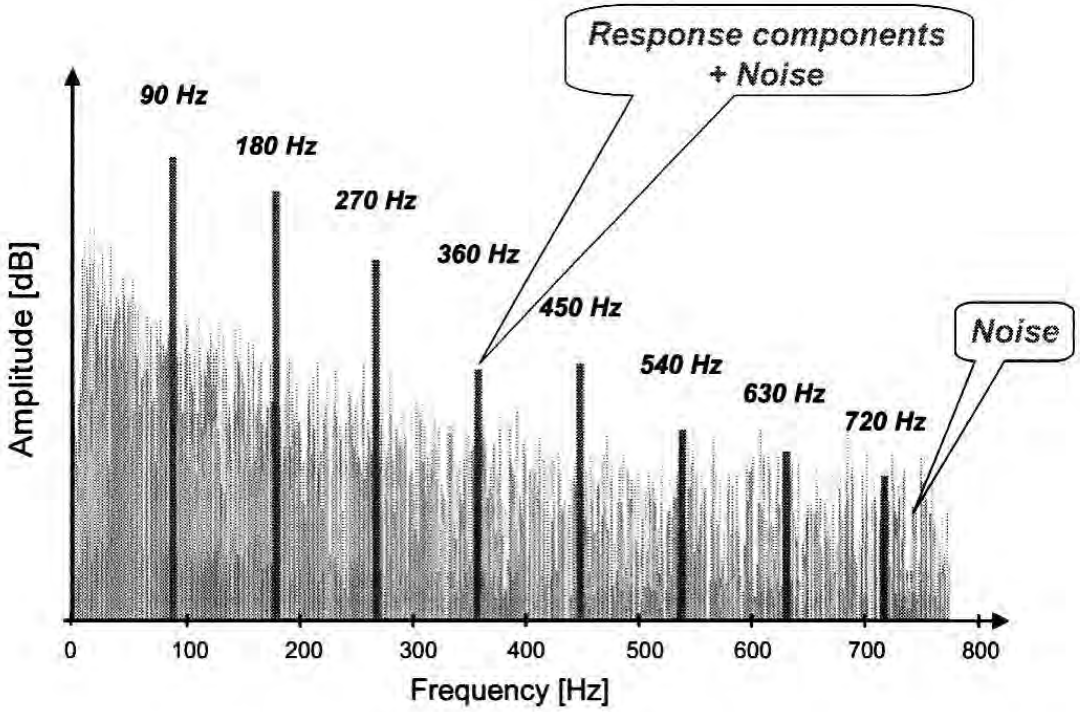
4000 Hz Chirp

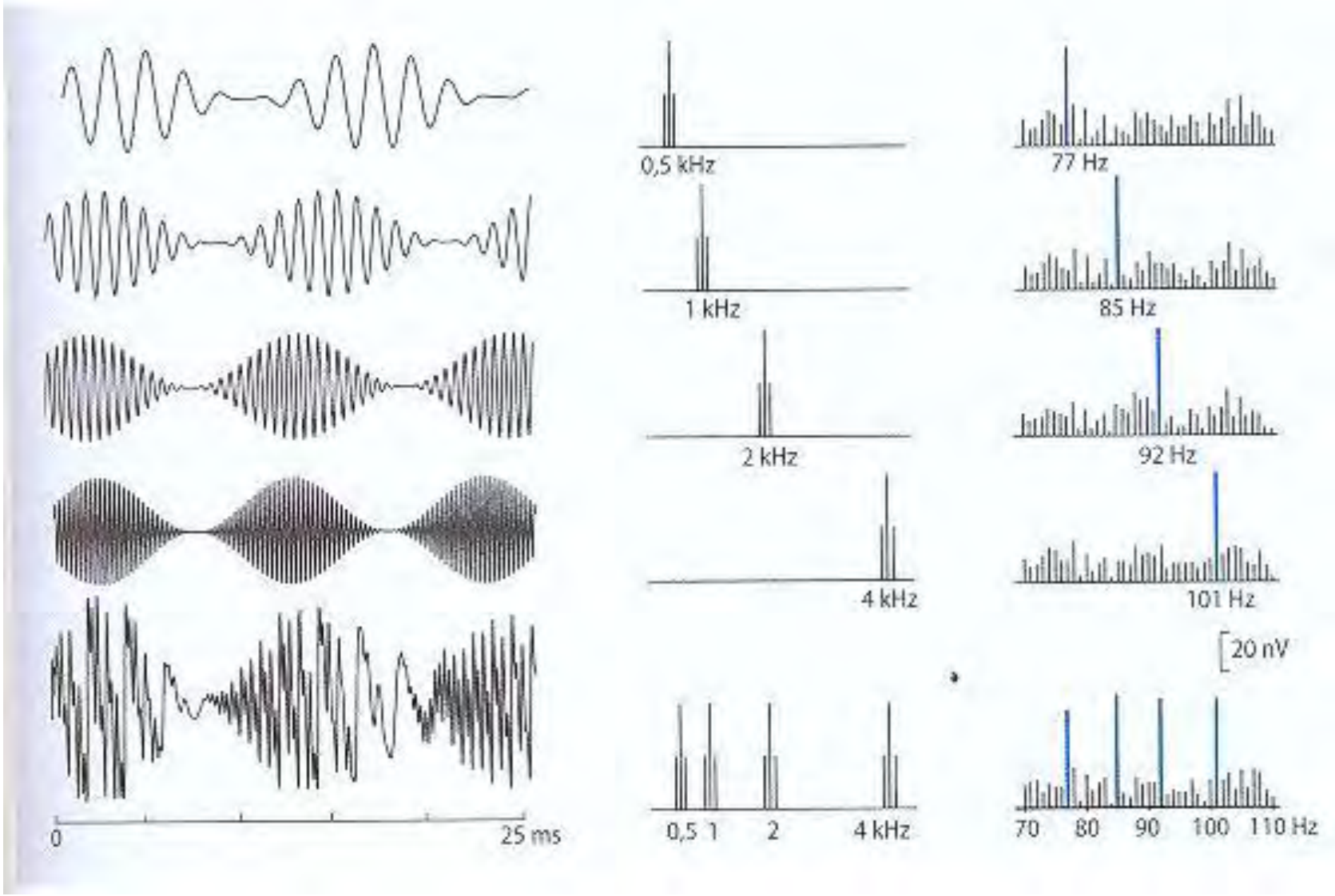


Even better and faster!

- The classic brain stem audiometry works with transient stimuli
  - Series of stimuli, whose response signals are summarized and analyzed.
- Newer techniques offer fast stimulus sets of continuous sinus tones that can generate a continuous response signal
  - ASSR = auditory staedy-state response
  - AMFR = Amplitude Modulation Following Response


0
5
10
15
Time [ms]


Response components
+ Noise
90 Hz
180 Hz
270 Hz
360 Hz
450 Hz
540 Hz
630 Hz
720 Hz
Noise
Amplitude [dB]
0
100
200
300
400
500
600
700
800
Frequency [Hz]


0,5 kHz
1 kHz
2 kHz
4 kHz
77 Hz
85 Hz
92 Hz
101 Hz
20 nV
0
25 ms
0,5 1 2 4 kHz
70 80 90 100 110 Hz