# Otoacoustic emission correlates of intracochlear pressure in humans: summating behavior

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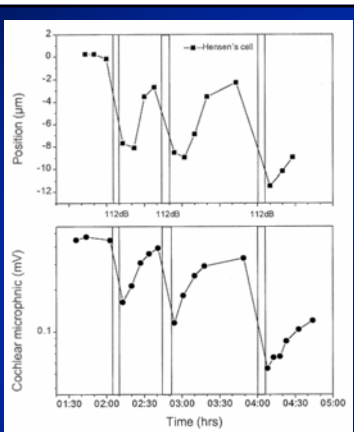
## Previous work

- An important feature of all direct measurement data (LePage 1980 ff) were the first reports of the presence of "dc-shifts" or summating behaviour seen in the motion of the basilar membrane
  - Behaviour correlated with the summating potential
  - Now associated with OHC length change and hydrops (Flock & Flock 2000)



Flock & Flock
Hear. Res. 2000



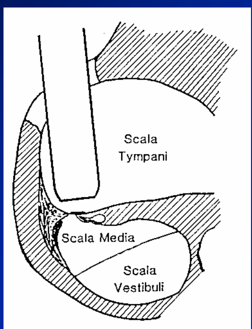


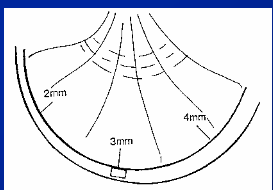

## Working Hypothesis

- The 'dc-shifts' seen in these animal experiments are intimately associated with stimulus-produced -
  - OHC length changes
  - Intracochlear pressure changes
- The basic cause of hydrops is associated with OHC activity and failure of its homeostatic regulation
  - In particular drift in OHC operating point



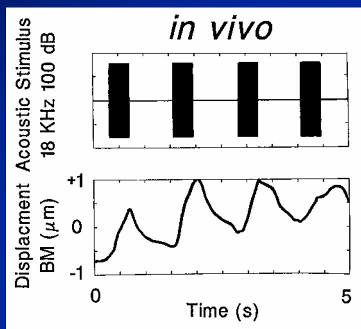
## Fiber optic sensor for basilar membrane displacement in guinea pig preparations



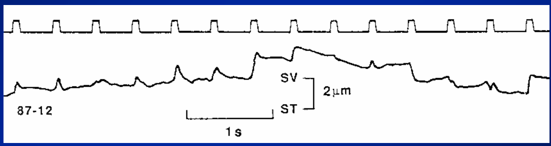



## Summating movements in the motion of the basilar membrane




LePage
Hear Res
1989

## Basilar membrane displacement change for a series of loud tone bursts > 100dB SPL)




LePage
Hear Res
1989

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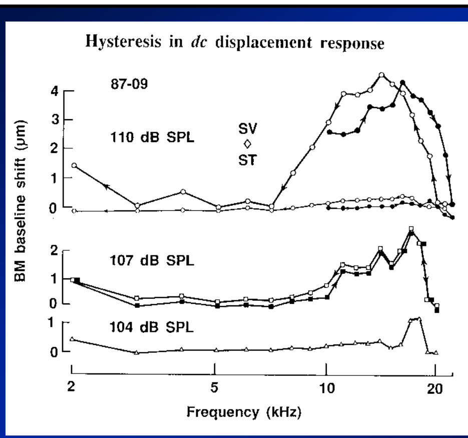


LePage
In: *Noise-Induced Hearing loss*
Dancer etal
1992

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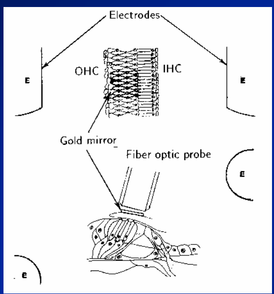
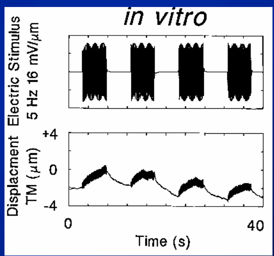
## Fresh cell preparation shows adaptation to stimulus onset




LePage, Reuter, Zenner
1990

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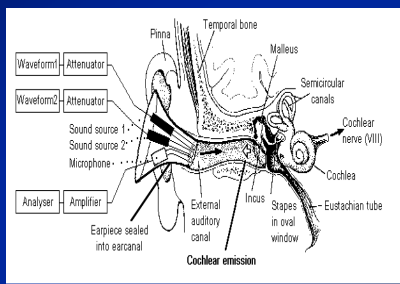
## Q: How to measure cochlear mechanics in humans?

**A: Basically limited to otoacoustic emissions….**

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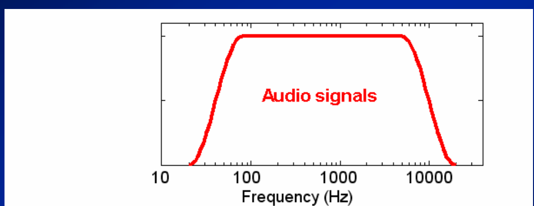
## Audio spectrum




Evoked OAE allow us to access assess cochlear behaviour within the auditory spectrum
i.e. $2f_1$-$f_2$…. Salt et al have now added $f_2$-$f_1$

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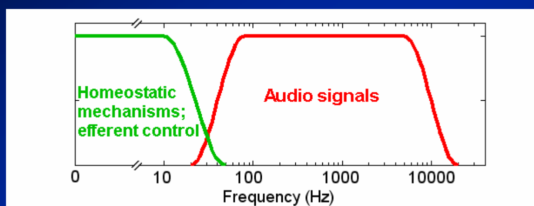
## Audio AND Control spectrum




**New experiment: Can we obtain direct measures of cochlear baseline behaviour by recording low-frequency pressure variation in the ear canal? (i.e. without assuming DPOAEs are necessary)**

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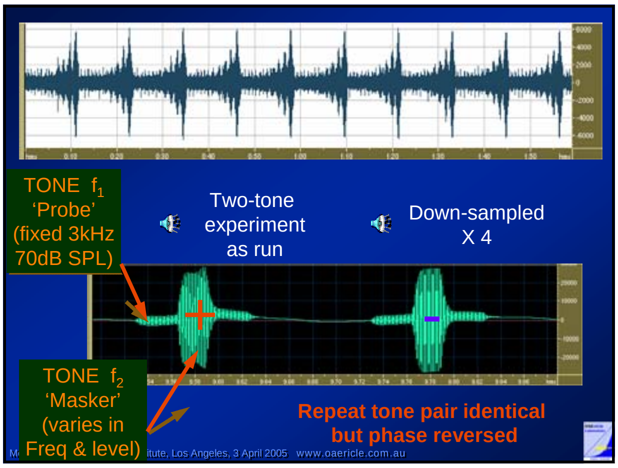
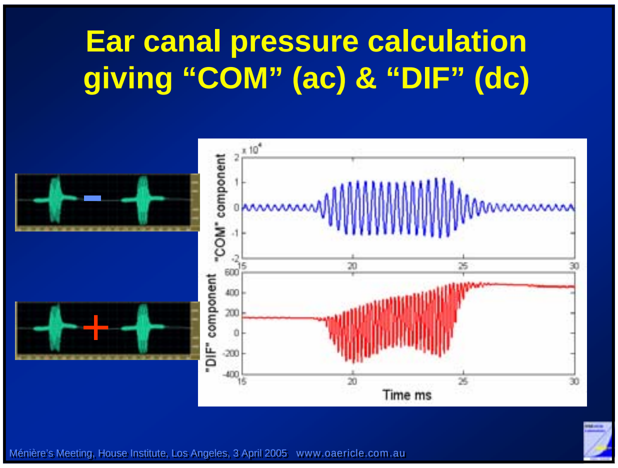

TONE $f_1$
'Probe'
(fixed 3kHz
70dB SPL)
Two-tone
experiment
as run
Down-sampled
X 4
TONE $f_2$
'Masker'
(varies in
Freq & level)
Repeat tone pair identical
but phase reversed


Ear canal pressure calculation
giving "COM" (ac) & "DIF" (dc)
"COM" component
"DIF" component
Time ms
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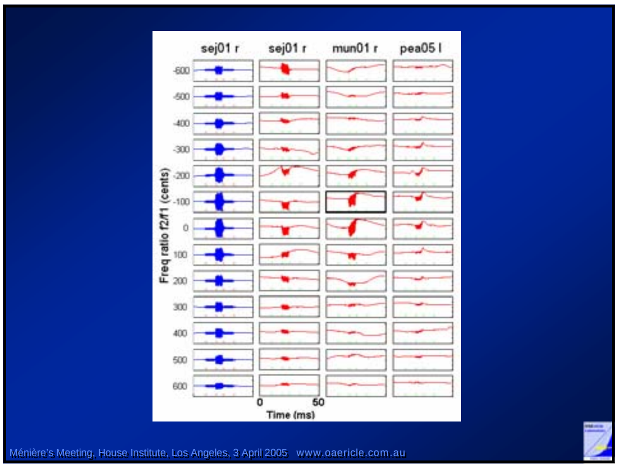
sej01 r
sej01 r
mun01 r
pea05 l
Freq ratio f2/f1 (cents)
Time (ms)
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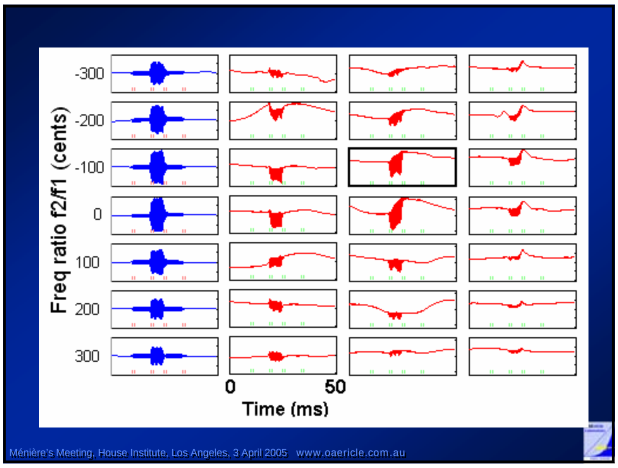
Freq ratio f2/f1 (cents)
Time (ms)
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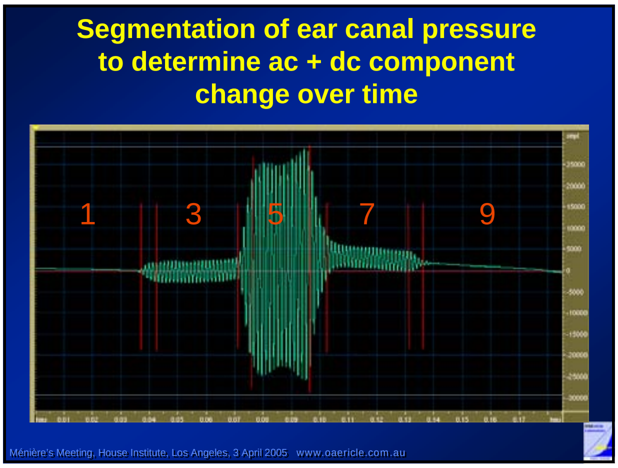
Segmentation of ear canal pressure
to determine ac + dc component
change over time
1
3
5
7
9
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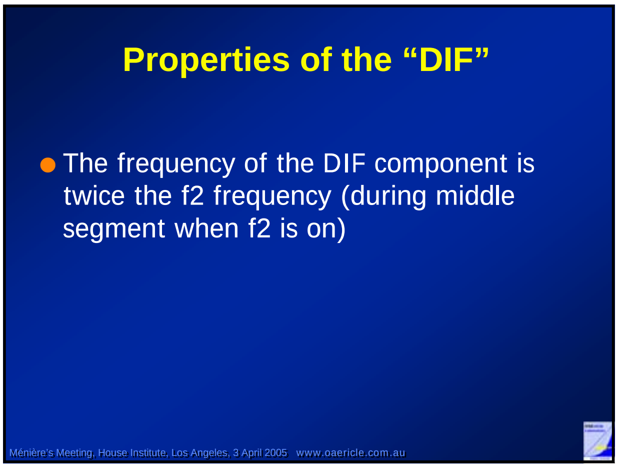
Properties of the "DIF"
The frequency of the DIF component is twice the f2 frequency (during middle segment when f2 is on)
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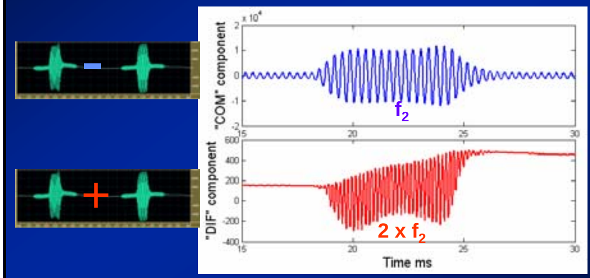
## Ear canal pressure calculation giving "COM" (ac) & "DIF" (dc)

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| $f_1$ | $f_2$ (cents difference) | Actual $f_2$ Hz delivered | measured frequency during $f_2$ tone | twice actual $f_2$ | Error in estimate |
|---|---|---|---|---|---|
| 3000 | -600 | 2,121.3 | 100 | 4,242.6 | |
| 3000 | -500 | 2,247.5 | 100 | 4,494.9 | |
| 3000 | -400 | 2,381.1 | 100 | 4,762.2 | |
| 3000 | -300 | 2,522.7 | 5000 | 5,045.4 | -0.90% |
| 3000 | -200 | 2,672.7 | 5400 | 5,345.4 | 1.02% |
| 3000 | -100 | 2,831.6 | 5600 | 5,663.2 | -1.12% |
| 3000 | 0 | 3,000.0 | 6000 | 6,000.0 | 0.00% |
| 3000 | 100 | 3,178.4 | 6300 | 6,356.8 | -0.89% |
| 3000 | 200 | 3,367.4 | 6700 | 6,734.8 | -0.52% |
| 3000 | 300 | 3,567.6 | 200 | 7,135.2 | |
| 3000 | 400 | 3,779.8 | 800 | 7,559.5 | |
| 3000 | 500 | 4,004.5 | 100 | 8,009.0 | |
| 3000 | 600 | 4,242.6 | 200 | 8,485.3 | |

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## Properties of the "DIF"

- The frequency of the DIF component is twice the f2 frequency (during middle segment when f2 is on)
- The DIF component displays summation behaviour which tends to change direction with each transition between segments
- The direction changes with $f_2$ frequency and level

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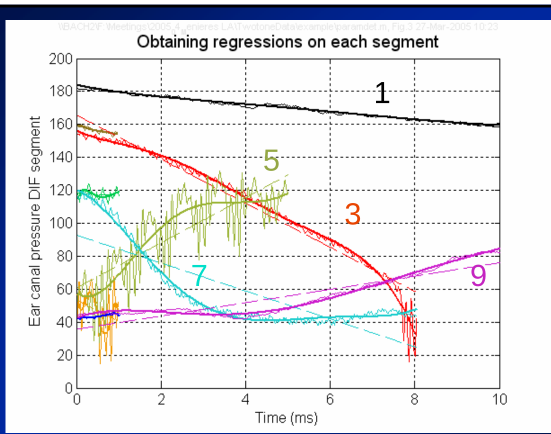


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## Results for "DIF" (SUMMATION COMPONENT)

- Focus upon important feature of data
  - change in slope of the DIF component with transitions between segments i.e.
    - Change slope from segment 1 to segment 3
      - i.e. PROBE ON
    - Change slope from segment 3 to segment 5
      - i.e. MASKER ON
    - Change slope from segment 5 to segment 7
      - i.e. MASKER OFF
    - Change slope from segment 7 to segment 9
      - i.e. PROBE OFF

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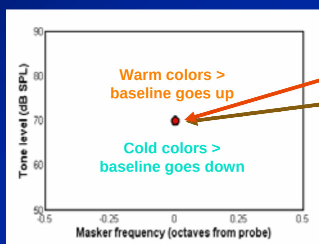
## Summation results are presented as Level vs Frequency contour plots




Probe (fixed)

Masker (varies with frequency and level)

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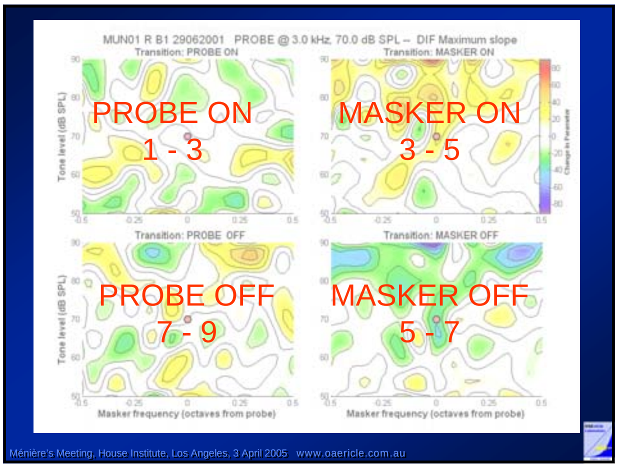
MUN01 R B1 29062001 PROBE @ 3.0 kHz, 70.0 dB SPL -- DIF Maximum slope
Transition: PROBE ON
Transition: MASKER ON
PROBE ON
1 - 3
MASKER ON
3 - 5
Transition: PROBE OFF
Transition: MASKER OFF
PROBE OFF
7 - 9
MASKER OFF
5 - 7
Tone level (dB SPL)
Masker frequency (octaves from probe)
Change in Parameter
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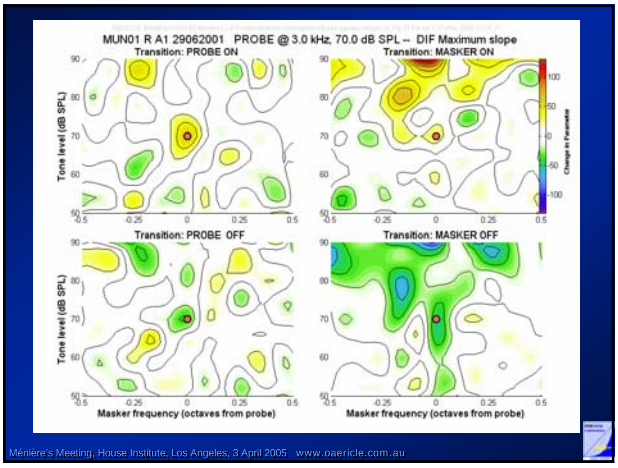
MUN01 R A1 29062001 PROBE @ 3.0 kHz, 70.0 dB SPL -- DIF Maximum slope
Transition: PROBE ON
Transition: MASKER ON
Transition: PROBE OFF
Transition: MASKER OFF
Tone level (dB SPL)
Masker frequency (octaves from probe)
Change in Parameter
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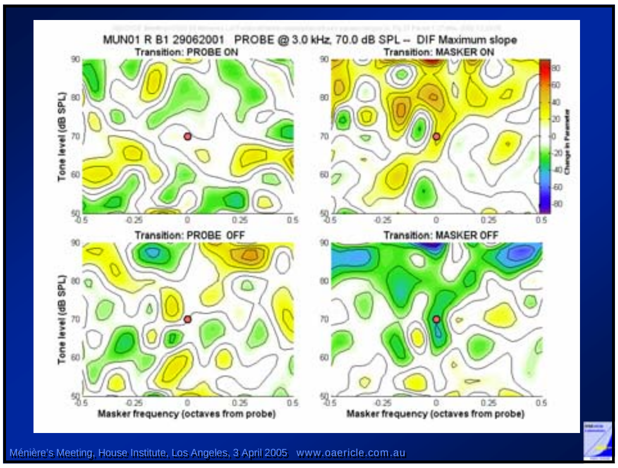
MUN01 R B1 29062001 PROBE @ 3.0 kHz, 70.0 dB SPL -- DIF Maximum slope
Transition: PROBE ON
Transition: MASKER ON
Transition: PROBE OFF
Transition: MASKER OFF
Tone level (dB SPL)
Masker frequency (octaves from probe)
Change in Parameter
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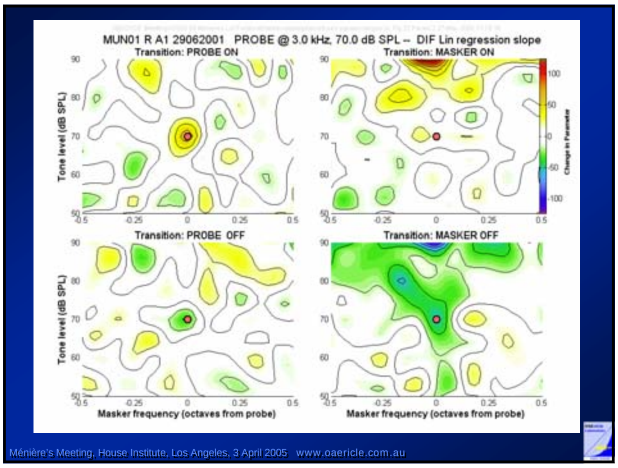
MUN01 R A1 29062001 PROBE @ 3.0 kHz, 70.0 dB SPL -- DIF Lin regression slope
Transition: PROBE ON
Transition: MASKER ON
Transition: PROBE OFF
Transition: MASKER OFF
Tone level (dB SPL)
Masker frequency (octaves from probe)
Change in Parameter
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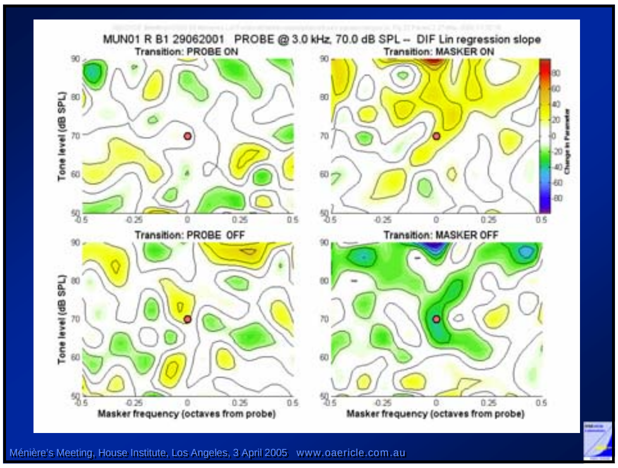
MUN01 R B1 29062001 PROBE @ 3.0 kHz, 70.0 dB SPL -- DIF Lin regression slope
Transition: PROBE ON
Transition: MASKER ON
Transition: PROBE OFF
Transition: MASKER OFF
Tone level (dB SPL)
Masker frequency (octaves from probe)
Change in Parameter
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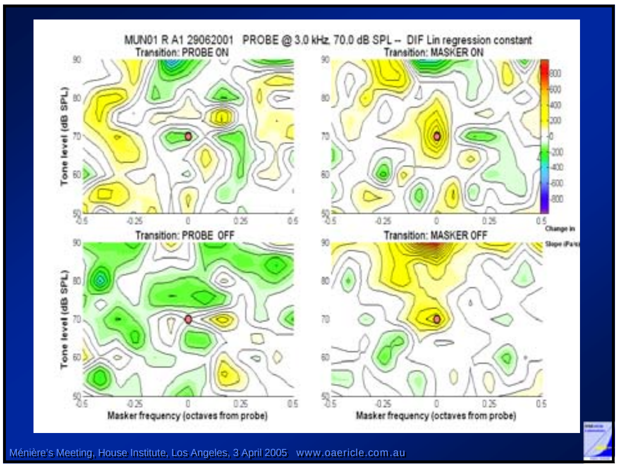
MUN01 R A1 29062001 PROBE @ 3.0 kHz, 70.0 dB SPL -- DIF Lin regression constant
Transition: PROBE ON
Transition: MASKER ON
Transition: PROBE OFF
Transition: MASKER OFF
Tone level (dB SPL)
Masker frequency (octaves from probe)
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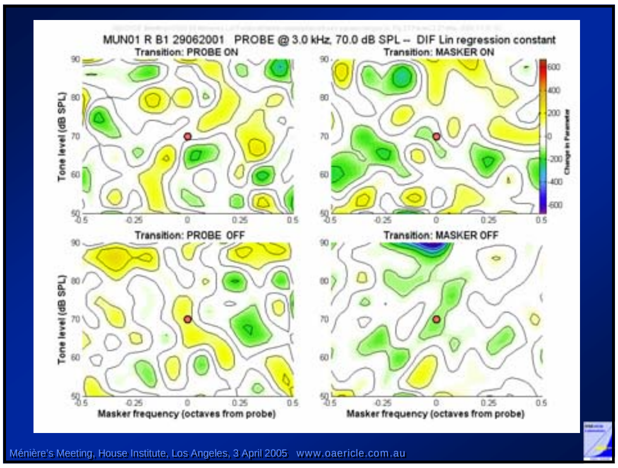
MUN01 R B1 29062001 PROBE @ 3.0 kHz, 70.0 dB SPL -- DIF Lin regression constant
Transition: PROBE ON
Transition: MASKER ON
Transition: PROBE OFF
Transition: MASKER OFF
Tone level (dB SPL)
Masker frequency (octaves from probe)
Change in Parameter
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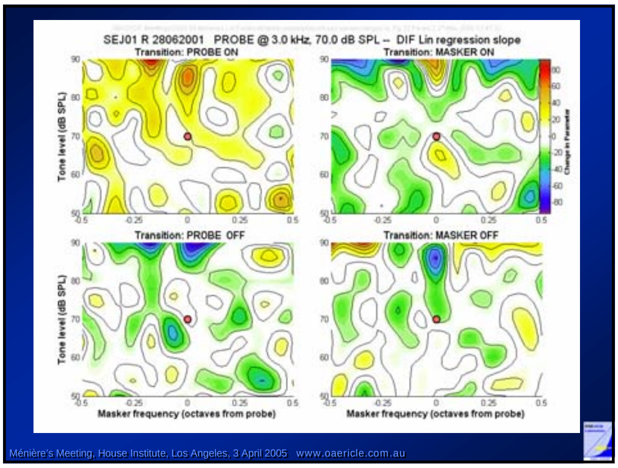
SEJ01 R 28062001 PROBE @ 3.0 kHz, 70.0 dB SPL -- DIF Lin regression slope
Transition: PROBE ON
Transition: MASKER ON
Transition: PROBE OFF
Transition: MASKER OFF
Tone level (dB SPL)
Masker frequency (octaves from probe)
Change in Parameter
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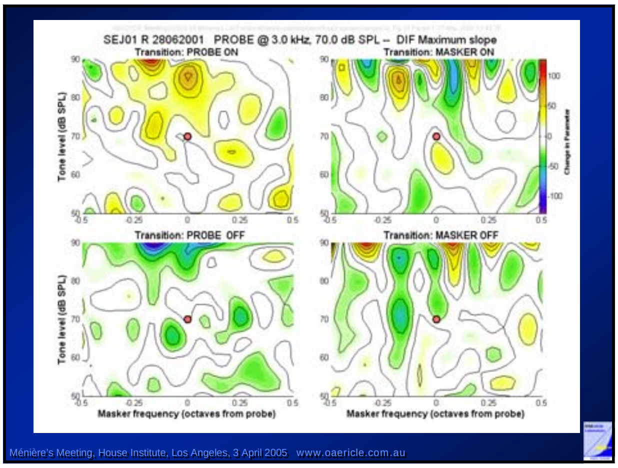
SEJ01 R 28062001 PROBE @ 3.0 kHz, 70.0 dB SPL -- DIF Maximum slope
Transition: PROBE ON
Transition: MASKER ON
Transition: PROBE OFF
Transition: MASKER OFF
Tone level (dB SPL)
Masker frequency (octaves from probe)
Change in Parameter
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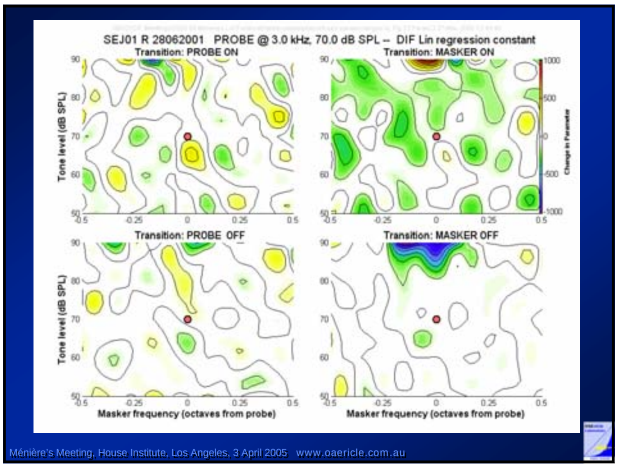
SEJ01 R 28062001 PROBE @ 3.0 kHz, 70.0 dB SPL -- DIF Lin regression constant
Transition: PROBE ON
Transition: MASKER ON
Transition: PROBE OFF
Transition: MASKER OFF
Tone level (dB SPL)
Masker frequency (octaves from probe)
Change in Parameter
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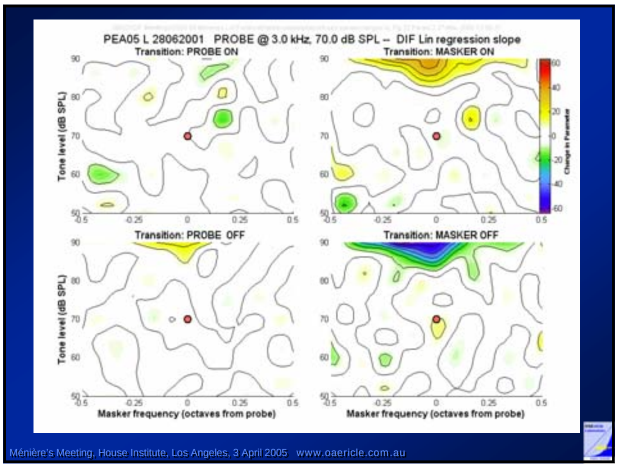
PEA05 L 28062001 PROBE @ 3.0 kHz, 70.0 dB SPL -- DIF Lin regression slope
Transition: PROBE ON
Transition: MASKER ON
Transition: PROBE OFF
Transition: MASKER OFF
Tone level (dB SPL)
Masker frequency (octaves from probe)
Change in Parameter
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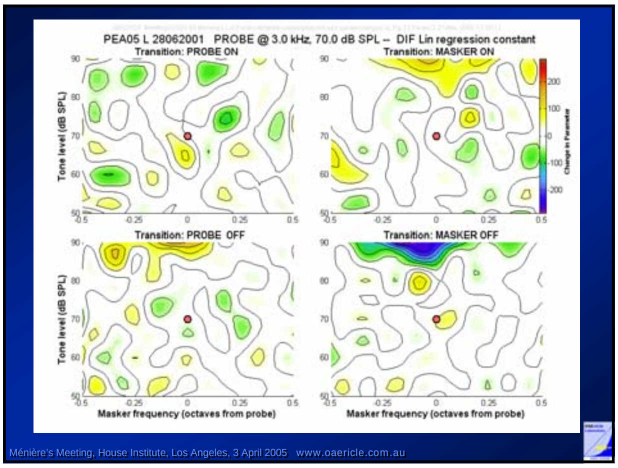
PEA05 L 28062001 PROBE @ 3.0 kHz, 70.0 dB SPL -- DIF Lin regression constant
Transition: PROBE ON
Transition: MASKER ON
Transition: PROBE OFF
Transition: MASKER OFF
Tone level (dB SPL)
Masker frequency (octaves from probe)
Change in Parameter
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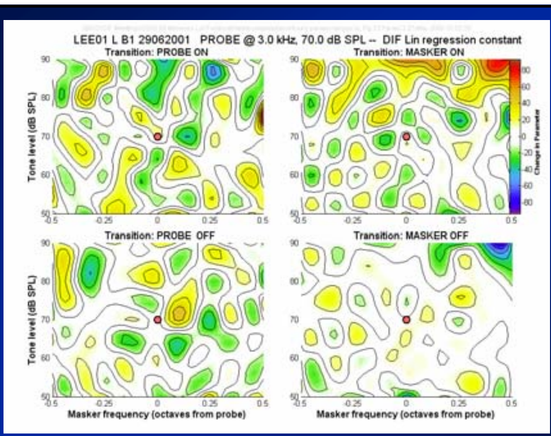


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## SUMMARY 1

- A novel approach has shown that even otoacoustic measurement does not have to be locked into ONLY behaviour within the auditory frequency band – it can access homeostatic mechanisms directly
- We have observed baseline pressure changes in the ear canal due to tone bursts
  - Filtering of low-frequency components is minimsed
  - Signal averaging is used to minimise external noise
  - Low frequency noise is further reduced by differencing a given response with a phase-reversed copy

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## SUMMARY 2

- There appears to be systematic changes of the otoacoustic emissions baseline with variation of masker tone frequency and level about a probe
  - For all subjects the largest summation rates occurred for masker tone levels of 85-90 dB SPL
- The clearest trend seen thus far is with MASKER ON and OFF
  - ON: Baseline moves up (condensation in ear canal)
  - OFF: Baseline moves down (rarefaction in ear canal)

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## SUMMARY 3

- The trends may be described as summating behaviour which *may be* analogous to summating potential and basilar membrane displacement baseline summation
- These baseline changes are likely to be related to changes in distortion products reported by others

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## SUMMARY 4

- However, the experiment seems to be interpretable in more fundamental terms
  - These baseline changes display properties which tend to display tuning, even mimicking two-tone suppression regions
  - therefore suggesting they are of cochlear origin, yet complex
- Together with the results of Flock (2000) these results support the hypothesis that the generation of hydrops and OHC mechanical operating point are related.

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