Brief summary of Jont Allen's Career

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[1] *Work done at: AT&T Bell Labs, Murray Hill, NJ*
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BY TOPIC

- Room Acoustics:
  - Image method for computing a room impulse response
  - Removing room reverberation (demo)
  - When is a room impulse response minimum phase?
- Signal Processing:
  - Short time inverse Fourier Transform
  - Time-varying low-pass filter applied to speech $\Rightarrow$ 2:1 compression
- Cochlear and middle ear mechanics:
  - 2D cochlear model
  - Resonant Tectorial Membrane
  - Ear canal impedance: New methods and theory
  - The ear drum has finite delay, and is an acoustic horn!
  - Pressure reflectance in the human ear canal
  - Method to measure power gain on the Basilar Membrane
- Neurophysiology (live animal experiments):
  - Phase and group delay in the Cat auditory nerve (AN)
  - Distortion products and two-tone suppression in the Cat AN

BY TOPIC

- Hearing aids:

  Mannaged the AT&T (ReSound) hearing aid development
  LGOB – loudness growth in the clinic

- Psychophysics:

  Edit reprint of Harvey Fletcher's 1951 book *Speech and hearing*
  Loudness and the intensity JND: Internal noise is Poisson!
  Neural noise for speech and audio coding

- Human Speech Recognition:

  How do humans recognize speech
  Extracting speech events for ASH

ROOM ACOUSTICS

- Image method for computing a room impulse response

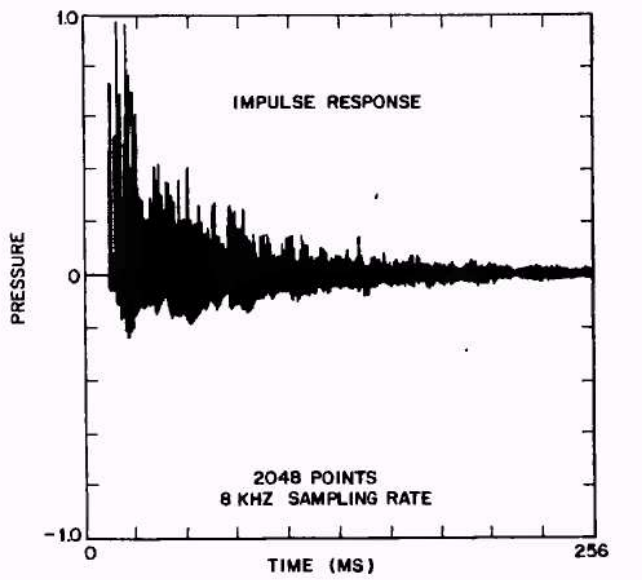
Introducing the effects of finite, angle independent wall absorption into Eq. (8) leads to the modified room impulse response

$$p(t,\mathbf{X},\mathbf{X}')=\sum_{p=0}^{1}\sum_{r=-\infty}^{\infty}\beta_{x1}^{|n-q|}\beta_{x2}^{|n|}\beta_{y1}^{|j-j|}\beta_{y2}^{|j|}\beta_{z1}^{|m-k|}\beta_{z2}^{|m|}$$

$$\times\frac{\delta[t-(|\mathbf{R}_p+\mathbf{R}_r|/c)]}{4\pi|\mathbf{R}_p+\mathbf{R}_r|}, \qquad (10)$$

where $\mathbf{R}_p$ is now expressed in terms of the integer 3-vector $\mathbf{p}=(q,j,k)$ as

$$\mathbf{R}_p=(x-x'+2qx',\ y-y'+2jy',\ z-z'+2kz'). \qquad (11)$$



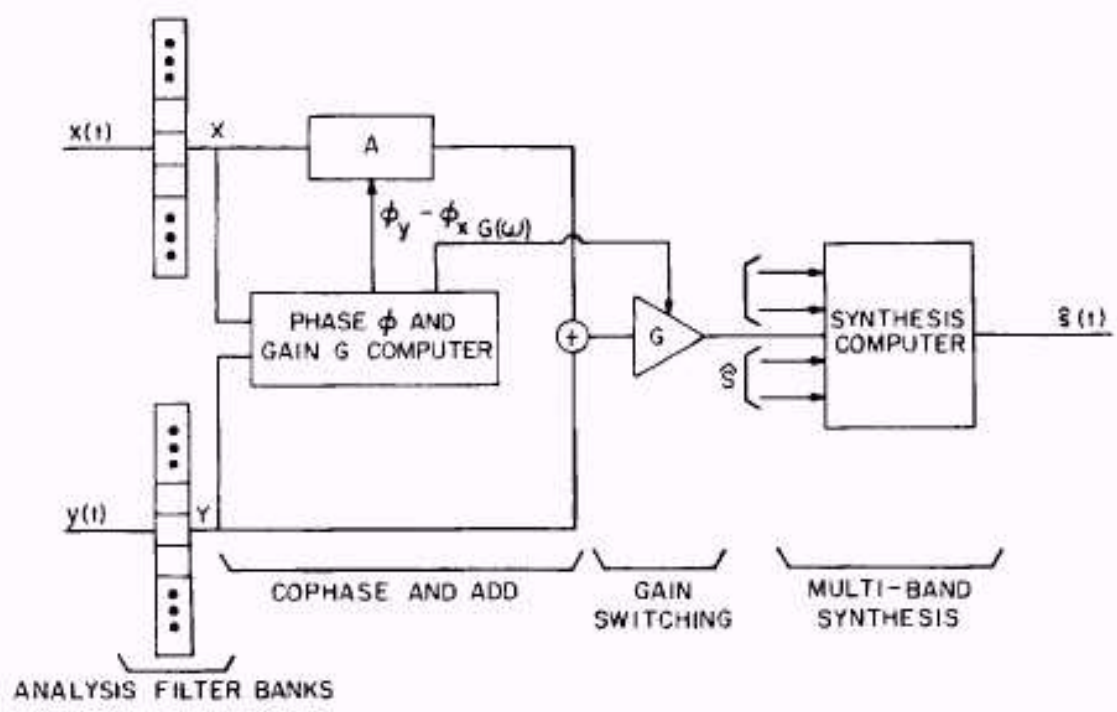
Removing room reverberation (demo)

When is a room impulse response minimum phase?

ROOM ACOUSTICS

Image method for computing a room impulse response

- Removing room reverberation (demo)



When is a room impulse response minimum phase?

SIGNAL PROCESSING

- Short time inverse Fourier Transform:

  From the *Poisson Summation Formula*

$$w(t) \star \sum_{l=-\infty}^{\infty} \delta(t - lR) = \sum_{l=-\infty}^{\infty} w(t - lR) = 1 + \epsilon(t) \tag{1}$$

  where $w(t)$ is any lowpass filter impulse response, and R such that

$$R < \frac{\text{Duration of } w(t)}{\text{time-bandwidth product}}$$

  This leads to:

$$s(t) = \sum_{l=-\infty}^{\infty} s(t) w(t - lR) \tag{2}$$

$$s(t) = \sum_{l=-\infty}^{\infty} \mathcal{F}^{-1} S_l(\omega) \tag{3}$$

  This is great for making nonlinear time-varying modifications to speech and audio (Allen 1977a; Allen et al. 1977; Allen and Rabiner 1977).

  Time-varying low-pass filter applied to speech $\Rightarrow$ 2:1 compression

COCHLEAR AND MIDDLE EAR MECHANICS

2D cochlear model

Resonant Tectorial Membrane

Ear canal impedance: New methods and theory

The ear drum has finite delay, and is an acoustic horn!

- Pressure reflectance in the human ear canal

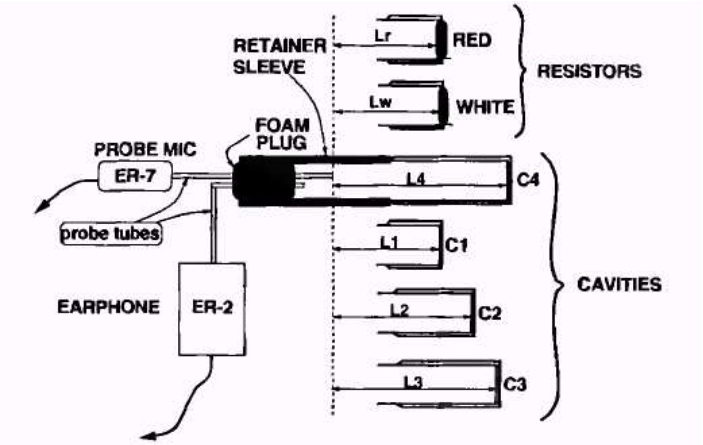
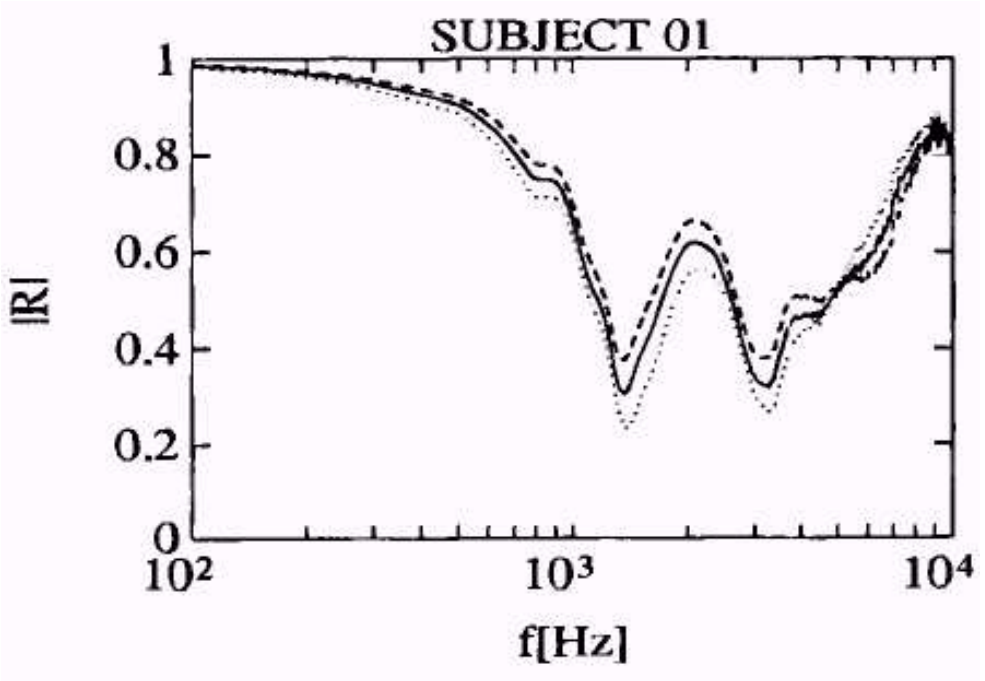


FIG. 1. The calibration system setup. The four cavities are used to calibrate the system, and the two resistor cavities are controls. The foam ear plug containing the sound tubes is calibrated and is then used to measure the human ear canal.

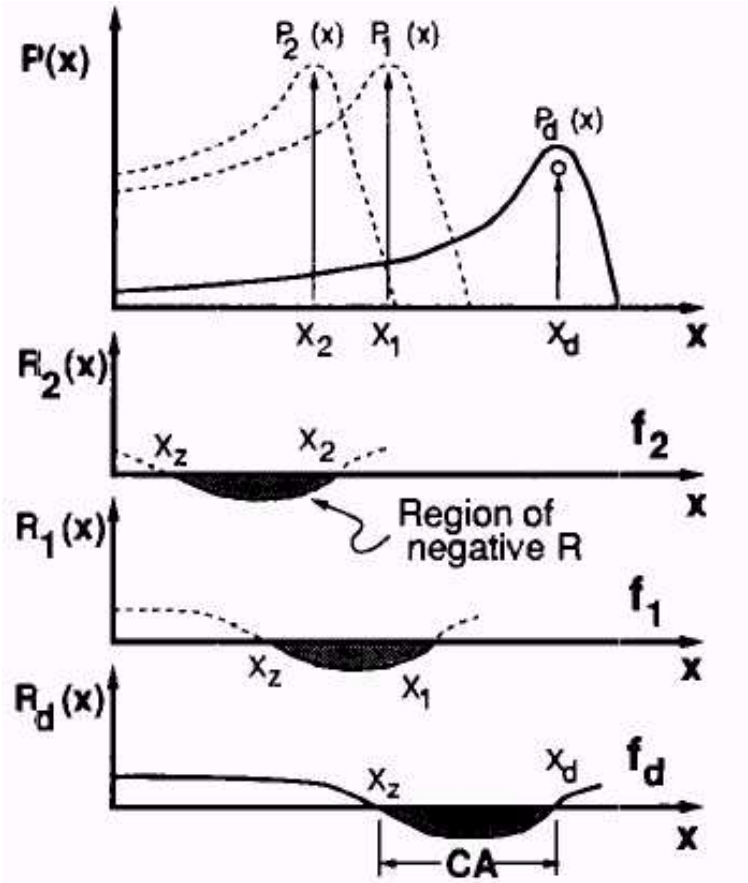


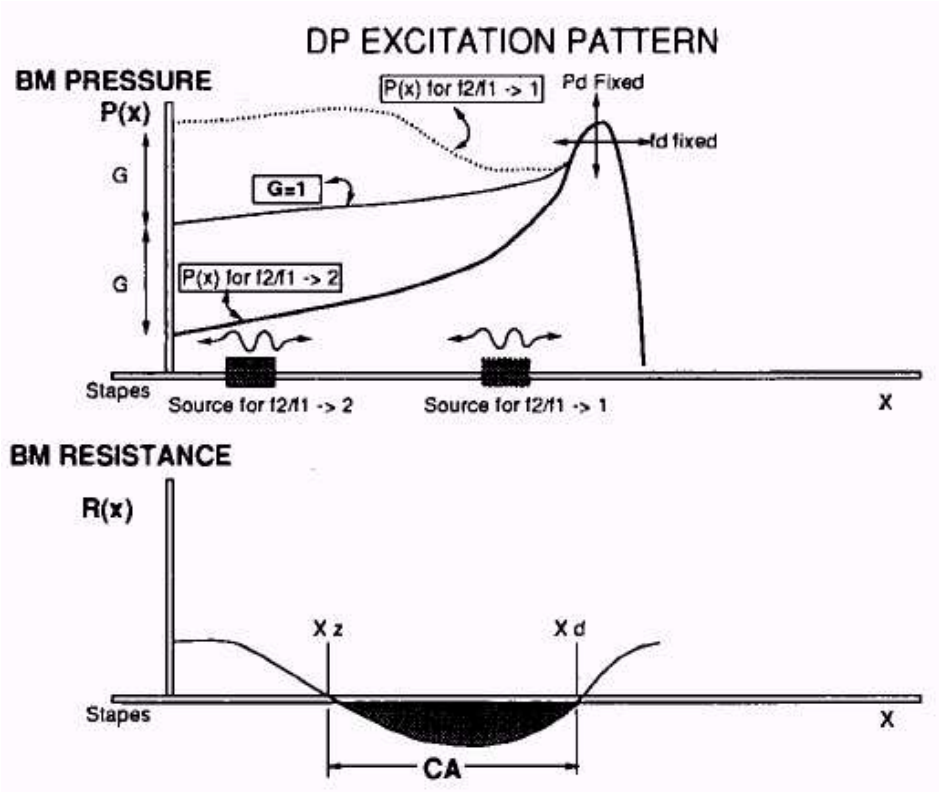
Method to measure power gain on the Basilar Membrane

COCHLEAR AND MIDDLE EAR MECHANICS

Pressure reflectance in the human ear canal

- Method to measure power gain on the Basilar Membrane

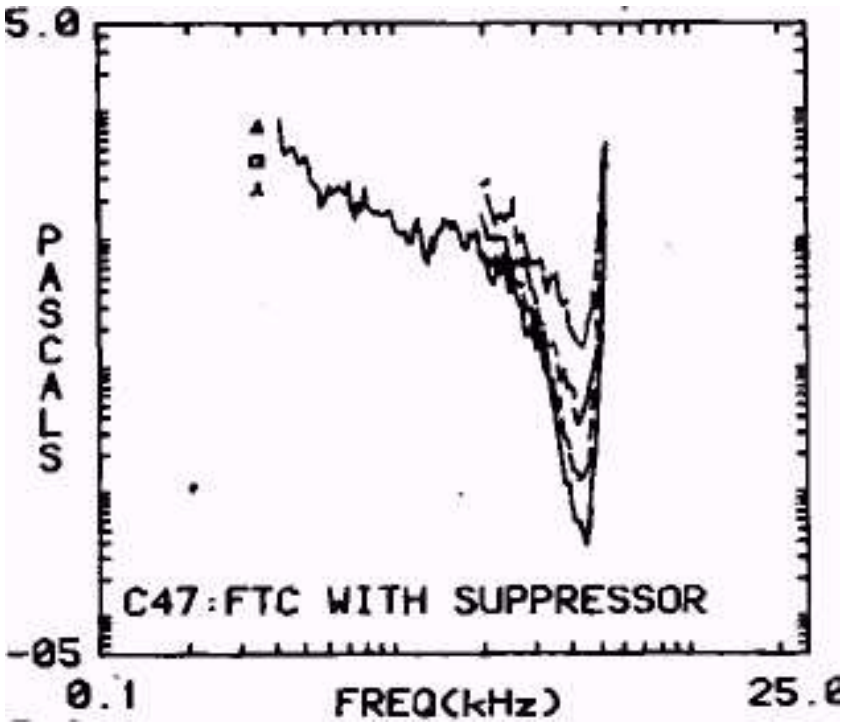


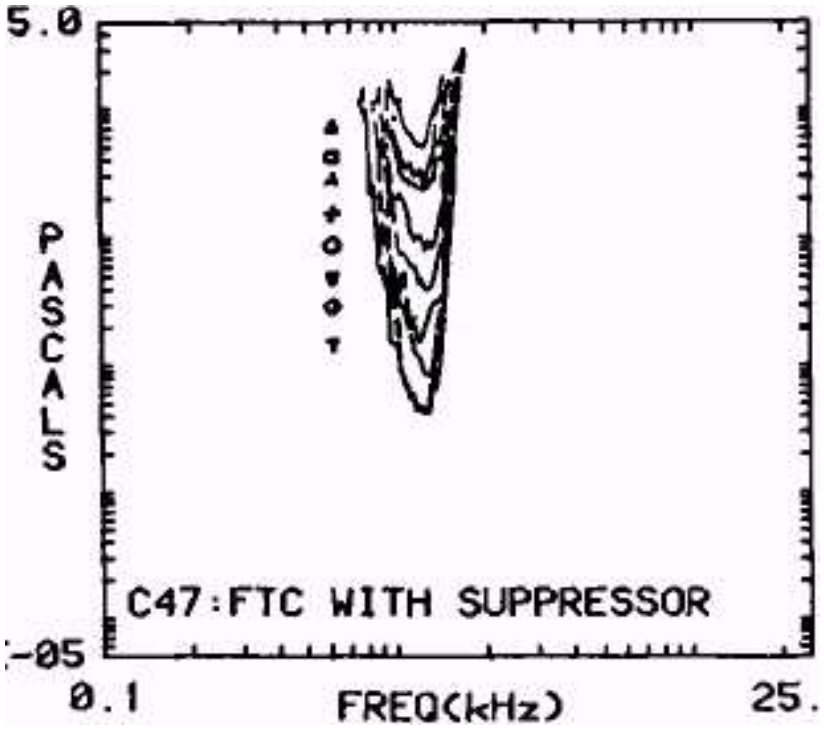


NEUROPHYSIOLOGY (LIVE ANIMAL EXPERIMENTS)

Phase and group delay in the Cat auditory nerve (AN)

- Distortion products and two-tone suppression in the Cat AN





HEARING AIDS

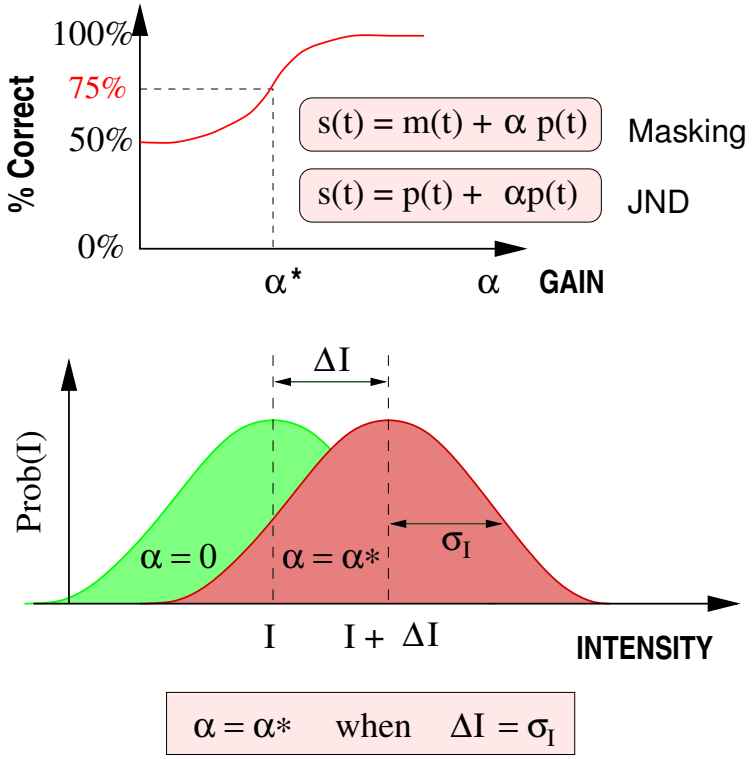
- Lead a group to develop the AT&T (ReSound) hearing aid
  - Invert *Loudness recruitment* with signal processing
  - Produced the first 2-band wide-dynamic range hearing aid
  - It was a dramatic commercial success ($>$150 $M/year)

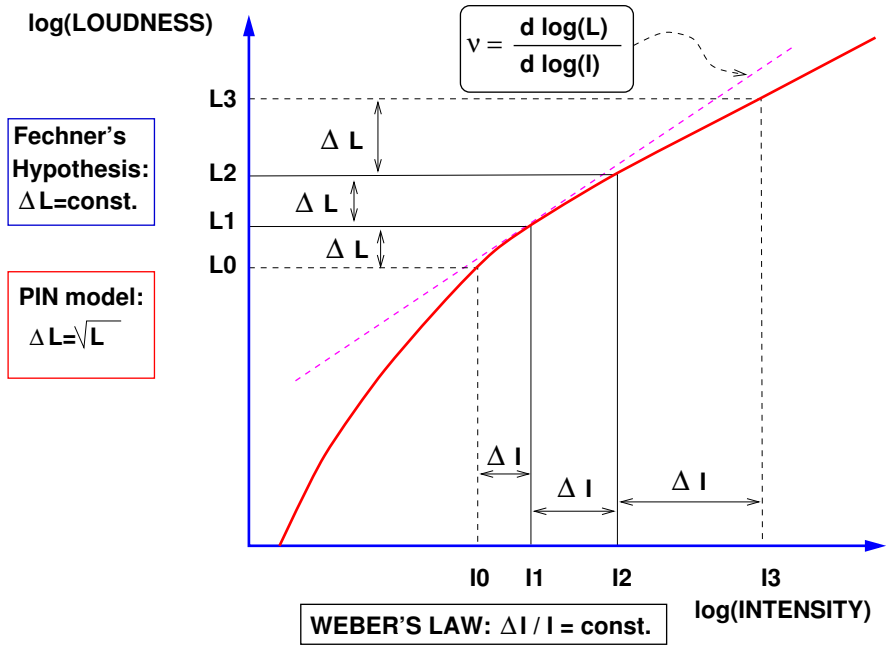
LGOB – loudness growth in the clinic

PSYCHOPHYSICS

Edit reprint of Fletcher's 1951 book

- Neural noise for speech and audio coding
- Loudness and the intensity JND: Internal noise is Poisson!

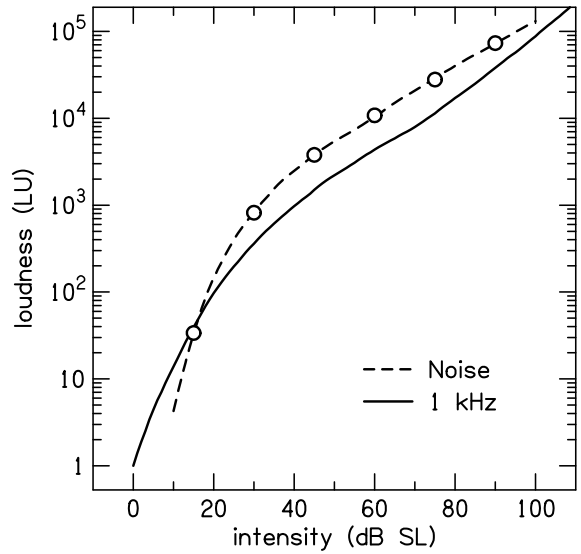


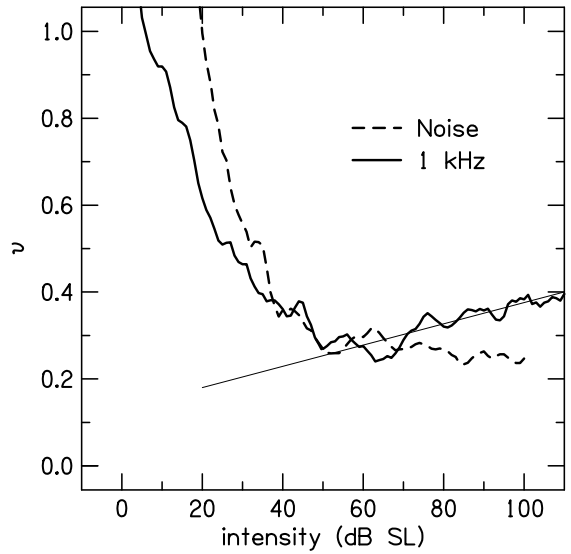


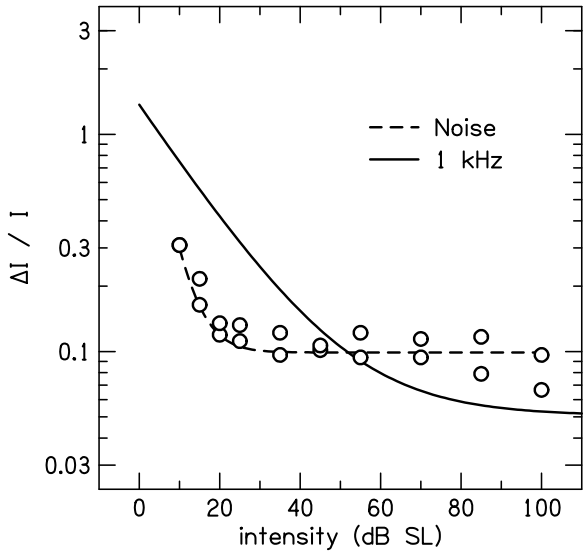
"The Law of comparative judgments." (Thurstone 1927)

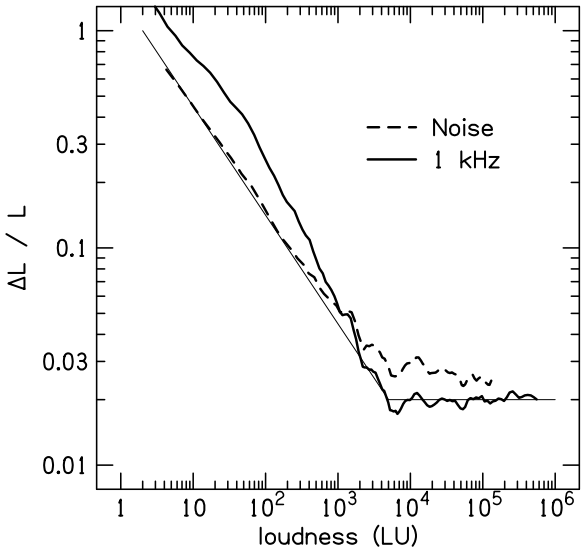
PSYCHOPHYSICS

- Construction:









HUMAN SPEECH RECOGNITION

How do humans recognize speech

- Extracting speech events for HSR

  This is the topic of my lecture, so lets stop here

TALK OUTLINE

- Papers I will very briefly discuss (chronological order):
  - 1976 Musical acoustics: Guitar strings inharmonicity
  - 1977 Signal processing: Short time inverse Fourier Transform
  - 1977 Cochlear mechanics: 2D cochlear model
  - 1977 Signal processing: Removing room reverberation (demo)
  - 1979 Signal processing: Inverse filtering room impulse response
  - 1979 Image method of finding room impulse response
  - 1980 Cochlear micromechanics: Resonant Tectorial Membrane
  - 1980 Adaptive Delta-mod: Inspired post-filtering
  - 1983 Phase and group delay in the Cat auditory nerve (AN)
  - 1985 Distortion products and two-tone suppression in the Cat AN
  - 1990 Hearing aids: LGOB – loudness growth in the clinic
  - 1991 Middle ear canal impedance: methods and theory
  - 1992 Method to measure power gain on the Basilar Membrane
  - 1994 Pressure reflectance in the human ear canal
  - 1995 Edit reprint of Fletcher's 1951 book
  - 1994 Speech recognition: How do humans recognize speech
  - 1997 Loudness and the intensity JND: Internal noise is Poisson!
  - 1997 Signal processing: Neural noise for speech and audio coding
  - 1998 ME The ear drum has finite delay, and is an acoustic horn!
  - 2001 Speech recognition: Extracting speech events for ASH

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