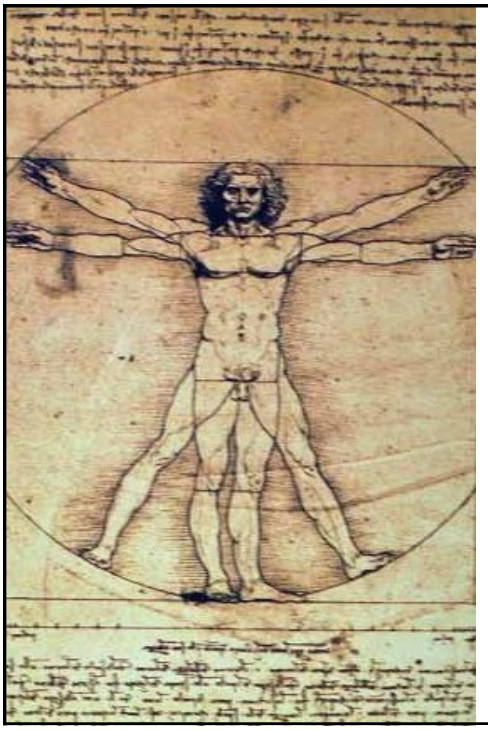


Interactive System
インタラクティブシステム特論(5)

Hiroyuki Kajimoto
kajimoto@hc.uec.ac.jp
Twitter ID kajimoto
Hash tag #itsys

Schedule

- 10/14 講義 Lecture
- 10/21 講義 Lecture
- 10/28 (Conference)
- 11/04 講義 Lecture
- 11/11 (Conference)
- 11/18 (Chofu-sai)
- 11/25 講義 Lecture
- 12/02 講義 Lecture
- 12/09 (Conference)
- 12/16 講義 Lecture／発表論文選択
- 12/23 (holiday)
- 01/06 講義 Lecture
- 01/13 講義 Lecture
- 01/20 発表 Presentation
- 01/27 発表 Presentation
- 02/03 発表 Presentation
- 02/10 発表 Presentation

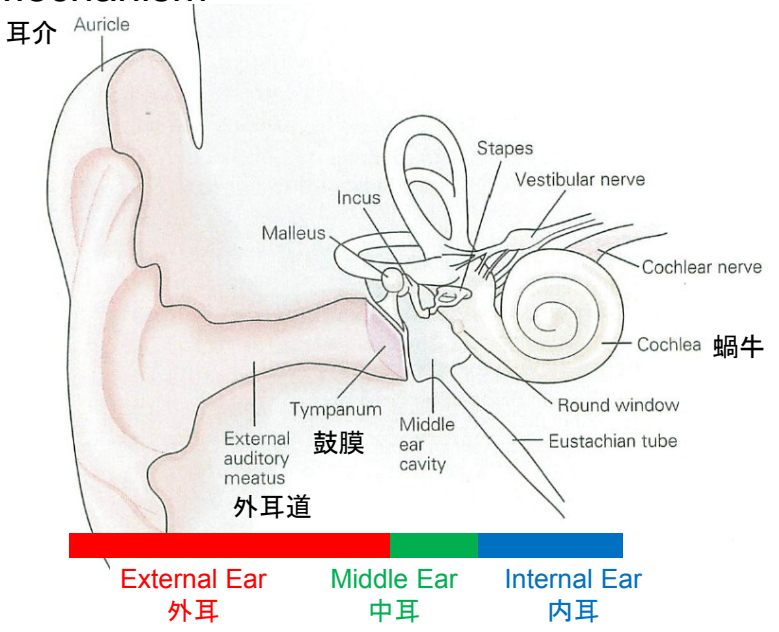
Outline

1. 人間計測手法／Measuring Human
2. 視覚／Human Vision System
3. 視覚センシング／Visual Sensing
4. 視覚ディスプレイ／Visual Display
5. 小テスト／Mini Test
6. 聴覚、聴覚インタフェース／Auditory Interface
7. 触覚、触覚インタフェース／Tactile Interface
8. 力覚、力覚インタフェース／Haptic Interface
9. 移動感覚インタフェース／Locomotion Interface
10. 最新のインタフェース研究／Recent Research
11. 小テスト／Mini Test

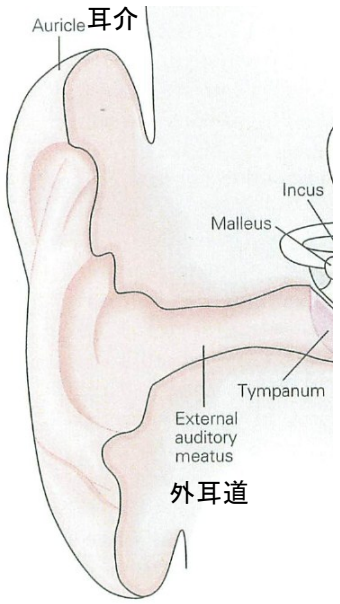
TODAY's TOPIC

1. Ear Mechanism
2. Auditory Perception
3. Interactive System
   1. Auditory Devices
   2. 3D Audio
   3. Synthesis of Auditory and other sensations
   4. Auditory sensation and welfare engineering

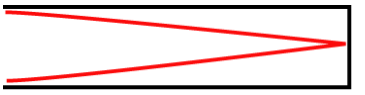
Ear Mechanism



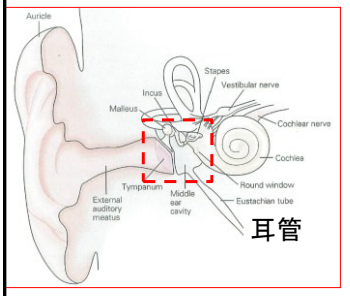
外耳／External Ear

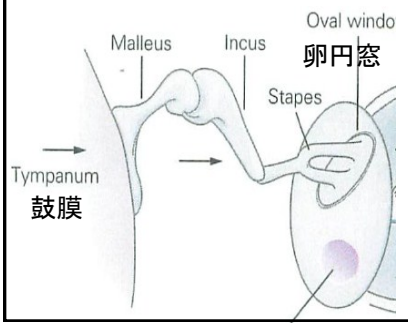


- 耳介／Auricle
  - 集音／Collection of sound
  - 方向定位／Directional sensation
- 外耳道／External Auditory Meatus
  - 共鳴管／A resonating pipe.
  - 2.5-3.5cm = 1/4λ
  - Lowest resonant freq. = 3-4kHz



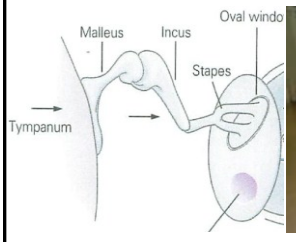
中耳／Middle Ear

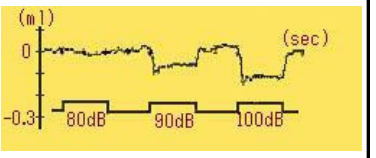




- 鼓膜／Tympanum
  - 厚み／Thickness 0.1mm
  - 直径／Diameter 8-9mm
  - 知覚可能最小振幅 ／Min. Amplitude 0.12 μm
- 耳小骨／Ear ossicles (tiny bones)
  - つち、きぬた、あぶみ骨 Malleus, Incus, Stapes
  - 増幅／Amplification
  - 筋肉が付属：強い音で硬くなる反射(減弱反射) ⇒伝達を減衰／Connected muscle modulate transfer efficiency (attenuation reflex)
- 耳管／Eustachian tube
  - 気圧調整／Connected to throat and keeps air pressure

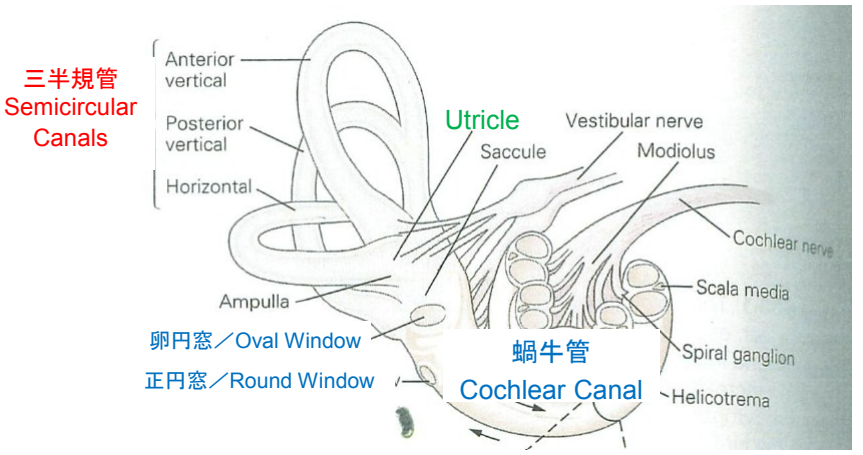
中耳検査／Examination of Middle Ear





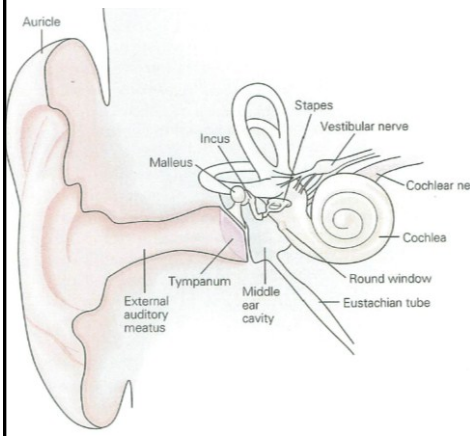
- 音を入れた際の反射音強度からインピーダンスを計測 Impedance measurement by reflected sound
  - ティンパノメトリー／Tympanometry
    - 外気圧を変動させた際の鼓膜の振動のしやすさ(インピーダンス)を検査 Measure tympanum's impedance while changing external air pressure
  - 耳小骨筋反射検査／stapedial reflex
    - 鼓膜に大きな音を入力したときの減弱反射を鼓膜の振動のしやすさ（インピーダンス）で検査 Measure tympanum's impedance while inputting very large sound

内耳／Internal Ear



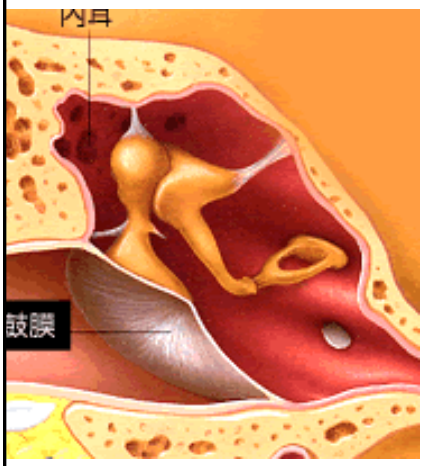
Sensory Complex:
Angular Acceleration, Acceleration, and Sound.

伝達のしくみ／Mechanical Transmission



1. Air Vibration
2. Tympanum Vibration
3. 3 Bone Conductions
4. Oval Window Vibration
5. (Lymph) Fluid Vibration
6. (Basilar)Membrane Vibration

中耳における増幅／
Lever Mechanism at Middle Ear

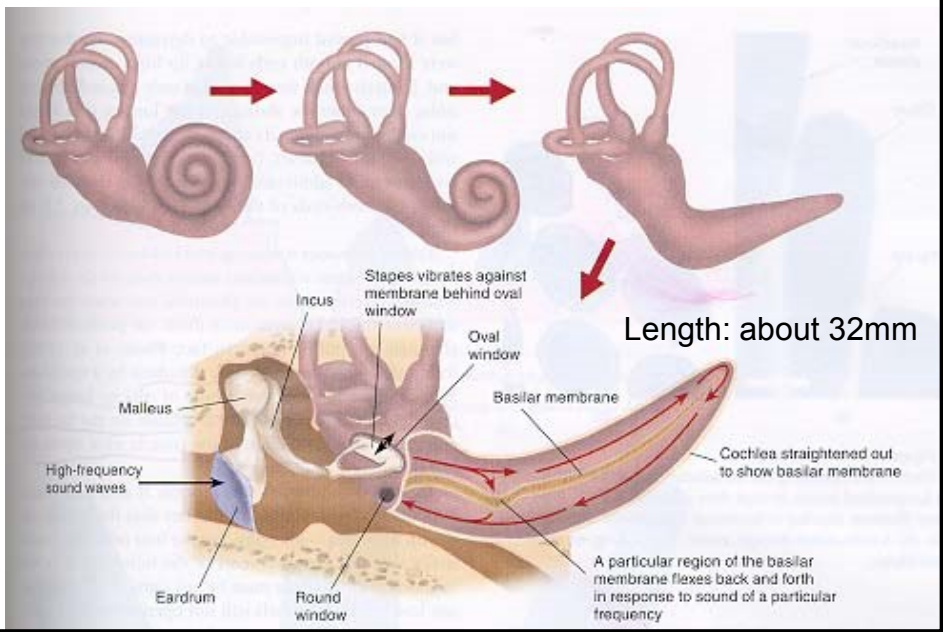


問題：空気振動で液体を駆動？
Problem: How to drive Fluid by Air?

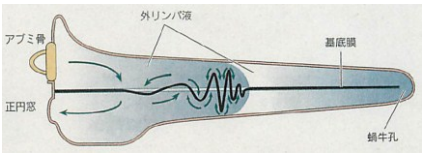
Fluid has 4000x more impedance than Air(Most energy is reflected)

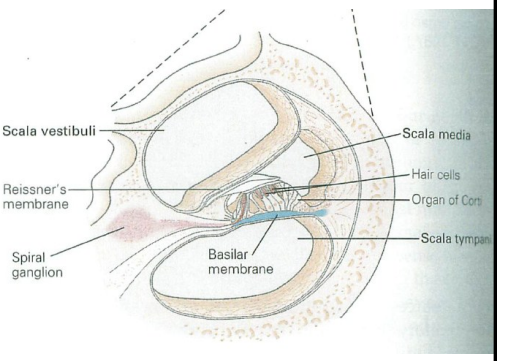
1. Tympanum size is 17x larger than Oval Window.
2. 3 Bones has 1.3x mechanical lever
3. In total, Force is magnified 22x, while amplitude is reduced.

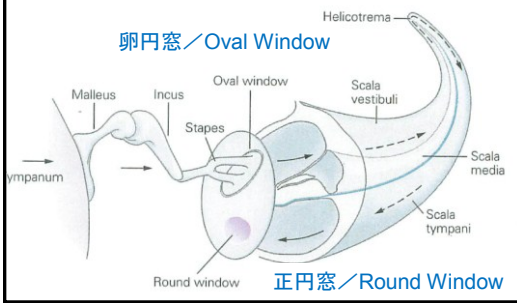
蝸牛管／Cochlear Canal = Snail Shape Tube



蝸牛管は基底膜で上下に区切られる
The Tube is divided by Basilar Membrane

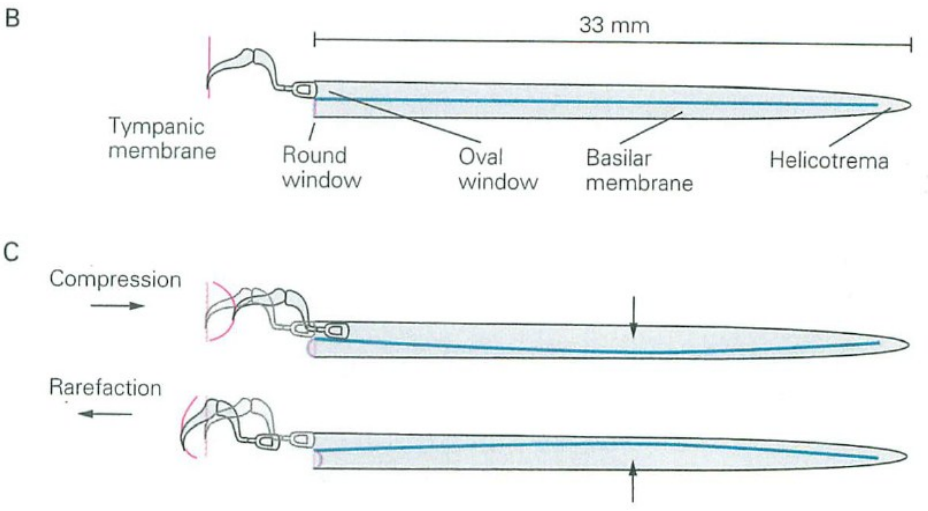




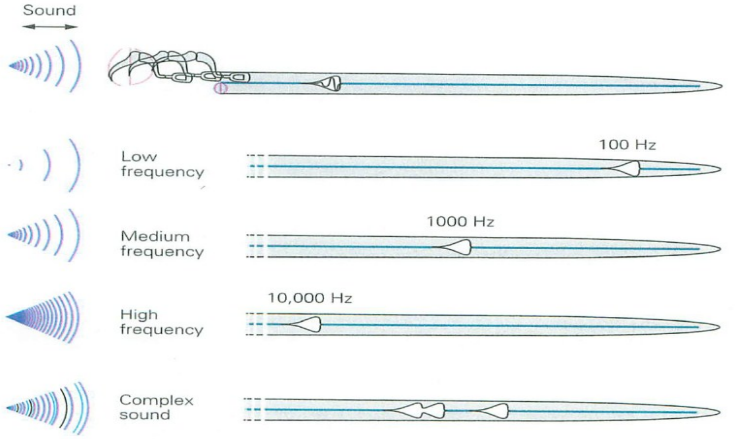


卵円窓から入力。正円窓が膨れる
(水は体積変化しないため)
Input from Oval Window,
terminated at Round Window.
(Water volume does not change)

基底膜の振動／Vibration of Basilar Membrane

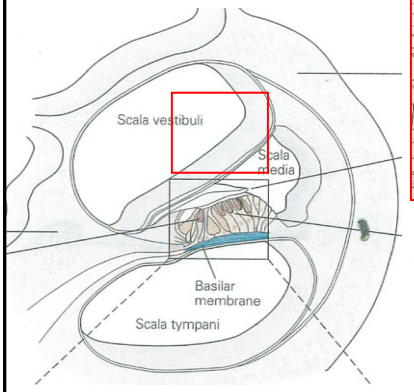


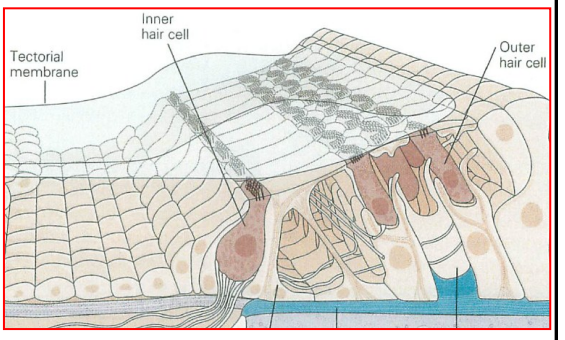
基底膜での周波数分解／
Frequency Analysis by the Membrane

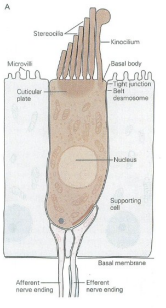


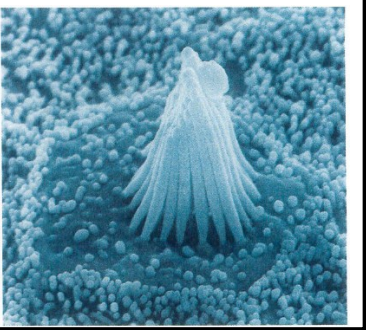
- Lower Frequency = Go Deeper
- Frequency is Converted to Spatial Pattern

基底膜上の有毛細胞
Hair Cell on the Membrane

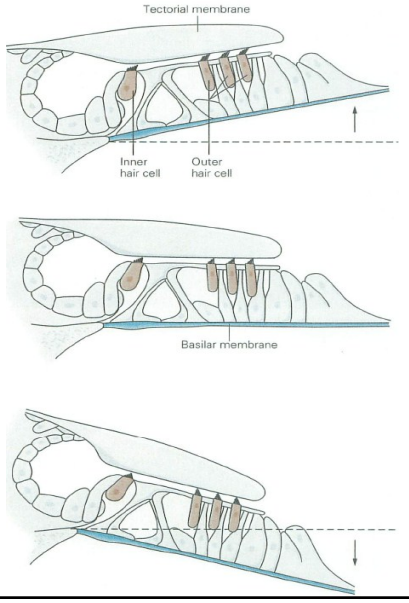




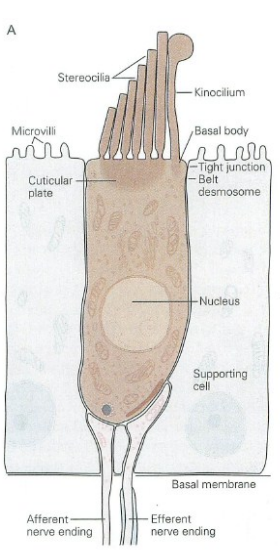


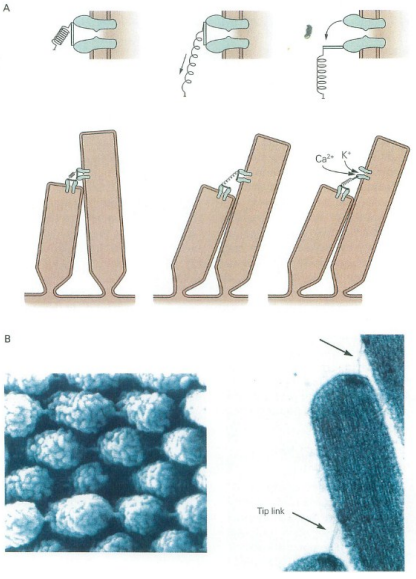


有毛細胞の駆動
Hair Cell is Driven by the Membrane

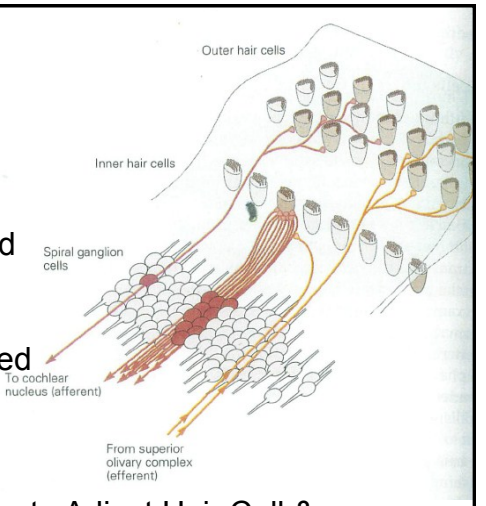


有毛細胞と機械的チャンネル開閉
Mechanical Channel on the Hair Cell





内有毛細胞と外有毛細胞
Inner and Outer Hair Cell

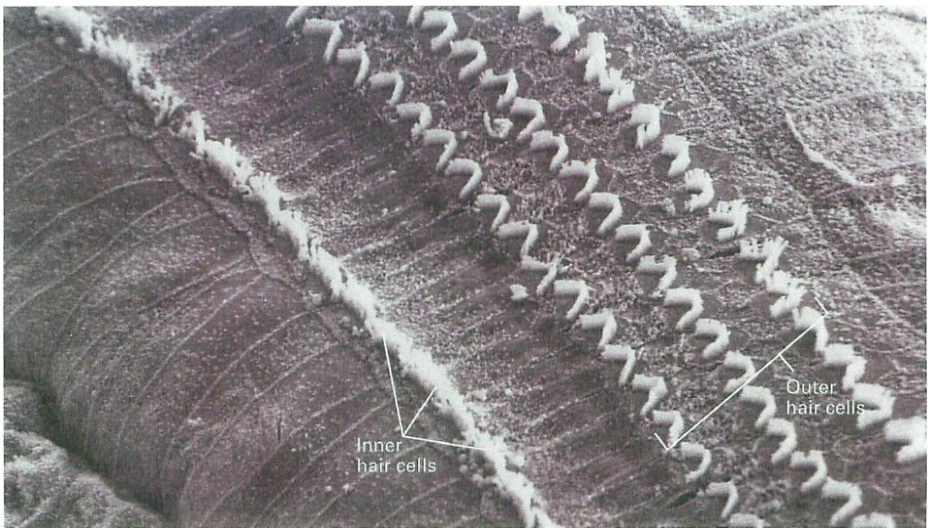


- Inner Hair Cell：Single Line
  - Sensory Nerve is Connected
- Outer Hair Cell: 3 Lines
  - Actuating Nerve is Connected
  - The role is still mystery.
- One Hypothesis:

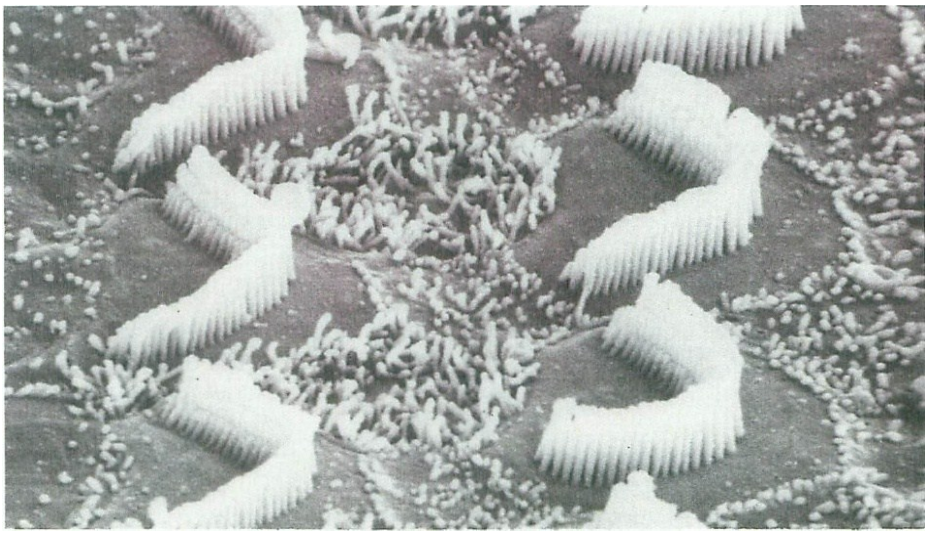
Outer Hair Cell works as Actuator to Adjust Hair Cell & Membrane Relative Position.

✓It vibrates with high frequency, and one cause of “noise in the ear” (buzzing)

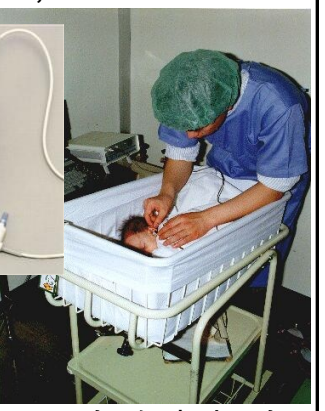
内有毛細胞と外有毛細胞／Inner & Outer Hair Cell



外有毛細胞／Outer Hair Cell (magnified)



耳音響放射／Otoacoustic Emission, OAE



•蝸牛が自ら音を発する。外部音に対する反応としても、無音時にも自発的に／Cochlea emits sound by itself, both as a reaction to external sound, and without external sound.
•外有毛細胞の活動によるとされる。It is due to outer hair cells
•聴覚系の検査のために用いられる。It is used as an examination tool for auditory system.

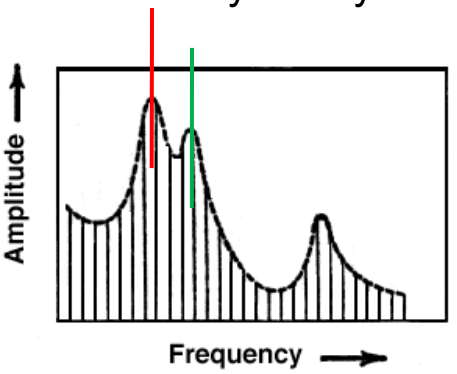
TODAY's TOPIC

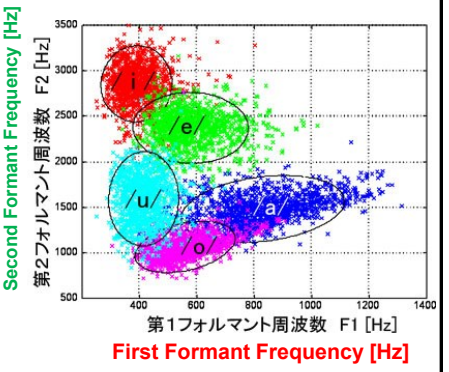
1. Ear Mechanism
2. Auditory Perception
3. Interactive System
    1. Auditory Devices
    2. 3D Audio
    3. Synthesis of Auditory and other sensations
    4. Auditory sensation and welfare engineering

周波数領域／Frequency Range

- 20Hz～20kHz (Higher than 20kHz = ultrasound)
  Become worse with aging
  – especially upper limit becomes lower.
    - "Mosquito Noise"：Children can hear, while Adults cannot.
    - Used for Cellphone ring

音は周波数分解されて知覚される／
Sound is analyzed by Frequencies.





- Ex. Formant
- Vowel is analyzed by “two major peaks”.
  - First Formant: 500～1000Hz
  - Second Formant:1500～3000Hz

スペクトラム・アナライザ
Spectrum Analyzer

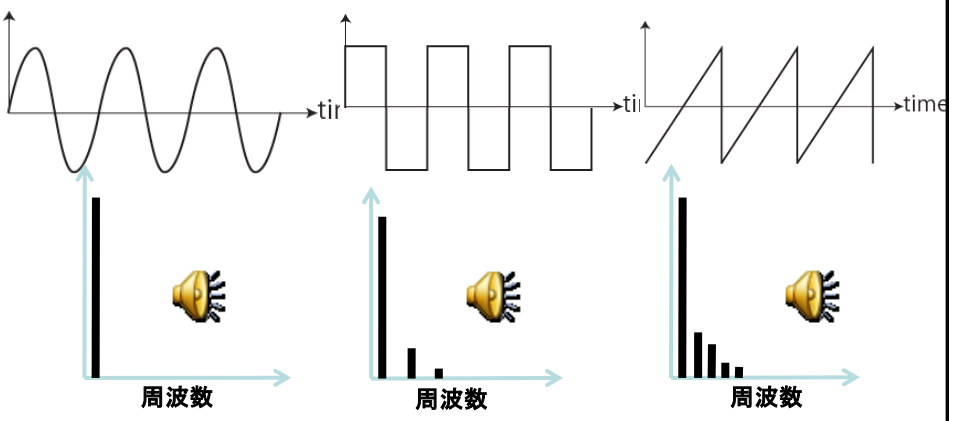
低 周波数 高
Low Frequency High

アイウエオ

しゃべるピアノ／Speaking Piano

http://www.youtube.com/watch?v=muCPjK4nGY4&feature=player_embedded

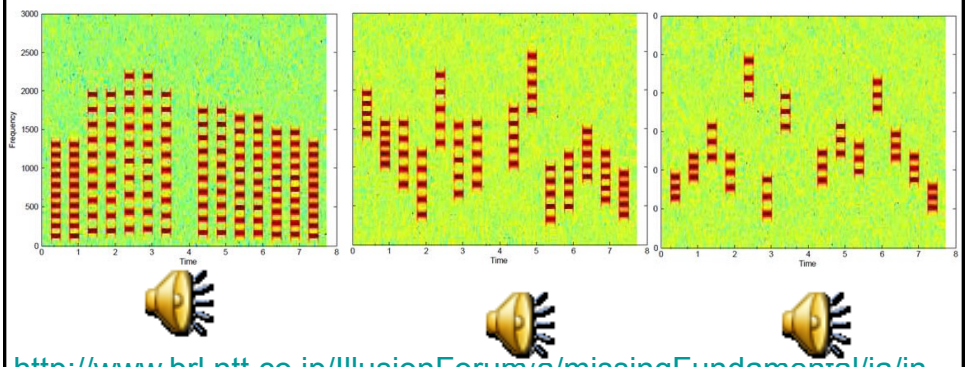
倍音構造の知覚／Perception of Harmonic Structure



これらを人は、「音色は違うけれど同じ」と思える
We Perceive these sound as the same pitch, altough tone is different.

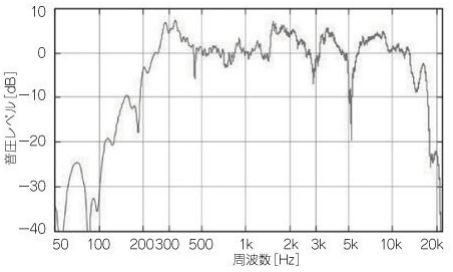
ミッシングファンダメンタル現象/ Missing Fundamental

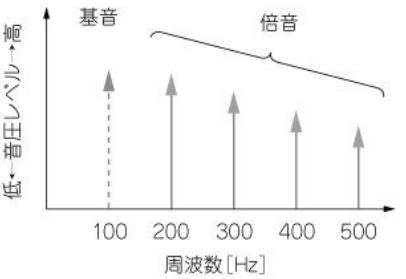
基底音が無くても、倍音成分の間隔で基底音を知覚できる
Without basis frequency, we perceive it by harmonic structure.



http://www.brl.ntt.co.jp/IllusionForum/a/missingFundamental/ja/index.html
↑このページは錯視・錯聴について最もまとまっているのでチェック

ミッシングファンダメンタルの応用
Application of Missing Fundamental



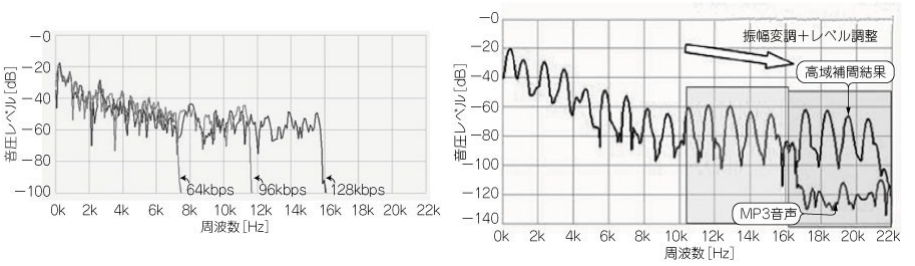


小型スピーカは低周波を出しにくい。Small speaker can't output low freq.

200Hz以上で、100Hzの倍音を聞かせると、100Hzの基音が聞こえる。
薄型テレビ（特に内蔵スピーカの特性が悪くなりがち）で採用。
Outputting 200,300,… frequency sound, we perceive 100Hz basis freq.
Thin TV (which has small speaker) applies this method.

http://www.kumikomi.net/archives/2009/09/dsp_1.php

倍音構造の応用
Application of harmonic structure

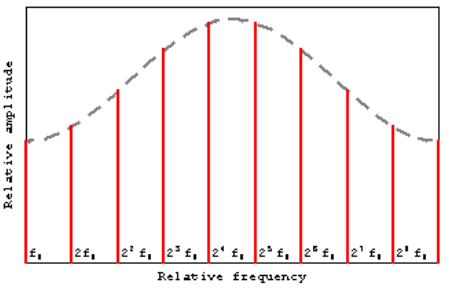


MP3等の圧縮では高周波領域カット→自然に聞こえない場合ある。
再生時、「楽器音には倍音構造がある」ことを利用、周波数を拡張。

As compression such as MP3 cuts off high freq., harmonic structure of musical instrument is utilized for compensation.

http://www.kumikomi.net/archives/2009/08/dsp.php?page=1

無限音階(シェパードトーン)/ Shepard Tone

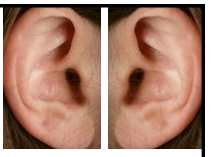


http://www-antenna.ee.titech.ac.jp/~hira/hobby/edu/sonic_wave/sh_tone/index-j.html

人間が周波数構造を知覚していることを利用、主観的には無限に上昇する音を作ることができる
Utilizing human perception of spectrum structure, infinitely rising (falling) sound can be generated.

YMO LOOM(1981)

音源定位／Sound Position Localization



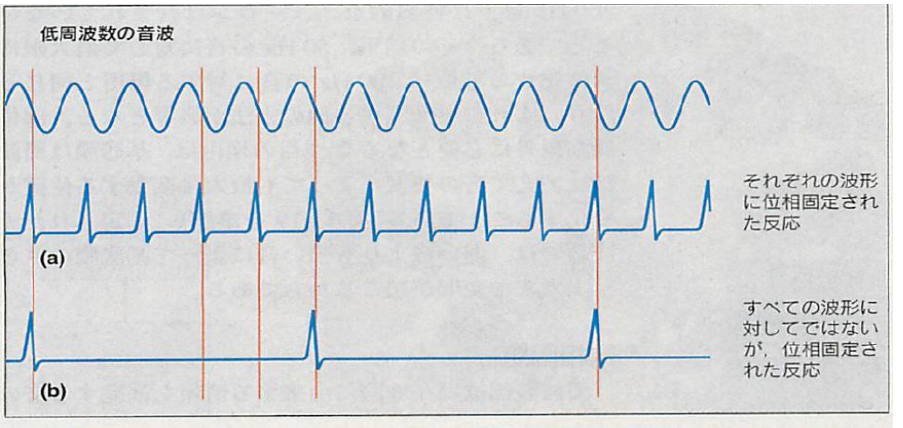
- 両耳の差／Difference of two ears
  - 20～2kHz 時間差、位相差／Temporal (Phase) Difference
  - 2kHz～ 強度差／Amplitude Difference

- 上下方向の定位：耳介による音色変化
  Earlobe filters the sound, so that sound tone changes with vertical position.

  Sound from Front: f1→0.9, f2→0.6, f3→0.5, …
  Sound from Back: f1→0.7, f2→0.9, f3→0.6, …
  Sound from Top: f1→0.5, f2→0.5, f3→0.3, …

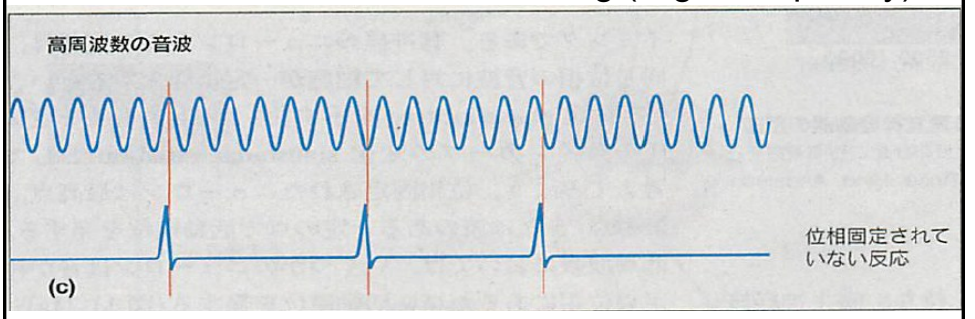
  - 純音の定位は不可能。未経験の音の定位も難しい
    Pure tone localization is impossible. Inexperienced sound is also difficult

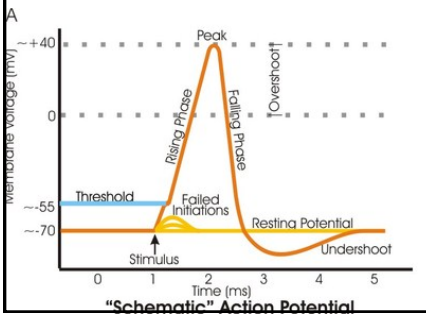
音源定位と神経コーディング(低周波)／
Sound localization and nerve coding (low frequency)



位相固定された活動 → 音源定位に神経活動のタイミングが使える
Nerve activity is phase-locked so that “timing” can be used for localization.

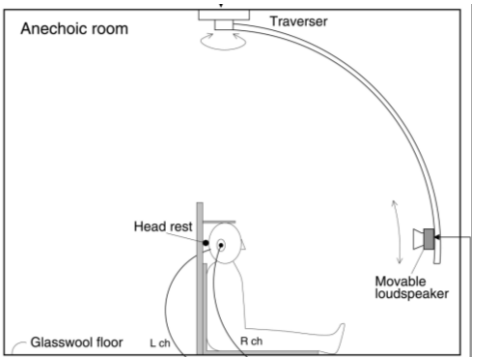
音源定位と神経コーディング（高周波）／
Sound localization and nerve coding (High Frequency)





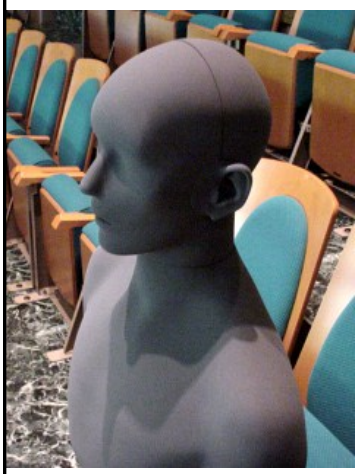
一周期の時間が神経の不応期より短いためランダムに活動→タイミングが使えないので強さだけが頼りになる
As one cycle is shorter than nerve's resting period, nerve activity is random and only intensity can be used for localization.

頭部伝達関数(HRTF) ／
Head-Related Transfer Function



- Head Filtering Characteristics are measured.
  - Parameters:
    - Sound Source Direction（**θ**, **ψ**）
    - Frequency **f**

Dummy Head



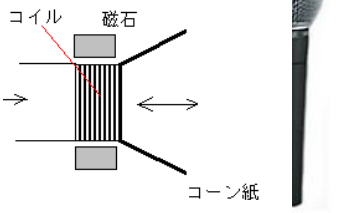
- Head Dummy, which has the same HRTF as human.
- Expensive ones
  - Not only shape, but surface textures and softness is the same as human.
- Microphone is inside the ears.

TODAY's TOPIC

1. Ear Mechanism
2. Auditory Perception
3. Interactive System
   1. Auditory Devices
   2. 3D Audio
   3. Synthesis of Auditory and other sensations
   4. Auditory sensation and welfare engineering

ムービングコイル型スピーカ＆マイク
Moving coil type speaker & microphone

- 電磁誘導の利用 Utilizing electromagnetic induction.
- 多くスピーカに用いられる Frequently used for speaker.
- 通常は磁石を固定，コイルを振動
  Ordinary, magnet is fixed, coil is vibrated.
- コイルは非常に軽く，高周波駆動が可能
  As the coil is very light, it can be driven very fast



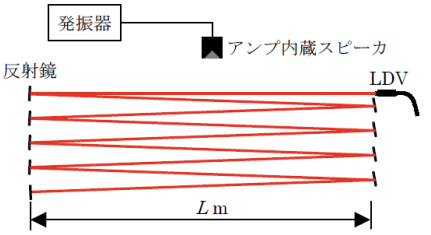
コンデンサマイク・スピーカ
Capacitance type microphone & speaker

- コンデンサマイク/ Microphone
  - 2枚の電極板距離の変化による静電容量変化を検出/ Detecting distance between two plates by measuring capacitance
  - 共振周波数が高いため可聴域ではフラットな特性。一般的に高性能。/ High resonant frequency means flat frequency charactestics.
- コンデンサスピーカ
  - 2枚の電極板に加える電圧の変化による電極板距離の変化により空気を駆動/ Distance between two plates is altered by applying voltage
  - 平面全体を駆動可能なため，平面型スピーカなどに用いられる/ Large plane is driven, enabling large thin speaker

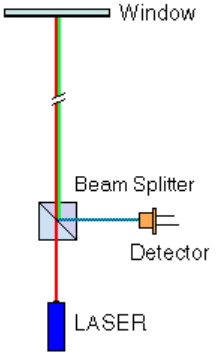
（参考）大平面スピーカ/ Large plane speaker

- モニタ前面を振動させる / Vibrates front plane of the monitor
- 振動子としては圧電素子等が用いられる / Piezo-electric actuator is used.

（参考）レーザーマイク / Laser microphone



ドップラー効果方式(滝沢他2003,
http://www.acoust.rise.waseda.ac.jp/publications/happyou/asj/asj-takizawa-2003march.pdf

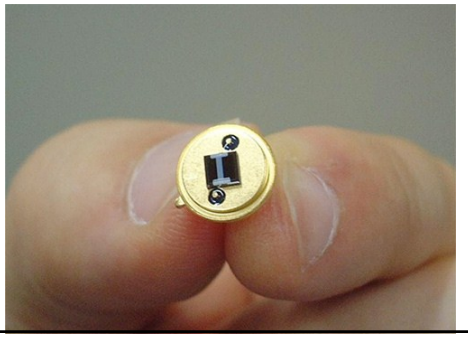


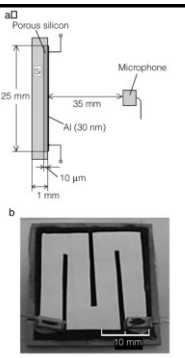
干渉計による振動検出

- レーザー光での検出：マイク自身による音伝達阻害がない。
  Detecting by laser. Ideally no “microphone”
  - ドップラー効果方式。粗密変化を測定
    Doppler effect. Measures density change
  - 干渉計方式。光路長変化を測定
    Interferometer. Measures distance change

(参考)温度スピーカ
Thermo Speaker

- 微小世界では温度も高速
  Heat transfer is fast enough in a small world.
- 電流によりジュール熱を生じさせ，熱による膨張で音を発生させる.
  Joule heat expands air around the device

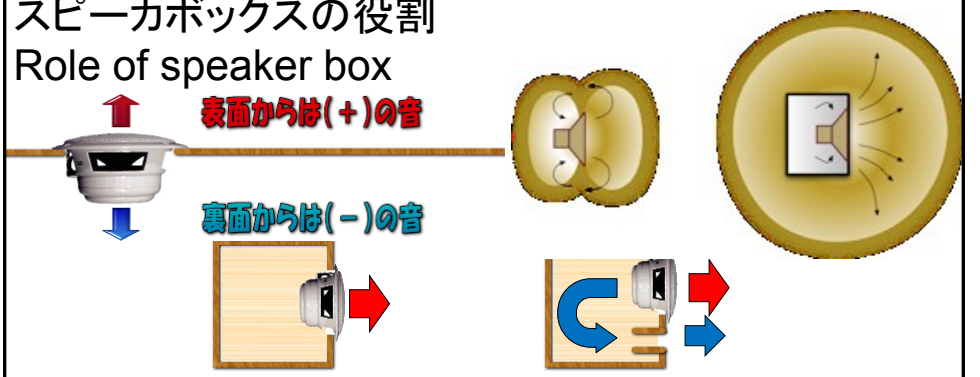




H. Shinoda, T. Nakajima, K. Ueno, and N. Koshida: Thermally Induced Ultrasonic Emission from Porous Silicon , Nature, 400, 853 - 855, August 26, 1999.

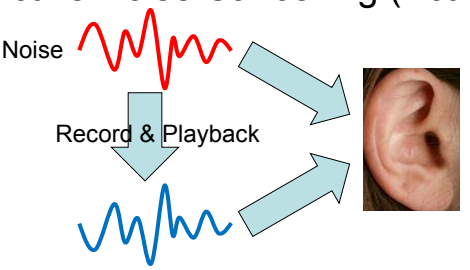
カンタム14、周波数0.1kHz-100kHzの広帯域小型スピーカーを開発(2010.6.25)
http://www.nikkan.co.jp/news/photograph/nkx_p20100625.html

スピーカボックスの役割
Role of speaker box



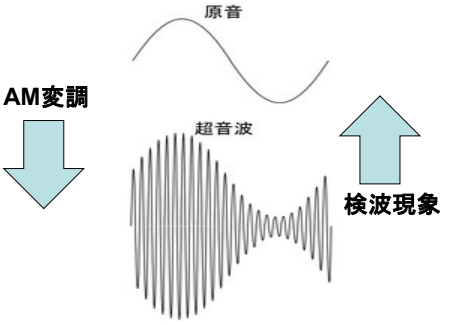
- スピーカ表裏で生じる逆位相の音圧による打ち消し効果を抑制
  Positive & negative pressures are sumultaneously produced by speaker. Box avoid the effect
- ボックスの共振特性を利用して苦手な低音を増強
  Box has resonant frequency → Enhance low frequency
- バスレフタイプ：特定の周波数の音を増強
  Bass-reflex type: Enhance certain frequency

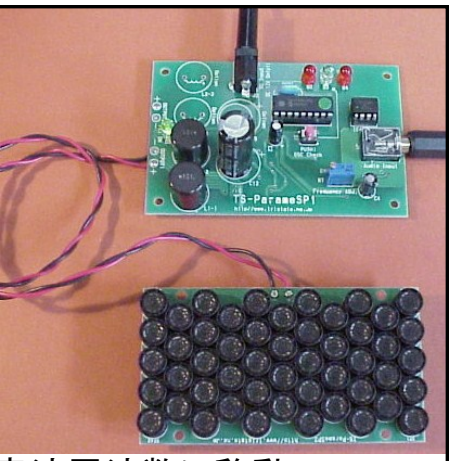
アクティブノイズキャンセリング／Active Noise Cancelling (Active Noise Control)



- 外からの音と逆相の音を出すことで効率よく音を消去
  Negative sound cancels external sound.
- 低周波は得意。高周波は苦手
  Low frequency components are easy to cancel.
- 記録場所と再生場所が近いほうが楽に実現→ヘッドフォンは理想的
  Microphone and speaker should be closer. Headphone is ideal.

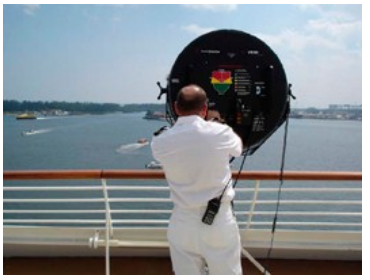
パラメトリックスピーカ／Parametric Speaker





- 可聴音をAM／FM変調し、超音波周波数に移動
  Audible sound is translated to high freq. sound by AM/FM
- 空気と物体の界面で検波、可聴音に戻る
  Demodulation at boundary between air and object.
- 指向性が極めて高い→インタラクティブシステムに向く
  Beam can be very narrow→applications for interactive systems

LRAD（Long Range Acoustic Device)

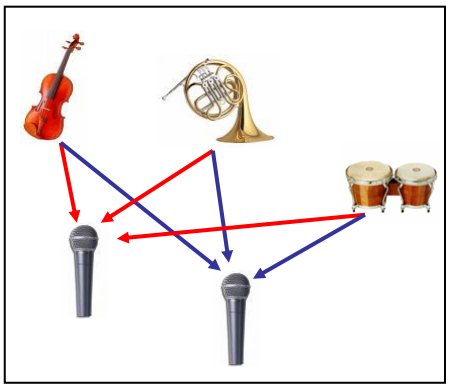


- パラメトリックスピーカの原理を用い、音エネルギーを遠くに飛ばす

TODAY's TOPIC

1. Ear Mechanism
2. Auditory Perception
3. Interactive System
    1. Auditory Devices
    2. 3D Audio
    3. Synthesis of Auditory and other sensations
    4. Auditory sensation and welfare engineering

Ordinary Recording and Playing

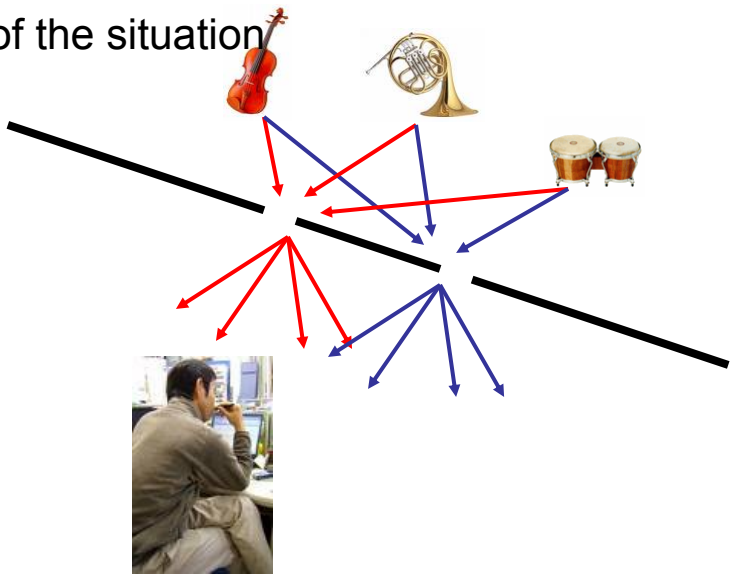


Record: by two microphones

WHY is it OK?

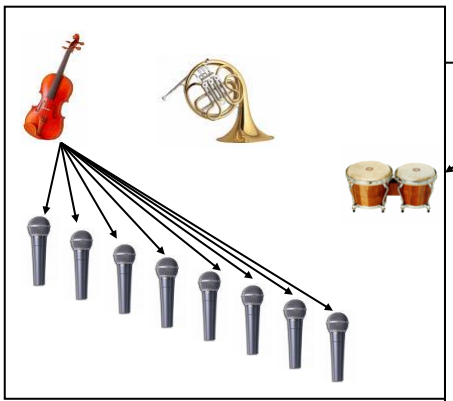
Play: by two speakers

Analysis of the situation



•Equivanent to Listen “through two holes on the wall”.
•Limited Naturalness, but almost OK.

Money solves the problem



Recording: N microphones

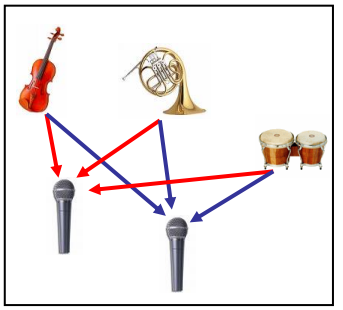
Playing: N speakers

Analysis of the situation



- **“Holes” on the wall become numerous.**
- **Sufficient number of holes destroy the wall**

What about Headphone?

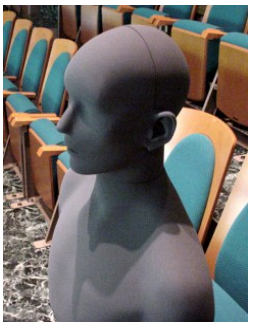


Normal Recording

Playing by Headphone

- Many information about Sound Source Position is Lost.
- Sometimes, Sound is Perceived as “Sound from Inside Head.

Binaural Recording



Dummy Head

Head Phone

Perfect Sound Localization,
Because All Three elements are replayed.

- Temporal Difference
- Amplitude Difference
- Frequency Change by Earlobe.

Vice Versa

Dummy Head

Speakers

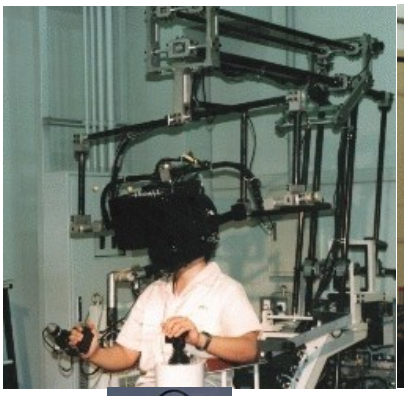
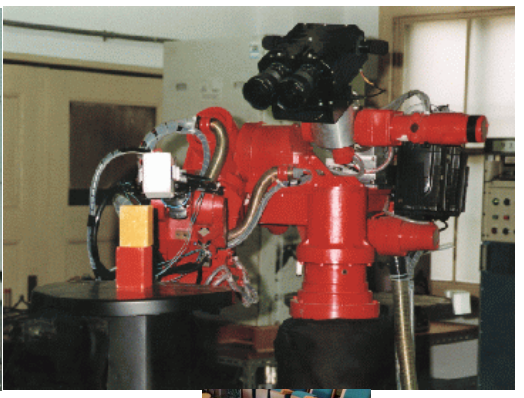
We've heard of something similar...

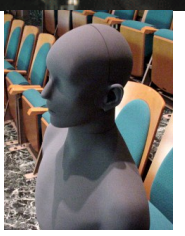
- Headphone＝HMD
- Speakers＝Ground Fixed Type Display





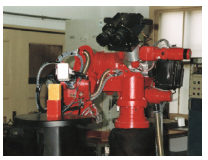
Review: HMD and Camera for it.

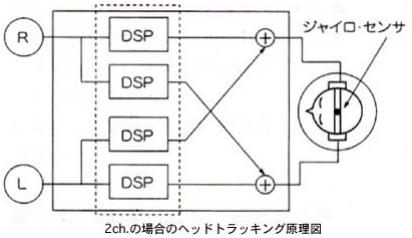


Head Tracking

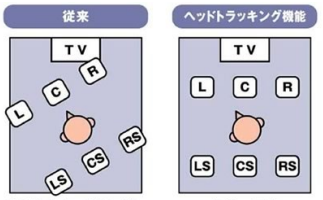
- Robot head should move according to the user's motion.



- Headphone system with gyro(angular velocity sensor) is already commercially available.



2ch.の場合のヘッドトラッキング原理図

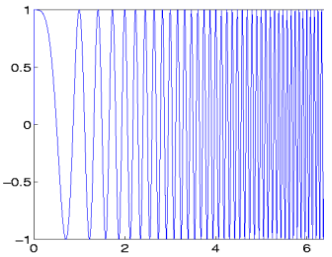


ヘッドトラッキングの効果例

Sound Field Reproduction

- Auditorium's sound characteristics is measured, just like HRTF

Put Point source speaker on the stage.



Impulse, or chirp signal (that contains all frequencies)

Microphone is put on the seat.

Sound Field Reproduction

Recording at anechoic room

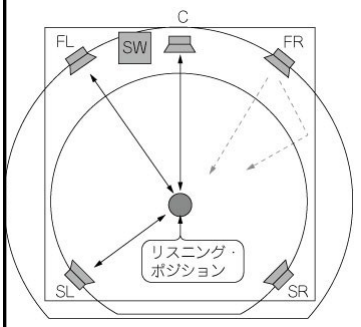
Add the auditorium's transfer function

Anechoic Room Experience

We do not have an experience of "truely no noise" situation.
We hear heartbeat of ourselves, and sometimes feel dizzy.

When you have time, go to ICC
(NTT Inter-Communication Center @ Hatsudai)
http://www.nttticc.or.jp/

サラウンドシステム/ Surround system



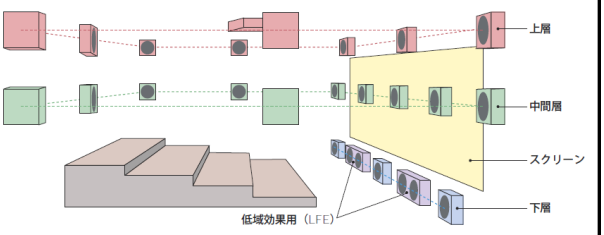
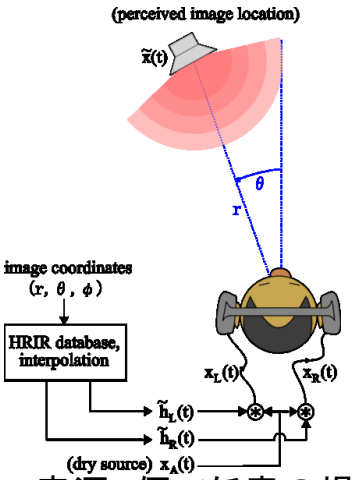
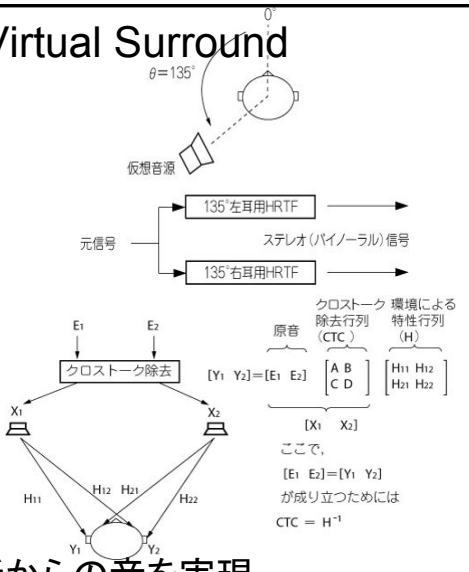


図　22.2マルチチャンネル音響システムのスピーカー配置

- 5.1ch, 7.1ch…
  - 各スピーカからリスニングポジションまでの距離（音の到達時刻）に応じた補正をすると音が「実体化」
- NHK技研の22.2ch
  http://www.gizmodo.jp/2006/09/nhk222_1.html

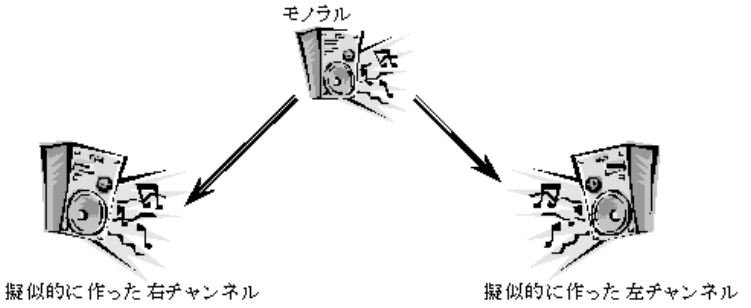
バーチャルサラウンド Virtual Surround





- 音源2個で任意の場所からの音を実現
  Present locational sound by only two speakers
- スピーカ2個の場合はクロストーク除去が必要
  2 speakers case, cross-talk should be eliminated

擬似立体音響/ Pseudo 3D sound?

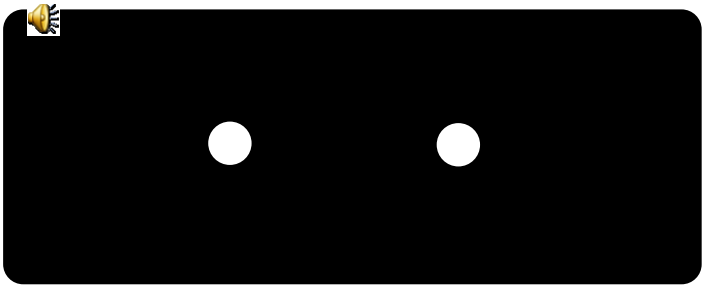


- モノラル音源をサラウンド「っぽく」する
  From mon-sound, pseudo surround sound can be generated
  - 位相反転。左右どちらかのチャンネルだけスピーカの結線を逆に
    Phase reversal by miss-connecting one line
  - フェイズシフト（位相ずらし）。左右どちらかのチャンネルだけ再生時刻を遅らせる（数ms～数十ms)
    Phase shift by delaying one line

TODAY's TOPIC

1. Ear Mechanism
2. Auditory Perception
3. Interactive System
   1. Auditory Devices
   2. 3D Audio
   3. Synthesis of Auditory and other sensations
   4. Auditory sensation and welfare engineering

視覚と聴覚の融合
Synthesis of visual and auditory sensations



- 破裂音で左右のボールの動きが変わる
  Click signal produces collision-reflection feeling

（参考）マガーク効果／*McGurk effect*

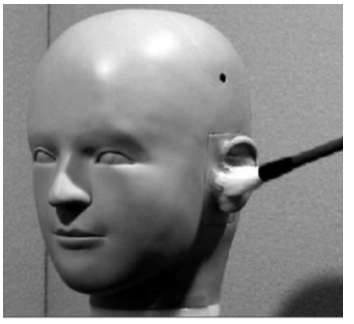
http://www.youtube.com/watch?v=Fke7GWcT5ko

味覚と聴覚の融合
Synthesis of gustatory and auditory sensations

- ポテトチップスのサクサク音は味覚に影響する
  Crisp sound of potato chips alters taste
- IG Novel Prize for Nutrition 2008

Zampini, M., & Spence, C. (2004) The role of auditory cues in modulating the perceived crispness and staleness of potato crisps. Journal of Sensory Studies, 19, 347-363.

触覚と聴覚の融合
Synthesis of tactile and auditory sensations



- Parchment-skin illusion: 手の感触が音によって変化．両手をこすり合わせている時に，その音を変化させて被験者に提示⇒高音域増幅で手の感触が滑らか・乾燥。高音域減衰で粗・湿感。
  Jousmaki, V et al.: Parchment-skin illusion: sound-biased touch, Curr. Biol, 1998

- ダミーヘッドの左耳に挿入したマイクロホンで，耳を筆でくすぐった時の音を録音、この音をヘッドホンで 提示すると耳にくすぐったさを感じる．
  北川：多感覚錯覚から見る身体のリアリティ、VR学会誌2005 http://www.brl.ntt.co.jp/people/kitagawa/pdf/399kitagawa.pdf

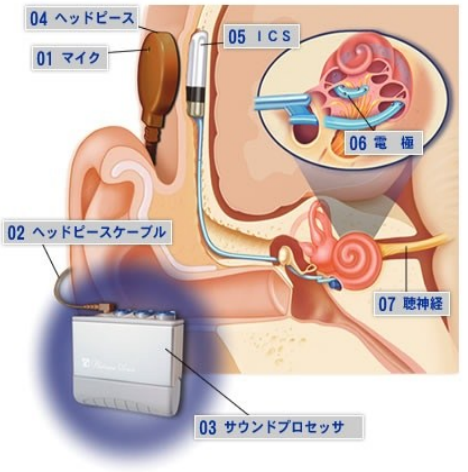
TODAY's TOPIC

1. Ear Mechanism
2. Auditory Perception
3. Interactive System
    1. Auditory Devices
    2. 3D Audio
    3. Synthesis of Auditory and other sensations
    4. Auditory sensation and welfare engineering

音と福祉工学／Sound in Welfare Engineering

- 聾唖者のサポート／Supporting deaf and mute
  - 人工内耳／Artificial inner ear
  - 人工咽頭／Artificial pharynx
- 視覚障害者のサポート／Supporting visually impared
  - 感覚代行／Sensory substitution
  - 視覚障害者の障害物知覚／Obstacle avoidance ability of the blind
- 高齢者のサポート／Supporting elderly
  - 補聴器／Acoustic aid
  - 骨伝導スピーカ
  - 再生音速度の低減(ビデオの早送りにも使われるように．これをリアルタイムに使う)

人工内耳／Artificial Inner Ear

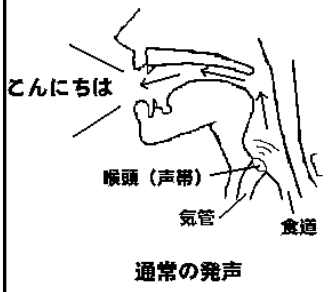


- 歴史：ボルタが最初に50Vを耳内部にかけた。／History: Volta first applied 50V inside ear (around 1800).
- 体外部：マイク，スピーチプロセッサ，送信コイル／External body: microphone, speech processor, transmission coil.
- 体内部：受信コイル、アンプ、電極／Internal body: receive coil, amplifier, electrodes
- 電極は8～22対．蝸牛に挿入され，感覚神経を電気刺激．脳に伝わり音として感じる／8 to 22 electrodes are inserted to cochlea, stimulating sensory nerves directly.

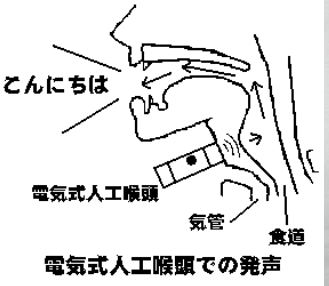
人工内耳／Artificial Inner Ear

www.youtube.com/watch?v=UQFxkhFiLAM

人工咽頭／Artificial pharynx



通常の発声



電気式人工喉頭での発声

- 咽頭ガン等で咽頭の摘出→声の元となる振動を作れない
  Pharynx is removed for cancer→Vibration cannot be generated
- 人工咽頭：振動により声の元を作る.
  Artificial pharynx: Generate vibration, as a source of voice

人工咽頭／Artificial pharynx

http://www.secom.co.jp/personal/medical/myvoice.html

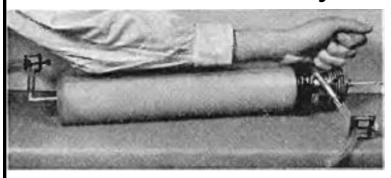
感覚代行1／Sensory Substitution 1

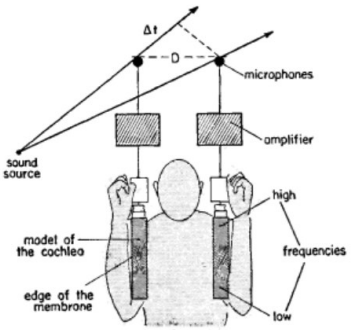
Sonic Guide

vOICe

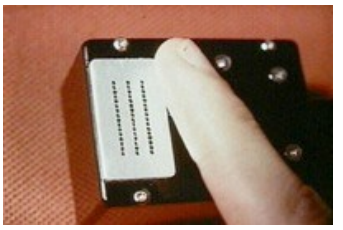
聴覚による視覚代行
Substitute visual sensation by auditory sensation

感覚代行2　触覚による聴覚代行／Sensory Substitution 2
Substitute audotory sensation by tactile sensation





G.v. Bekesy(1955) Human Skin Perception of Traveling Waves Similar to Those in the Cochlea



http://www.human.rcast.u-tokyo.ac.jp/?p=2&pp=0&l=1&r=1111

Tactile Vocoder

触覚で音を聞く。基本アイデア：周波数分解して皮膚に分布提示
Listening by tactile sensation.
Basic idea: Frequency components are presented to different position of the skin, just like cochlea.

視覚障害者の障害物知覚
Obstacle sensation of the visually impaired

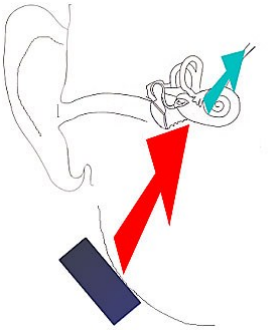
- アクティブセンシング／Active Sensiong
  反響音の知覚による定位（エコロケーション）／
  Perceive location by sound “echo” (echolocation)

- パッシブセンシング／Passive Sensing
  周囲雑音の強さ、音色の変化により定位
  簡単には「音響的影」／
  Perceive obstacle by noise reduction (acoustic shadow) and change of tone color

音響的影の提示による障害物検知
Obstacle avoidance by presenting acoustic shadow

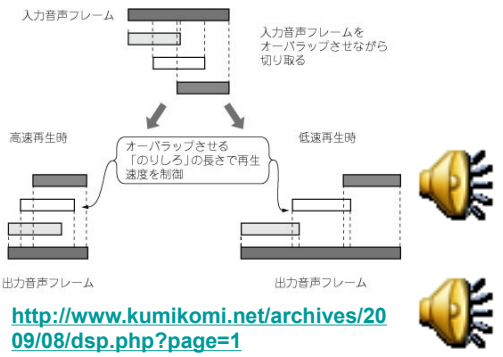
松尾, 岡野, 橋本, 梶本：音響的影の提示による気配感覚の増強，日本バーチャルリアリティ学会 第12回大会論文集(2007年9月福岡)，2007.

高齢者のサポート 1：補聴器と骨伝導
Supporting elderly: hearing aid and bone conduction



- 骨を振動させて音を伝える／
  Inner ear is directly vibrated by bone conduction
- 特に外耳，中耳に問題がある難聴で威力を発揮／
  Effective if problems are in external ear or middle ear.

高齢者のサポート 2：速度の低減
Supporting elderly: speed reduction



http://www.kumikomi.net/archives/2009/08/dsp.php?page=1

携帯型話速変換機
http://www.human.rcast.u-tokyo.ac.jp/?p=2&pp=0&l=1&r=1114

●音声信号を遅らせる（ただし信号のピッチは変えない）
Ordinary, speed reduction changes pitch. By signal processing, speed reduction while preserving pitch is possible.

●携帯電話の場合はリアルタイム処理
For mobile phone, the signal processing is done real-time.

小テスト／Mini Test 次回開始まで

以下の全てに100字以内程度で解答せよ／Answer all questions within 50 words

1. 耳介の役割について説明せよ Explain role of auricle
2. 外耳道の役割について説明せよExplain role of external auditory meatus
3. ティンパノメトリーについて説明せよExplain Tympanometry
4. 耳小骨筋反射について説明せよ Explain Stapedial Reflex
5. 内耳基底膜の働きについて説明せよ Explain role of basilar membrane.
6. 内耳有毛細胞の働きについて説明せよ Explain role of hair cells on the basilar membrane.
7. 耳音響放射について説明せよ Explain otoacoustic emission
8. フォルマントについて説明せよ Explain formant
9. ミッシングファンダメンタル現象について説明せよ Explain missing fundamental phenomenon
10. 無限音階について説明せよ Explain shepard tone
11. 低周波音の音源定位の方法について説明せよ Explain localization by low frequency sound.
12. 高周波音の音源定位の方法について説明せよ Explain localization by high frequency sound.
13. 上下方向の音源定位について説明せよ Explain localization of vertical sound position.
14. 頭部伝達関数について説明せよ Explain head related transfer function
15. パラメトリックスピーカについて説明せよ Explain parametric speaker
16. マガーク効果について説明せよ Explain McGurk effect
17. 人工内耳について説明せよ Explain artificial inner ear.
18. エコーロケーションについて説明せよ Explain echolocation