Bionic Ears

Introduction into State-of-the-Art Hearing Aid Technology

28c3
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Abstract

In many social situations being hearing impaired is a serious handicap, not only for elderly people. Today's hearing aids are tiny computers that do a decent job in signal processing. During the last years, the progress in this technology was significant, amongst other things by switching from analog to digital devices. Since this field becomes more and more related to computer technology, there is even more improvement to be expected. In particular, it turns into a more and more interesting playground for hackers.

Unfortunately, we are still quite far away from what was promised as the future in that 70es TV series "The Bionic Woman" [1]. Starting with a brief introduction about audiology, I will present current technical solutions (and political non-solutions) for hearing aids. Besides the hearing aids themselves, there exist a couple of interesting peripheral solutions for specific situations such as using the phone, listening to concerts and talks, or just consuming music with an mp3 player. All these not only enhance the user's life, they also open the door for creative hacks. Although the hearing-aid hacking community is still rather small, I will present some current projects and ideas for future ones.

[1] http://en.wikipedia.org/wiki/The_Bionic_Woman

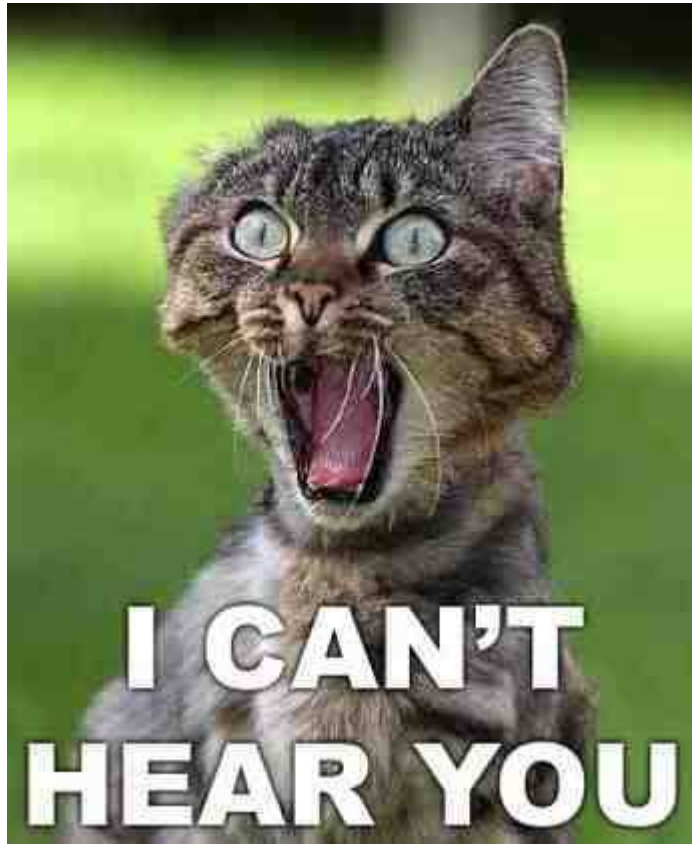
Documentation of this Talk

- slides soon available on http://hackandhear.com
- detailed speaker notes
- recording (hopefully) available
- (maybe) subtitles

Me

- software engineer
- based in Munich
- software geek, not a hardware hacker
- signal processing / datamining background
- medical engineering background
- don't work for hearing aid company
- hearing-impaired for 3.5 years

Disclaimer:
This is a personal pet project.
I am here on my own terms and not on behalf of my employer.



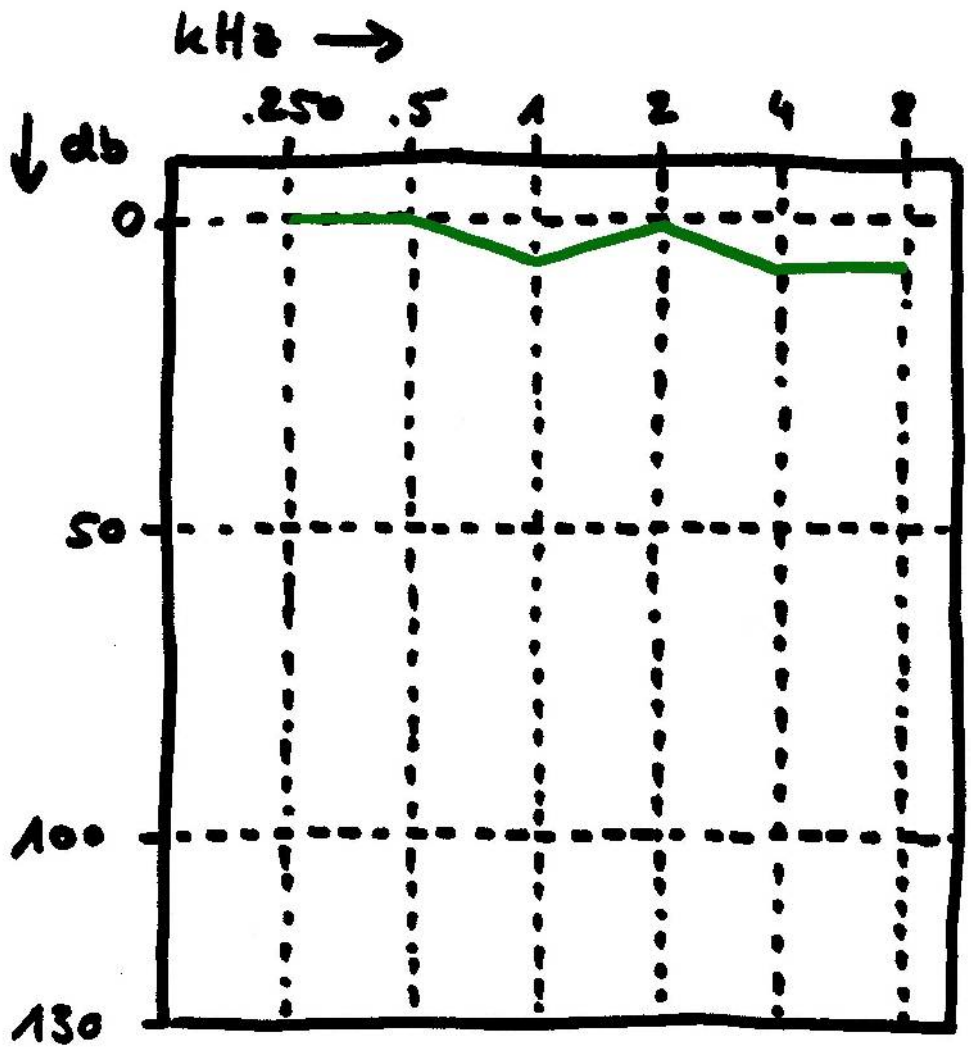
What's this about?

hack and hear

- Audiology
- Getting hearing aids
- Hearing aid models and features
- Peripheral hardware
- Hacking
- Self-tuning
- Conclusions

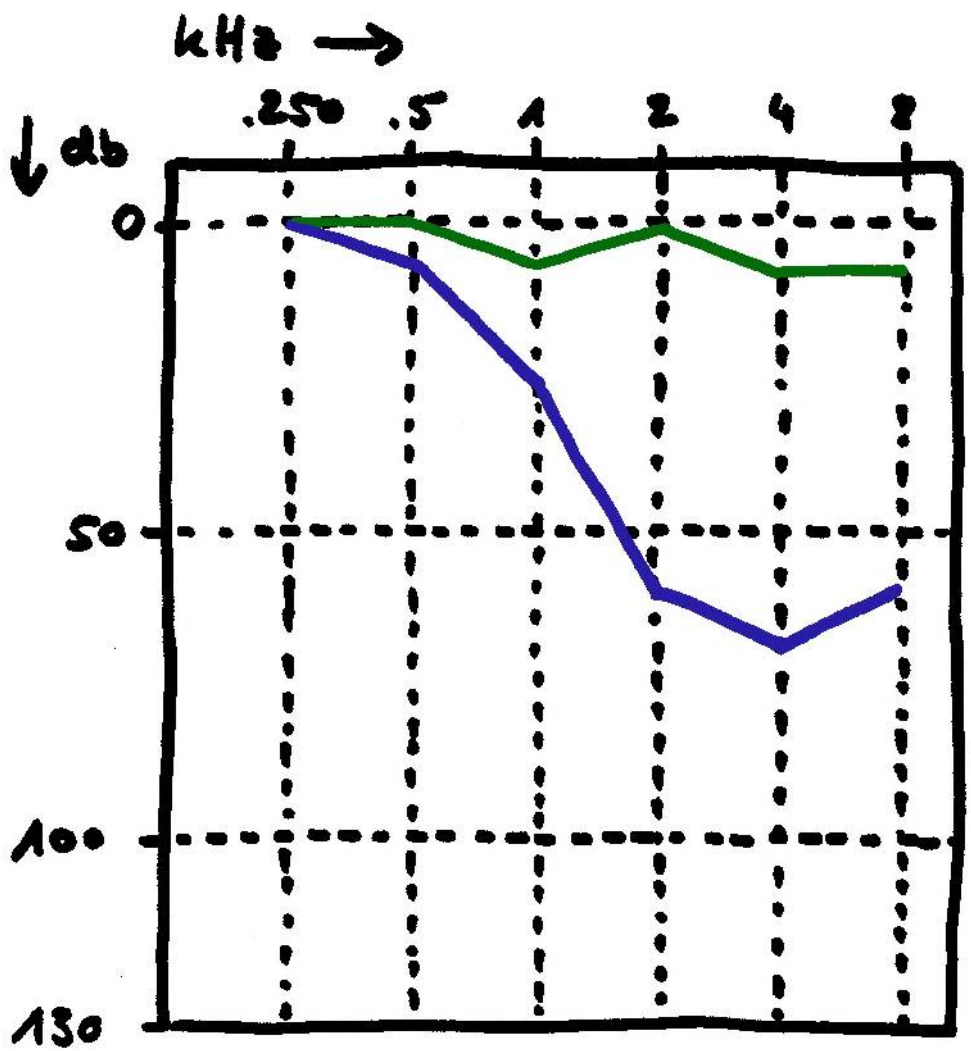
Audiology

Audiogram



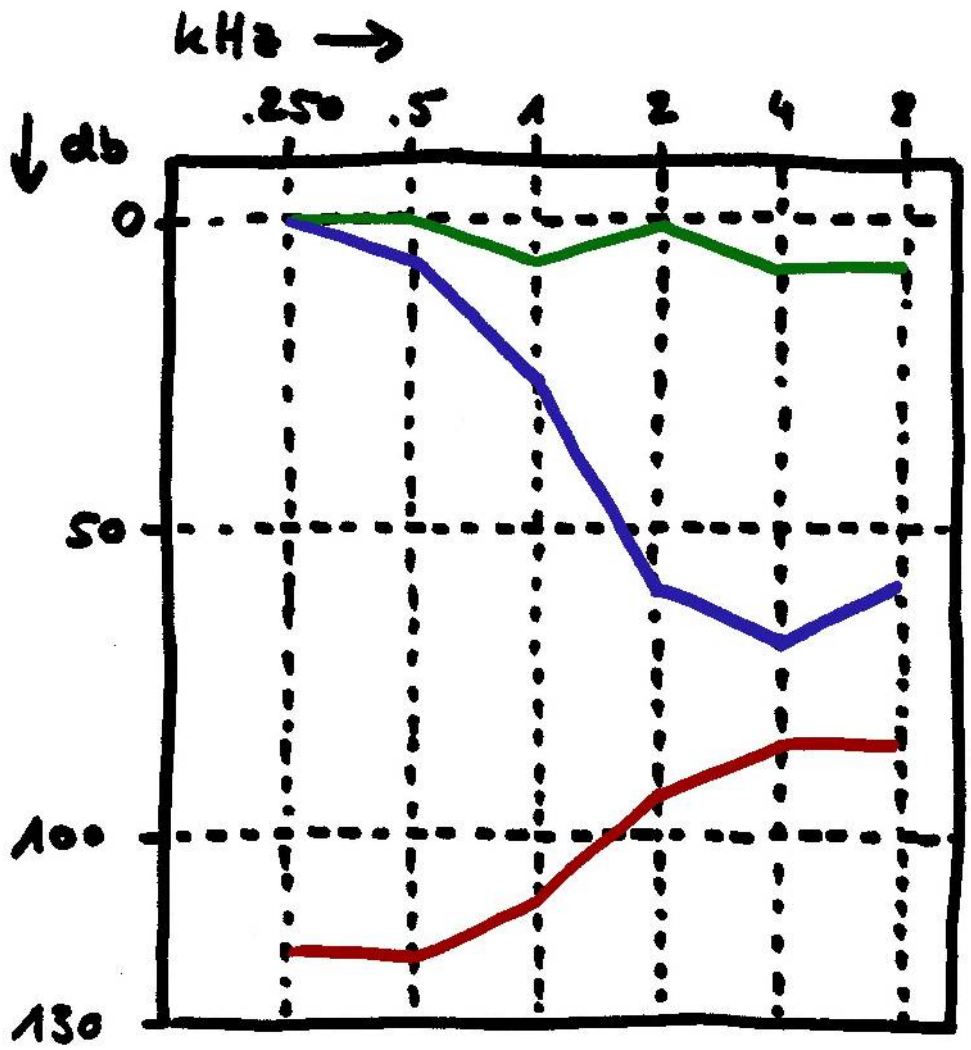
- x-axis: frequency in kHz
- y-axis: volume of signal in db
- healthy person

Audiogram



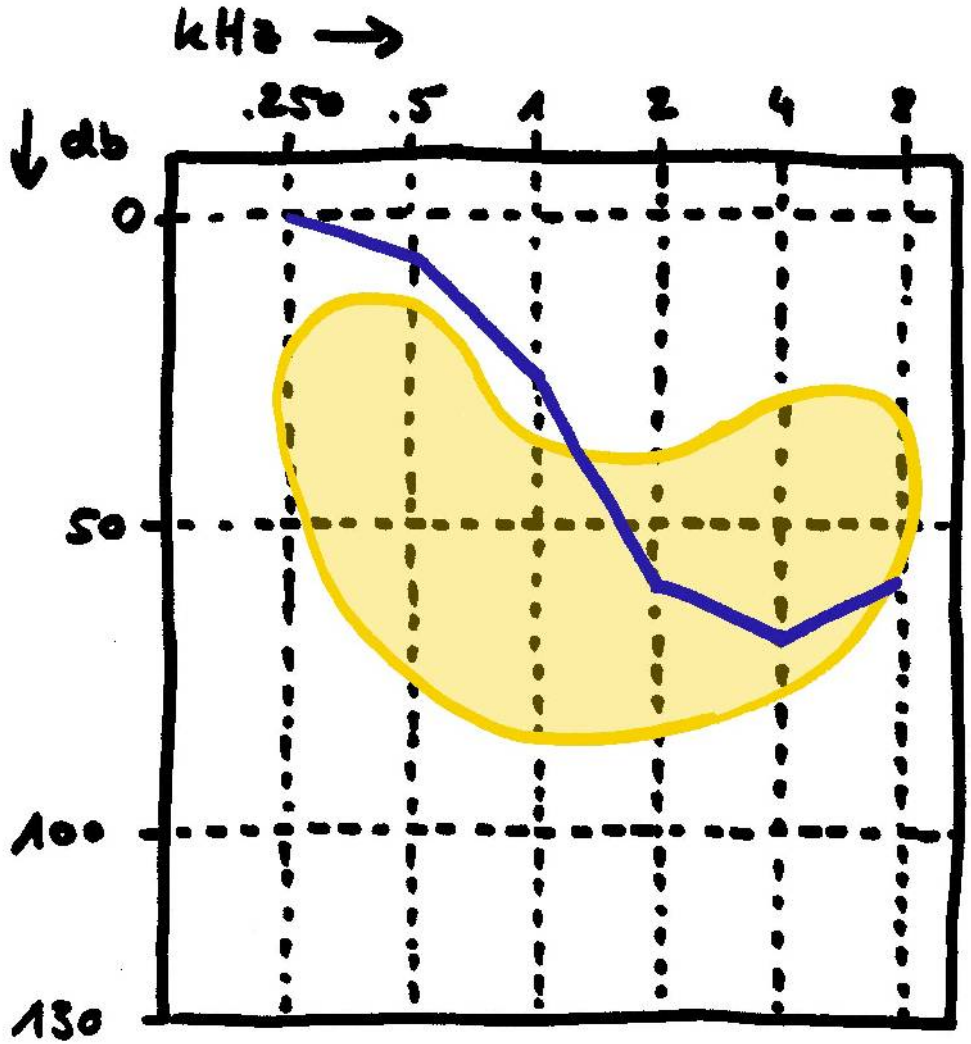
- green: healthy person
- blue: typical hearing impaired

Audiogram



- green: healthy person
- blue: typical hearing impaired
- red: level of discomfort for hearing impaired

Audiogram



- blue: typical hearing impaired
- yellow: area where speech happens
- hearing aids focus on compensating loss in speech banana

Source: http://en.wikipedia.org/wiki/Speech_banana

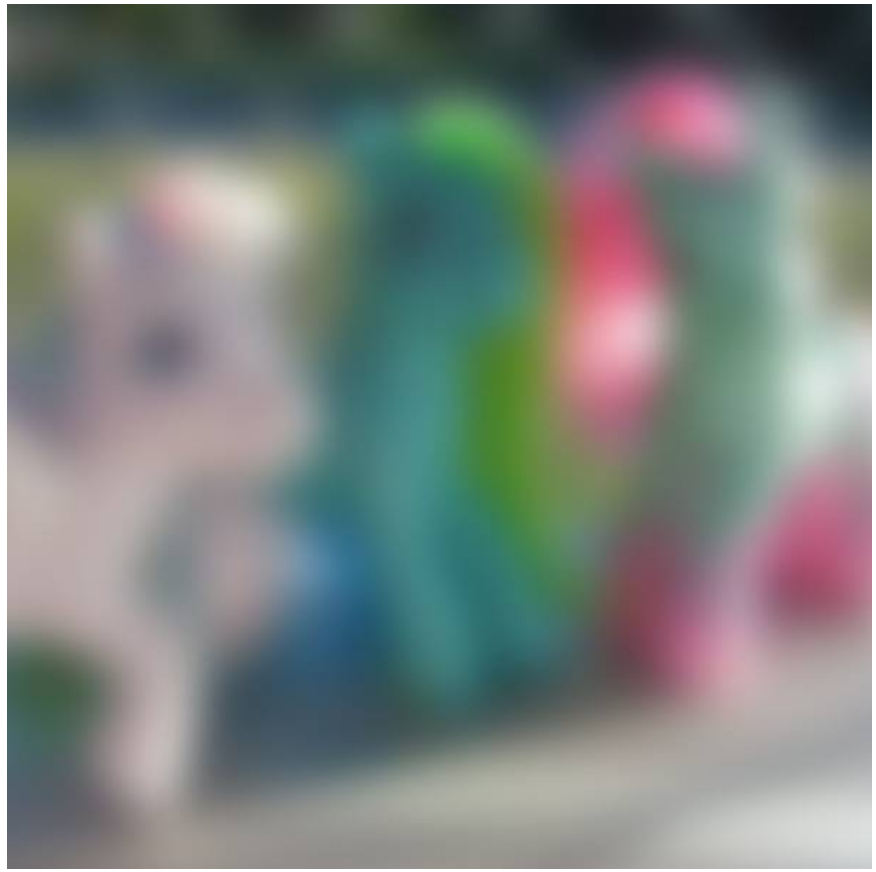
How I Hear (Example)

- Song “Sad Robot” by Pornophonique

Source of “Sad Robot”: http://www.pornophonique.de
Source of tinnitus sounds: http://www.ata.org/sounds-of-tinnitus

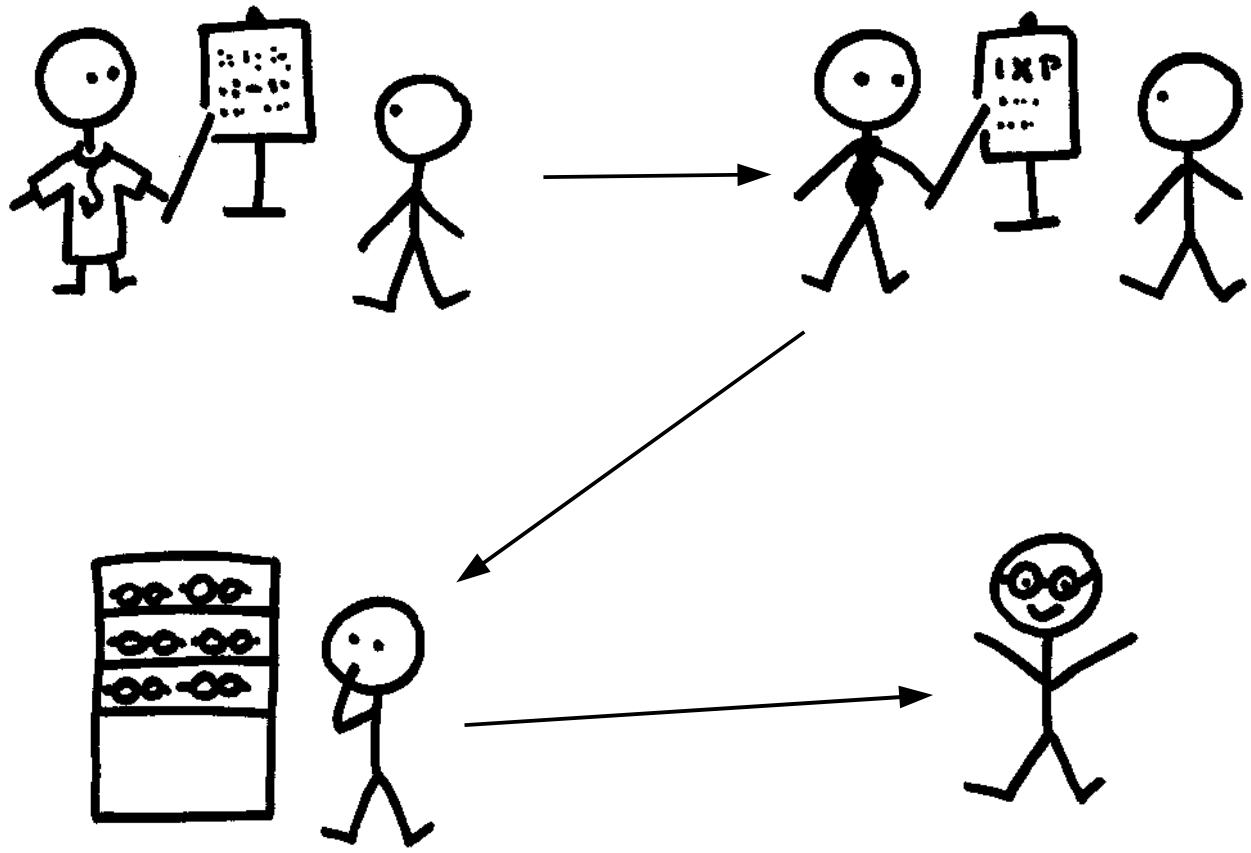
Getting Hearing Aids

Need Glasses?



Source of image: http://www.flickr.com/photos/dreamcicle/3630841638/sizes/l/in/photostream/

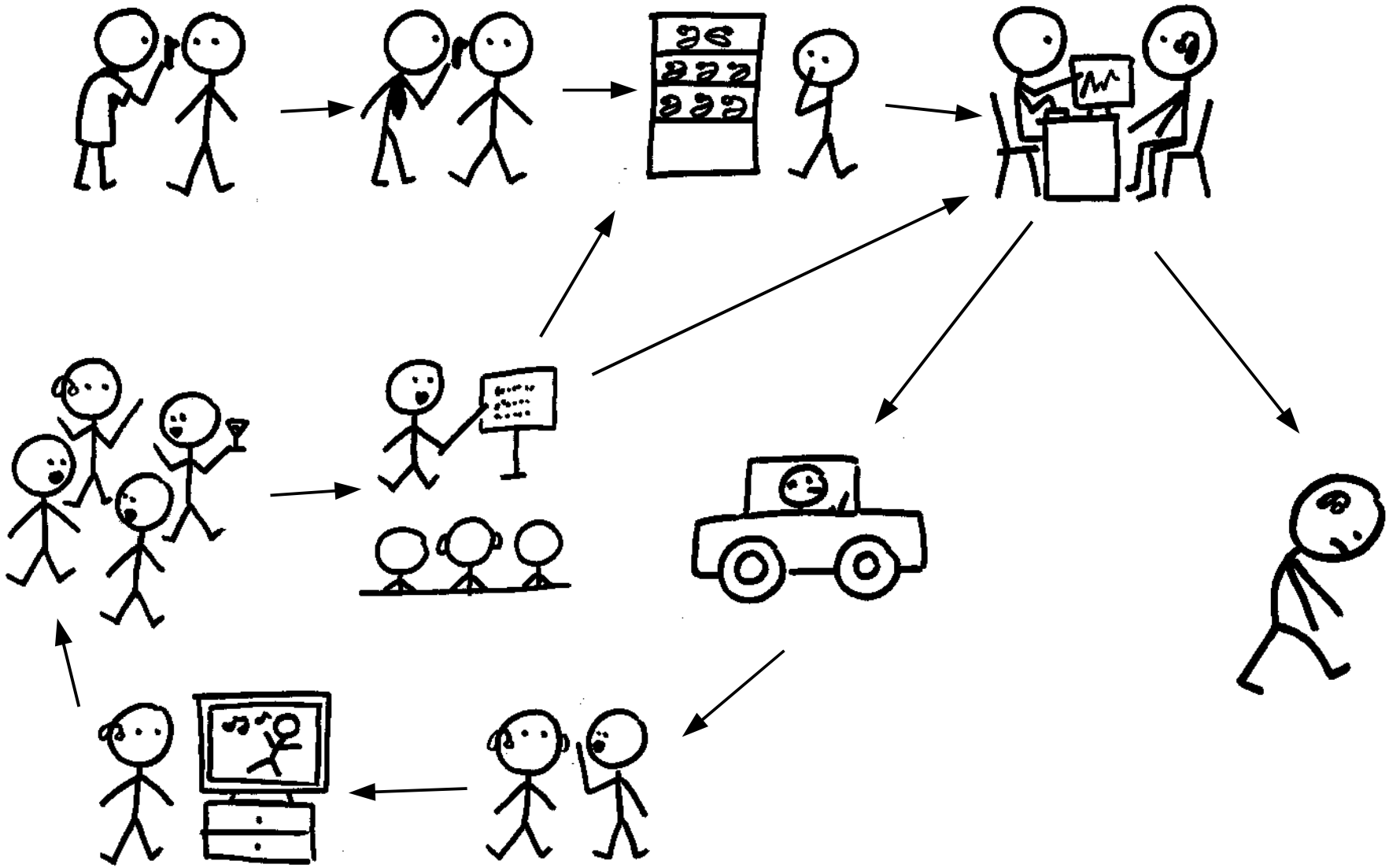
Getting Glasses



Ponies!

Source of image: http://www.flickr.com/photos/dreamcicle/3630841638/sizes/l/in/photostream/

Getting Hearing Aids



Hearing Aid Models and Features

Models of Hearing Aids

In-Ear

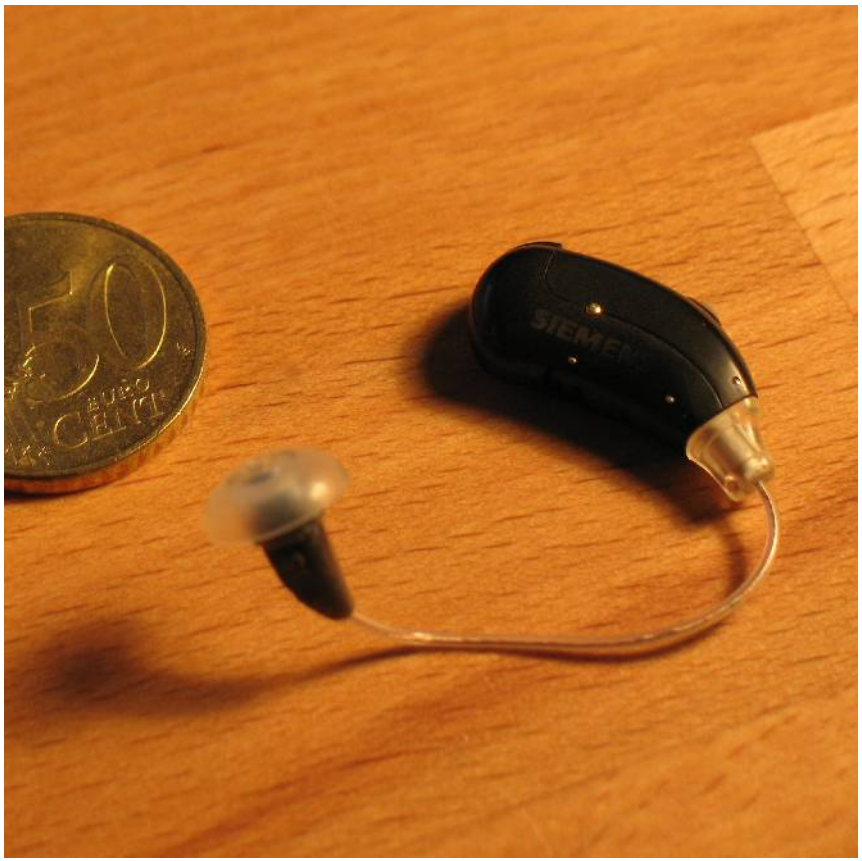
Behind-Ear

Cochlear Implant

Source of images:
http://www.flickr.com/photos/portland_mike/2993507037/
http://www.flickr.com/photos/umhealthsystem/5494712579/sizes/o/in/photostream/
http://www.flickr.com/photos/oaspetele_de_piatra/4581664897/sizes/o/in/photostream/

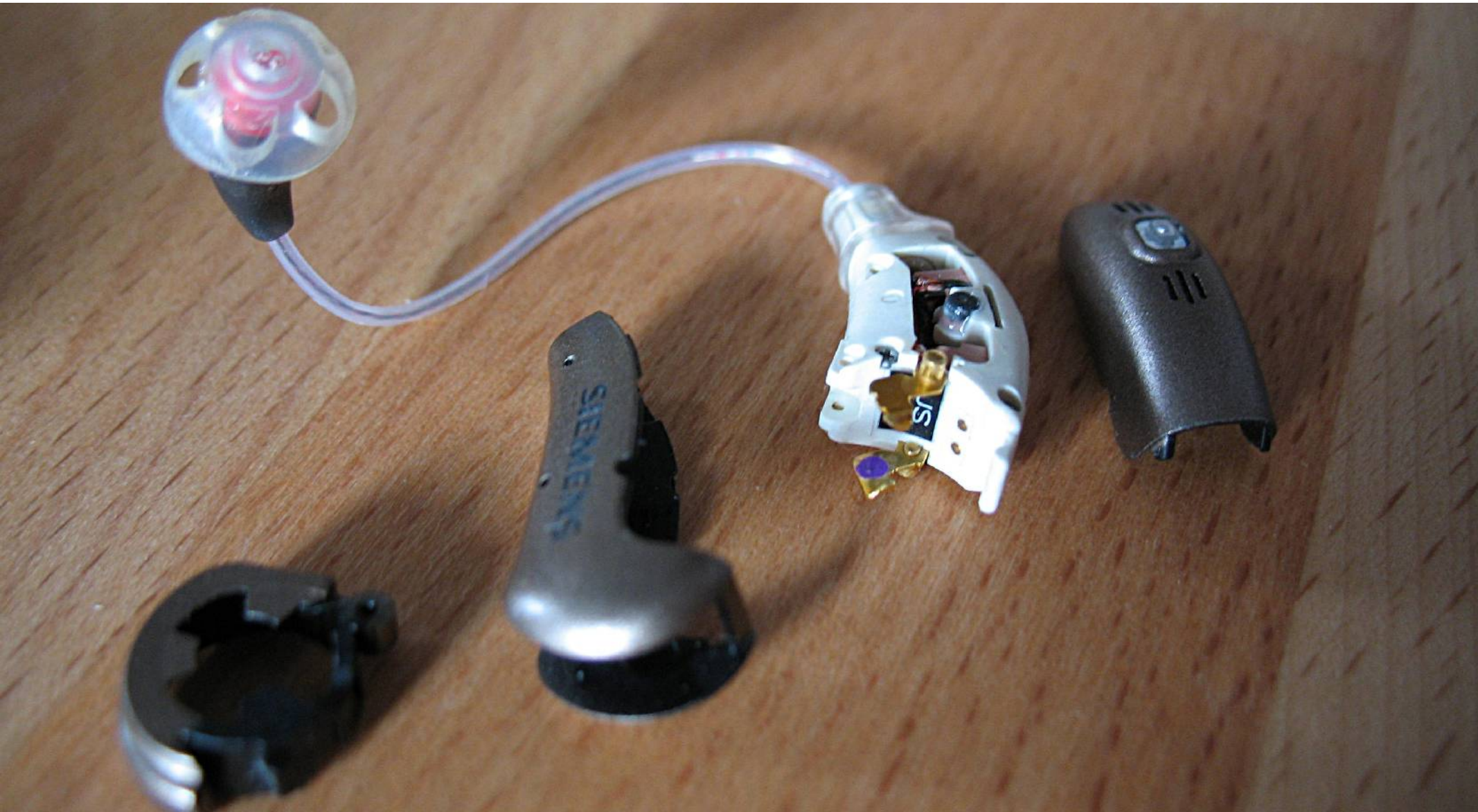
Visibility of Hearing Aids

Size of Hearing Aids



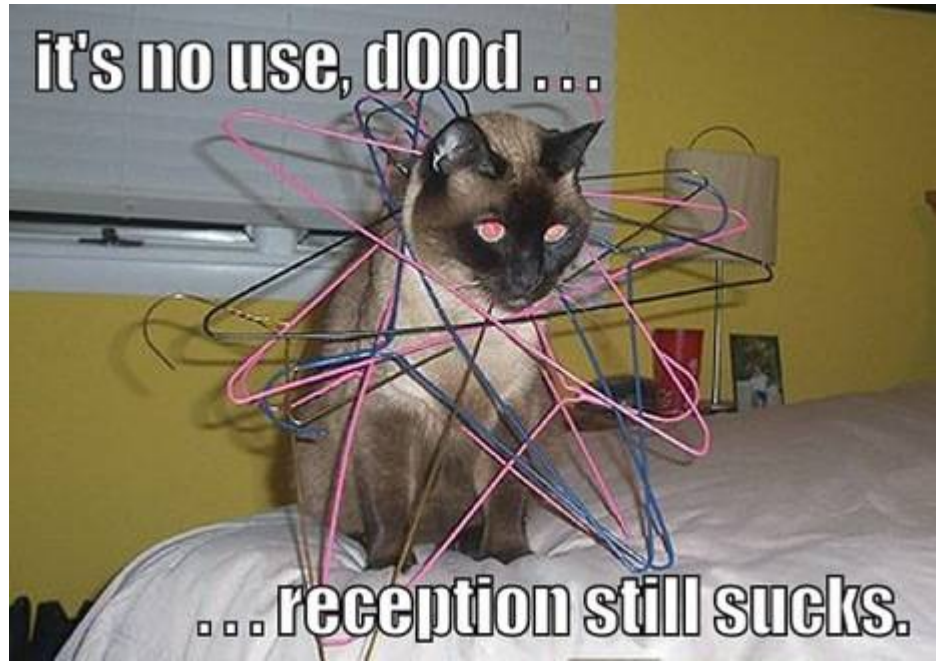
Hearing Aids

hack and hear

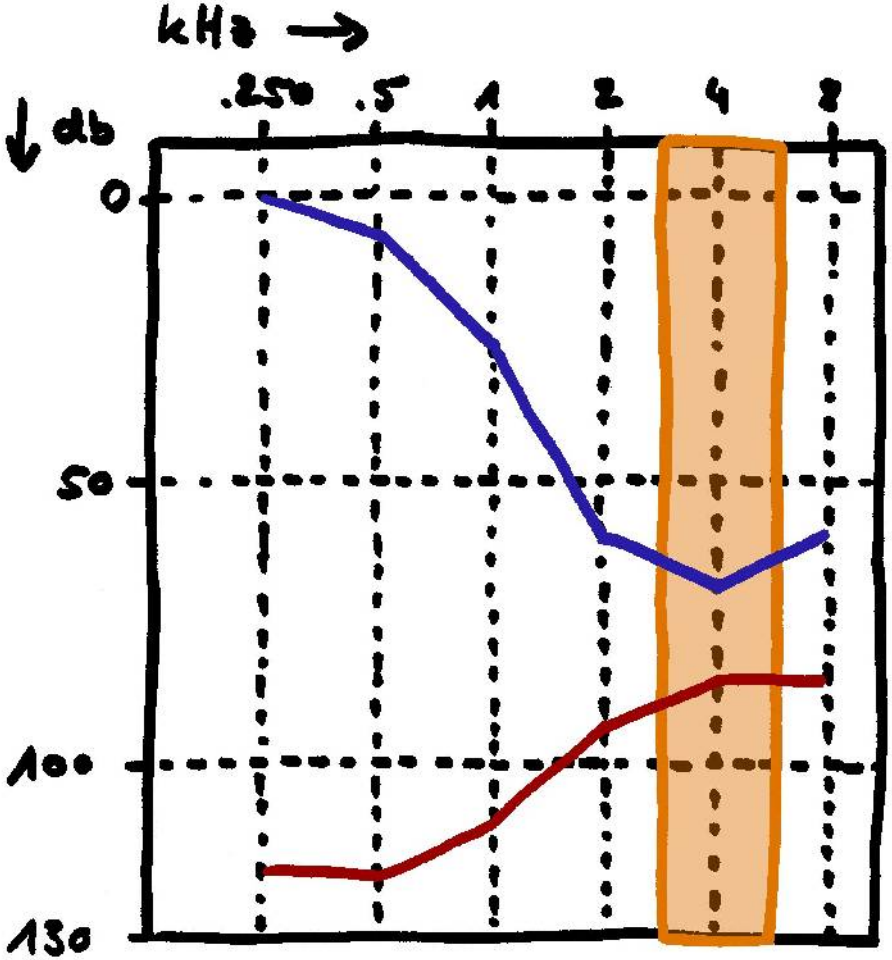


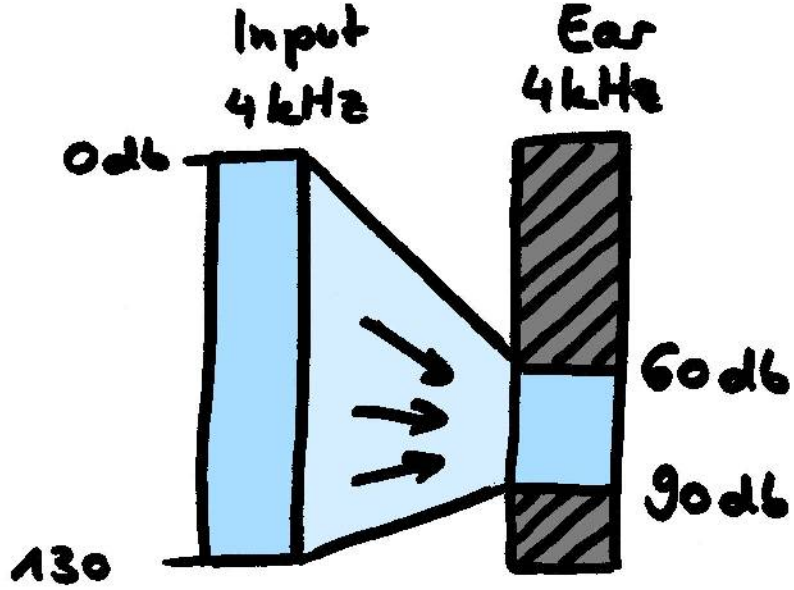
Digital Hearing Aids

- Standard in first world countries
- Make a lot more features possible
- Real time sound processing
  - analyze signal and react to it instantly

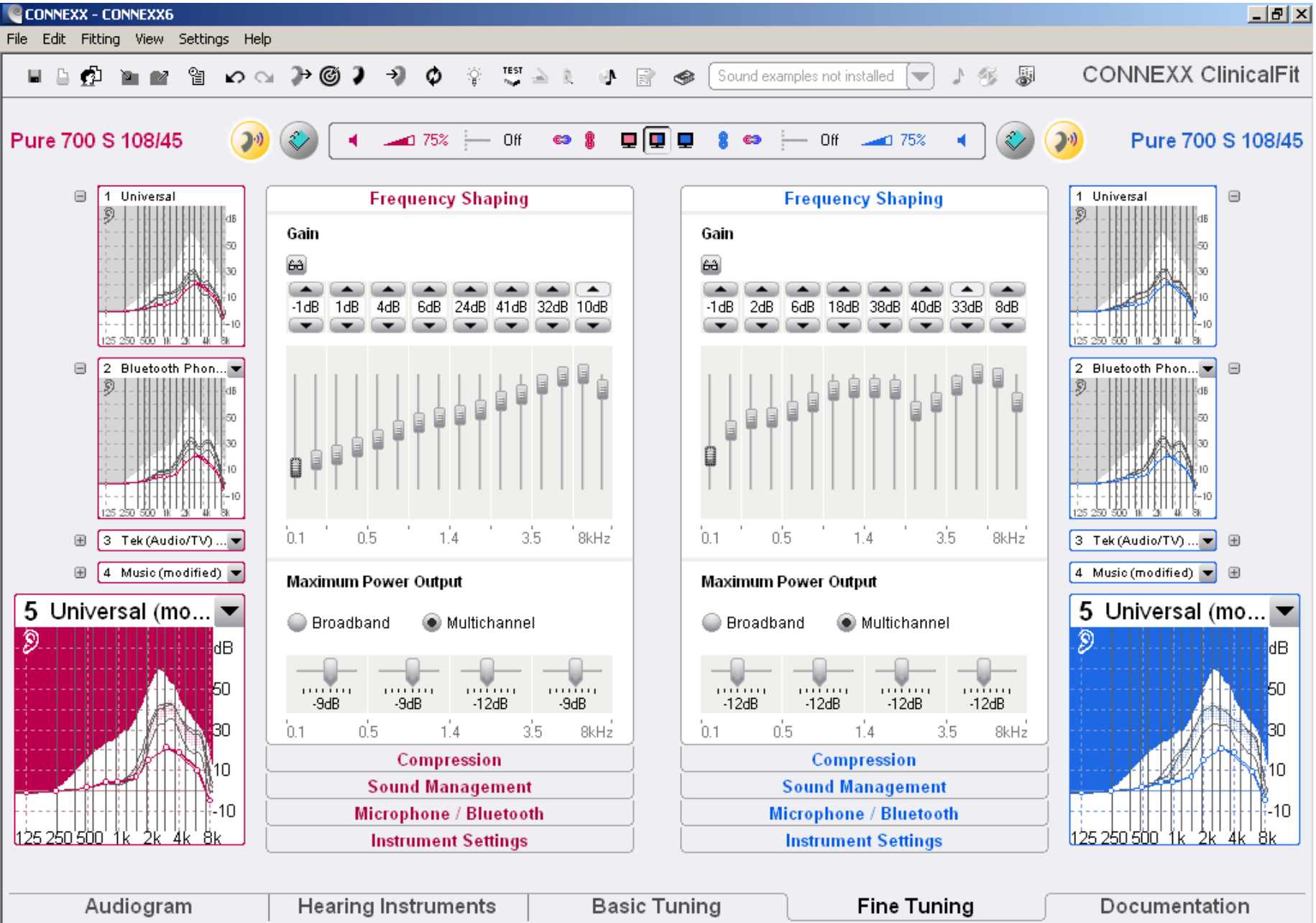


Compression





Frequency Shaping



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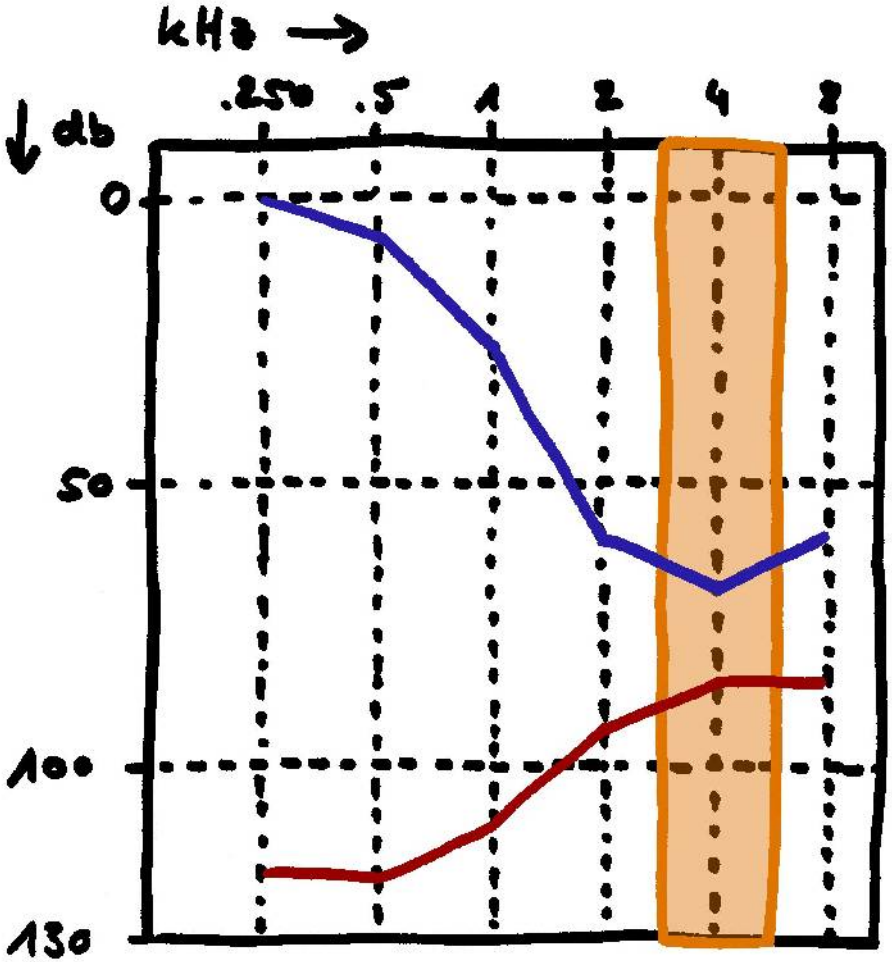
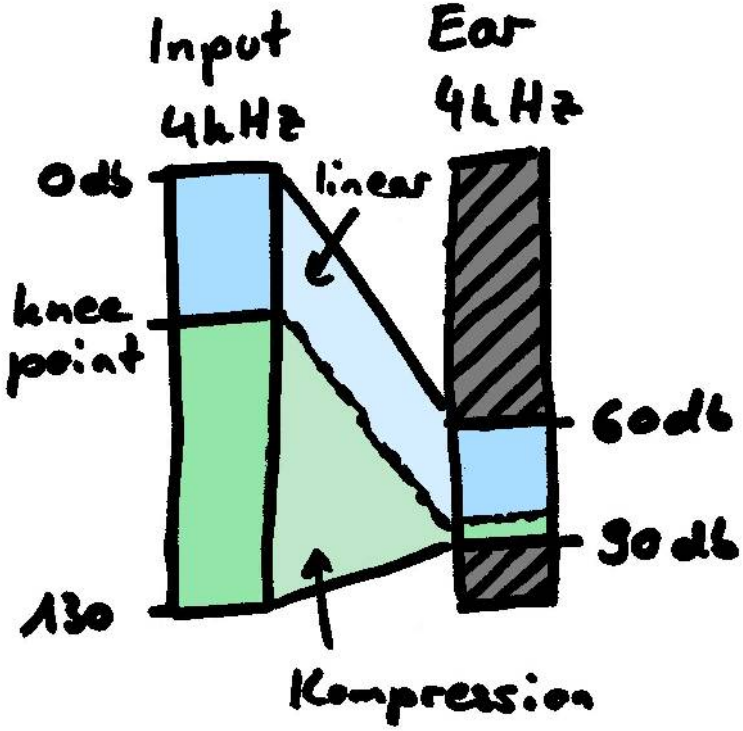
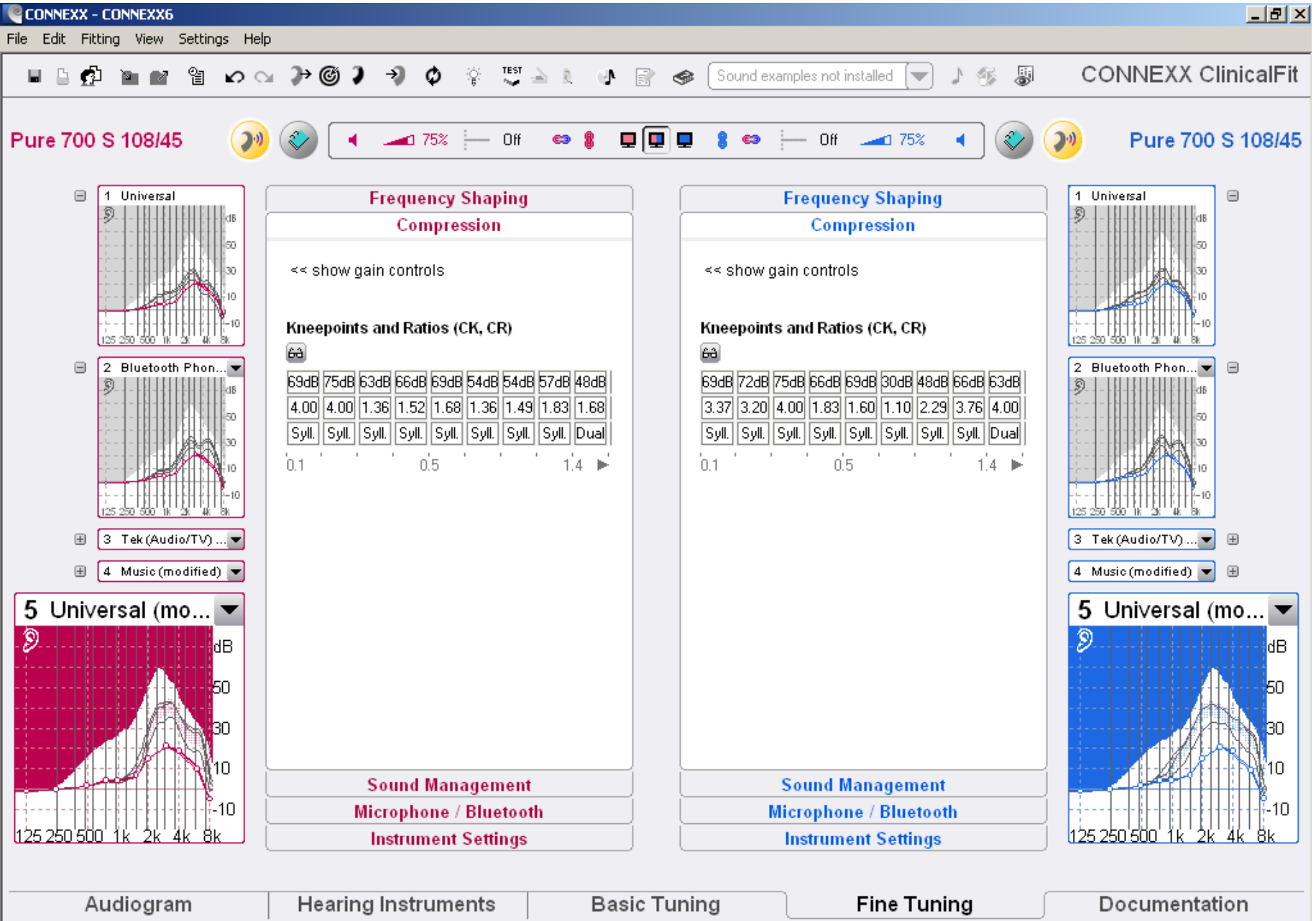


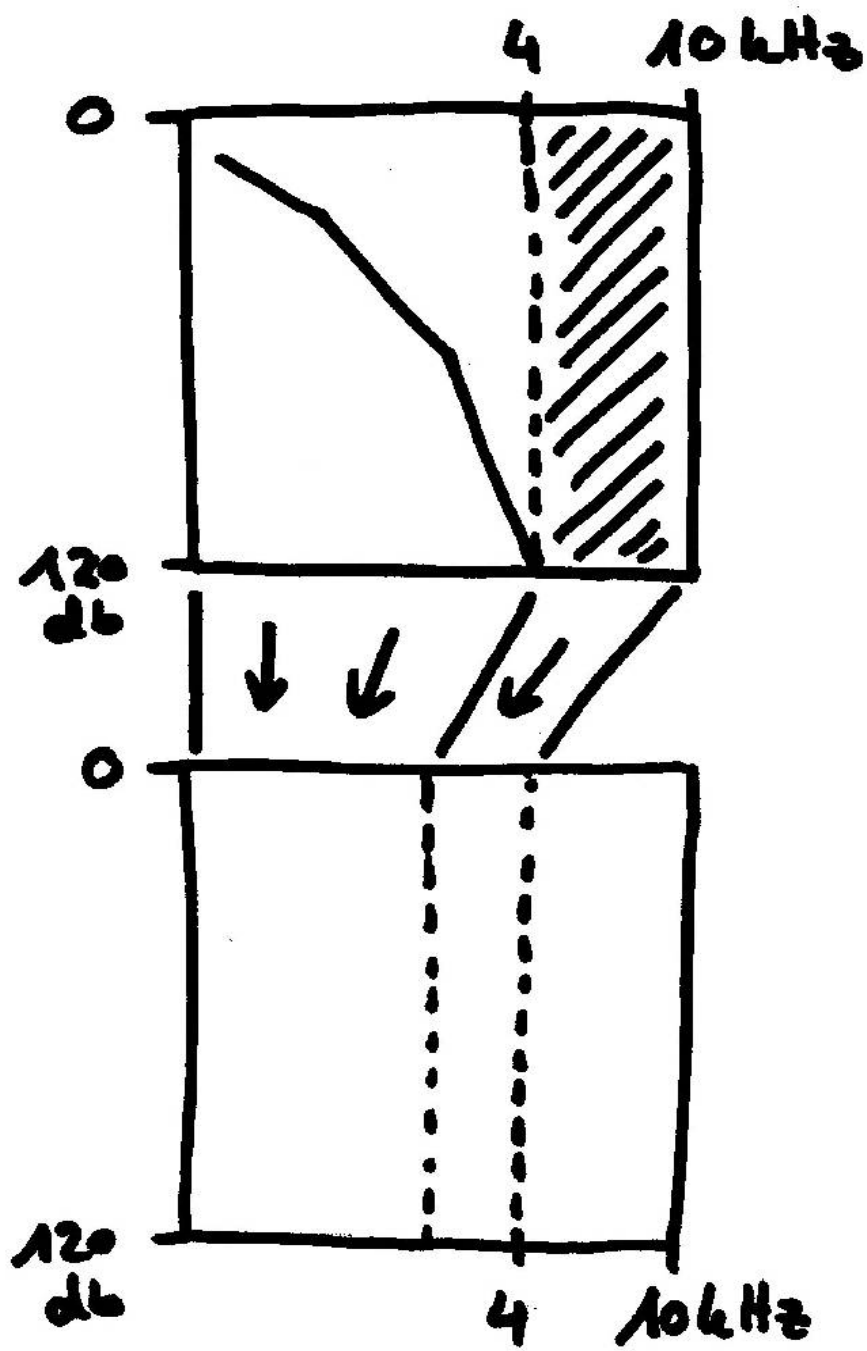


Compression



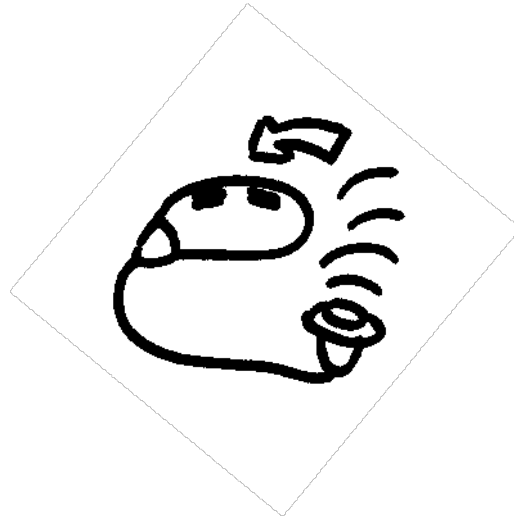
Frequency Compression

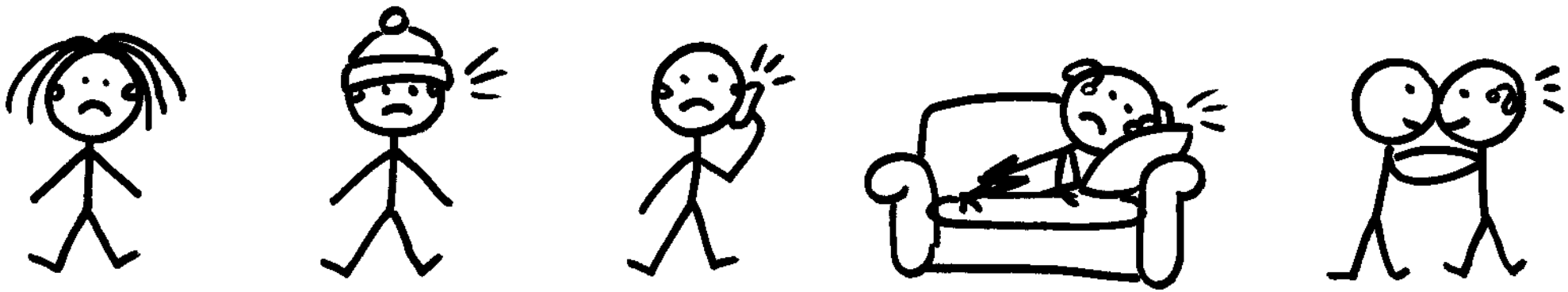
- what if complete loss on one band?
- compress the frequency space
- works only with closed hearing aids
- only one brand (phonak)



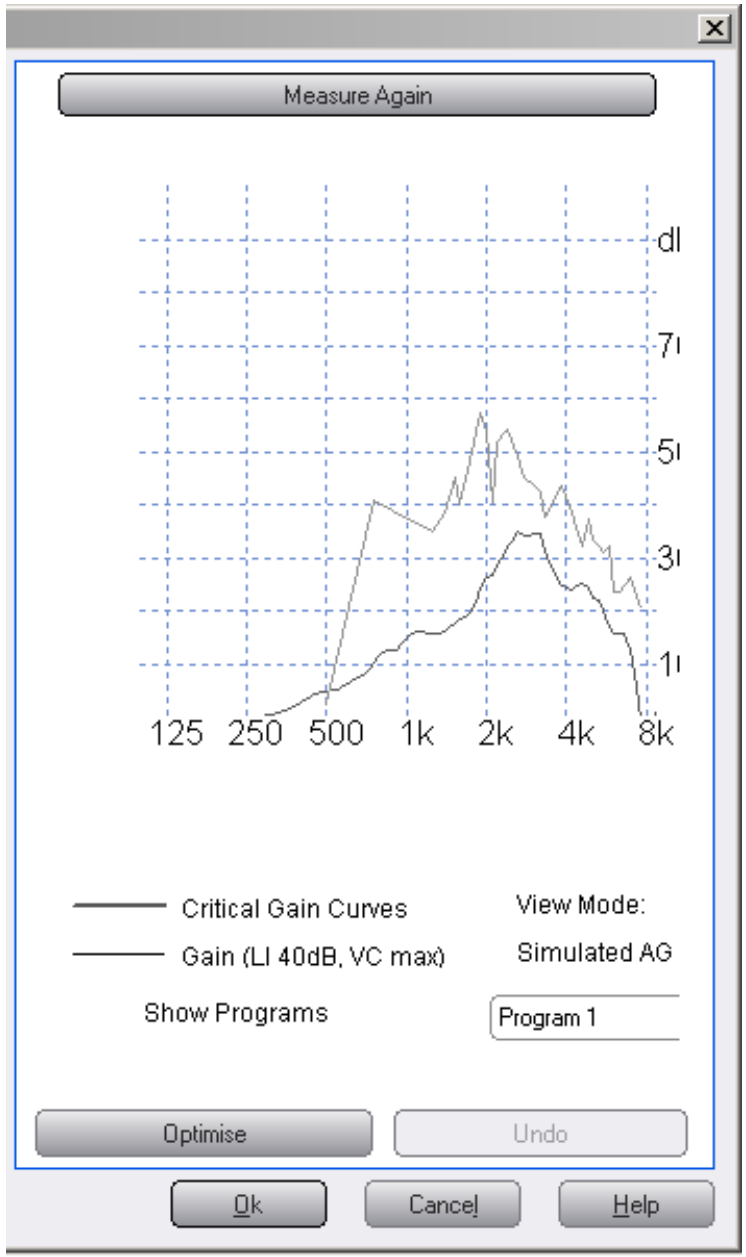
Problem: Feedback Loops

- Hearing aid amplifies its own signal
- Whenever something gets close to the hearing aids
- Especially for open hearing aids



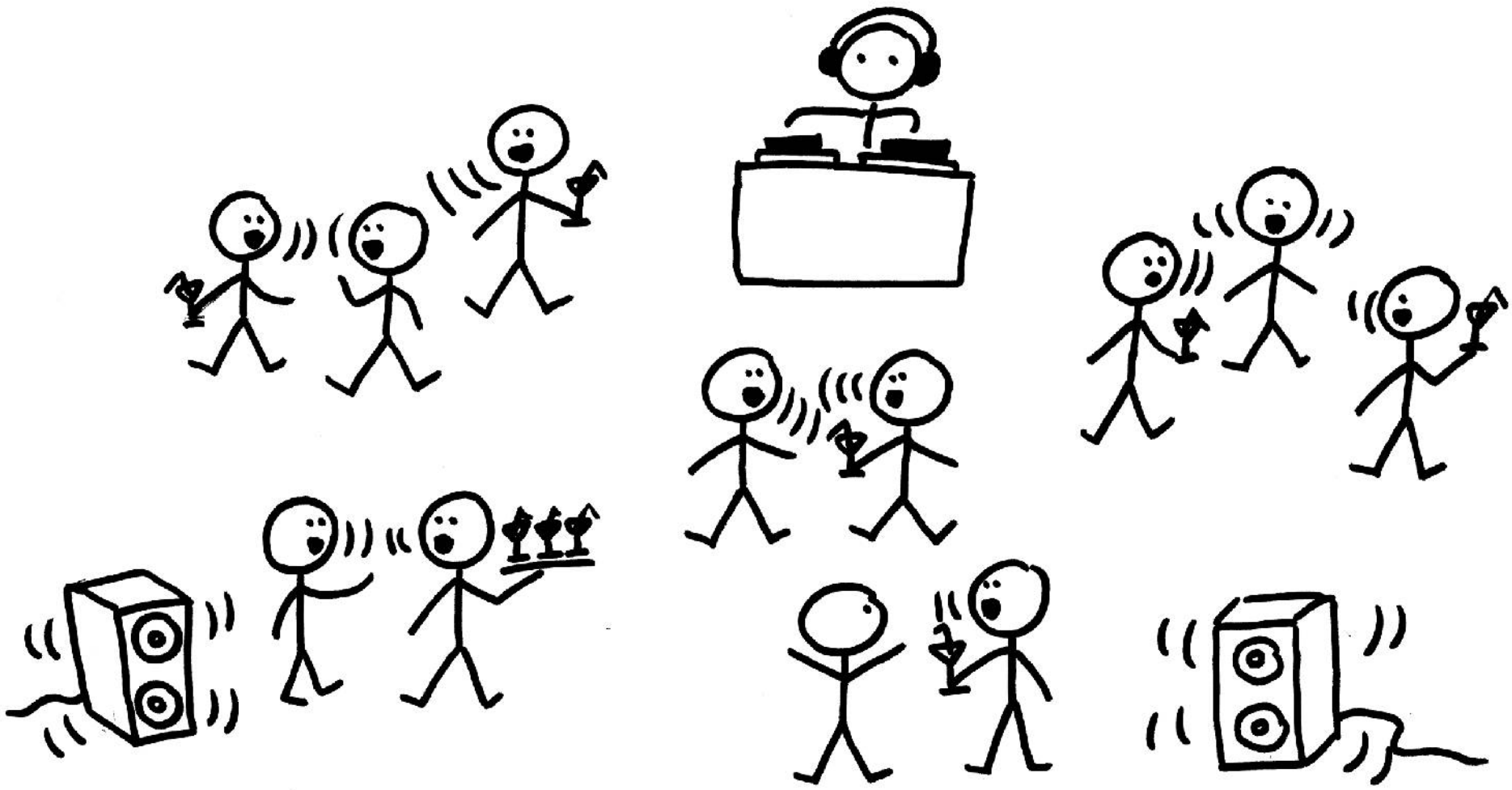


“Solution” for Feedback Loops



- Detect “clear” sinus signals
- Send an unhearable flag
- Damp affected frequencies
- Adapt in real time
- Problems:
  - music contains clear sinus signals
  - damped frequencies are needed for speech recognition
- Analog hearing aids did not have a measure against it

Cocktail Party Problem



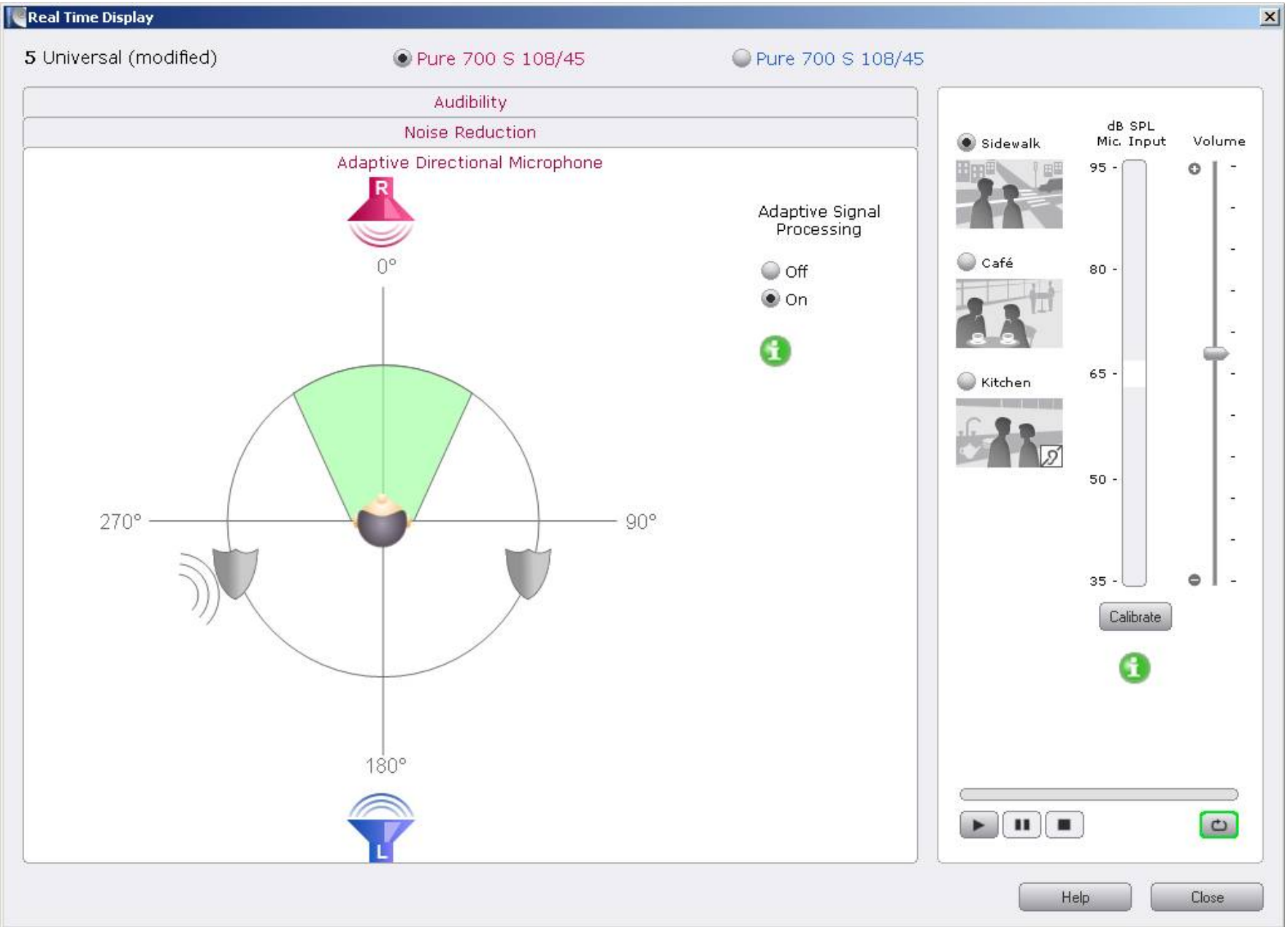
Directional Hearing

- **Human ear:**
- Use two ears + brain
- Uses the pinna

- **Hearing aids:**
- 2 microphones per ear
- inter-hearing-aid communication
- situation recognition / different programs
- automatic focus
- use the pinna
  (in-ear hearing aids only)

Source: http://en.wikipedia.org/wiki/Pinna_(anatomy)#Pinna_notch

Directional Hearing



Fore- and Background

- Low frequencies travel further than high ones
- Brain uses this to extract foreground signal and source location
- HAs amplify high frequencies
- HAs filter background signal

Realtime Monitor

Humidity

- Most hearing aids are not waterproof
- No swimming with friends
- No pool parties
- No (social) water sports
- No sweating
- No audiobooks in the bathtub
- No heavy rain
- Drying material necessary

- very recent development: water and dust resistancy
- example: Phonak HAs claim certification of IP67
- no damage due to dust
- 30 min, 1 meter under water: no irreparable damage

M H2O

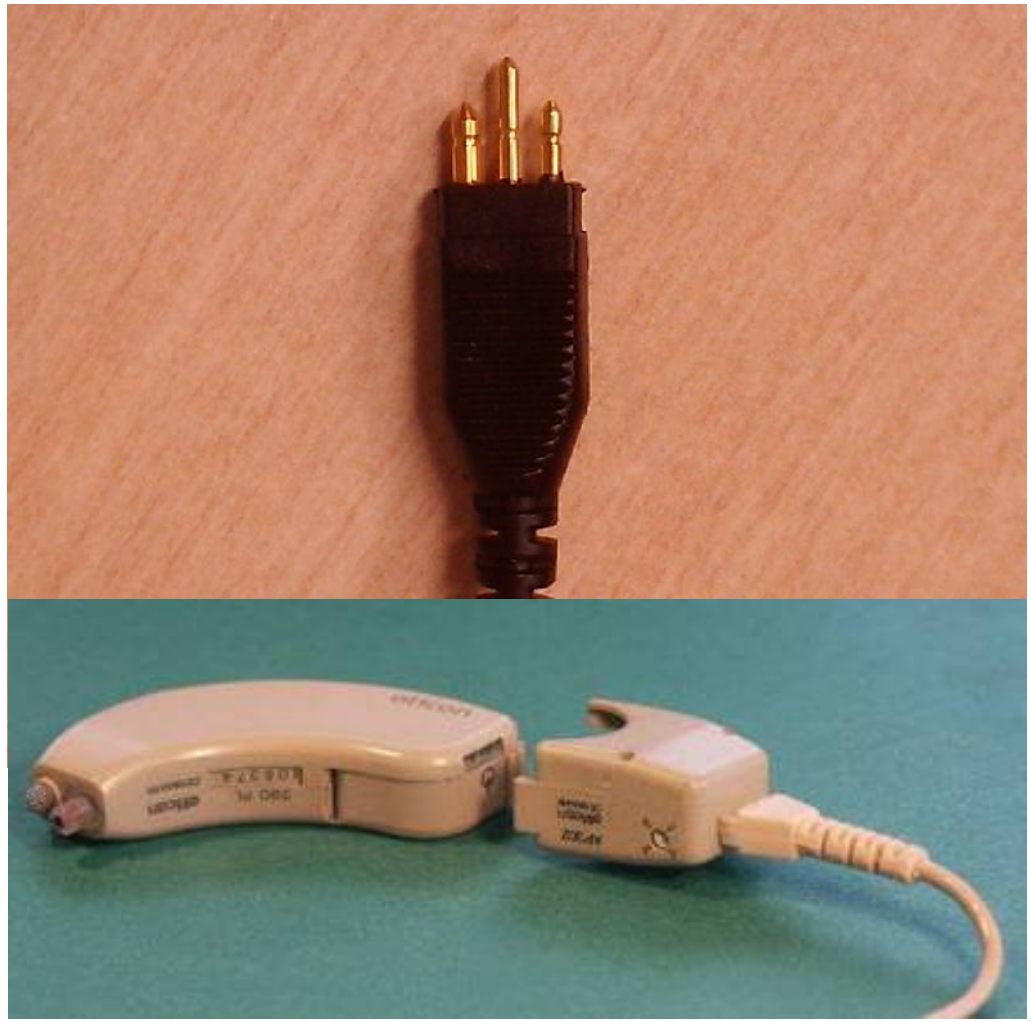
Naída S CRT

Nios S H2O

Peripheral Hardware

DAI interface

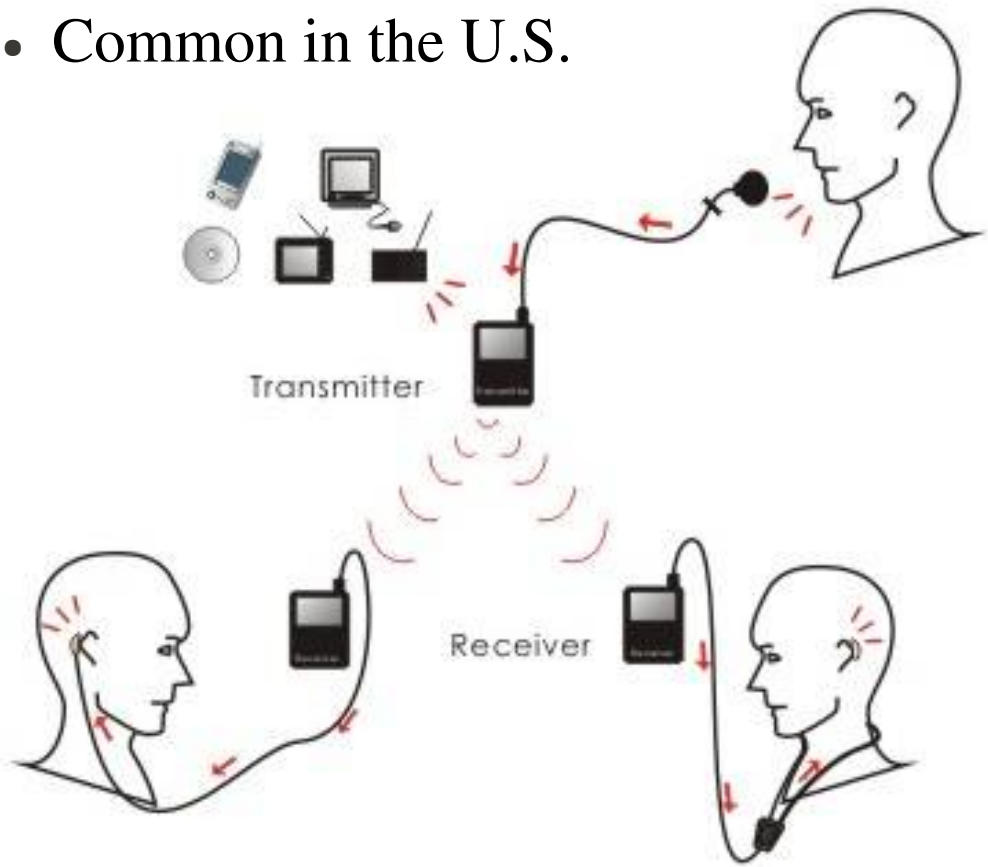
- “direct audio input”
- also called “Euro Adapter”
- cables for all kinds of devices
- Pro:
  - no interference with wireless devices
  - variety of cables available
  - used for FM / Bluetooth adapters
- Con:
  - it's a cable
  - too big for really small hearing aids



Source: http://www.audiologyonline.com/management/uploads/articles/HABootCable.jpg

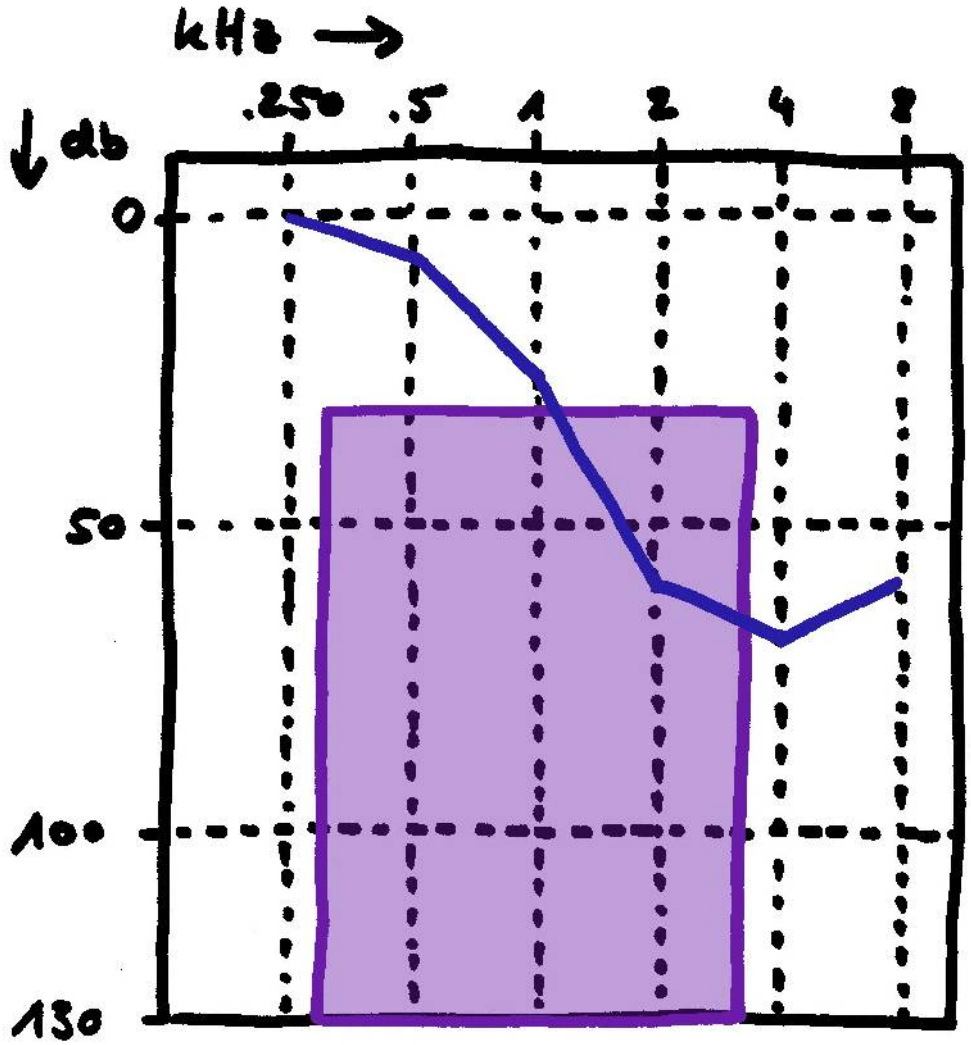
FM systems

- FM receiver in hearing aids
- FM transmitter connected to source
- Common in the U.S.



- Pro:
  - lots of hardware available
  - different setups
  - (some) standards
- Cons:
  - Interference
  - sound quality
  - incompatibility between systems

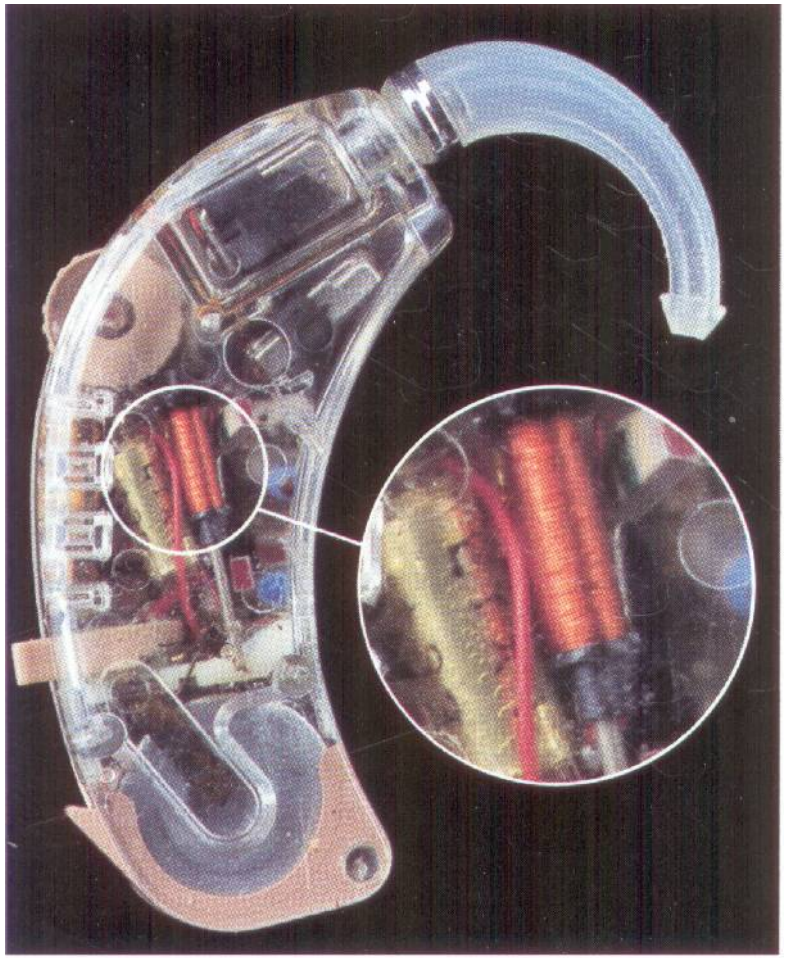
Calling on the Phone



- lip reading
- frequency range of phone signal: 300Hz - 3400Hz
- background noise: full range
- signal is altered and unnatural
- missing base
- bad reception
- hearing only in one ear
- feedback loops

Source: http://de.wikipedia.org/wiki/Telefonnetz

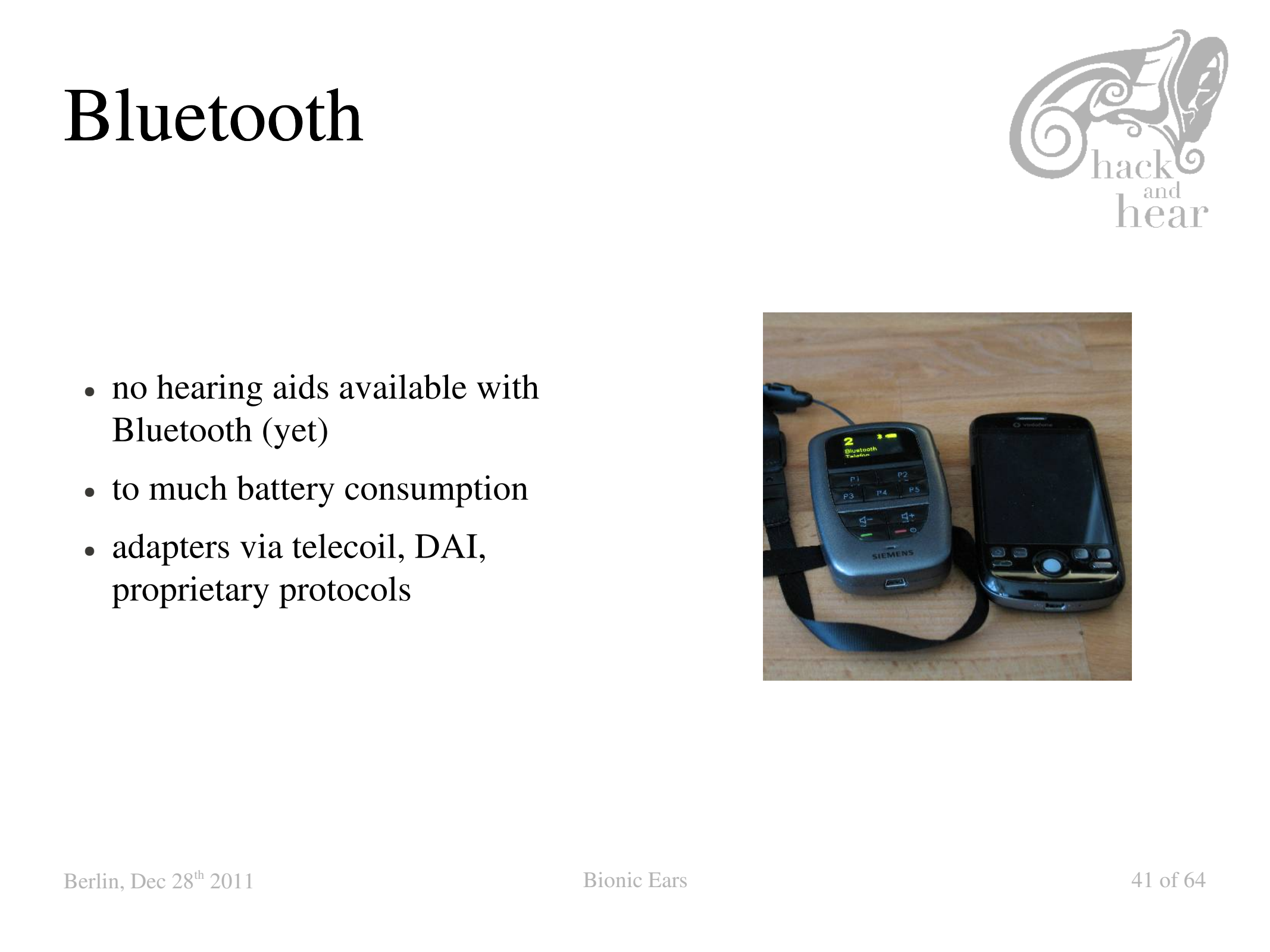
Telecoil and Audio Induction Loop



- telecoil / T-coil in hearing aids
- audio induction loops connected to source
- phone, room installation, cars, adapters
- technology rather old
- widely used in Europe
- cons: interference, sound level differences when moving head, high initial costs
- pros: microphones are automatically switched off, standard in even for new phones, some hearing aids use both ears, DYI kits available

Source: http://en.wikipedia.org/wiki/Audio_induction_loop

Bluetooth



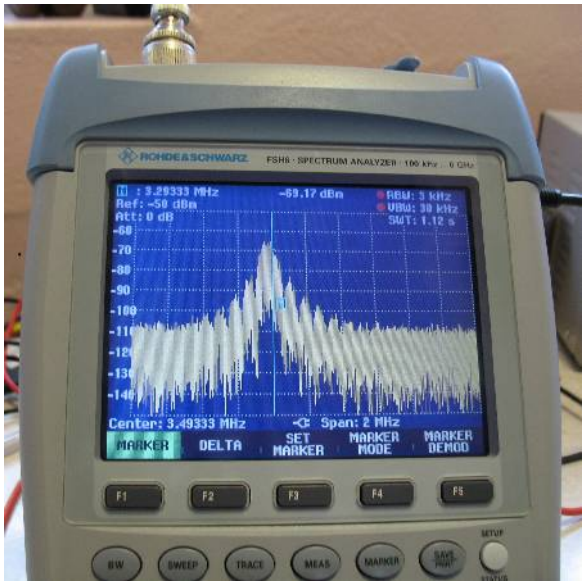
- no hearing aids available with Bluetooth (yet)
- to much battery consumption
- adapters via telecoil, DAI, proprietary protocols

Phonak ICOM

- example of a wireless adapter
- uses telecoil to talk to hearing aids
- interfaces: DAI, aux-in and bluetooth
- FM systems via DAI
- warning regarding pace makers

Source: http://www.remorina.com/clients/eBay/images/icom/iCom_02.jpg

Siemens Tek



- adapter + remote control
- proprietary NFC protocol between adapter and hearing aids
- signal around 3.3Mhz
- compatible with any bluetooth speaking source (in theory)
- mobile phones, land line phones, computers
- comes with an additional tra TV
- costs: 400 EUR (no insuran
- new version “mini tek”

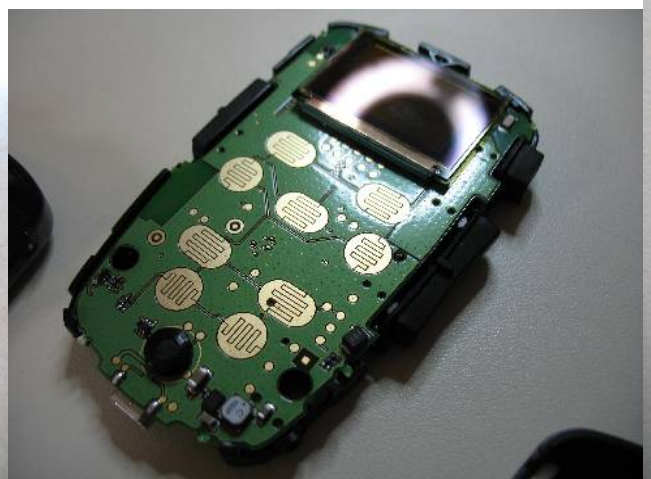
Bionic Ears

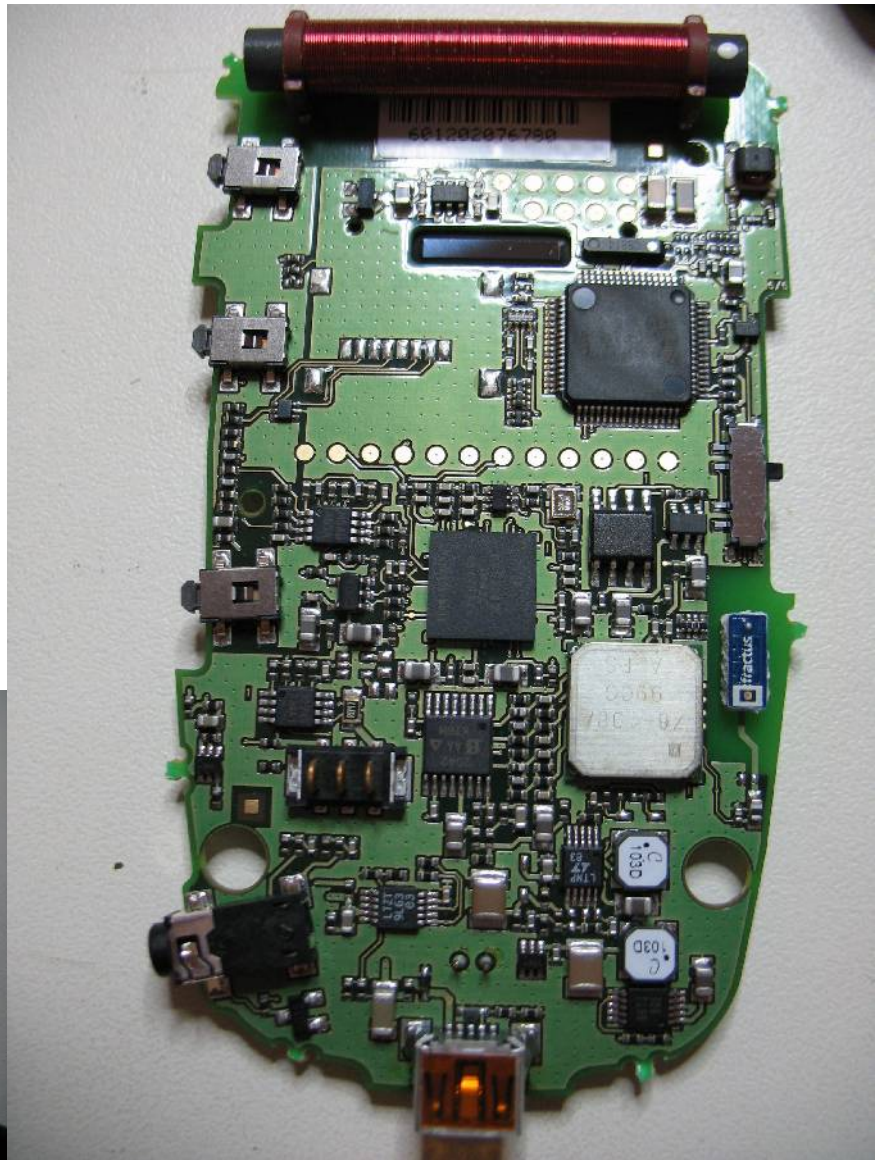
Source: http://hearing.siemens.com/en/04-products/20-minitek/minitek.jsp

Siemens Tek w Transmitter

Siemens Tek Inside

- coupled with hearing aids using hearing aid tuning software
- identifies with 7-character serial number
- latency is crucial (encryption?)
- bluetooth pin “0000”
- ear-2-ear communication unauthenticated





Hacking

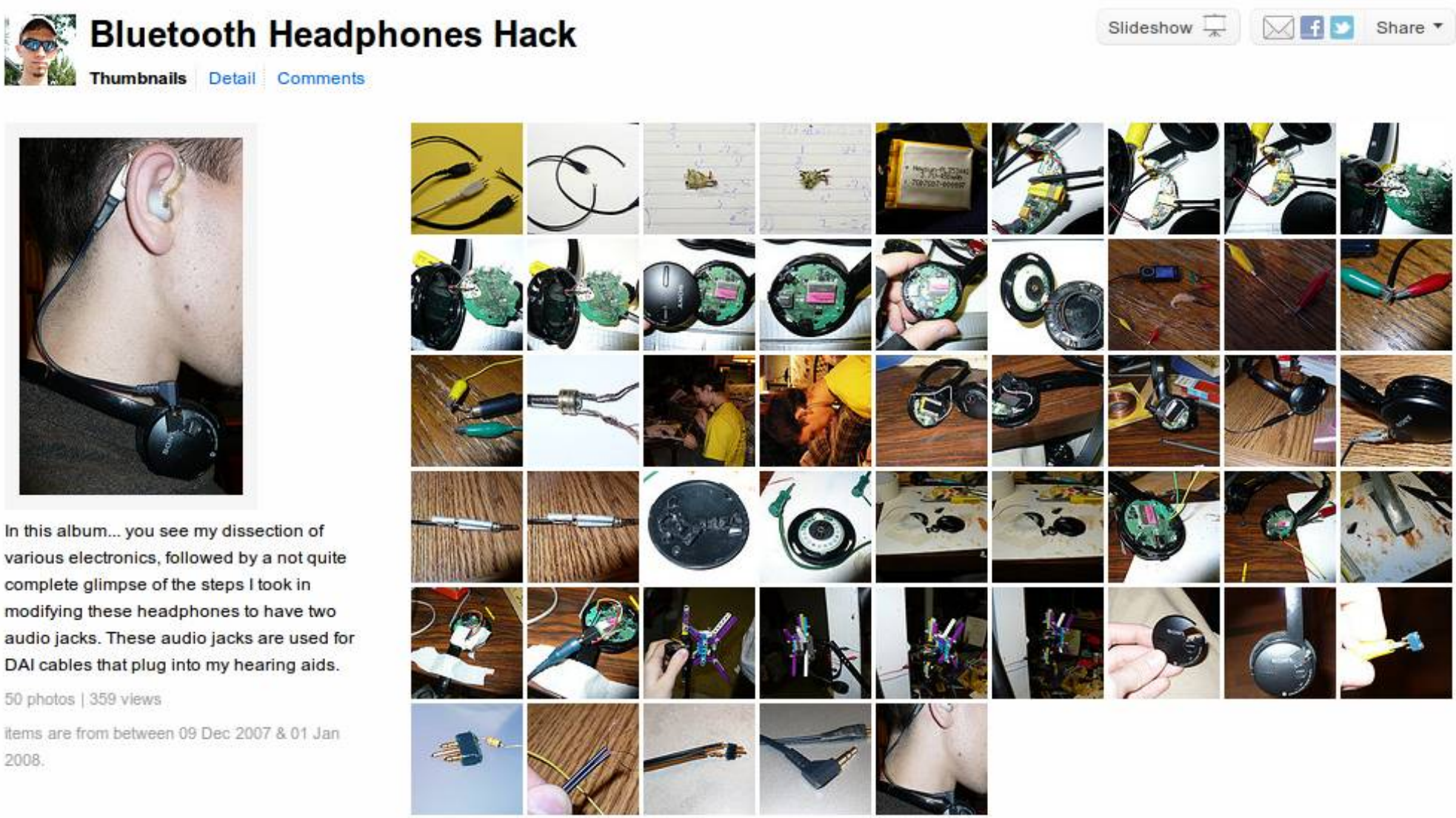
Hacking “Scene”

- barely existing
- devices too expensive
- mostly: compatibility issues, asking for technical advice
- a little hacking on peripheral hardware

http://hearingaidhacks.livejournal.com/

DYI Bluetooth Adapter

by Gertlex

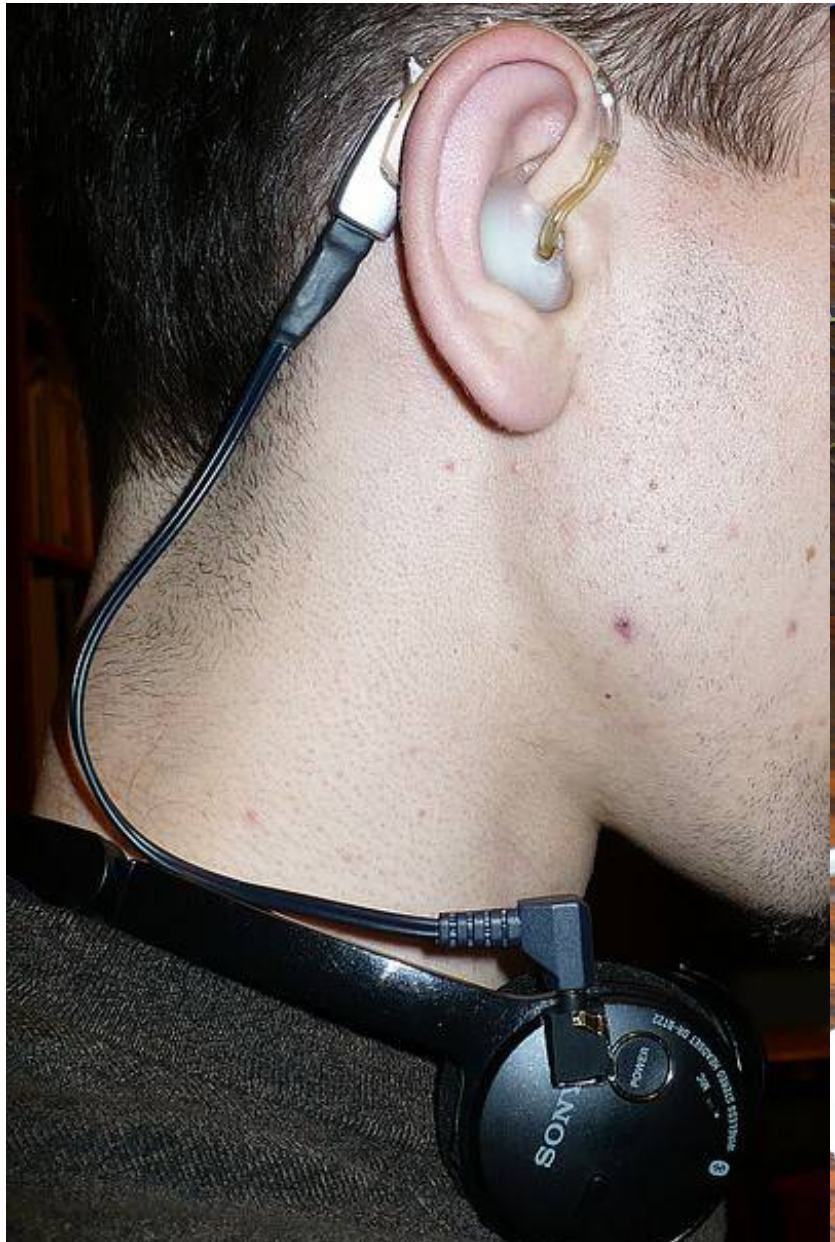


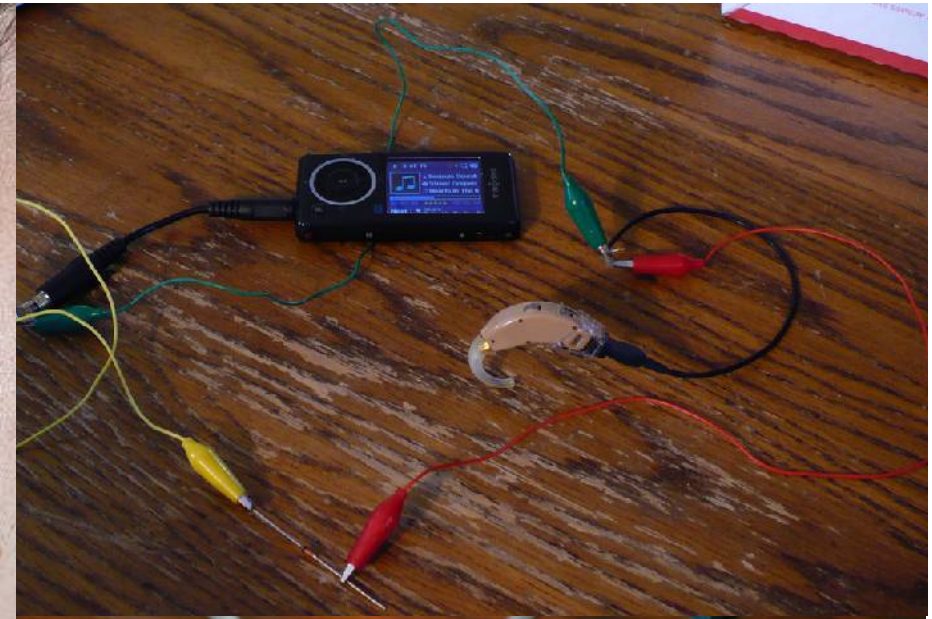
Source: http://www.flickr.com/photos/gertlex/sets/72157603510310486/

DYI Bluetooth Adapter

by Gertlex

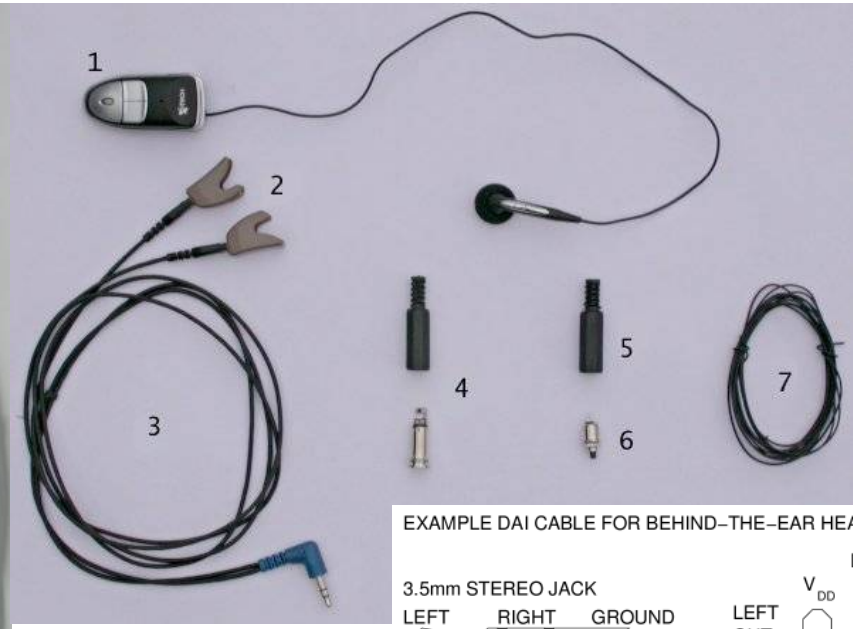
hack and hear

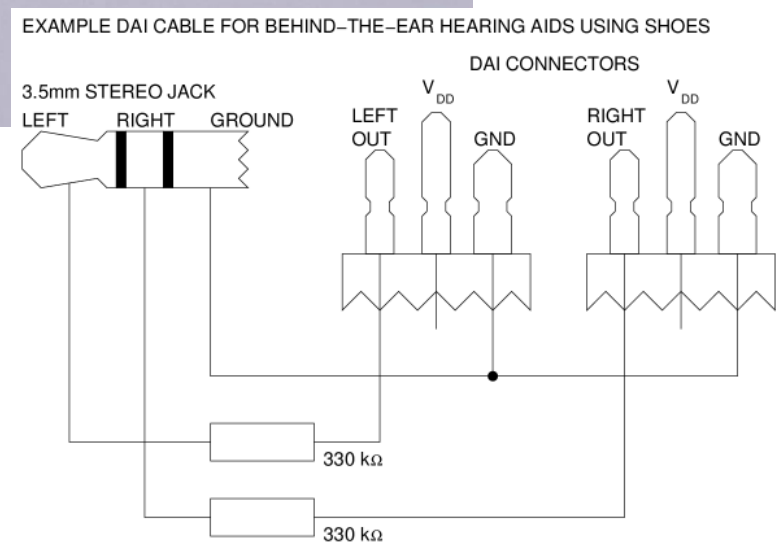




DYI Bluetooth Adapter

by Neil Ferguson





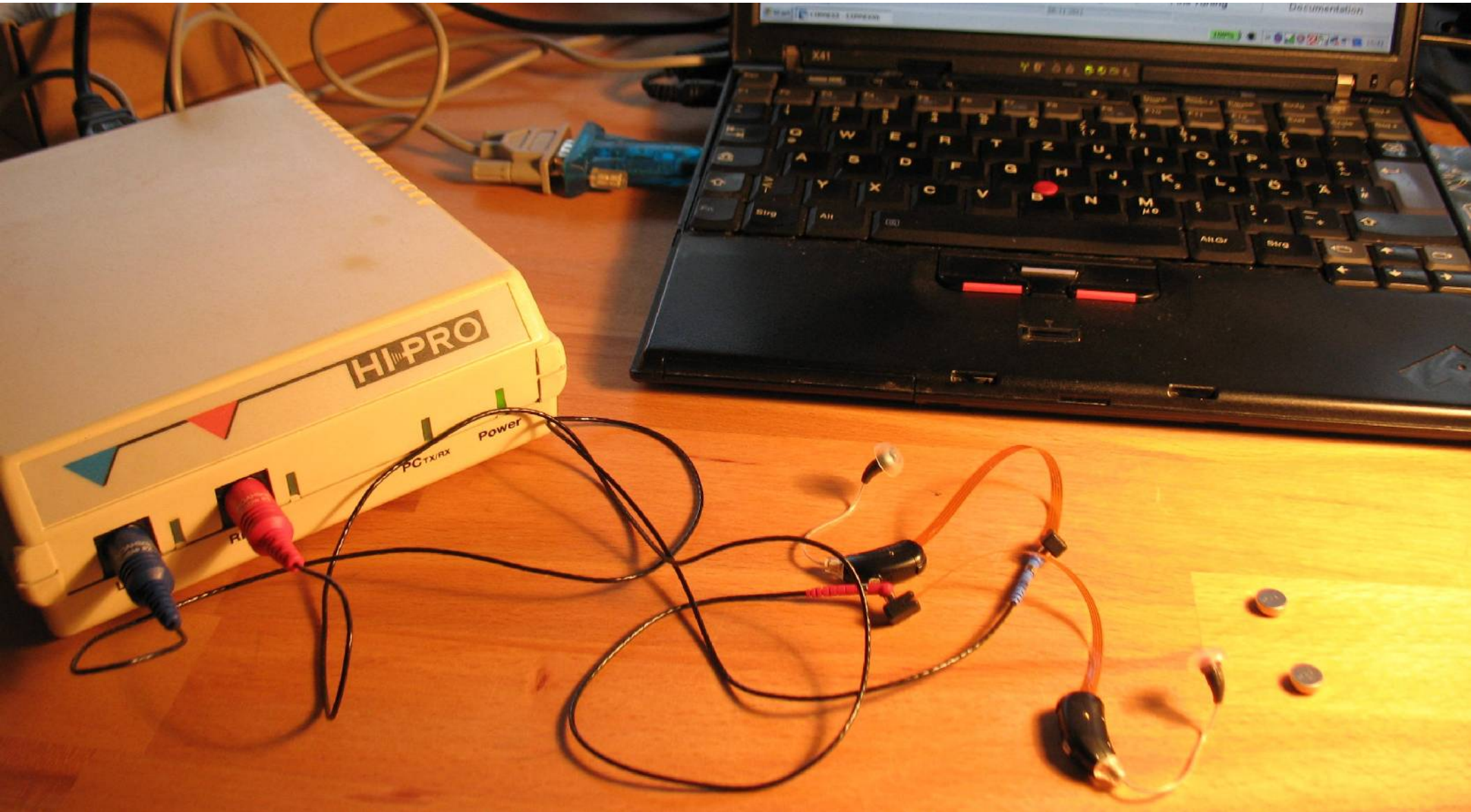
Source: http://gfern.com/btha/btha.html

Self-Tuning

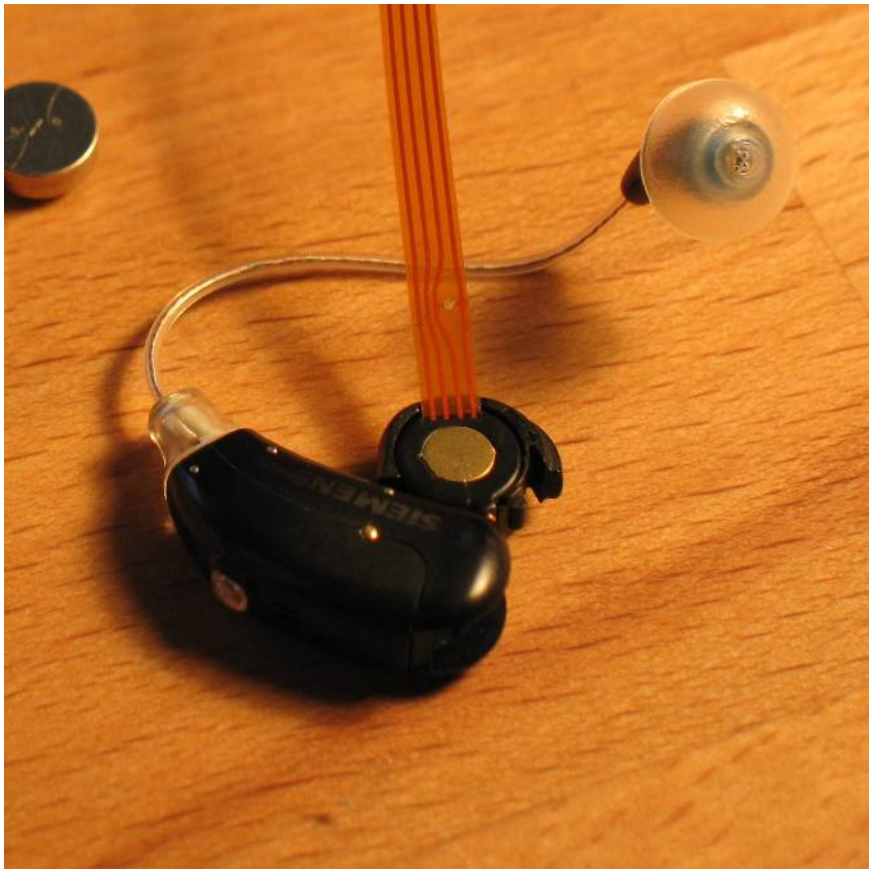
Tuning

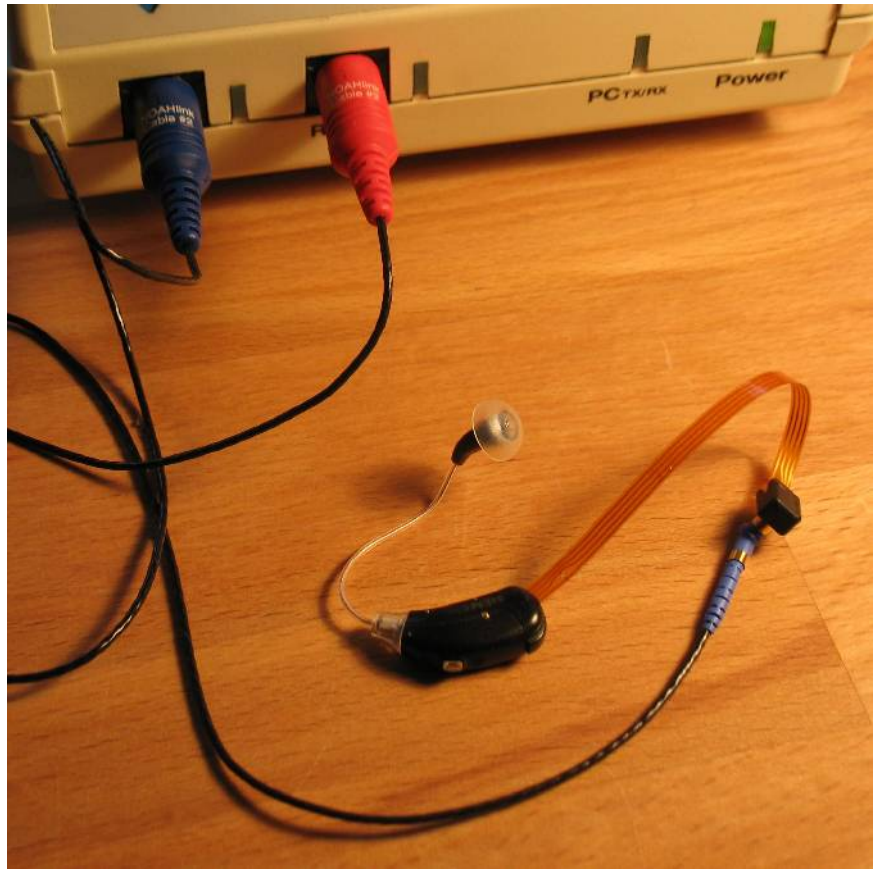
- special hardware: hipro (serial/usb/bluetooth)
- software: noah + modules for each brand
- sold only to doctors and audiologists
- medical equipment (no ebay etc.)
- there is a self-tuner “scene”
- no customer support, no warranty
- exception: americahears.com

Hipro (Serial Version)



Hipro-HA interface

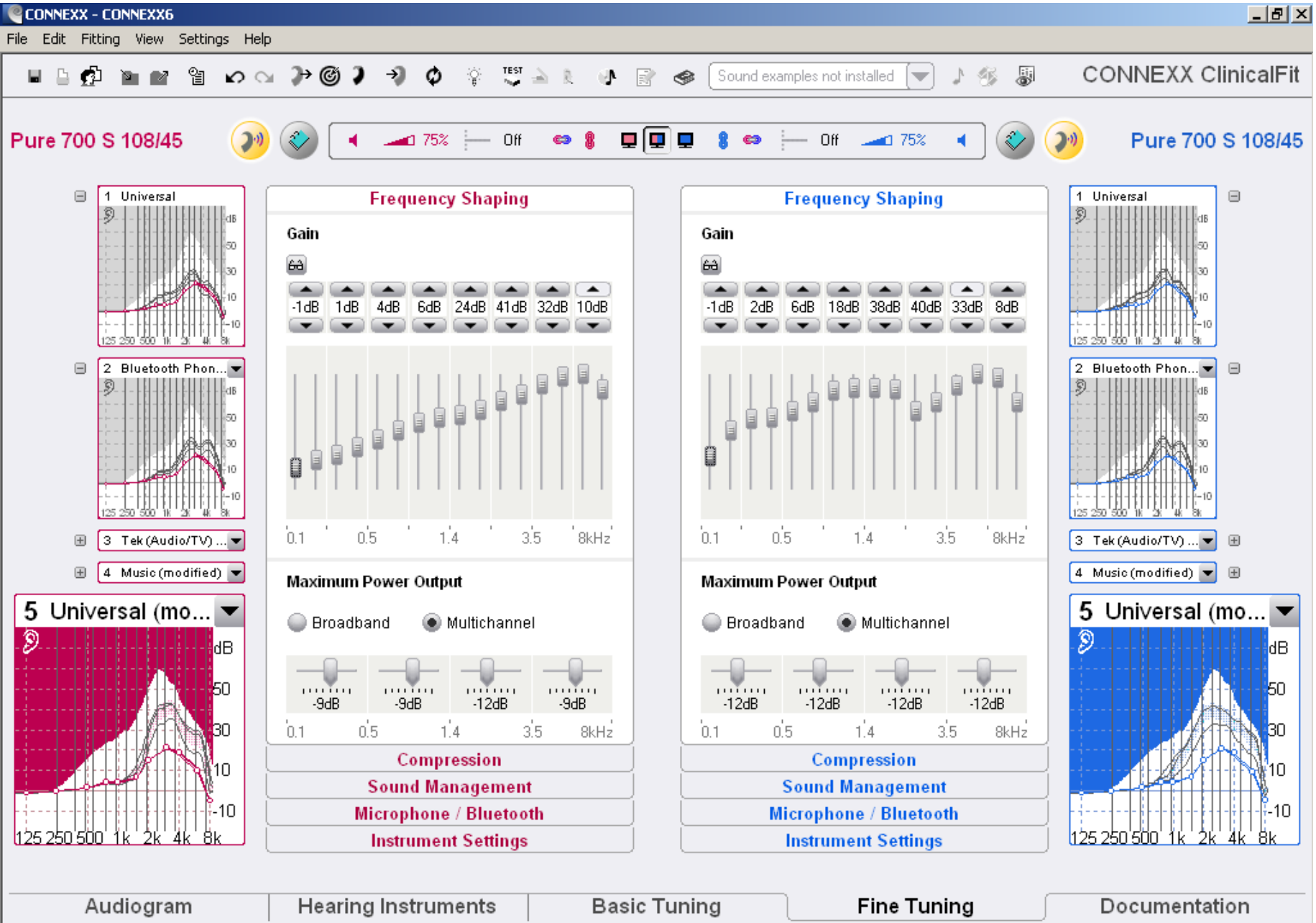




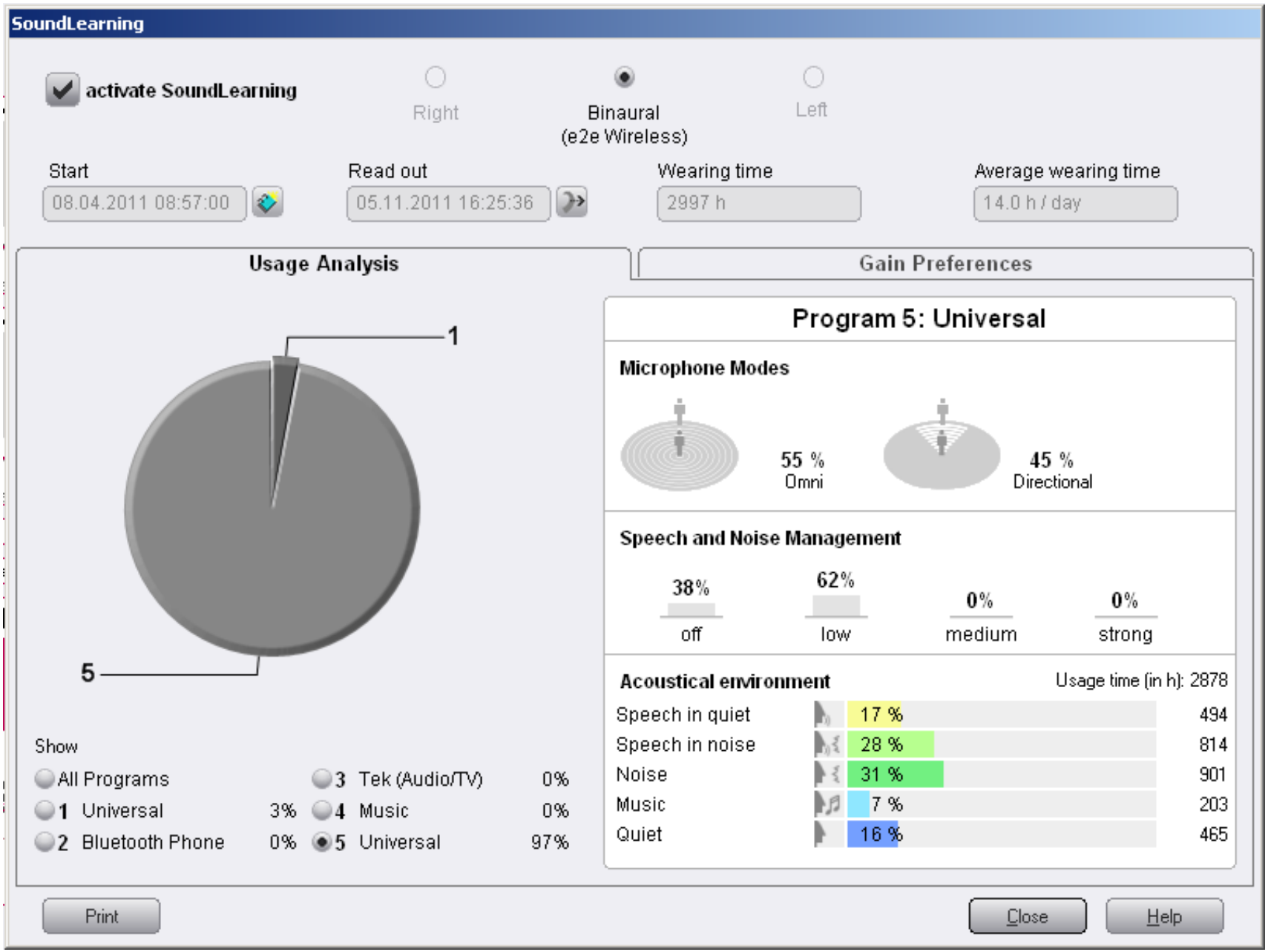
Hipro (Bluetooth Version)

hack and hear

Tuning Software



Big Brother


SoundLearning
activate SoundLearning
Right
Binaural
(e2e Wireless)
Left
Start
08.04.2011 08:57:00
Read out
05.11.2011 16:25:36
Wearing time
2997 h
Average wearing time
14.0 h / day
Usage Analysis
Gain Preferences
1
5
Program 5: Universal
Microphone Modes
55 %
Omni
45 %
Directional
Speech and Noise Management
38%
off
62%
low
0%
medium
0%
strong
Acoustical environment
Usage time (in h): 2878
Speech in quiet
17 %
494
Speech in noise
28 %
814
Noise
31 %
901
Music
7 %
203
Quiet
16 %
465
Show
All Programs
1 Universal 3%
2 Bluetooth Phone 0%
3 Tek (Audio/TV) 0%
4 Music 0%
5 Universal 97%
Print
Close
Help

Cochlear Implants

Cochlear Implants

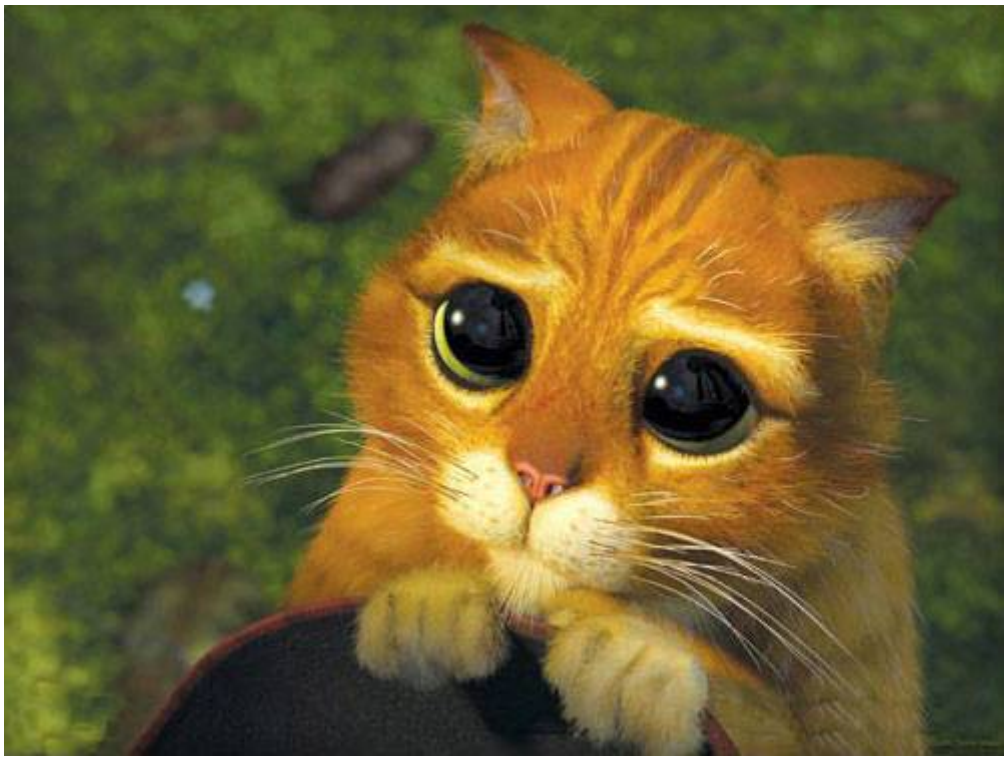
Source of images:
http://www.flickr.com/photos/yaccesslab/5431069155/
http://www.flickr.com/photos/oaspetele_de_piatra/4581664897/sizes/o/in/photostream/

Cochlear Implants

- makes deaf people hear
- surgical insertion of device
- destroys any remaining hearing
- surgery might affect other nerves
- signal is different:
  brain has to adjust
- technology usually 5 years
  behind
- no standards, no interoperability
  between brands

Conclusions

Want!



- better service
- consideration of young people's needs
- better signal processing
- (open) standards

Ideas

So einfach –
Apps für alle Anforderungen

Wir haben die Audéo S Apps in vier Hauptbereiche zusammengefasst.

- "hearing aid app market"
- crowdsourcing
- language / speaker / location specific programs
- use info from smartphone
- write your own filters?

Thanks!

- Questions?
- Slides and speaker notes on hackandhear.com
- Give Feedback, please!

Credits:

- Heike Pott heike-pott.de
- LupusE, Nicolas
- Habo, Jump
- Kevin, the Chaoswelle guys
- ThinkPad, Heiko
- and all I forgot to mention ...