NIH (NIDCD) initiative to develop real-time portable signal processing tools for advancing research on hearing loss compensation

Caslav (Chas) Pavlovic, BatAndCat Corporation, Palo Alto, CA USA

Unless otherwise indicated the information provided is based on the author's personal analysis and opinions relative to the NIH (NIDCD*1) initiative

*1 The National Institute for Deafness and Other Communication Disorders

Roger Miller & Amy Donahue (2016 IHCON)

“These research tools will

- *incorporate open-source design principles to enable basic and clinical research studies beyond what is widely done today,*
- *lower barriers for hardware and software development,*
- *and facilitate translation of these advances into widespread use with hearing aids, cochlear implants, and consumer electronics devices.“*

Also and very importantly:

- *“… open design approach will require a unique emphasis on outreach and dissemination activities to ensure widespread and effective use of these research tools by outside laboratories”*

- *“open software is a link across all awardees“*

Academic (R01) vs Small Business (SBIR) awards

“<u>Academic (R01) awards</u> uniquely suited to:

... doing research leading to publications

...organizing efforts to use and enhance instruments through data-driven competitions

...organizing special sessions at conferences

... creating test data and procedures

... developing performance benchmarks that track key measures of algorithm function across different implementations and hardware platforms

Not be expected to:

... resolve requests for user support

... vend hardware to the user community “

“<u>Small Business (SBIR) awards</u> uniquely suited to:

... designing, vending, and enhancing hardware platforms on an ongoing basis throughout the award

... providing substantial increments in the computational power over the project period

... servicing user requests to resolve issues arising from individual attempts to use these tools “

Projects funded

Six awards were given starting July 2016, and one pending July 2017 to

- span a broad area of possible solutions
- create a critical mass of researchers working and cooperating using open system components
- provide systems and support to additional outside labs engaged in hearing healthcare

Some common goals:

10 ms end-to-end latency in the hearing aid mode;

C or C++ programability;

Availability of basic hearing aid algorithms ready to interface with user developed algorithms.

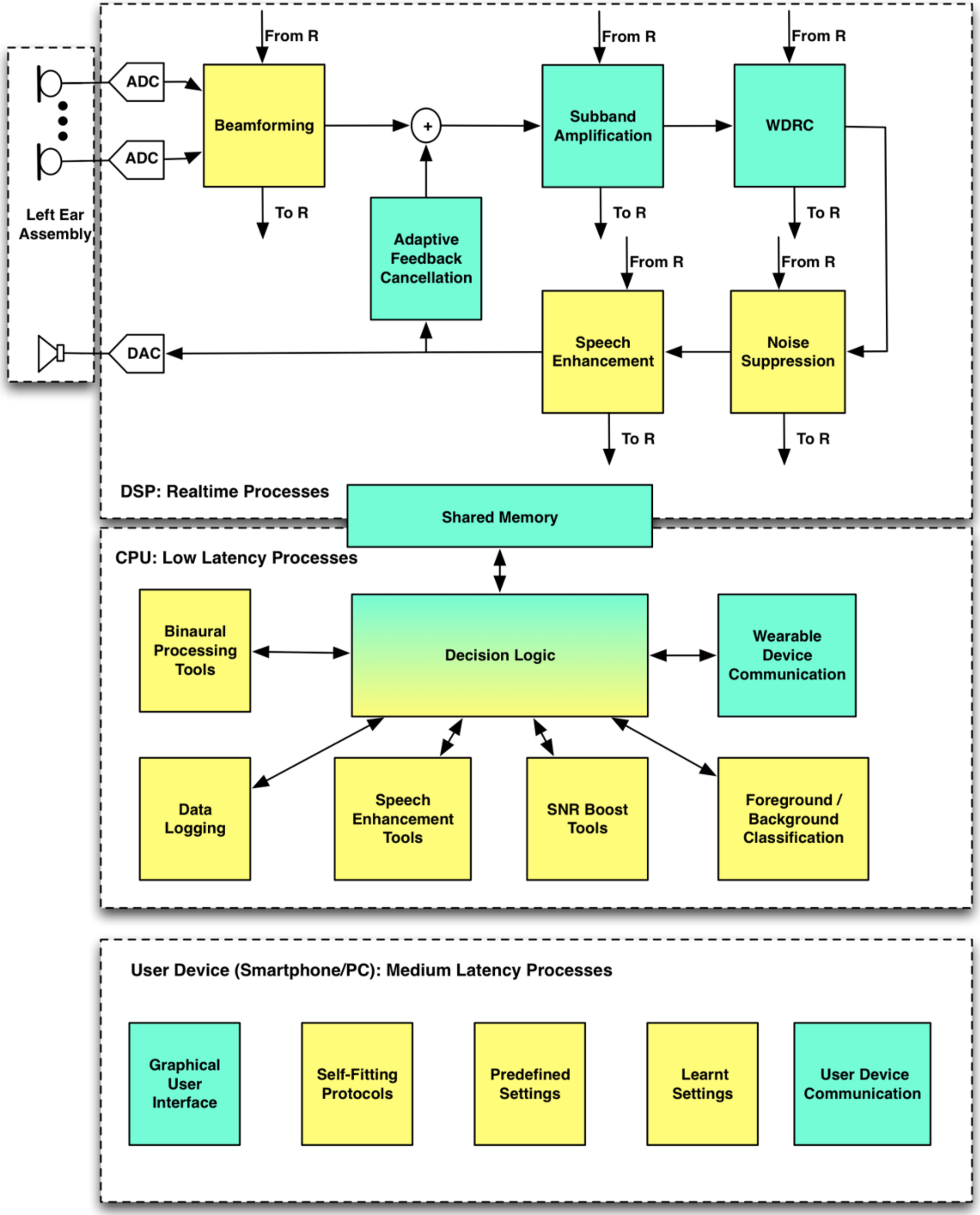
RO1 Award
Smartphone-Based Open Research Platform for Hearing Improvement Studies
Issa Panahi, Nasser Kehtarnavaz, and Linda Thibodeau
University of Texas, Dallas, USA

Android and iOS systems, running C shells to:

- Use the phone as a RM harnessing the signals from the existing phone microphones ("Roger" - like device).
    - Wired and wireless version
- Use the phone itself as a hearing aid
    - Wired and wireless version
- Use the phone to provide auditory training

Main challenges and thus research areas:

- Optimizing signals for microphone clusters not arranged into optimal arrays
- Reducing different latencies to be below maximum values for the purposes (RM, Hearing Aid, wired and wireless)
- Adapting to the system where phone processing and interrupts are of the highest priority



RO1 Award

A Real-time, Open, Portable, and Extensible Speech Lab

Hari Gurudadri, UC San Diego, CA, USA

- Initial MHA implementation on a MacBook
- Depending on the negotiations with Qualcomm, the 2nd generation on either
    - Snapdragon system on chip or
    - TI SoC with an ARM-15 and C66 floating point DSP
- Both systems are controlled and programmed by an Android phone

RO1 Award:

Open Community Platform for Hearing Aid Research

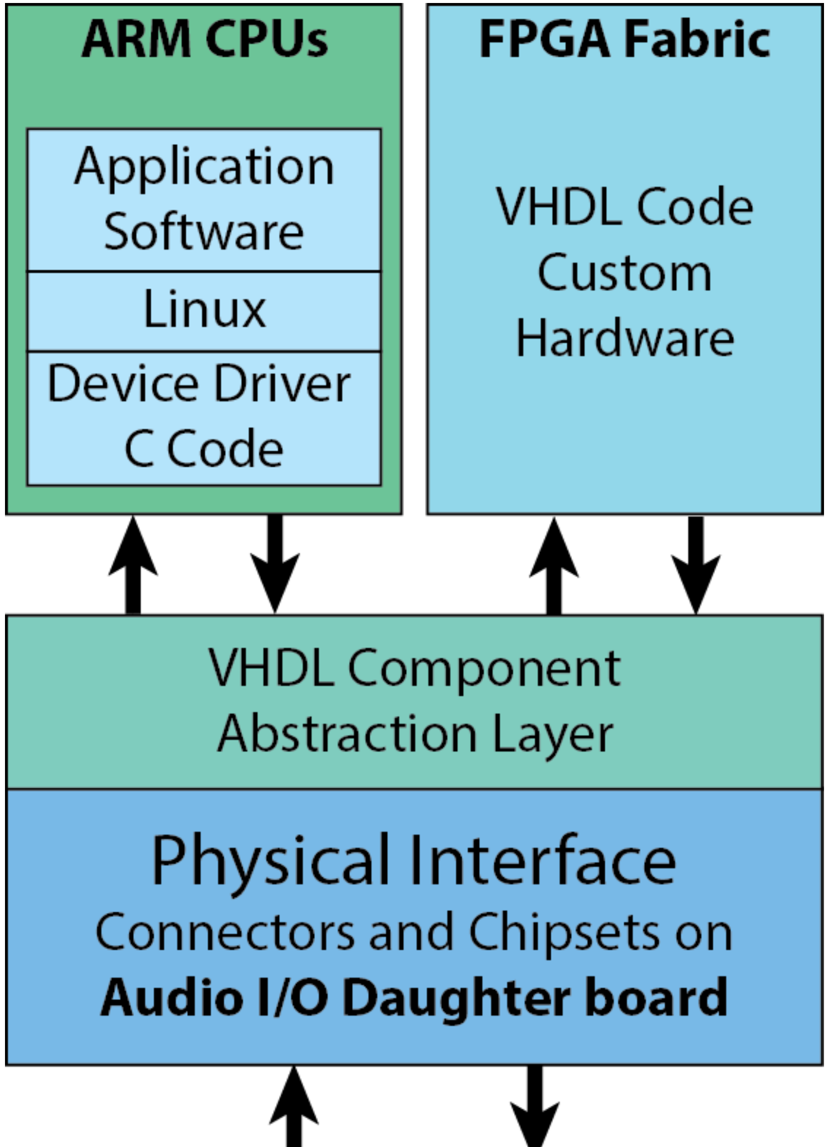
Volker Hohmann, University of Oldenburg, Germany and
Chas Pavlovic,BatAndCat Corporation, Palo Alto, CA, USA

- To be presented by Volker Hohmann in this session
- A complementary SBIR to be presented at the end of the talk

SBIR Award:

Development of an Open Speech Signal Processing Platform

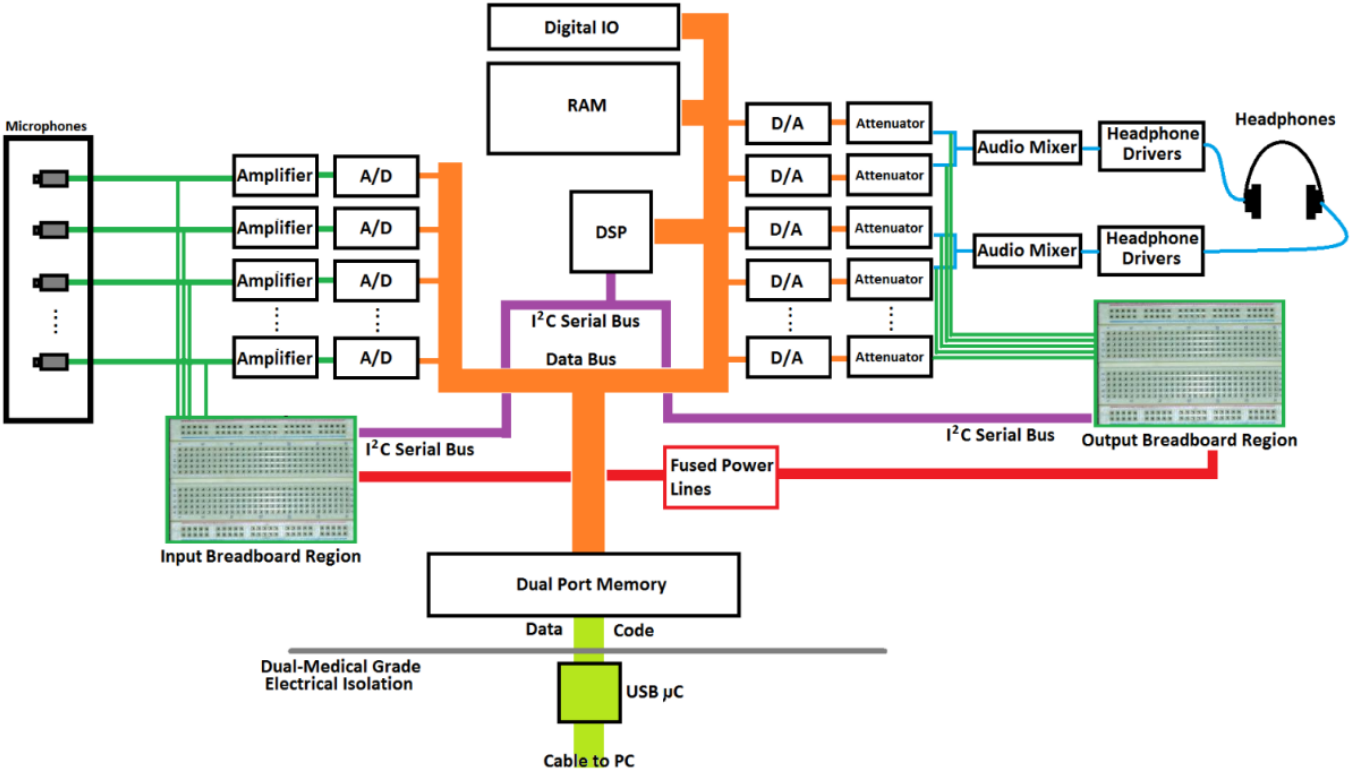
Ray Weber & Ross Snider, Flat Earth, Inc, Bozeman, MT, USA



- The platform is based on the SoC FPGAs
- FPGAs allow deterministic low-latency signal processing
- Applications run on top of Linux, which is running on the dual ARM Cortex A9 CPU
- Applications interact with the FPGA fabric
- I/O daughter cards:
  - analog and digitals mics; speaker driver; headphone driver; BT Transceiver; Wi-Fi Transceiver, etc.

SBIR Award:
Open Hardware and Software System for Speech and Signal Processing

Rafael Delgado, Intelligent Hearing Systems, Miami, FL



TI TMS family (TMS320vc33 then 320C6727B)

Independent A/D for each channel allowing synchronous sampling

Similarly independent D/As

128 kHz sampling rate

150 dB output attenuator

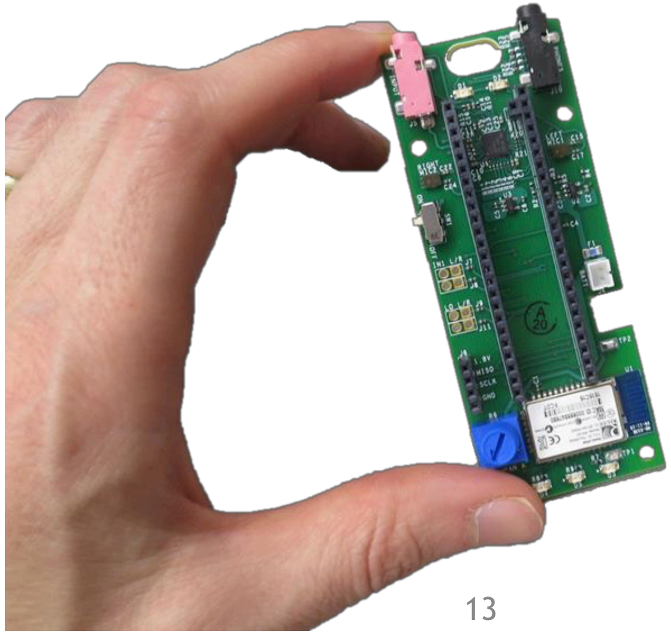
Extra space on the circuit board to incorporate user designed circuitry with access to I2C and I2S to control other external devices.

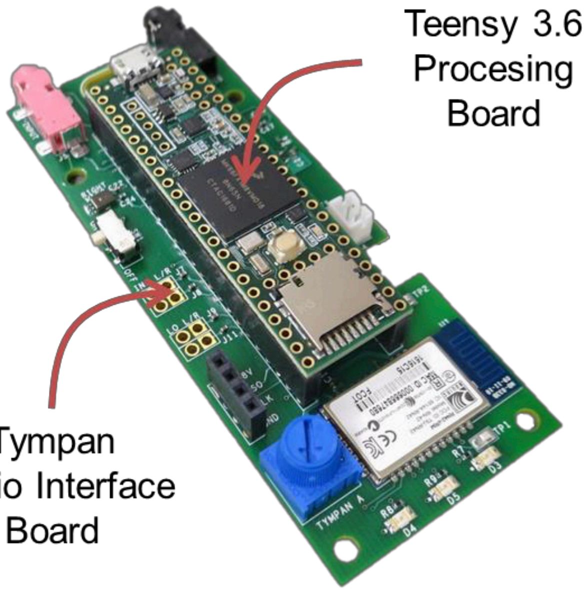
Interfaces to PC for programming, loading firmware, etc.

SBIR Award: Open Source System for Audio Processing

Odile Clavier, Creare Inc., Hanover, NH, USA

- 1st generation hardware: Teensy 3.6 + custom audio interface board with NXP 180 MHz M4 ARM and floating point support
- Relies on Arduino software development environment
- A GUI interface will be provided to facilitate developing new algorithms
- Next generation: TI TMS320C6748 or ARM M4





SBIR Award: Portable Hearing Laboratory
Chas Pavlovic, BatAndCat Corporation, Palo Alto, CA, USA

Fully productized wearables to achieve

- small size, robustness, low internal noise, excellent antenna, and low distortion
- realistic input and output interfaces (e.g. RIC) for achieving high validity of results
- form factors adequate for comfort and esthetic acceptability to enable long-term wear required for adaptation to the new code
- fully programmable connectivity means, down to the link layer, (BT classic, BLE) to enable development of sophisticated algorithms for improving SN
- smart phone libraries for user control and programming
- Linux environment to support the software of the complementary R01

Capitalizes on the prototype BatAndCat technology (developed on NIDCD SBIR grant) to connect to one another and provide exceptional SNR

- High quality stereo earphones
- Connects to phone (for phone conversation and programming)
- Personal sound amplifier (x2)
- RM for a companion without a device

1st Generation:

- Introduce Cortex A7 Core
- Linux environment
- low power programmable BT, BLE module(s)
- number of realistic output interfaces

2nd Generation:

- Super small size device
- Licensed soft core on own silicone

Extra Slides - Subject Testing

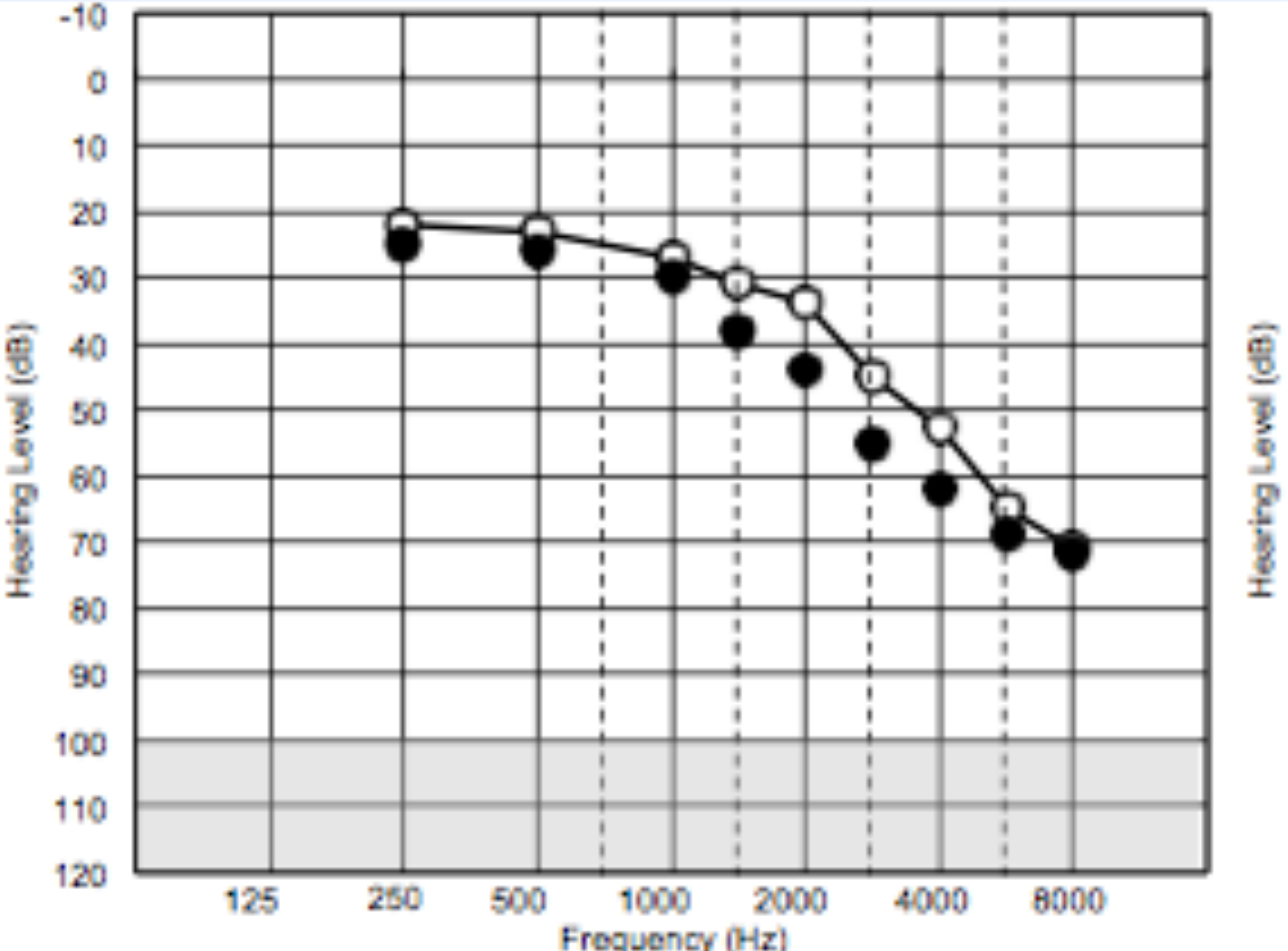
Latency

Mode	*Codec*	RF *Latency*	*End to End*
Music	**AptX**	**35 ms**	**40 ms**
Device to device	**mSBC**	**20 ms**	**less than 25 ms**
Amplification only			**3.5 - 7 ms**

Tests

- 45 subjects were tested with respect to the performance in
  - **direct 1:1 mode,**
  - **self-fit hearing aid mode (5 presets), and**
  - **audiologist-fit hearing aid mode (NAL)**
- Two environments: laboratory and the field tests.
- Subjects: between 30 dB and 60 dB 4-frequency PTA.

Average Pure Tone Audiogram
Worse and Better Ears



Laboratory Tests

- The testing was done in a room;16 x 14 x 9.5' (LWH).
- The speech was presented at 63 dB SPL at the position of the listener from a head and torso simulator (HATS) 48" from the subject.
- Two listening environments simulating noisy restaurants at 0 and -10 dB SNR.
- After the test the subjects were asked to fill-in a device questionnaire.

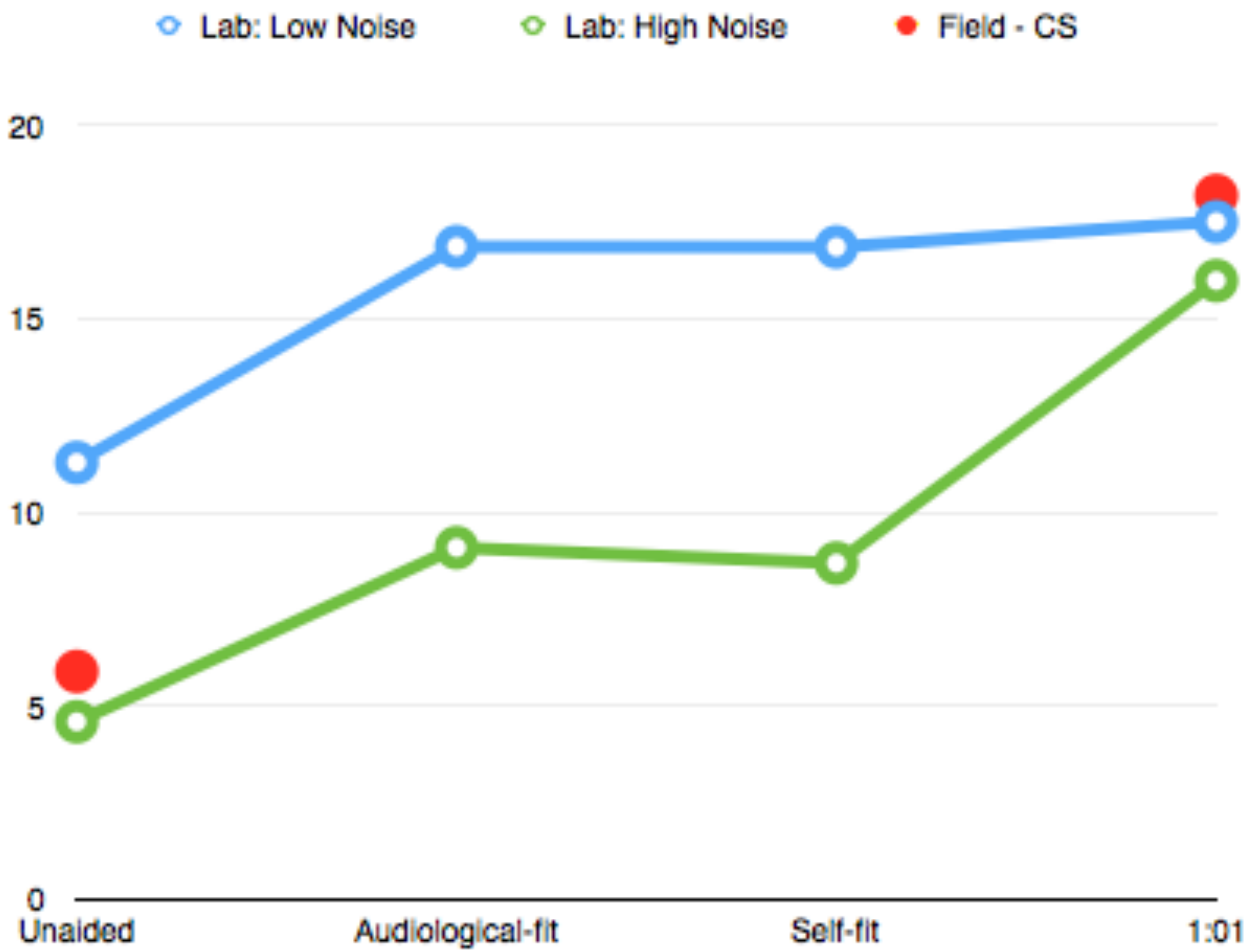
Scaling speech understanding

- A categorical scaling of Purdy and Pavlovic (1992).
- Speech understanding rated on a 1-20 scale
- 20 = the highest possible speech understanding and
  1 = cannot understand speech at all.
- 8 conditions, 4 modes (unaided, self-fit, audiologist-fit, 1:1) and two noise levels
- Each conditions repeated 11 times in random manners

Field Testing

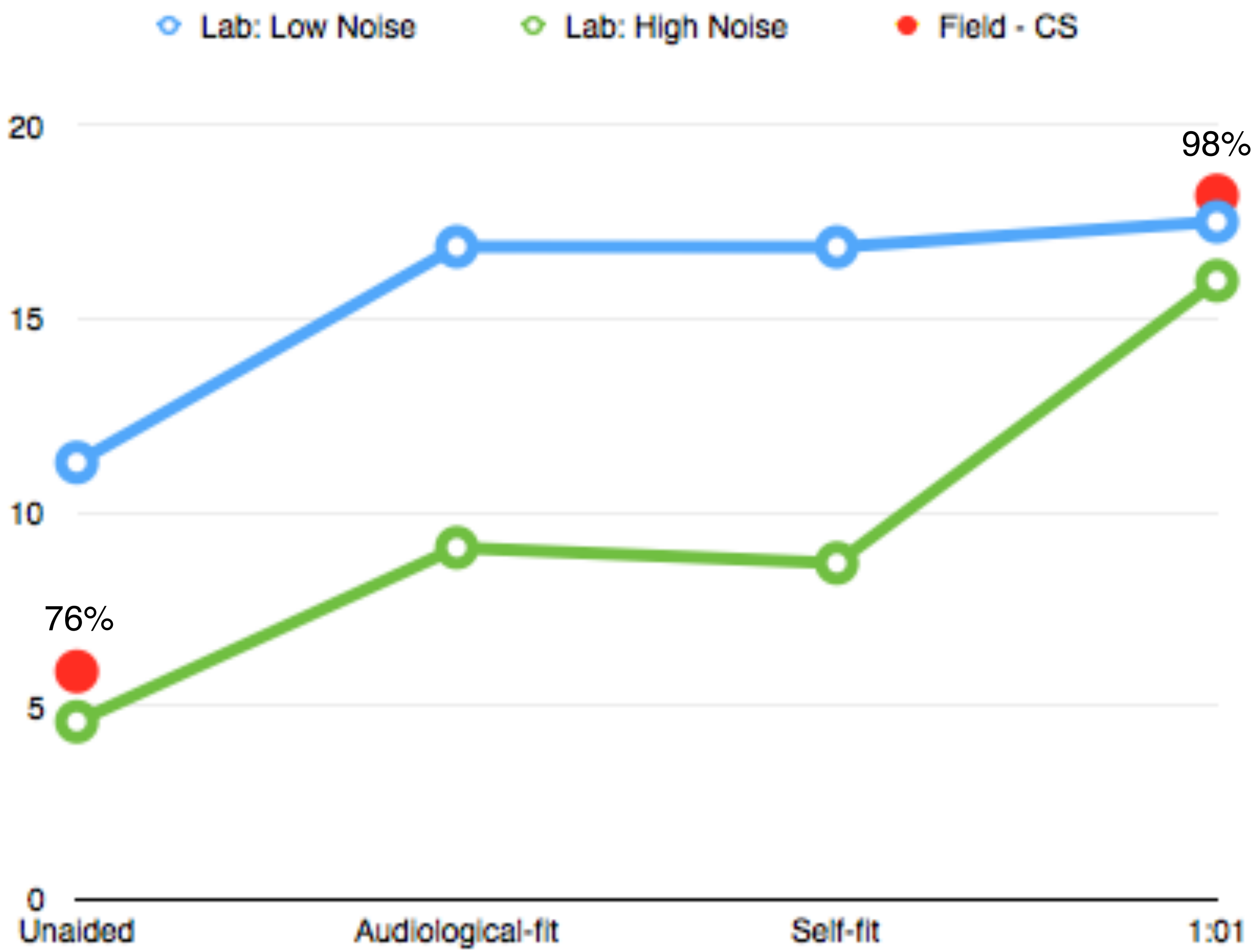
- Focused on 1:1 mode versus the unaided performance
- Pairs of subjects talking to each other in different restaurant environments.
- The subjects estimated both, the perceived speech intelligibility in percent, and a value on 1 - 20 categorical scale.

Results



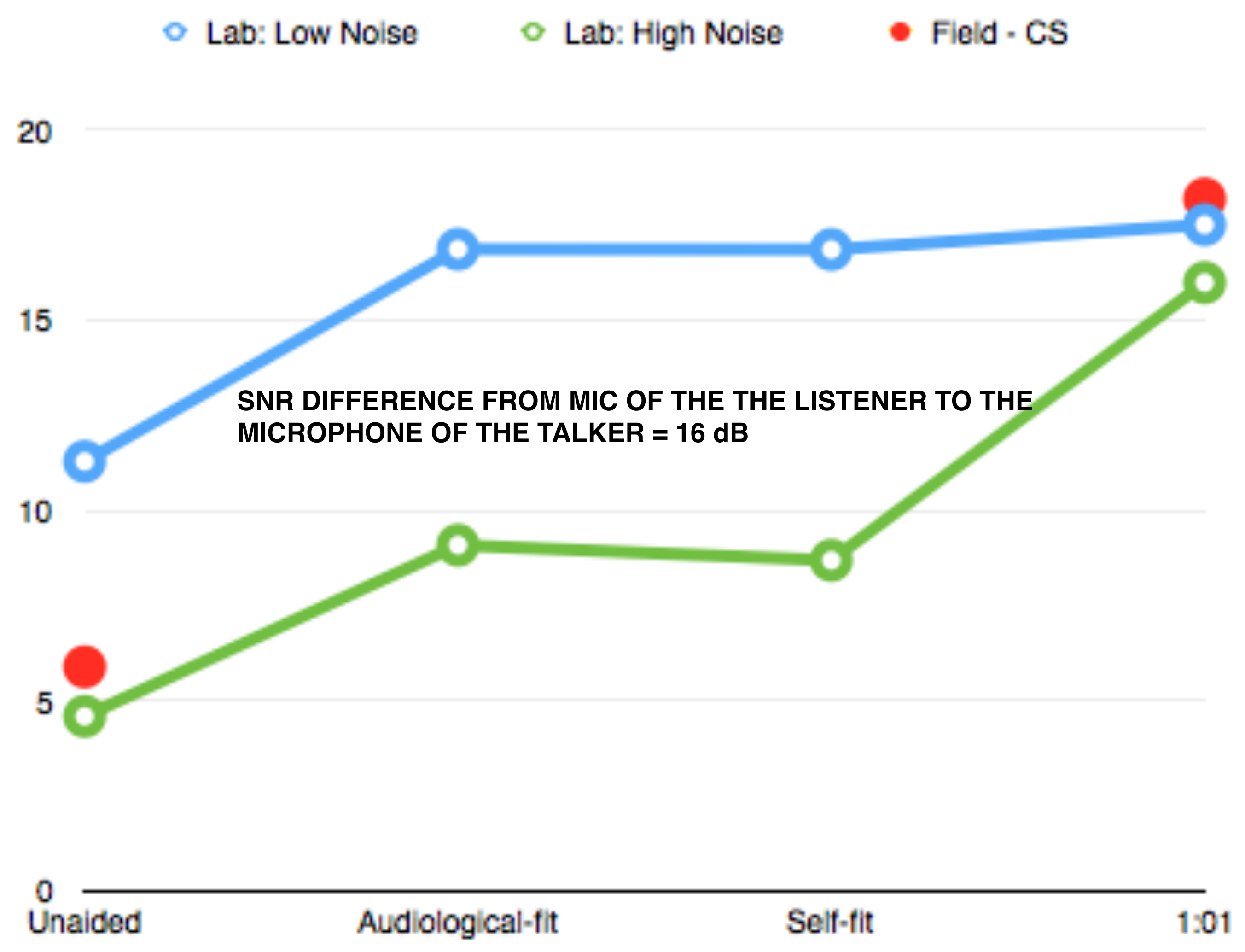
Lab: Low Noise
Lab: High Noise
Field - CS
20
15
10
5
0
Unaided
Audiological-fit
Self-fit
1:01

Results



Lab: Low Noise
Lab: High Noise
Field - CS
20
15
10
5
0
98%
76%
Unaided
Audiological-fit
Self-fit
1:01

Results



Lab: Low Noise
Lab: High Noise
Field - CS
20
15
10
5
0
SNR DIFFERENCE FROM MIC OF THE THE LISTENER TO THE MICROPHONE OF THE TALKER = 16 dB
Unaided
Audiological-fit
Self-fit
1:01

Conclusions

- Connectivity appears to enhance performance in noise far better than any hearing aid.
- In typical restaurant situations an objective16 dB SNR improvement is measured.
- In difficult listening conditions, this may represent doubling of the available speech spectrum and is consistent with subjective estimates of the listeners.
- This is 10 dB or more what hearing aids can do.

Questionnaire

- 87% of subjects who have had experience with other products find Music more effective and 13% find it similar.
- **Despite the size of the device and its visibility when worn, 82% of subjects could see themselves wearing and using this product in public social situations like restaurants and parties**.
- Before being told the target price of the device the average price estimate was $1110, but the range was very wide: $200 to $5000.
- **When the target price of $299 was disclosed, 58% of subjects stated being very or extremely interested in buying it, 38% somewhat interested, and 4% not at all interested.**