

# On Mitigating Acoustic Feedback in Hearing Aids with Frequency Warping by All-Pass Networks

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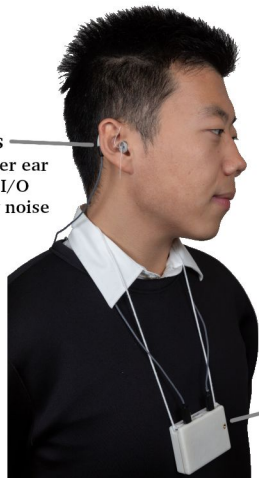
Qualcomm Institute of Calit2  
University of California, San Diego

# *To enable psychophysical investigations beyond what is possible today*

– Miller and Donahue  
Open Speech Signal Processing Platform  
Workshop, NIH, Bethesda, MD, Oct. 2014

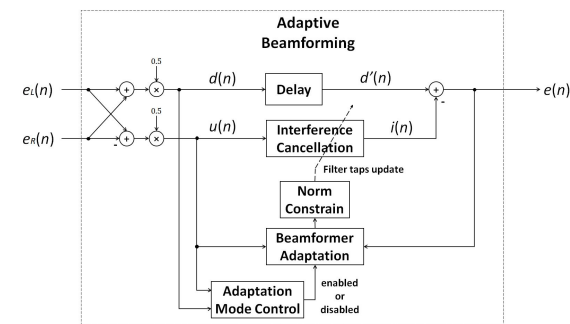
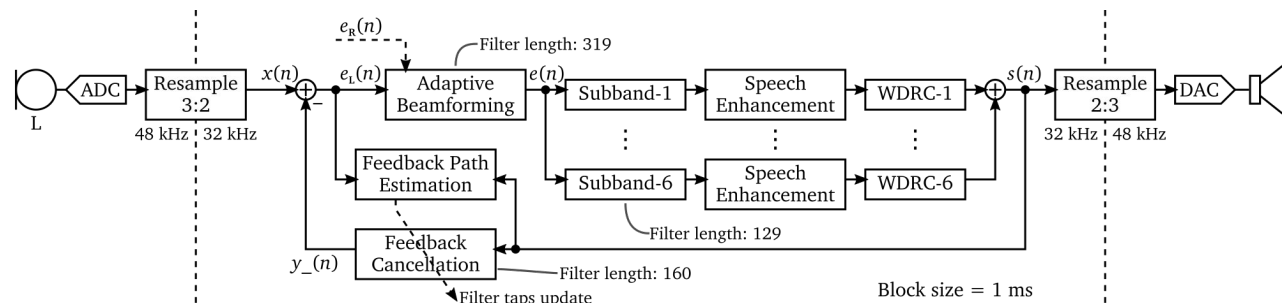
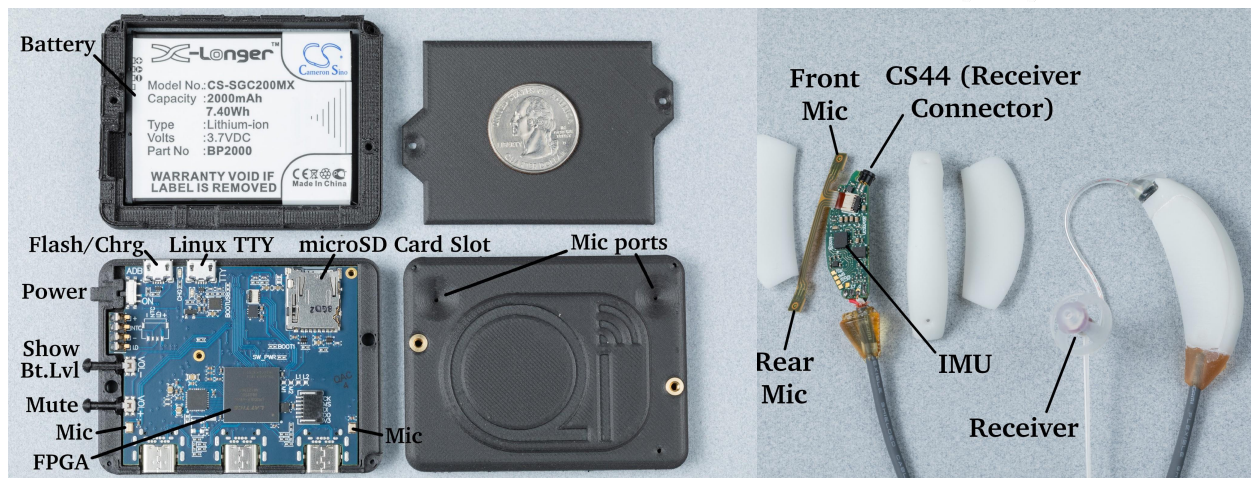
### OSP BTE-RICs

- Up to 4 mics per ear
- 24-bit, 48 kHz I/O
- High gain, low noise
- IMU sensors



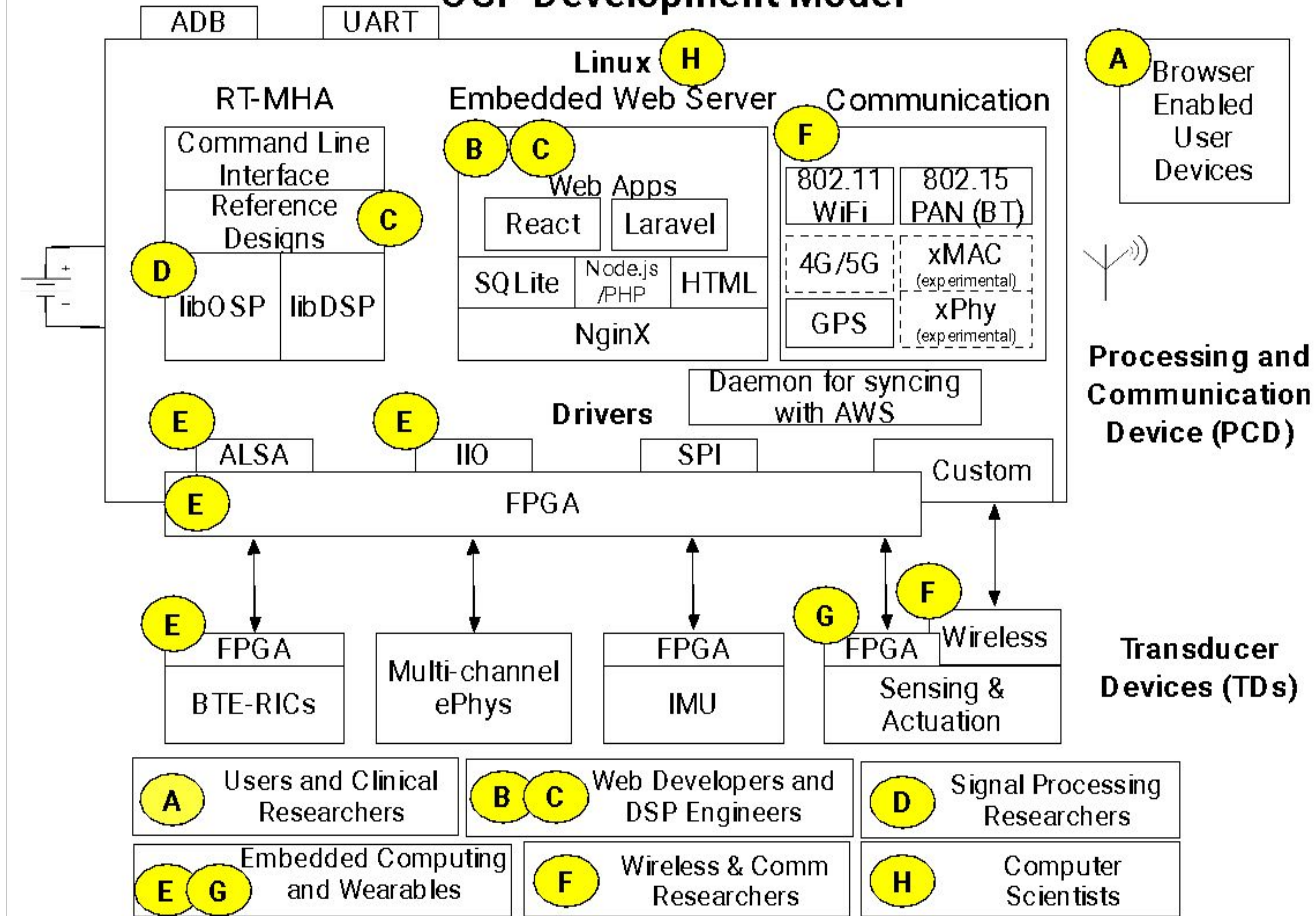
### OSP PCD

- 4+ hour battery
- Quad-core smartphone CPU
- Advanced real-time master hearing aid algorithms
- WiFi hotspot & Embedded Web Server for control & monitoring HA in real time

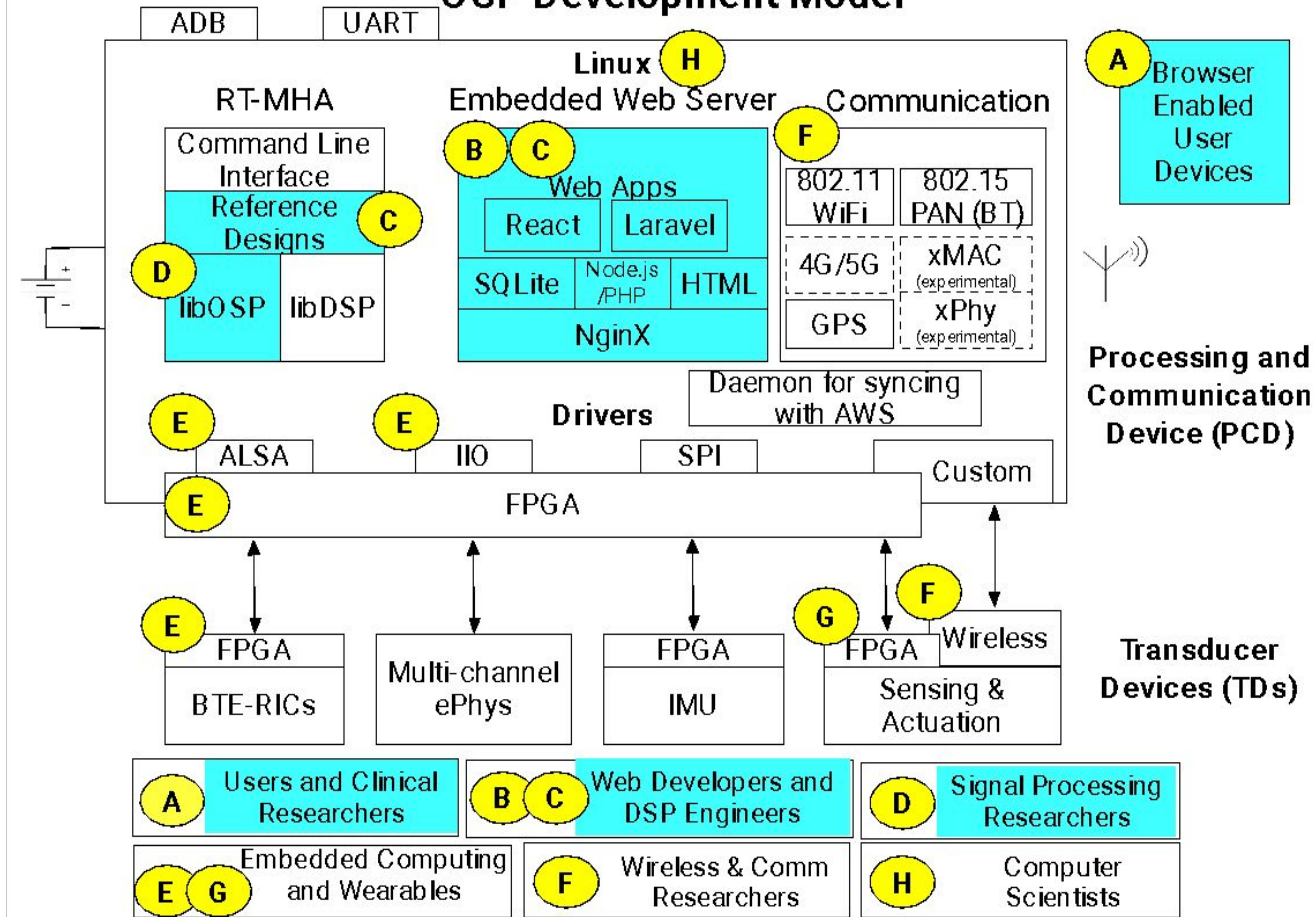


Pisha, et al., (2019), IEEE Access

## OSP Development Model



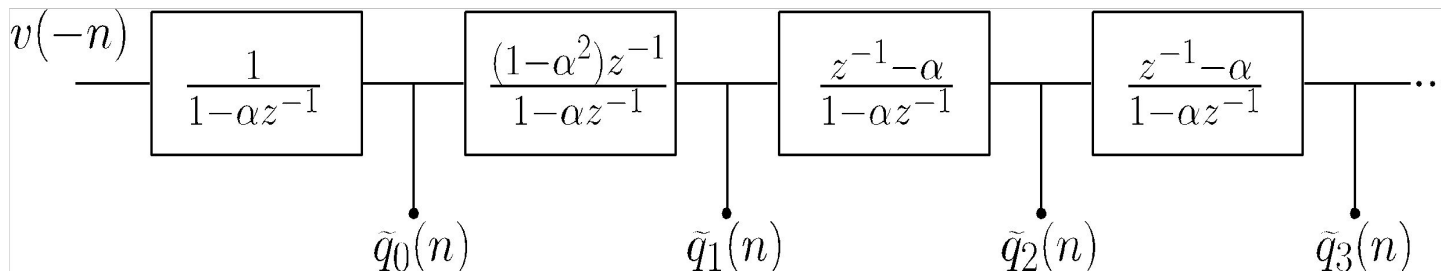
## OSP Development Model



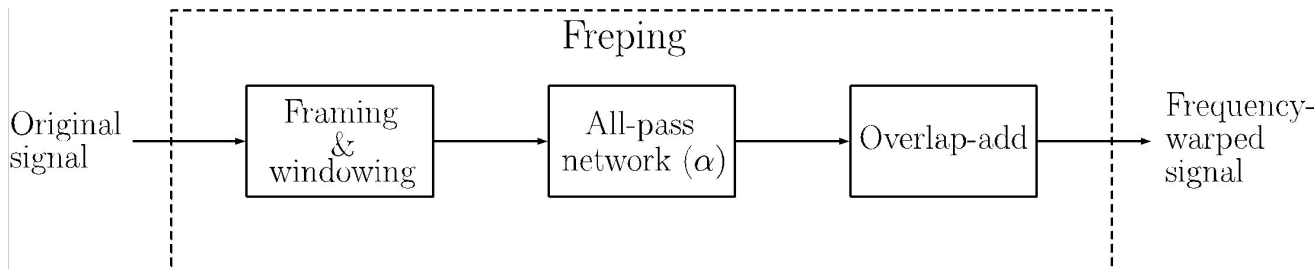
# Freping – A portmanteau for **F**requency War**p**ing

## Allpass Network

Discrete Representation of Signals,  
Oppenheim and Johnson, IEEE Proceedings, 1972.



## Realtime frequency warping



# When do Hearing aids howl? Nyquist Stability Criteria (NSC) due to acoustic feedback

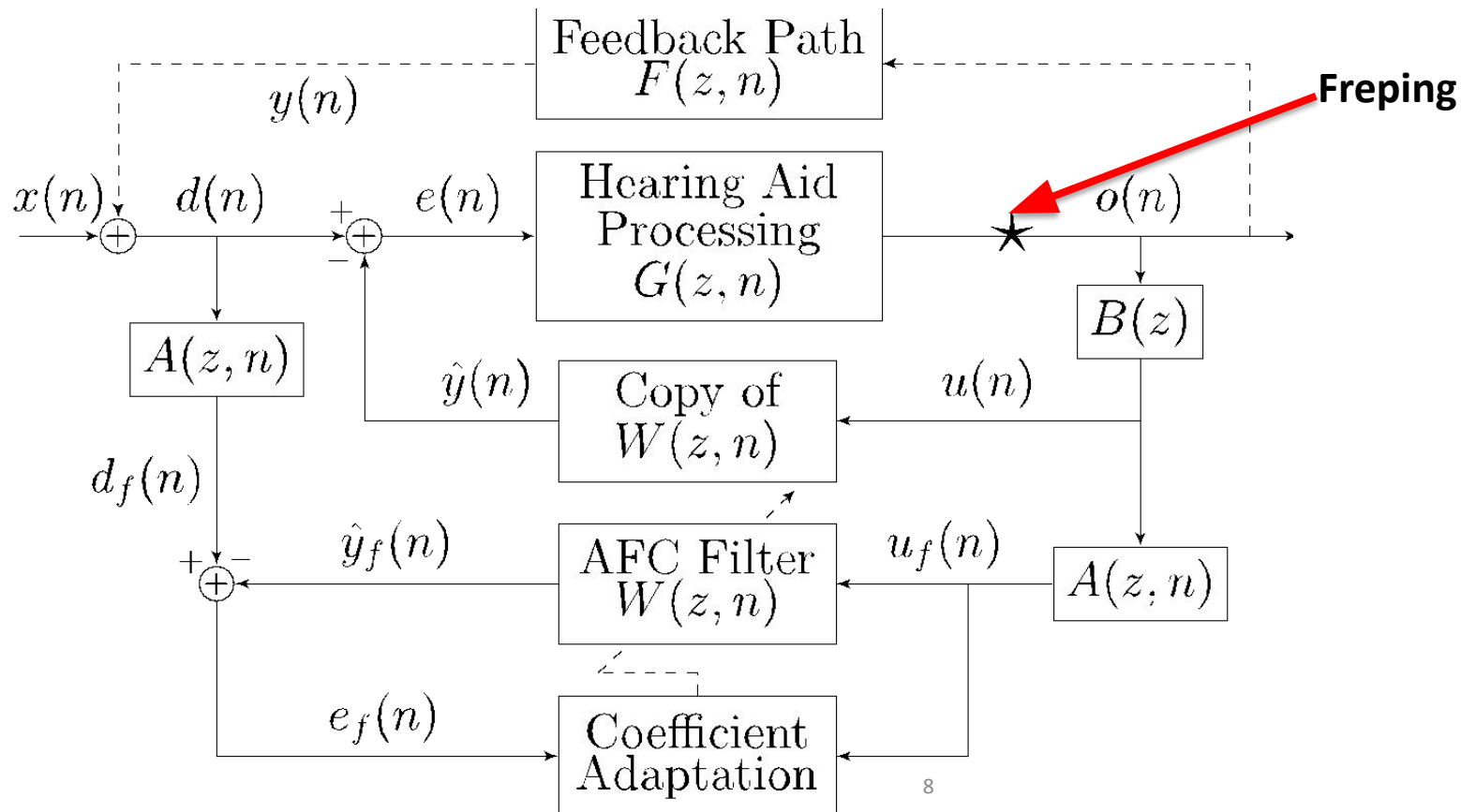
$$\left| G(e^{j\omega}, n) \begin{pmatrix} F(e^{j\omega}, n) & \hat{F}(e^{j\omega}, n) \end{pmatrix} \right| \geq 1, \quad (\text{magnitude cond.})$$

$$\angle G(e^{j\omega}, n) \begin{pmatrix} F(e^{j\omega}, n) & \hat{F}(e^{j\omega}, n) \end{pmatrix} - m2\pi, \quad (\text{phase cond.})$$

$\hat{F}(e^{j\omega}, n)$  is the feedback path estimate.

- The class of LMS algorithms break the magnitude condition
- Freqing breaks both magnitude and phase conditions

# Freping for AFC and Frequency Warping in RT-MHA





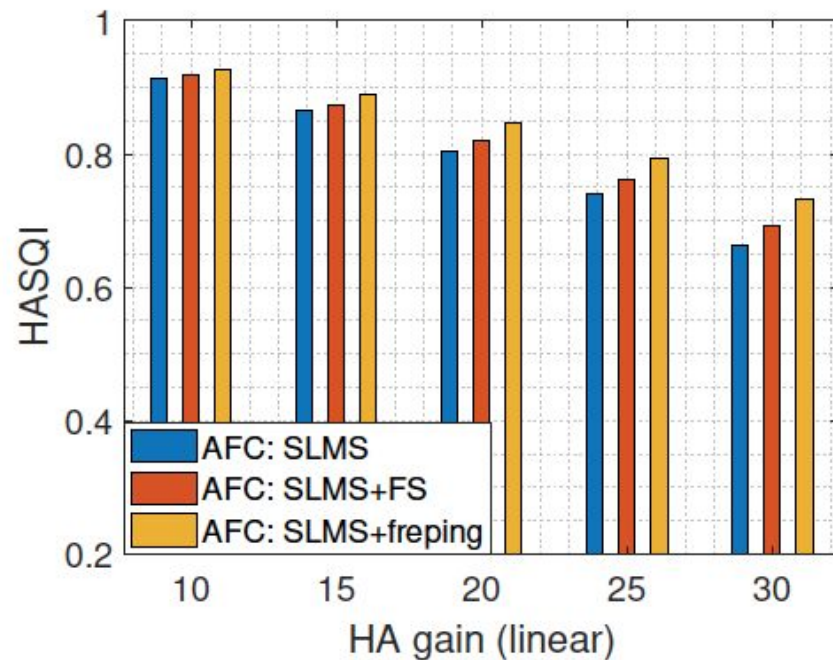
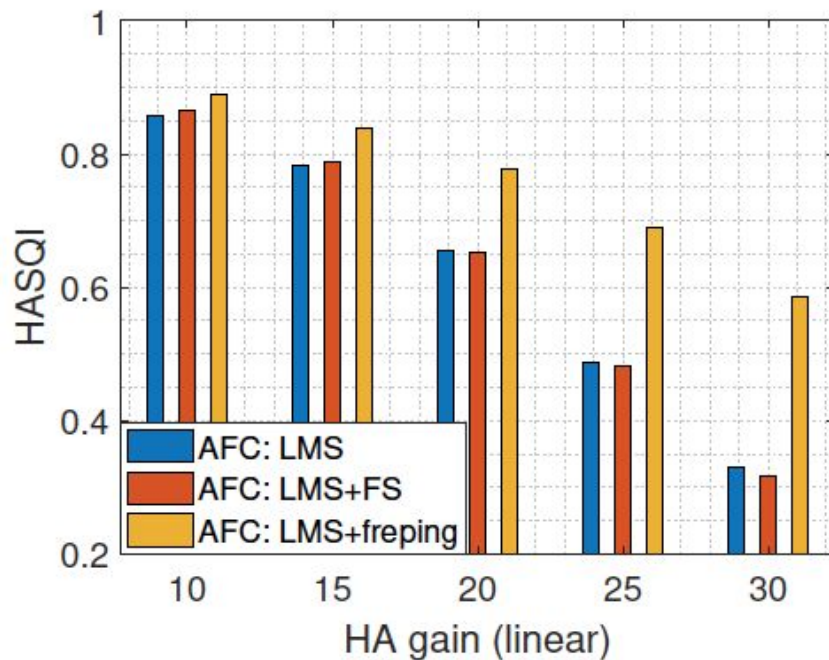
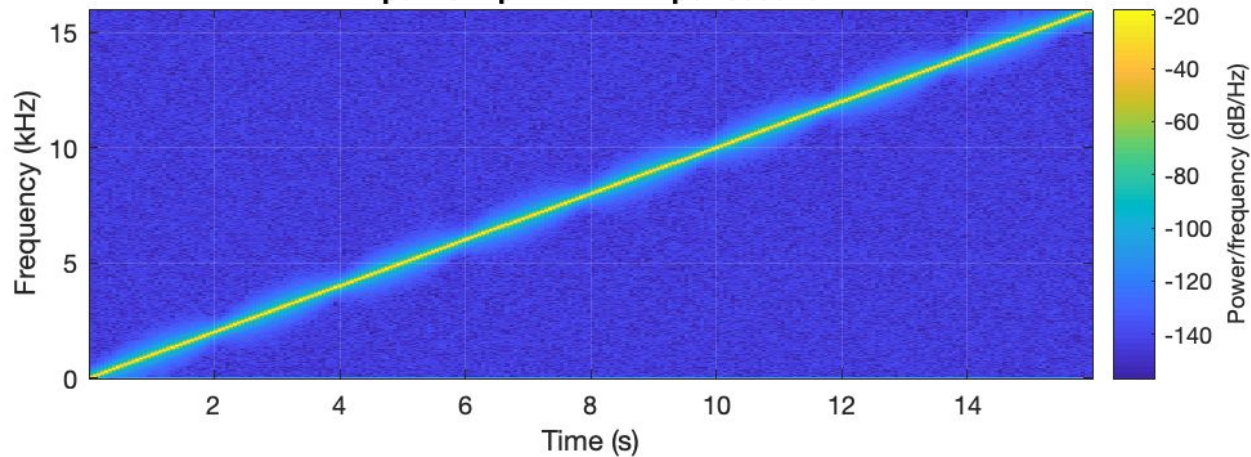


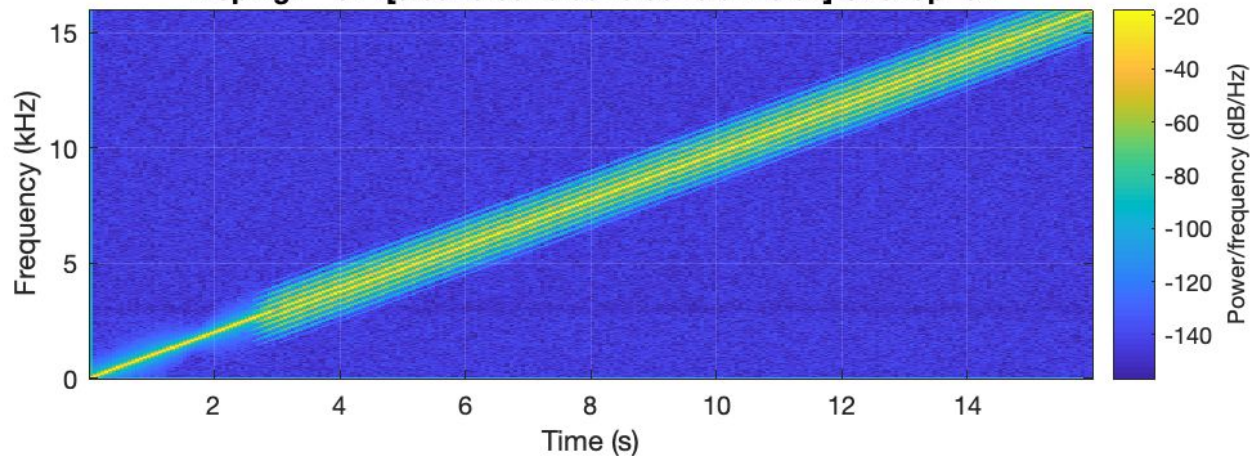
Figure 8: *HASQI comparison of feedback-compensated signal.*

Input: Chirp with 1 kHz per second

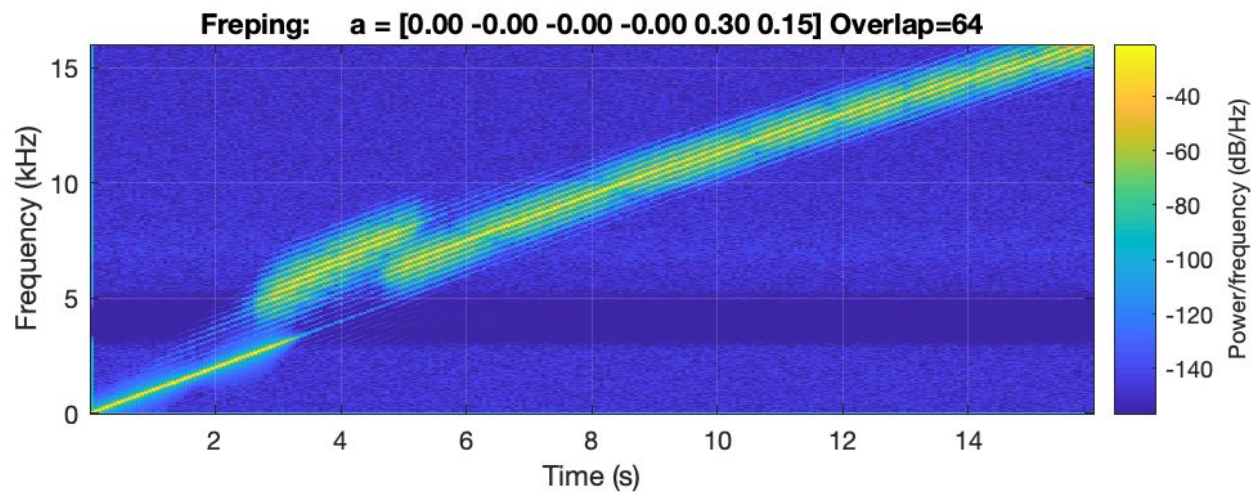
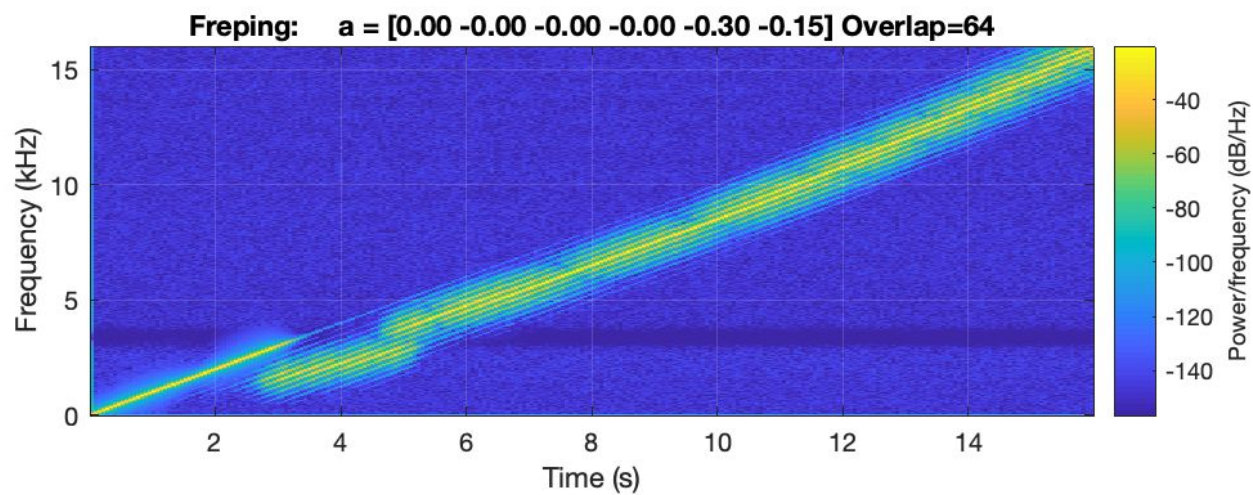


MPEG\_es01\_input.wav

Freping:  $a = [0.00 \ -0.00 \ -0.00 \ -0.00 \ -0.02 \ -0.02]$  Overlap=64



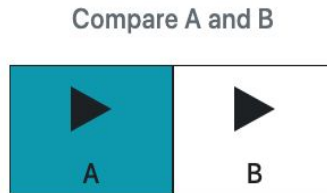
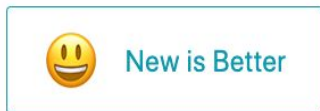
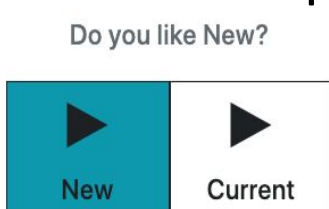
MPEG\_es01\_AFC.wav





# Machine Aided Self Fitting (Selfi) Research

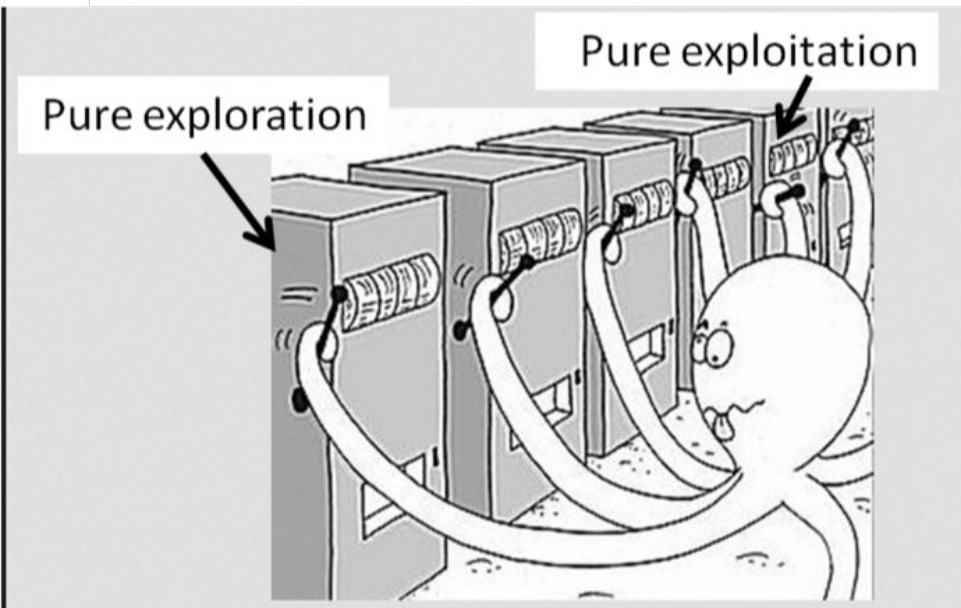
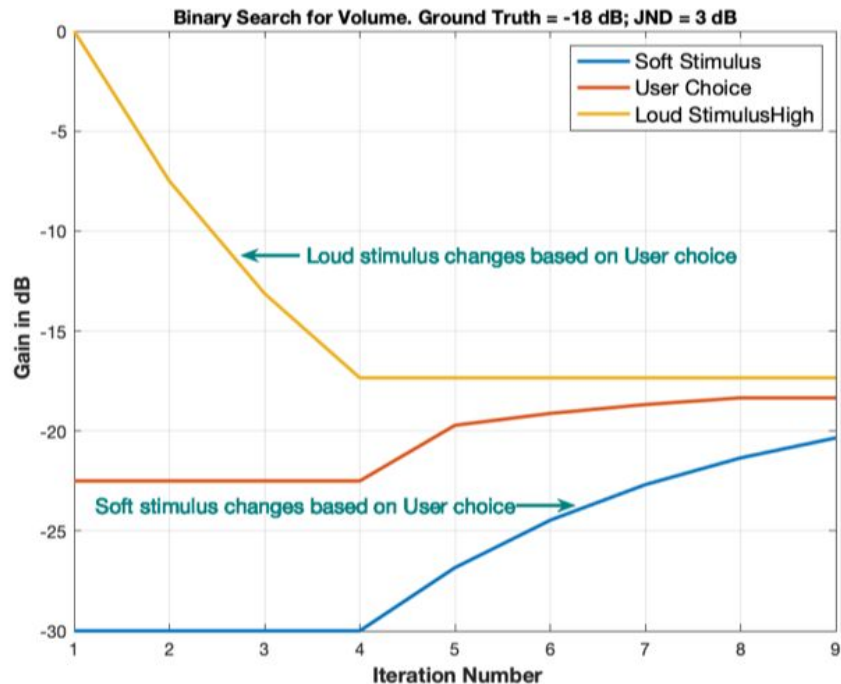
- Yeah, there's an app for that!



User preference (left) &  
Just Noticeable Differences

- {skin, skim}, {state, skate}, {peer, poor}, {lock, locks}, ...

# The Machine's Role in Selfi Research

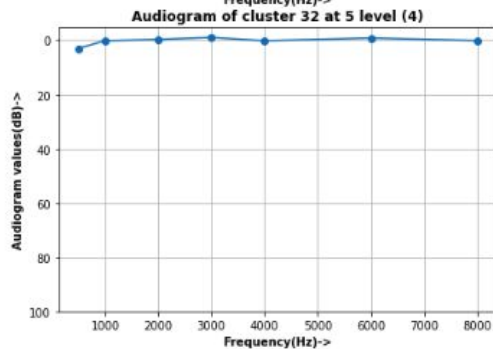
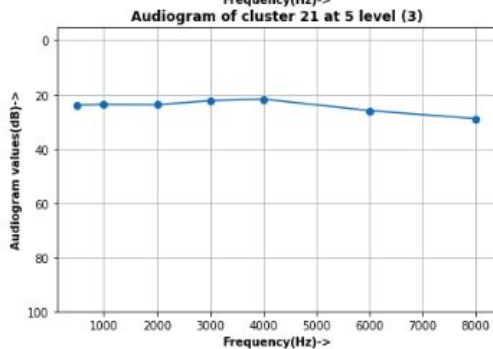
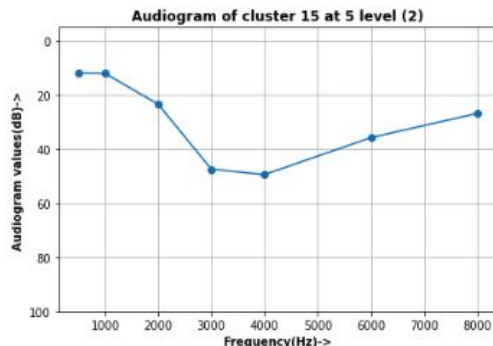
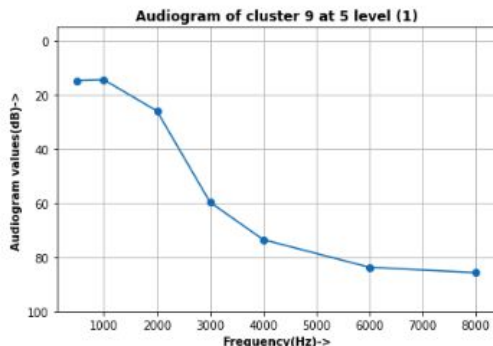


The structure of HA parameters is “known” –  
Closed form search techniques

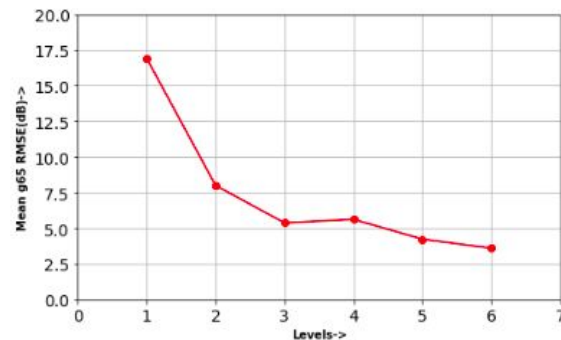
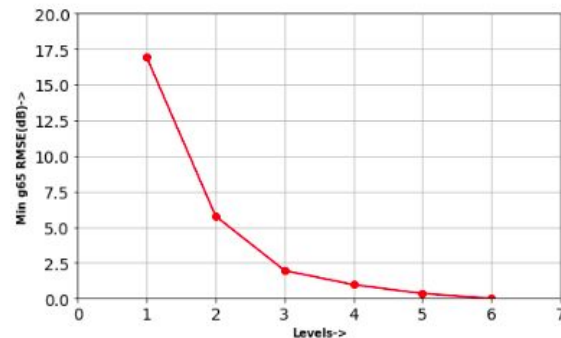
The structure of HA parameters is “unknown” –  
Stochastic search techniques

# Big Data to Rescue

## Vector Quantization based Codebook clustering



## Min(left) and Mean(right) g65 gain RMSE between all clusters vs level of clusters (256 clusters)



NHANES (~30,000 PTAs) → Clustering → NAL-NL2 prescriptions → Binary Search Tree Fitting (BSTFit) → Selfi Refinement



How to *enable psychophysical investigations beyond what is possible today? – OSP*

1. *What discoveries can clinical researchers make with the platform?*
2. *What discoveries can we translate to clinical practice?*

# Takeaway Message

- Researchers from multiple disciplines
  - leverage contributions from others to advance their domain and
- Participate in promoting hearing healthcare

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## Further details

- Wednesday Morning (Crown)
  - 3aPP3. Noise management features of the open speech platform
  - 3aPP4. Researcher and user interfaces for studies of hearing-aid self adjustment
  - 3aPP5. Open speech platform: Web-apps for hearing aids research
- Wednesday Afternoon (Crown)
  - 3pSP15. Self-fit generation of the wide range compression parameters in hearing aids
- <http://openspeechplatform.ucsd.edu/> and <https://github.com/nihospr01/OpenSpeechPlatform-UCSD>



# Backup

# Collaborators (2018)



**SAN DIEGO STATE  
UNIVERSITY**



University of Colorado  
Boulder



**Northwestern  
University**



**UNIVERSITY  
OF MINNESOTA**

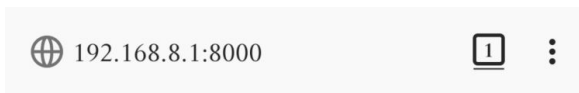


**National Acoustic  
Laboratories**  
*A Division of Australian Hearing*



**THE UNIVERSITY  
OF IOWA**

**Ryerson  
University**



## The Open Speech Platform

Webapps for research.

### Researcher Page

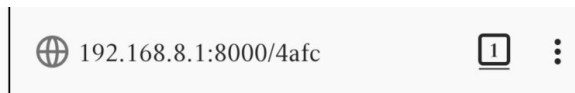
Includes amplification, noise and feedback parameters.

### Ecological Momentary Assessment (EMA)

Includes an EMA webapp, using which an end user can respond to a prompted question or set of questions.

### 4 Alternate Forced Choice (4AFC) Task

Includes a 4AFC Task webapp in which an end user can play a sound on click and select a response from 4 options.



## 4AFC Web App

Press play and select the word you hear



states

sates

state

sate

Next

### Goldilocks Researcher Page

Read ▾

Save

Save-as

Listener ID: 0000

Tester ID: 0000

Listener PIN: 0000

Control via:

CR/G65

G50/G80

AFC:

On

Off

Set

	0250	0500	1000	2000	4000	8000	All
CR	1	1	1	1	1	1	
G50	20	20	20	20	20	20	
G65	20	20	20	20	20	20	
G80	20	20	20	20	20	20	
Knee	45	45	45	45	45	45	
MPO	110	110	110	110	110	110	
Attack	5	5	5	5	5	5	
Release	100	100	100	100	100	100	
Targets	0	0	0	0	0	0	
LTASS	0	0	0	0	0	0	
Thresh	0	0	0	0	0	0	
L Mult	0	0	0	0	0	0	
H Mult	0	0	0	0	0	0	

L

V

H

Adjustments

Step

2

2

1

Num:

3

2

Min

-40

-40

-40

First:

V

H

Max

21

40

20

First:

Sequence

Volume only

2/3

Transmit

Continue

4K-250px

ID: 0000

### Self-Adjustment

CRISPNESS

Less

More

LOUDNESS

Less

More

FULLNESS

Less

More

Final Okay