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

Presented at the 178th Acoustical Society of America Meeting, December 2019

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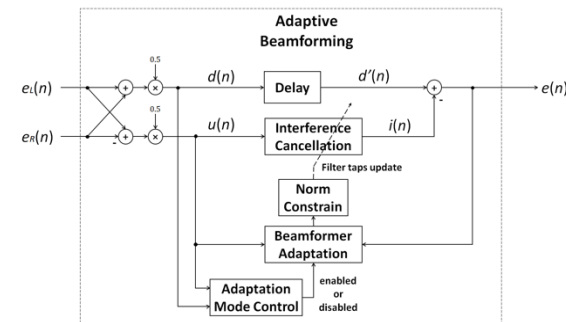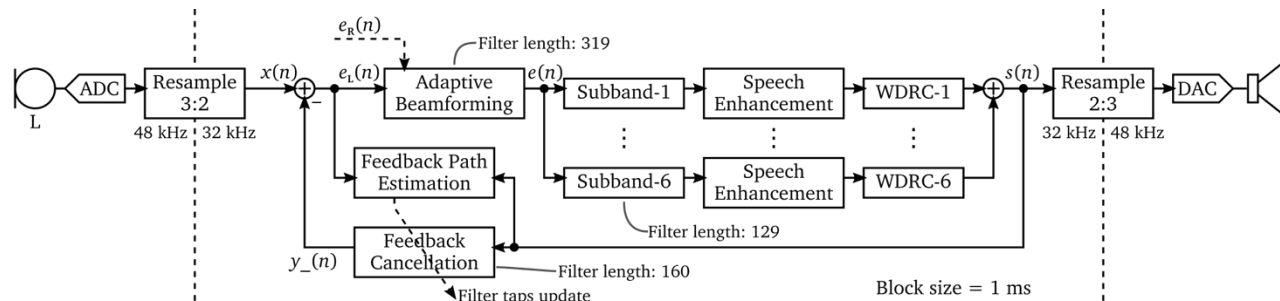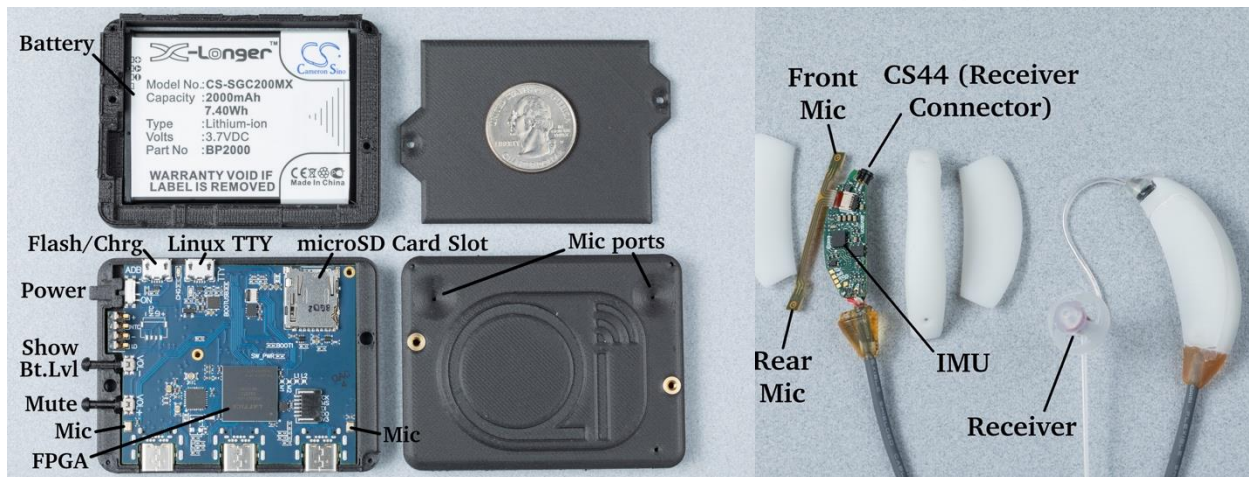University of California, San Diego

To enable psychophysical investigations beyond what is possible today

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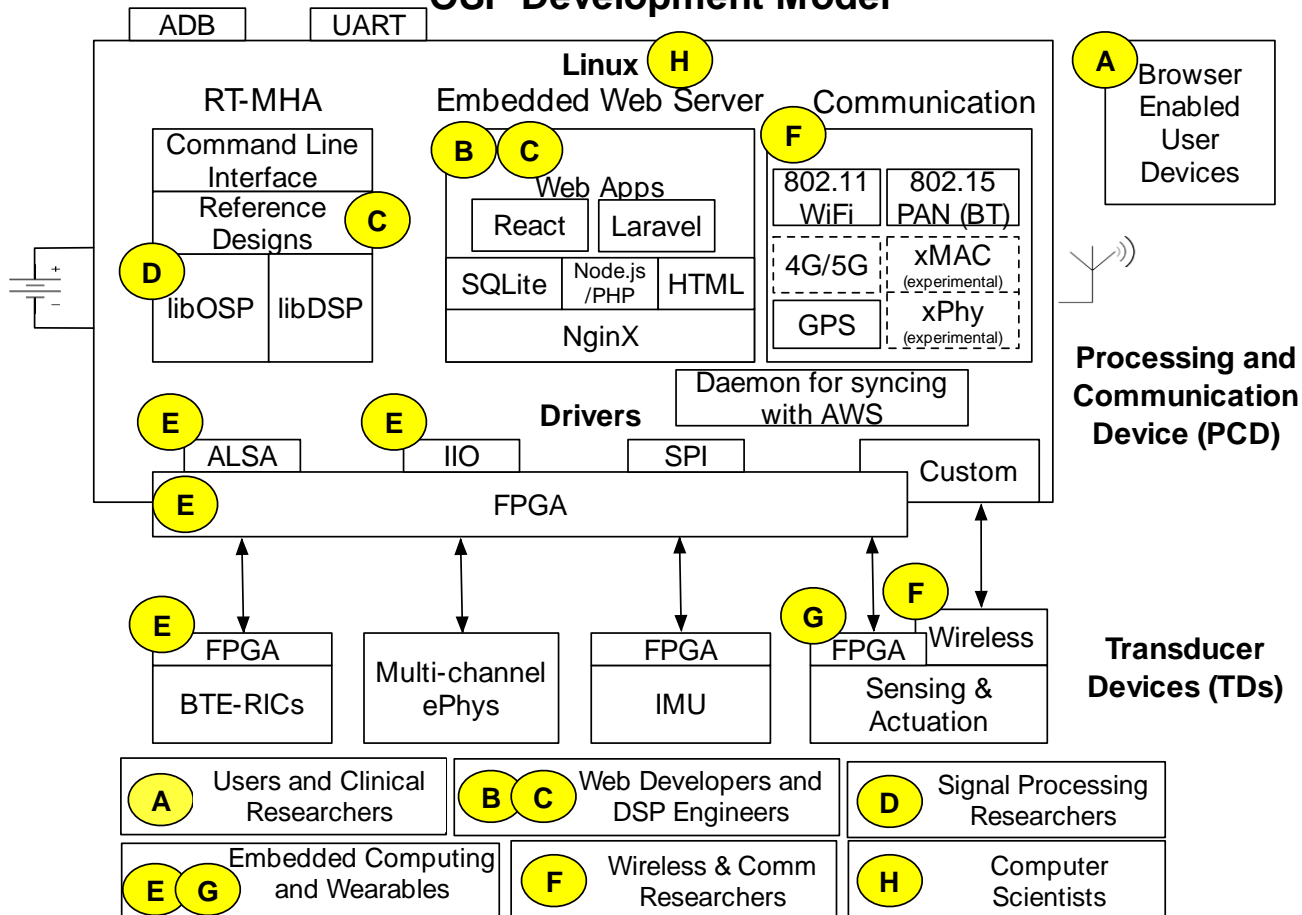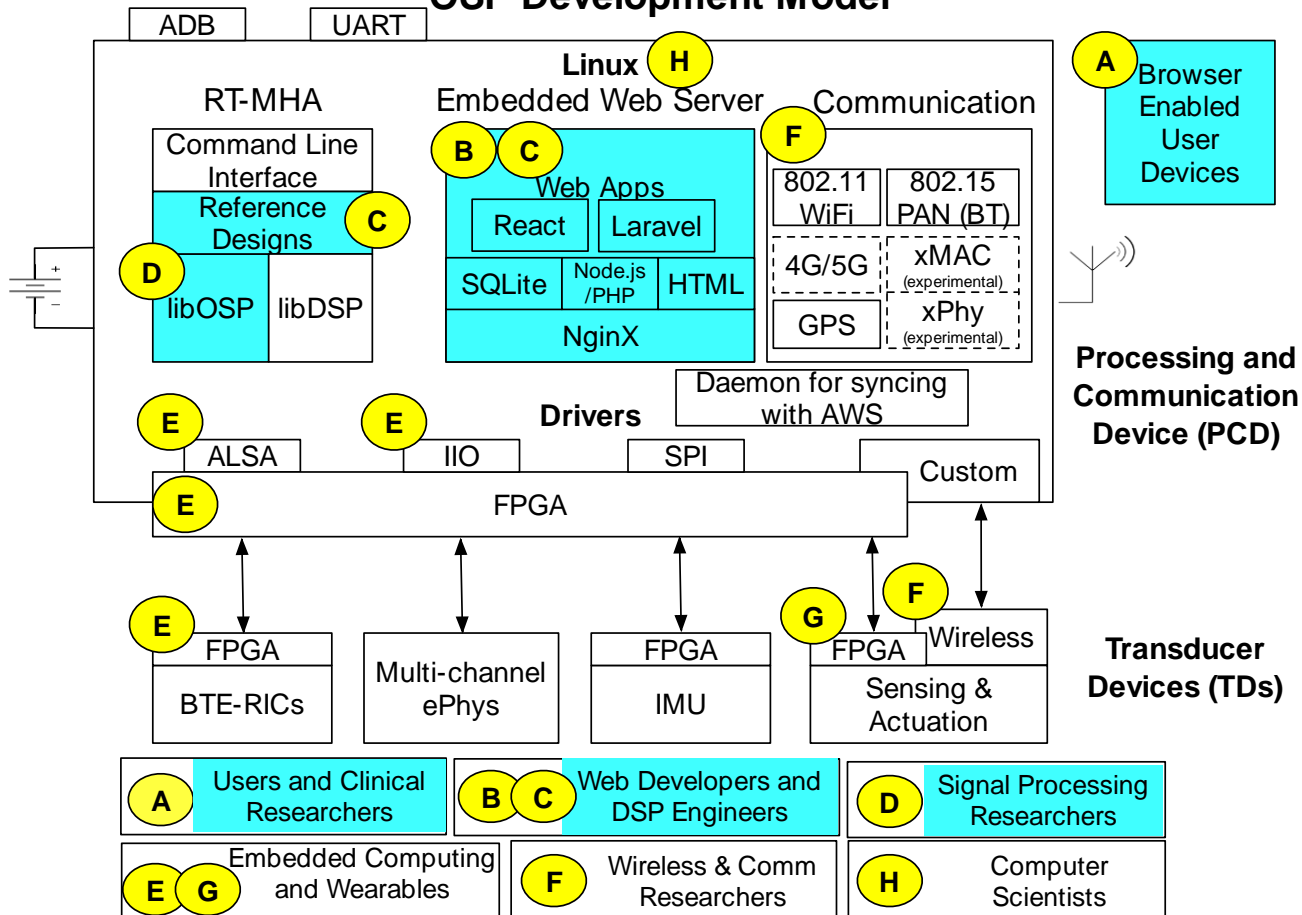Open Speech Signal Processing Platform Workshop, NIH, Bethesda, MD, Oct. 2014

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

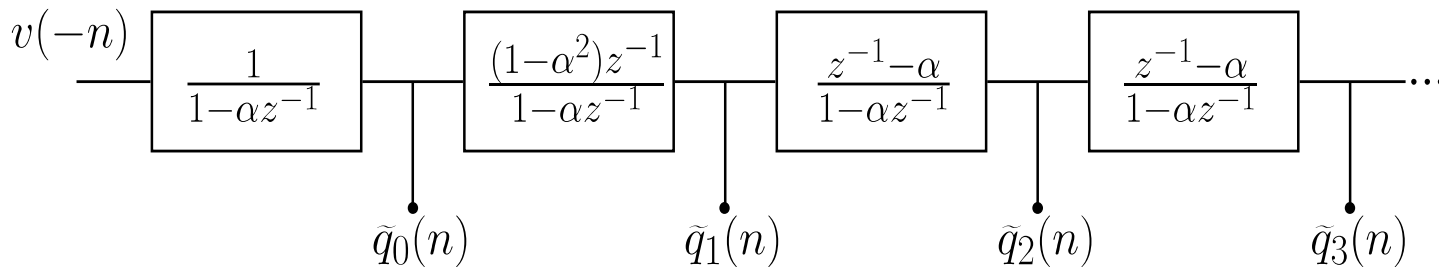OSP Development Model

OSP Development Model
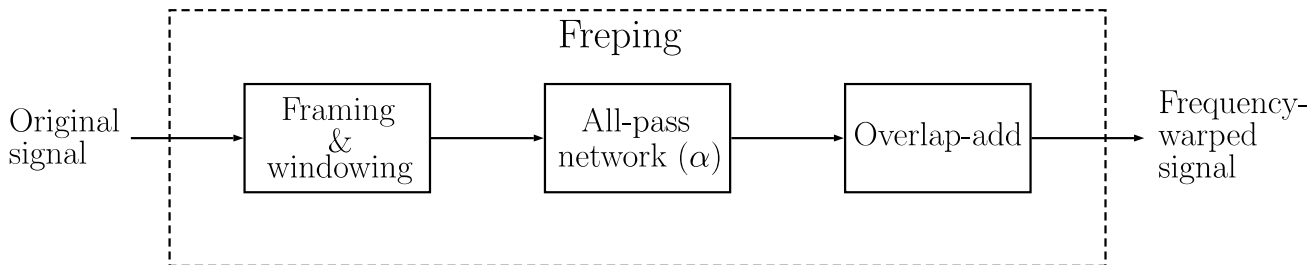
Freping – A portmanteau for **Fre**quency War**ping**

Allpass Network

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

$v(-n)$ — $\dfrac{1}{1-\alpha z^{-1}}$ — $\dfrac{(1-\alpha^2)z^{-1}}{1-\alpha z^{-1}}$ — $\dfrac{z^{-1}-\alpha}{1-\alpha z^{-1}}$ — $\dfrac{z^{-1}-\alpha}{1-\alpha z^{-1}}$ — ...

$\tilde{q}_0(n)$ $\tilde{q}_1(n)$ $\tilde{q}_2(n)$ $\tilde{q}_3(n)$

Realtime frequency warping

Freping

Original signal → Framing & windowing → All-pass network (α) → Overlap-add → Frequency-warped signal

When do Hearing aids howl? Nyquist Stability Criteria (NSC) due to acoustic feedback
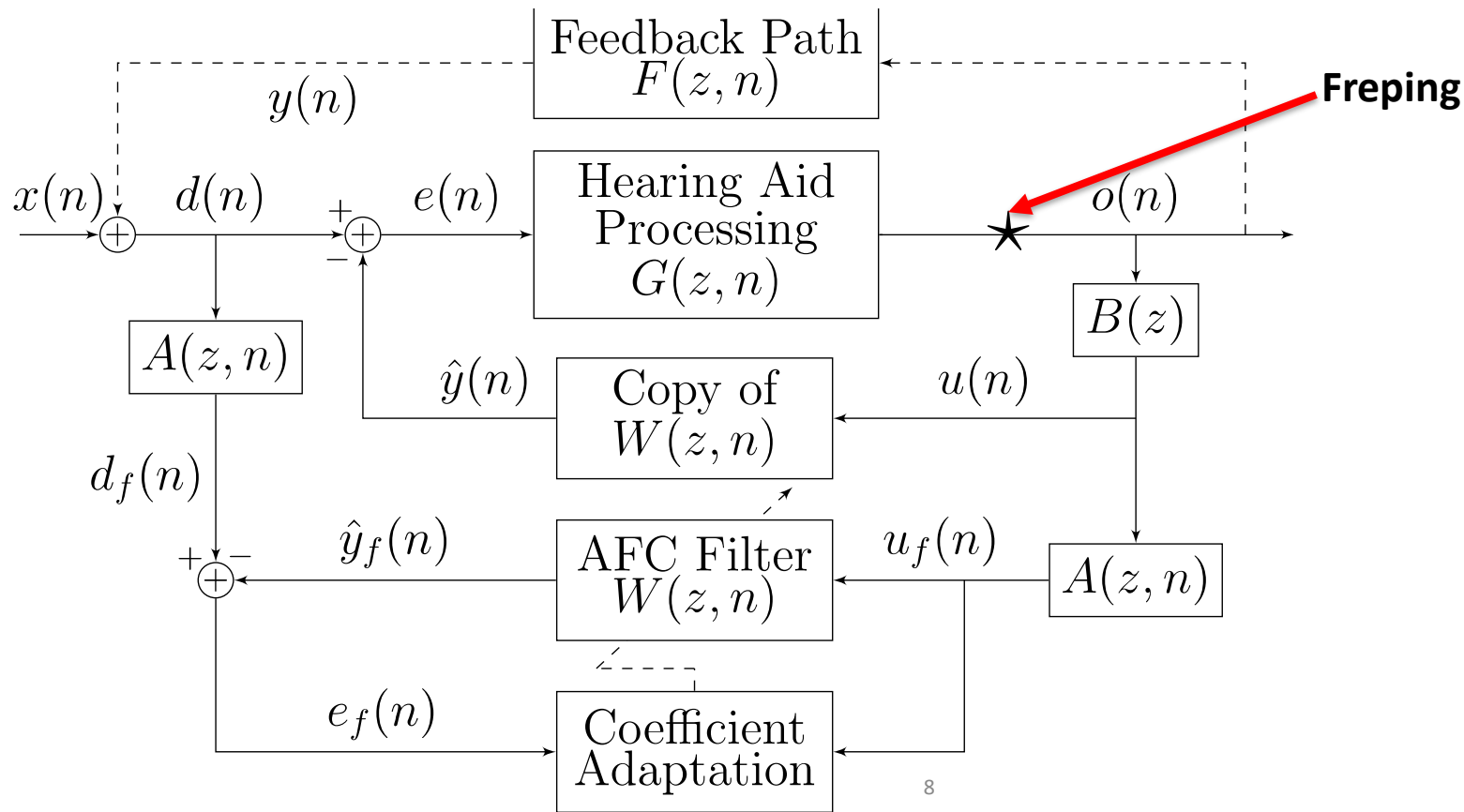
$$\left| G(e^{j\omega}, n) \left(F(e^{j\omega}, n) - \hat{F}(e^{j\omega}, n) \right) \right| \geq 1, \quad \text{(magnitude cond.)}$$

$$\angle G(e^{j\omega}, n) \left(F(e^{j\omega}, n) - \hat{F}(e^{j\omega}, n) \right) = m2\pi, \quad \text{(phase cond.)}$$

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

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

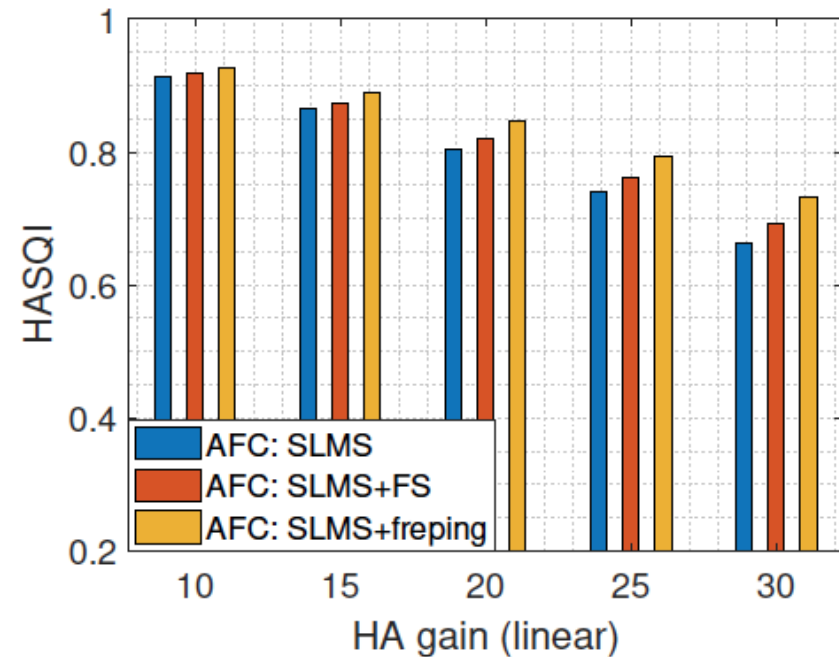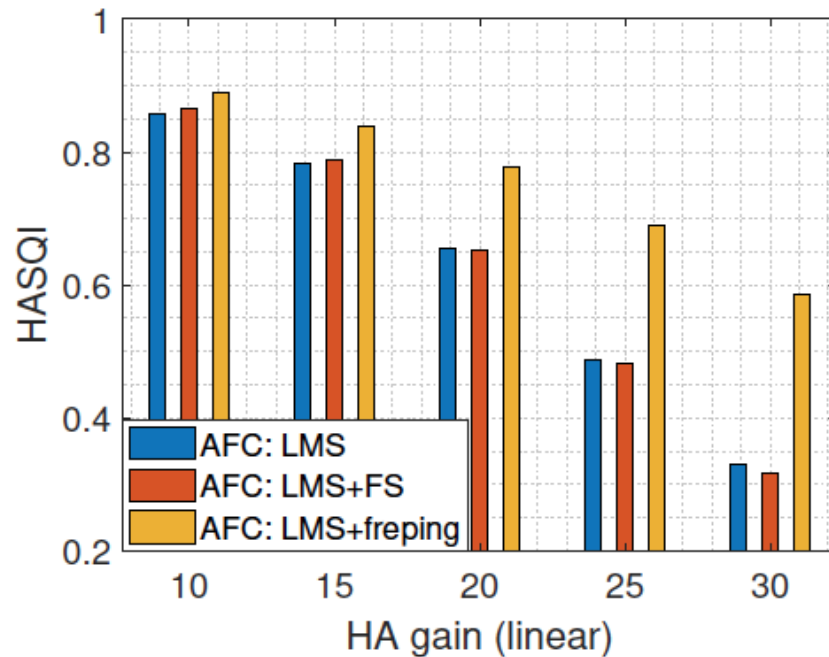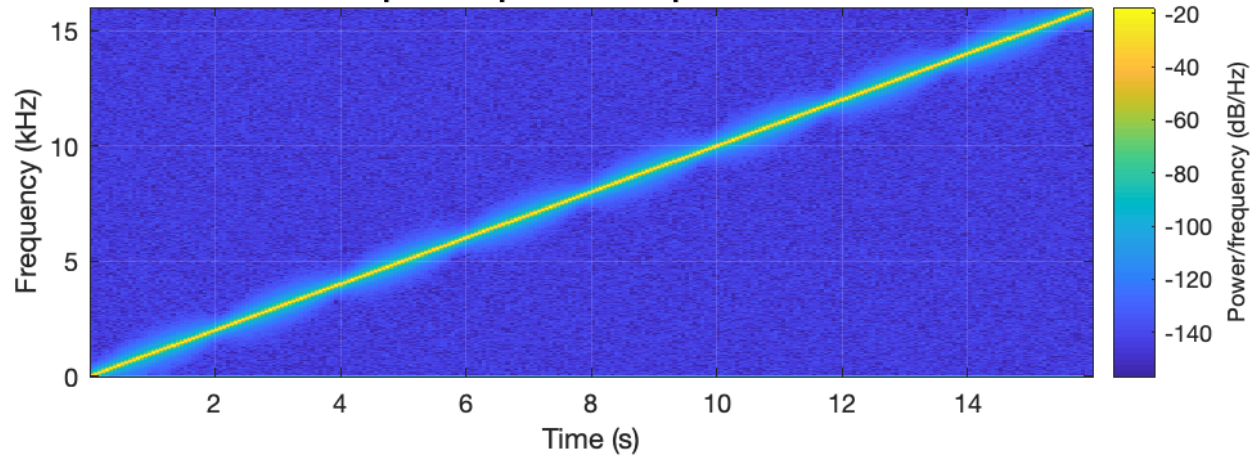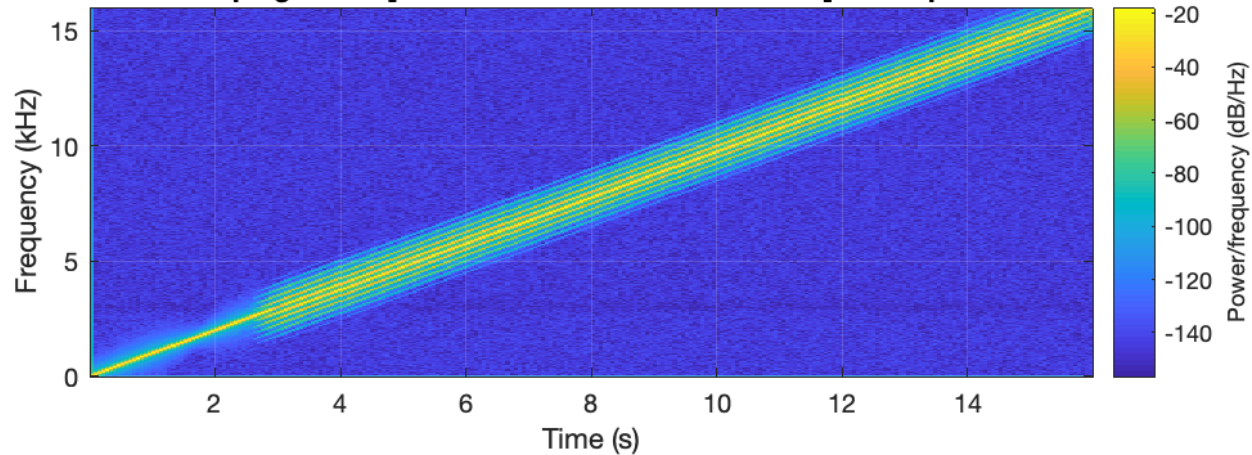# Freping for AFC and Frequency Warping in RT-MHA

Figure 8: *HASQI comparison of feedback-compensated signal.*
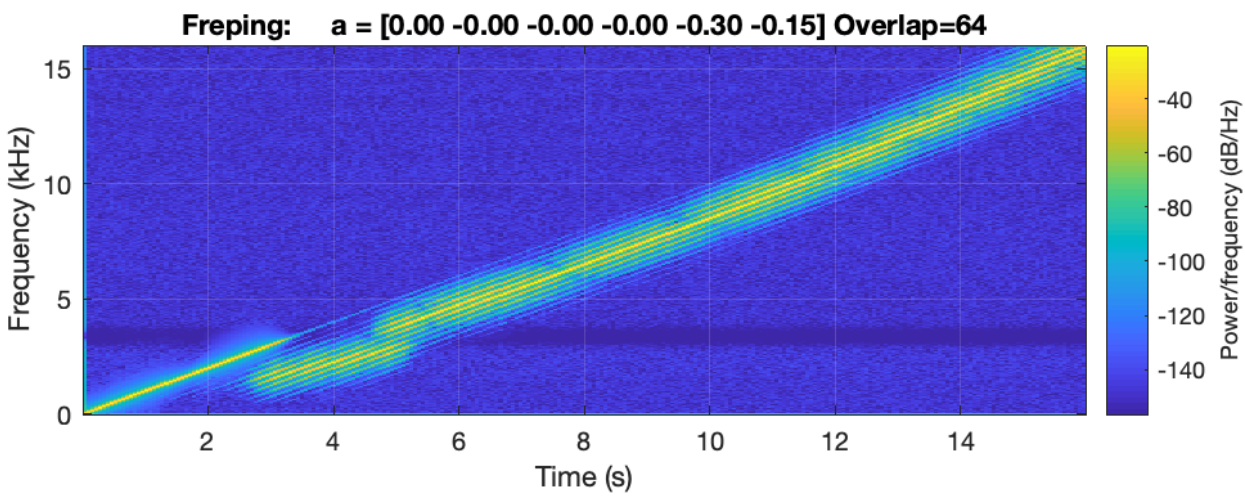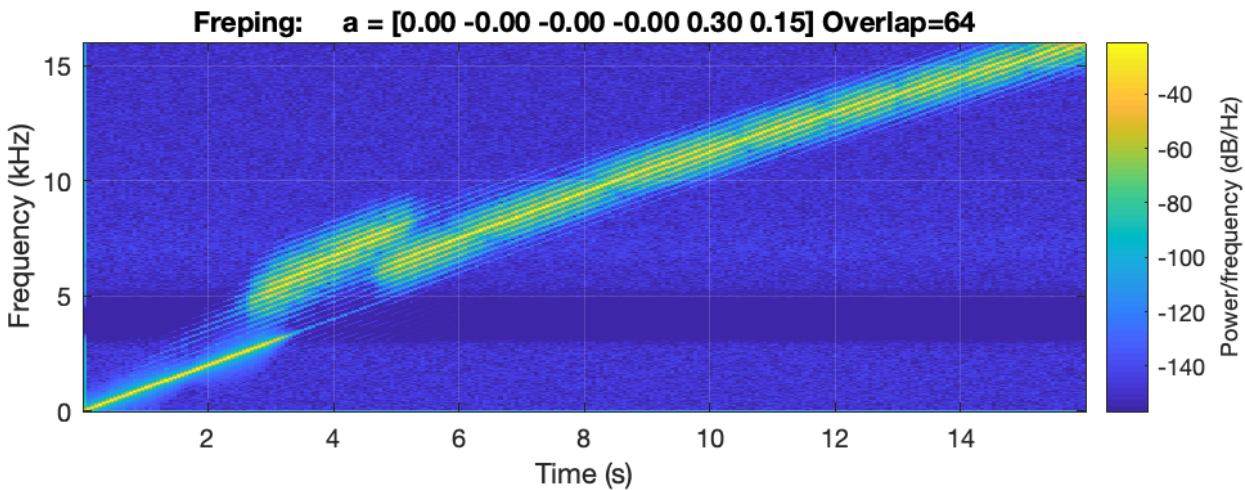
Input: Chirp with 1 kHz per second

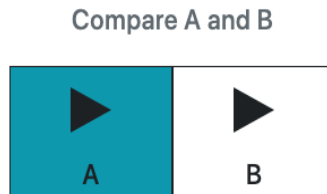Freping: a = [0.00 -0.00 -0.00 -0.00 -0.02 -0.02] Overlap=64

MPEG_es01_input.wav

MPEG_es01_AFC.wav

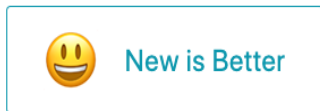**Freping: a = [0.00 -0.00 -0.00 -0.00 -0.30 -0.15] Overlap=64**

MPEG_es01_FL.wav
(frequency lowering in bands 4, 5)

Freping: a = [0.00 -0.00 -0.00 -0.00 0.30 0.15] Overlap=64

MPEG_es01_FU.wav
(frequency increasing in bands 4, 5)

Machine Aided Self Fitting (Selfi) Research

- Yeah, there's an app for that!

Do you like New?

New | Current
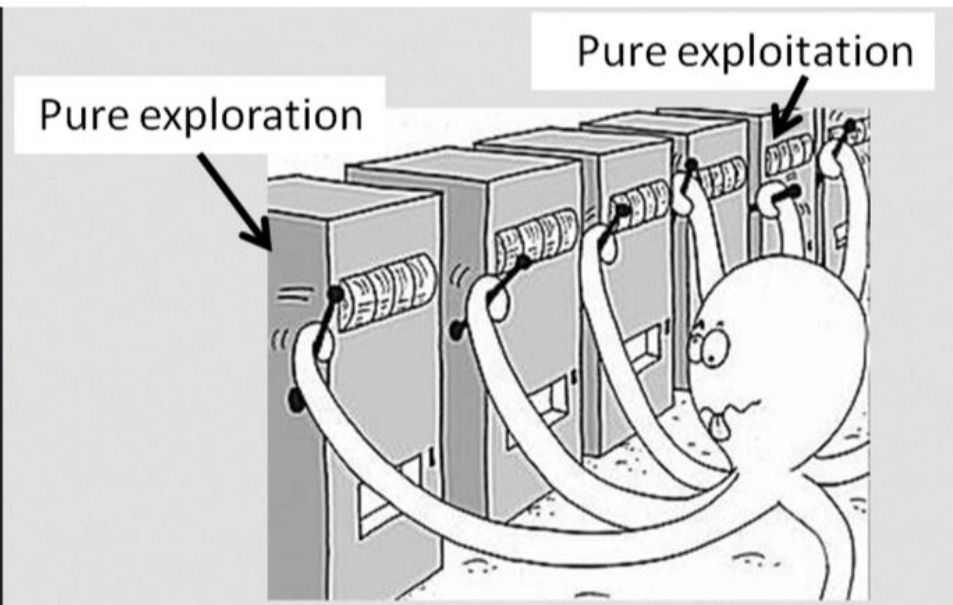
😃 New is Better

😞 New is Worse

✅ Both are Same

Compare A and B

A | B

Same
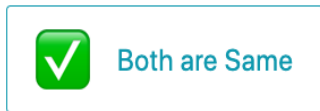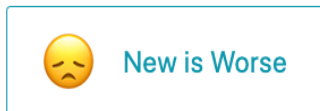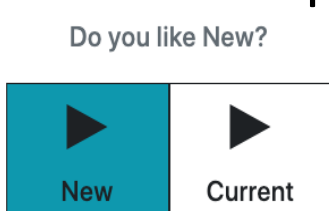
Different
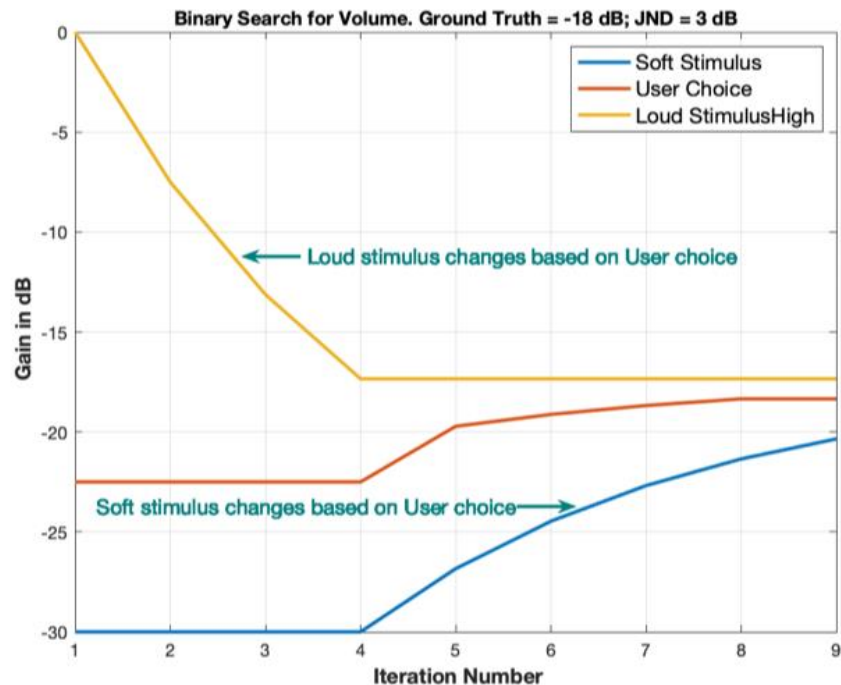
User preference (left) &

Just Noticeable Differences

- {skin, skim}, {state, skate}, {peer, poor}, {lock, locks}, …
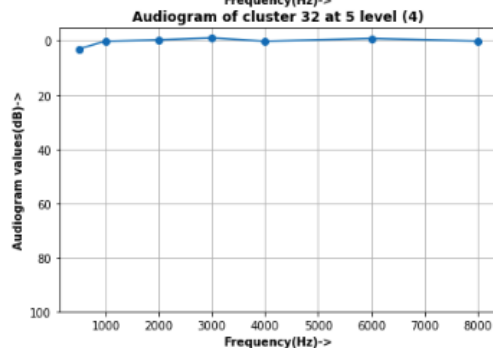
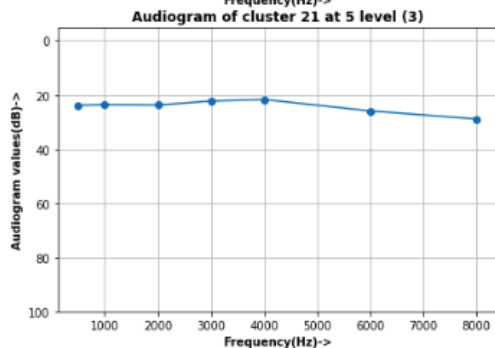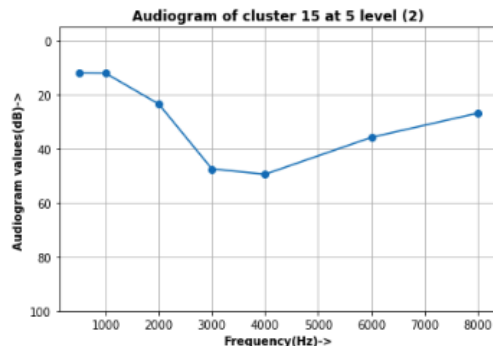# The Machine's Role in Selfi Research

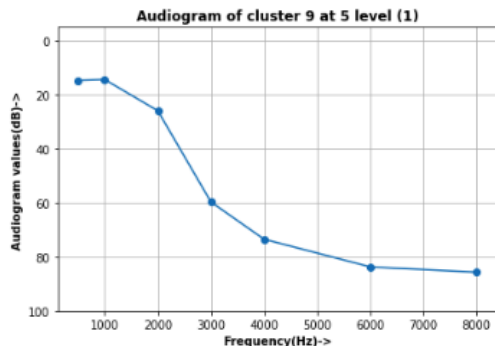Binary Search for Volume. Ground Truth = -18 dB; JND = 3 dB

The structure of HA parameters is "known" – Closed form search techniques
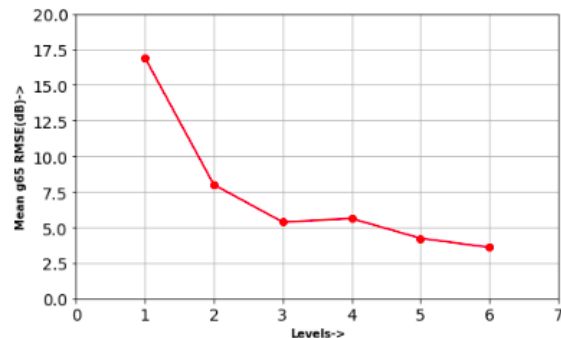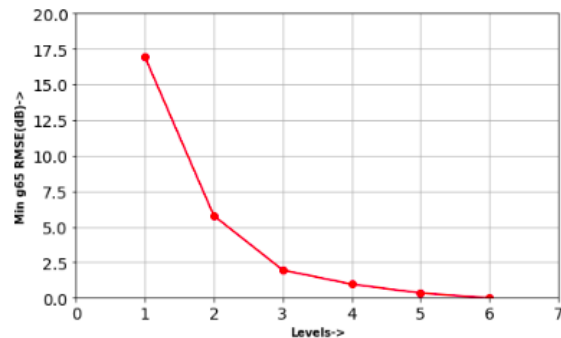
The structure of HA parameters is "unknown" – Stochastic search techniques

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

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)

UC San Diego
QUALCOMM INSTITUTE

192.168.8.1:8000

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.

192.168.8.1:8000/4afc

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

Trasmit	Continue

ID: 0000

Self-Adjustment

CRISPNESS
| Less | More |

LOUDNESS
| Less | More |

FULLNESS
| Less | More |

| Final Okay |