Machine Learning and Signal Processing Technologies for Assistive Hearing Devices

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Assistive Technology: Assistive Listening and Speaking Devices (by Dr. Yu Tsao)

FM system

- Conventional FM systems
- Smarthear
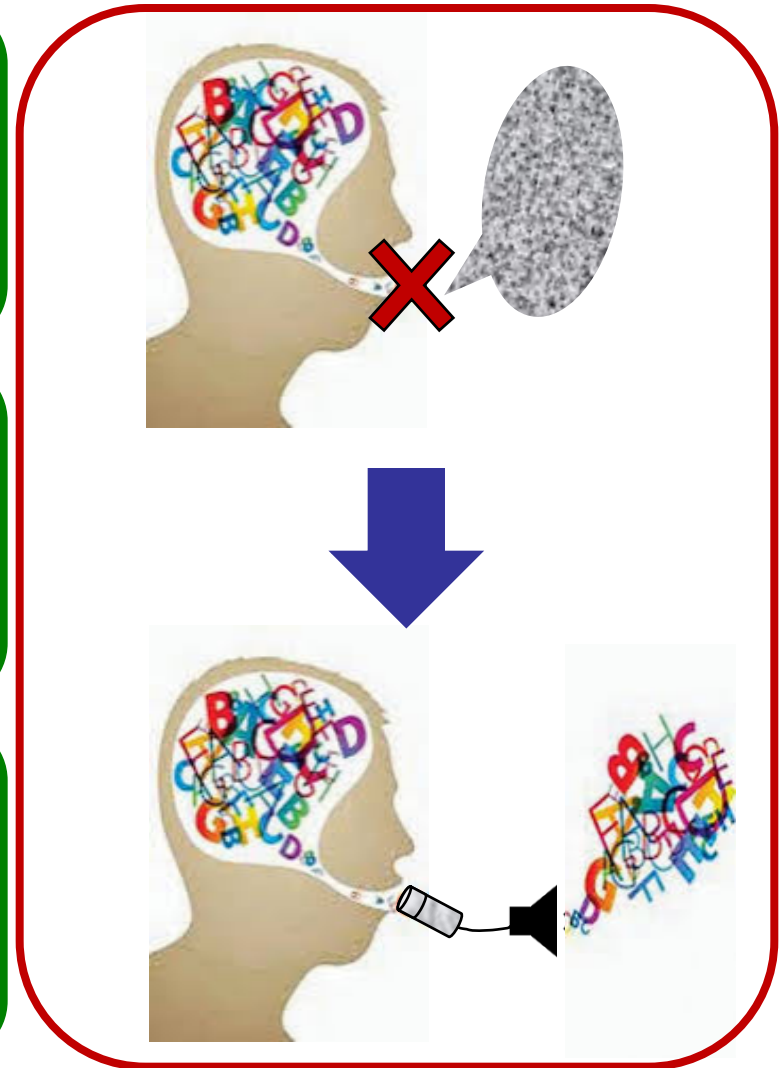- Two modes of Smarthear

Hearing aids

- Current issues
- Noise reduction (NR)
- Amplification scheme (AS)

Cochlear implants

- Signal processing of CI
- Current issues
- Noise reduction (NR)

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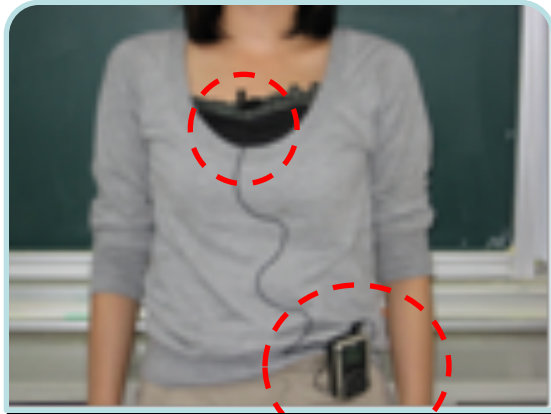- Noise reduction (NR)
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Conventional FM System

Speaker wears microphone and transmitter

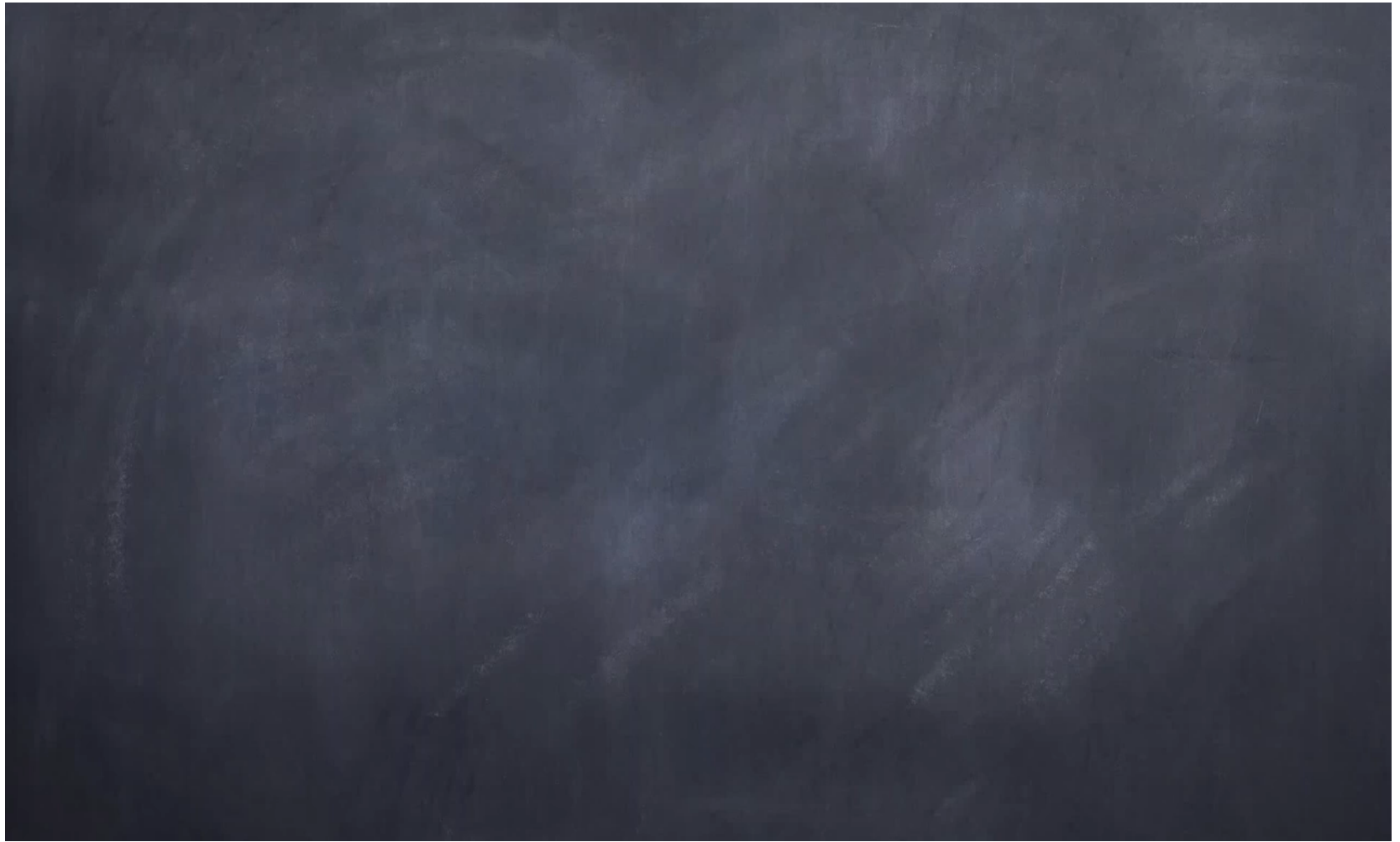A direct receiver for individuals with minor hearing loss

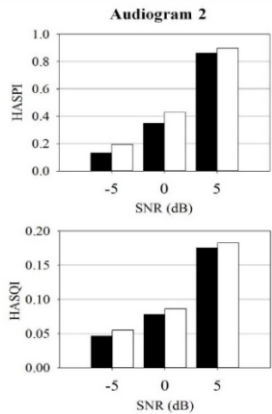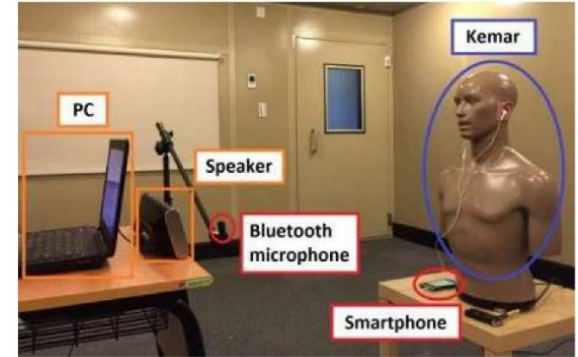Receiver plus an HA for individuals with more severe hearing loss

➢ Speaker and listeners must wear the additional systems
➢ Stigma and inconvenience
➢ High cost: ~ 80,000 NTD（microphone+ transmitter+ receiver）

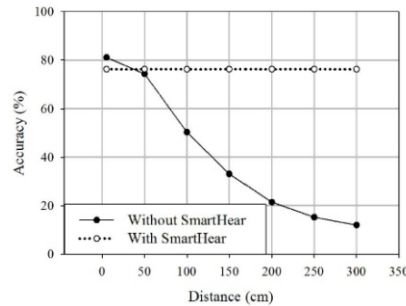➡ Smarthear: smartphone-based FM system

SmartHear

SmartHear 2.0

Hearing test

Speech recognition test

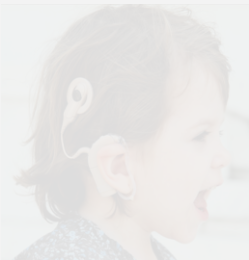# Assistive Technology: Assistive Listening and Speaking Devices (by Dr. Yu Tsao)

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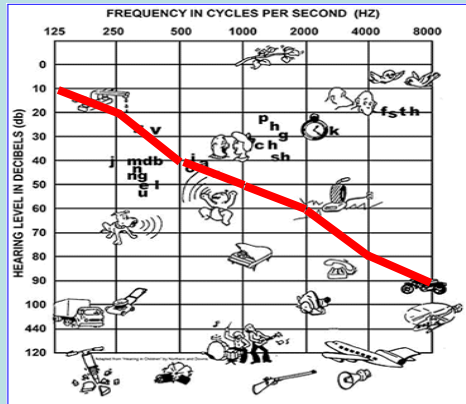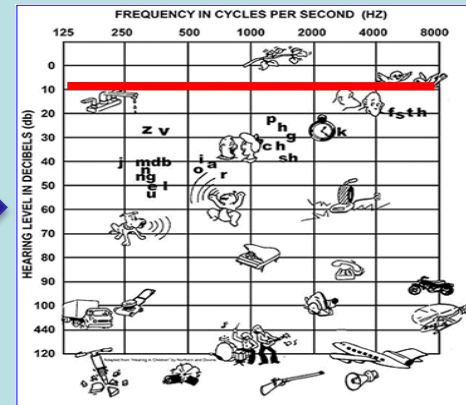- Current issues
- Noise reduction (NR)

Hearing Aids

Only enlarge the volume is not enough!
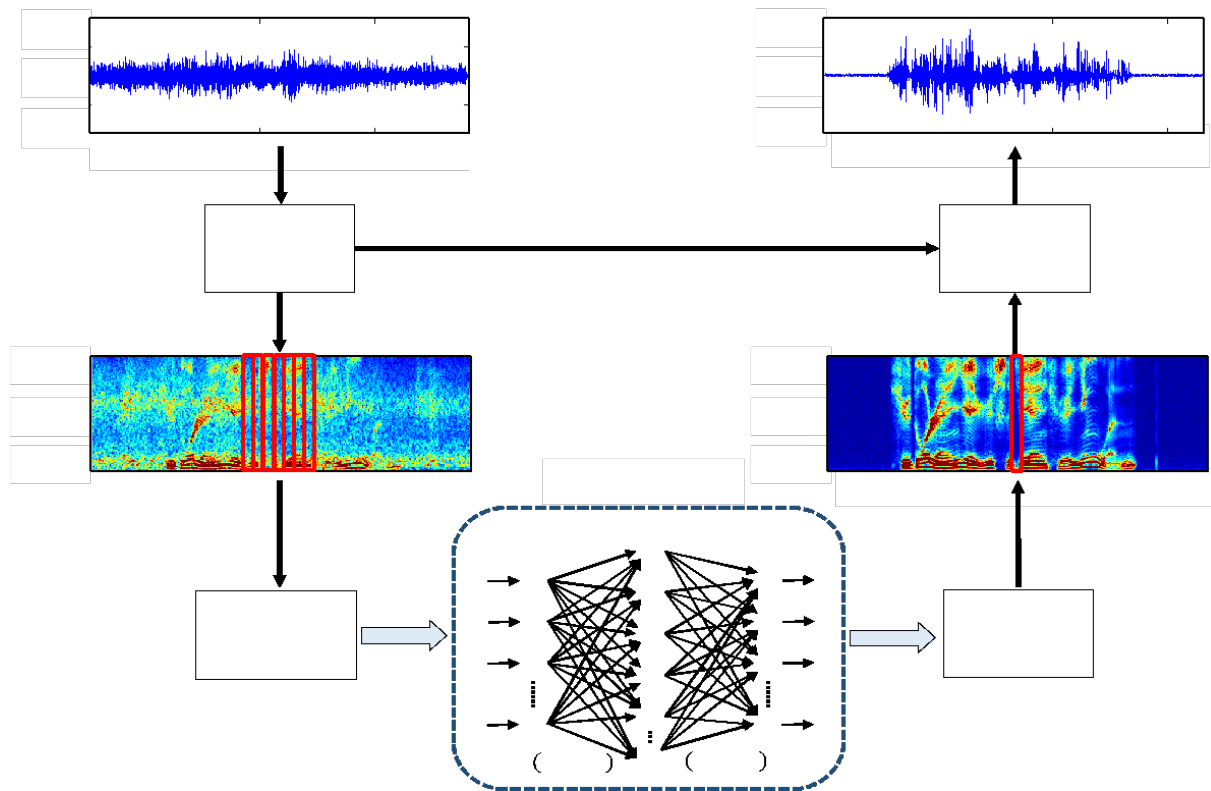
Audiograms

Hearing loss → Normal hearing

A Critical Issue of HA

- Kochkin investigated the users' satisfaction of hearing instrument in United States that the first prevalent requirements was :
  - ➢ **95%** of hearing aid user seek the improvement to listen speech in noise.
- The hearing-impaired person **needs a better signal-to-noise ratio (SNR)** than that of a normal-hearing person.
- We proposed to use the **DL-based noise reduction (NR) methods** in digital hearing aids.
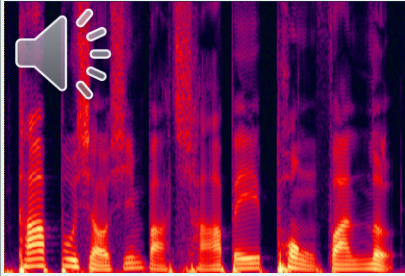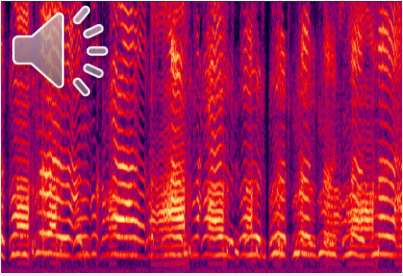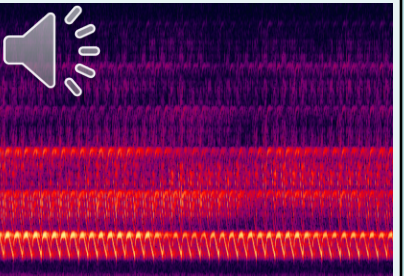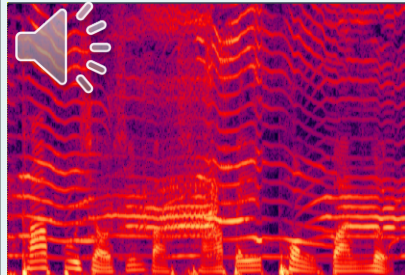
DL in Speech Signal Processing
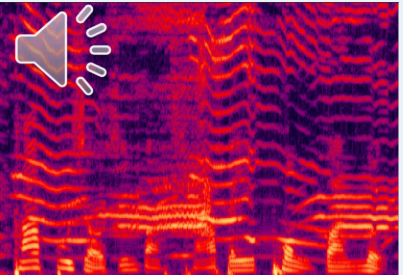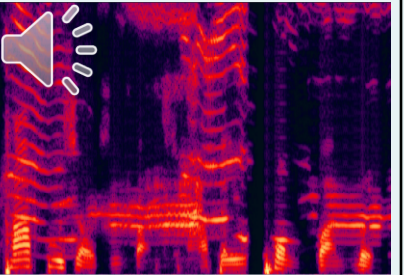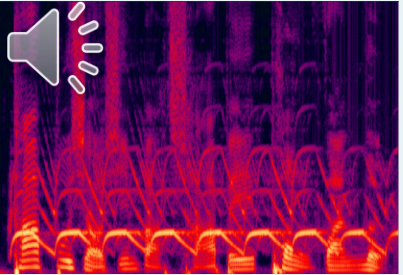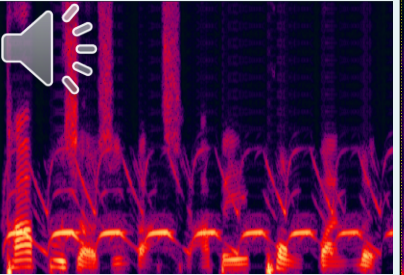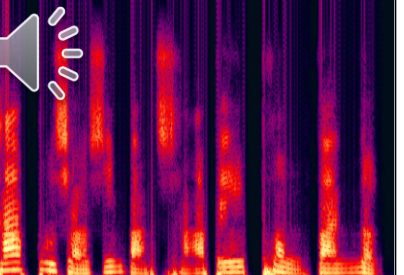
$$\theta^* = \arg\min_{\theta}\left(F(\theta) + \eta^1\left\|\boldsymbol{W}^1\right\|_F^2 + \cdots + \eta^L\left\|\boldsymbol{W}^L\right\|_F^2\right),$$
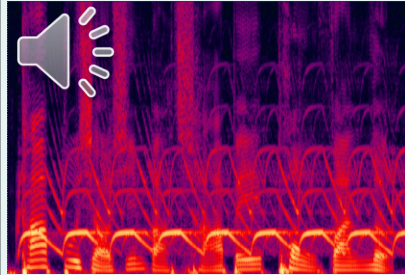
$$F(\theta) = \frac{1}{M}\sum_{m=1}^{M}\left\|\boldsymbol{X}_m^{LPS} - \widehat{\boldsymbol{X}}_m^{LPS}\right\|_2^2,$$

➢ X. Lu, Y. Tsao, S. Matsuda and C. Hori, "Speech Enhancement based on Deep Denoising Autoencoder," Interspeech 2013.

Denoising

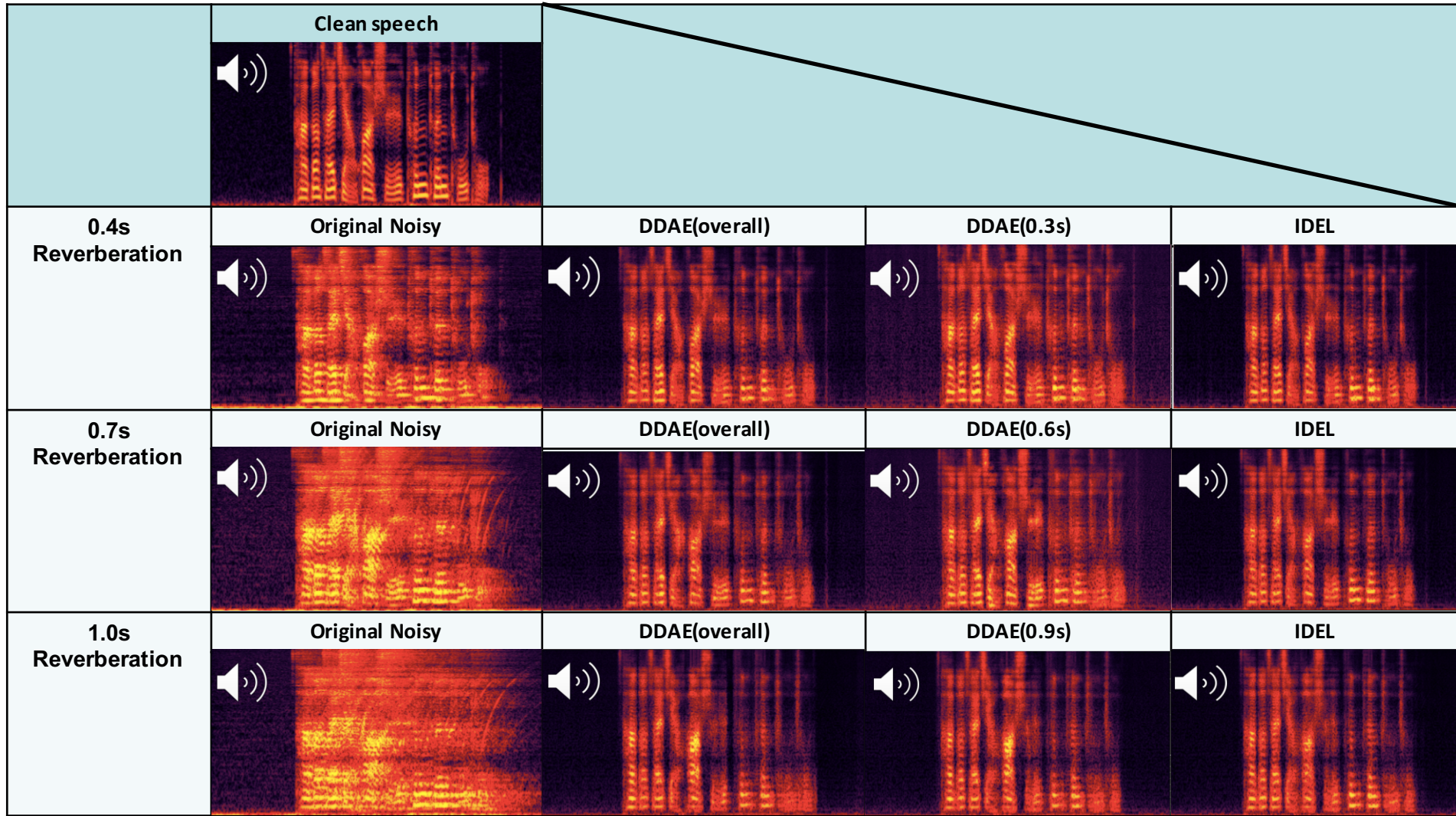|	Clean speech	Noise: 2baby Crying	Noise: Siren	
2baby Crying	Original Noisy	MMSE (Trandtional-1)	KLT (Trandtional-2)	DDAE
Siren	Original Noisy	MMSE (Trandtional-1)	KLT (Trandtional-2)	DDAE

De-reverbaration

	Clean speech			
0.4s Reverberation	Original Noisy	DDAE(overall)	DDAE(0.3s)	IDEL
0.7s Reverberation	Original Noisy	DDAE(overall)	DDAE(0.6s)	IDEL
1.0s Reverberation	Original Noisy	DDAE(overall)	DDAE(0.9s)	IDEL

Evaluation Results (Subject Tests)
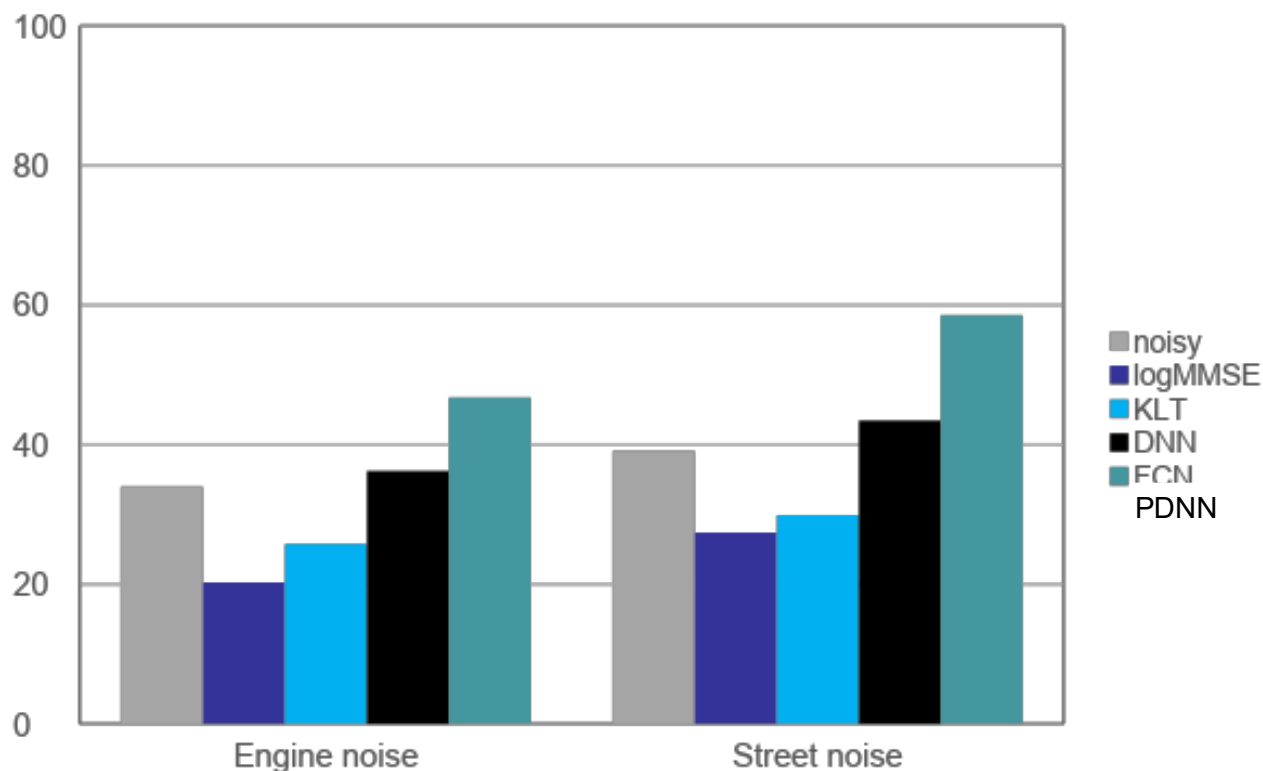
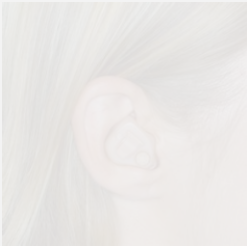Clinical trial: 8 CI subjects.

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Cochlear Implant (CI)

- Surgically implanted device that **electrically stimulates** surviving auditory nerve fibers to provide sound for those with **severe hearing loss.**

- Over **200,000** users worldwide.

- FDA approved in 1985, now approved for children as young as **12 months.**
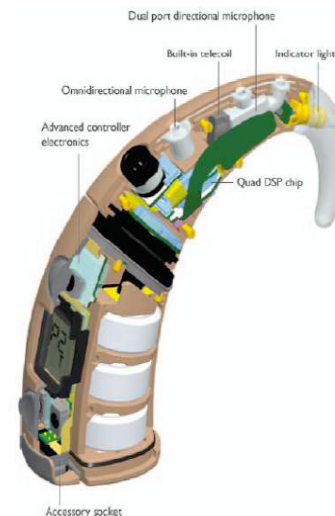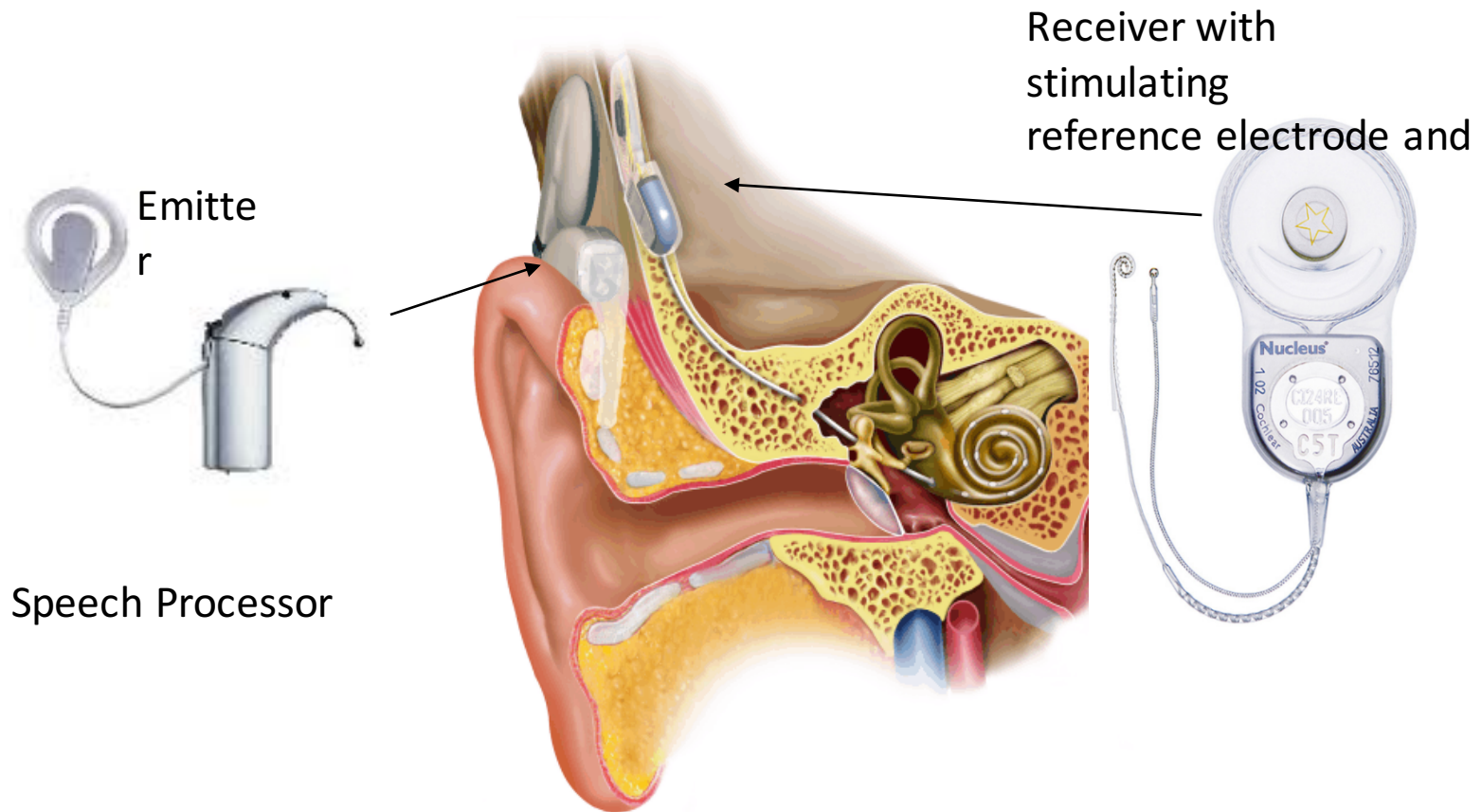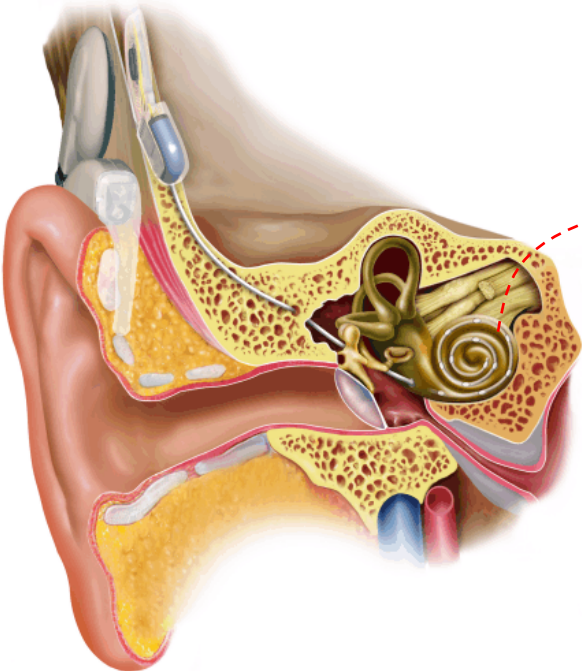
CI Device

Transmitter coil

Speech processor:
1. Microphone.
2. DSP chip.
3. Battery
4. Others…

CI Device

Emitter

Speech Processor

Receiver with stimulating reference electrode and

CI Device

Traveling wave theory

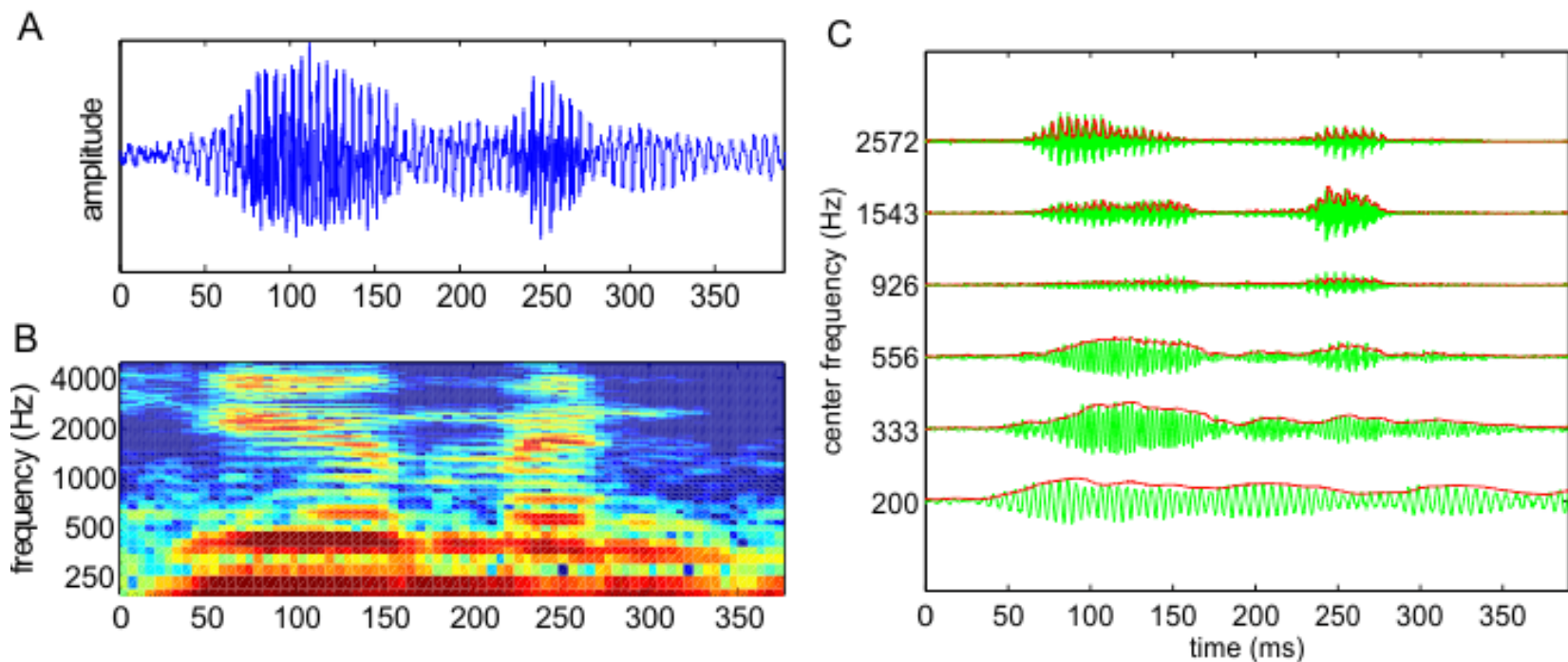NOBEL PRIZE WINNER
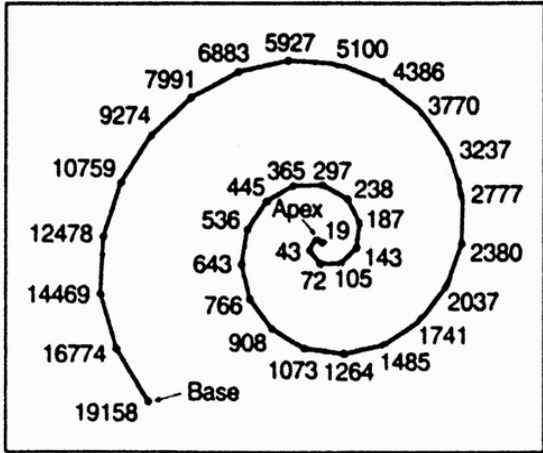
1961

Von Békésy, Georg (1960). Experiments in hearing. Ed. Ernest Glen Wever. Vol. 8. New York: McGraw-Hill.

Bandpass and Envelope Extraction

(A) Waveform of the word "human" spoken by a native American speaker. (B) Spectrogram of the same word. (C) Green lines: Output of a set of six bandpass filters in response to the same word. The filter spacing and bandwidth in this example are two-thirds of an octave.

A Critical Issue of CI

- The tremendous progress of CI technologies in the past three decades has enabled many CI users to enjoy **high level** of speech understanding **in quiet**.

- For most CI users, however, the performance of speech understanding **in noise** still remains **challenging**.

  ➢F. Chen, Y. Hu, and M. Yuan, "Evaluation of Noise Reduction Methods for Sentence Recognition by Mandarin-Speaking Cochlear Implant Listeners," Ear and hearing, vol. 36, no. 1, pp. 61-71, 2015.
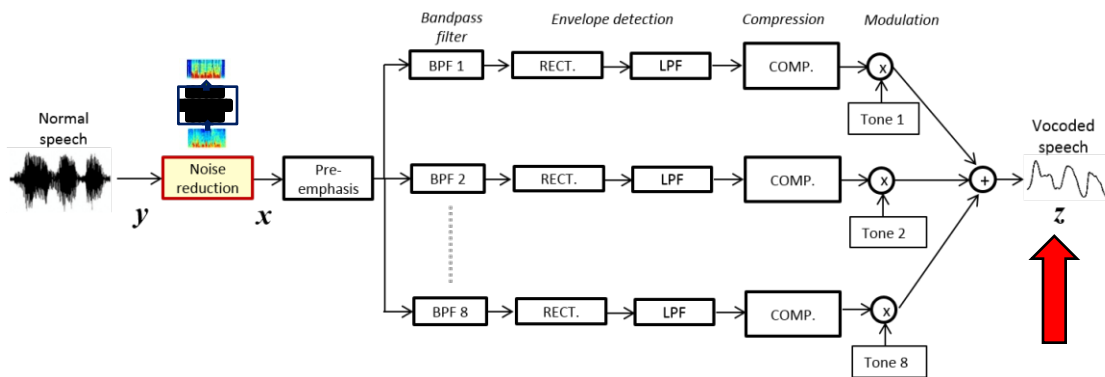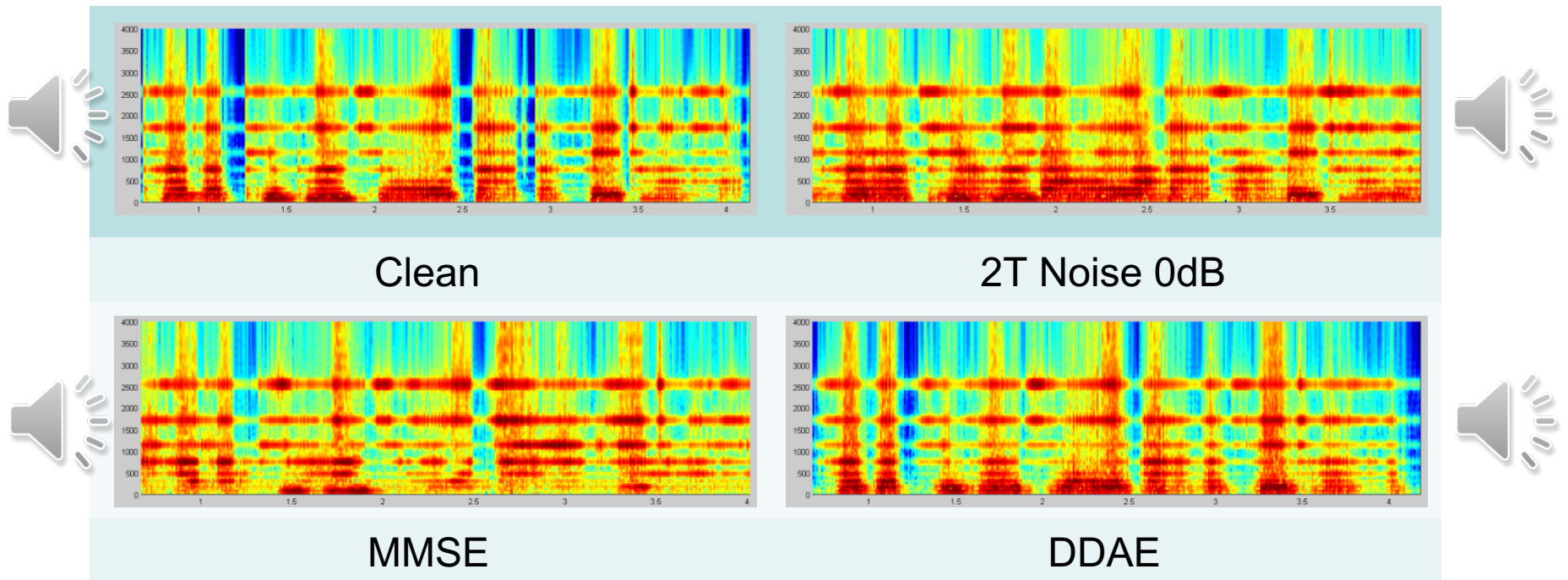
- **Deep learning** based speech enhancement (SE) for CI.
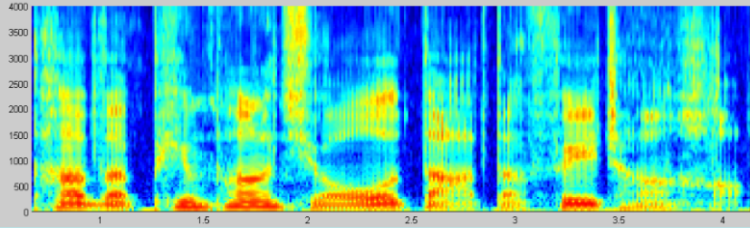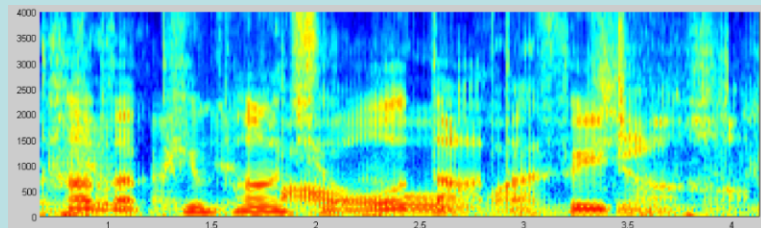
Signal Processing of CI

DDAE on CI

DDAE
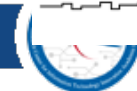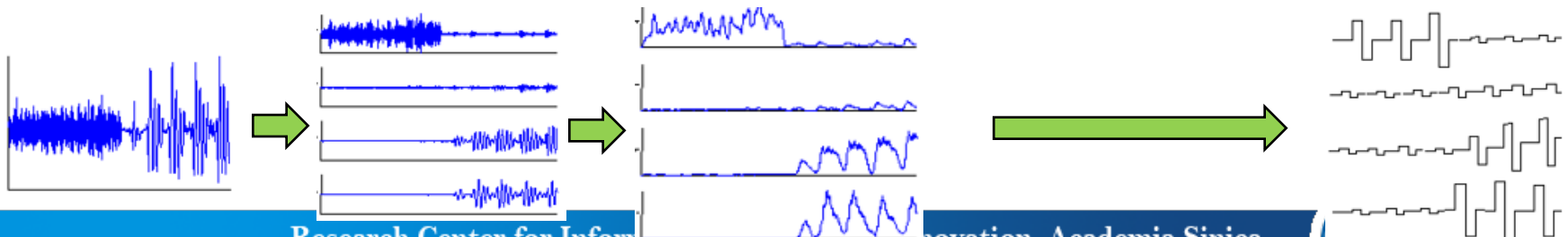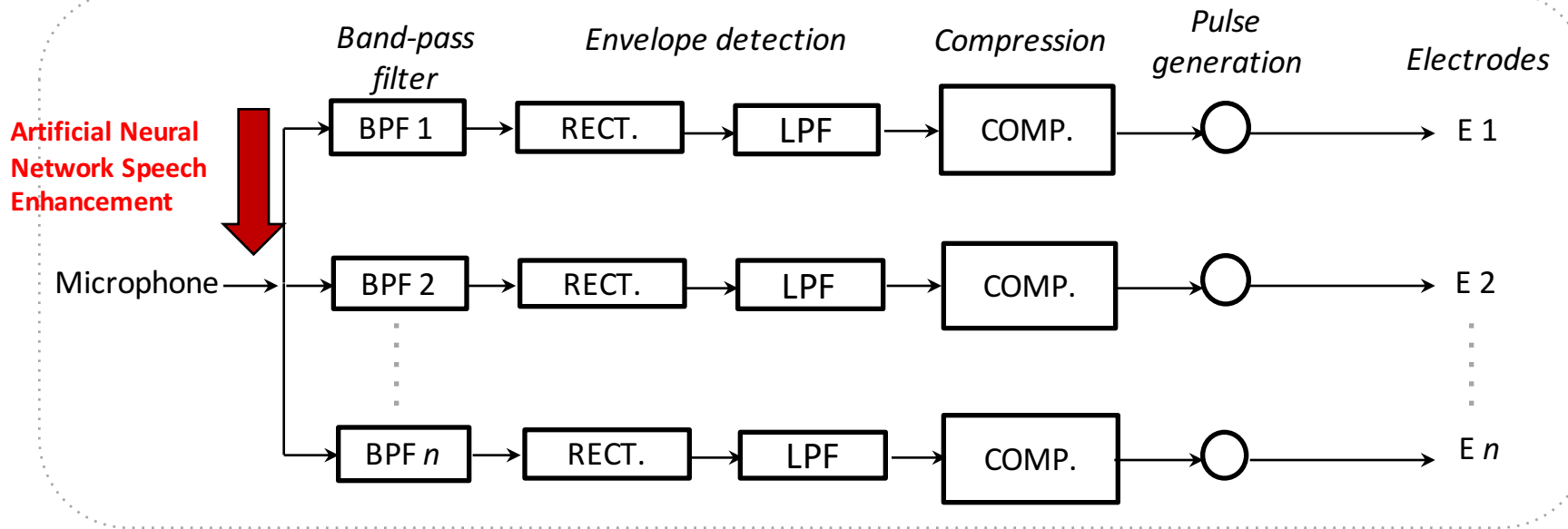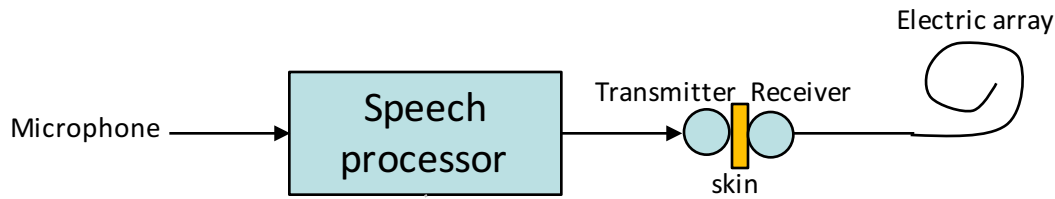
Vocoded Speech
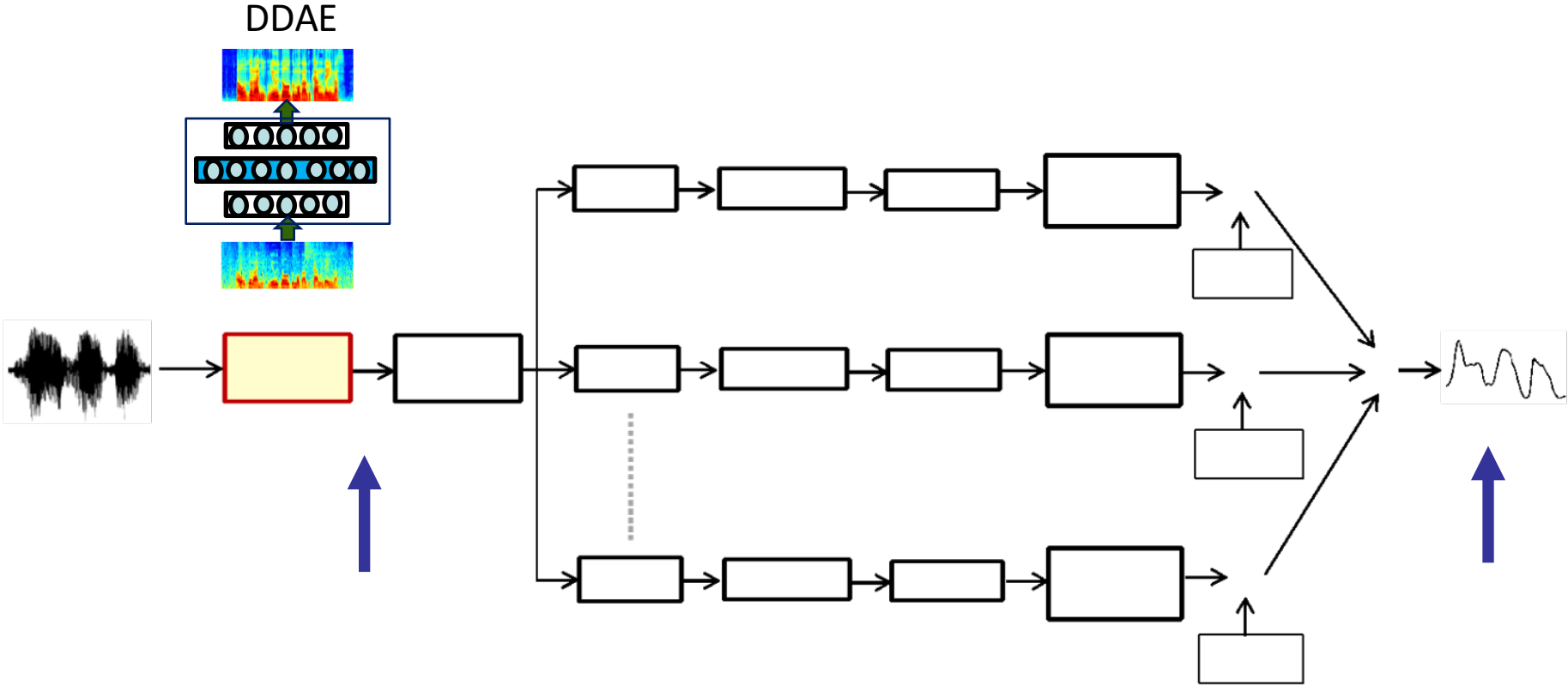
Clean

2T Noise 0dB

MMSE

DDAE

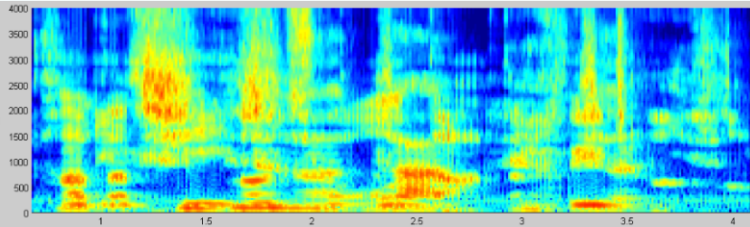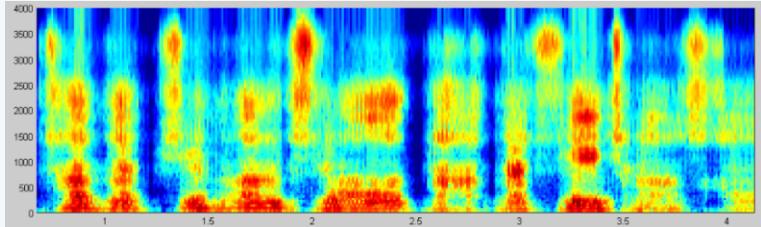# Normal Speech

Clean
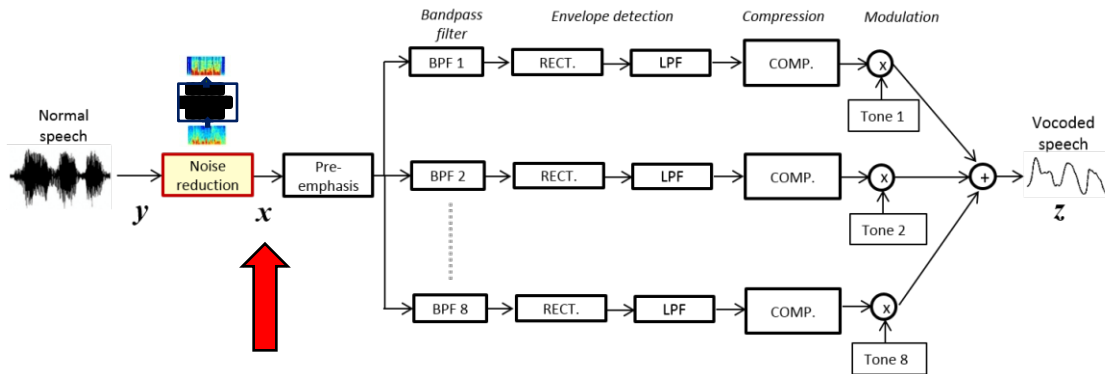
Babble Noise 0dB
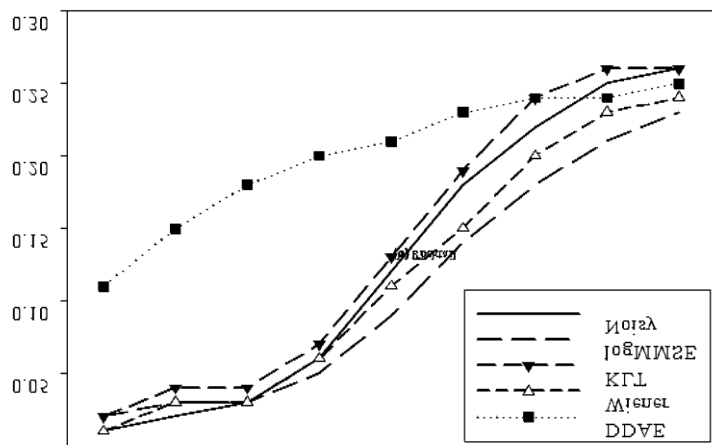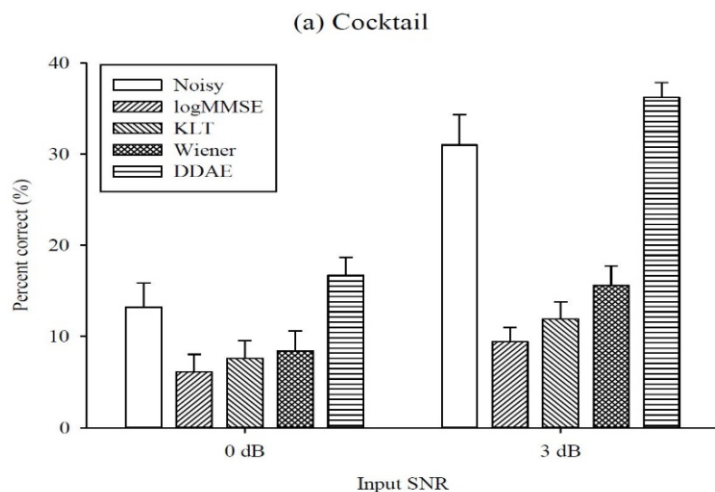
MMSE

DDAE

Evaluation Results (Simulations and Subject Tests)

Objective evaluation (NCM)

(a) Cocktail

Vocoder results: 10 normal hearing subjects.

Clinical trial: 9 CI subjects.

➢ Y.-H. Lai, F. Chen, S.-S. Wang, X. Lu, Y. Tsao, and C.-H. Lee, "A Deep Denoising Autoencoder Approach to Improving the Intelligibility of Vocoded Speech in Cochlear Implant Simulation," IEEE Transactions on Biomedical Engineering.

➢ Y.-H. Lai, Y. Tsao, X. Lu, F. Chen, Y.-T. Su, K.-C. Chen, Y.-H. Chen, L.-C. Chen, P.-H. Li, and C.-H. Lee, "Deep Learning based Noise Reduction Approach to Improve Speech Intelligibility for Cochlear Implant Recipients," Ear and Hearing.
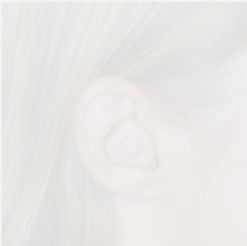
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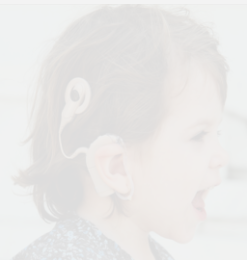
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