DEEP HEARING

FREE US FROM **NOISE**

Video conferences, calls, and lectures.
For all types of online communication,
anytime, anywhere, be free from noise.

FREE US FROM **NOISE**

Comfortable communication between people is essential in developing valuable relationships, both personal and professional. As much of our contact is now ONLINE, it is more important than ever to create noise-free environments for stress-free online communication.

Deep Hearing aims for a world where all can communicate with each other clearly, anytime and anywhere.

With technology based on years of research into the convergence of artificial intelligence and human hearing, we strive to develop innovative solutions to free online communication from noise.

DEEP HEARING

1. Noise reduction app
2. Voice signal preprocessing module
3. Directional noise removal device

Deep Hearing Milestones

2021

Mar. Released our noise reduction application

2020

Dec. Selected as a member of TIPS, the Tech Incubator Program for Startups in Korea

Dec. Received investment from Bluepoint Partners

Jun. Inaugurated CEO Kang-Hun Ahn

2019

Oct. Signed an MOU with Samsung Medical Center Hearing Lab

Sep. Certified as a Venture Business

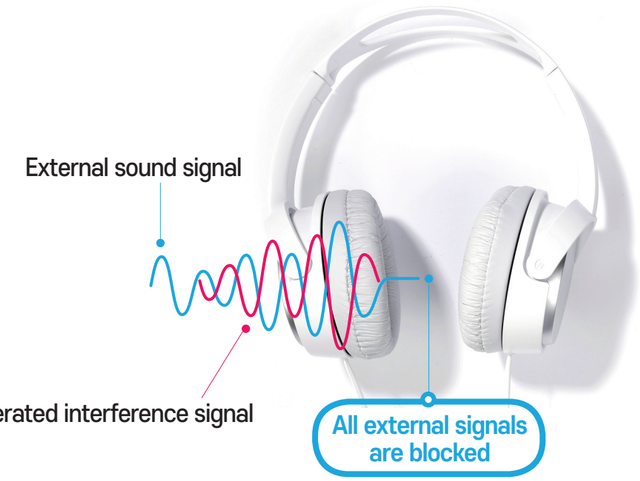
Mar. Incorporation of Deep Hearing

ABOUT DEEP HEARING

— Different from conventional noise reduction approaches —

Introducing the unique information-based approach of Deep Hearing©

Typical noise reduction technology



Deep Hearing's information-based noise reduction technology

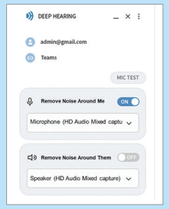
—

In any day-to-day environment, Deep Hearing can completely filter out background noise through sound signal preprocessing technology, leaving only the target voice for clear communication.

Solution & Product

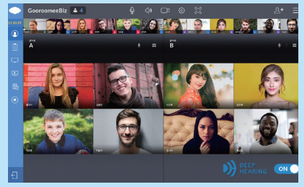
Noise reduction application

- ✓ Noise-free teleconferencing with one click
- ✓ Works with various platforms such as Zoom, Webex, MS Teams, and more



Voice signal preprocessing module

- ✓ Operates as a Chrome extension with no need to install separate programs
- ✓ Can be embedded into the customer's own platform, with SDK and API provided

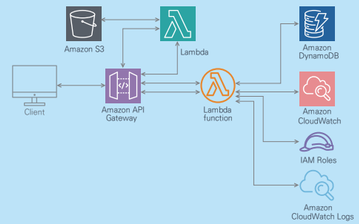


Directional noise removal device

- ✓ Directional AI microphone that passes only the voice of a specific speaker
- ✓ Connects via USB port for immediate use

Deep Hearing speech enhancement API

- ✓ File-based speech enhancement API for business



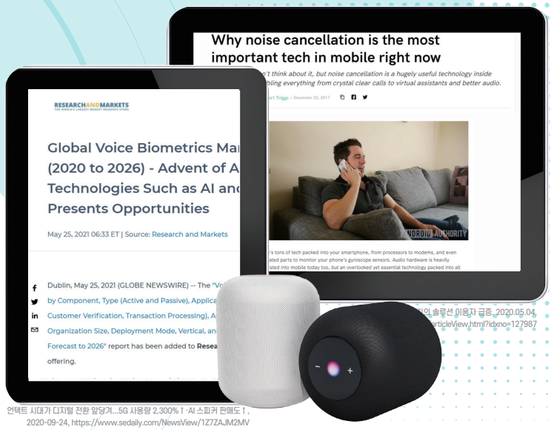
AI hearing enhancer

- ✓ Real-time single channel speech enhancement on a chip

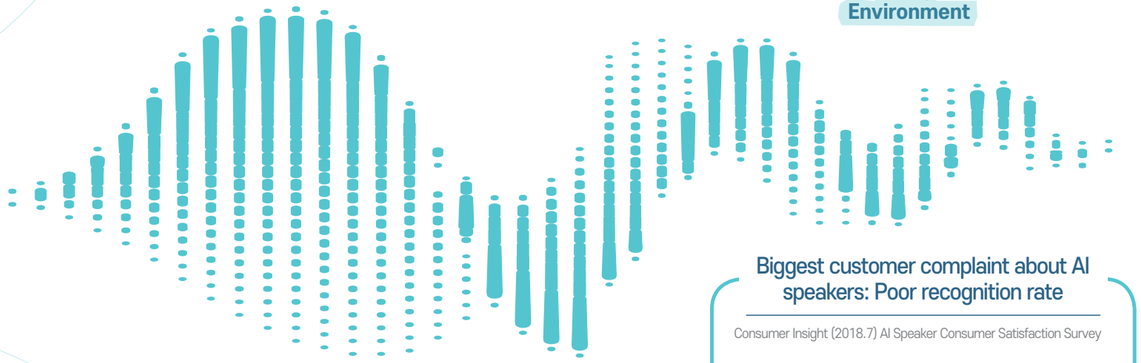
Howling-free mobile device solution

- ✓ Used by policeman, fireman, security guard

In the modern world of smart devices, the technical demand for voice delivery has exploded.



In environments with high levels of background noise, signal processing becomes more and more critical.
For practical purposes though, research into speech signal preprocessing is lacking.

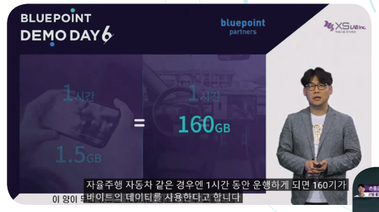


Increasing difficulty in signal processing in noisy environments

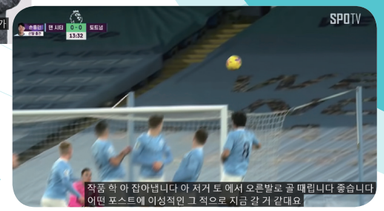
Phone call | Video conference | Virtual assistant (Smart speaker) | Audio-zoom

Most of the latest voice signal processing technologies suffer from severely reduced performance in noisy environments.

Auto-subtitles work well in a quiet environment



Auto-subtitles prone to errors in noisy environments



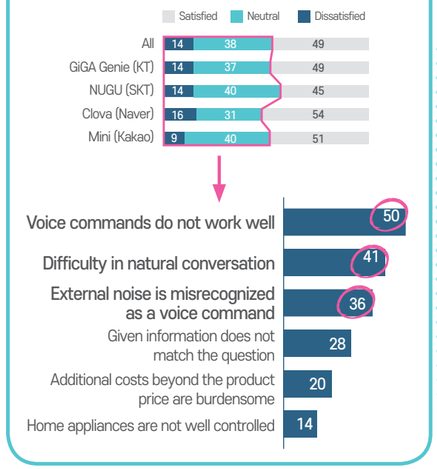
Noisy Environment

For video conferencing and voice recognition technologies like STT*, this is a key stumbling block.

*STT : Speech to text

Biggest customer complaint about AI speakers: Poor recognition rate

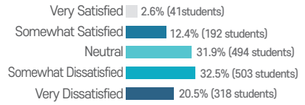
Consumer Insight (2018.7) AI Speaker Consumer Satisfaction Survey



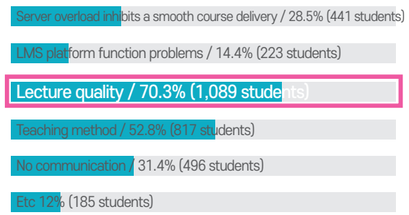
Reduced student satisfaction from noises during video lectures

Myongji University Student Survey (2020.03)

Q. Are you satisfied with the online lectures currently in progress?



Q. What inconveniences you while taking online lectures? (Multiple answers available)



DEEP HEARING GUIDE

01

Class just got a whole lot more interesting!

Students—normally discouraged from active participation by having to turn their mics on & off—freely speak up naturally during class with no delays just like in an in-person class environment.

Deep Hearing noise cancelling technology distinguishes between the speaker and background noise, allowing mics to stay on with no worries over unwantedsounds being picked up, encouraging increased participation.

02

Stop dreading work meetings!

Employees—often frustrated by howling or reverberation when in a meeting room with multiple connected devices—hear no feedback from the device speakers during conferences, allowing each member to contribute naturally without having to repeat themselves.

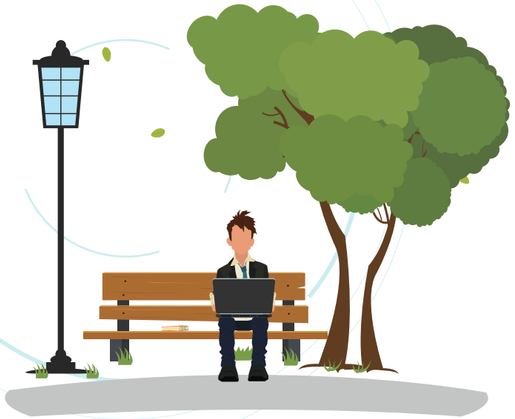
Deep Hearing cuts out all howling issues by blocking speaker noise, allowing for stress-free meetings with no disturbances.

03

On the go ... with confidence!

Mobile people—having to take an urgent video call in the less-than-ideal location of the car, bus, or while walking outside—are able to hear and be heard as clearly as in their office, despite being surrounded by the general din of the outdoors.

Deep Hearing suppresses outdoor background noise as if it isn't even there.



04

Remote work no longer means remote!

People video conferencing for work at home or a cafe—typically wary of sudden, loud sounds such as from the baby crying or kids playing, vacuum cleaner, or just general commotion—pay no mind to construction noise, heavy trucks rumbling by, or sudden voices or crashes in the background.

Deep Hearing mutes abrupt noises while the speaker's voice remains clean & clear, giving the feeling of being in the same room.

05

No more frustrating smart speakers!

Smart speakers—continually mixed up by voices from the TV and sounds from the home, even picking up singers' voices from music the speaker itself is playing—better hear the questions and give accurate responses, only when prompted.

Deep Hearing removes background noise so that only intended prompts get through accurately, making smart speakers actually smart.

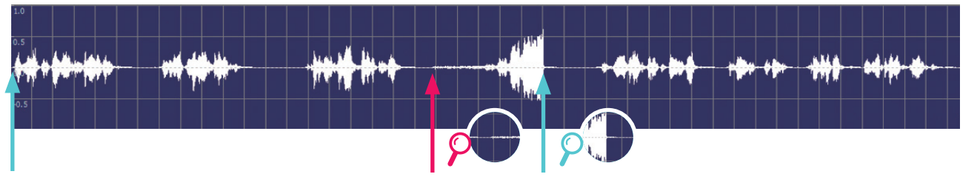
DEEP HEARING FEATURES

Feature I : Howling elimination

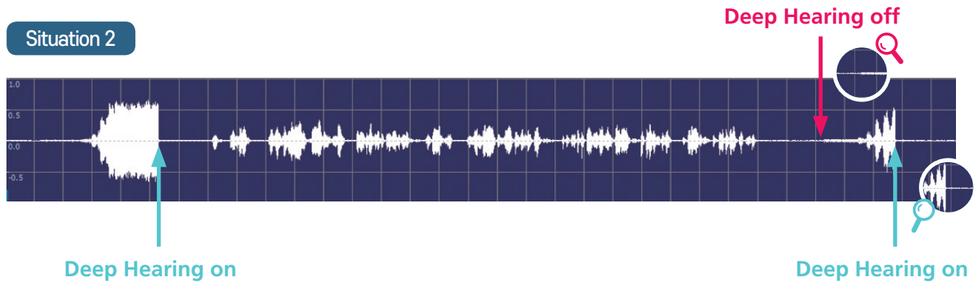
When video conferencing with multiple computers in the same place,
Deep Hearing shows excellent suppression of sudden howling.

- ✓ **Feedback loop that leads to howling : Laptop 1 mic input → Laptop 2 speaker output → Picked up as Laptop 1 mic input**
- ✓ Sudden howling can be suppressed in real-time when Laptop 1 turns on Deep Hearing Noise Reduction

Situation 1



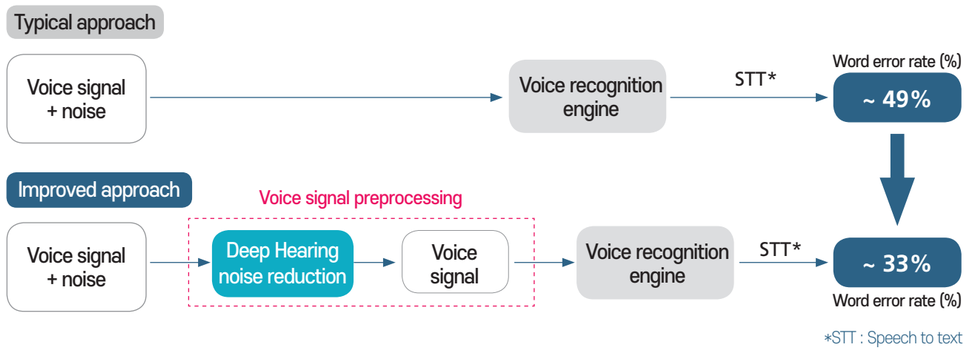
Situation 2



Large, annoying spikes in loud sounds disappear immediately through noise reduction technology

Feature II : Speech recognition improvement

In environments where voice recognition is poor due to excessive noise, the Deep Hearing solution reduces word error rates by delivering only clear speech through noise reduction preprocessing.



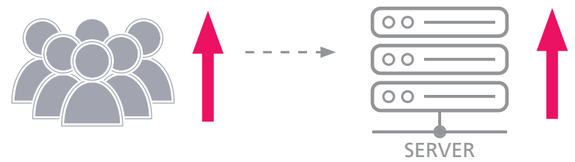
*STT : Speech to text

Feature III : In-browser capability

Web browsers have difficulty in processing heavy calculations quickly while running JavaScript. Deep Hearing not only reduces the number of calculations but also speeds them up through a lightweight neural network and adopting WebAssembly.
Our solution works on any browser based on Chromium (Chrome, Edge, Opera, and more)

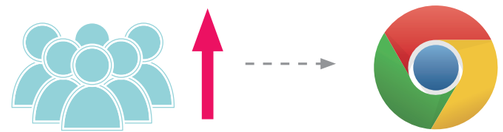
Noise removal processing : Server-based

As the number of users increases, server processing loads increase, and so do server costs.



Noise removal processing : Browser-based

Even with increasing users, all processing is done on each local user's browser, freeing up server costs.



FEATURES COMPARISON

Model A (Windows and android app)

Latency	Frame size	Param size	Complexity
16 ms	8 ms	743 K (3.05 MB)	230 MMACS

Model B (ARM embedding)

Latency	Frame size	Param size	Complexity
16 ms	8 ms	20 K (84.1 KB)	2.43 MMACS

Performance on Voicebank & DEMAND dataset

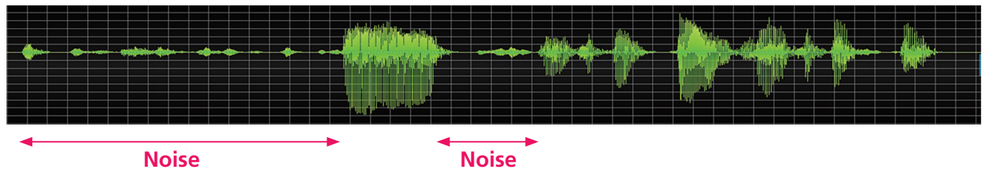
	CSIG	CBAK	COVL	PESQ	SSNR	STOI
Noisy	3.35	2.44	2.63	1.97	1.68	0.92
Model A	4.04	3.47	3.49	2.91	9.71	0.94
Model B	3.79	3.27	3.21	2.65	9.12	0.93

Noise reduction performance comparison : Deep Hearing vs. Zoom

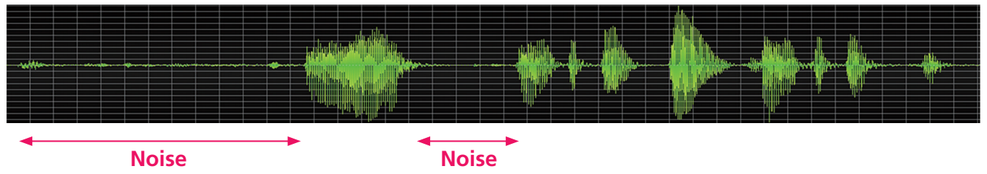
(Test environment : Loud television near the mic)

→ Deep Hearing removed the unwanted voices from the TV. Zoom's "High" level noise reduction function could not.

ZOOM



Deep Hearing



PRODUCT SPEC

Ultra-lightweight AI model : Time delay and computation

Latency	Param	FLOPS
24ms	35k	355M

Latency : Algorithm latency (buffer latency)
Param : Number of parameters
FLOPS : Number of floating operations per second

Improvements in objective measures of speech quality

Dataset : Voicebank (speech) & DEMAND (noise)

ΔCSIG	ΔCBAK	ΔCOVL	ΔPESQ	ΔSSNR	ΔSTOI
+ 0.60	+ 0.97	+ 0.76	+ 0.86	+ 7.86	+ 0.02

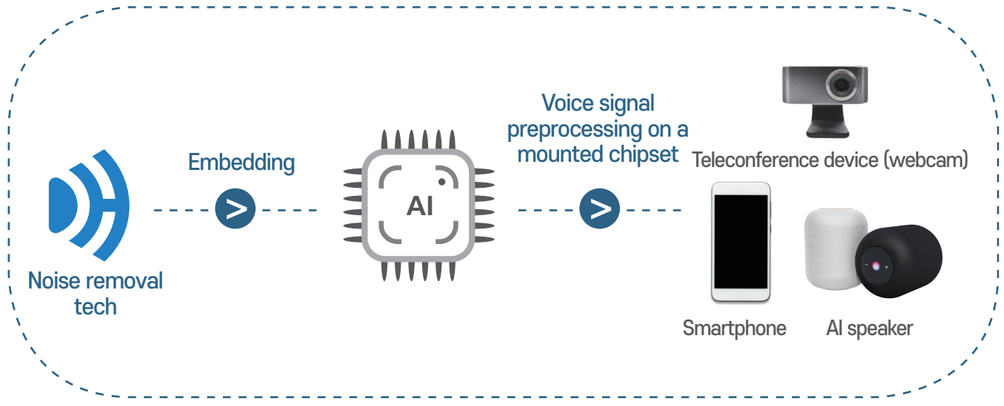
CSIG : Mean opinion score (MOS) prediction of signal distortion (< 5)
CBAK : MOS prediction of the intrusiveness of background noise (< 5)
COVL : MOS prediction of the overall effect (< 5)
PESQ : Perceptual evaluation of speech quality (< 4.5)
SSNR : Segmental SNR (< ∞)
STOI : Short-time objective intelligibility (< 1)

Key performance indicator comparison with latest AI models

	CSIG	CBAK	COVL	PESQ	SSNR	STOI
Noisy	3.35	2.44	2.63	1.97	1.68	0.92
SEGAN, 2017	3.48	2.94	2.80	2.16	7.73	0.93
WAVENET 2018	3.62	3.23	2.98	-	-	0.93
TF-GAN, 2018	3.80	3.12	3.14	2.53	-	-
DFL, 2018	3.86	3.33	3.22	-	-	-
D+M, 2019	3.94	3.35	3.33	2.73	9.40	-
Deep Hearing	**3.95**	**3.41**	**3.39**	**2.83**	**9.54**	**0.94**

PRODUCT DEVELOPMENT

Directional noise reduction technology that can be embedded as a preprocessing chipset for use with the microphones of existing devices.



CURRENT PROJECTS

- Launched video conference noise reduction app
- Softbridge : Dedicated noise reduction solution for video conferencing
- Samsung Electronics : Voice audio processing technology exchange
- Gooroomee : Dedicated noise reduction solution for video conferencing
- KAIST : Online class noise reduction app supply
- Cybertel Bridge : Noise reduction solution supply for firefighter/police communication networks
- LG U+ : Noise reduction solution supply

+

- SaltLux : AI voice enhancement solution
- NHN Dooray : AI voice enhancement solution

PATENT

- (Granted) Information-based Sound Volume Control Apparatus and Method thereof (KR 10-1689332)
- (Application) Method For Enhancing Quality Of Audio Data, And Device Using The Same (PCT/KR2020/016507)
- (Application) Beamforming Method And Beamforming System Using Neural Network (KR 10-2020-0146191)

JOURNAL PAPER

- Origin of The Higher Difficulty in The Recognition of Vowels Than Handwritten Digits in Deep Neural Networks
- Language and Noise Transfer in Speech Enhancement Generative Adversarial Network
- Physical Limits to Auditory Transduction of Hair-Cell Bundles Probed by a Biomimetic System

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