Title:	Improving Auditory Experience for Hearing Impaired Listeners Using Unique Combination of Conventional and Parametric Loudspeakers
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Summary

Non-wearable assistive hearing devices helps hearing impaired (HI) listeners (having lesser sensitivity at some frequencies) to enjoy TV and radio broadcasts, without wearing hearing aids. Many individuals with hearing impairment consider wearing a hearing aid as a stigma. Hence, non-wearable assistive hearing devices are generally preferred over hearing aids. Such non-wearable assistive hearing devices are usually attached onto TV or radio. While the non-wearable hearing devices avoid the need to turn up sound level of the TV or radio to compensate for the hearing impairment, it should be noted that the processed sound from such devices is projected to all the listeners and such processed audio tends to be unpleasant to normal listeners.

To overcome the above-mention problem of non-wearable assistive hearing device, we propose an audio system, referred as parametric assistive hearing device (PAHD), to improve the experience of HI listeners while not affecting normal listeners that are sitting within close proximity of the HI listeners. The PAHD comprises of a unique combination of parametric loudspeakers (a class of directional loudspeaker) and conventional loudspeakers as well as a series of audio processing algorithms. These algorithms are able to extract a set of audio information that is crucial in enhancing the listening experience of HI listeners, and this processed audio content is transmitted by the parametric loudspeaker.

Using PAHD, HI listeners experience an audio signal (formed by the combination of sound from conventional and parametric loudspeakers) that is tailored to compensate their hearing impairment, so that they can better enjoy the audio content. Only HI listeners would hear the combined sound and the rest of the listeners would experience the original audio content from the conventional loudspeaker since the parametric loudspeaker is directed to the HI listeners only. Therefore, PAHD avoids the need to increase the volume of a TV or radio to partially compensate the hearing impairment of HI listeners.

HI listeners usually have lower sensitivities at certain frequencies, increasing the overall volume (which increases level for all frequencies) to compensate hearing loss is undesirable for both the HI and normal listeners as it might lead to further damage to the listeners' hearing. Based on the hearing impairment profile of the HI subject, PAHD

only amplifies the frequencies that the HI listener has lower sensitivities and prevents further damage to the hearing of the HI listener. Through our subjective testing, we have shown that PAHD increases the level for the pre-defined frequencies, which can be matched to the hearing impairment profile of an individual.

Aim of Research

The aim of this research is to develop a functional prototype of PAHD, which is used to improve the experience of HI listeners while not affecting listeners with normal hearing that are sitting within close proximity of the HI listeners. This audio system comprises of a unique combination of parametric loudspeakers (a class of directional loudspeaker) and conventional loudspeakers as well as a series of audio processing algorithms. The outcome of this research is divided into four key deliverables, which are as follows:

i. Algorithm development and simulation,
ii. Fixed-point digital signal processor implementation,
iii. Hardware development, and
iv. Subjective experiments and system tuning.

Method of Research and Progression

The key idea of this research is to combine the conventional and directional loudspeakers to create two sound zones in front of a TV or radio that allows normal and impaired listeners to enjoy TV or radio simultaneously, as shown in Fig. 1.

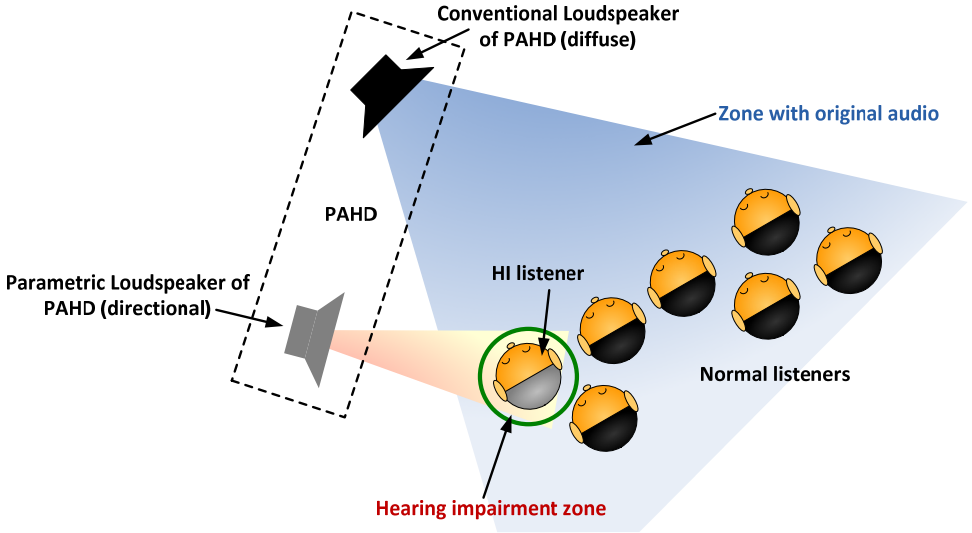


Fig. 1. Two sound zones generated by PAHD.

The conventional loudspeaker is used to create the sound zone for the normal listeners and combined sound from conventional and directional loudspeakers creates the hearing impairment zone that allows HI listeners to hear better.

Results of Research

Based on the four deliverables of the research plan, we started the simulation of several audio signal enhancement algorithms on the PC. The first deliverable also involves the porting of the developed algorithm on PC to a low-cost and power efficient digital signal processor (DSP), and we have selected the Texas Instrument VC5505 EzDSP USB stick (see Fig. 2). We have successfully optimized the PC developed algorithm to run on the EzDSP USB stick in real-time, which has limited precision and limited computing capability as our the second deliverable.

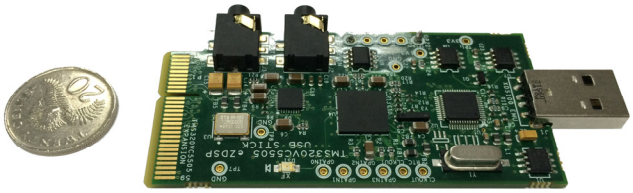
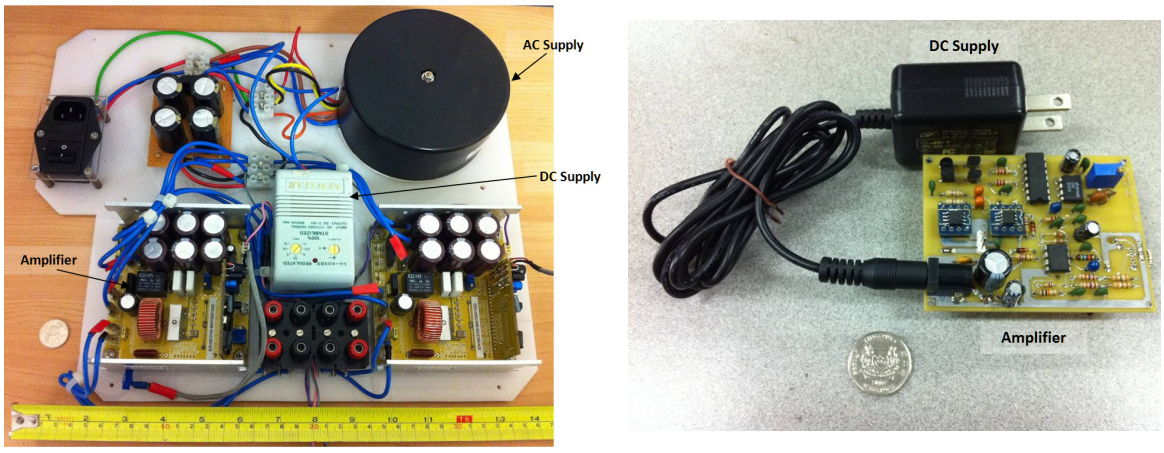


Fig. 2. VC5505 EzDSP USB Stick DSP Kit

The third deliverable of this research comprises of the development of specialized amplification units for the ultrasonic emitters used in the directional loudspeakers. Based on the characteristics of the ultrasonic emitters, a specialized amplifier has been designed and this amplifier has smaller form factor and higher power efficiency (see Fig. 3). By matching the impedance of ultrasonic emitters to the amplifier, higher power efficiency and higher sound pressure level are achieved as compared to our previous amplifier designs for the directional loudspeaker.



(a) (b)

Fig. 3. Specialized amplifier for directional loudspeaker (a) previous amplifier measuring at 38cm × 33cm × 10 cm and (b) new amplifier measuring at 7.5cm × 5.7cm × 2cm.

From our subjective testing, listeners are able to differentiate the two sound zones from the PAHD using our latest demonstration system (see Fig. 3) in NTU.

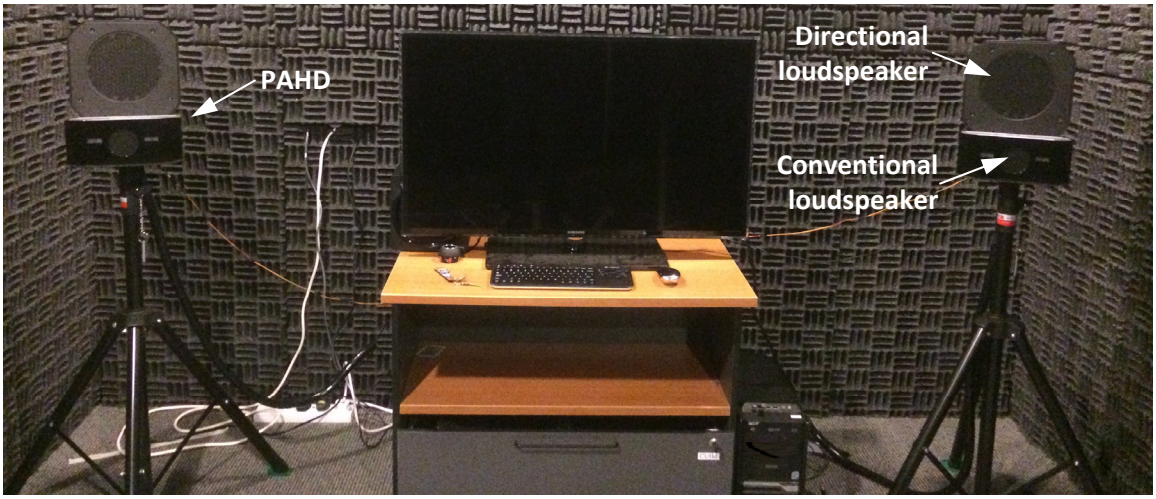


Fig. 3. Latest PAHD demonstration setup in NTU. A pair of PAHD is shown in here.

Future Areas to Take Note of, and Going Forward

This research has proven the effectiveness of PAHD, and we have been discussing with several ENT doctors at Tan Tock Seng Hospital regarding possible collaborations, and currently we have planned/submit two proposals for the continuation of the research work conducted with the MSIWF grant, and these proposals are as followed:

i. Nanyang Technological University – National Healthcare Group Ageing Research Grant on Experimentation of a novel sound system to enhance listening for hearing impaired and elderly (awarded)
ii. National Research Foundation Proof of Concept Grant on Audire – An assistive hearing device (to be submitted in July 2014)

Means of Official Announcement of Research Results

We have planned for several medical and engineering publications with the collaboration of ENT doctors at Tan Tock Seng hospital.