

## OBJECTIVES

To develop an inexpensive hearing aid that has all of the functionality of a high-end hearing aid, including:

- Amplifying specific frequency bands according to a person's audiogram
- The ability of the user to select the direction in which they wish to listen and to hear sounds in that direction louder than other directions

This will be done in the form of:

- A full software hearing aid simulation
- A hardware proof of concept of a hearing aid which demonstrates limited functionality

## SYSTEM DESIGN

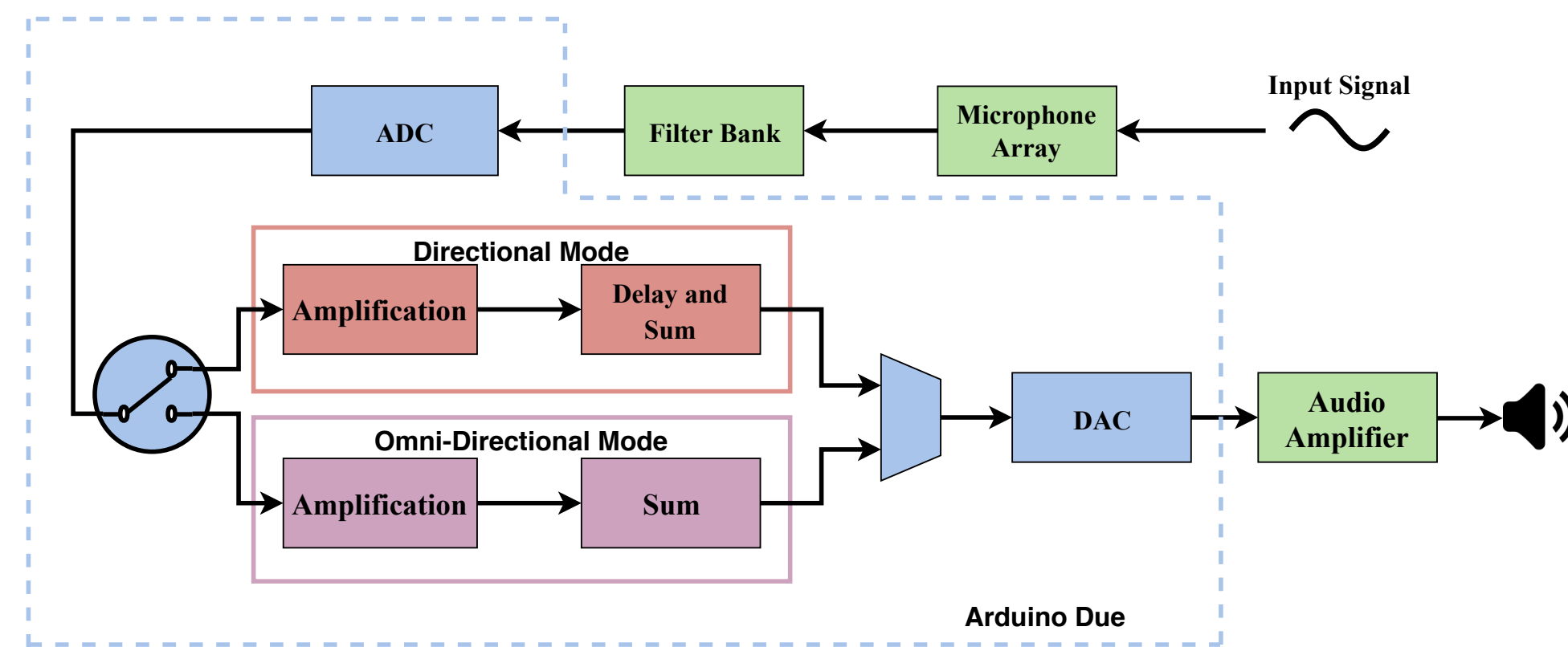


Figure 1: Hearing aid system overview

## Simulated vs Hardware Hearing Aid

Table 3: Comparison of simulated and hardware hearing aids

Property	Simulation	Hardware
Number of Microphones	10	4
Bandwidth	0.25-8 kHz	2.8-3.5kHz and 5.6-7 kHz
Filter order	14	2
Type of filters	$\frac{1}{3}$ Octave bandpass	$\frac{1}{3}$ Octave bandpass
Number of filters	16 per microphone	2 per microphone
Number of steerable angles	19 ( $10^\circ$ increments)	5 ( $0^\circ, 60^\circ, 90^\circ, 120^\circ, 180^\circ$ )

## Device Testing

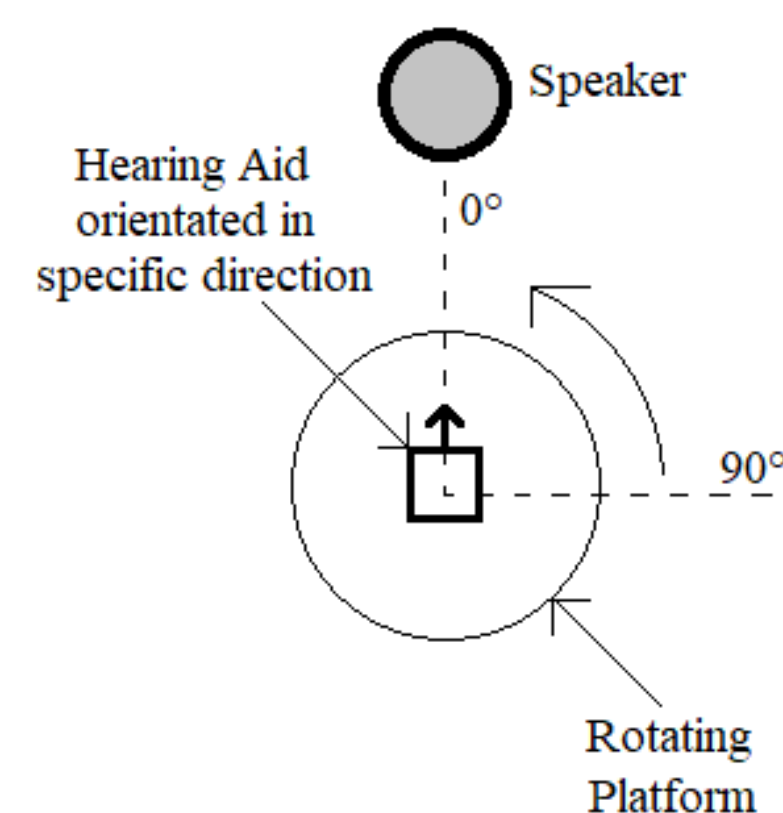


Figure 2: Procedure for testing the hearing aid

## RESULTS: SIMULATION

In the figure below, the frequency spectrum of the output from the hearing aid is compared to that of the original signal so that the effects of compensatory amplification can be seen

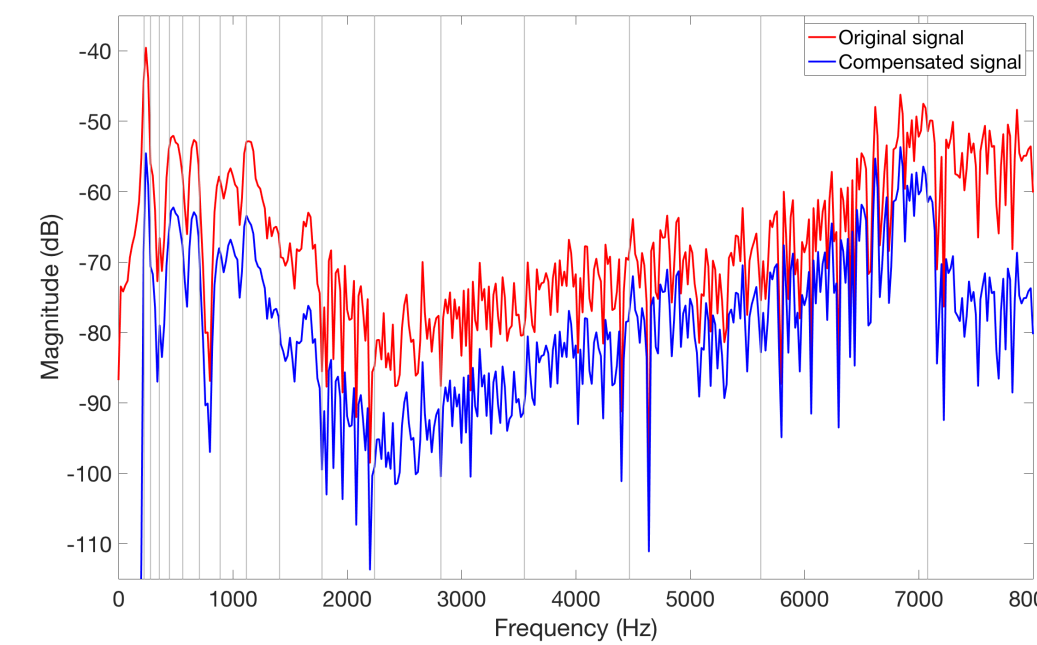


Figure 3: FFT of the input signal and the output signal from the hearing aid

The polar plot shows the normalised magnitudes of the signal at various angles, with respect to the user, when the dial is facing  $90^\circ$

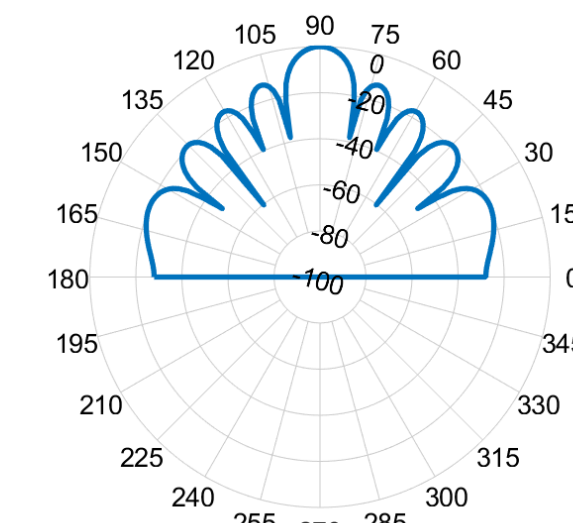


Figure 4: Gain applied to the output signal when the beam is steered to  $90^\circ$

## RESULTS: HARDWARE

The effects of compensatory gain are illustrated below through the application of different amplifications to the two frequency bands

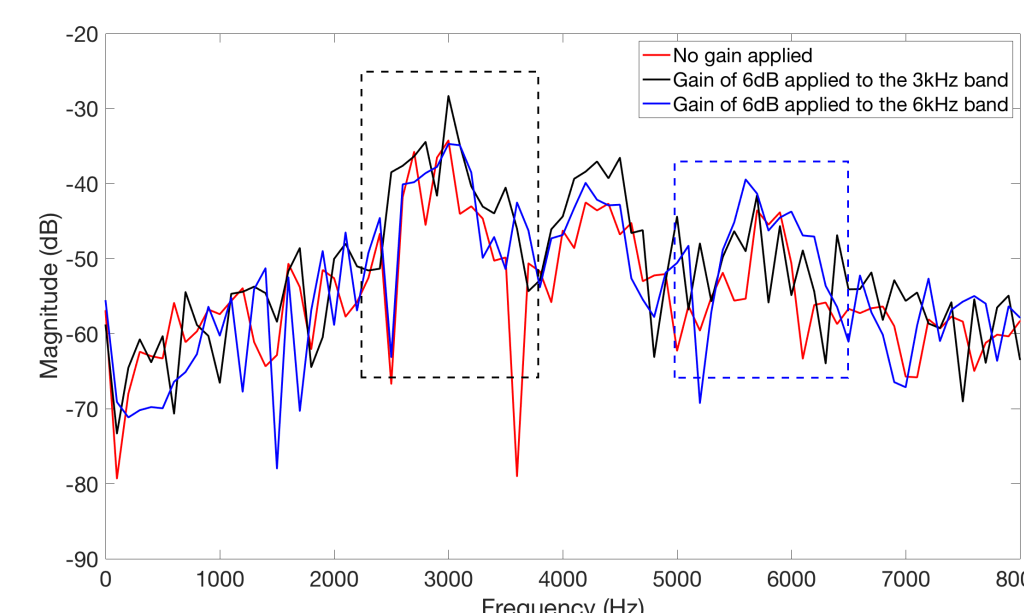


Figure 5: FFT of the output signal from the hearing aid with various amplifications

A simulated response was created using 4 microphones. This response was compared to the measured response acquired during device testing

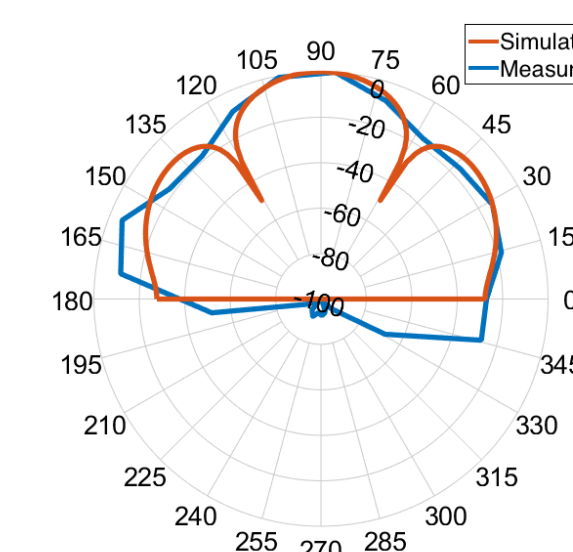


Figure 6: Gain applied to the output signal when the beam is steered to  $90^\circ$

## RESULTS: HARDWARE

The error in the directionality feature was calculated by comparing the measured and the simulated polar plots for each steerable angle. Compensatory gain error was calculated using the difference between the desired and measured gain at the centre of each frequency band

Table 1: Average error in the directionality feature

Angle $^\circ$	Average Error (%)
0	46.6
60	30.7
90	12.7
120	22.7
180	51.7

Table 2: Error in the compensatory gain feature

Compensated frequency band (Hz)	Error (%)
2820 - 3550	0.81
5620 - 7080	19.56

## FUTURE WORK

For future development of the hearing aid, a number of improvements could be made including:

- Making use of higher quality omni-directional microphones
- Creating an integrated circuit chip to handle the preprocessing of the audio signals
- Making use of more microphones to improve the precision of the directionality feature
- Embedding the microphones and circuitry into headphones to reduce the size of the device

## CONCLUSION

This project is a proof of concept that an inexpensive, fully functional, adaptive hearing aid can be produced. Amplification to specific frequency bands in accordance with provided audiograms can be achieved. Additionally, it is possible to achieve directionality in hearing aid devices by utilizing array theory

- Average error between simulated and measured beam steering = 32.9%

## REFERENCES

- [1] D. V. Anderson, R. W. Harris, and D. M. Chabries. Evaluation of a hearing compensation algorithm. *1995 International Conference on Acoustics, Speech, and Signal Processing*, 5:3531–3533, 1995.