AN INVESTIGATIONAL STUDY INTO THE DESIGN OF A LOW COST, ADAPTIVE HEARING AID

KAYLA-JADE BUTKOW & KELVIN DA SILVA   School of Electrical & Information Engineering, University of the Witwatersrand

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
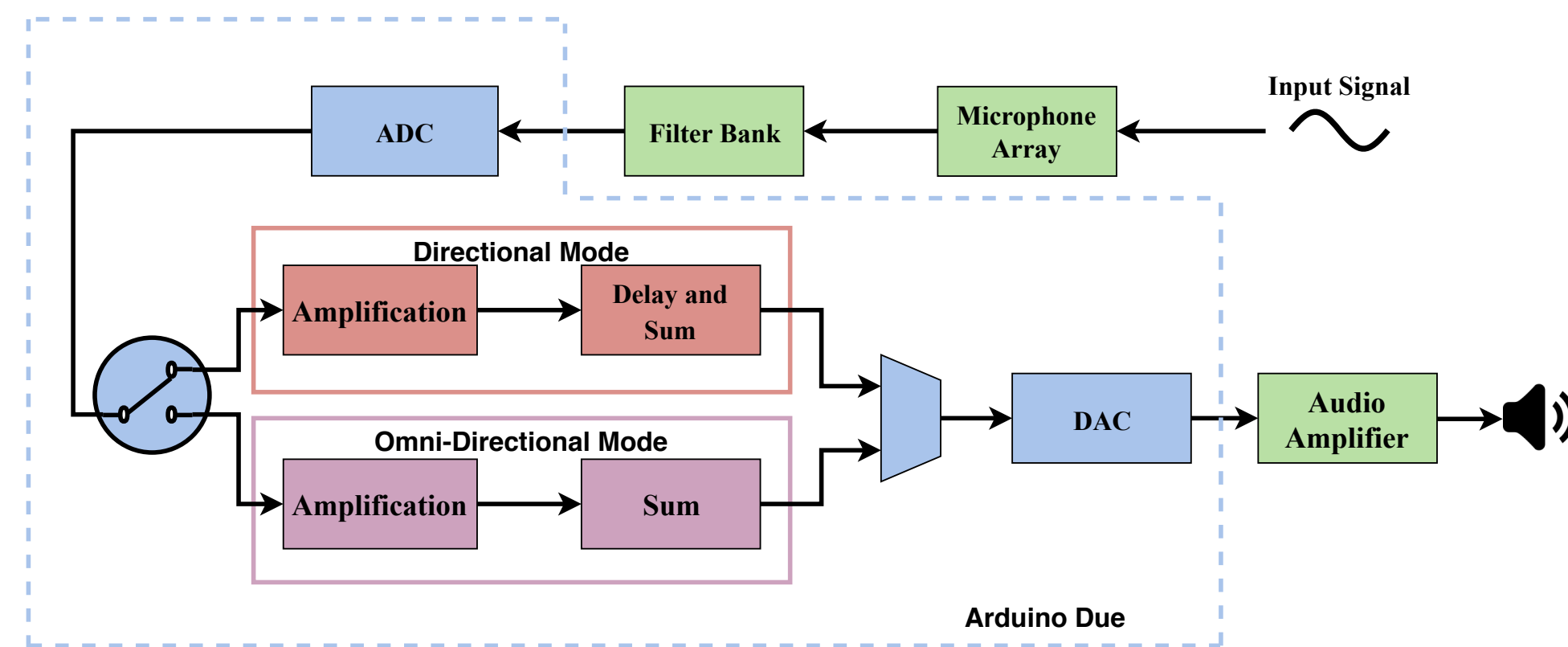
SYSTEM DESIGN

Figure 1: Hearing aid system overview

Simulated vs Hardware Hearing Aid

Table 3: Comparison of simulated and hardware hearing aids

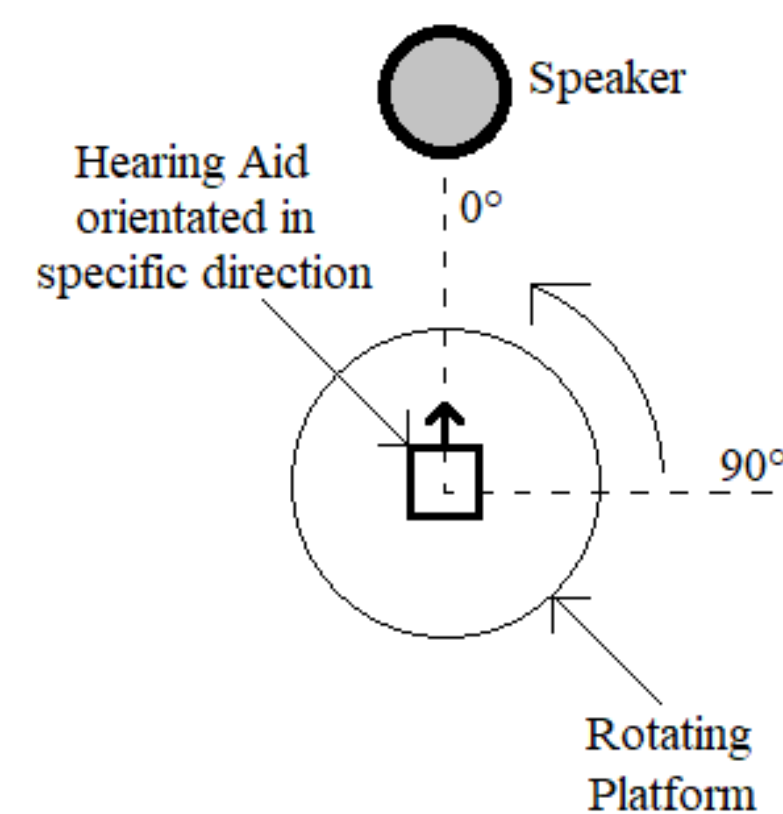| Property	Simulation	Hardware
# of Microphones	10	4
Bandwidth	0.25-8 kHz	2.8-3.5kHz and 5.6-7 kHz
Filter order	14	2
Type of filters	$\frac{1}{3}$ Octave bandpass	$\frac{1}{3}$ Octave bandpass
Number of filters	16 per microphone	2 per microphone
Number of steerable angles	19 (10° increments)	5 (0°, 60°,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

Device Testing

Figure 2: Procedure for testing the hearing aid

RESULTS: SIMULATION

The simulation results are depicted through a comparison of the original and compensated frequency spectra from a single frame of recorded voice audio. The polar plot shows the normalized gain of the simulated microphone array when the dial is facing 90°.
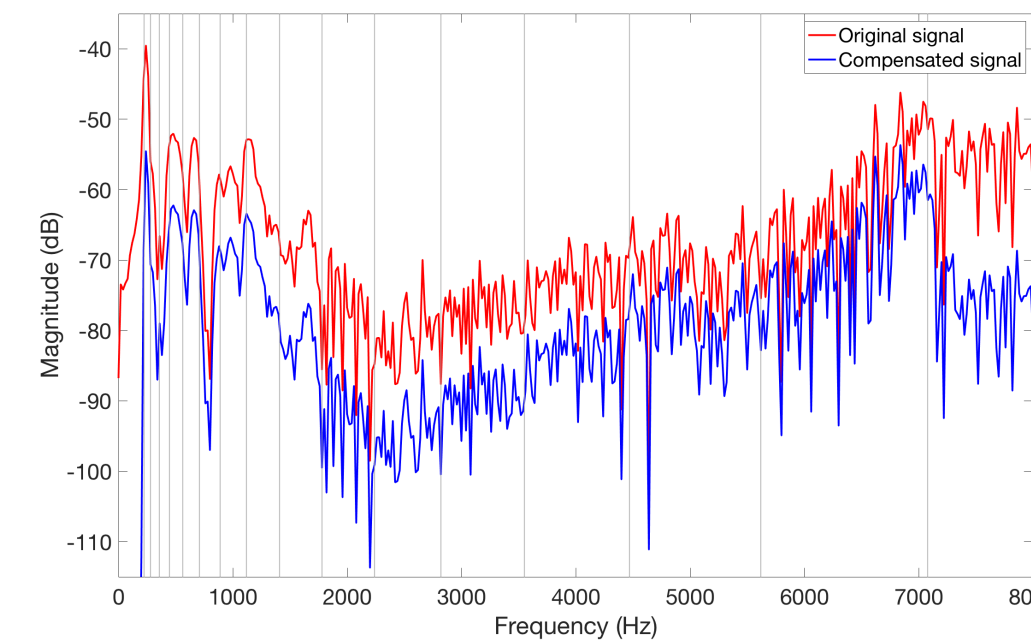

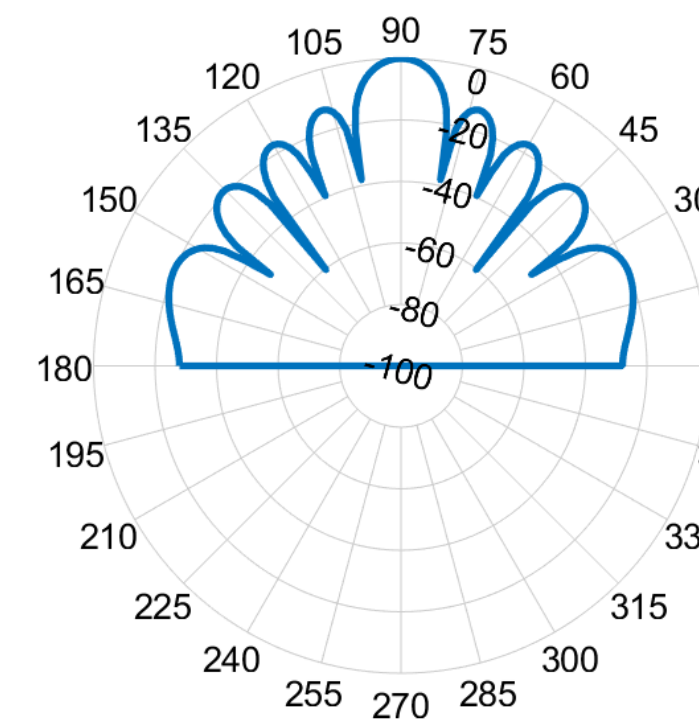**Figure 3:** FFT of the input signal and the output signal from the hearing aid

Figure 4: Gain applied to the output signal when the beam is steered to 90°
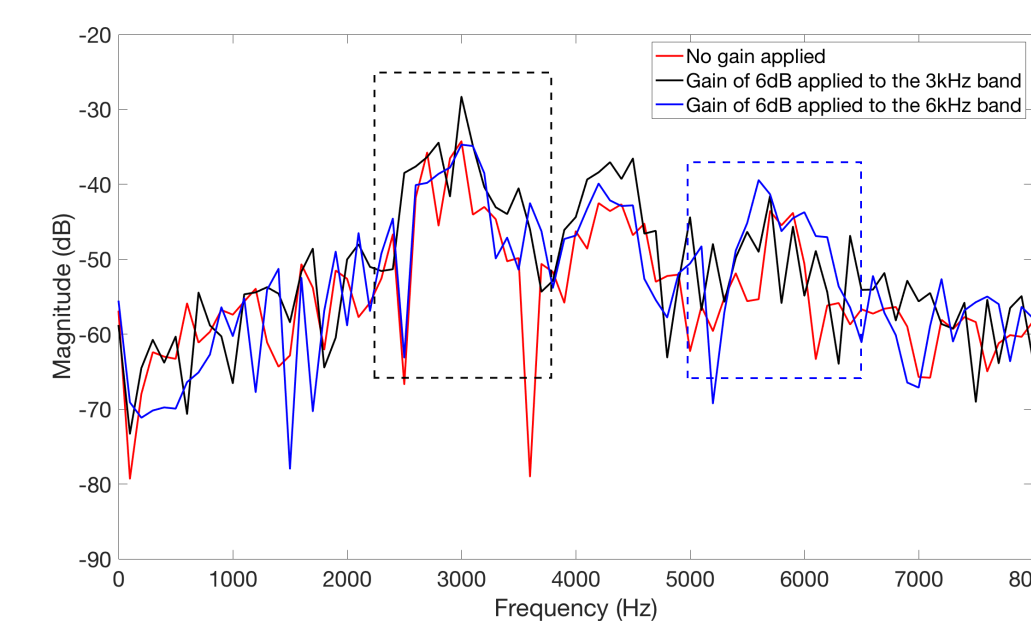
RESULTS: HARDWARE

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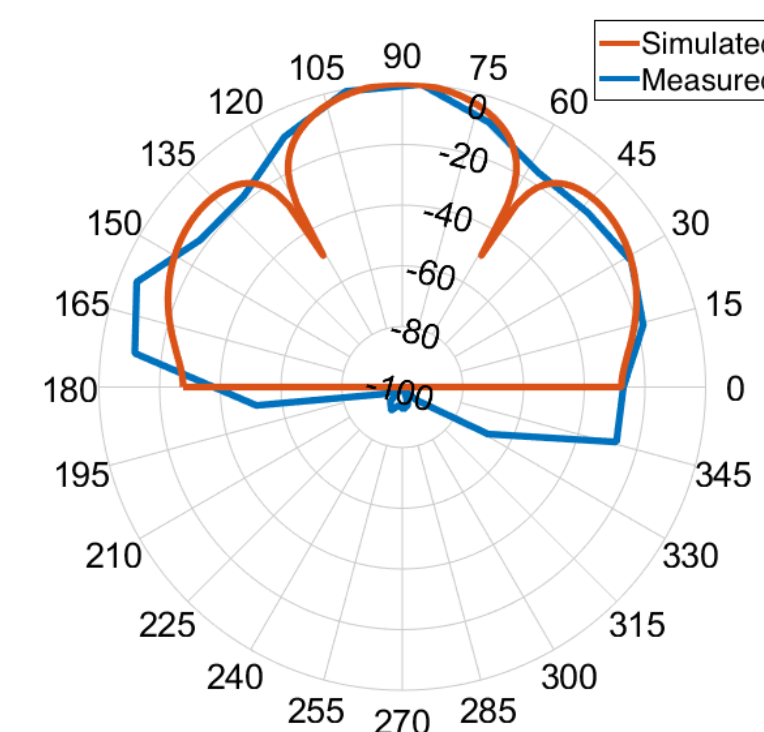

Figure 6: Gain applied to the output signal when the beam is steered to 90°

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	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 (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
- Emdedding the microphones and circuitry into a pair of headphone 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 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.