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

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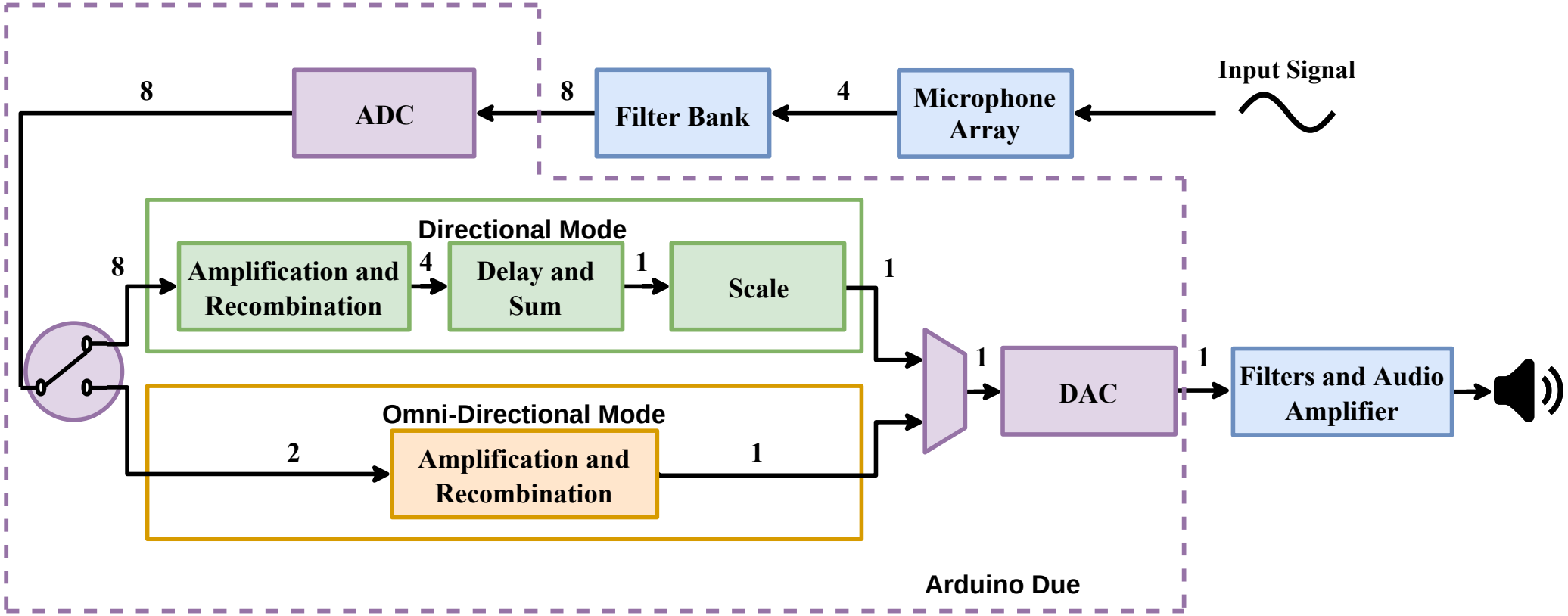
Outline

- Objectives and Specifications
- System Block Diagram
- Simulated vs Hardware Hearing Aid
- Hearing Aid Functionality
- Results
- Future Work and Conclusion

Objectives and Specifications

- To develop a low cost hearing aid
- Functionality:
  - Amplifying specific frequency bands according to a person's audiogram
  - User tuneable directionality
- Done in the form of:
  - Software simulation
  - Hardware proof of concept

System Block Diagram

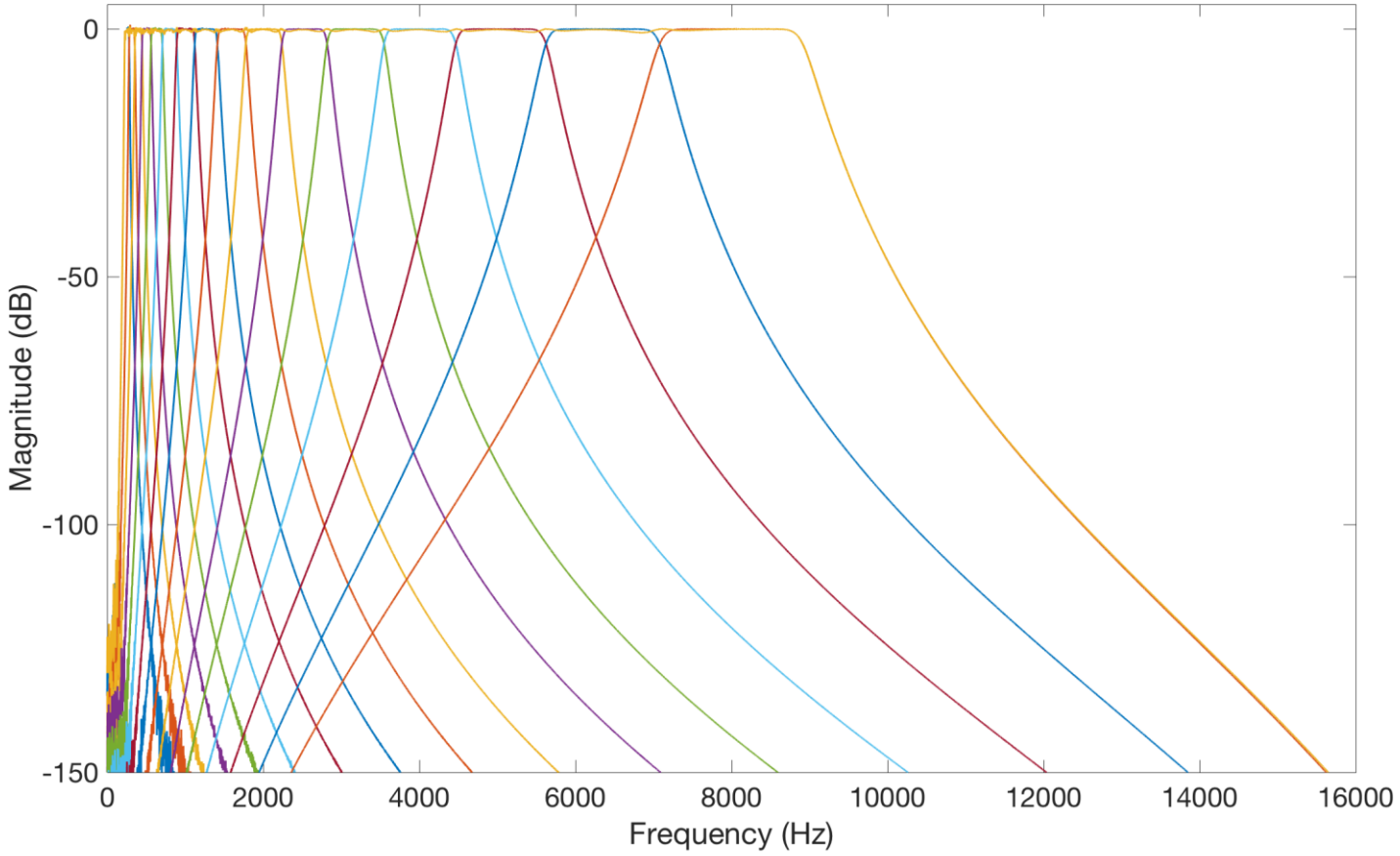


Simulated vs Hardware Hearing Aid

Property	Simulation	Hardware
Number of microphones	10	4
Device Bandwidth	0.25–8 kHz	2.8-3.5 kHz and 5.6-7 kHz
Filter Order	14	2
Filter Bandwidth	1/3 Octave	1/3 Octave
Types of filters	Butterworth FIR bandpass	Butterworth bandpass
Number of filters	16 per microphone	2 per microphone
Number of steerable angles	19 (10° increments)	5 (0°, 60°, 90°, 120°, 180°)
Real time data acquisition	No	Yes

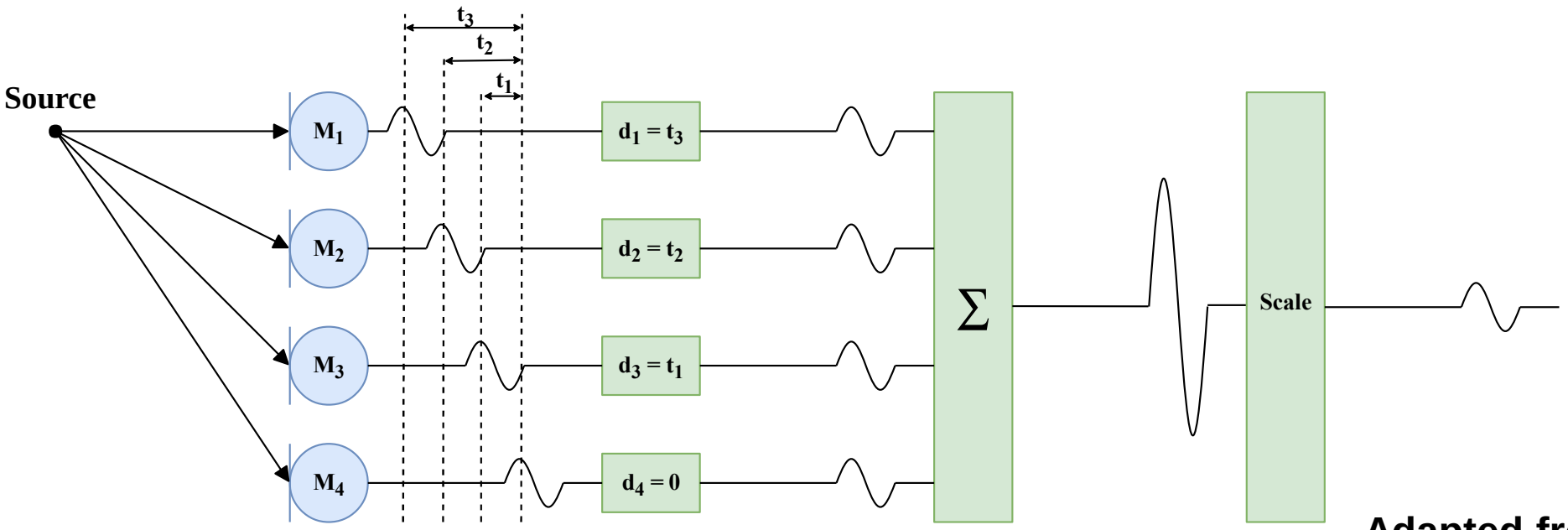
Compensatory Amplification

- **Audiogram matching: requires amplification of individual frequency bands**



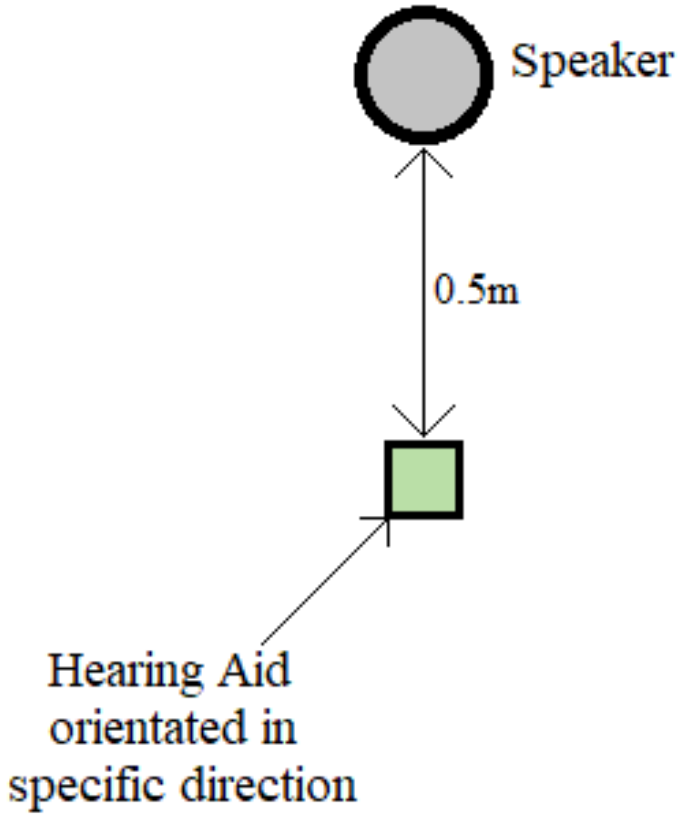
Directionality

- Amplification in a user specified direction
- Delay-and-sum beamforming

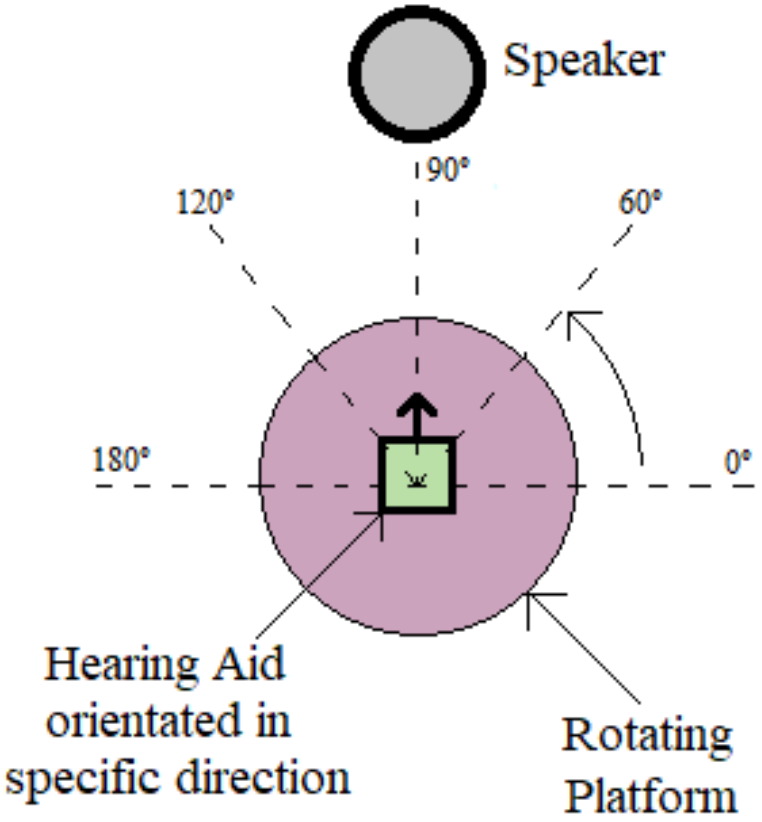


Adapted from [1]

Testing



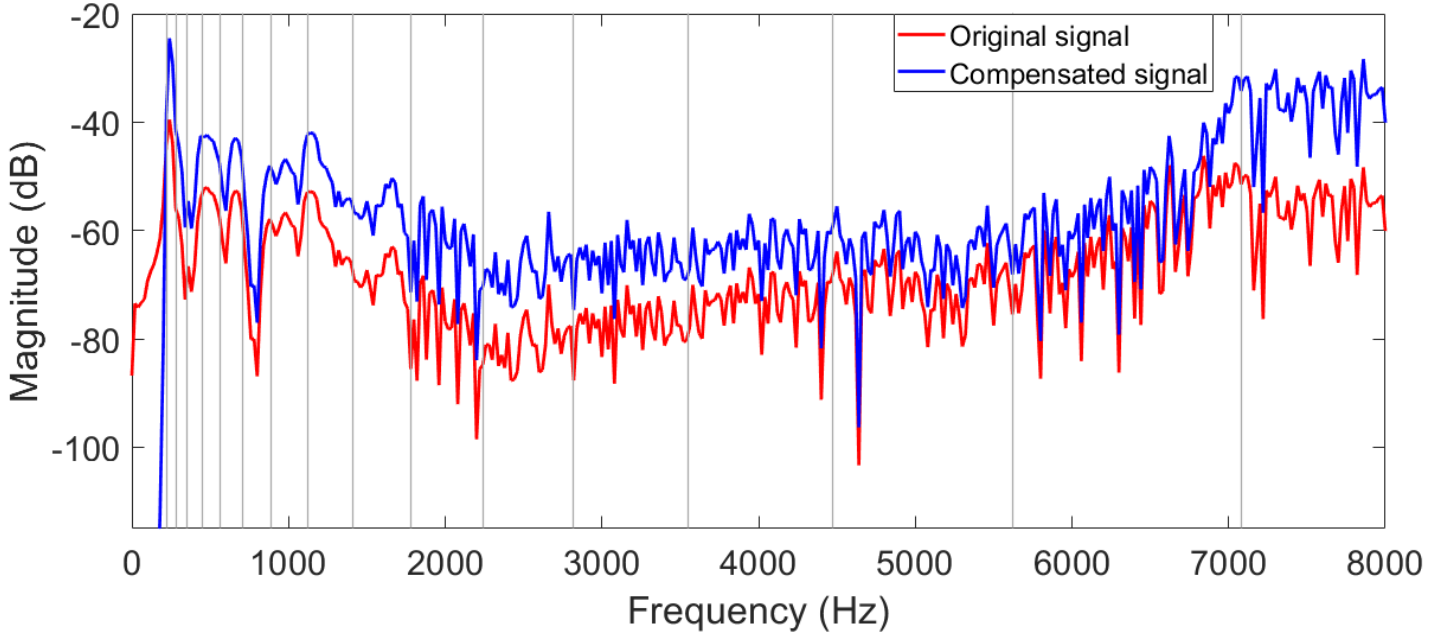
Compensatory gain



Directionality

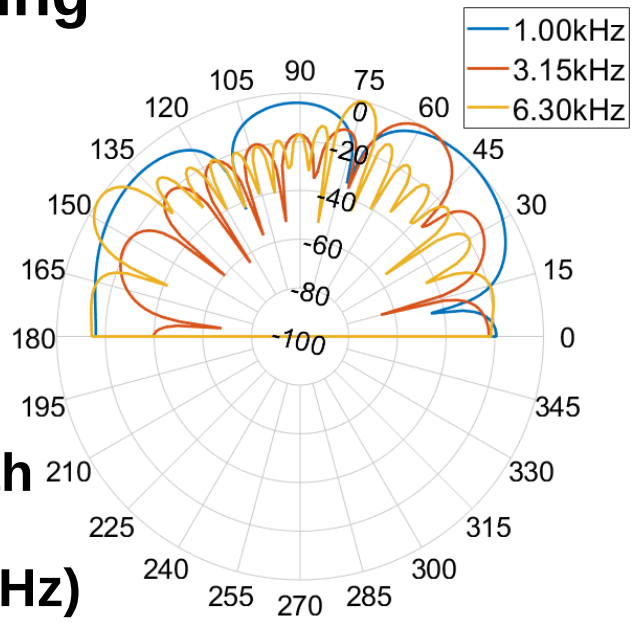
Results: Simulation

- **Matched to an audiogram**
- **Average error per frequency band: 1.41%**

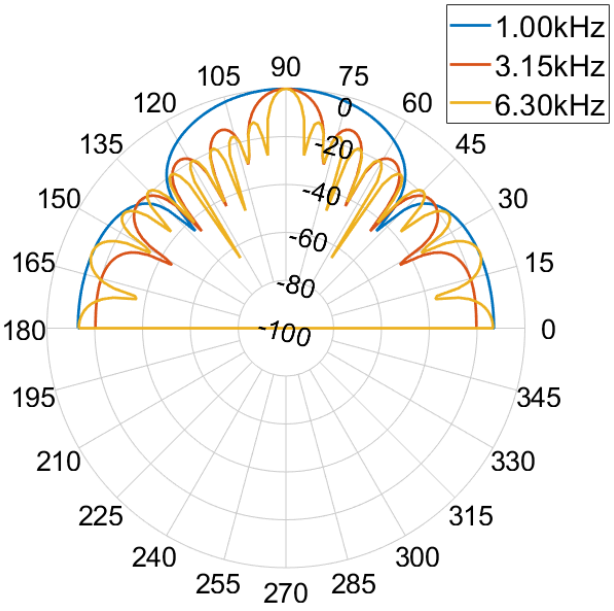


Results: Simulation

- **Most precise steering at 3.15 kHz**
- **Spatial aliasing**
  - $d < \frac{\lambda_{min}}{2}$
  - d= 5cm
  - λ_{min}= wavelength of maximum frequency (3.4 kHz)



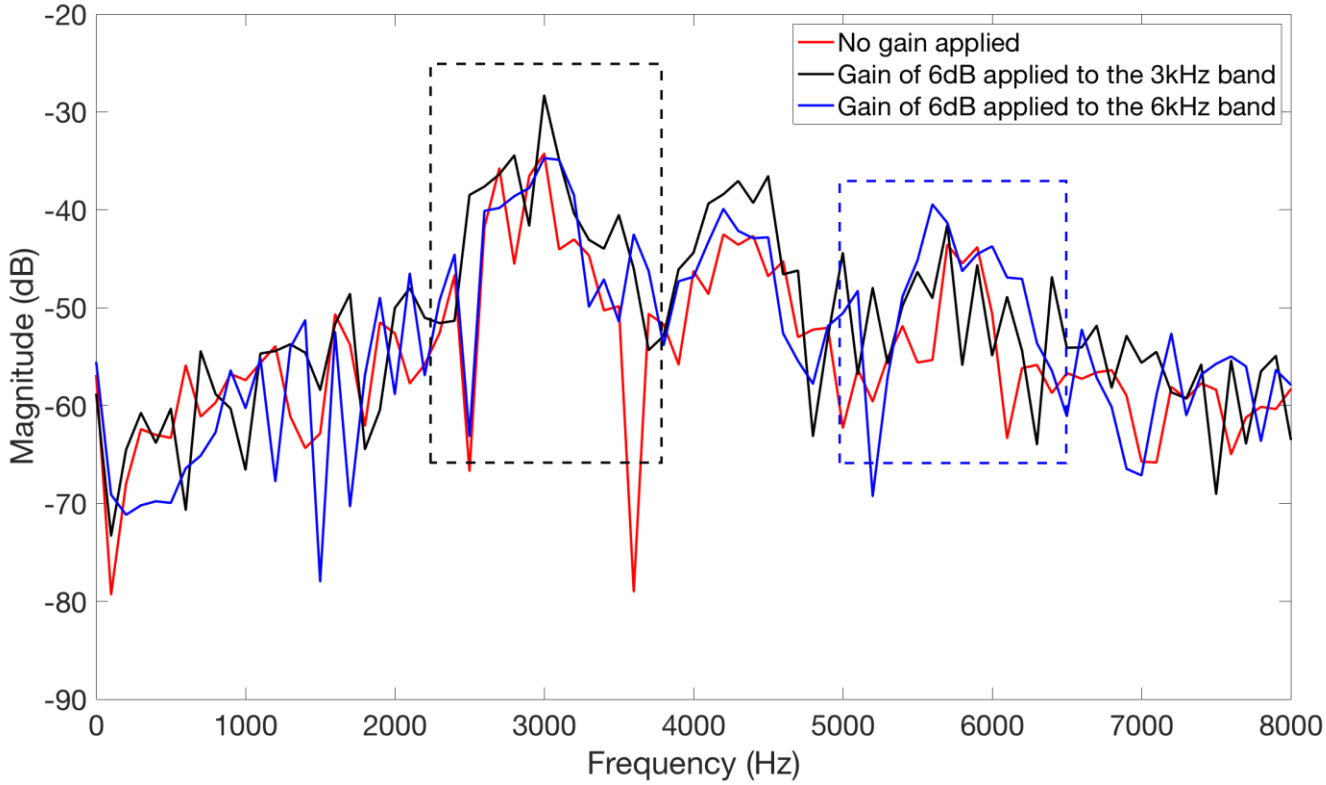
60°



90°

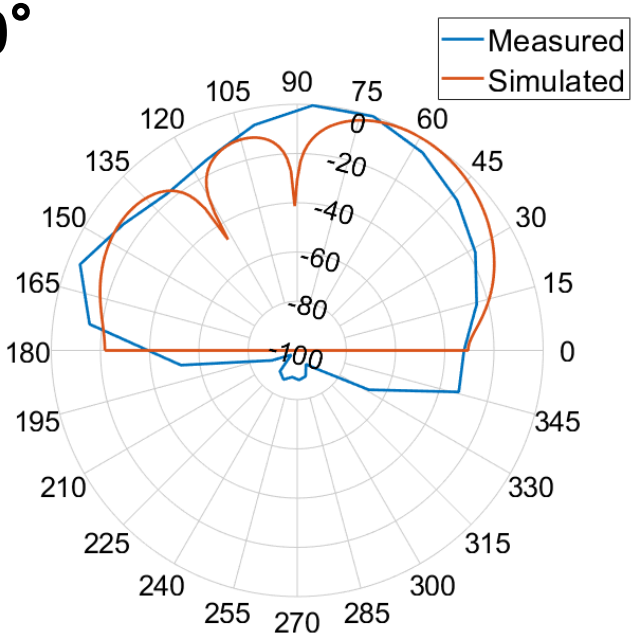
Results: Hardware

- **Total cost: R1462.61**
- **Input sound frequency: 3.15 kHz**
- **Error caused by interaction of stop-bands**

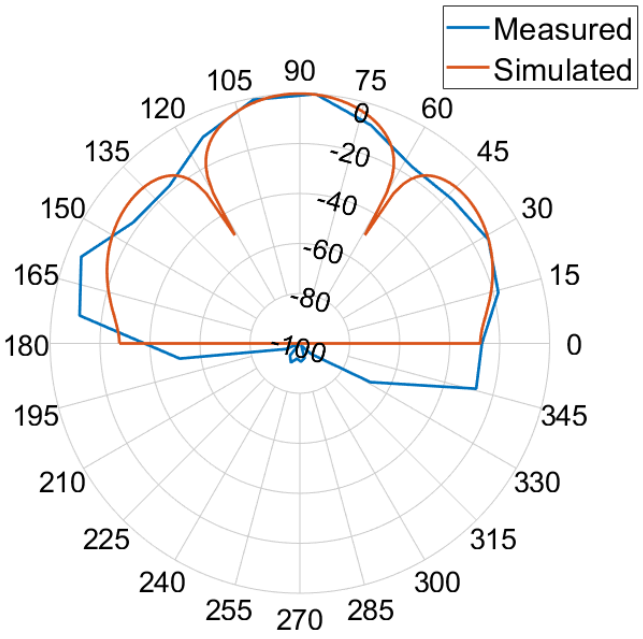


Results: Hardware

- **Most accurate at 90°**
  - **No time delay**
- **Increased error in other directions**
  - **Integer number of sample shifts**



60°



90°

System Error Analysis

Compensatory Amplification	Applied Frequency (kHz)	Frequency Band (kHz)	Error (%)
	3.15	2.82 - 3.55	0.81
	6.30	2.82 - 3.55	15.34
	3.15	5.62 - 7.08	19.56
	6.30	5.62 - 7.08	3.67

Directionality	Dial Angle (°)	Average Error (%)
	0	46.6
	60	30.7
	90	12.7
	120	22.7
	180	51.7
	Omni-directional	42.7

Future Work

- **Higher quality omni-directional microphones**
- **Integrated circuit chip**
  - **Pre-processing of the audio signals**
- **Embedding circuitry into headphones**
  - **Reduce the size of the device**
  - **Make the device more user friendly**

Conclusion

- **Objectives and specifications have been met**
- **Low cost – under R1500**
- **Full hearing aid simulation**
  - **Compensatory amplification**
  - **Steerable directionality**
- **Concepts proven in hardware**

References

[1] L. Tiete et al. “Detecting Laterality and Nasality in Speech with the Use of a Multi-Channel recorder.” *Sensors (Basel, Switzerland)*, vol. 14, pp. 1918-1949, 02 2014.

Questions?