Wall Of Sound

Vectorized Acoustic Deterrence of Elephants Research (VADER)

Team Leads: Arpad Voros, Hunter G. Cook

Team Members: Greyson Fitts, Nwaf Alamro, Morgan Pyrtle

Sponsors: Army Research Office: Paul Reid, Stephen Lee

Mentors: Dr. Pitts, Dr. Gupta, Dr. Schiefele

Project Background

Problem: In sub-Saharan Africa, elephants frequently impede onto and destroy farmland

- Negative economic impact + loss in livelihood
- Human-elephant conflict → loss in lives
  - Kenya reports 50-120 elephant deaths annually. 200 humans killed between 2010-2017
  - India reports larger annual deaths in both. Over half a million individuals affected solely from elephant crop-raiding annually

Previous ARO Solutions:

- E-collars with negative stimulus (shock, vibration, noise)
- RFID tag alert system
- Infrasound detection system
- Long Range Acoustic Device (LRAD)

Goal: Test the possibility of deterring elephants from farmland using a “wall of sound”

Project Overview

Requirements:

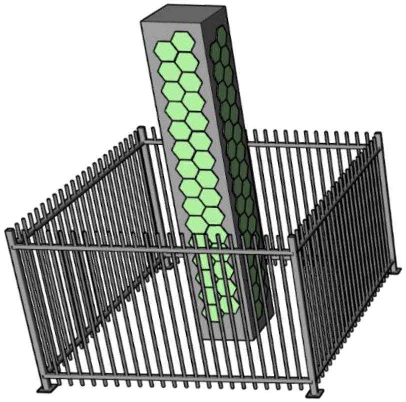
- Test the efficacy of a "wall of sound" by designing and constructing a prototype in the form of a **test bench**
- Broadcast sounds within range of elephant hearing that are known* to deter
- Not cause any physical or psychological harm

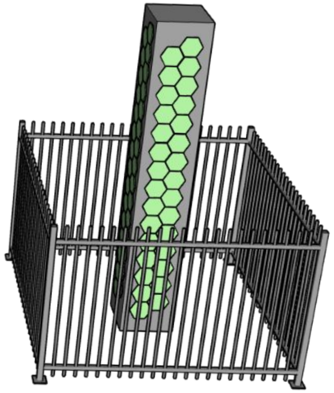
Challenges:

- Achieve directional sound
- Emit at long distances to imitate a long fence
- Play any desirable sound
- Tackle elephant habituation
- Multitude of acoustic barriers

** - sounds are known to irritate, make uncomfortable, but not necessarily tested to make an elephant leave an area*

Design Intention





Final Design Overview

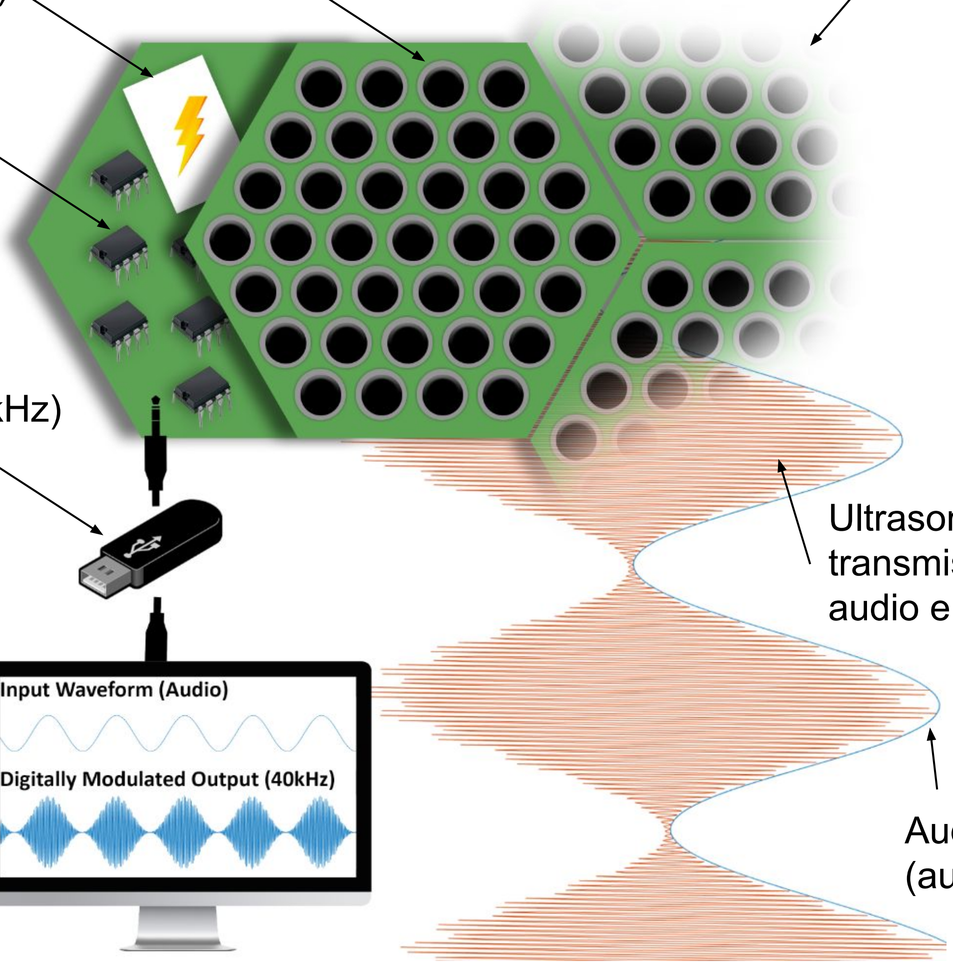
Modular PCB design to allow shared power and audio with neighboring arrays (to form a line)

Ultrasonic Transducer Array

Power over Ethernet (60 Vpp)

Amplifier Array
Customizable for filters, gain, etc

Digital to Analog Converter (192kHz)

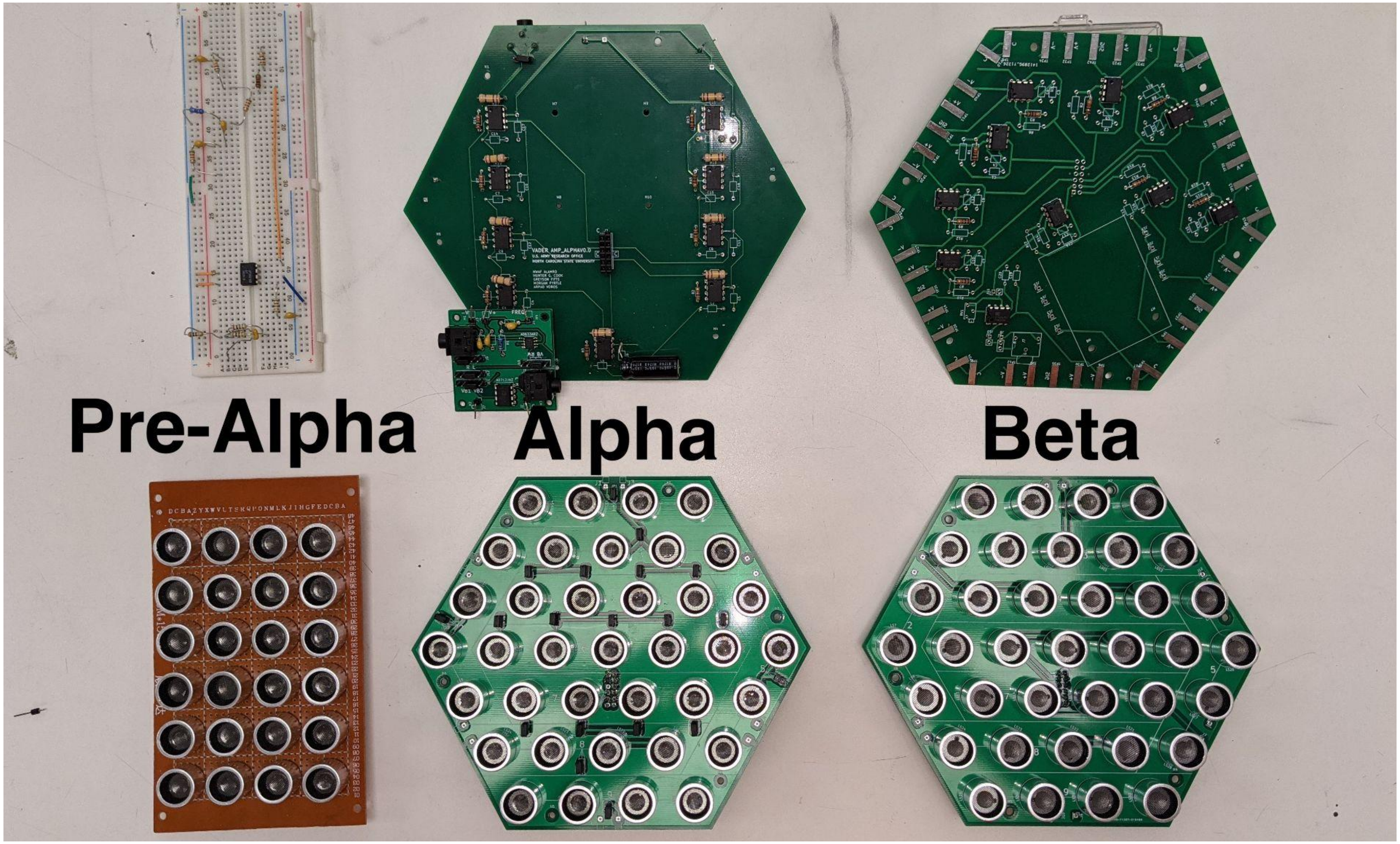


Ultrasonic, highly directional transmission signal carrying audio envelope (inaudible)

MATLAB script for making waveforms usable in this system. Simple GUI interface, meant to showcase research possibilities with this system

Audio on envelope (audible)

Design Iterations

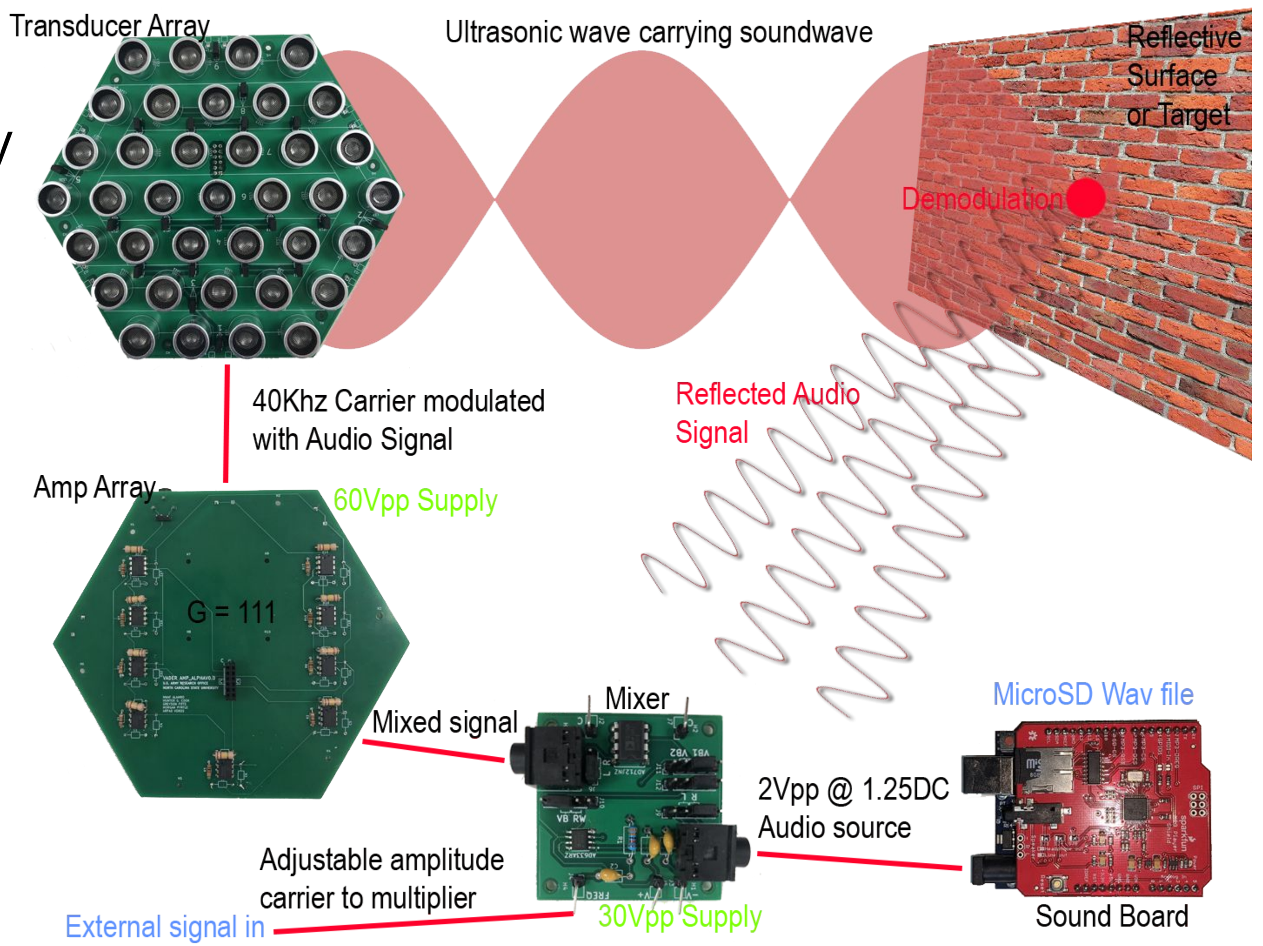


Pre-Alpha Demonstration

- 20 transducers powered by a single amplifier. Not enough, thus ratio reduced to ~4-5 transducers per amplifier
- Larger PSU for louder volume
- Need power amplifiers (previously used audio amplifiers)
- Testbench to be stationary: shifting focus onto proof of concept

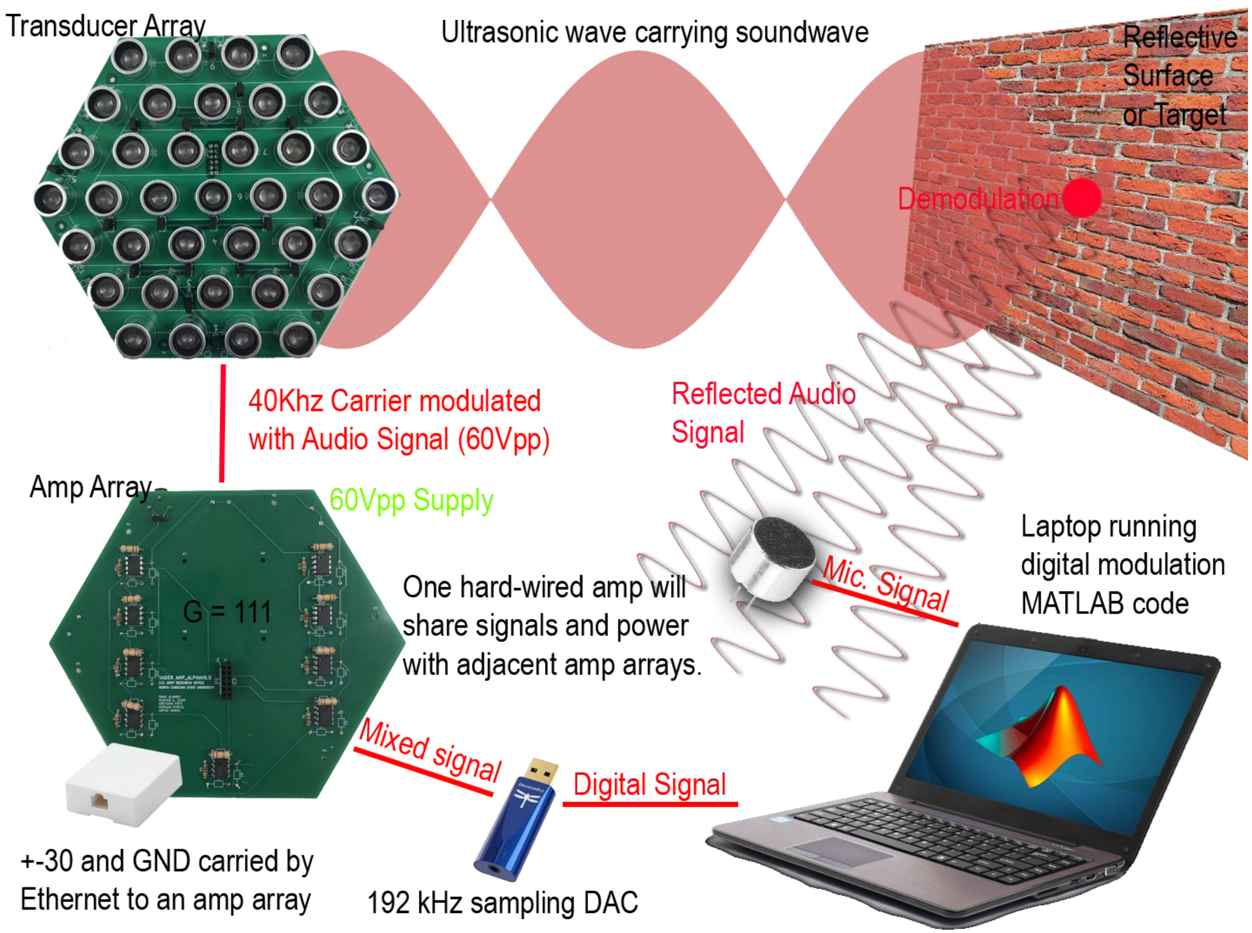
Alpha Demonstration

- Hysteresis caused by analog mixer
- Inefficient power solution
- Focus on alternative modulation techniques, traditional AM (DSBAM) introduces high THD and IMD



Beta Demonstration

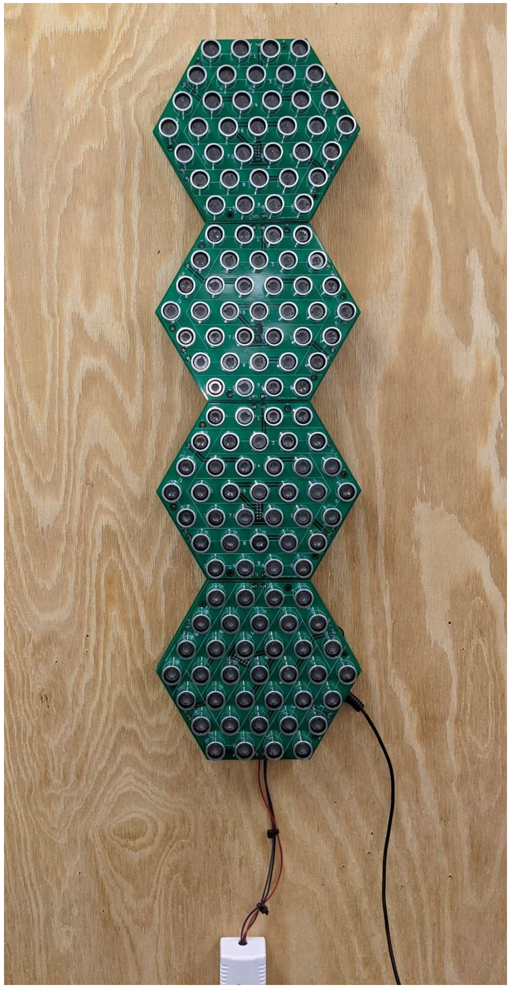
- Remove mixer due to hysteresis issue, utilize DAC in its place
- Power over ethernet for effective power solution
- Allows for digital modulation techniques
- No adjustments on amplifiers



Final Design

Design choices & justification:

- Modular design allows for easy removal/insertion of modules (transducer and amplifier board)
- Easy power solution using ethernet housing
- Filtering, buffering, and gain changing capabilities on amplifier board
- Stand to easily move to testing locations
- Very simple MATLAB interface, conducive to research



MATLAB GUI

```
_Callback(hObject, eventdata, handles)
popup_samprate (see GCBO)
 to be defined in a future version of MATLAB
with handles and user data (see GUIDATA)

lstr(get(hObject,'String')) returns popup_samprate contents as cell array
Object,'Value')} returns selected item from popup_samprate


bject creation, after setting all properties.
_CreateFcn(hObject, eventdata, handles)
popup_samprate (see GCBO)
 to be defined in a future version of MATLAB
ndles not created until after all CreateFcns called

ols usually have a white background on Windows.
MPUTER.
hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))
oundColor','white');
```

Modulation Techniques

Distortion Analysis and Reduction for the Parametric Array

Ee-Leng Tan[1], Woon-Seng Gan[1], PeiFeng Ji[2] and Jun Yang[2]

[1] Nanyang Technological University, School of Electrical & Electronic Engineering, 639798, Singapore
etanel@ntu.edu.sg, ewsgan@ntu.edu.sg

[2] Institute of Acoustic, Chinese Academy of Sciences, Beijing, China
jipeifeng@mail.ioa.ac.cn, jyang@mail.ioa.ac.cn

Article

Experimental Evaluation of Distortion in Amplitude Modulation Techniques for Parametric Loudspeakers

Ricardo San Martín [1,*], Pablo Tello [1], Ana Valencia [1] and Asier Marzo [2]

[1] Acoustics Group, Institute for Advanced Materials and Mathematics—INAMAT, Universidad Pública de Navarra, 31006 Pamplona, Spain; tello.106735@e.unavarra.es (P.T.); ana.valencia@unavarra.es (A.V.)

[2] UpnaLab, Institute of Smart Cities—ISC, Universidad Pública de Navarra, 31006 Pamplona, Spain; asier.marzo@unavarra.es

2008

Modified Amplitude Modulation
(using Orthogonal Carrier)

2020

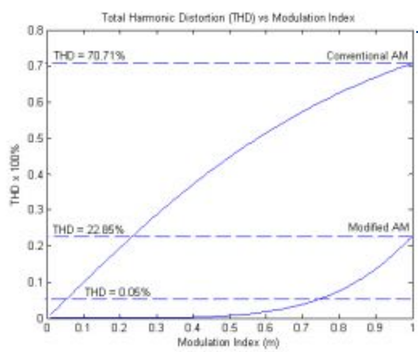


Figure 6 Comparison of THD between improved AM and conventional AM

average from
0→ 20kHz
sweep

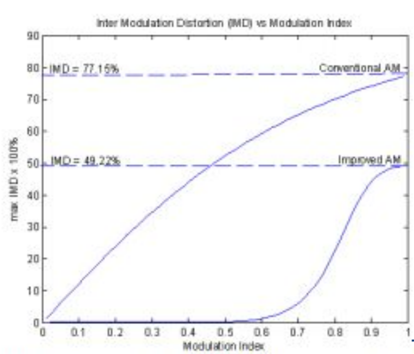
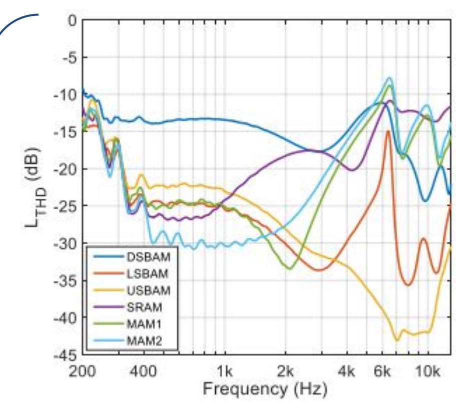
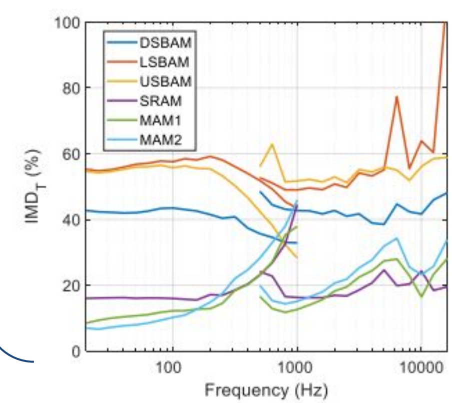


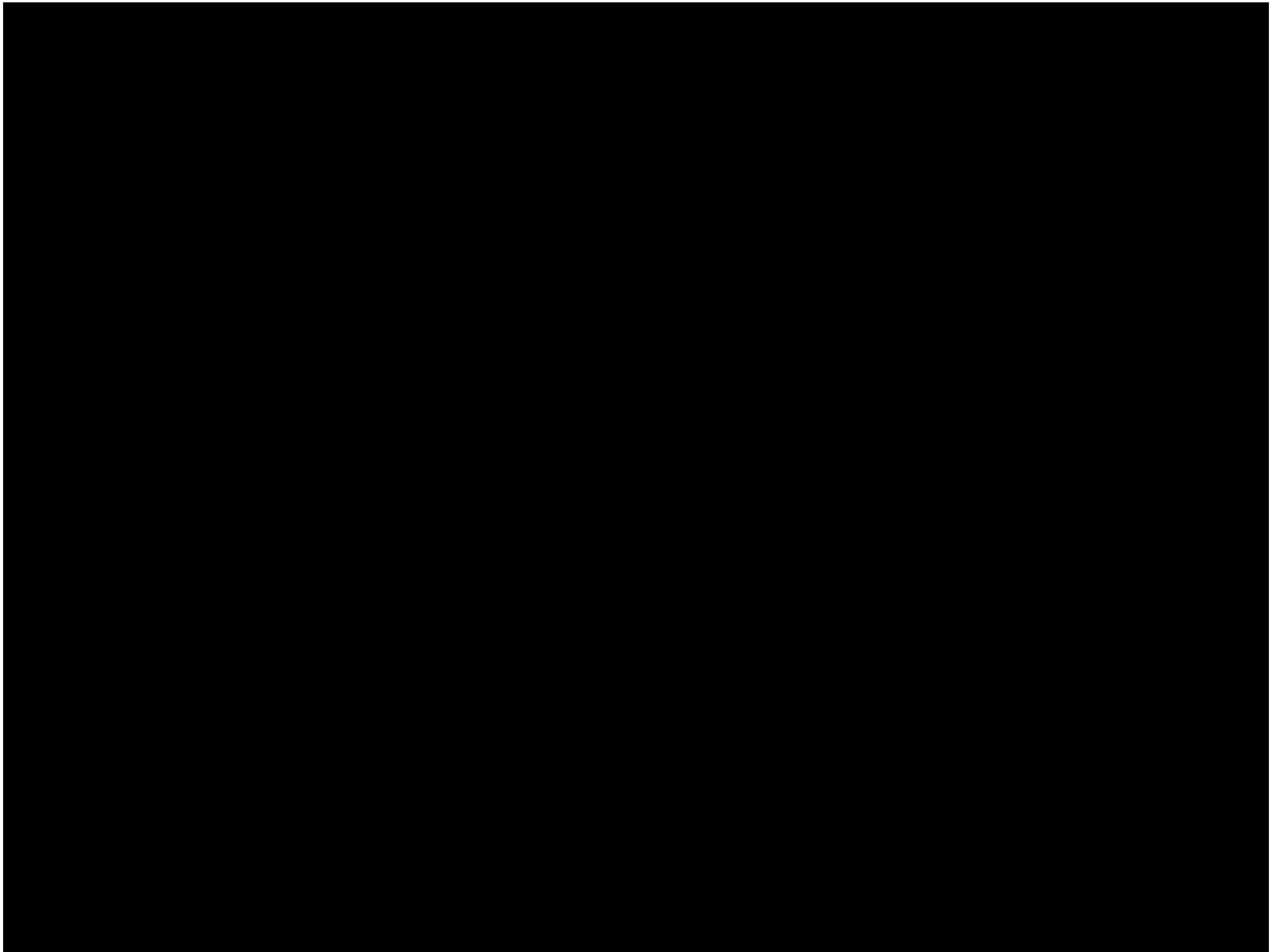
Figure 7 Comparison of IMD between improved AM and conventional AM



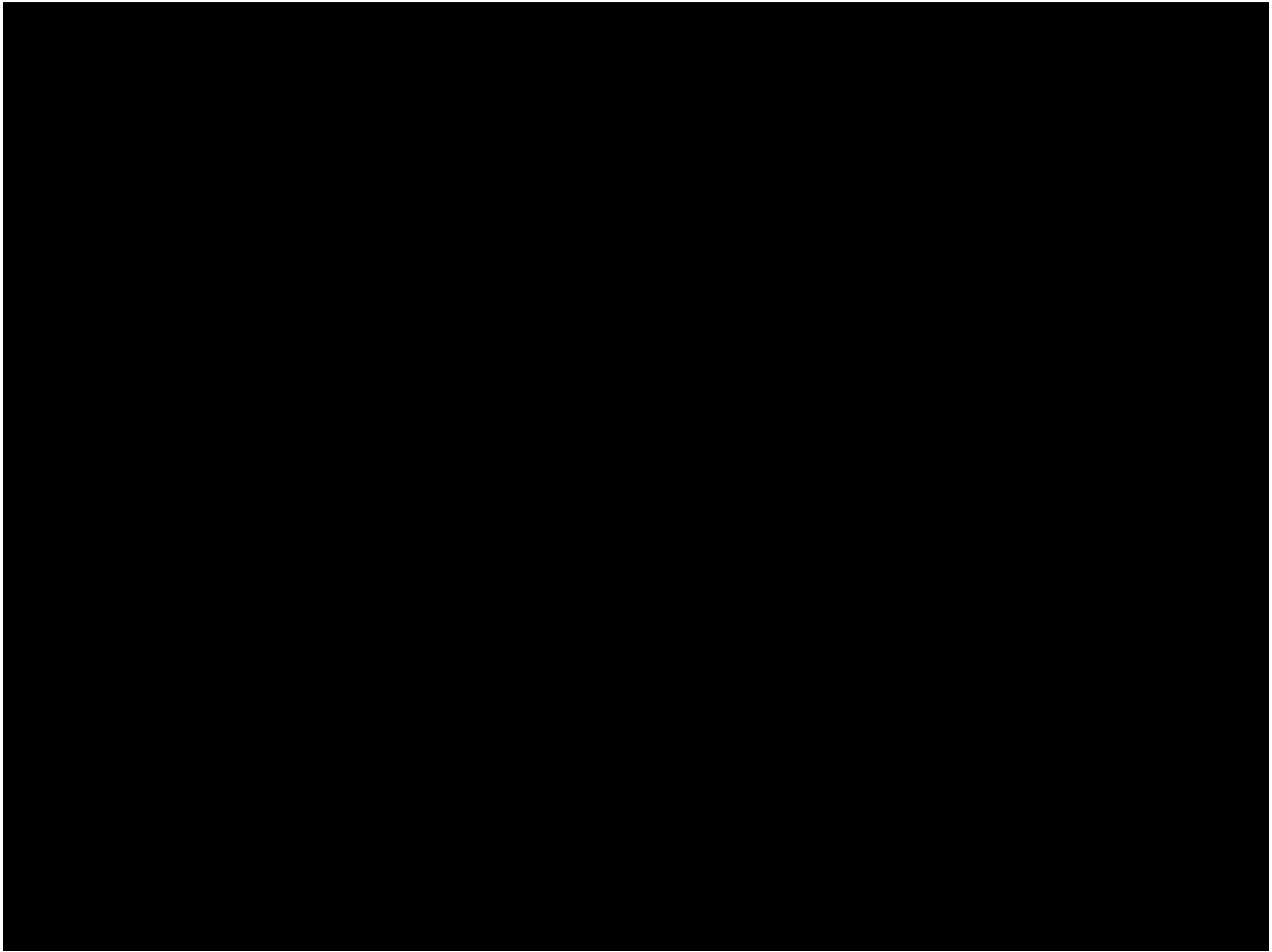
m = 1



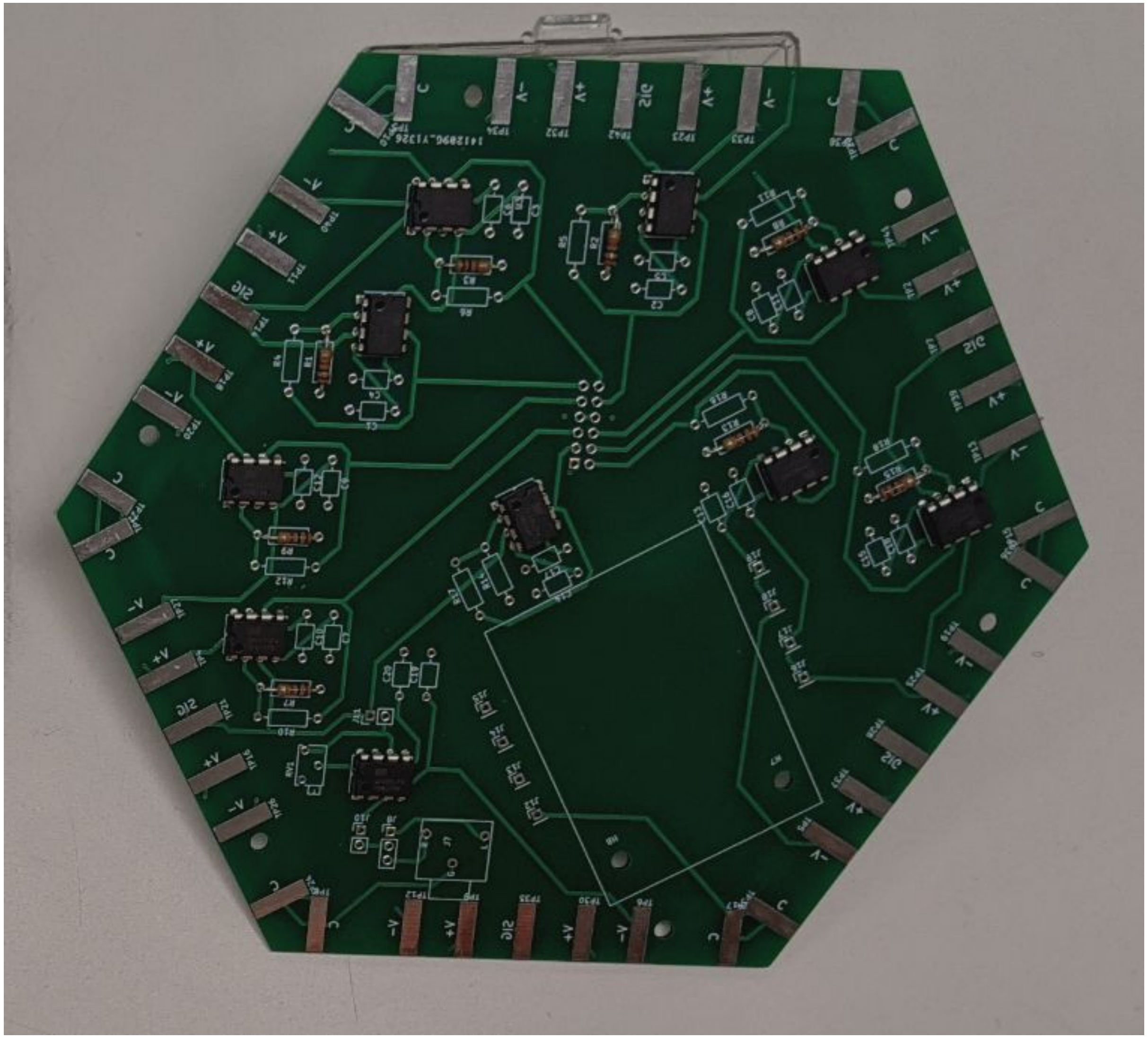
Setup for Testing

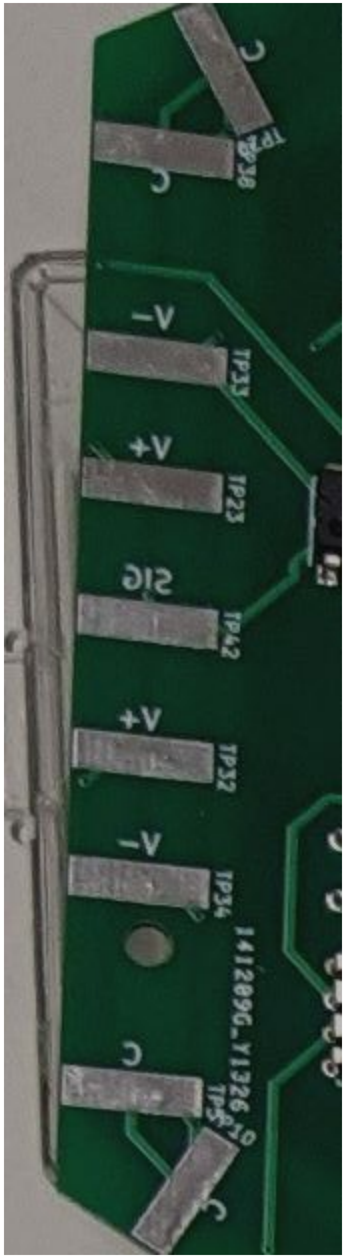


Modularity



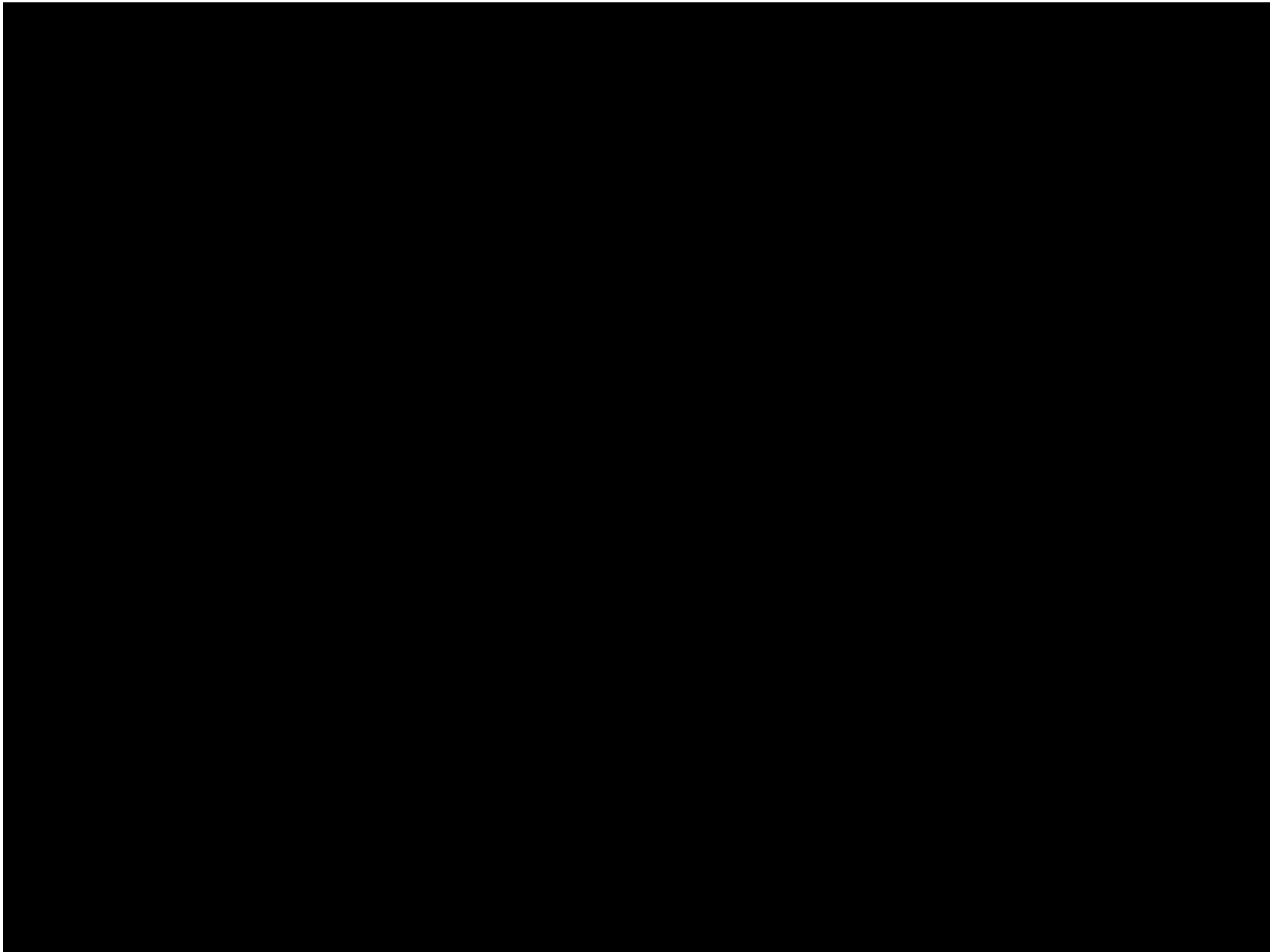
Modularity



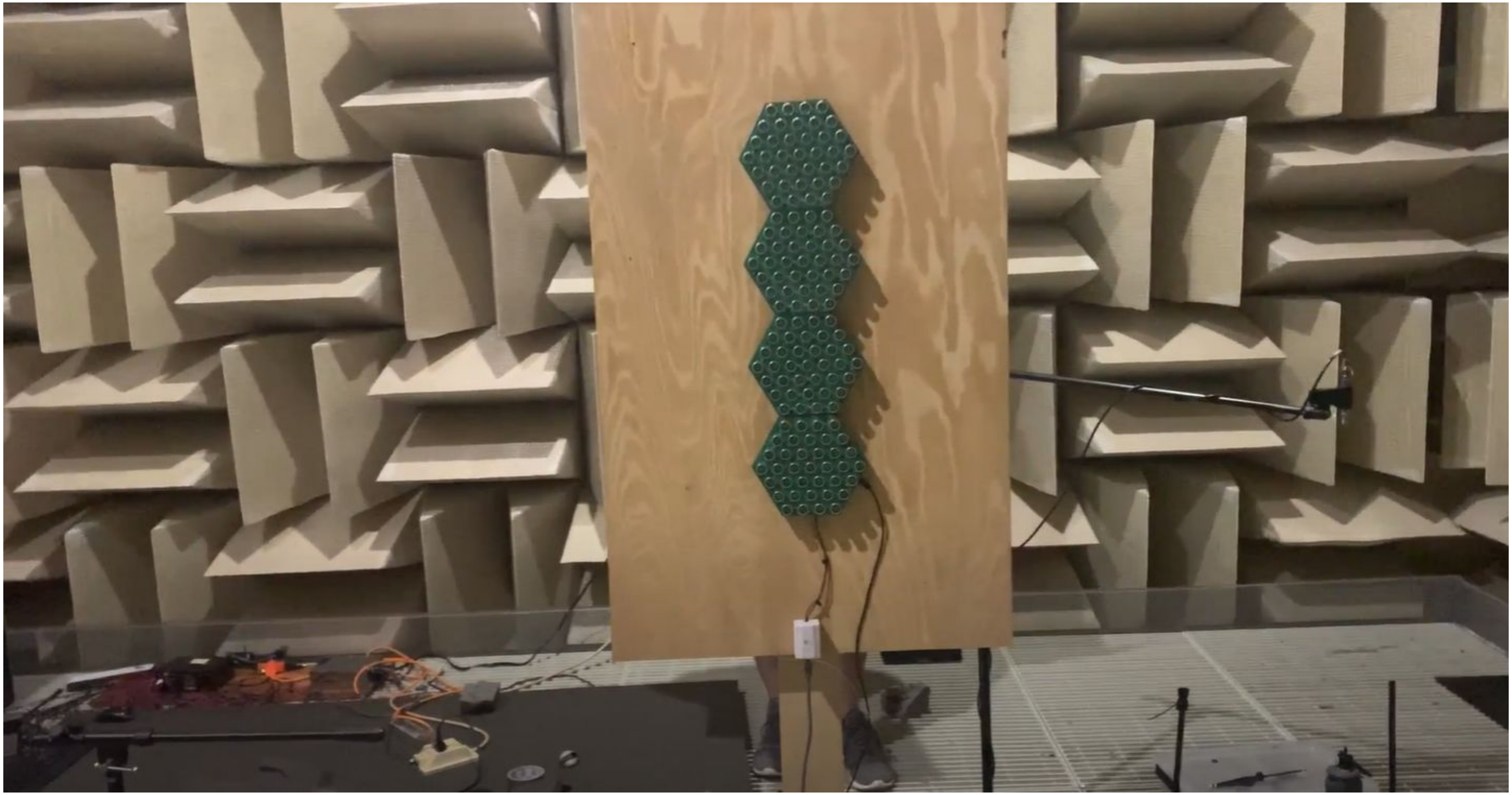


Demonstration

(Audio playing full volume during demos, the quietness is product of directionality)

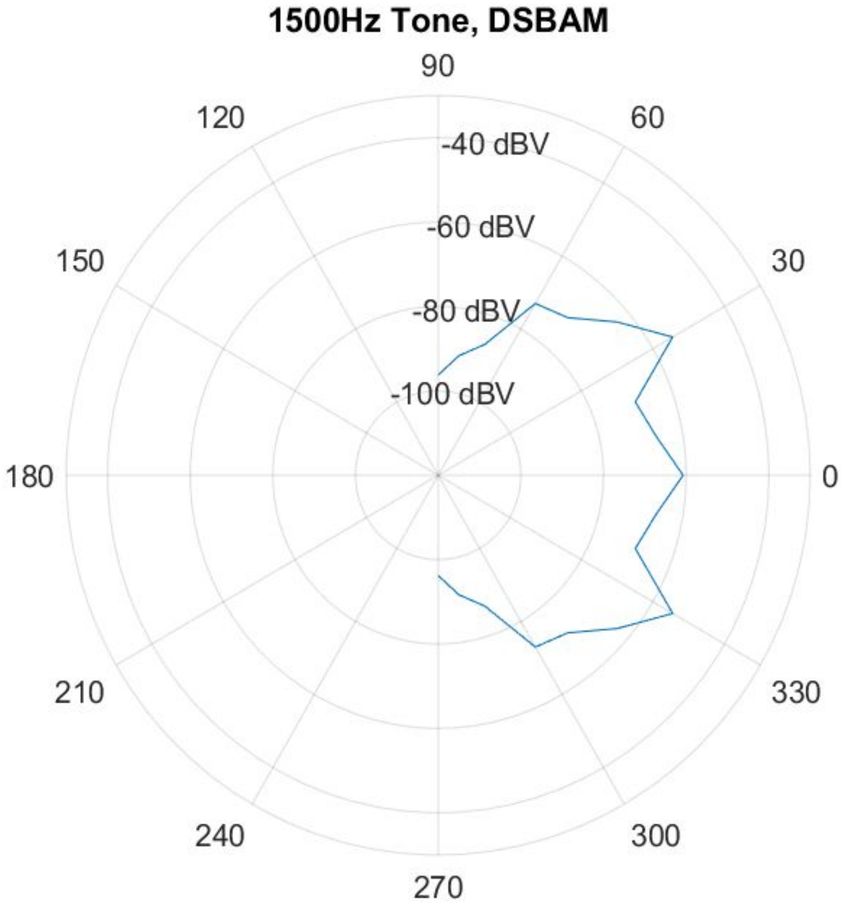


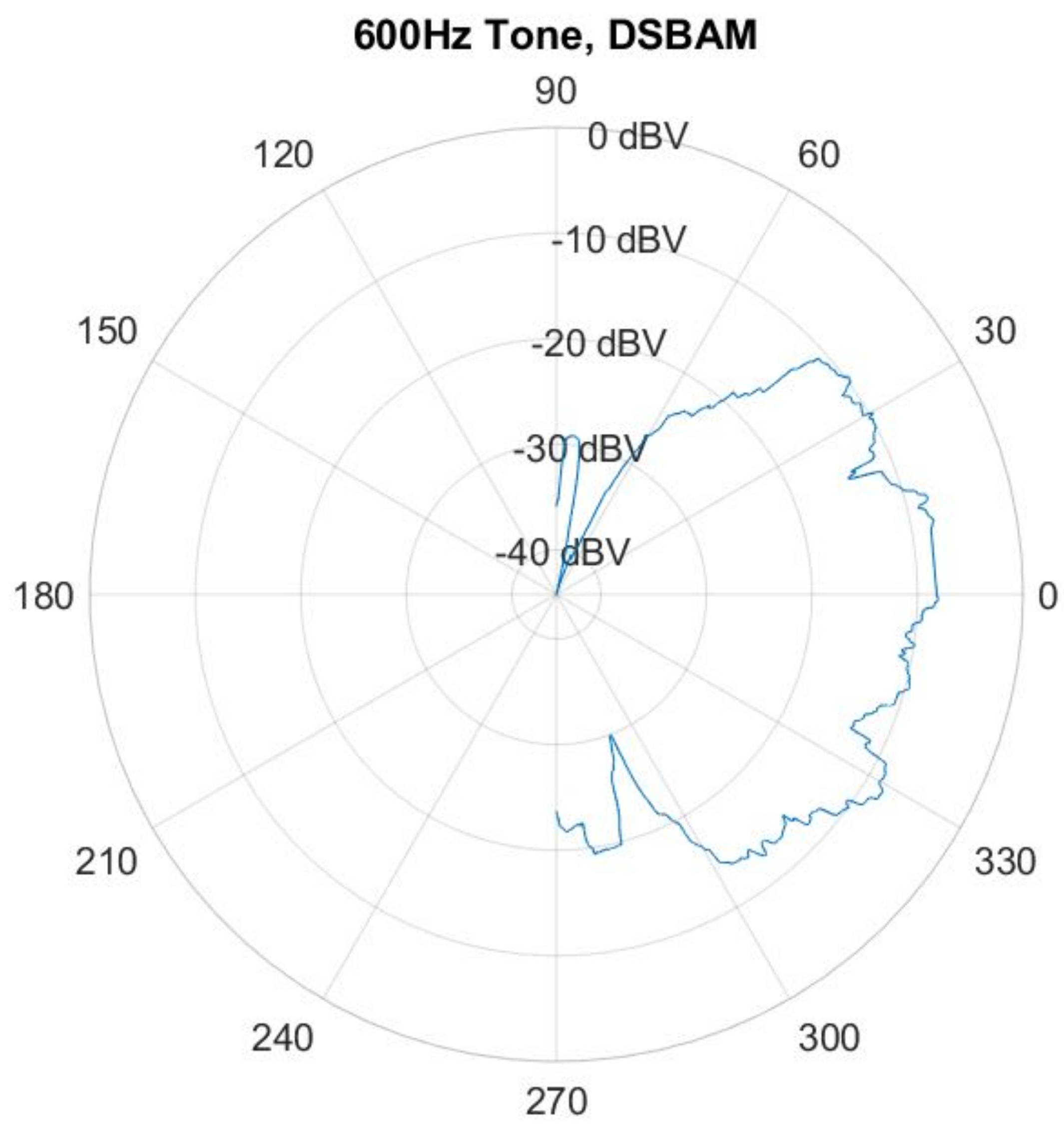
Anechoic Chamber



Radiation Pattern

- Microphones convert vibrations in air into electrical current which becomes an audio signal
- MEMS Microphone capable of detecting audio from 6 Hz - 20 kHz
- Analyze amplitudes of received signals to determine radiation pattern (The basis for research capable on our system)
- Measurements taken at specific distance and angle




600Hz Tone, DSBAM
90
120
60
150
30
180
0
210
330
240
300
270
0 dBV
-10 dBV
-20 dBV
-30 dBV
-40 dBV

Moving Forward

- Implement audio soundshield, sample at 192kHz
  - Plays audio randomly (prevent habituation)
- Test on elephants
- Physically modular, "click" into place for on the fly arrangement changes
- Significantly more research on theory, which can be confirmed or denied on our testbench

Future Research Capabilities

- Improving sound quality
  - Signal processing
  - Modulation techniques
  - *Additional ultrasonic phenomena*

- Improving directionality
  - Focusing sound with phasing
  - *Additional ultrasonic phenomena*

- Improving measurements
  - Acoustic film in front of microphone
  - Condenser microphone
  - 3D radiation pattern
  - Higher resolution radiation pattern (using consistent measurement methods)

Thank You!

Thank you for your time and attention

Please email us any questions you may have!

hgcook@ncsu.edu
aavoros@ncsu.edu

Backup Slides

Backup: MAM

Distortion Analysis and Reduction for the Parametric Array

Ee-Leng Tan[1], Woon-Seng Gan[1], PeiFeng Ji[2] and Jun Yang[2]

[1] Nanyang Technological University, School of Electrical & Electronic Engineering, 639798, Singapore
etanel@ntu.edu.sg, ewsgan@ntu.edu.sg

[2] Institute of Acoustic, Chinese Academy of Sciences, Beijing, China
jipeifeng@mail.ioa.ac.cn, jyang@mail.ioa.ac.cn

2008

Article

Experimental Evaluation of Distortion in Amplitude Modulation Techniques for Parametric Loudspeakers

Ricardo San Martín [1,*], Pablo Tello [1], Ana Valencia [1] and Asier Marzo [2]

1 Acoustics Group, Institute for Advanced Materials and Mathematics—INAMAT, Universidad Pública de Navarra, 31006 Pamplona, Spain; tello.106735@e.unavarra.es (P.T.); ana.valencia@unavarra.es (A.V.)
2 UpnaLab, Institute of Smart Cities—ISC, Universidad Pública de Navarra, 31006 Pamplona, Spain; asier.marzo@unavarra.es

2020

Modified Amplitude Modulation
(using Orthogonal Carrier)

$$P_1(t) = P_0 e^{-\alpha x} \left\{ \begin{array}{l} [1 + mg(t)]\sin\omega_c t \\ + \left[1 - \frac{1}{2}m^2 g^2(t) - \frac{1}{8}m^4 g^4(t)\right]\cos\omega_c t \end{array} \right\}.$$

$$p_{MAM1}(t) = [1 + ms(t)]sin(\omega_c t) + \left[1 - \frac{1}{2}m^2 s^2(t)\right]cos(\omega_c t),$$

$$p_{MAM2}(t) = [1 + ms(t)]sin(\omega_c t) + \left[1 - \frac{1}{2}m^2 s^2(t) - \frac{1}{8}m^4 s^4(t)\right]cos(\omega_c t).$$

Backup: MAM (cont.)

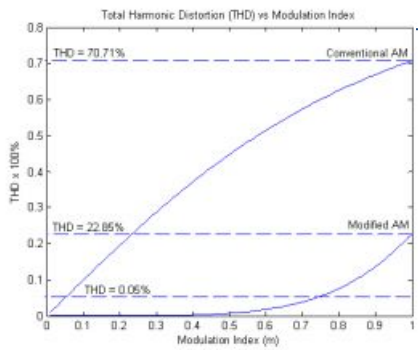


Figure 6 Comparison of THD between improved AM and conventional AM

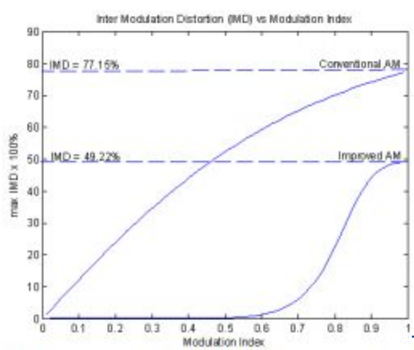
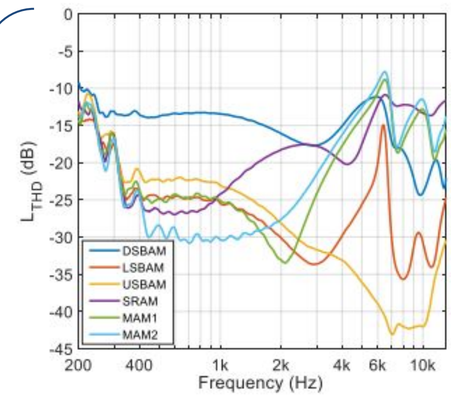
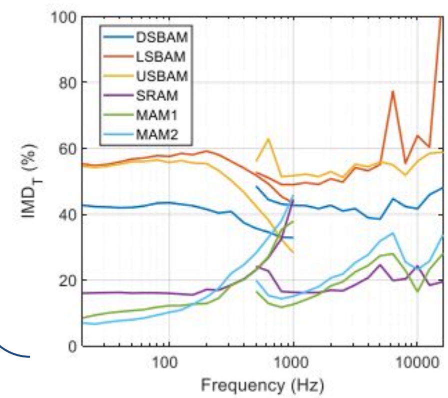


Figure 7 Comparison of IMD between improved AM and conventional AM

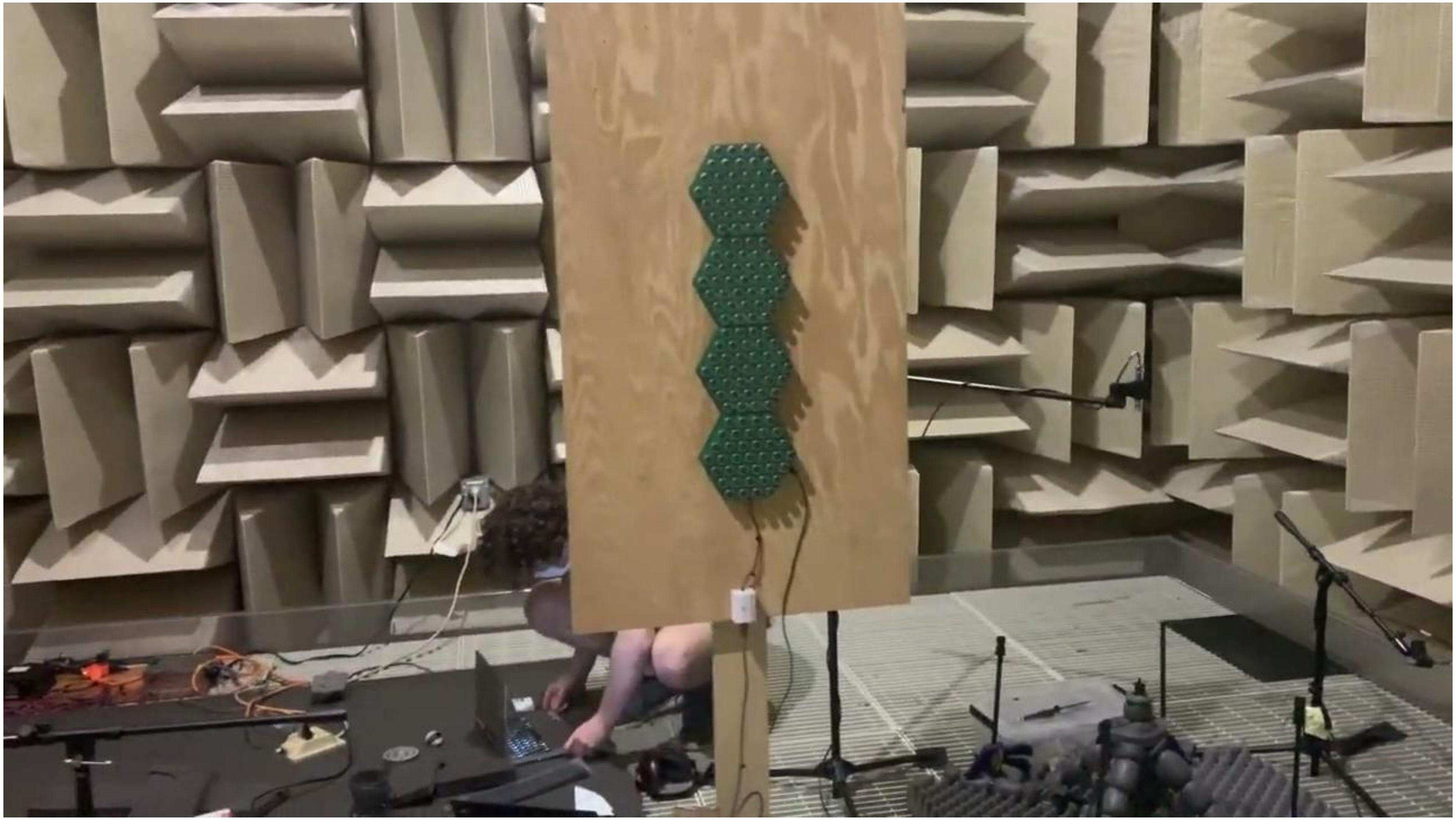
average from
0→ 20kHz
sweep

m = 1





Backup: Anechoic

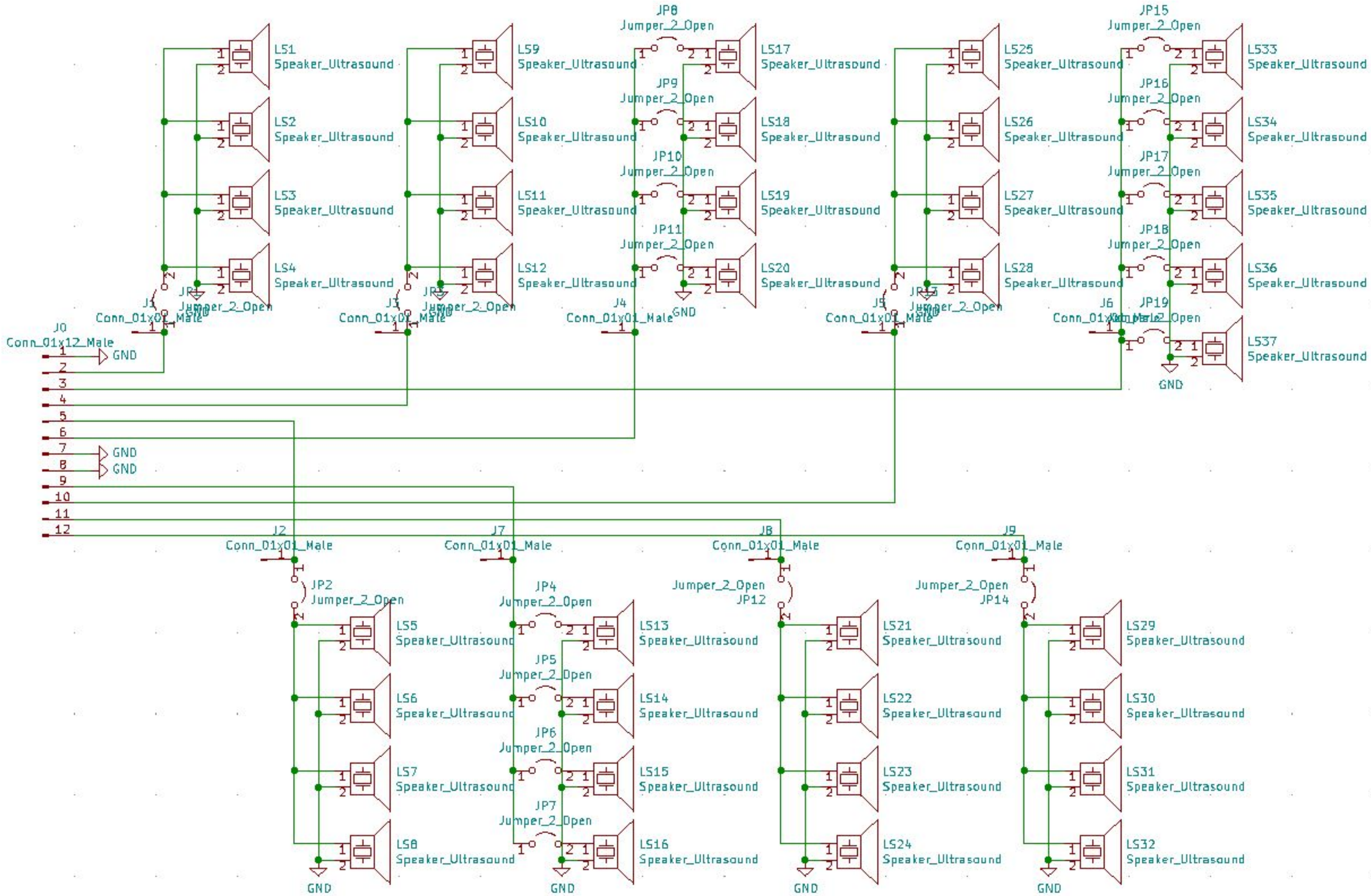


Backup: Elephant Deterring Sounds

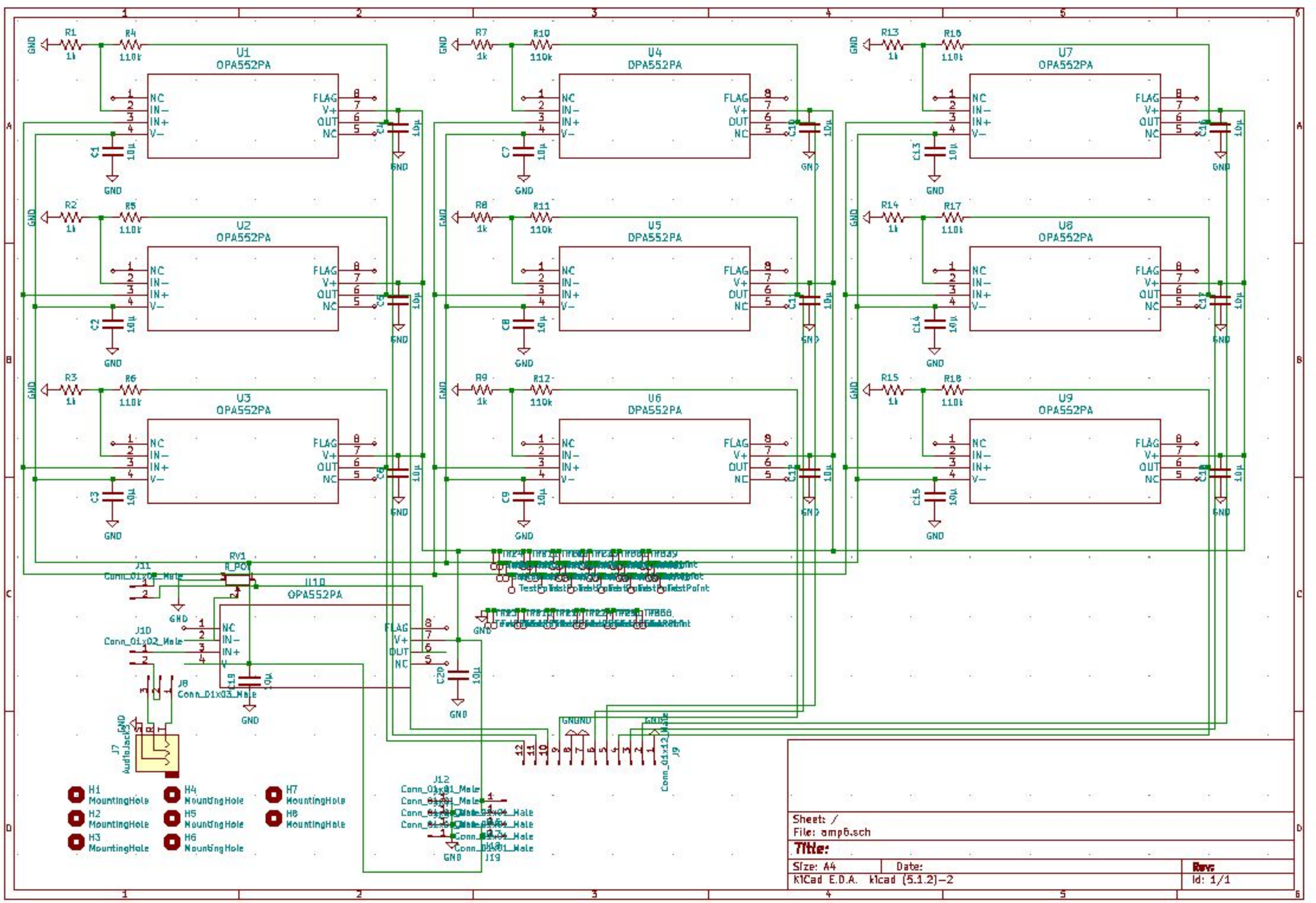
Dr. Skip Scheifele (world renown animal audiologist) and Lisa Scheifele (elephant specialist) helped us come to the conclusion:

- Play different sounds, change up duty cycle, fade in/out to prevent habituation
- Good candidate sounds for deterrence:
  - African honey bee swarm sounds
  - Construction noise
  - 55/56 Hz female warning tone (relatively new find, not yet tested)
  - Random unsettling sounds
- Progressive increasing volume is good idea, as elephant can gauge its own comfort rating

Backup: Transducer PCB Schematic



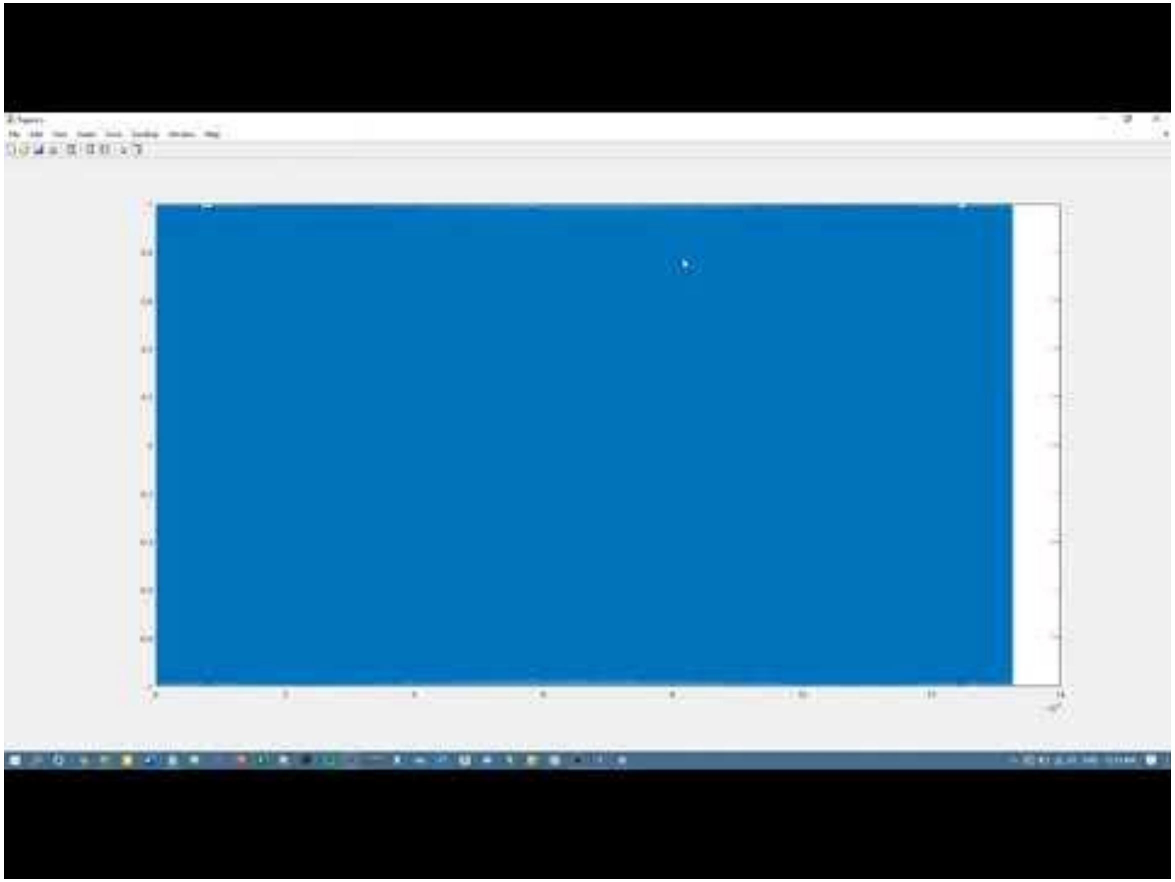
Backup: Amp PCB Schematic



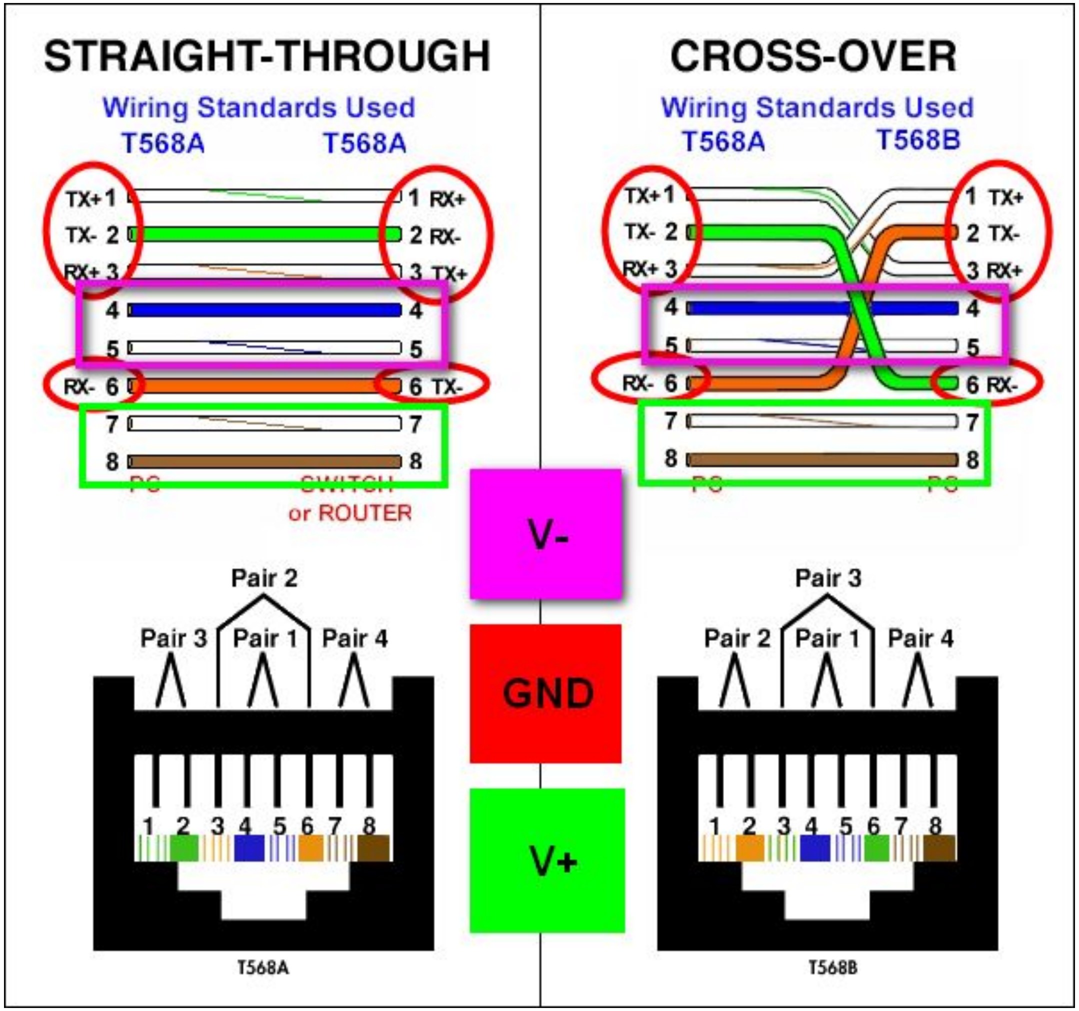
Backup: GUI (simple demo)

```
_Callback(hObject, eventdata, handles)
popup_samprate (see GCBO)
 to be defined in a future version of MATLAB
with handles and user data (see GUIDATA)

lstr(get(hObject,'String')) returns popup_samprate contents as cell array
Object,'Value')} returns selected item from popup_samprate


bject creation, after setting all properties.
_CreateFcn(hObject, eventdata, handles)
popup_samprate (see GCBO)
 to be defined in a future version of MATLAB
ndles not created until after all CreateFcns called

ols usually have a white background on Windows.
MPUTER.
hObject,'BackgroundColor'), get(0,'defaultUicontrolBackgroundColor'))
oundColor','white');
```

Backup: GUI (in-depth demo)



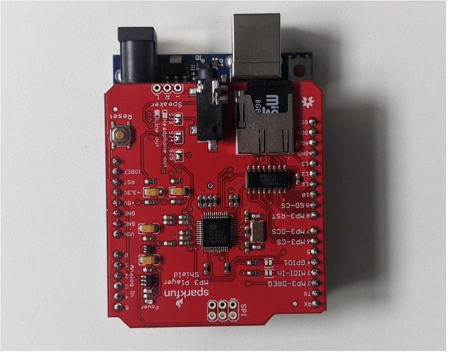
Backup: Ethernet standard accountability



Backup: Sound Board

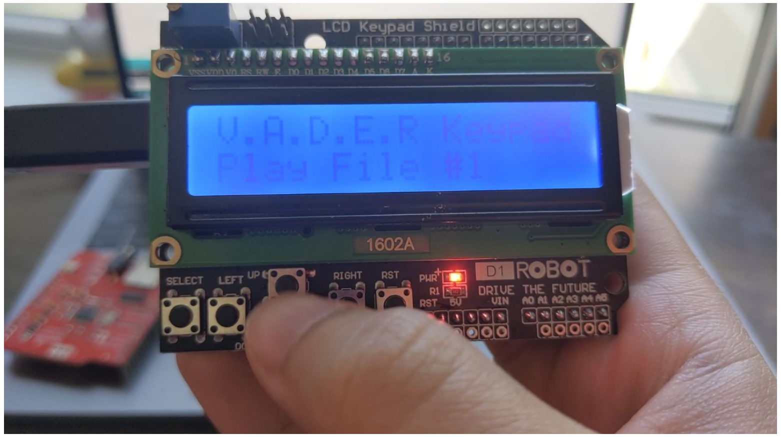
Sound Shield

- Uses VS1053 IC on an Arduino Uno
- Sound files are uploaded on a 16GB micro SD card.
- Files can be in WAV, MP3, VMA, AAC etc..
- Using the Arduino IDE, you can play, stop, and change the volume of the tracks.
- VS1053 DAC max output is 50kHz (unfortunately).

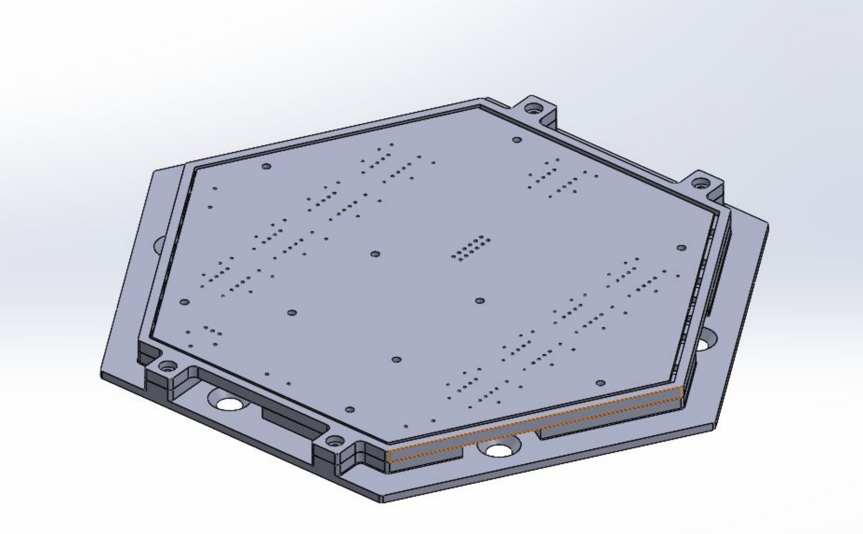


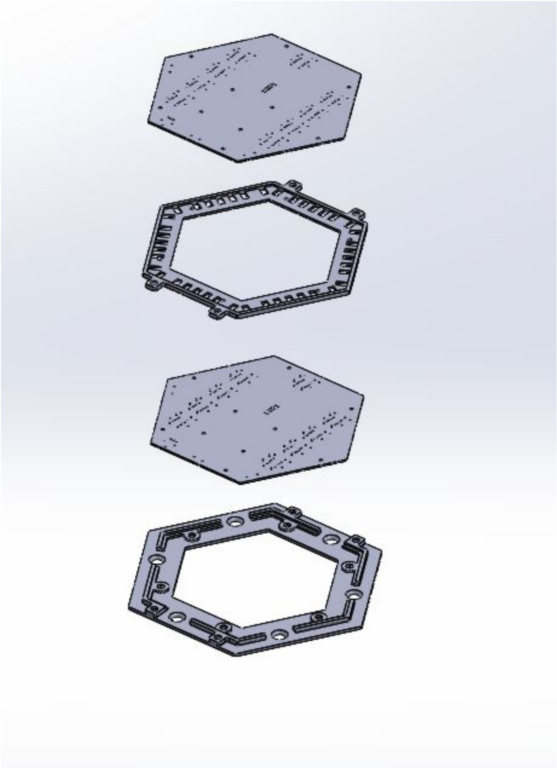
Keypad and LCD Control

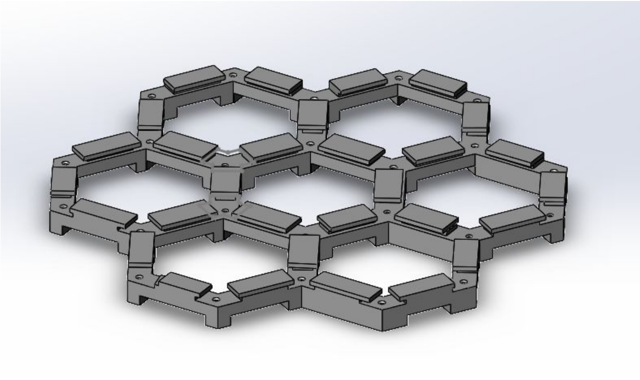
- Capability of playing different tracks
- Shows filename on LCD
- No connection to a laptop

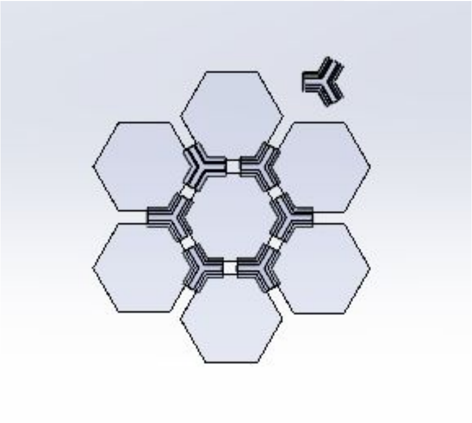


Backup: Connectors

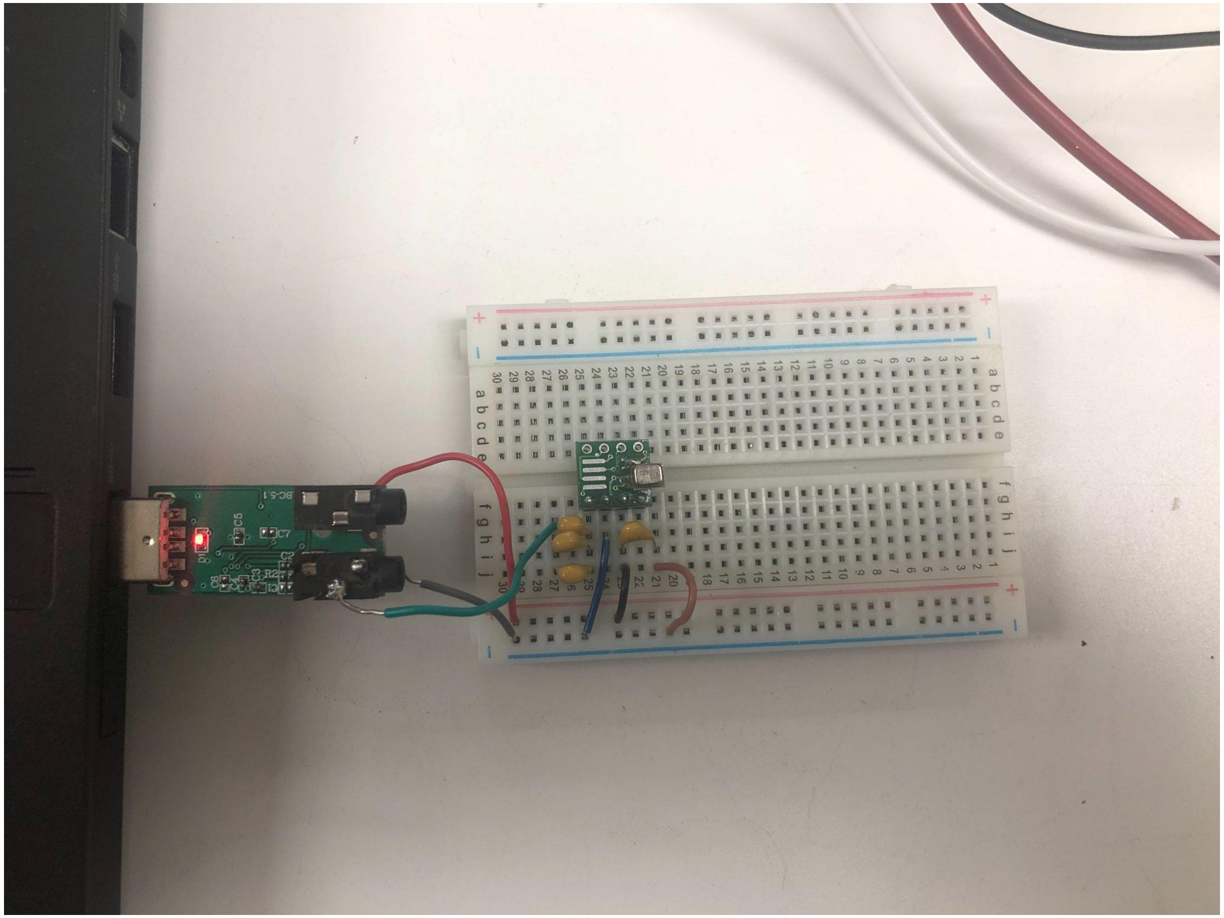








Backup: Microphone



Backup: Pre-Alpha Setup