Project 21:
Wall Of Sound

Preliminary Design Review

VADER

Vectorized Acoustic Deterrence of Elephants Research

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Sponsors: Army Research Office: Paul Reid, Stephen Lee

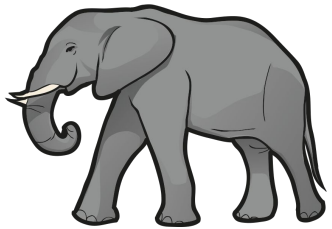
Mentors: Dr. Pitts, Dr. Gupta, Dr. Schiefele

Project Background

Problem: Elephants in Sub-Saharan Africa impede on crops of farmers, frequently leading to loss in annual yield & livelihood, dangerous human-elephant conflict, and fatality of both parties.

Solution: Create a passive deterrence system which inhibits elephants from trespassing onto farmland.

Impact: Reduces the number of casualties on both sides, humans and elephants.



Project Scope

Key Requirements

- Frequency ranges to broadcast: 10Hz - 20kHz
- Deter elephants with a passive, safe acoustic system
- Does not require direct user attention to operate
- Does not enrage the elephant or cause it bodily harm.
- Does not harm people when active.

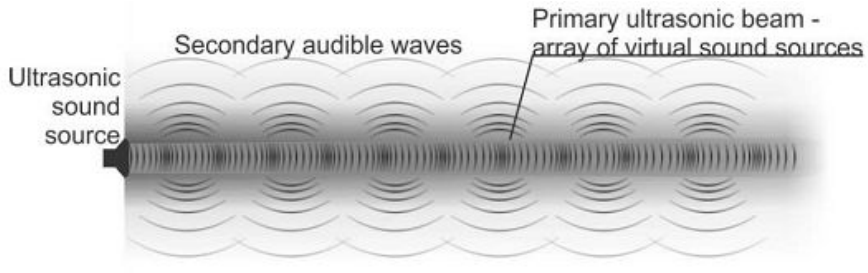
Key Constraints

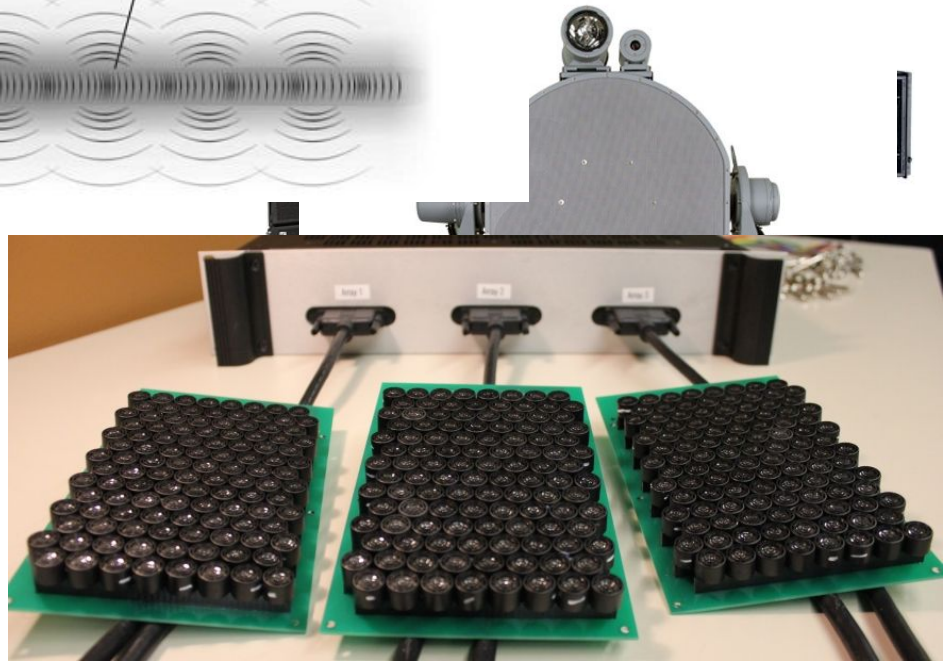
- Terrain and vegetation
- Differences in weather patterns
- Actively working vs. detection based
- Curious animals/angry elephants destroying the device
- High frequencies known to upset animal

System Design

Design Decisions

- Linear Phas
- Parabolic L
- Parametric Array





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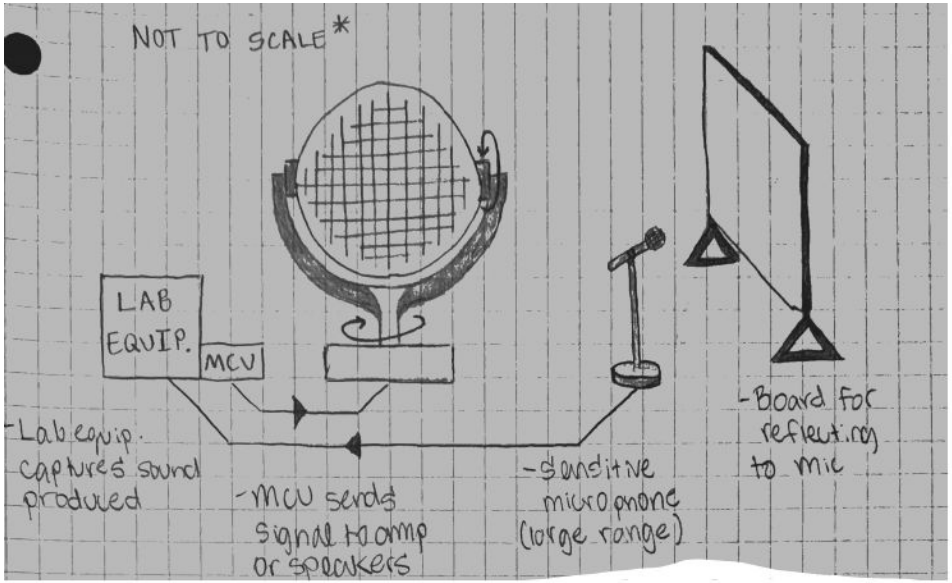
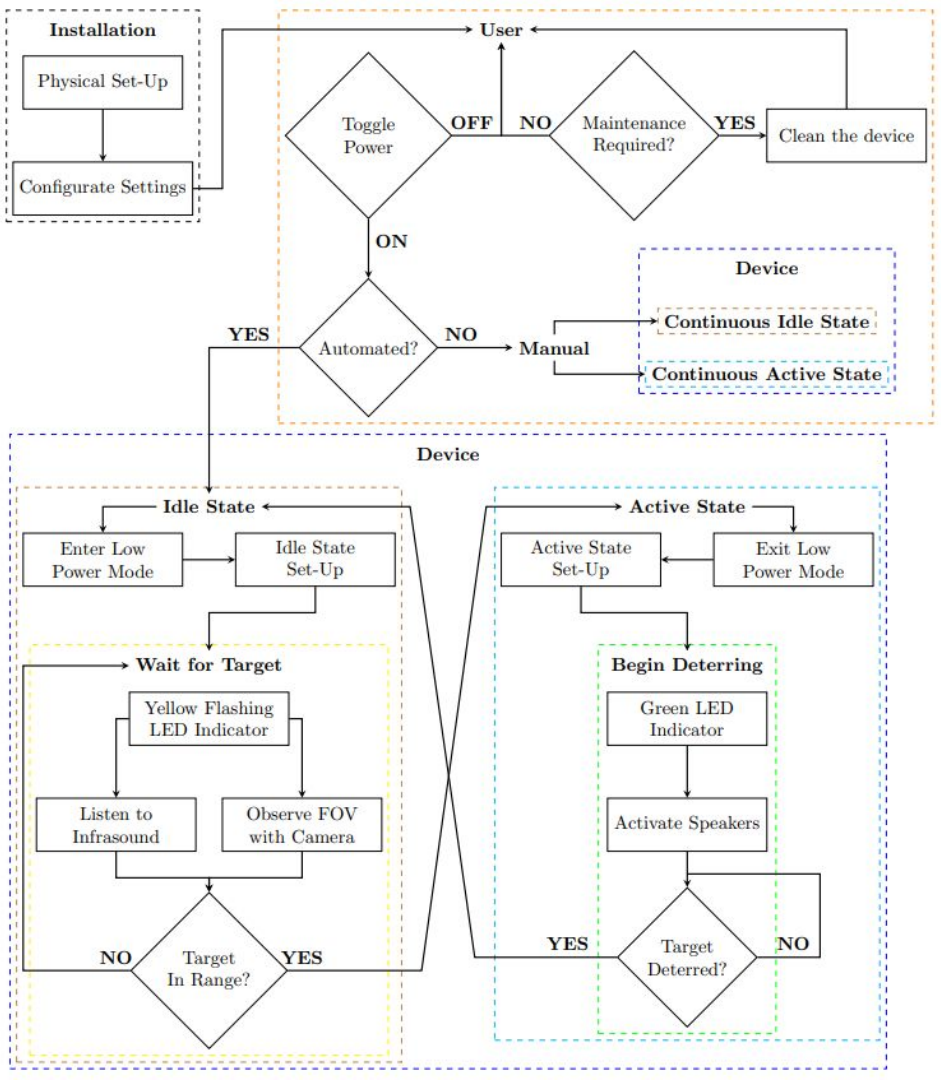
System Concept Design

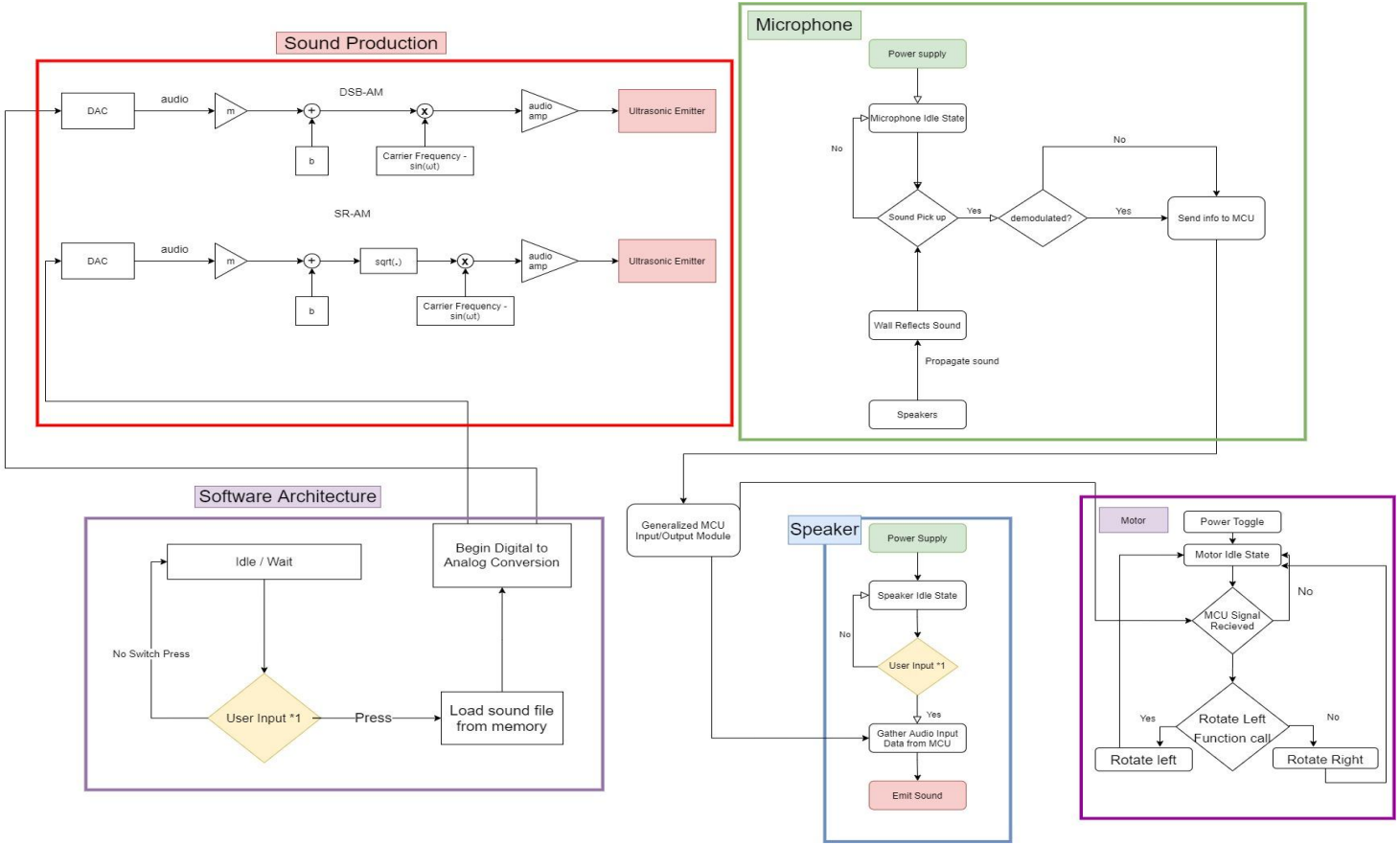
Aimable/Configurable Parametric Speaker
w/ Microphone to catch sound reflections



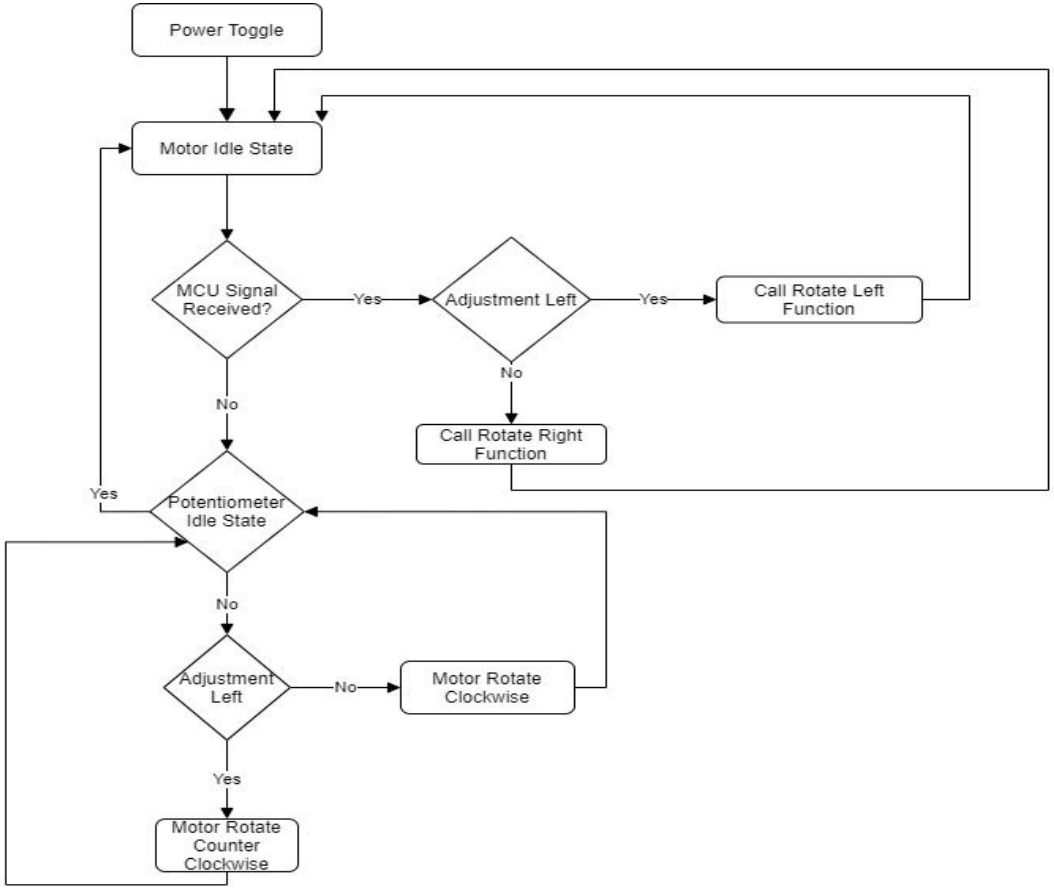
User Operation Flowchart



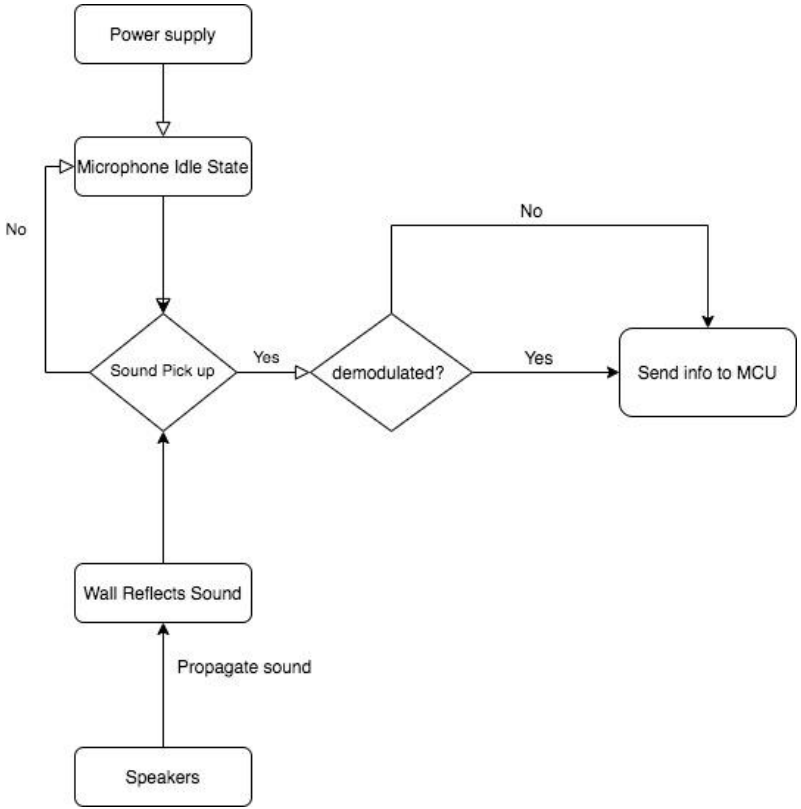
Detailed Subsystem Concept Diagram



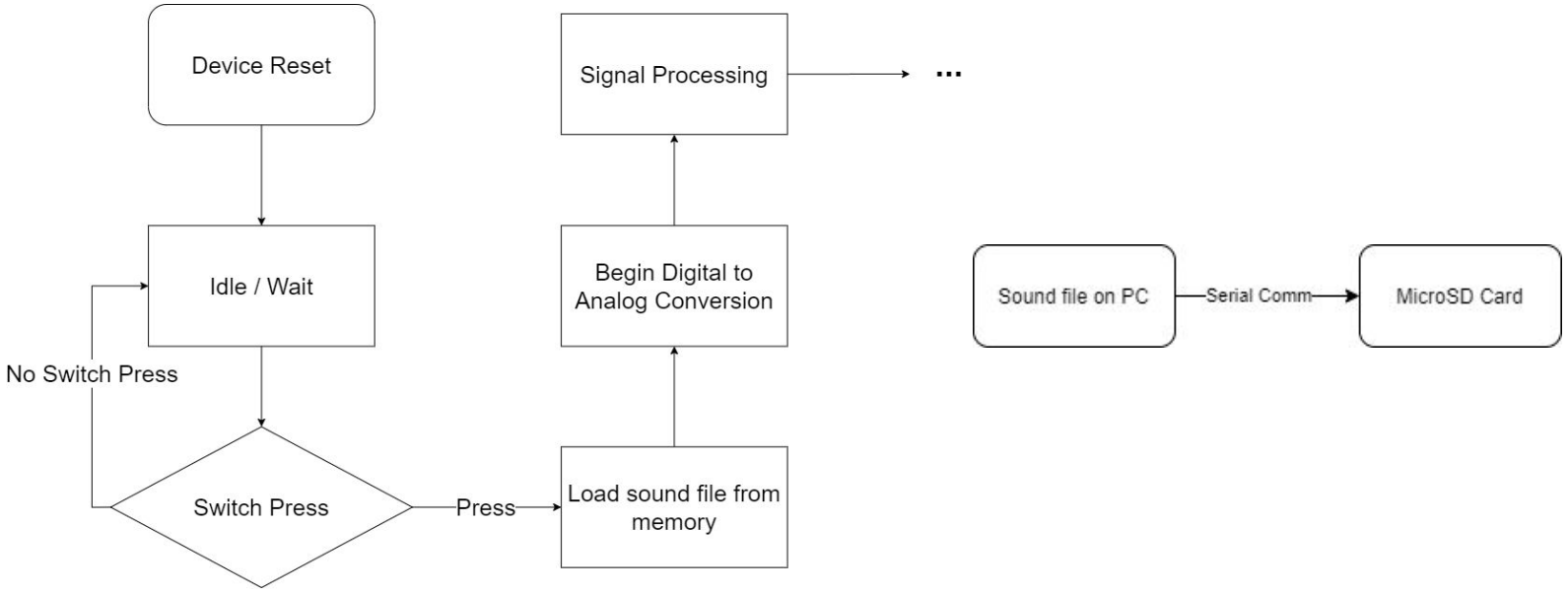
Motor Controller Flowchart



Microphone Flowchart

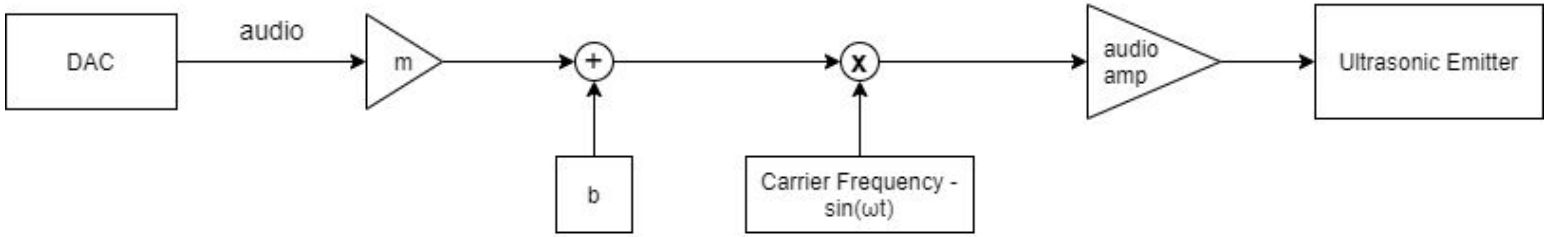


Software Architecture for Testbench

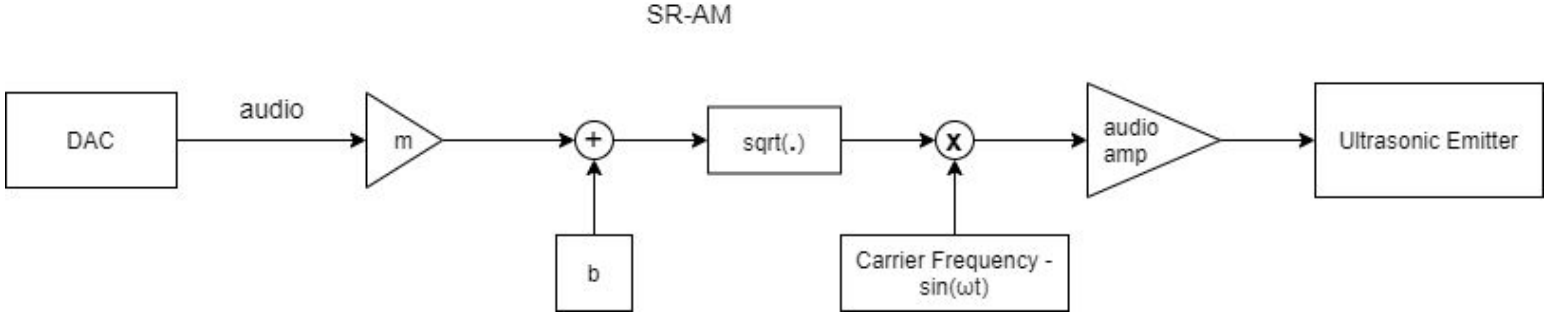


Analog Modulation Techniques

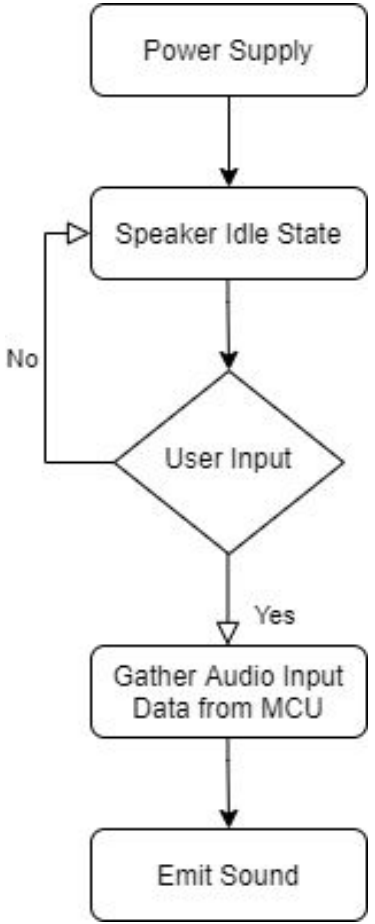
DSB-AM



SR-AM



Speaker Flowchart



Prototype Motor Controller Trade-Offs

Motor Controller	PWM Motor Speed Controller 6V - 60V Variable Speed/Forward and Reverse Switch Pulse Width Modulation DC Speed Regulation	Cytron 20Amp Bi-Directional 6V-30V DC Motor Driver Speed Controller 60A Peak	PN00218-CYT14 Motor Driver 2 Channels 30Amp 7V-35V DC SmartDriveDou MDDS30
Cost	$14.99	$19.80	$65.00
Voltage Range	6V - 60V	6V-30V	7V-35V
MCU Compatible?	No	Yes	Yes
Ease of Use	High	Medium	Low

Microphone Trade-Offs

Microphones	**Geophone - SM-24**	**ICS-40300**	Presonus
Cost	$59.95	$2.80	$100
Frequency Response	10Hz - 240Hz	6 Hz - 20.0 kHz	20Hz - 20kHz
Software	C (code exists)	InvenSense own software	Commercial software (e.g. MLSSA)
Ease of Use	Needs soldering/basic components	Needs soldering/basic components	Commercial product
Size	1 x 1.5 inches	0.186 x 0.148 inches	7.5 x <1 inches

Microcontroller Trade-Offs

MCU	Arduino Uno	**Freedom KL25z w/ Shield**	TI MSP430
Cost	$22	$15	$10
Memory	32 Kb	128 Kb + MicroSD on Shield	8kb
Processing Power Max Clock Speed	16 mHz	48 mHz	16 mHz
Power Usage (LPM - Max)	45mA - 80mA	Very Low* - 22.56mA	Very Low* - 40mA
Experience/Ease of Use	None	High	Moderately High

Analog Multiplier Trade-Offs

Device	**AD633**	MPY634	Ad hoc Multiplier	**Modulate Digitally**
Cost	$6	$12	Cheap	Free
Feasibility	Very Easy	Very Easy	Time Consuming	Easy
Power Usage	Less	Less	More	Least
Latency	Low	Low	Med	High
Results	Slightly sub-ideal	Slightly sub-ideal	Ideal	Non-ideal

Speaker Trade-Offs

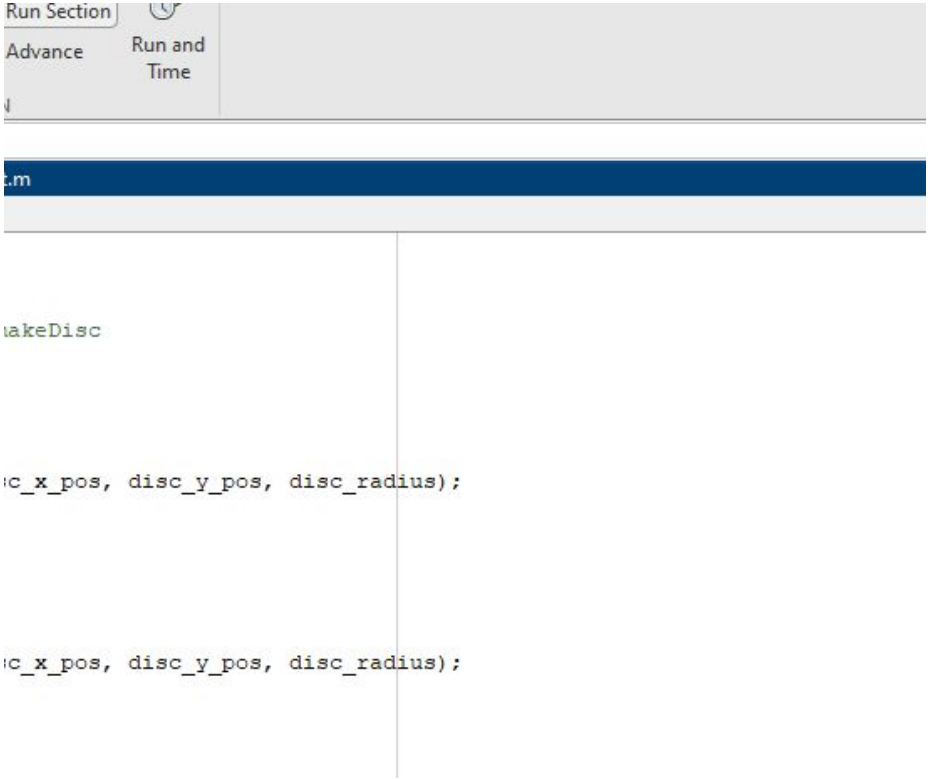
Device	KS-4140A	D33A16	RT16mm40kHz	**MSO-AT1640H12R**
Cost	$0.38 per + expensive shipping	$1.50 per + negotiable shipping	$0.33 per + decent shipping	$0.30 - $0.80 per + low shipping
Frequency Range	35kHz - 45kHz	39.2kHz - 40.8kHz	39kHz - 41kHz	39kHz - 41kHz
Transmittance	>90 dB	114 dB	>115 dB	>115 dB

Simulation

Acoustic Simulation

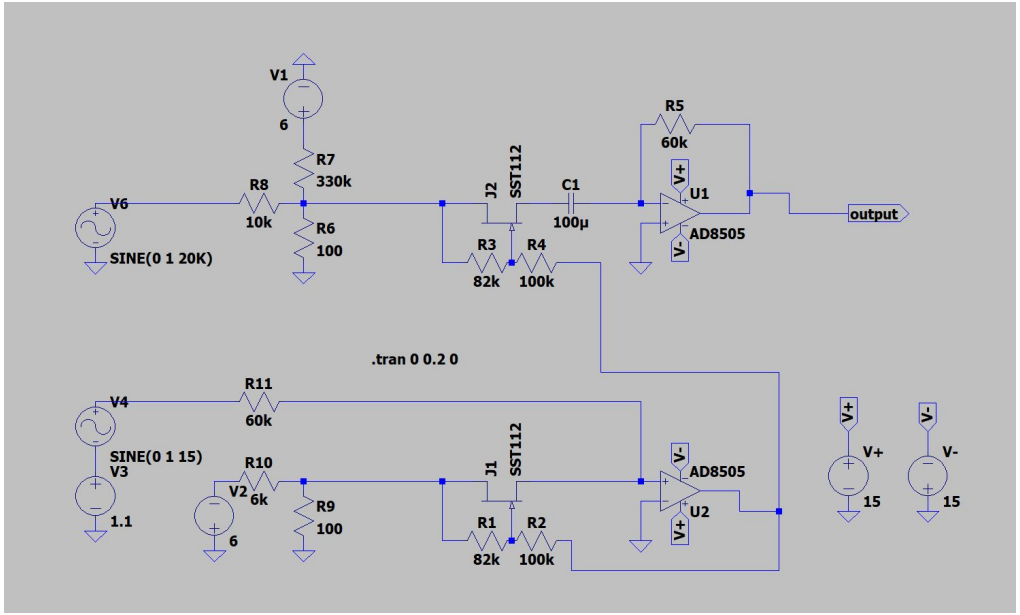
- Using various MATLAB packages to simulate ultrasonic non-linear effects
  - K-Wave
    - Primary, general case
    - Numerical analysis of 2-3D wave equation
  - ULTRASIM
    - Specialized to ultrasonic acoustics, ultrasonic imaging, and transducer design
  - FOCUS
    - Specialized for continuous transient ultrasound, varying media (non-linearity)

Acoustic Simulation



Analog Modulation Simulation

- Using LTSpice to simulate different parts
- Ideal to simulate prior to material purchasing



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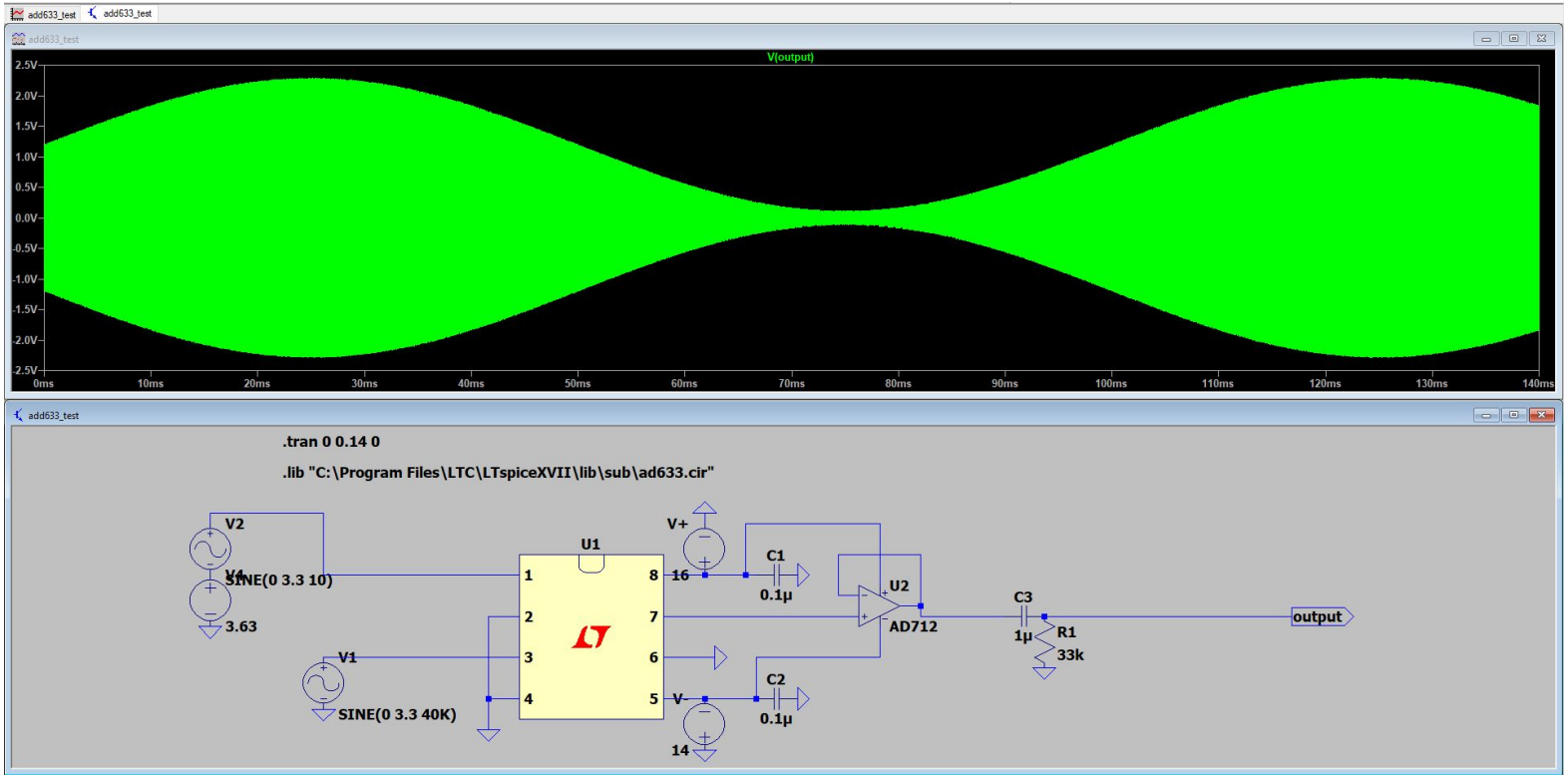
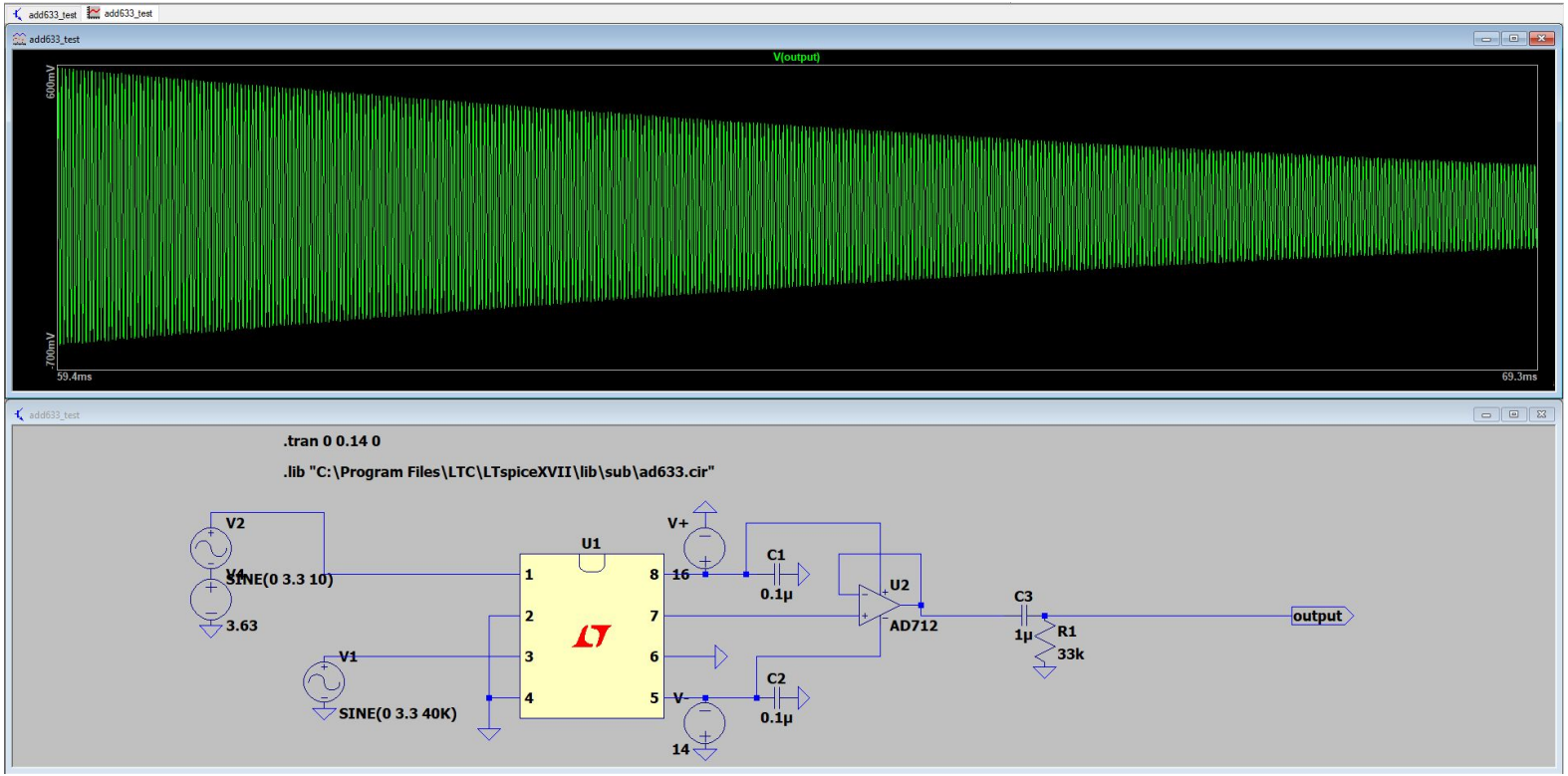


Analog Modulation Simulation



Project Plan

Plans for Prototype

- Signal mixing technique fully functional with speaker array
- Operational LED Indicators
- Speaker array configuration determined for near ideal “Wall”
- Field implementation determined (multiple vs. single unit)
- Fully ready for testing on an elephant

Roles and Responsibilities

Arpad:

- Technical: Simulation (MATLAB, LTSpice), MCU Programming, PCB Design, Signal Mixing, Modeling
- Admin: Website Manager, Part Selection

Greyson:

- Technical: Motor Controller Programming/Directionality
- Admin: Part Purchasing

Hunter:

- Technical: MCU Programming, Testbench Design, Procedure
- Admin: Sponsor Contact, Meeting Scheduler

Morgan:

- Technical: Mechanical Assembly, Simulation (MATLAB)
- Admin: Meeting Minutes

Nwaf:

- Technical: PCB Design, Signal Mixing, Mechanical Assembly
- Admin: Part selection

2020 Timeline *Subject to change

	Oct. Wk3	Wk4	**Nov.** Wk1	Wk2	Wk3	Wk4
Group	PDR		Testbench Assembly (TA)	TA, Collect Data	Debug/ Testing	Decide Availability
Deadlines	**PDR**				**Design Day**	
Arpad	Acoustic Simulation (AS), Part Selection, CAD, LTSpice Simulations	AS, PCB Design, MCU Programming	AS, MCU Programming, PCB Design & Purchase, Set-Up and Assembly	Set-Up and Assembly, Debug Phase	Debug Phase	Adjustments & Improvements
Greyson	Order Parts	MCU Programming	MCU Programming			
Hunter		MCU Programming	3D Print Necessary Materials	Work with testbench/ Improve data collection	Compile data in meaningful way	
Morgan		Acoustic Simulation	Testbench Assembly; Acoustic Simulation	Testbench Assembly		
Nwaf	Test Methods	PCB Design	PCB Design & Purchase	Work with testbench		Adjustments & Improvements

Cost Analysis for Testbench

Device	10-16mm 40khz transducer	ICS-40300	Geophone	Analog Multiplier - AD633	Frequency Generator - AD9833
Cost	$175.00	$12.00	$59.95	$19.20	$19.40

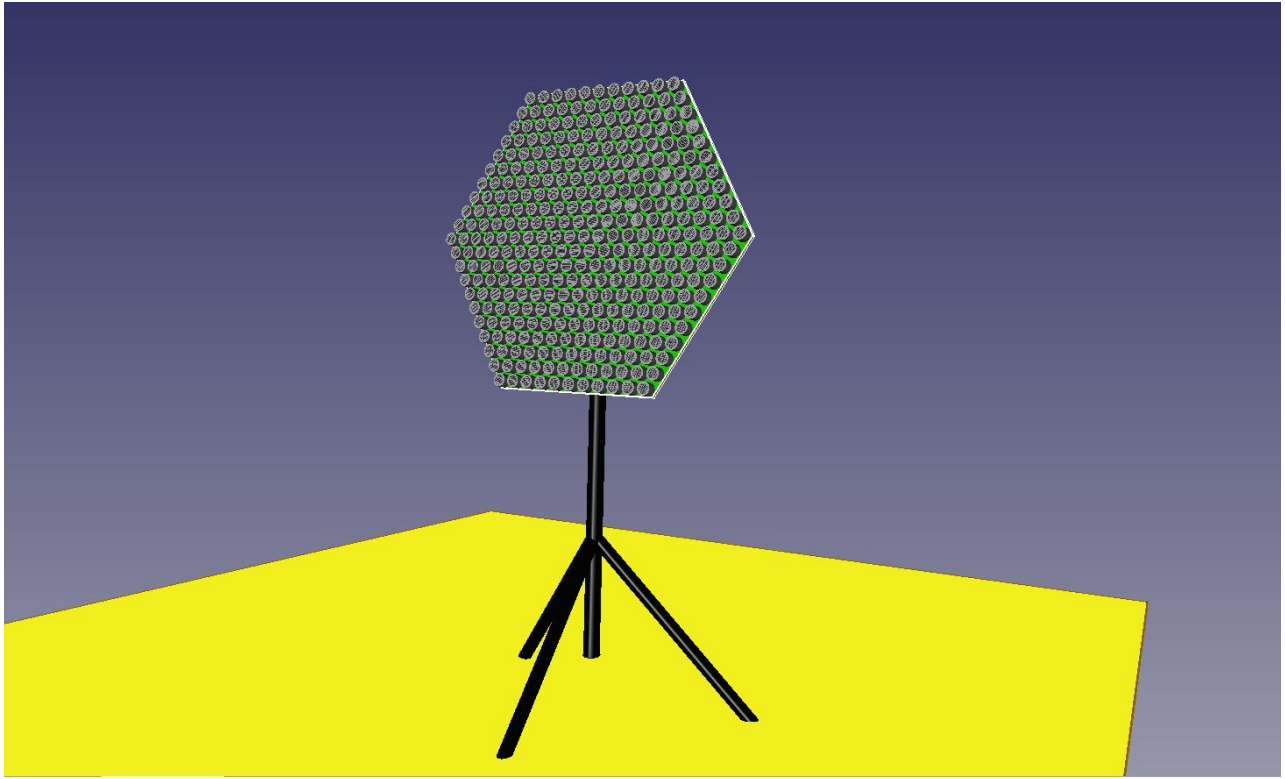
Excel purchasing form:

https://docs.google.com/spreadsheets/d/1BVZyShNdetvotFzQIGQ5tDb_D-vviOZ-A75umamQiTI/edit?usp=sharing

Testbench - CAD Model

- 420 mm in diameter (roughly 16.5 inches)
- 331 16mm diameter ultrasonic transducers in parallel

- Mockup product will be more rectangular, vertical
- Will first test spatial resolution and efficacy of directionality and attenuation with this, then improve upon



Mockup Product Demo

- **User Operation:**
  - Easy installation and set up
  - Audio file selection
  - System should simply toggle between on and off
  - LED indicators will tell the user the state of the system
- **User Experience:**
  - Less worry about crop destruction or loss of life
- **Look & Feel:**
  - Light, easily transportable
  - 'Blend' in with nature, birdhouse, etc.
- **Placement:**
  - To be determined from testbench
  - Multiple units might be required

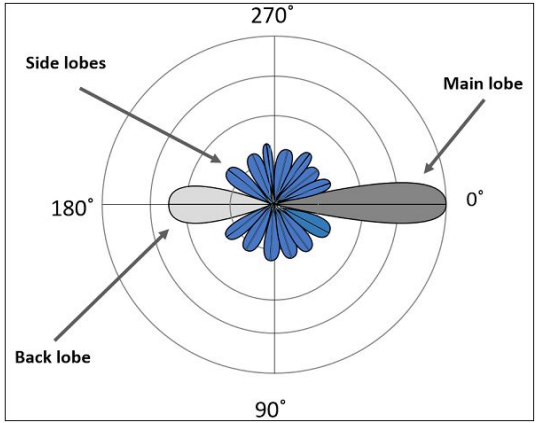
Questions?

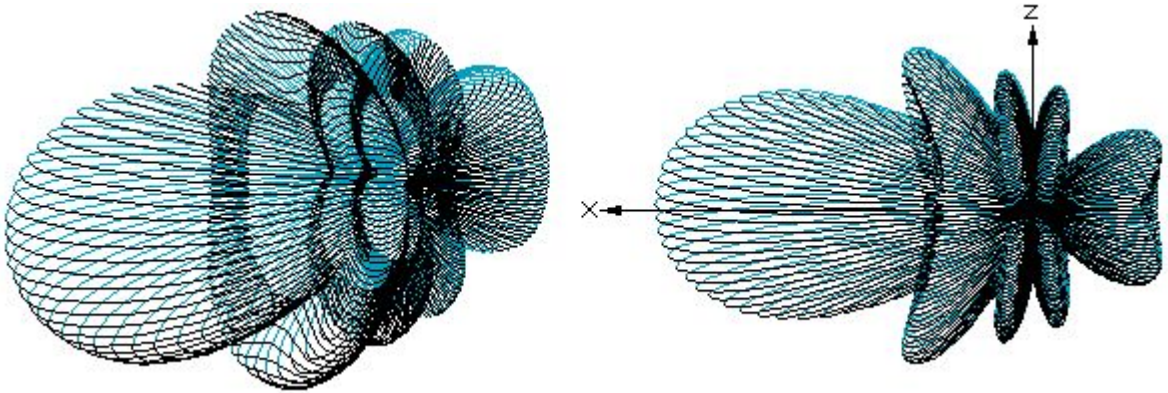
Which Wall of Sound Team Is Better?

- Team VADER

How are we utilizing the testbench?

- Sound intensity and microphone location will be gathered to develop a sound map
- Cylindrical coordinates to measure amplitude and THD
- Adjusting parameters of the test bench should let us see how the sound map changes in shape and effectiveness as a Wall of Sound
- Radiation Pattern





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