Sdmay18-39
Sound Effect Devices for Musicians

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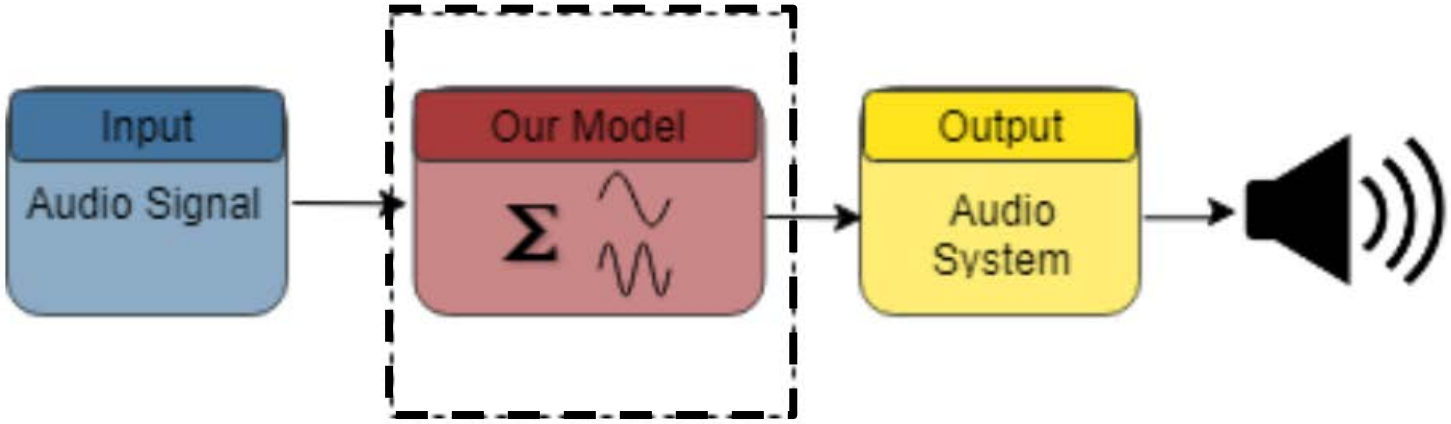
Project Definition

Purpose: Develop a vacuum tube emulator

- Intended for audio production
- Completely defined in software
- Ability to enhance the vacuum tube “audio profile”



Motivation

- Music industry places high value in vacuum tube sound
  - But quantitatively speaking, Vacuum tubes are worse!!

Solid State Technology	Vacuum Tube Technology
• Inexpensive • Durable, easy to maintain • Power efficient • Better linearity	• Expensive • Frequent maintenance • Fragile • Large heat dissipation

Vacuum Tubes are only kept around because of their sound!

Requirements – What must this product deliver?

Functional

- Emulator must reproduce the:
  - Spectral characteristics
  - Temporal characteristics
  - → *With statistical validity*

- Product must be robust, accurate across:
  - Audio band
  - broad input range

Non-Functional

- Customizability– Emulator to offer immense personalization

→ Putting the “Super” in “Super-tube”

Market/Literature Survey

Academia

- AES Publications cite:
  - Harmonic content [1]
  - Dynamic nonlinearities of vacuum tubes [1]

Conclusion:

- Research lacks a closed form algorithm for emulation
- No attempts to modify beyond pure emulation

[1]

Industry

- Effects Pedals (Ibanez Tube Screamer)
- Software modelling – unidirectional, linear fitting

Conclusion:

- Distinct absence of closed form algorithm.
- Intellectual Property
- Again, no tuning of model characteristics – what is modelled is what you get

[2]

Resource Requirements

- Hardware
  - Vacuum tube technology (guitar & home-audio)
  - Data collection test-bench(s)
    - Function generators
    - Oscilloscope
    - High-res audio A/D converters
- Software
  - MATLAB
  - Audacity

Risk Identification and Mitigation

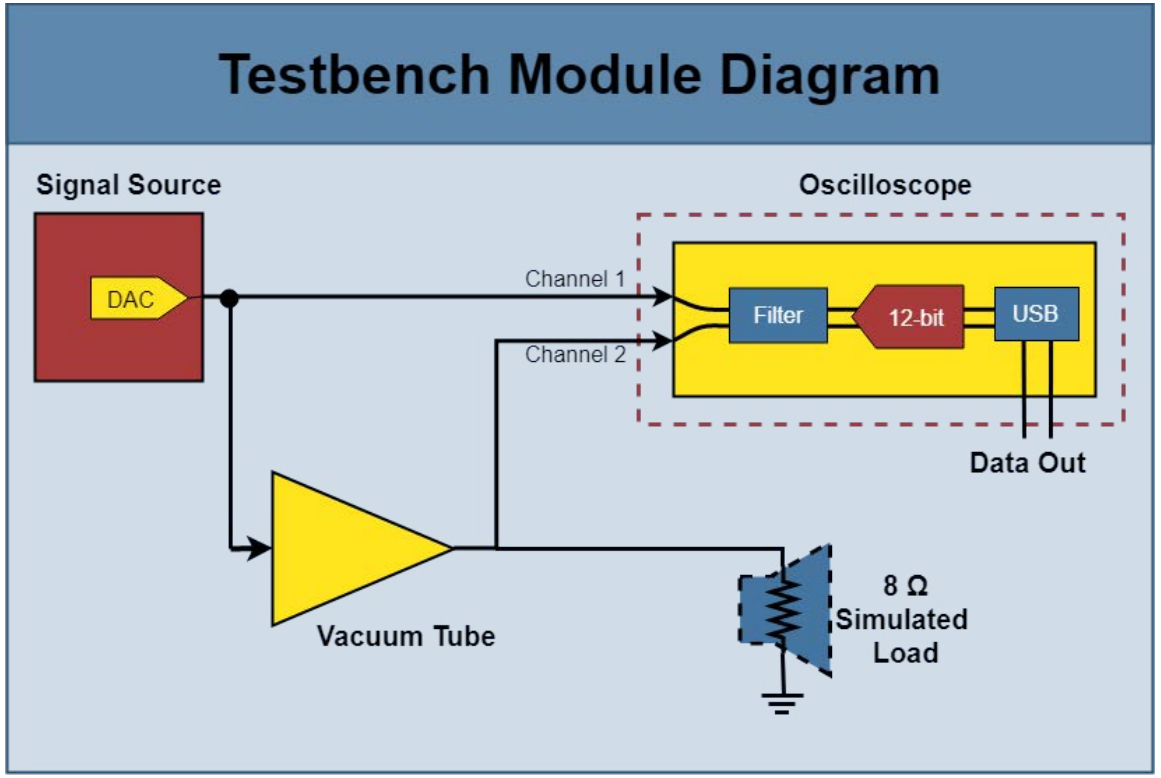
- Fast Fourier transform
- Effects as a function of amp temp
- Complex input signals
- Test bench optimization
- Fourier series

Design Process

- Basic strategy is a cycle between
  I. Acquire data from real vacuum tubes
  II. Process data and develop regressed model
  III. Validate model goodness-of-fit compared to original data
  IV. Expand data set and explore additional modifications

I. Data Acquisition from Real Vacuum Tubes

- We need real data from real vacuum tubes
- We want to analyze transfer characteristics that include clipping
- Range of measured data:
  - 22 frequencies over audio band
  - Each at 5 different amplitudes



II. Data Processing and Emulator Development

- Failed Emulators:
  - Transfer Functions, Non-Linear Functions

- Successful Emulator:
  - Sum-of-Sines/Fourier Series (5 Harmonics)

$$M(t) = C_0 + \sum_{k=1}^{N} \alpha_k \sin(k\omega t + \phi_k)$$

III. Data Processing and Emulator Development (Cont'd)

Emulator Pseudocode:

```
for each data signal {
        Sync Input Data to Phase Shift 0
        Initial Modeling
        Adjust Amplitude Parameters to be [0, ∞]
        Adjust Phase Shift Parameters to be [-π, π]
        Final Remodeling
}
```

IV. Model Validation

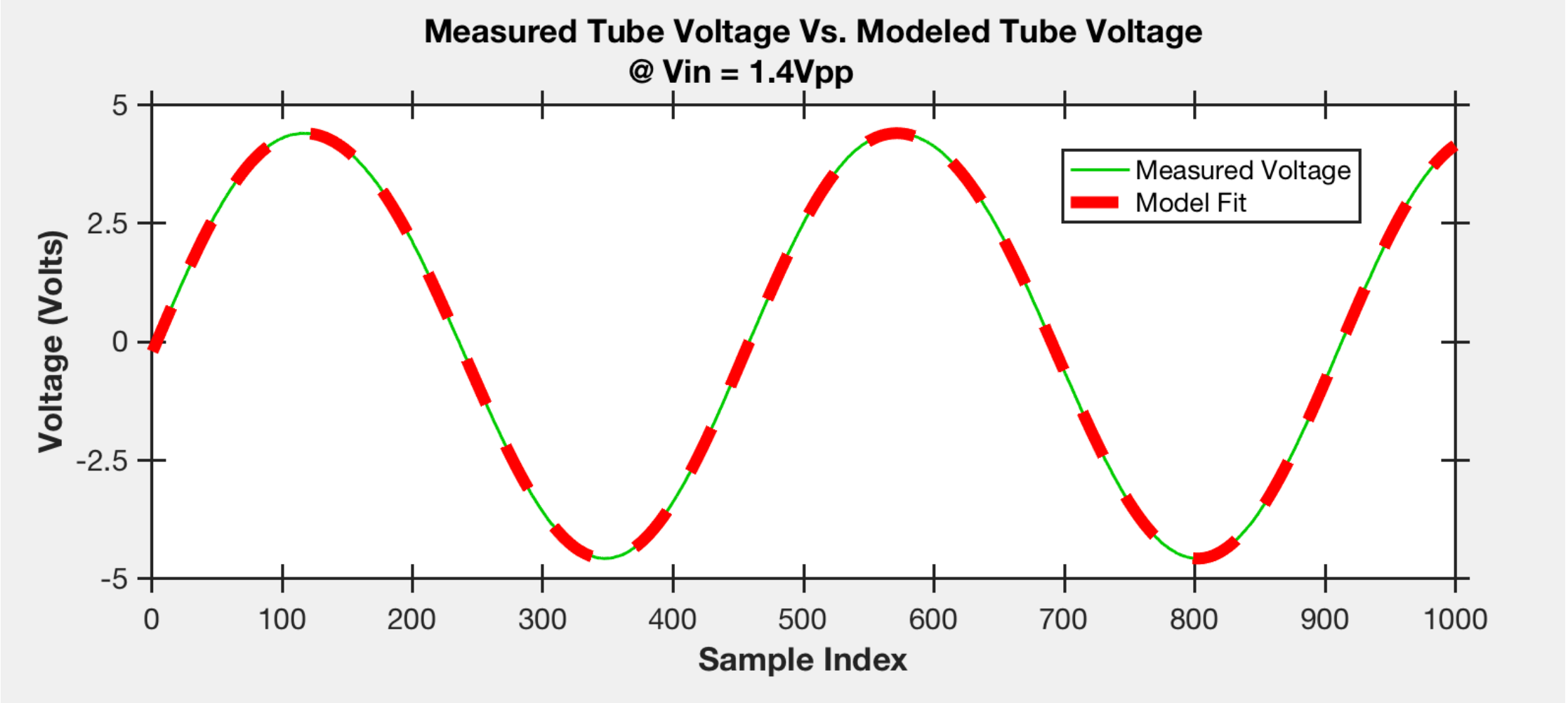
Figures of Merit :

1) Tube amplifier model achieves an audio profile that is unique and preferred by musicians

2) The model accurately tracks real vacuum tube real vacuum-tube amplifier characteristics

3) The model produces the desired audio profile negating the need for a tube amplifier

IV. Model Validation



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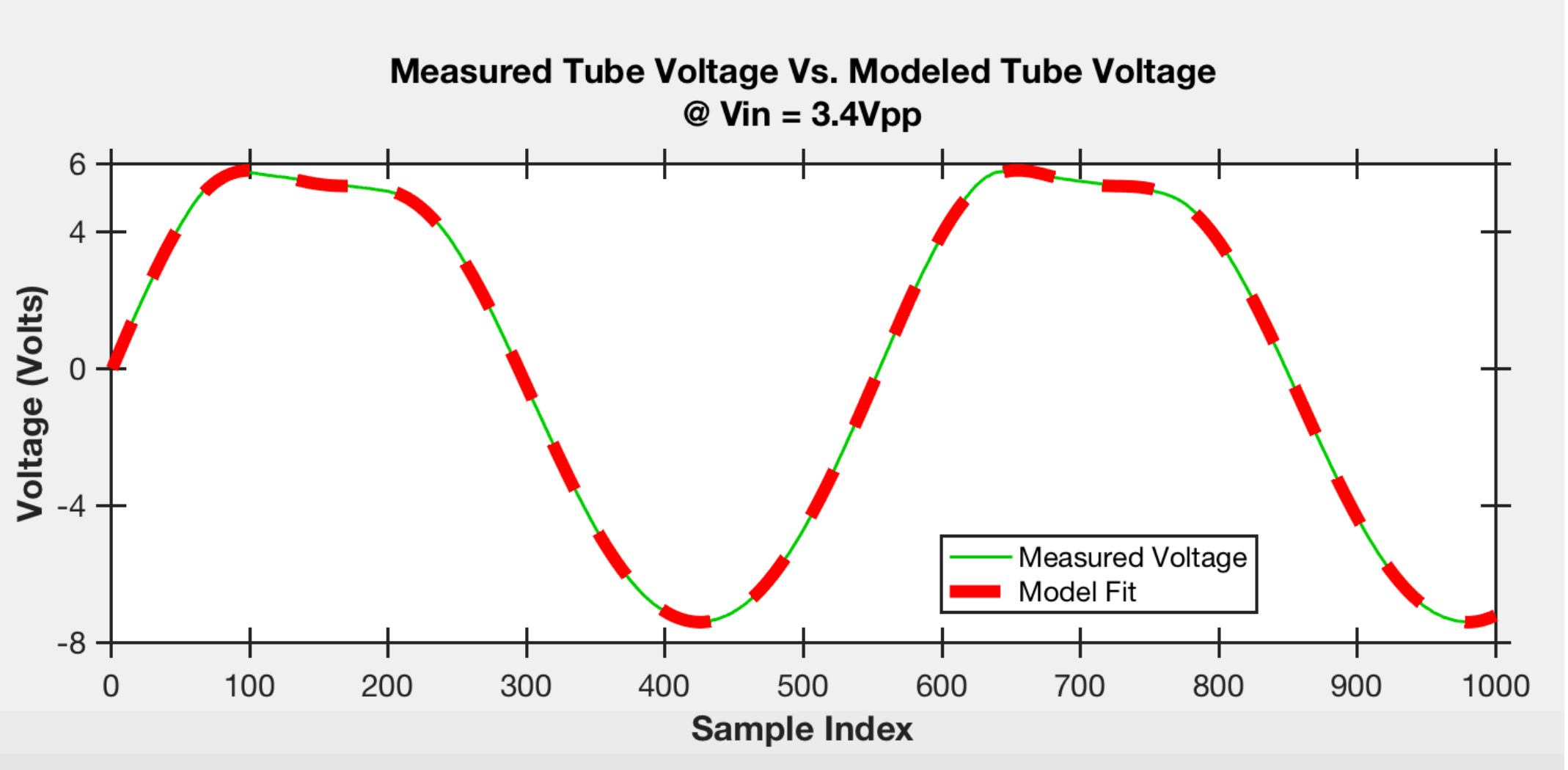

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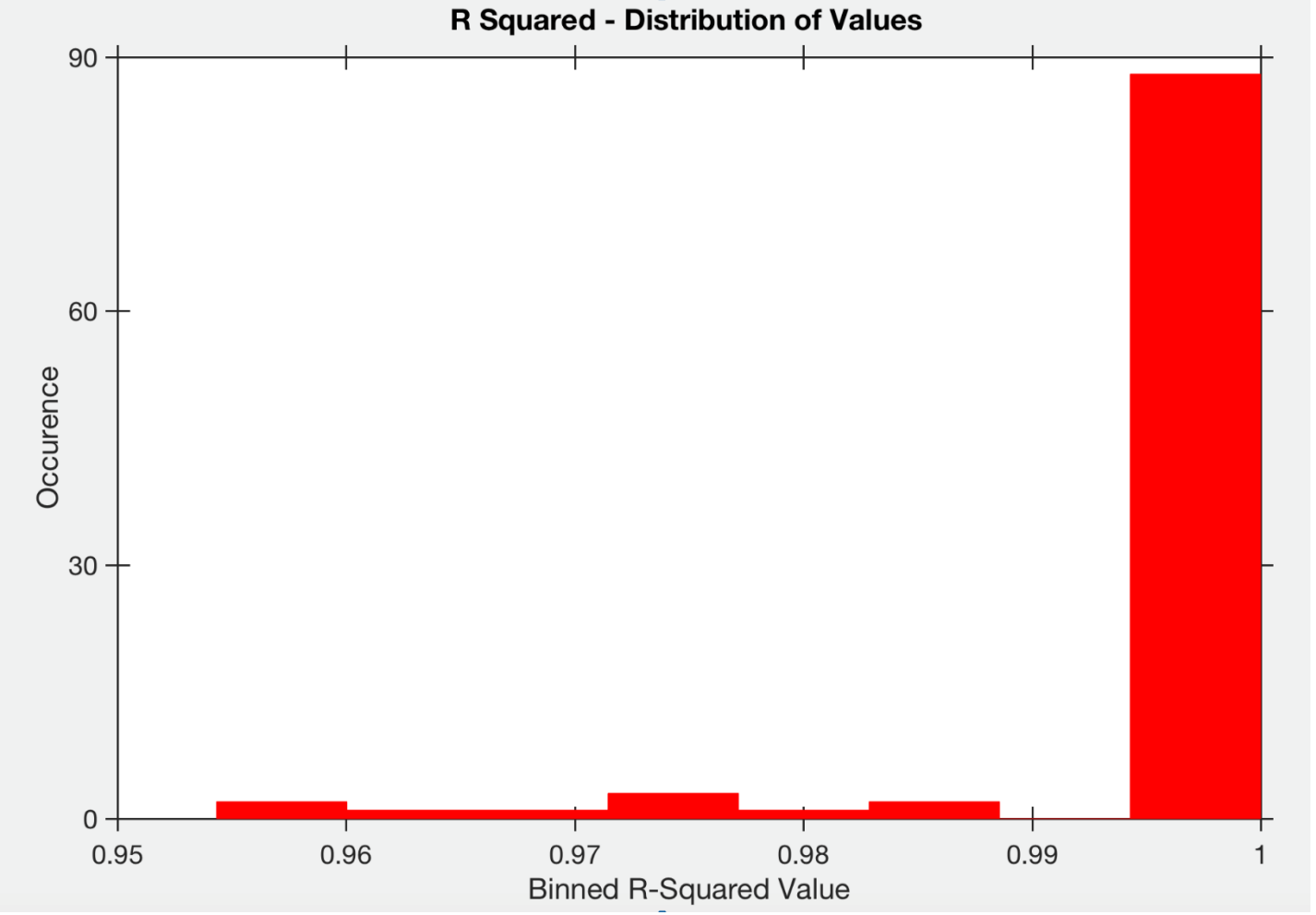
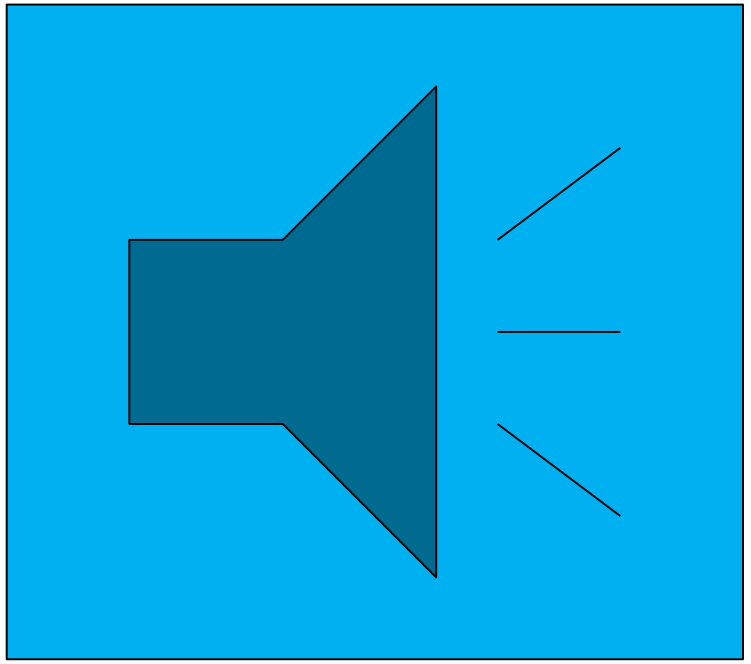


Subjective Listening Tests

- Asked population to listen to sound samples
- Recorded results to prewritten questions
- Mixed results



What do YOU think?

Demo

Going Forward

- **Summary**
  - Devised our own idea for practical sound effect
  - Successfully developed an engine for our “Supertube” Emulator
  - Emulator has objectively high accuracy and can modify performance

- **What’s next?**
  - Develop interpolating strategy for multi-tone signals
  - End-use user interface considerations

Questions?

REFERENCES

[1] D. Andrzej, S. Maleczek, M. Kin, Audio Engineering Society Convention Paper 7806, 1-5 (7 May, 2009)
[2] Ibanez. *Ibanez Logo.* Outlaw Custom Designs. 22 April 2018