Neural Modeling of Magnetic Tape Recorders

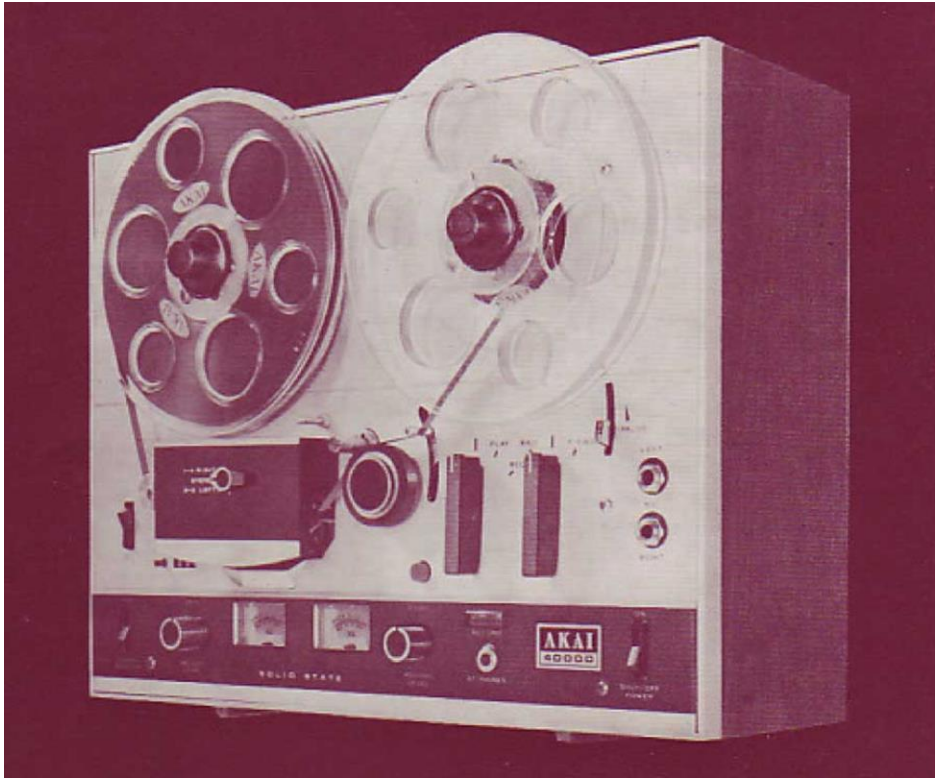
Otto Mikkonen, Alec Wright, Eloi Moliner, & Vesa Välimäki

7th September 2023

Aalto-yliopisto
Aalto-universitetet
Aalto University

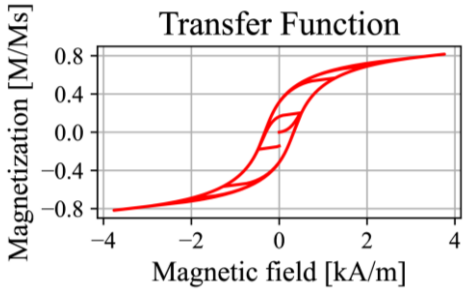
Outline

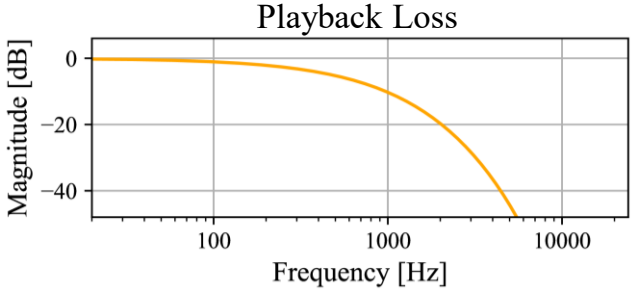
- **Magnetic Recording**
- **Proposed Method**
  - Modeling
  - Training
  - Experiments
- **Conclusions**

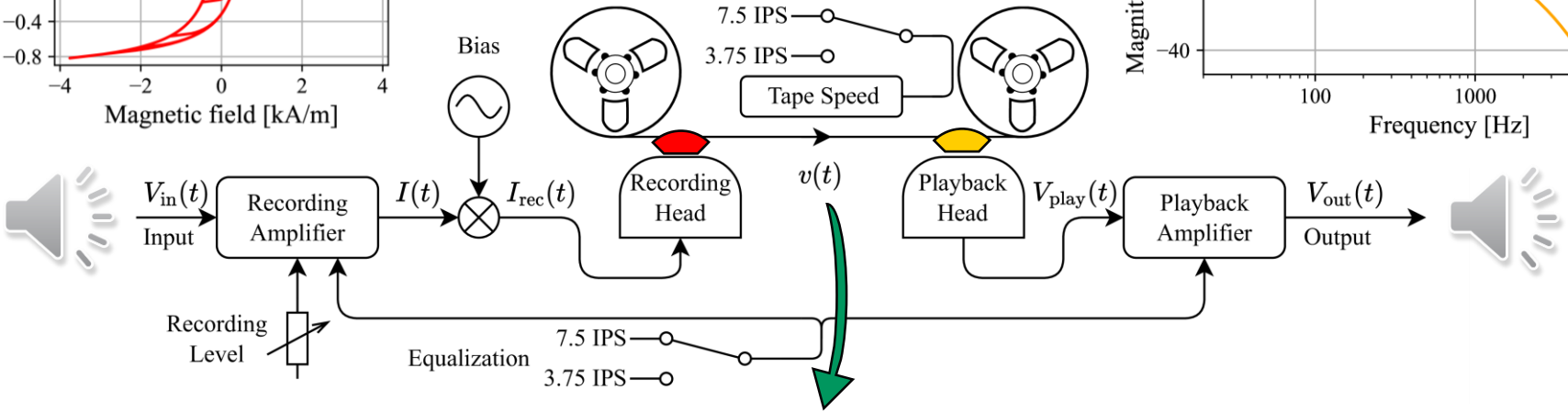


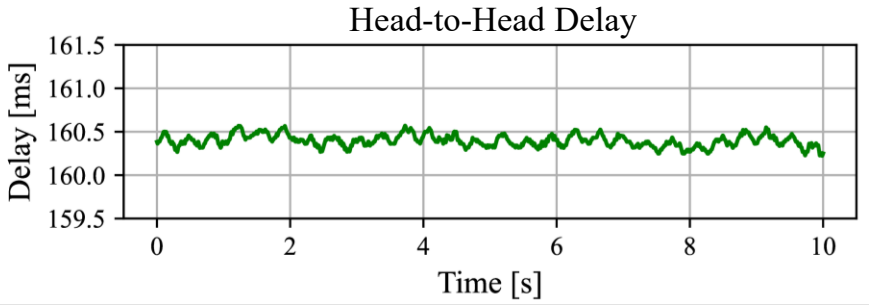
Akai 4000D reel-to-reel recorder

Magnetic Recording



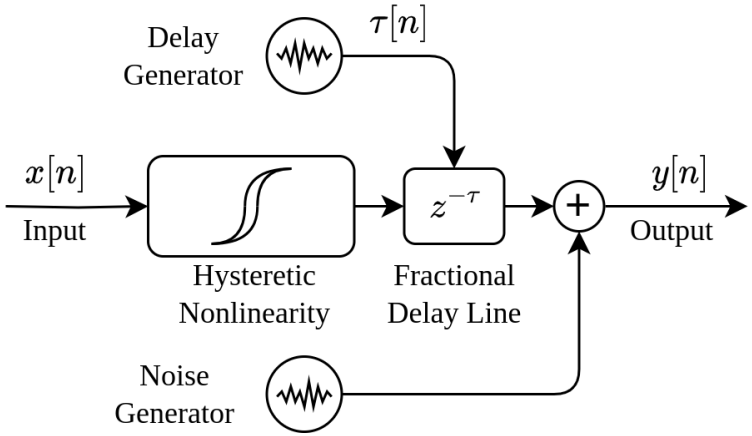






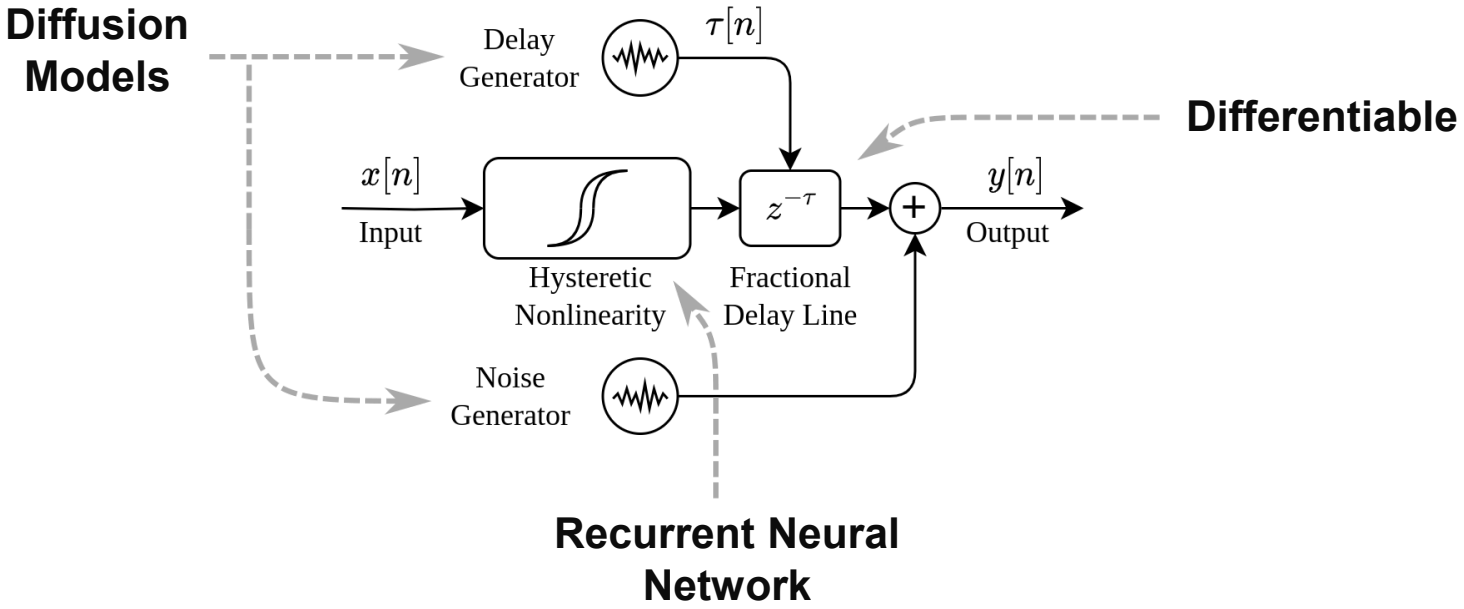
Aalto-yliopisto
Aalto-universitetet
Aalto University

Proposed Grey-Box Model



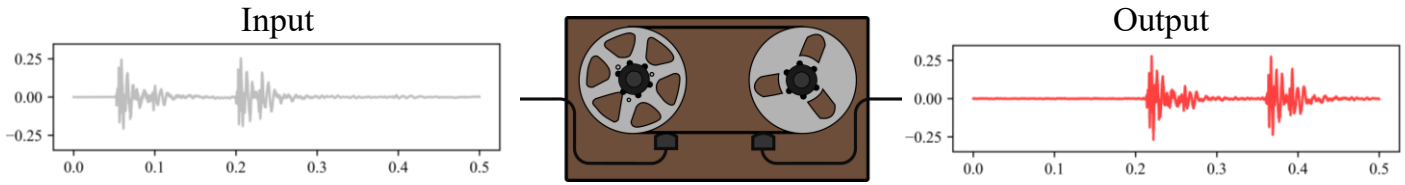
- ”Recording Path” (Nonlinearity + Delay Line)
- Delay Generator
- Noise Generator

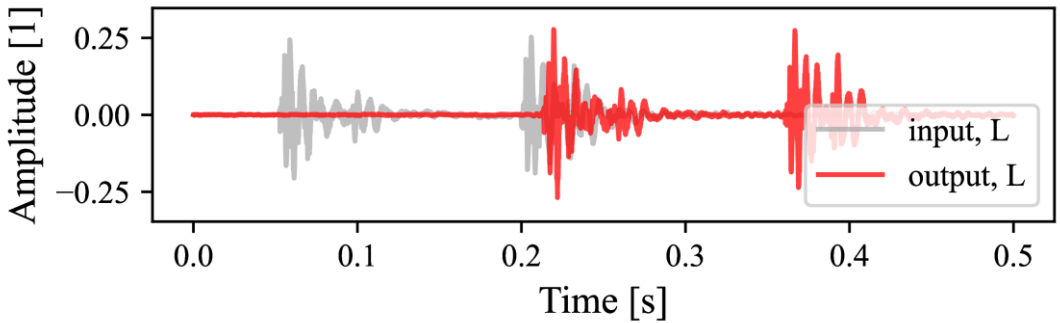
Proposed Grey-Box Model



Wright, et al. “Real-Time Black-Box Modelling with Recurrent Neural Networks.” In Proc DAFX, 2019.
Engel, et al. “DDSP: Differentiable Digital Signal Processing.” In Proc. ICLR, 2020.
Moliner, et al. “Realistic Gramophone Noise Synthesis Using a Diffusion Model.” In Proc. DAFX, 2022

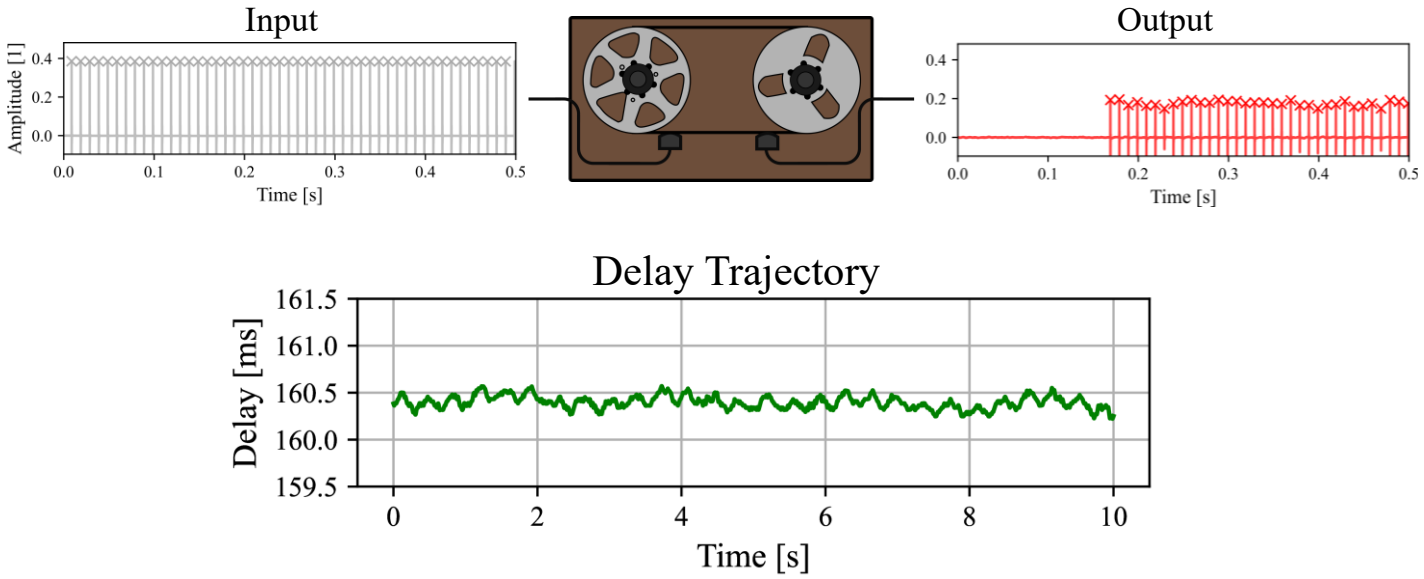
Training The Nonlinearity





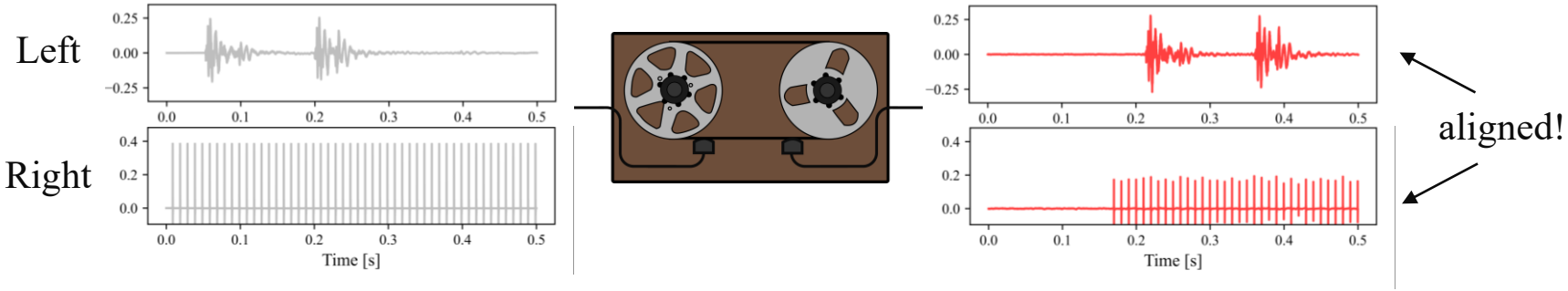
Problem: Inputs and outputs are not aligned

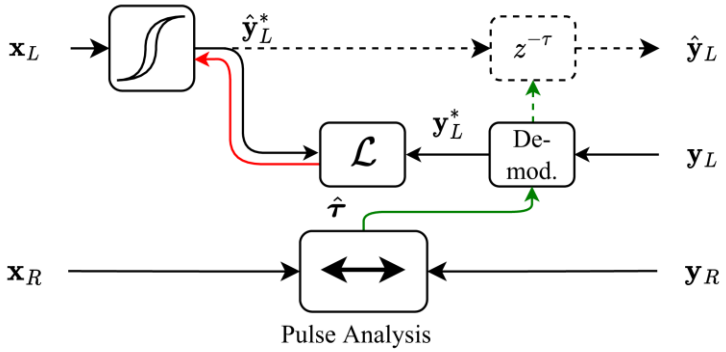
Training The Nonlinearity



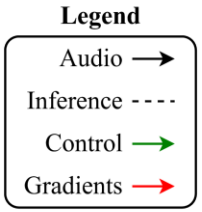
Solution: Let's track some delay trajectories and use them!

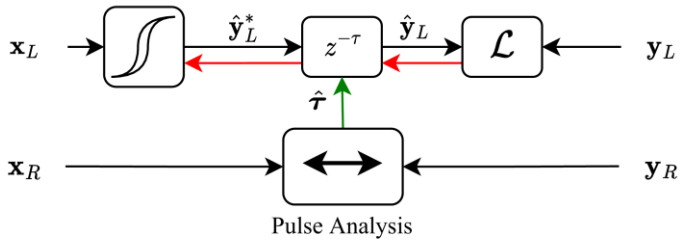
Supervised Schemes





"Supervised 1"



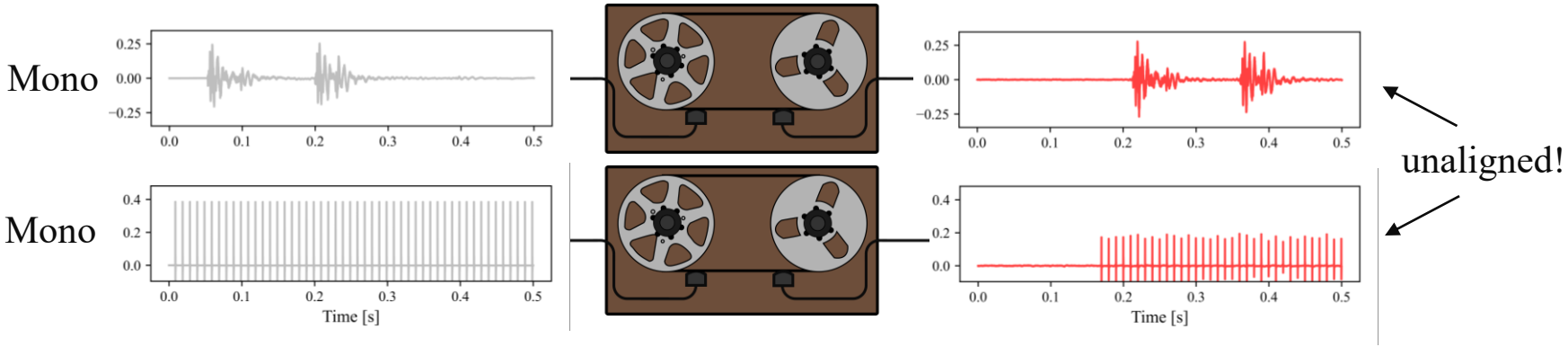


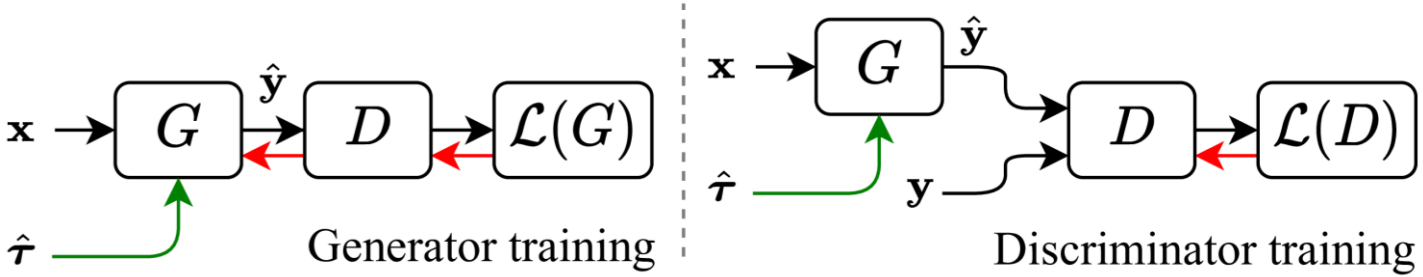
"Supervised 2"

Aalto-yliopisto
Aalto-universitetet
Aalto University

Kaloinen. "Neural Modeling of the Audio Tape Echo Effect."
Masters Thesis, Aalto University, 2022.

Adversarial Scheme





Aalto-yliopisto
Aalto-universitetet
Aalto University

Wright, et al. “Adversarial Guitar Amplifier Modelling with Unpaired Data.” In Proc. ICASSP. 2023

Experimental Setup

Experiment 1 – Toy Data

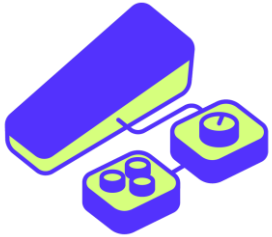
- Python-wrapped CHOWTape

Experiment 2 – Real Data

- Akai 4000D reel-to-reel

Input Data

- SignalTrain (Hawley et al., 2020)



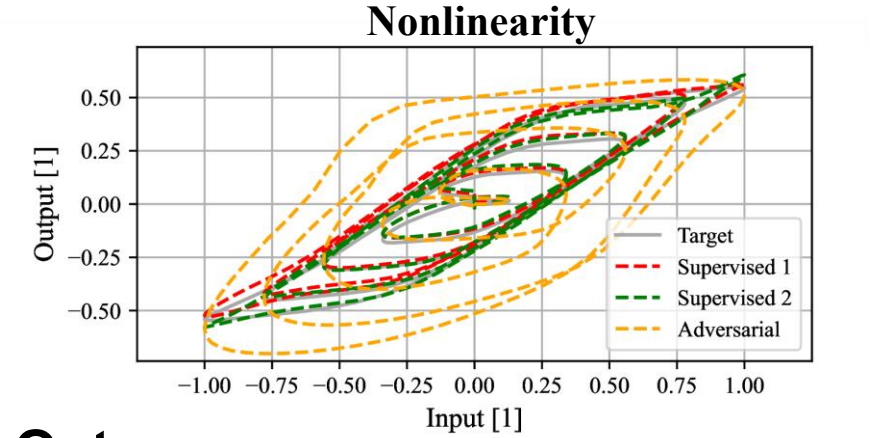
Pedalboard
© Spotify

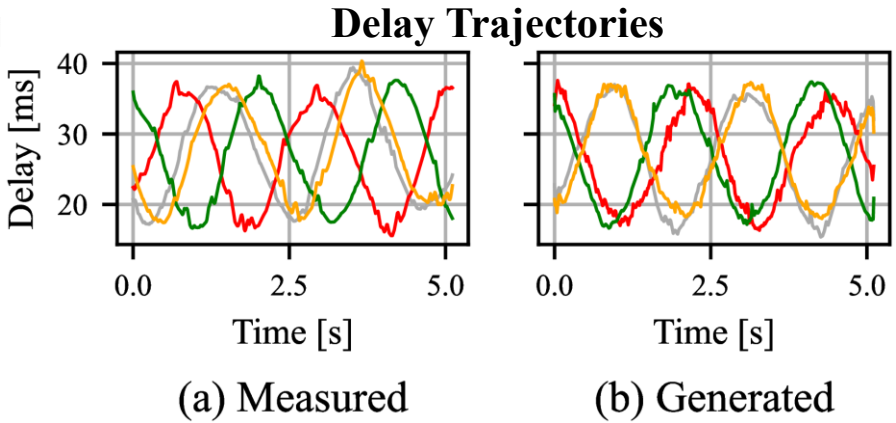
CHOWTape
© Chowdhury DSP

Data Collection: Akai 4000D

Aalto-yliopisto
Aalto-universitetet
Aalto University

Exp. 1 - Toy Data





(a) Measured (b) Generated

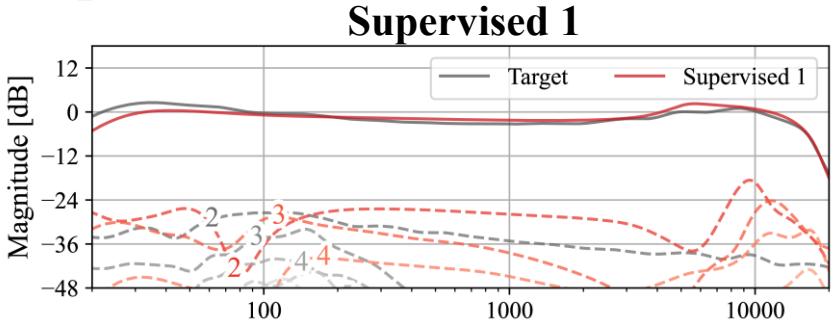
- **Outcomes:**
  - RNN learns magnetic hysteresis
  - Supervised schemes work better than adversarial
  - Diffusion model captures the delay trajectory distribution

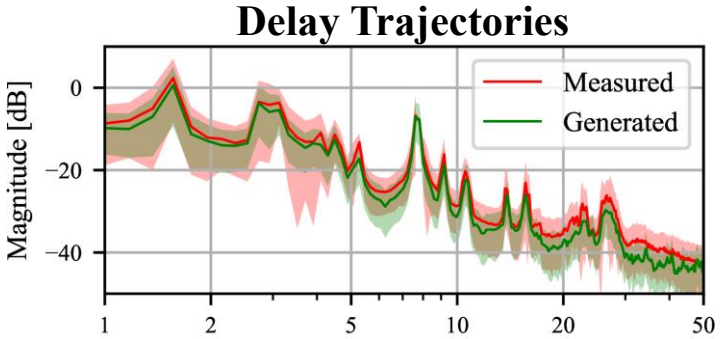
Input	Target	Model: Real Trajectory	Model: Generated Traj.

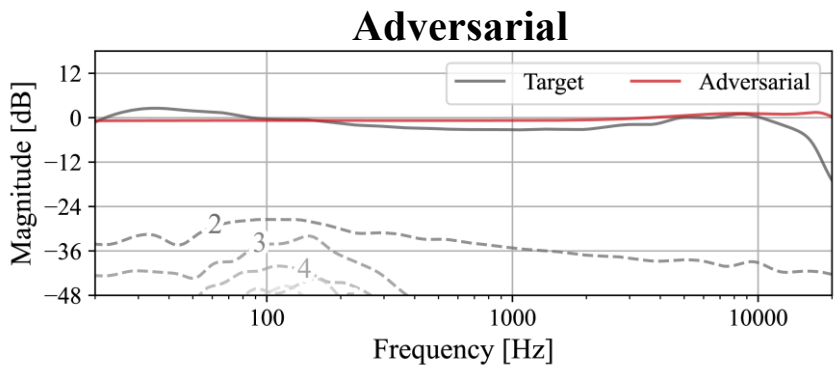
Aalto-yliopisto
Aalto-universitetet
Aalto University

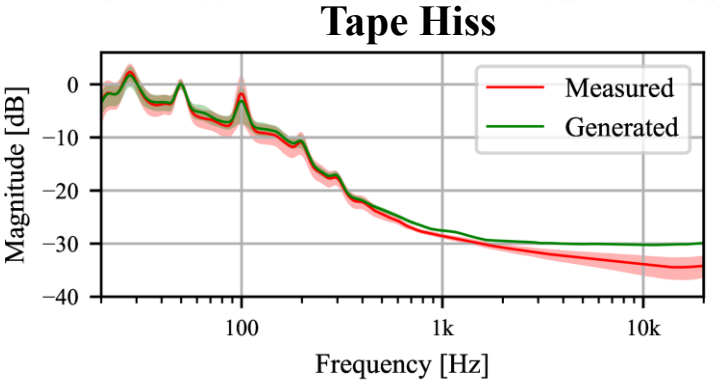
Exp. 2 – Real Data

Input  Target  Model 









- RNN learns linear response and produces harmonic distortion
- Adversarial scheme fails to learn the character
- Diffusion model captures delay trajectory and tape hiss distributions

Conclusions

- **In this work**
  - Grey-box model for VA tape recorders
  - Training schemes for stereo and mono devices
  - Delay trajectory and tape hiss generation with diffusion
- **What do next?**
  - Improve system for monophonic case
  - Alternative generator architectures?

I’m looking for work, come talk to me!

Thanks!

aalto.fi

Aalto-yliopisto
Aalto-universitetet
Aalto University