

# ElectriSense: Single Point Sensing Using EMI for Electrical Event Detection & Classification in the Home



Sidhant Gupta, Matthew Reynolds\*, Shwetak Patel

**UbiComp Lab** @ University of Washington

\*Duke University, Durham

Build low-cost, easy to install  
technologies that **sense human activity**  
in the home



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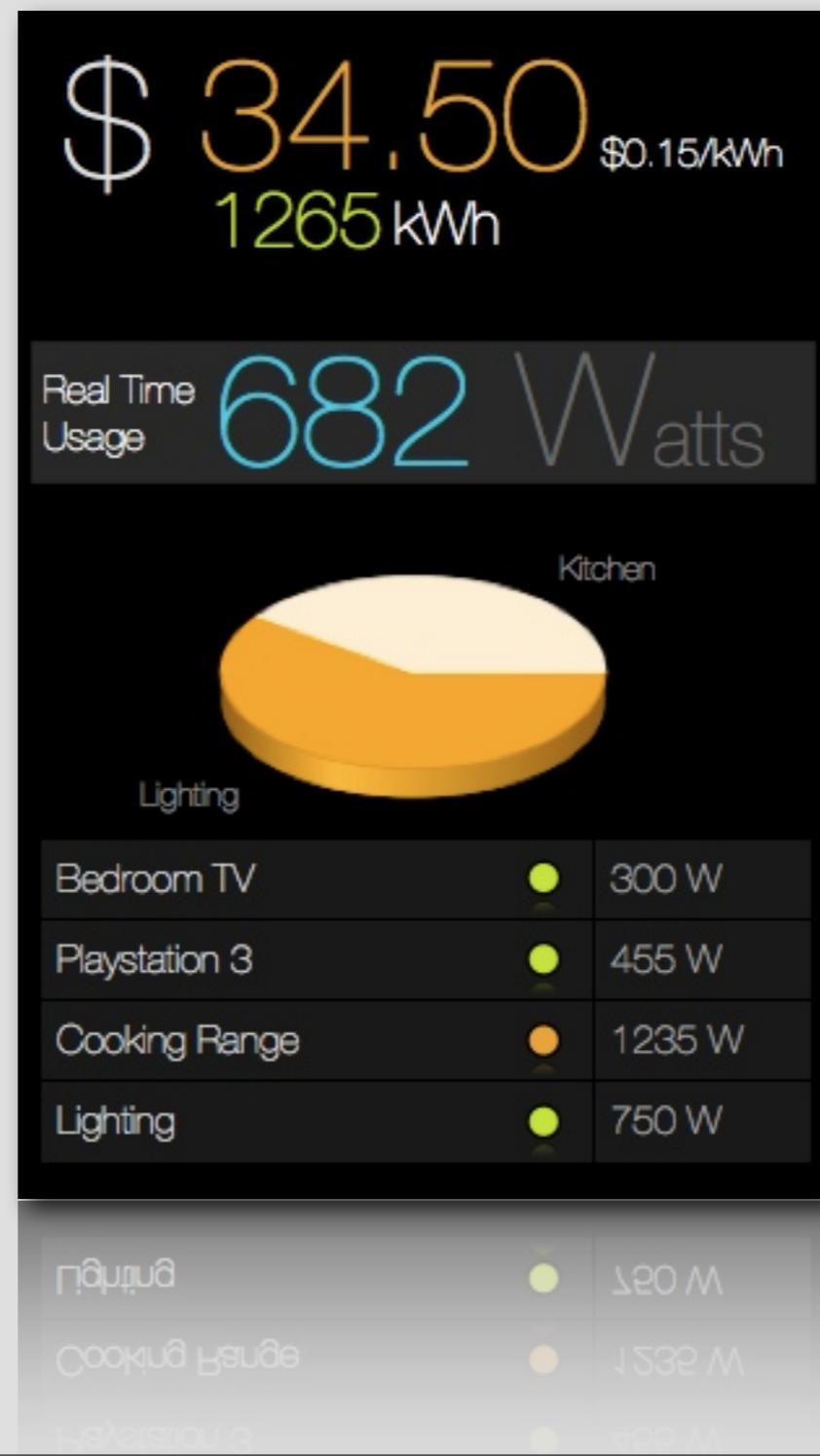
Friday, October 15, 2010



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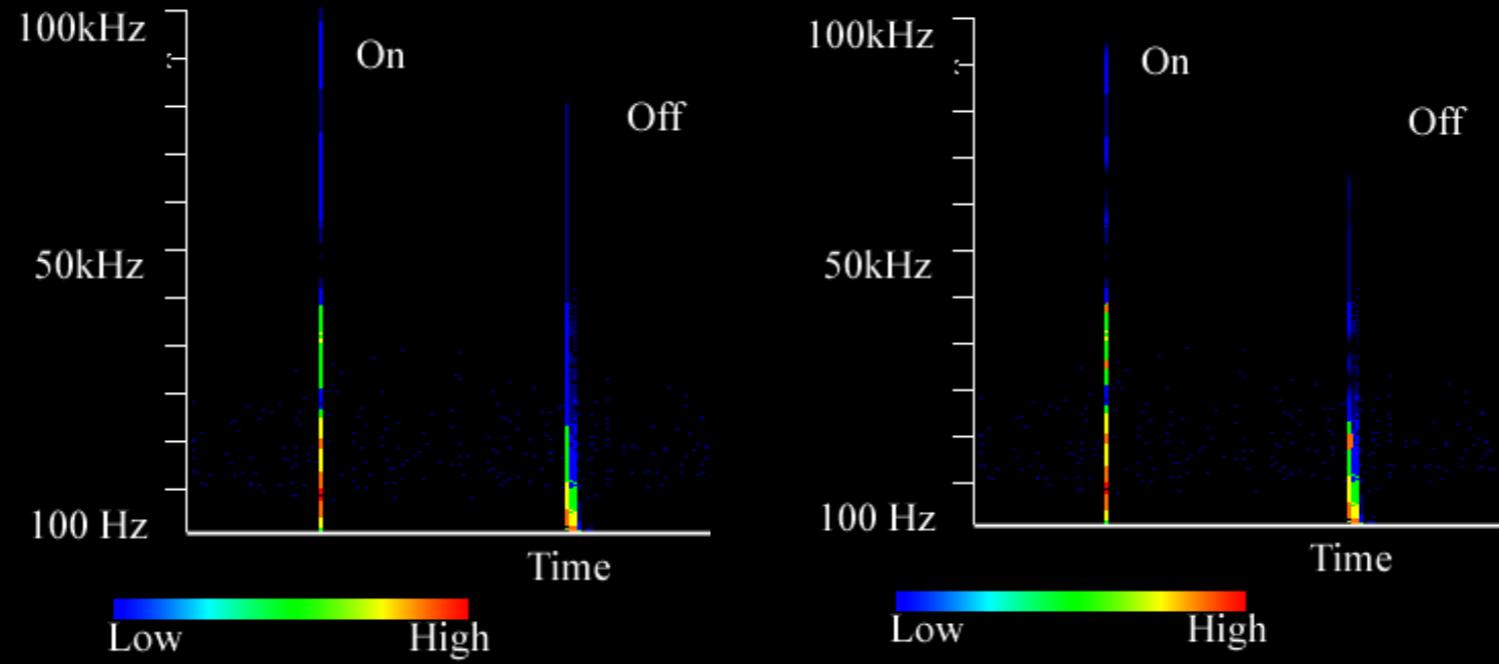
Friday, October 15, 2010

# Energy Feedback



# Appliance usage is a great indicator of current user activity





## At the flick of a switch: Detecting and Classifying Unique Electrical Events on the Residential Power Line.

Shwetak N. Patel, Thomas Robertson, Julie A. Kientz, Matthew S. Reynolds, and Gregory D. Abowd  
*UbiComp 2007*

**Big step forward in sensing electrical  
device usage**

Transient noise is generated when a  
**physical switch** is turned on/off

Key problem is signal **depends** on  
both the **device** and **switch**

Most modern consumer electronics  
have a **soft-switch**

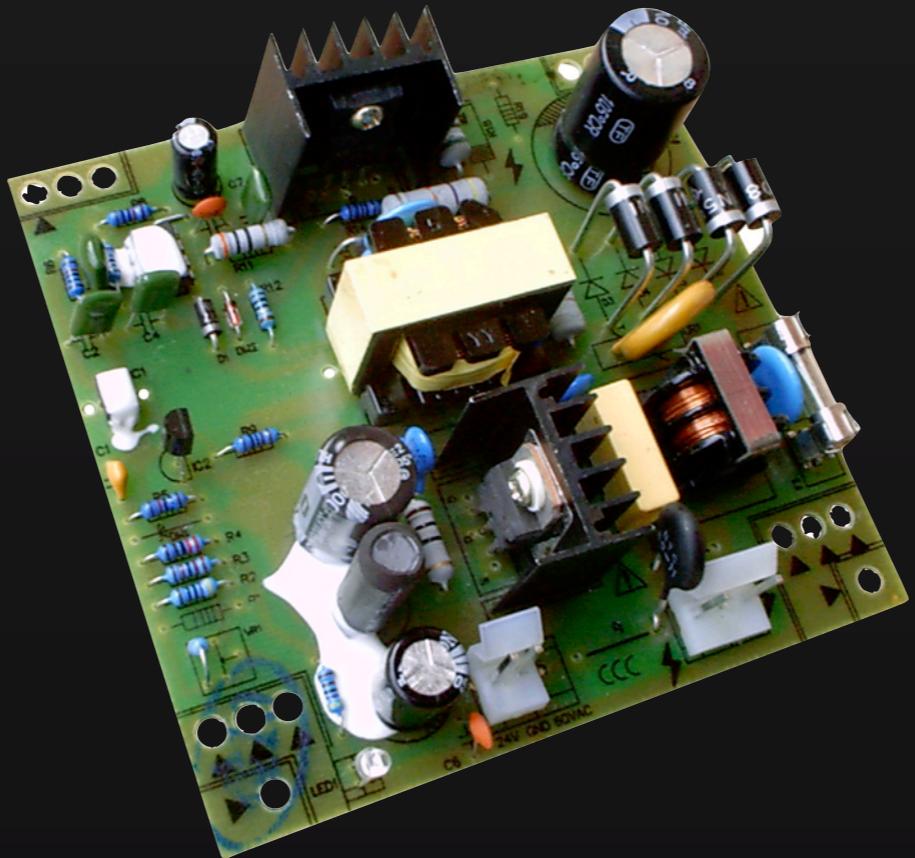
# Different class of devices

# Switched Mode Power Supply

SMPS based appliances are becoming  
increasingly prevalent



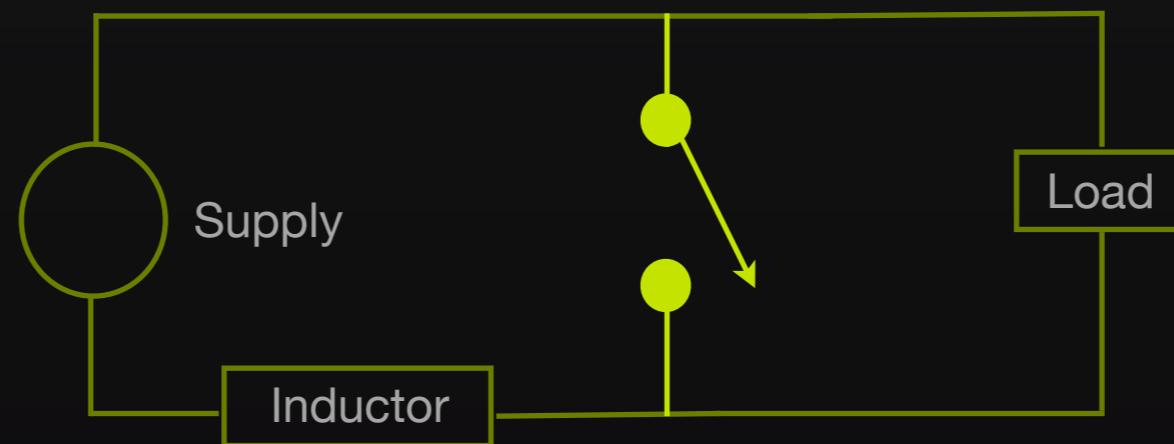




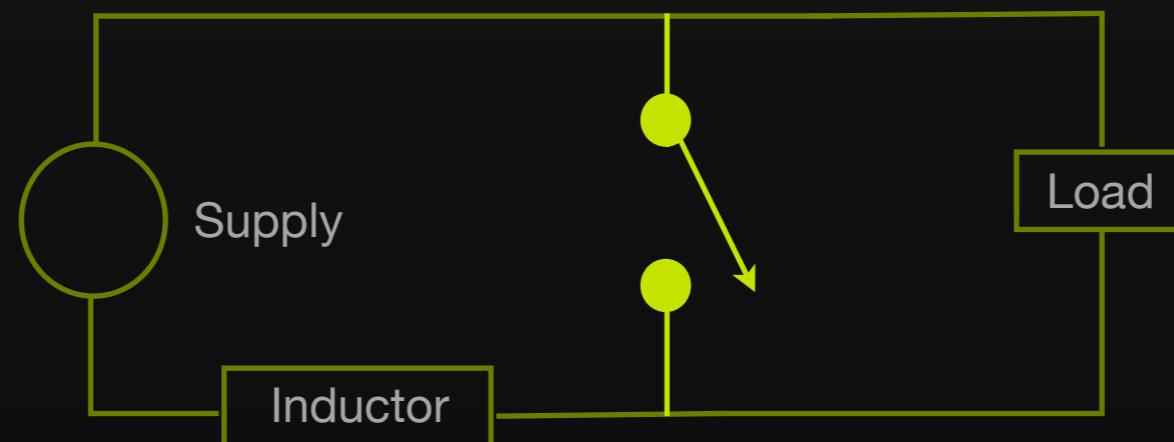
Efficient and small in size.

Stores energy in inductors & switches it in and out at high frequency.

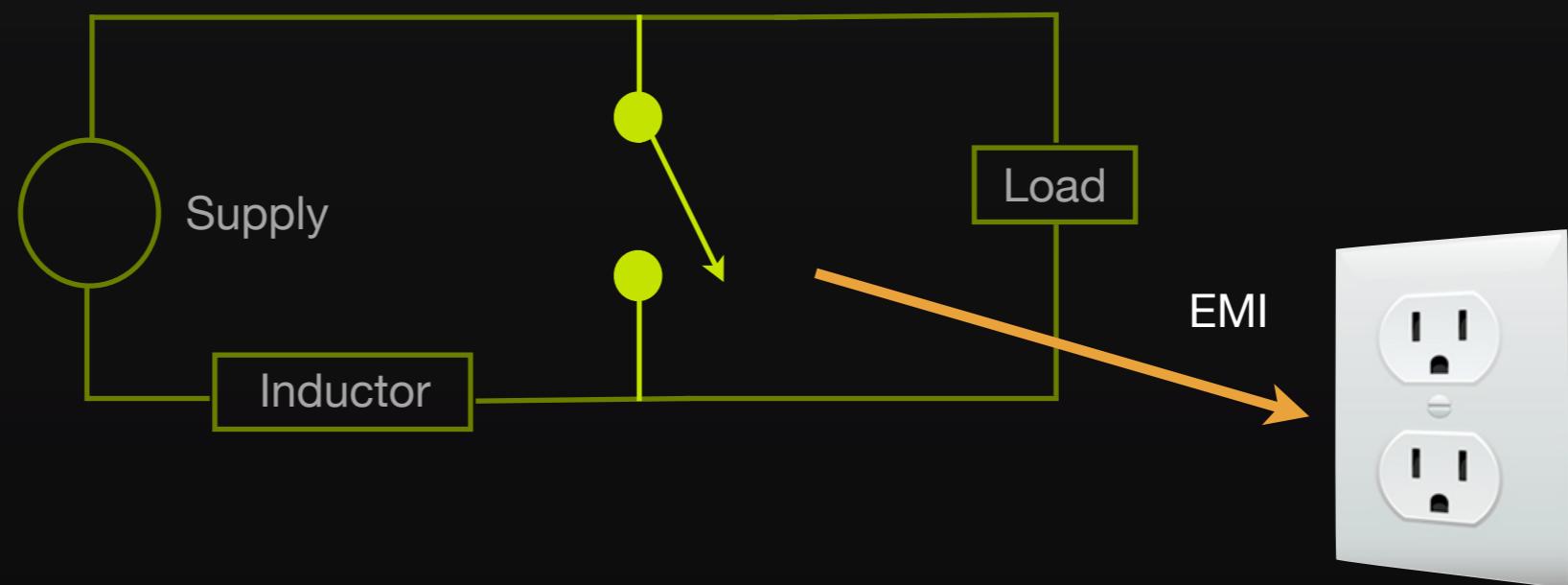
Switching Operation generates **high frequency**  
Electro Magnetic Interference (**EMI**)

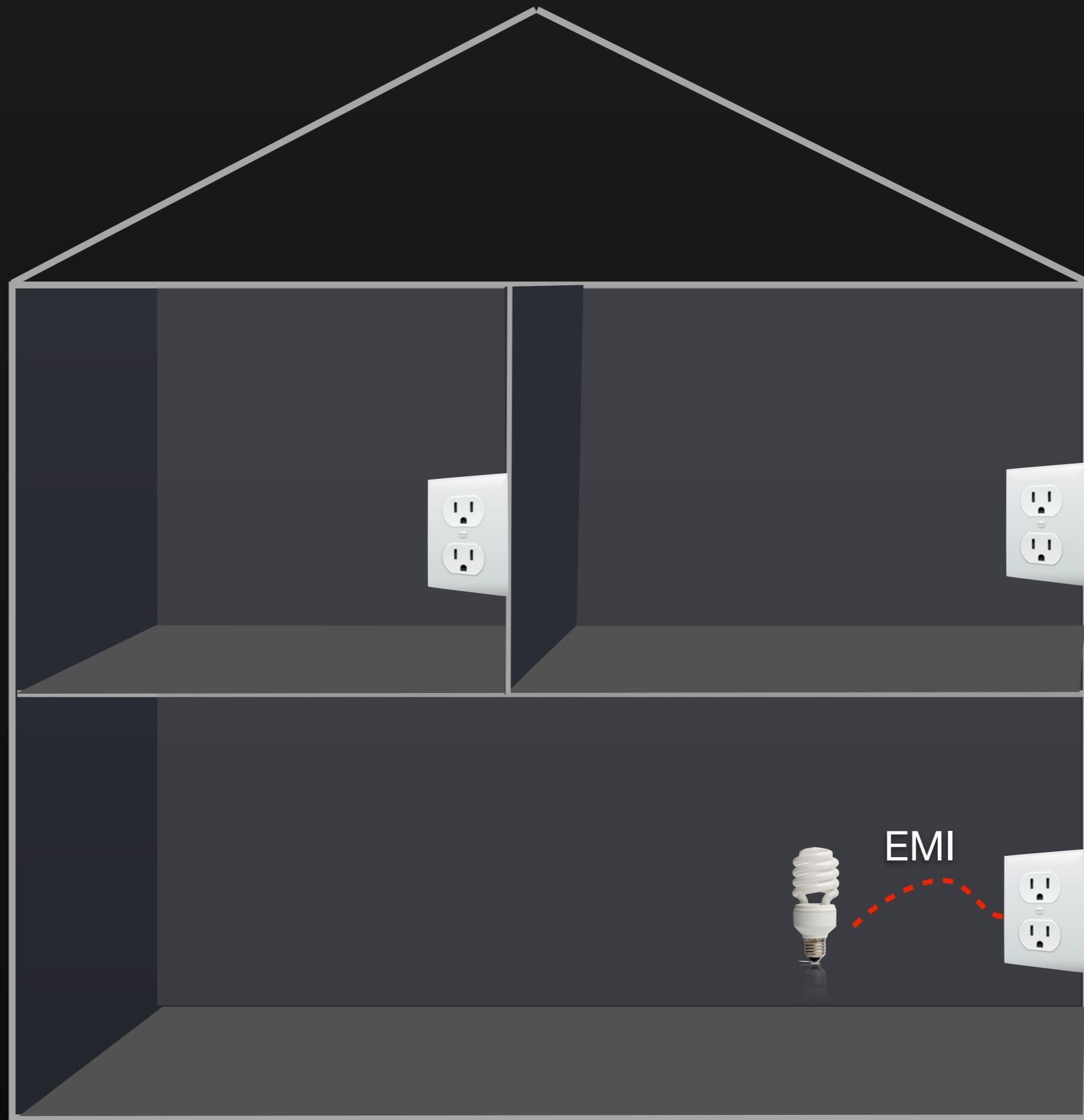


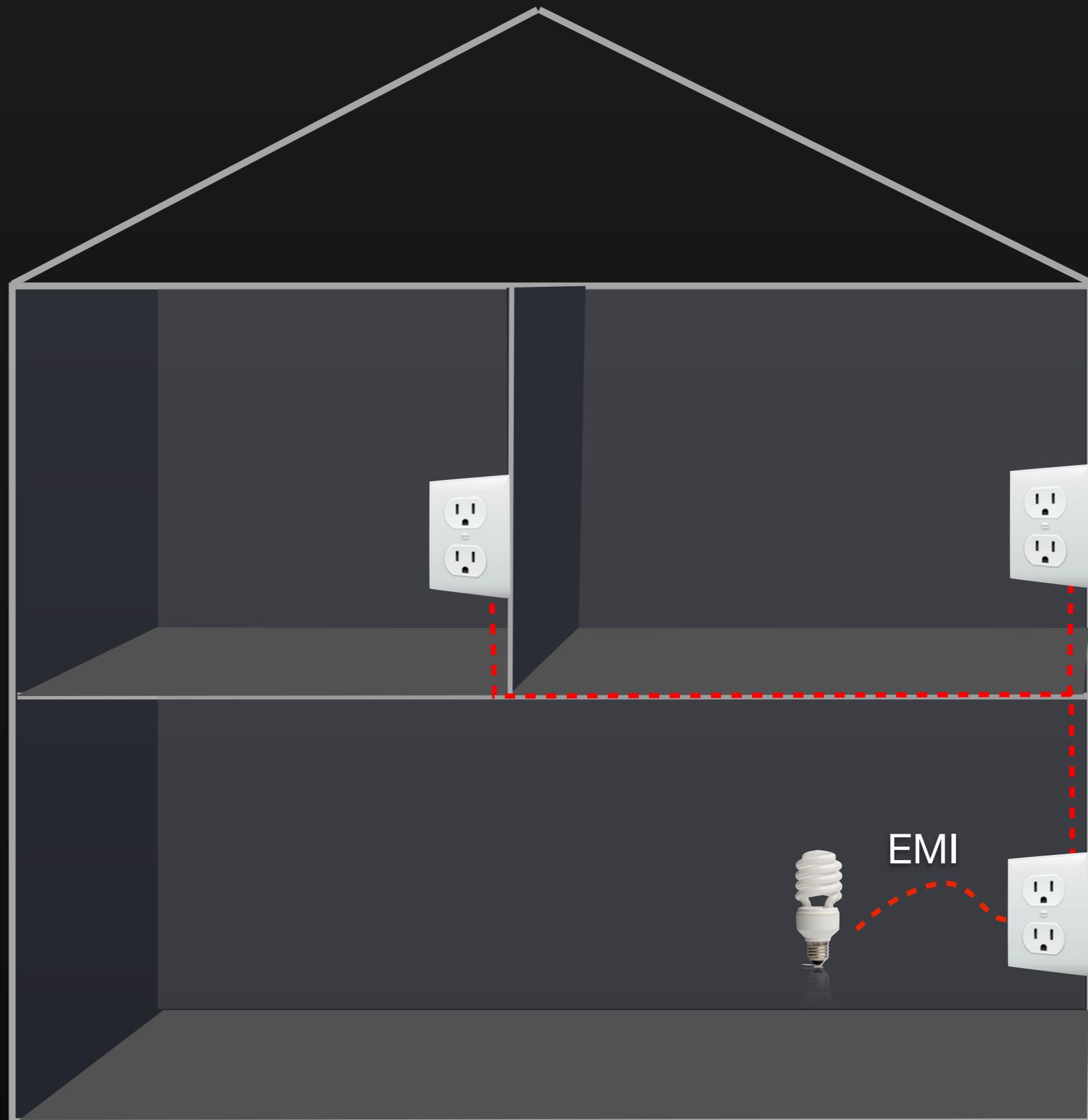
Switching Operation generates **high frequency**  
Electro Magnetic Interference (**EMI**)



Switching Operation generates **high frequency**  
Electro Magnetic Interference (**EMI**)



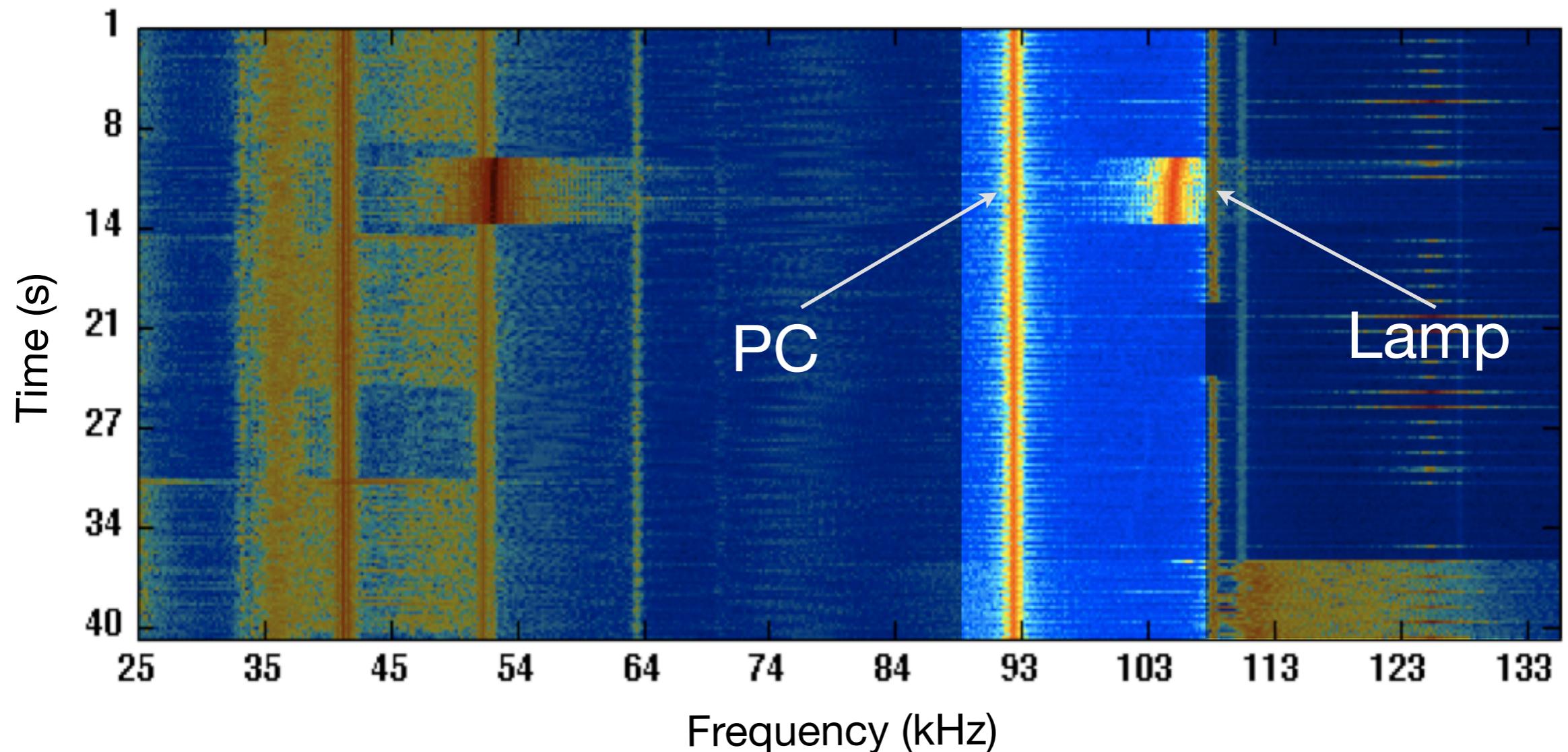






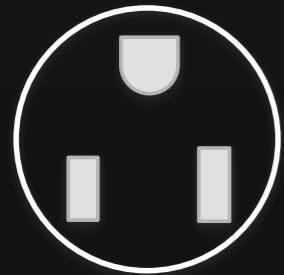


# What EMI on power line looks like



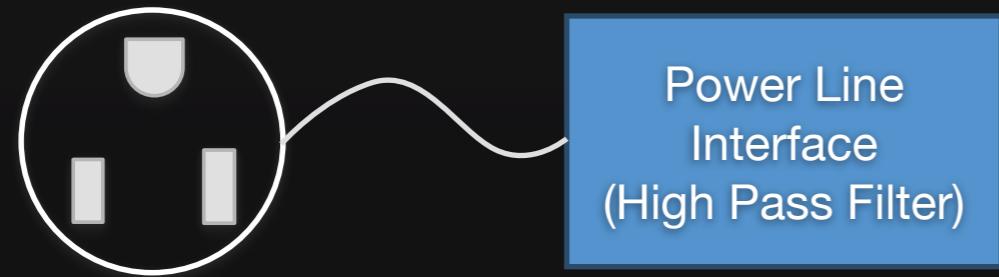
# Capture System

# Capture System



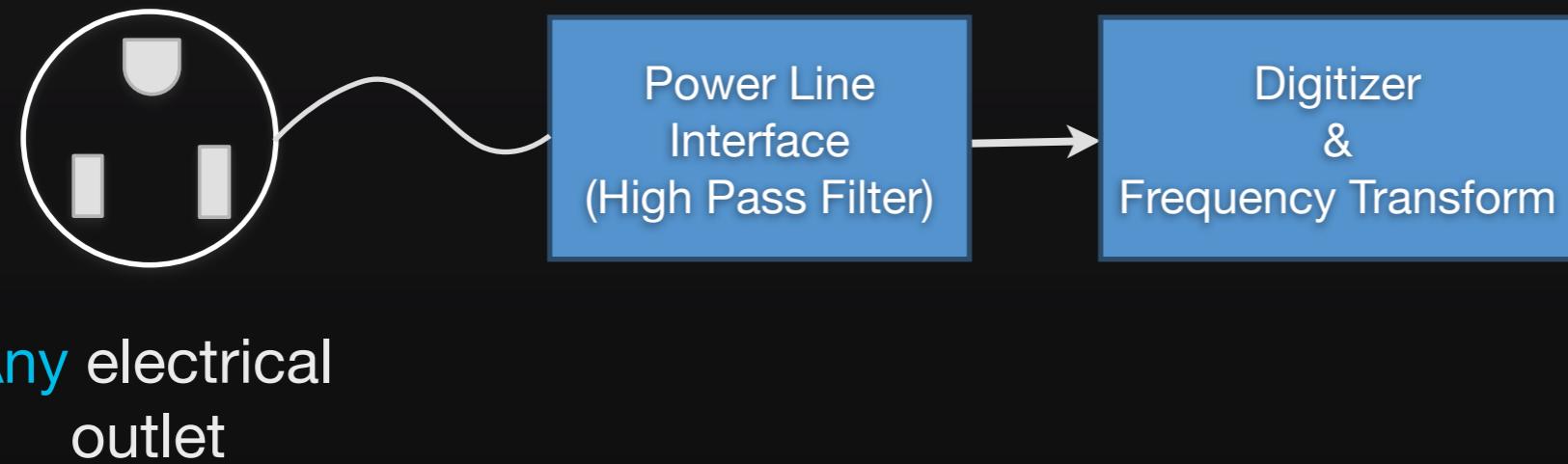
Any electrical  
outlet

# Capture System

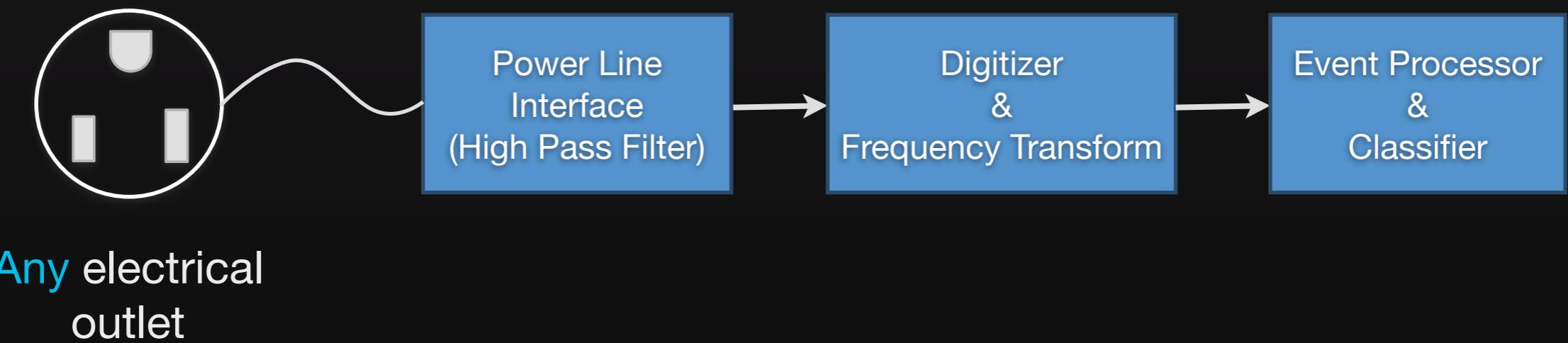


Any electrical outlet

# Capture System

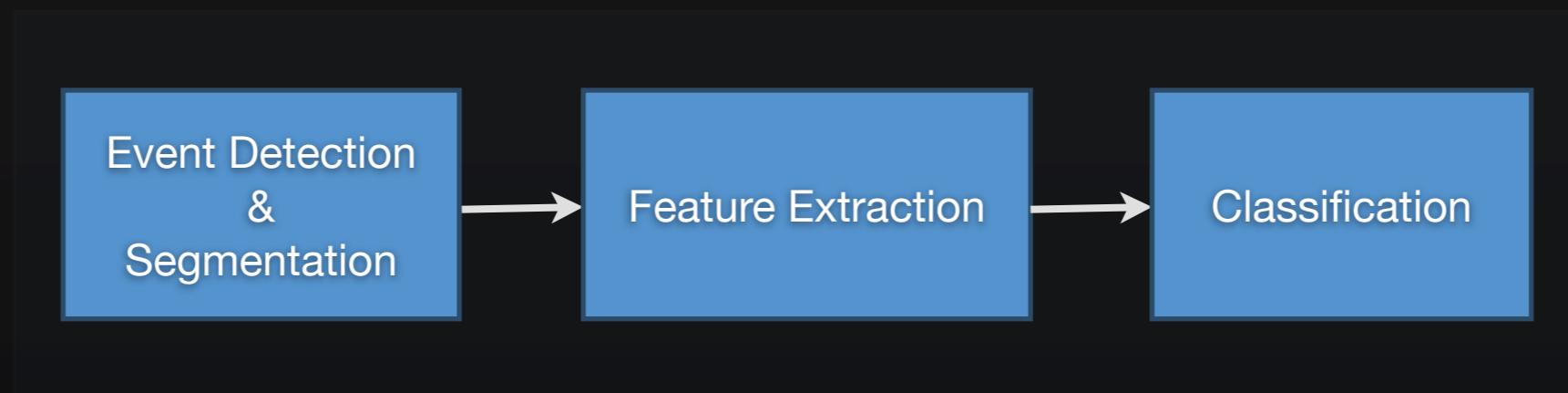


# Capture System



# Capture System

# Event Processing

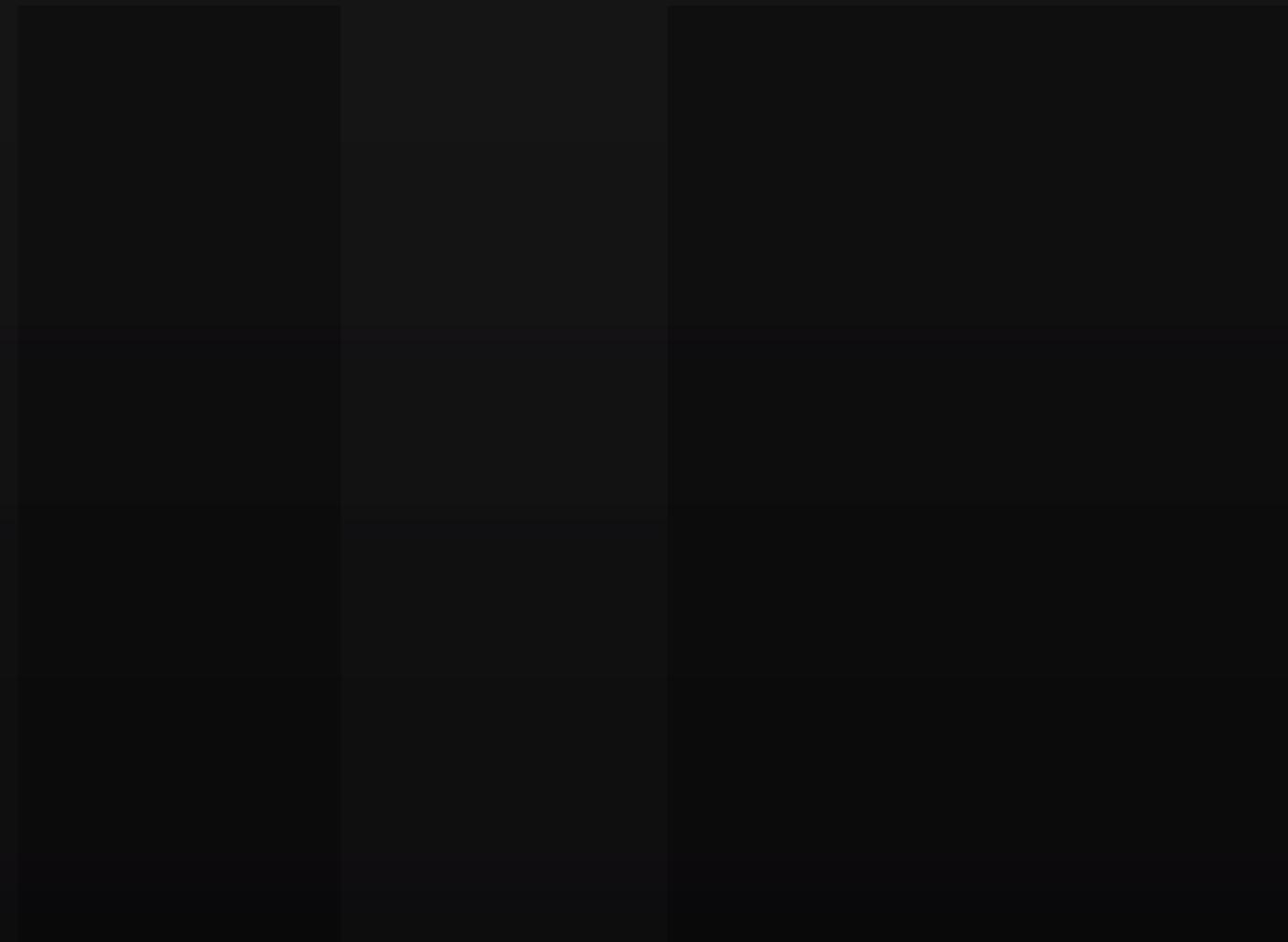


# Event Processing



# 1

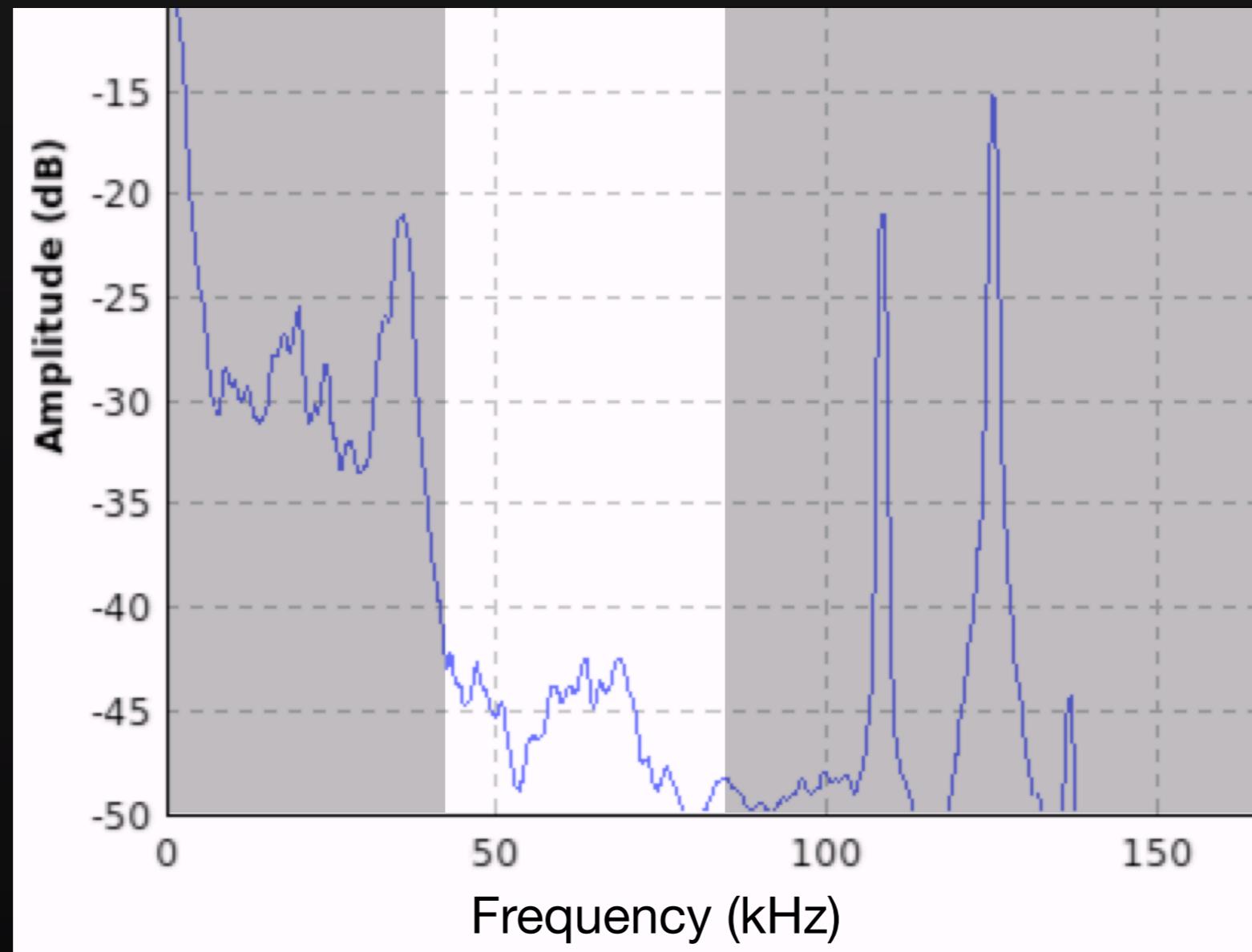
# Event Detection & Segmentation



Frequency (kHz)

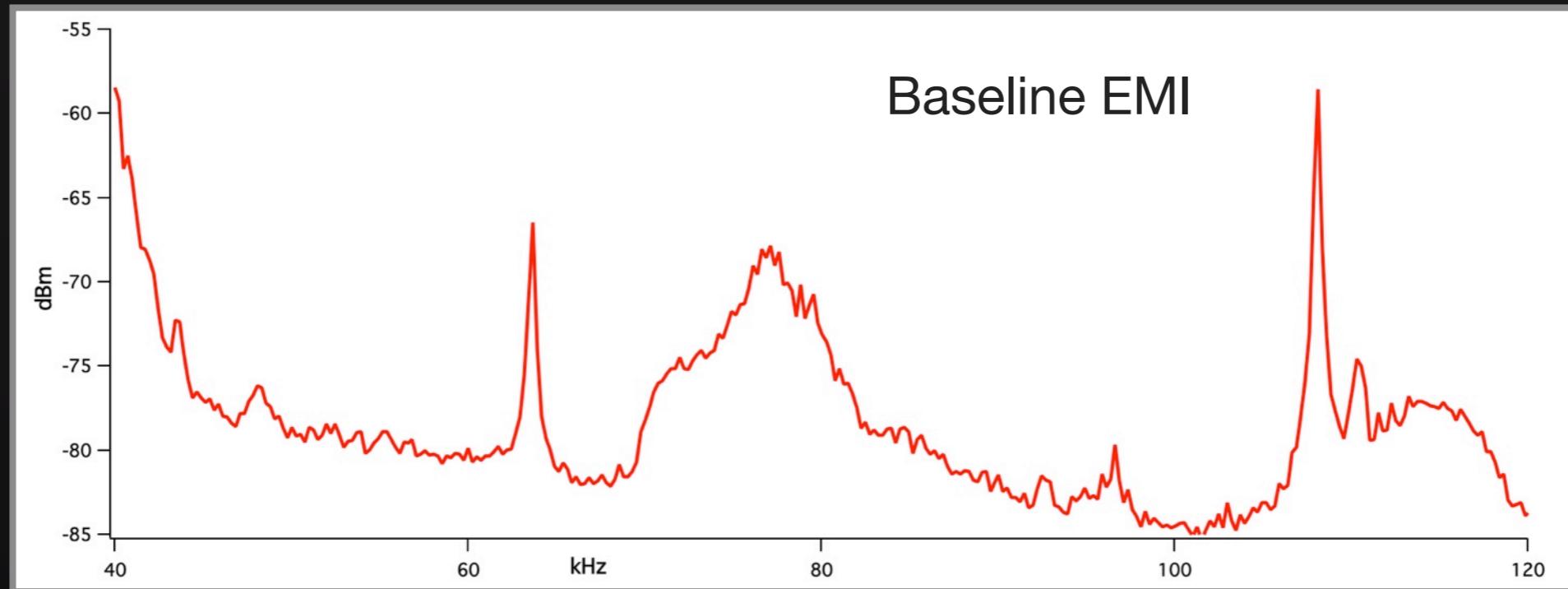
# 1

# Event Detection & Segmentation



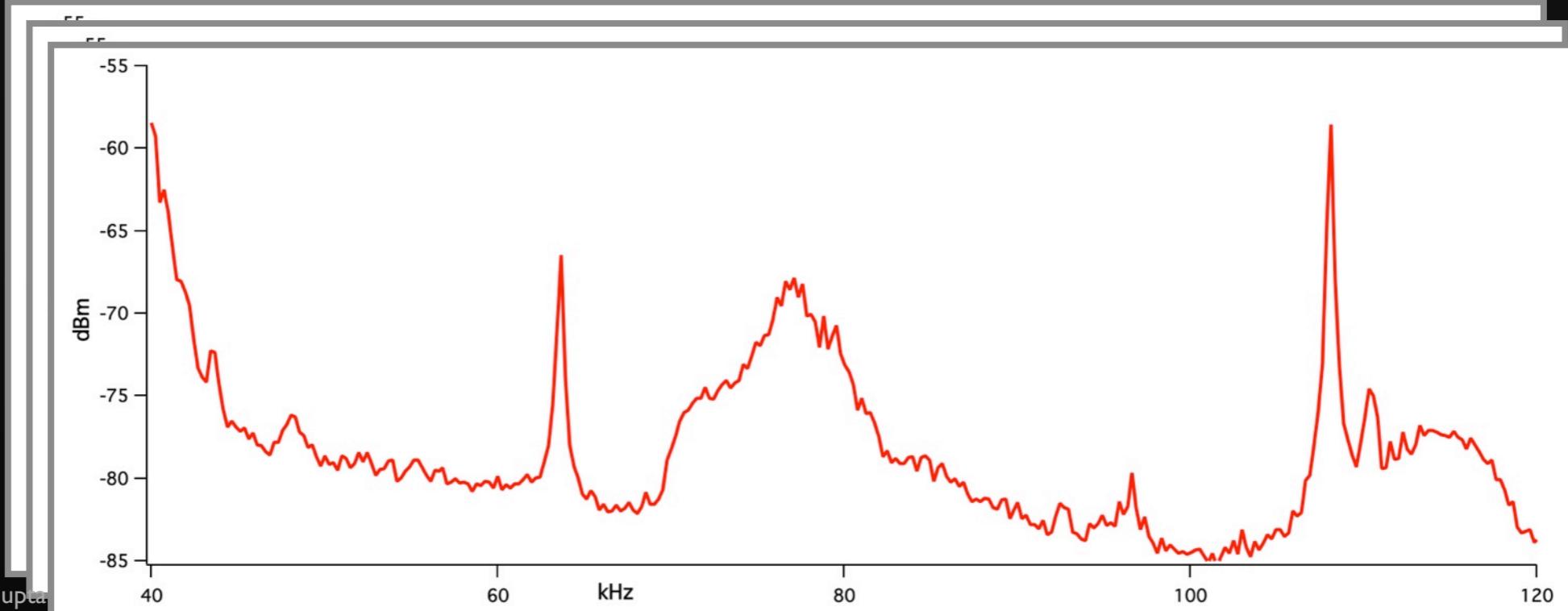
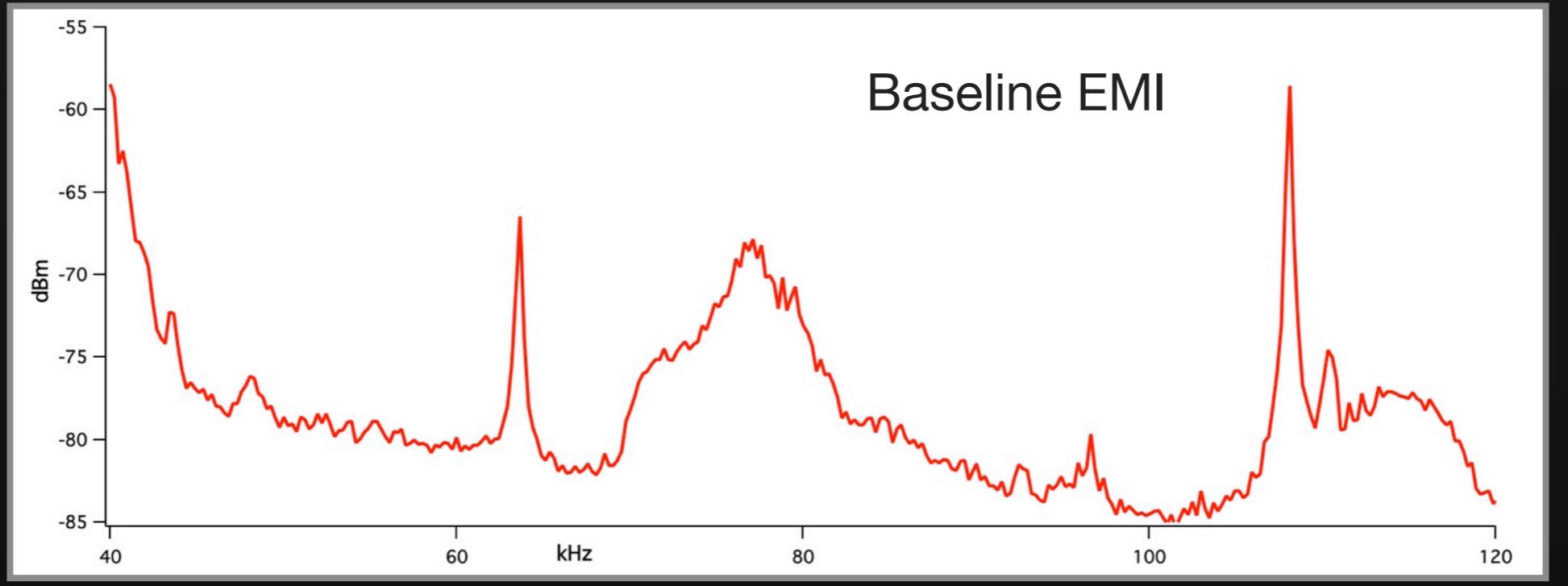
# 1

# Event Detection & Segmentation



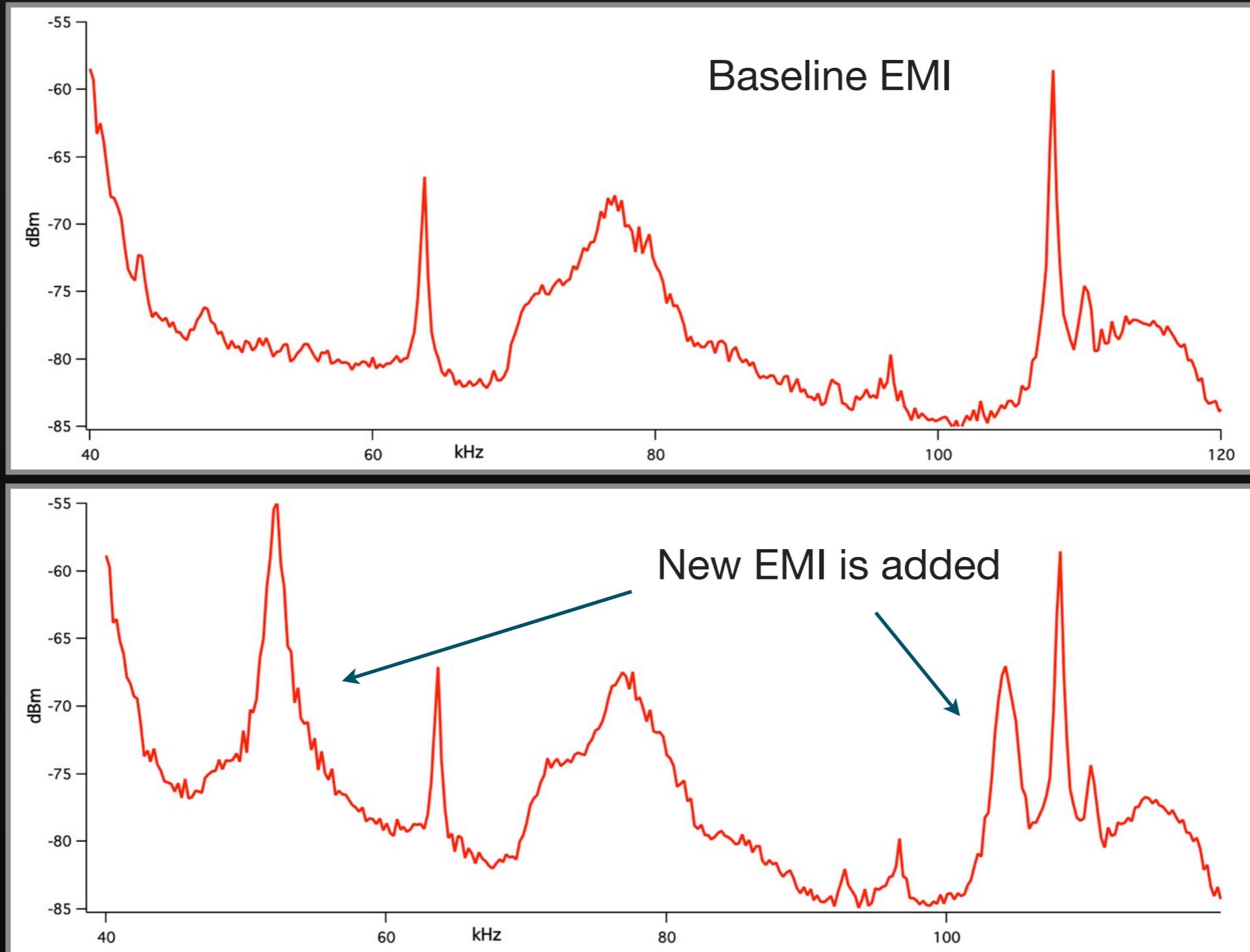
# 1

# Event Detection & Segmentation



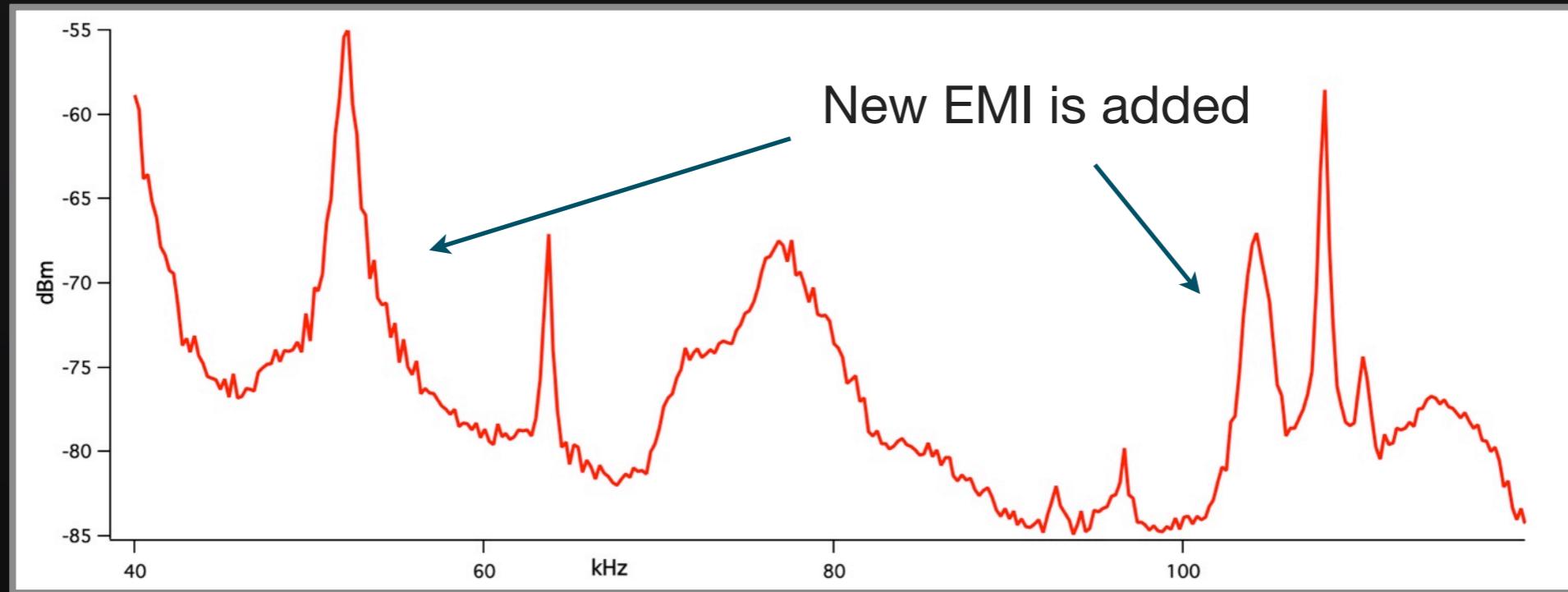
# 1

# Event Detection & Segmentation



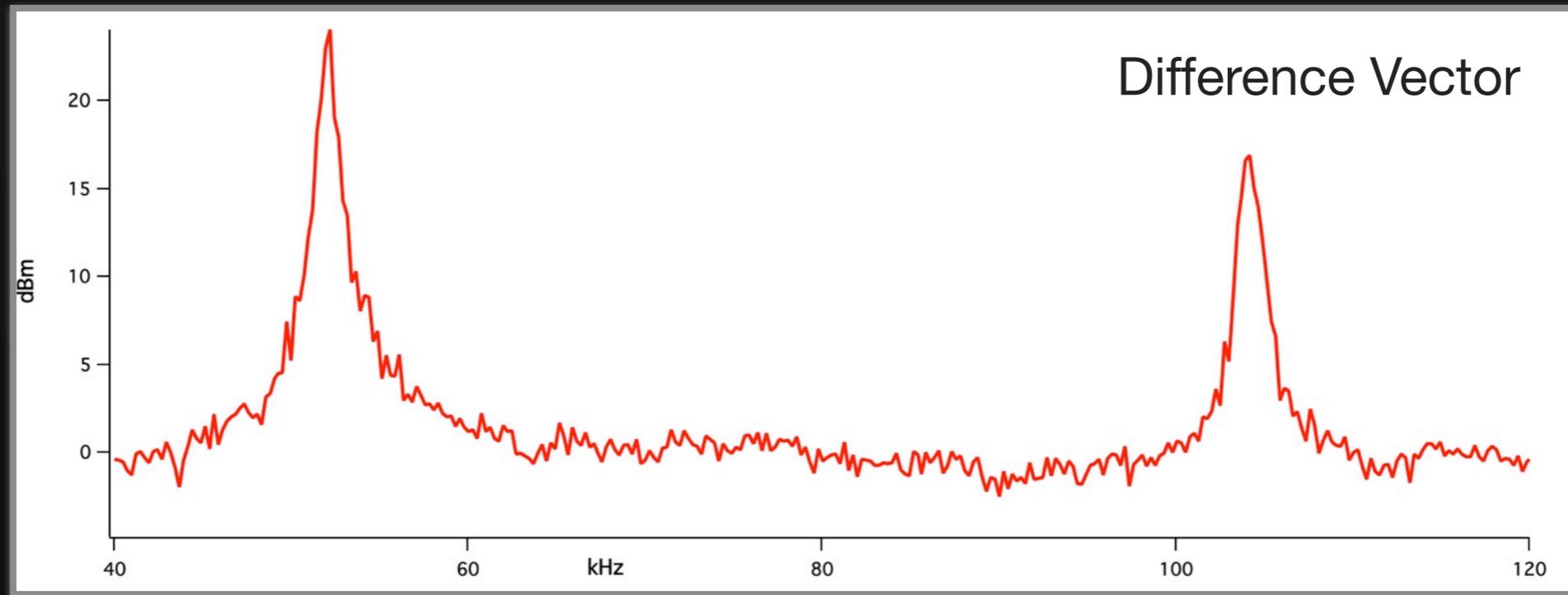
# 1

# Event Detection & Segmentation

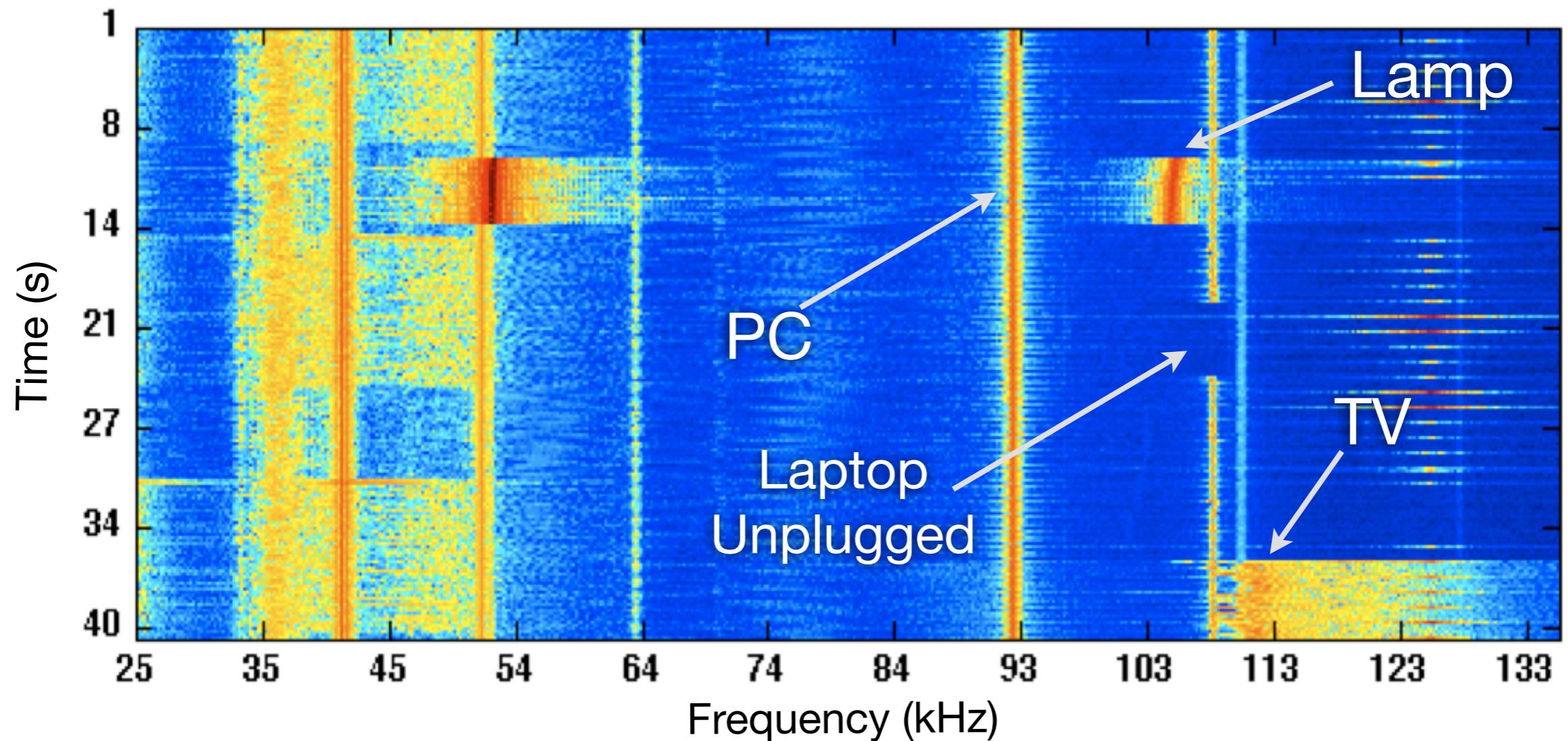


# 1

# Event Detection & Segmentation

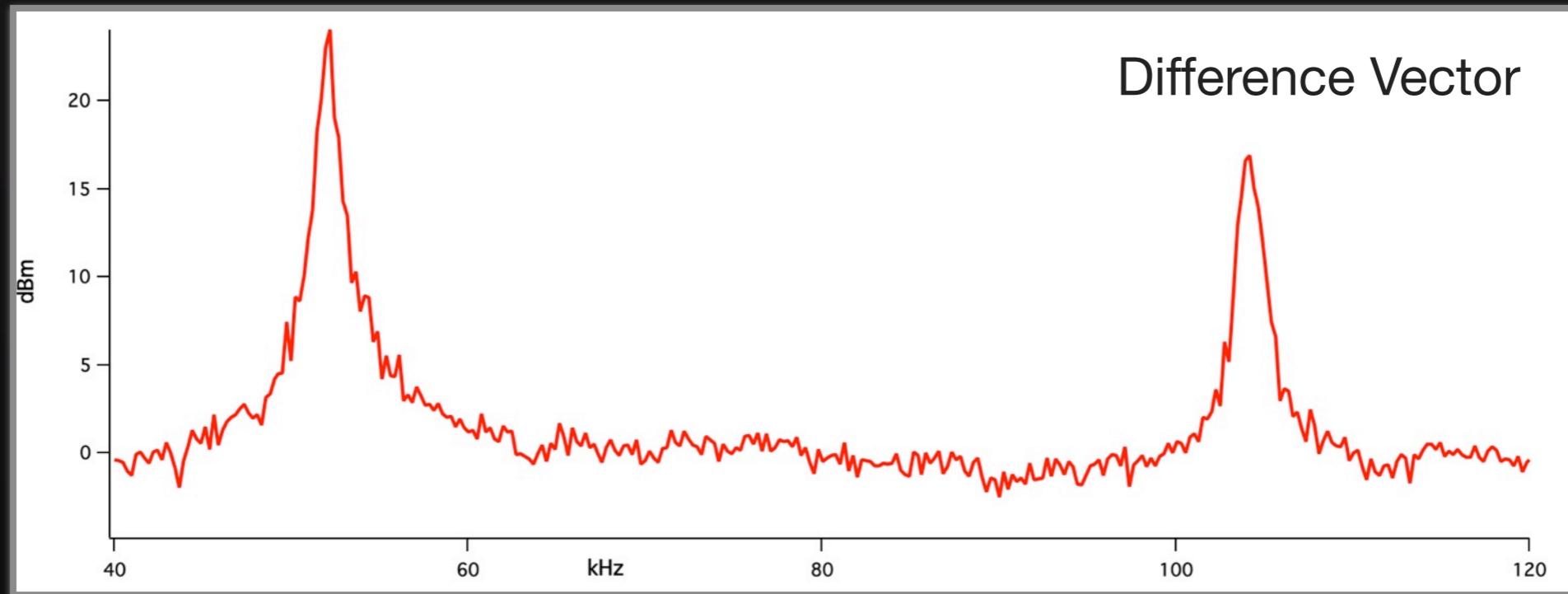


# Features



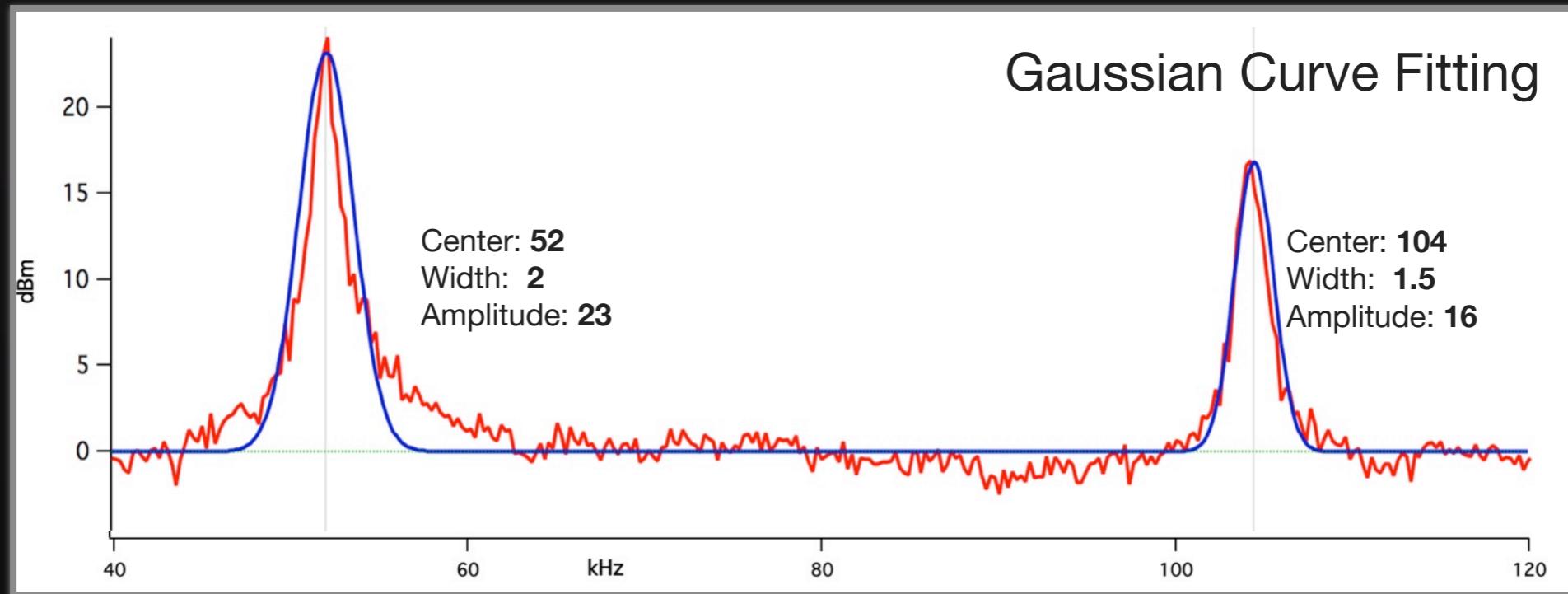
# 2

# Feature Extraction



# 2

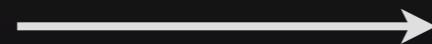
## Feature Extraction



Three features are extracted for each peak.

3

# Event Classification



# 3

## Event Classification

Three  
features from  
strongest peak



Nearest Neighbor  
Classifier

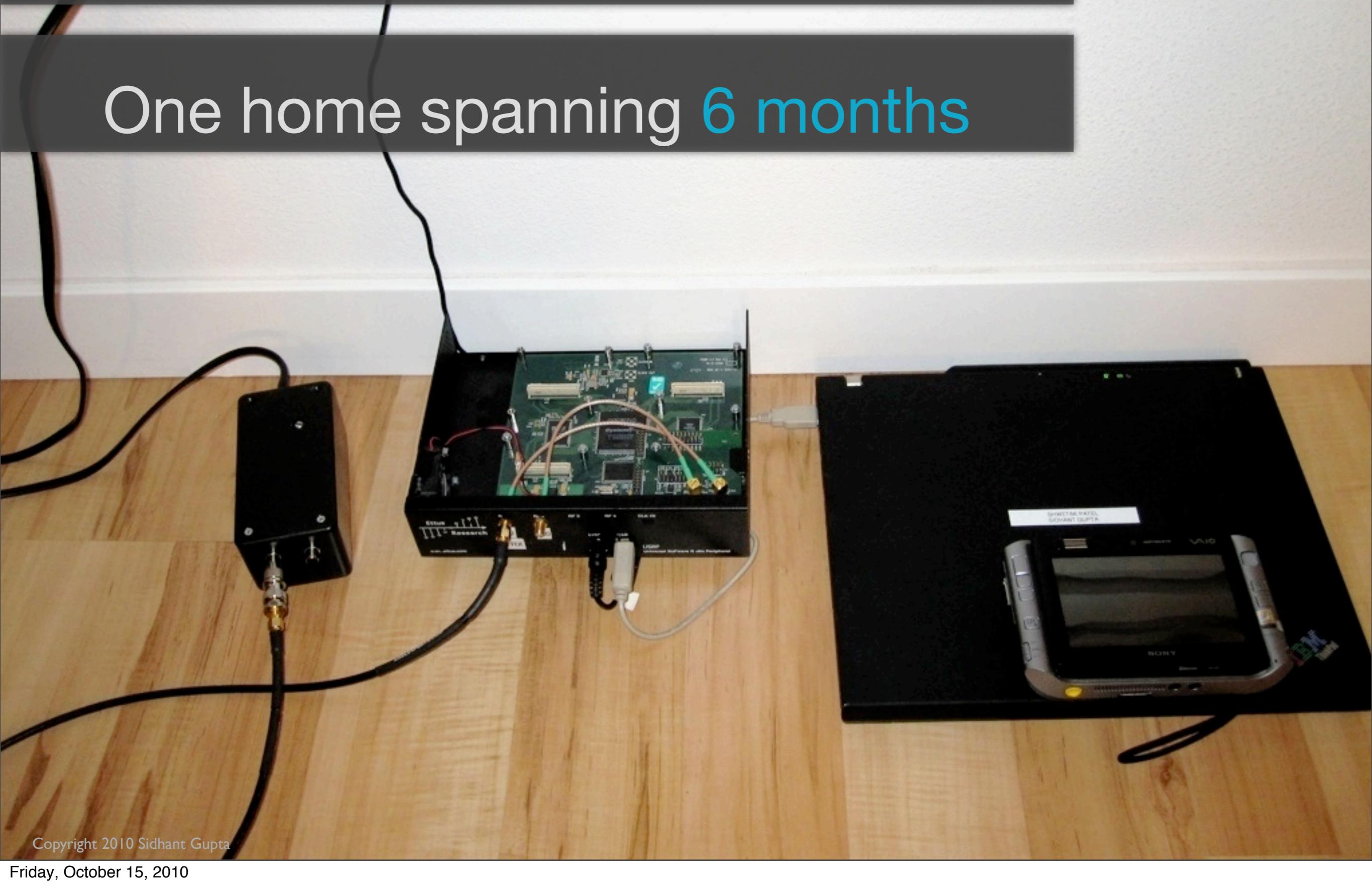
Are these features good enough for  
accurate identification?

Do signatures remain **stable** over **long**  
**period of time?**

Can training be minimized by applying  
signature from one home to another?

In home deployments in 7 homes

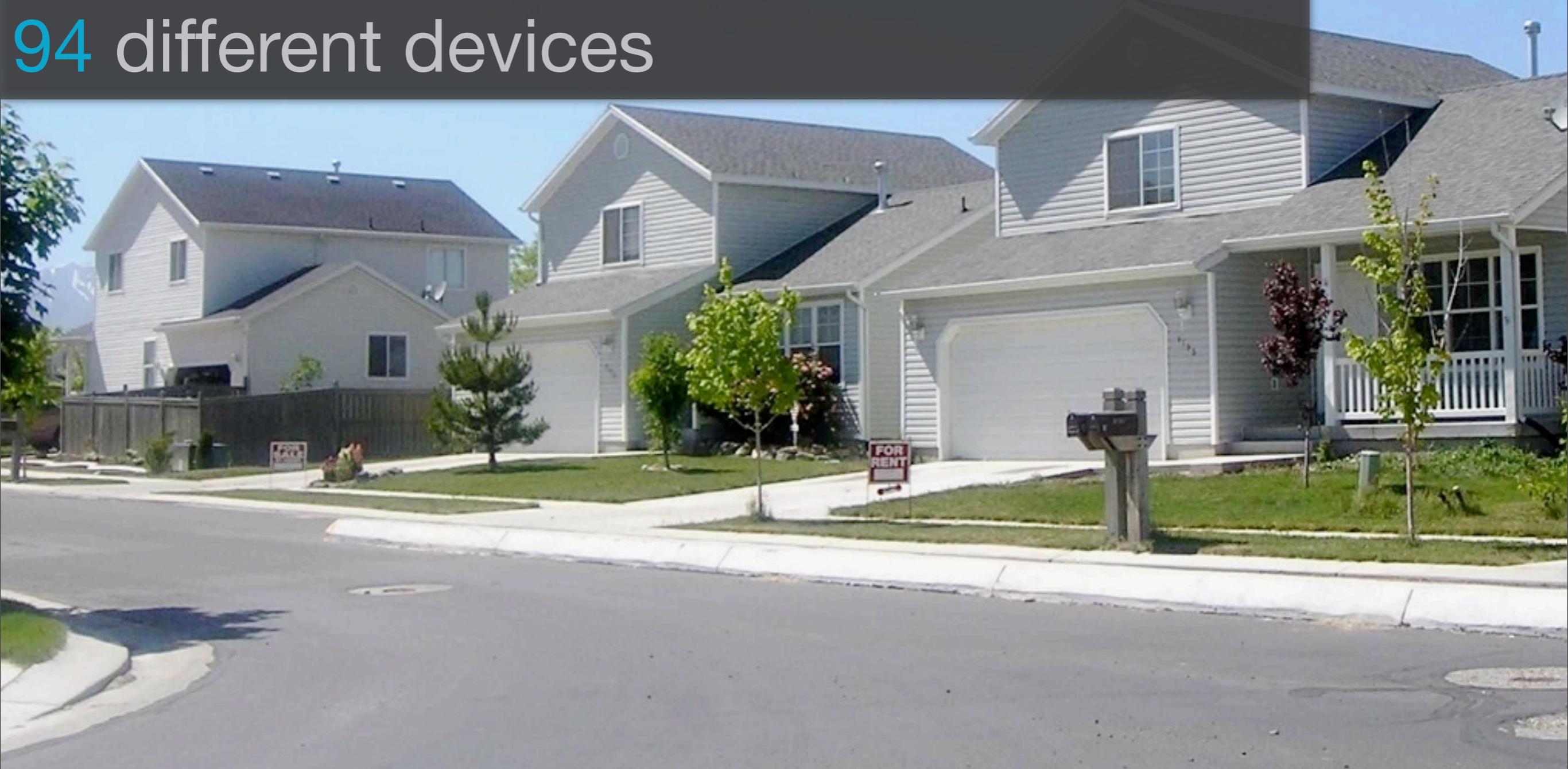
One home spanning 6 months



Apartments & Houses.

Home sizes: **650 - 3000** sq. ft.

In total **2576** electrical events captured  
**94** different devices



# Data Collection Procedure

Phase 1: Controlled Experiments

Phase 2: Under Naturalistic Setting

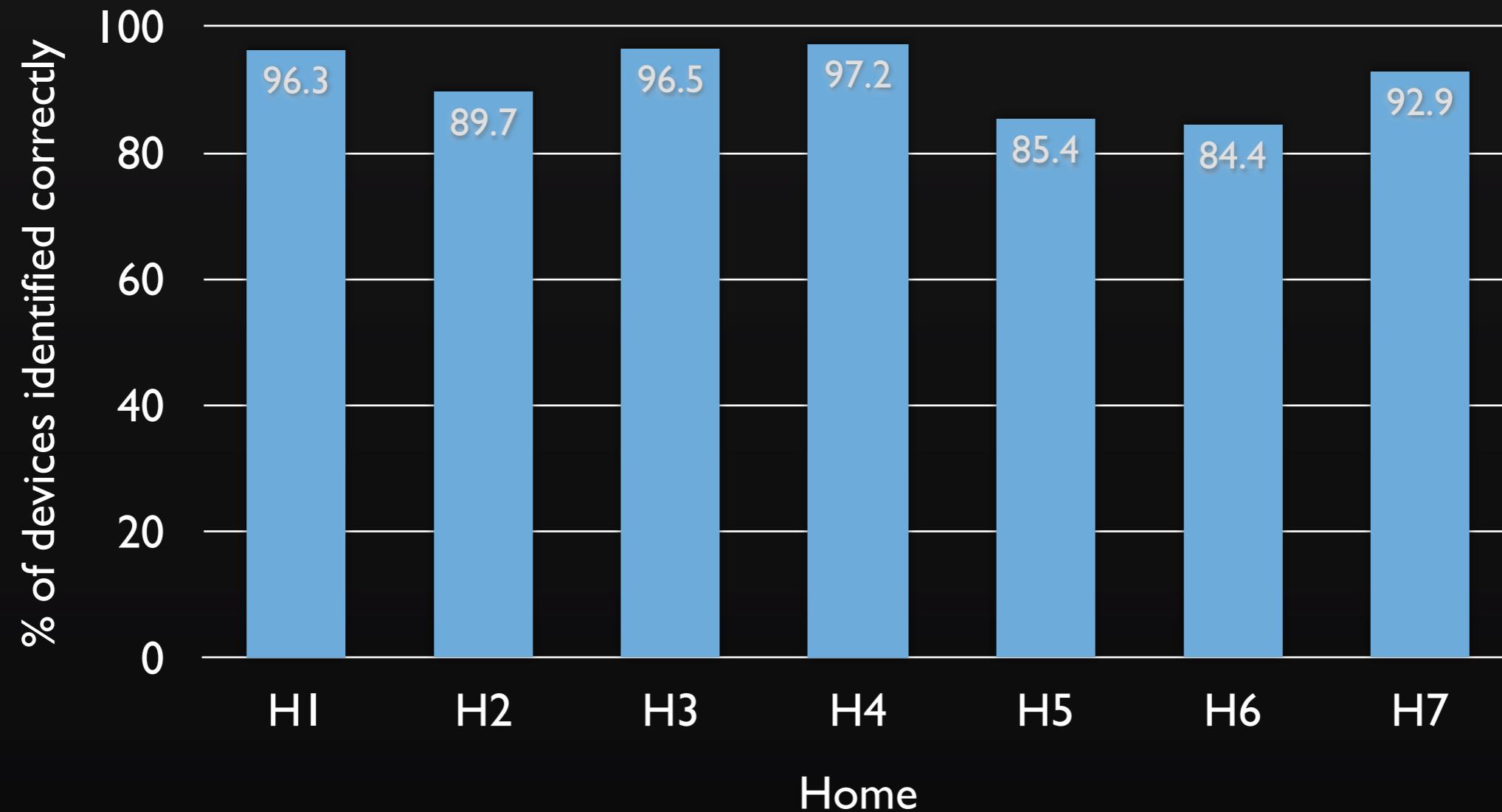
# Data Collection Procedure

Data from 6 month deployment  
was mostly naturalistic

# Accuracy in identifying devices in each home

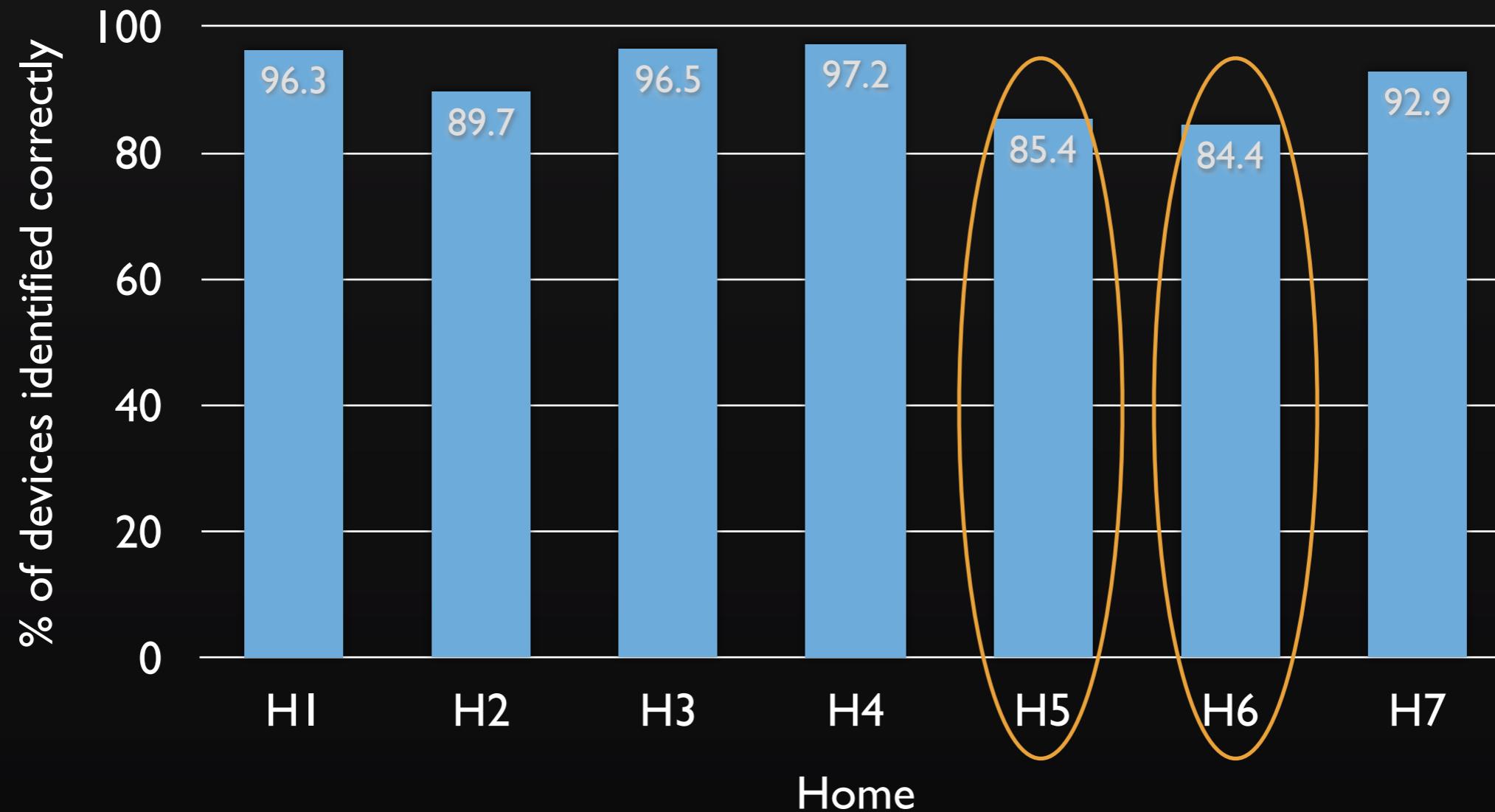
# 10 Fold Cross Validation

Average %: 91.75

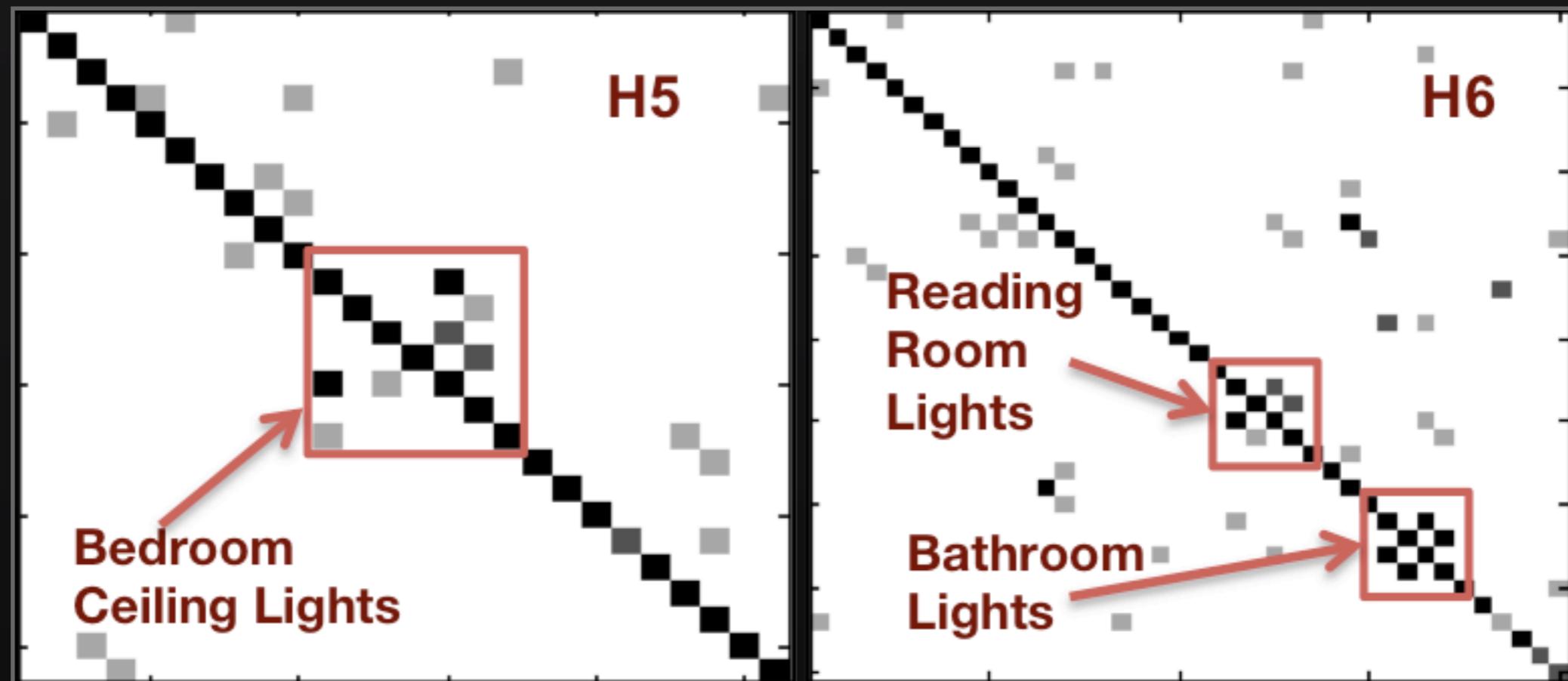


# 10 Fold Cross Validation

Average %: 91.75

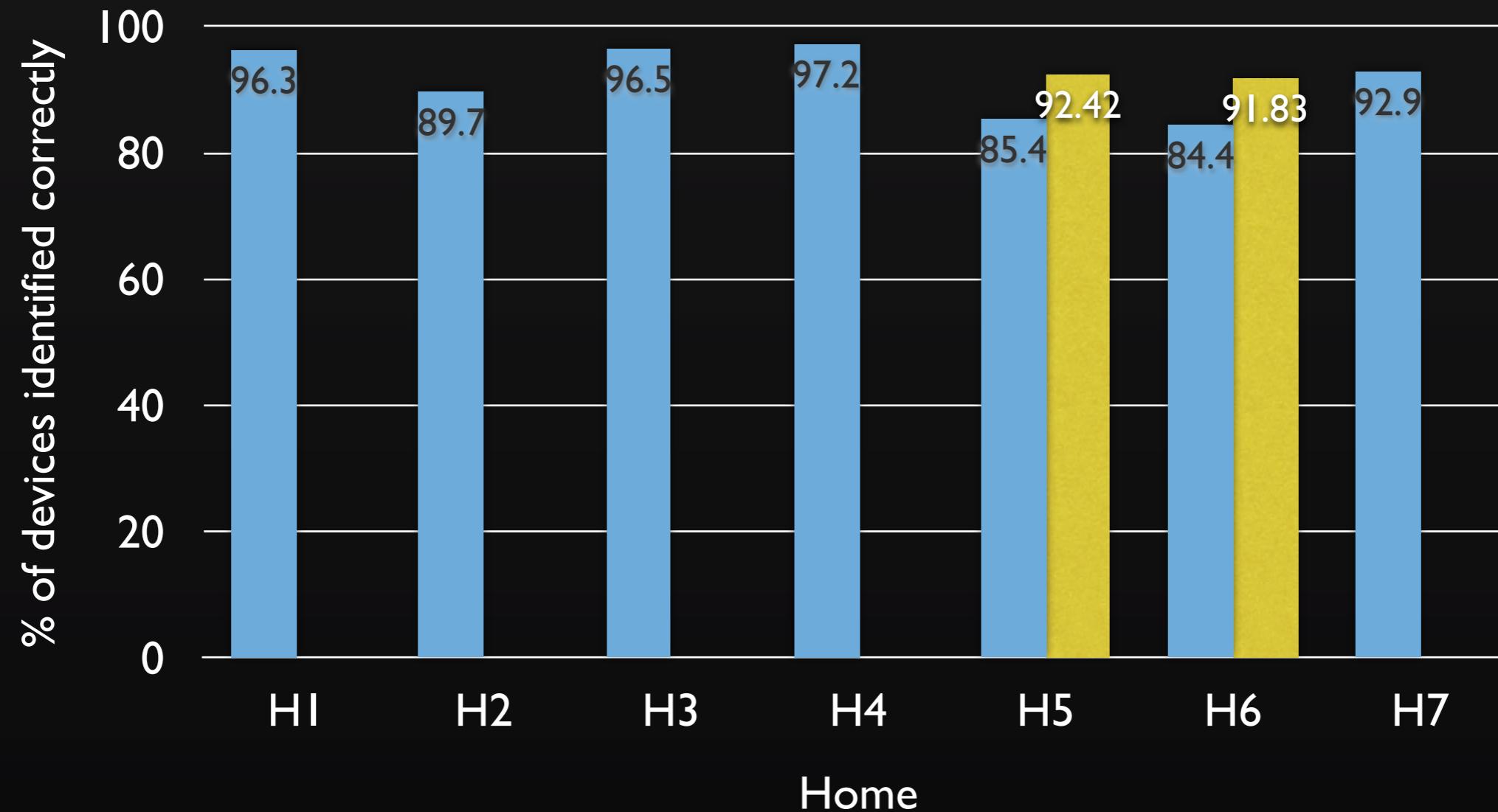


# Confusion Matrices



# 10 Fold Cross Validation

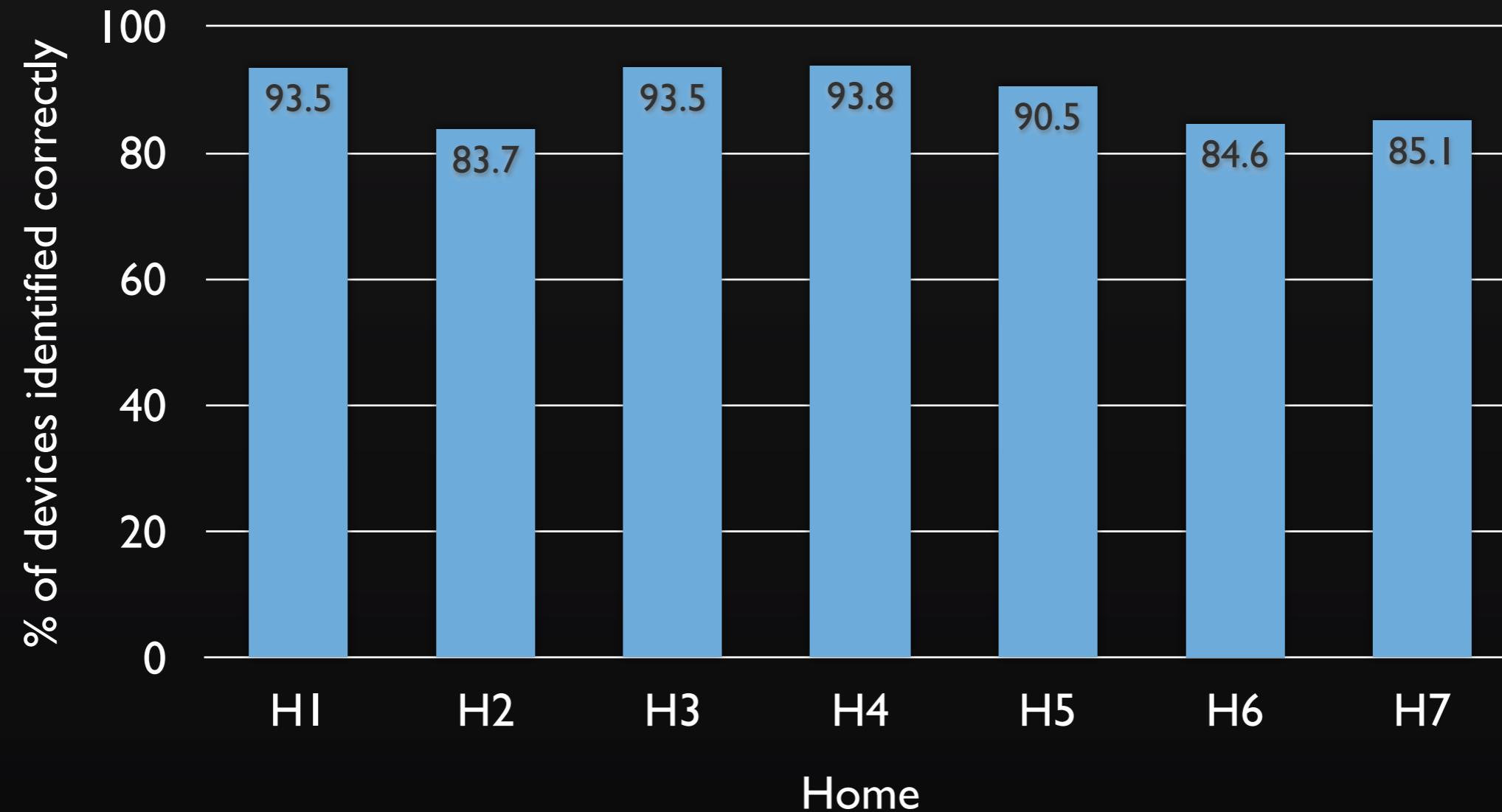
Average %: 93.82



Training on a **single sample** for each event

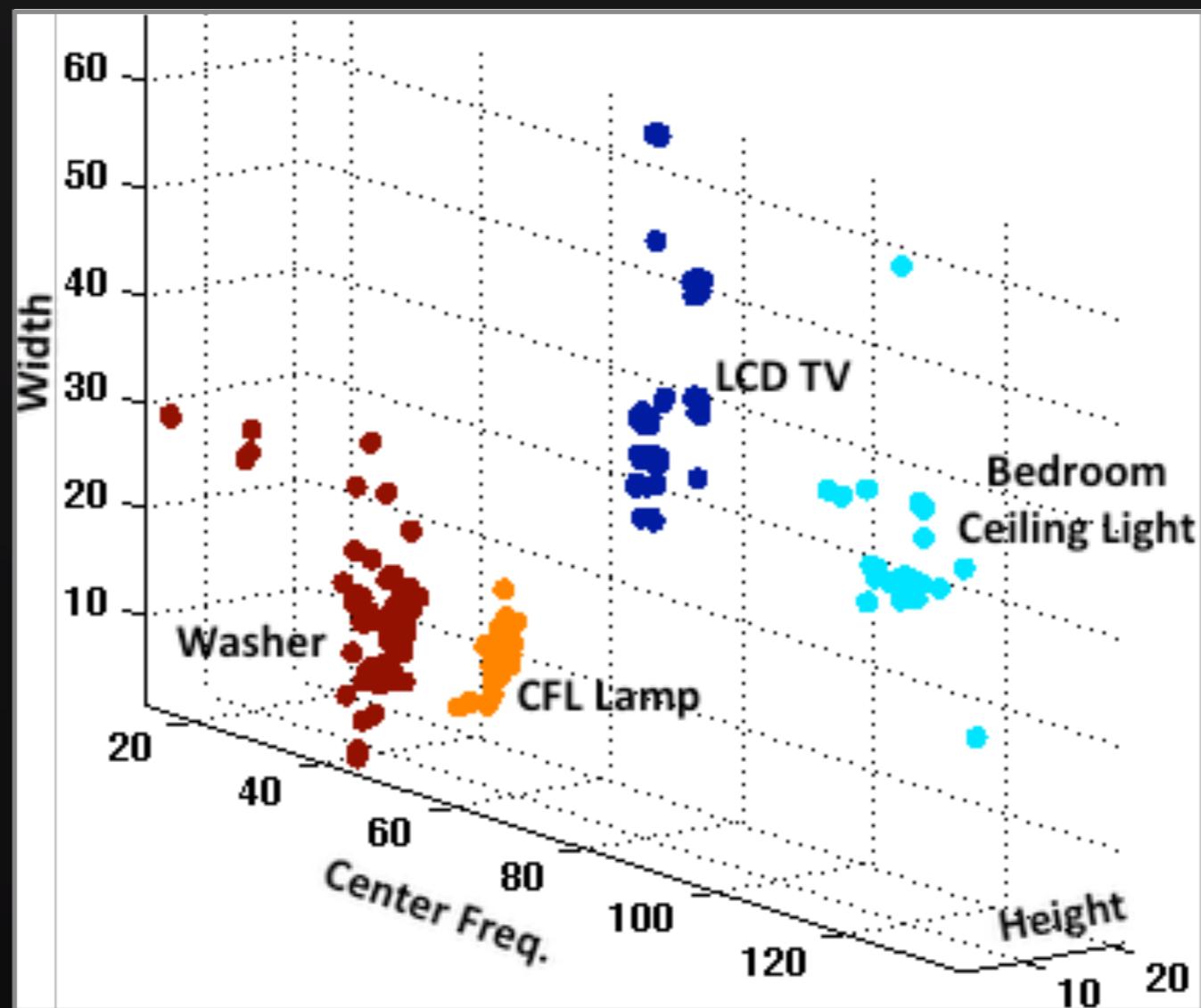
# Minimal Training Performance

Average %: 89.25



# Stability of signals over time

# Samples in Feature Space



Potentially **minimizing** training by  
applying signatures across home

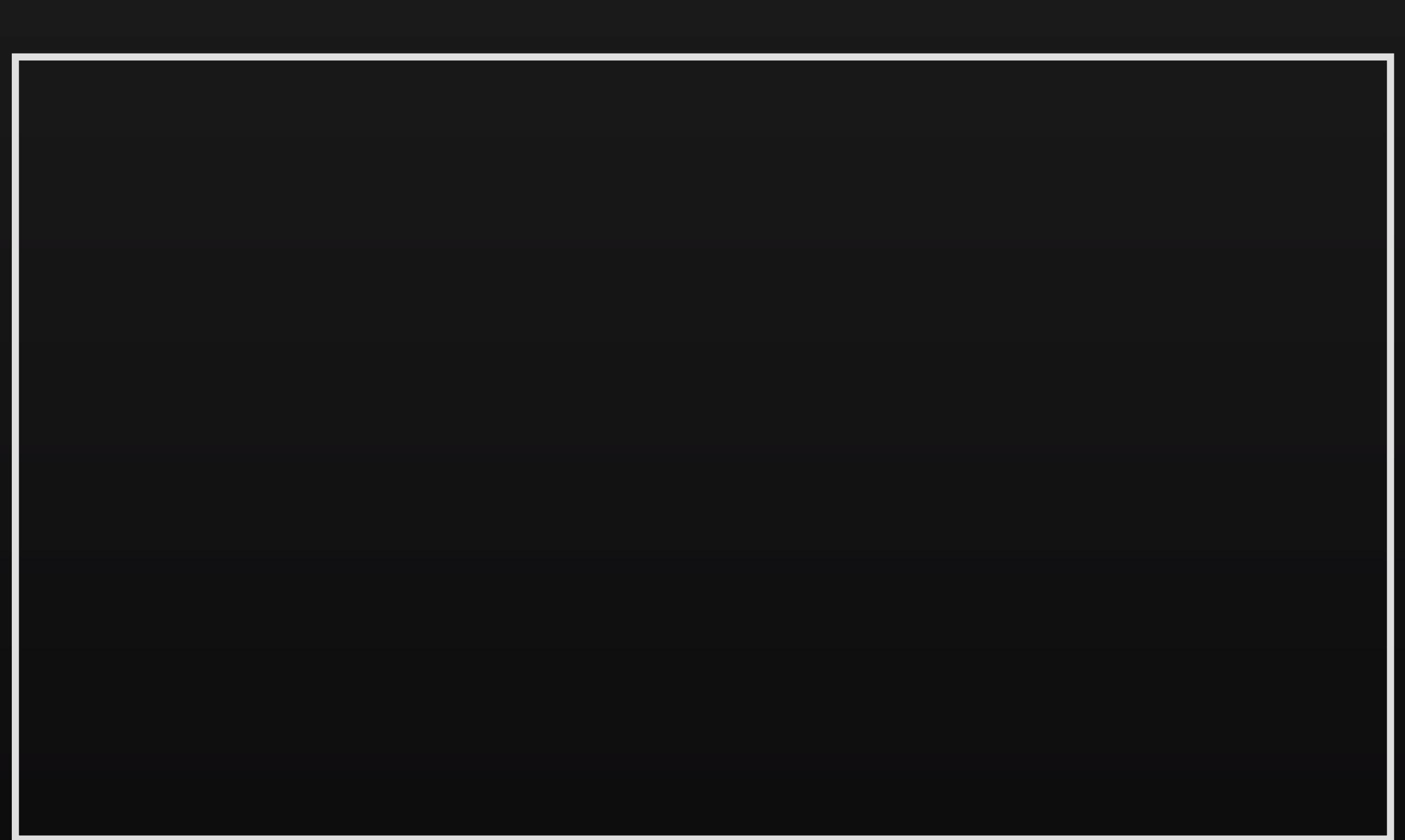
We collected data for four of our own  
devices in each home

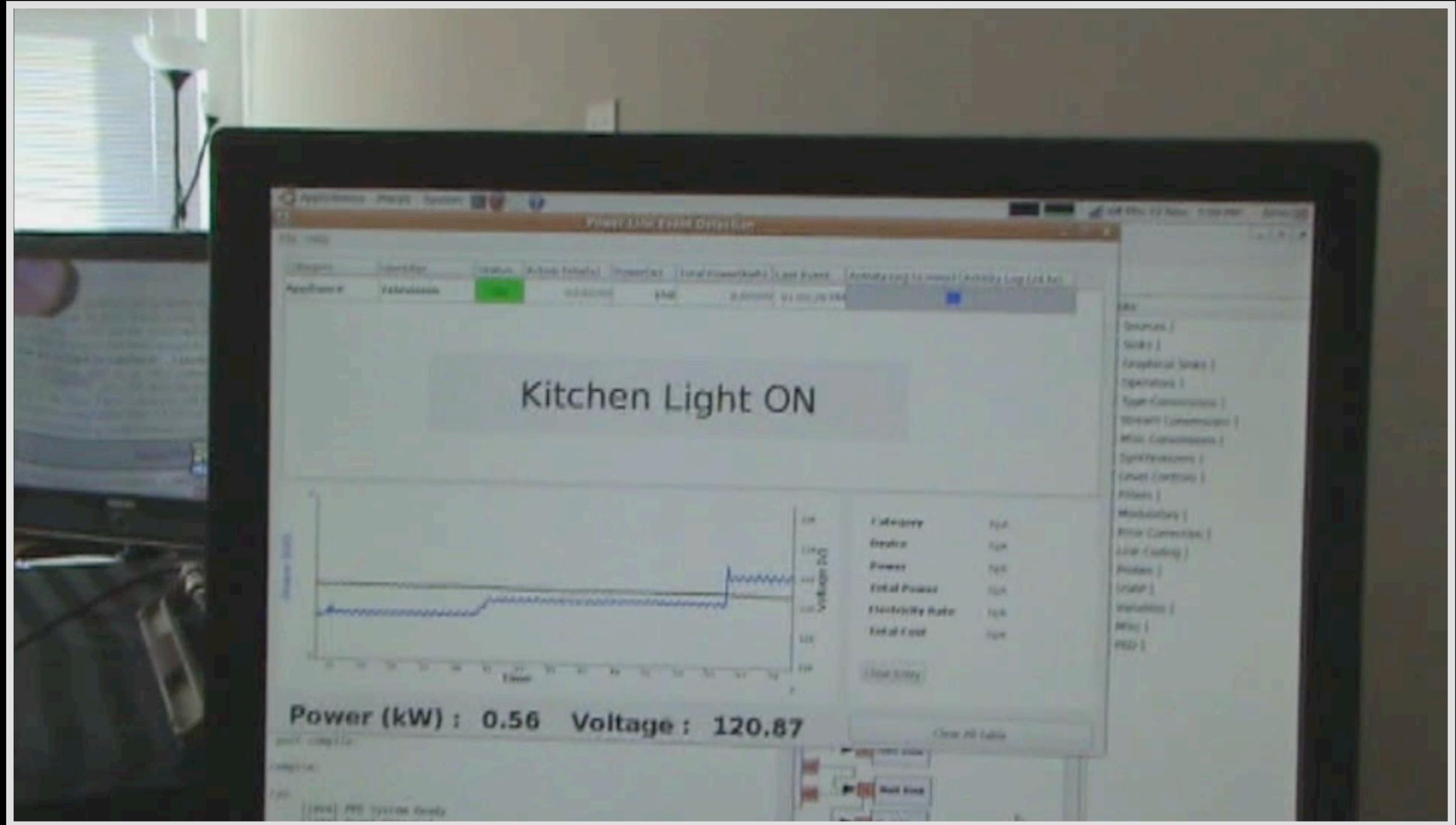
Two of the three features remain  
consistent

Average accuracy: 100%

Can signatures from one device be applied to **another** given they are **similar models**

Signature similar enough to yield an  
accuracy of **100%**





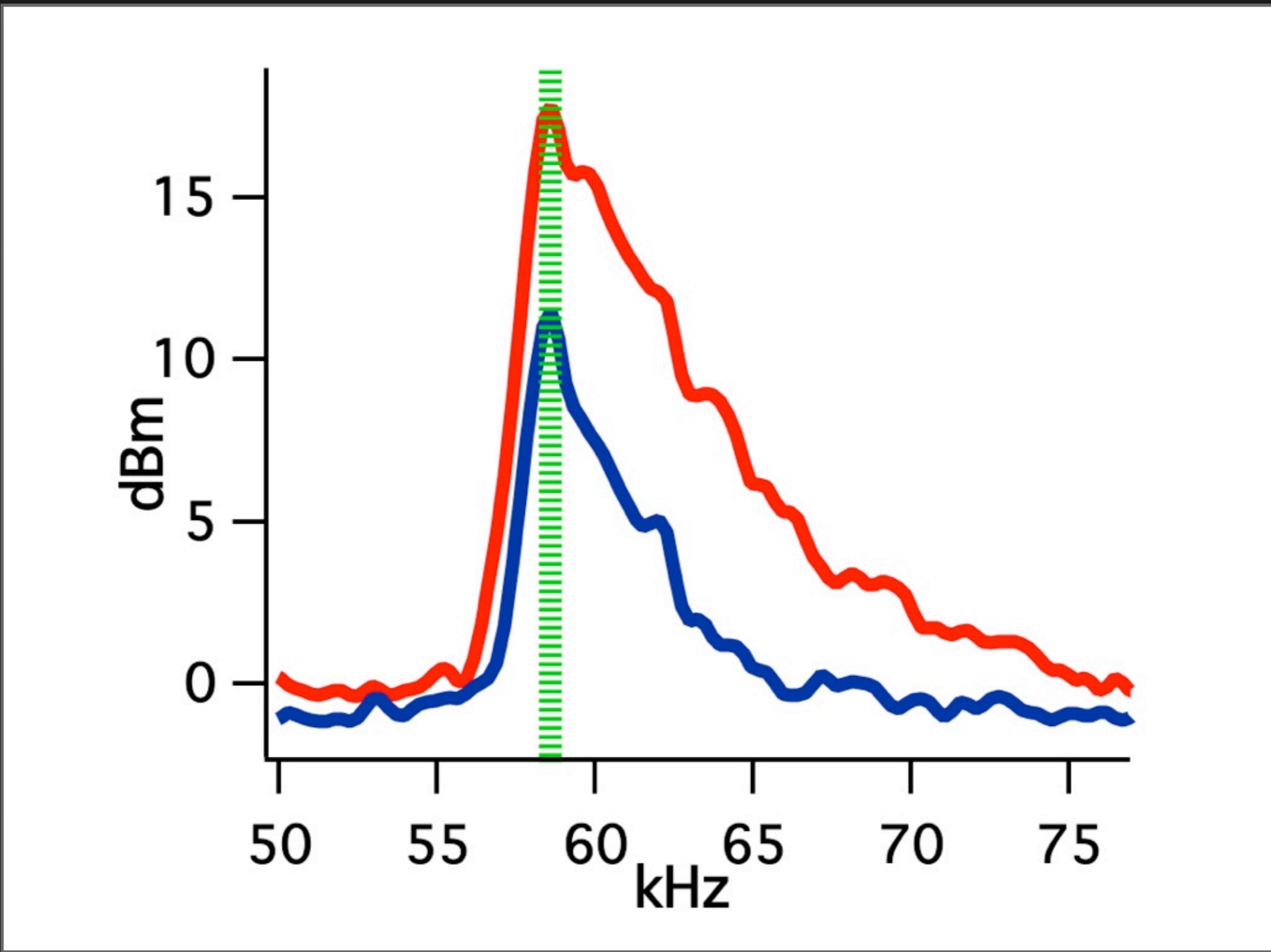
ElectriSense is a **low-cost**, **practical** sensing system that provides **whole-home** electrical device usage from a **single point**

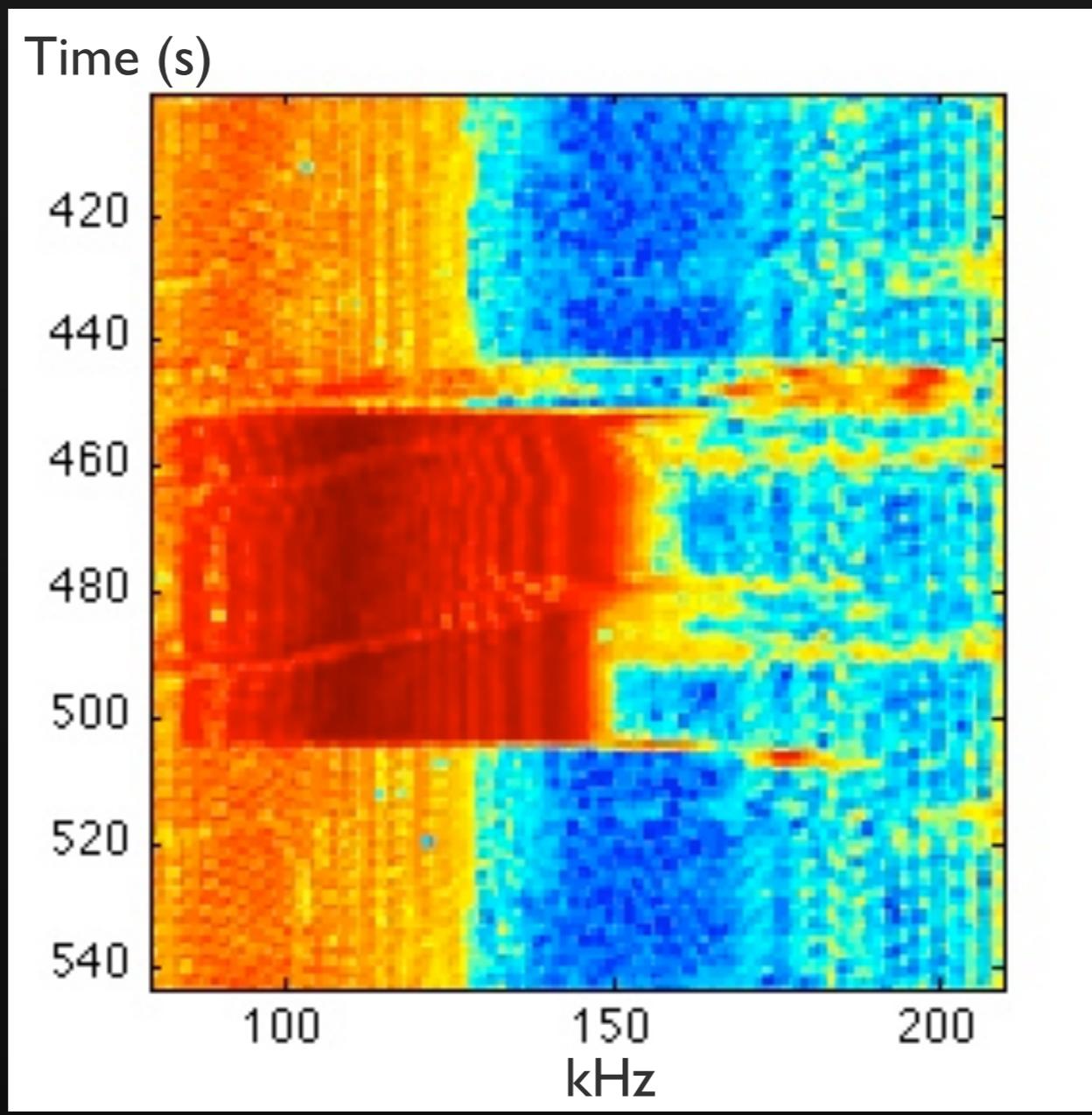
# Questions?



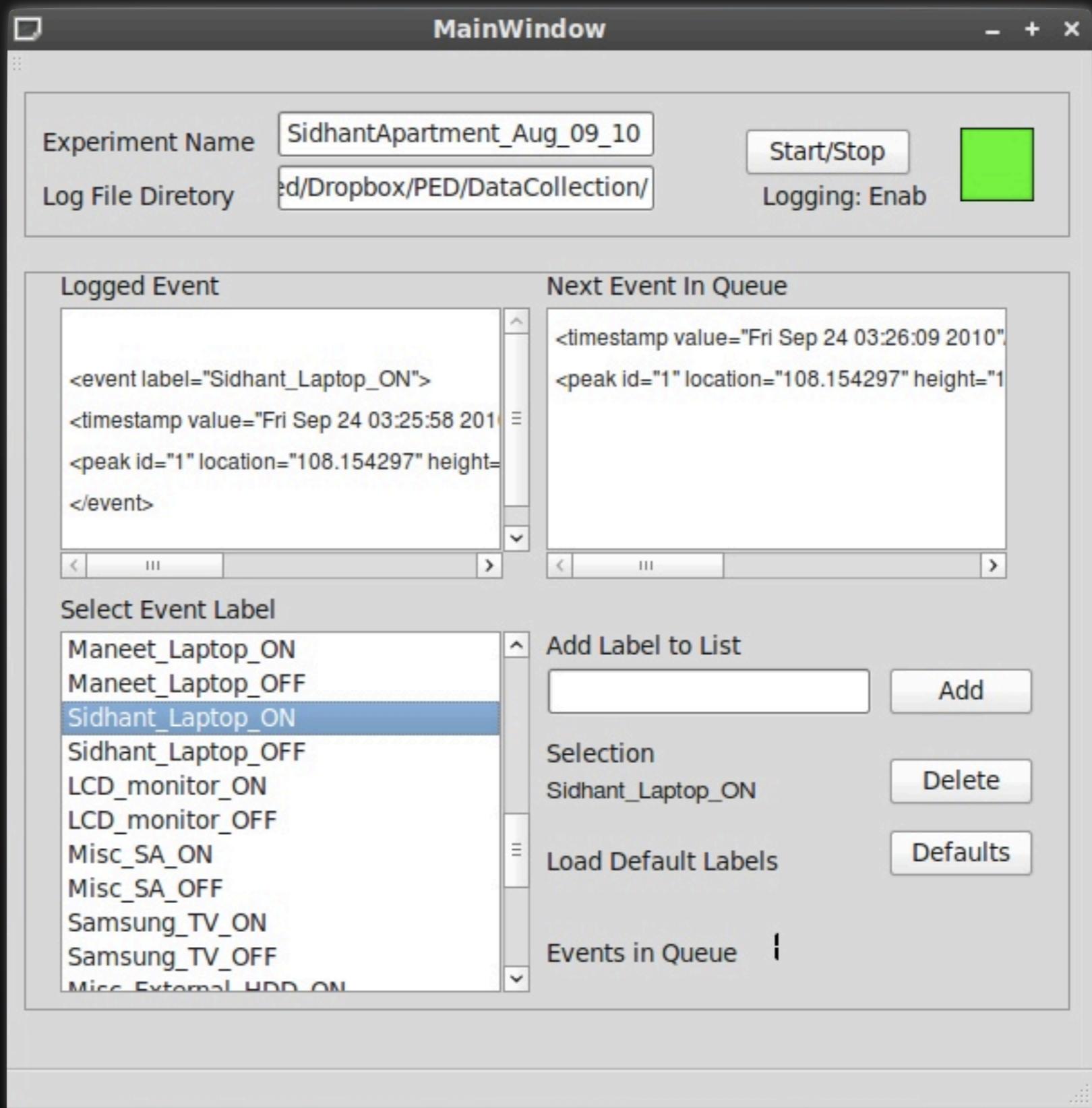
[sidhant@uw.edu](mailto:sidhant@uw.edu)  
<http://ubiCompLab.cs.washington.edu>

<http://www.sidhantgupta.com>





# In Field Labeling Tool





Tapia, E.M., Intille, S.S., Larson, K.: Activity recognition in the home setting using simple and ubiquitous sensors. *Pervasive 2004*.

Tapia, E.M., Intille, S.S., Lopez, L., and Larson, K. The design of a portable kit of wireless sensors for naturalistic data collection. *Pervasive 2006*.