QinetiQ

Measurements for Remote Identification of Electrical Equipment

Specialists' Meeting on Remote Intelligence of Building Interiors

QINETIQ/17/01715




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Agenda

1. Introduction

2. Experimental Approach

1. Spectral signatures
2. Current transient signals

3. Results

1. Device identification by spectra
2. Device identification from current transients

4. Conclusions & Future Work

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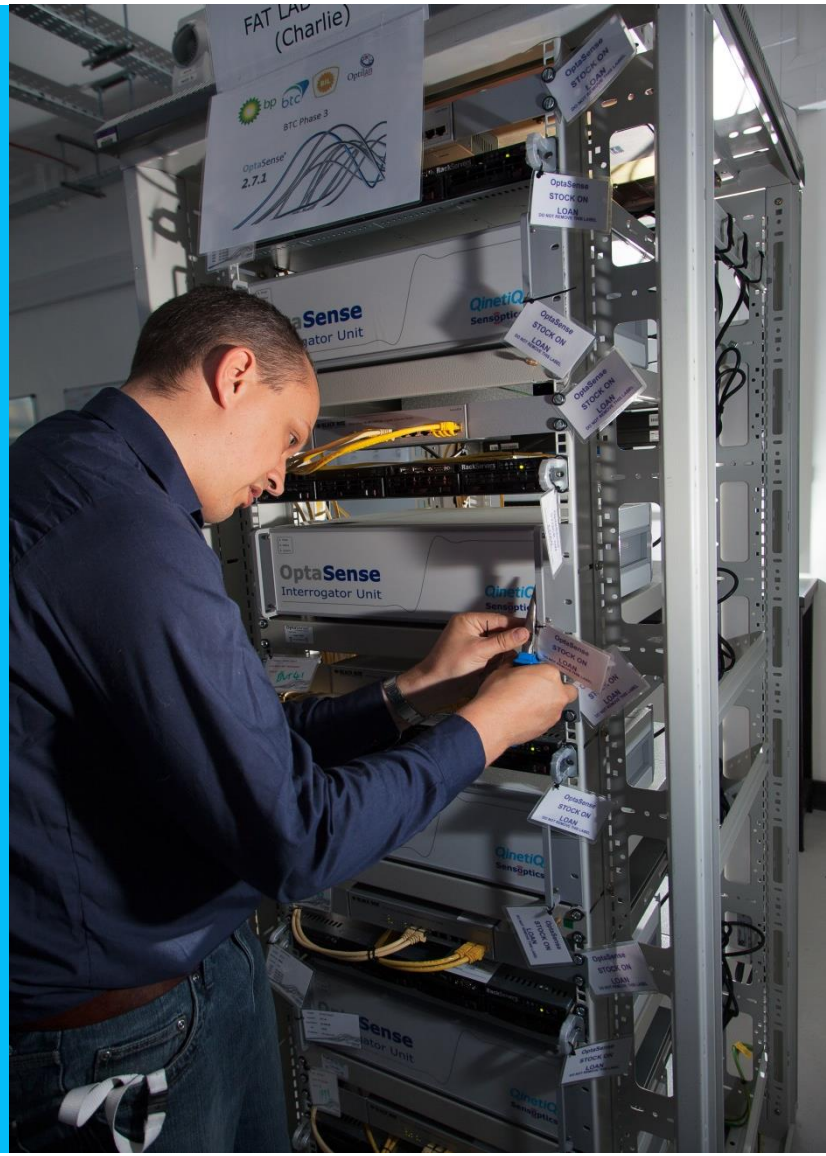
1. Introduction

Introduction

- **Modern electrical equipment, even if tested for electromagnetic compatibility (EMC), still unintentionally injects signals onto the mains electricity supply**
- **EMC testing looks at peak magnitude of these signals**
  - Ensures that they stay below allowed thresholds
  - Not concerned with other characteristics of the signal
- **Inductive loads produce a noticeable impact on the mains signal**
- **Switched mode power supplies will also induce a measureable harmonic signal**
- **Particular makes or items of equipment may produce unique detectable signals**

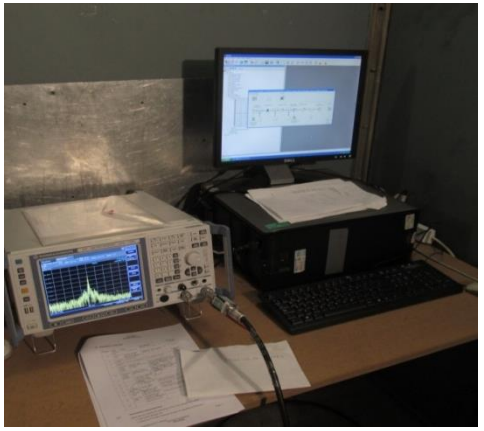
2.1 Experimental Approach

Spectral Signatures



Measuring Spectral Signatures

- **Rohde & Schwarz ESR7 EMI Test Receiver and controller PC**



- **Mains filtered by LISN (Line Impedance Stabilisation Network) device**
  - Recorded signal is unique to the device(s) being tested, with no noise injected from other devices in the building
  - Provides about 100 dB of filtering, and an additional 40 dB is provided by spectral analyser

- **Records in 2 passes:**
  - 9 to 150 kHz at 200 Hz bandwidth
  - 150 kHz to 3 MHz at 9 kHz bandwidth
  - 10 second integration time for each pass

- **EMC test houses typically look at maxima of peaks**
  - We also recorded average spectra over integration time

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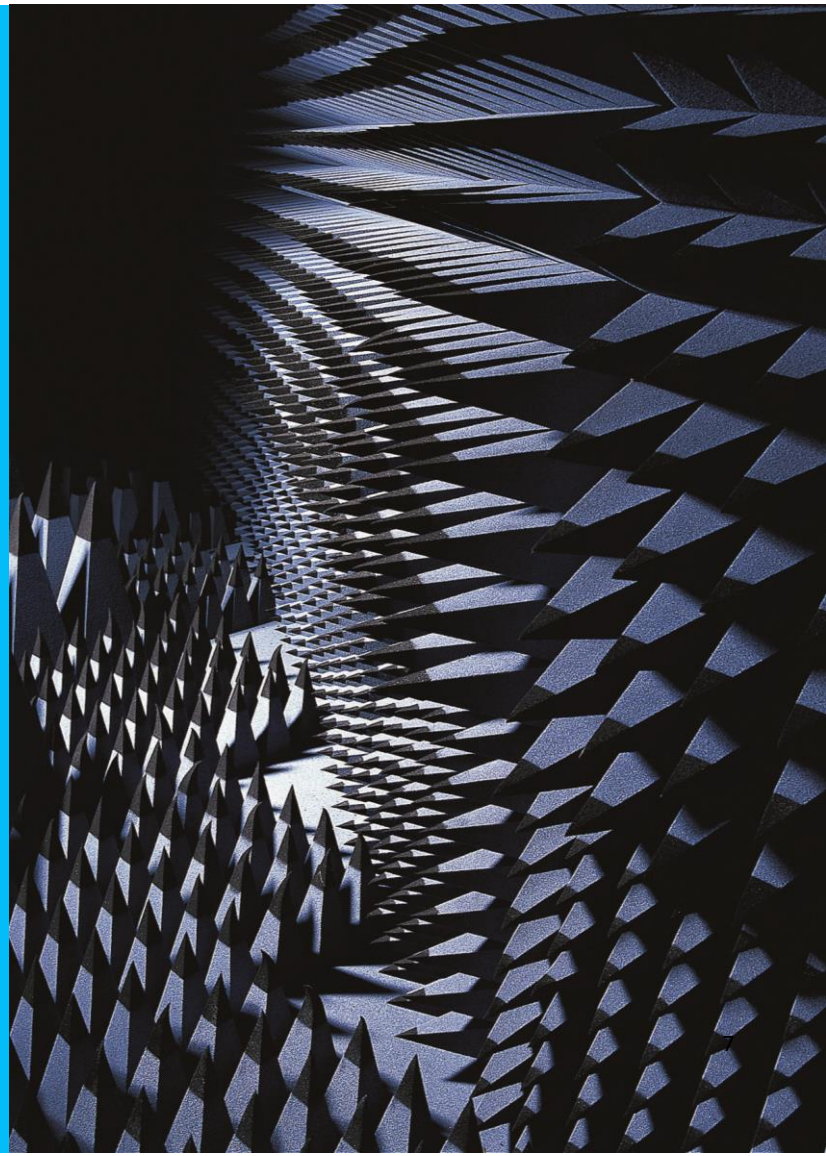
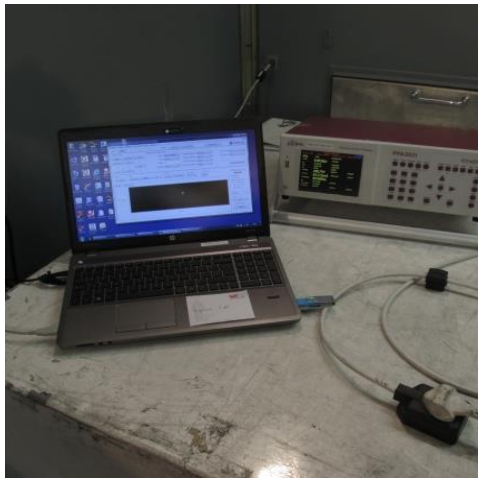
2.2 Experimental Approach

Current Transients



Measuring Current Transients

- **Uses a Newtons 4th Power Analyzer (PPA5531)**
- **Current measured at 20 ms resolution**
  - Occasionally sample rate changes to 30 & 40 ms
- **Transient signals were recorded with and without the LISN**
  - No significant noise was observed in the absence of the LISN



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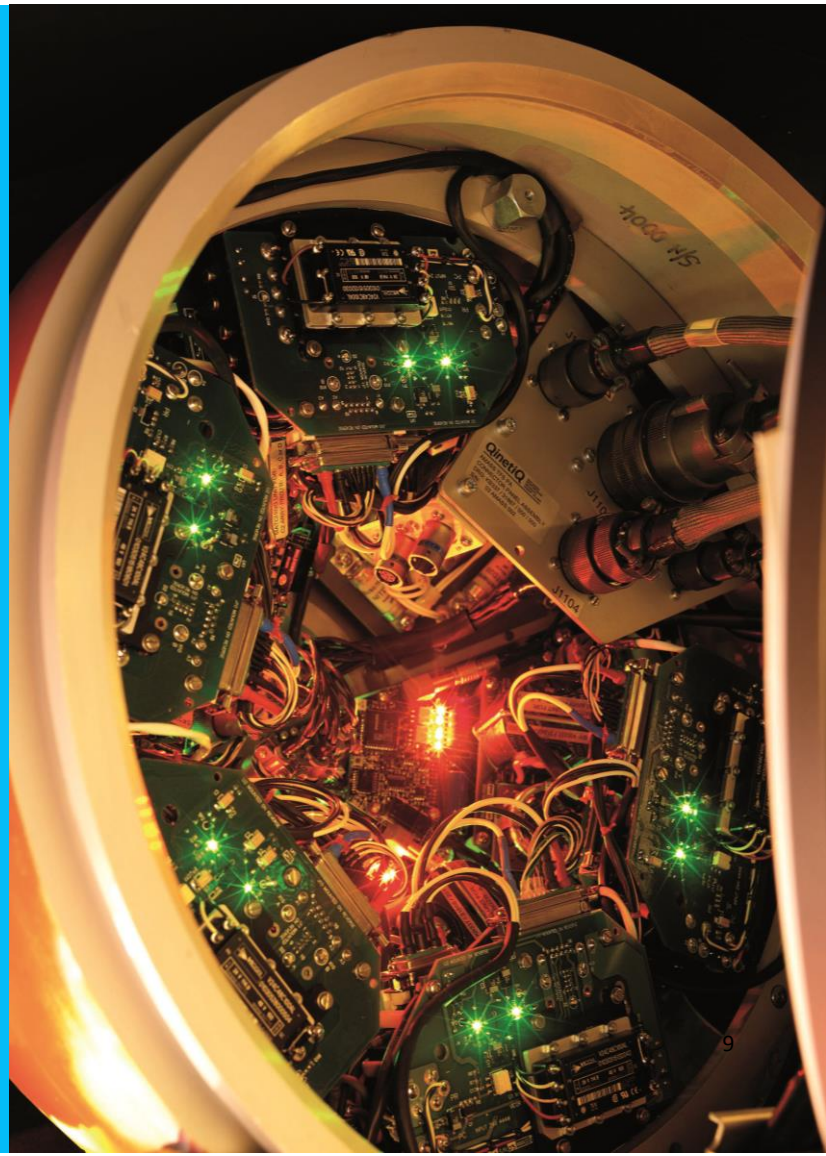
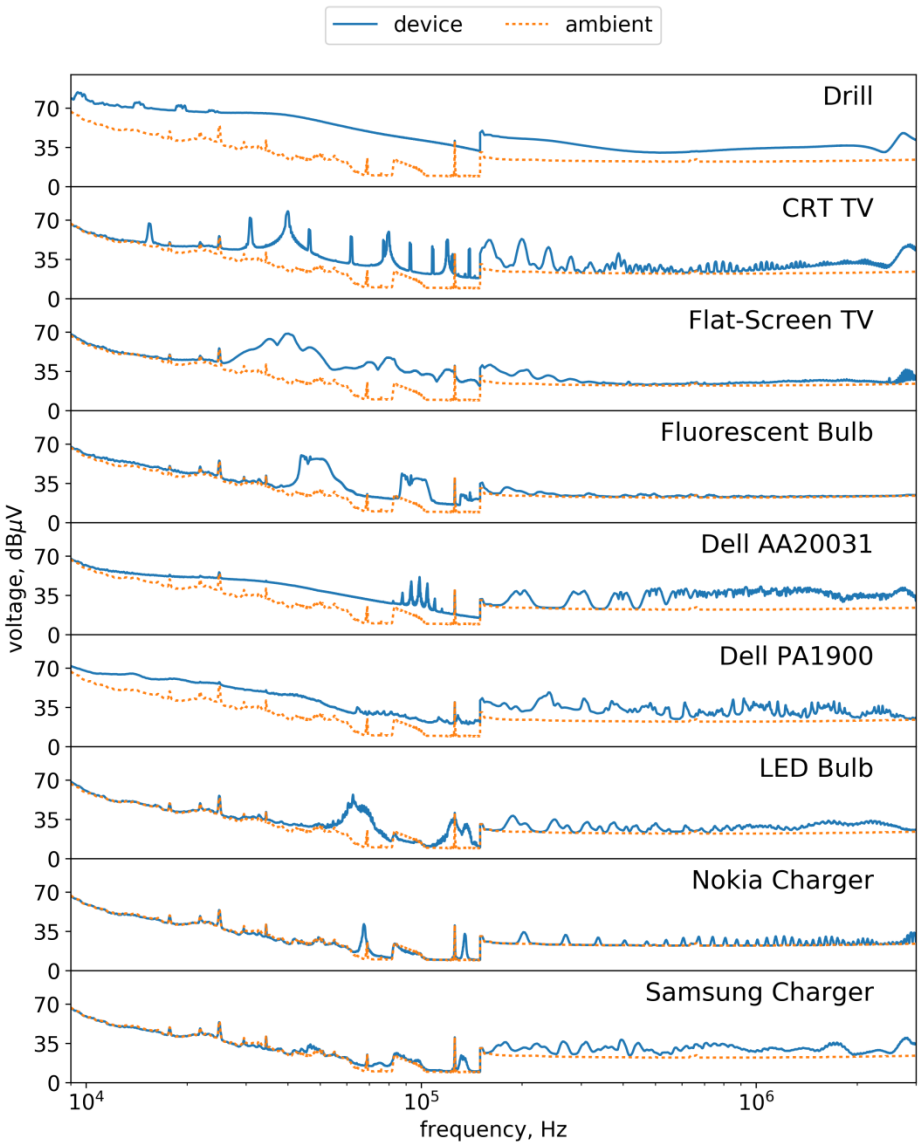
3.1 Results

Device Identification from Spectra

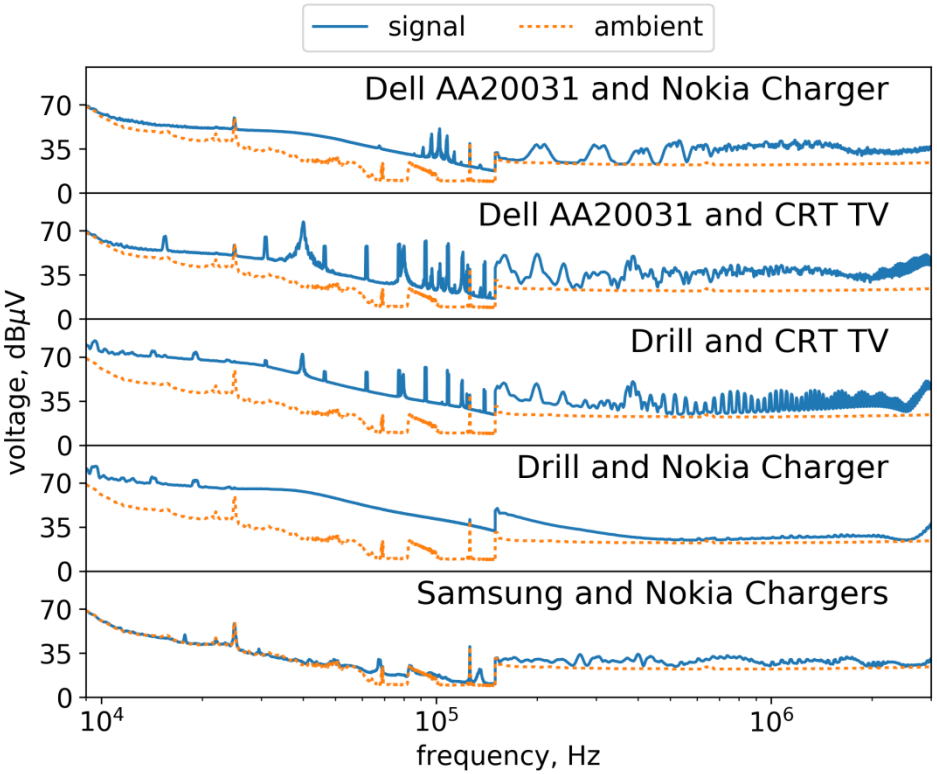


Device Identification from Spectra
Classifying individual Devices

- **Visually distinctive device signatures**
  - I could easily tell which device was being measured from its spectra in the lab
- **Multiple measurements of the same device at different times gave near identical spectra**
  - Signal above 2 MHz less stable
- **Ambient also has clear peaks**
  - Some of these are easily associated with radio broadcasts

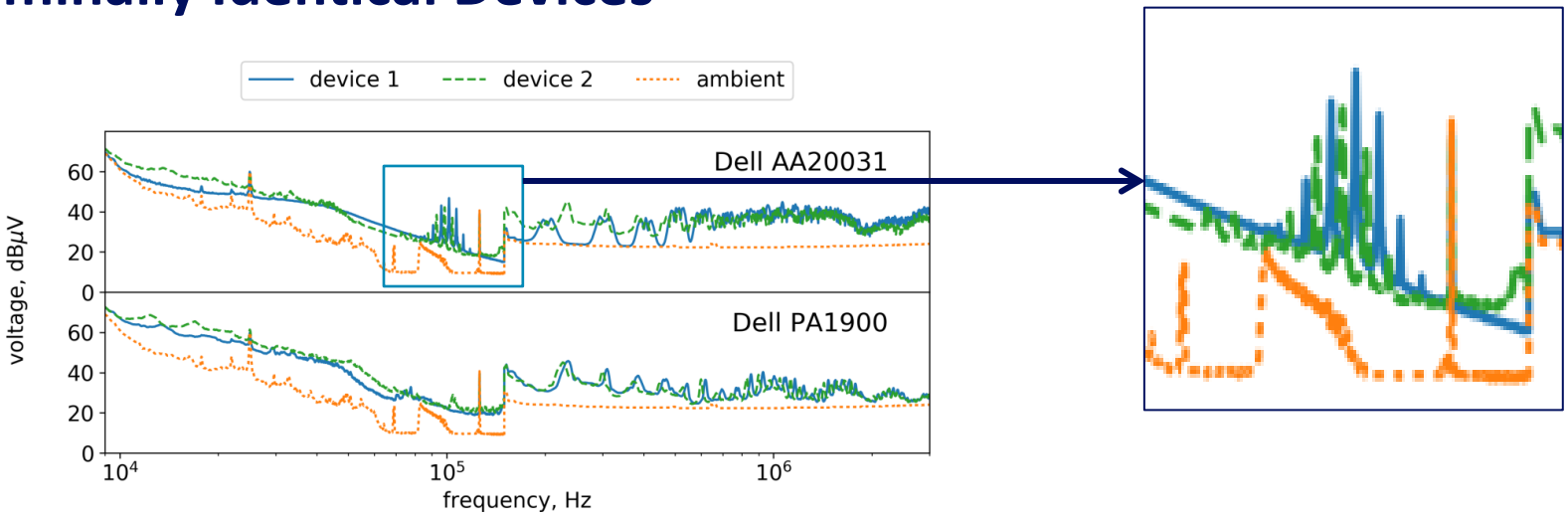


Device Identification from Spectra Identifying Devices in Combination



- When measuring for multiple devices running at the same time there are generally clear features from both
- Exception is when running the drill with a low power device (Nokia phone charger), and the signal from the drill dominates the features from the phone charger

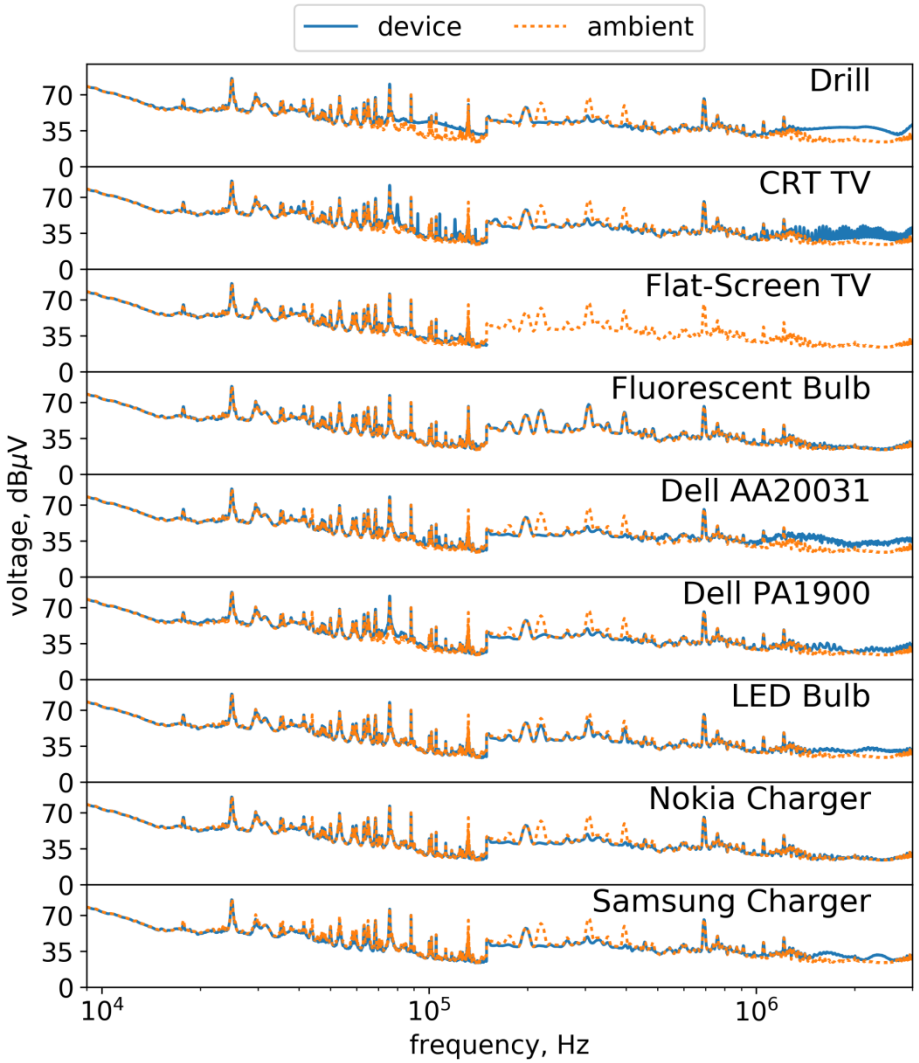
Device Identification from Spectra Nominally Identical Devices



- **The spectra for nominally identical devices are overall similar**
- **There appears to be a constant shift in both axes**
  - Assumed to be due to manufacturing tolerances of various capacitors in the switch mode power supply
- **May be enough to identify a specific instance of a device in the presence of other intelligence information**

Device Identification from Spectra Unfiltered Mains Signal

- **Lack of any filtering of the background mains signal**
  - N.b. this was at an EMC testing facility including multiple test chambers and 2 floors of office equipment
- **Some features of the high powered devices are visible**
- **How much filtering would be needed for measuring these signals in a typical house?**



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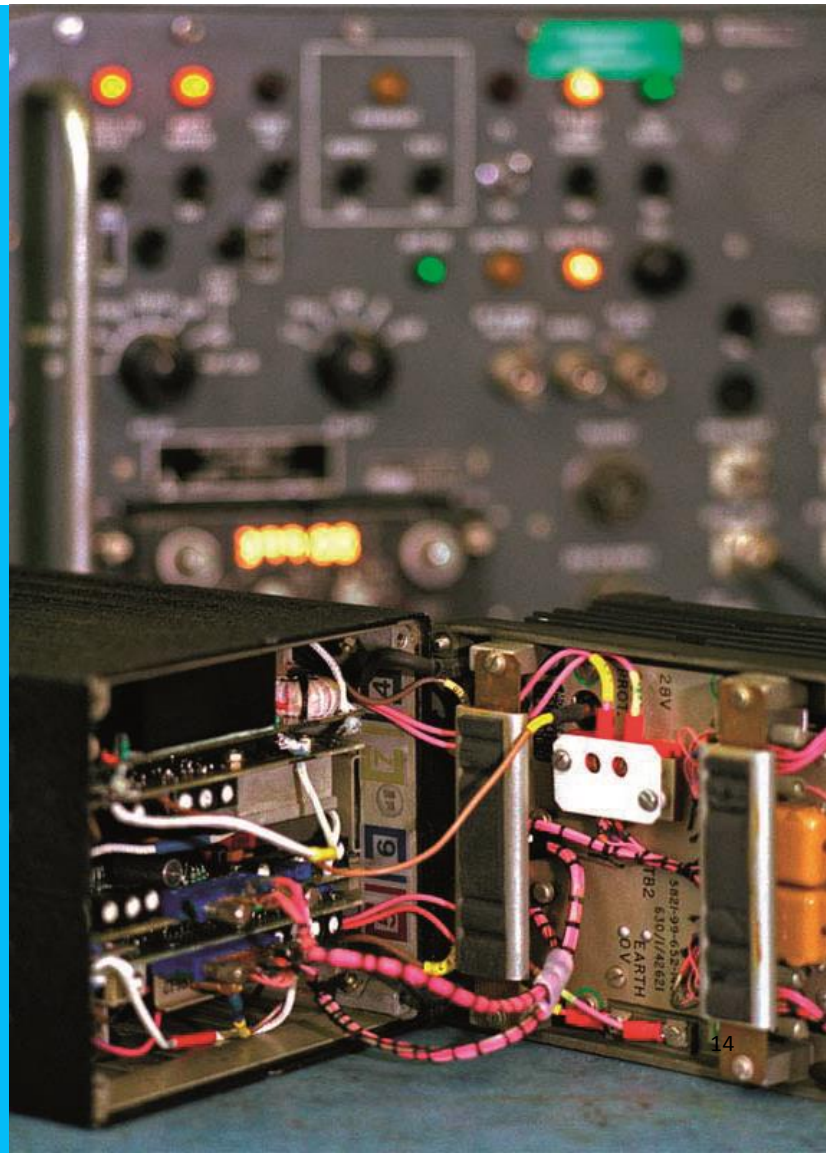
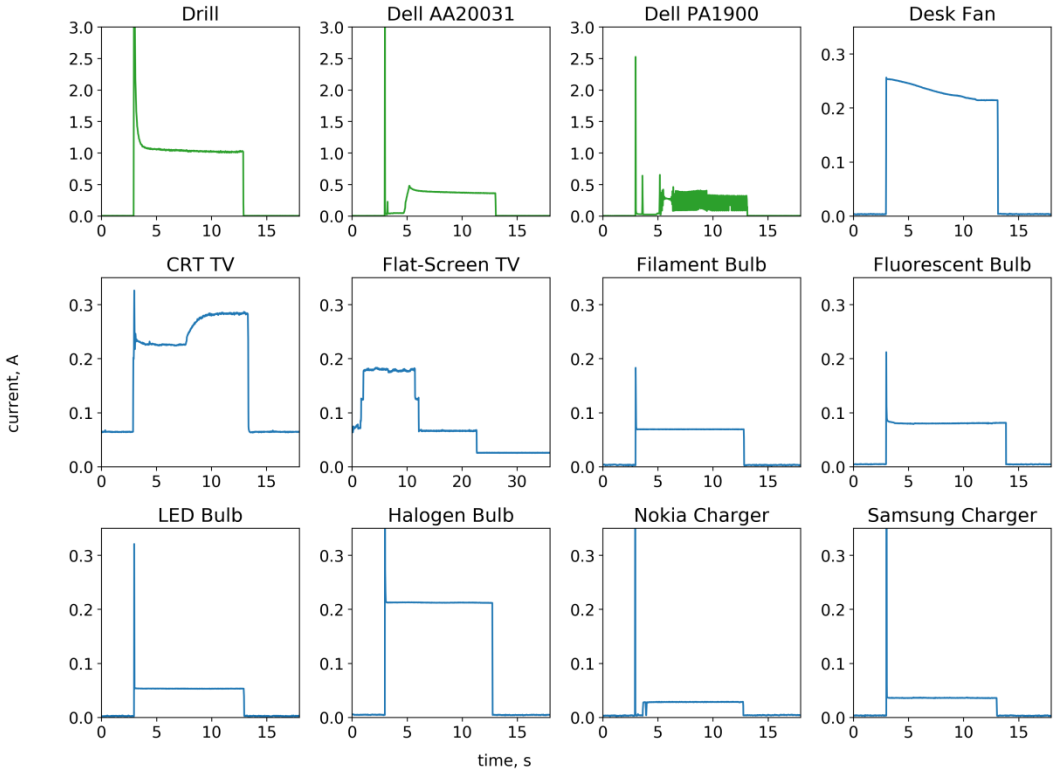
3.2 Results

Device identification from Current Transients



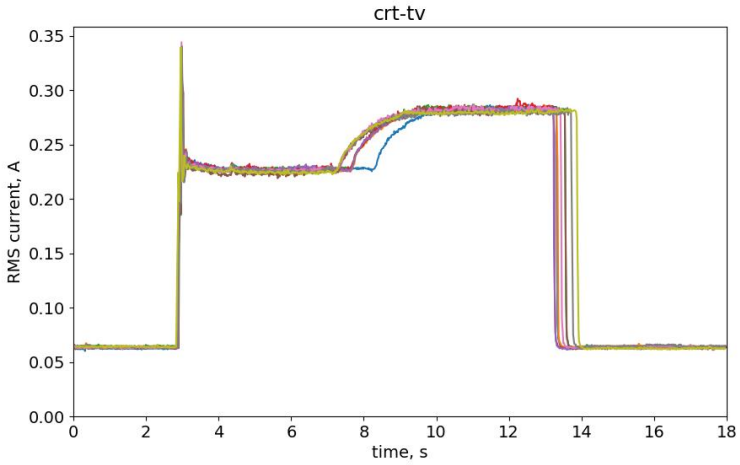
Device Identification from Current Transients

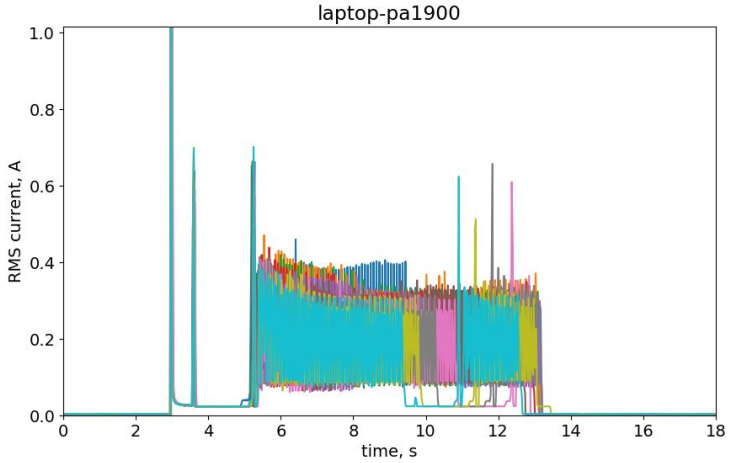


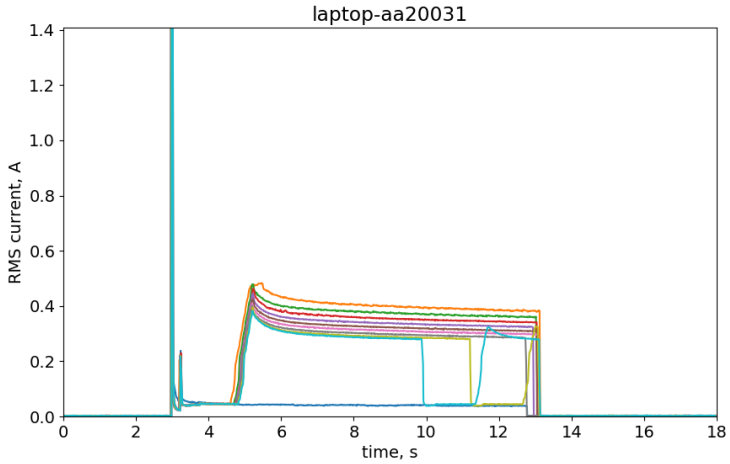
- **In general there is a pattern of in-rush current followed by a steady state**

- **Simple devices have similar transients**
  - More complex devices show more obvious features
  - Both the TV's also draw a measurable standby current

Device Identification from Current Transients







- **Transient features are consistent across different test runs**
- **The PA-1900 laptop power supply has a particularly noisy transient signal**

4. Conclusions

Conclusions

- A range of common household electrical devices can be identified from the power density spectrum of the voltage they superimpose onto the mains
- Some devices are readily identifiable when passively measuring these signals
- Particular instances of the device appear to be separable
- Current transient signals could provide useful pattern of life information

Future Work

- **Apply machine learning techniques to classify devices**
  - Initial experimentation with the raw data and no feature extraction shows promise
  - Expert knowledge could be used to identify important features, and provide manually defined features for higher discrimination capability
- **Typical levels of background noise expected in the field are not known**
  - How much filtering would be required to apply this work in the field?
- **Spectral feature changes over time could be used as another discriminator**
  - Would require short integration times

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