Exploring ENF for Information Forensics

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What is ENF?

- **Electric Network Frequency** – nominally 60Hz in North America and 50Hz mostly elsewhere.
- ENF fluctuates around the nominal value due to changing loads in the power grid.
- ENF can be captured by audio/video recordings due to electromagnetic influences.
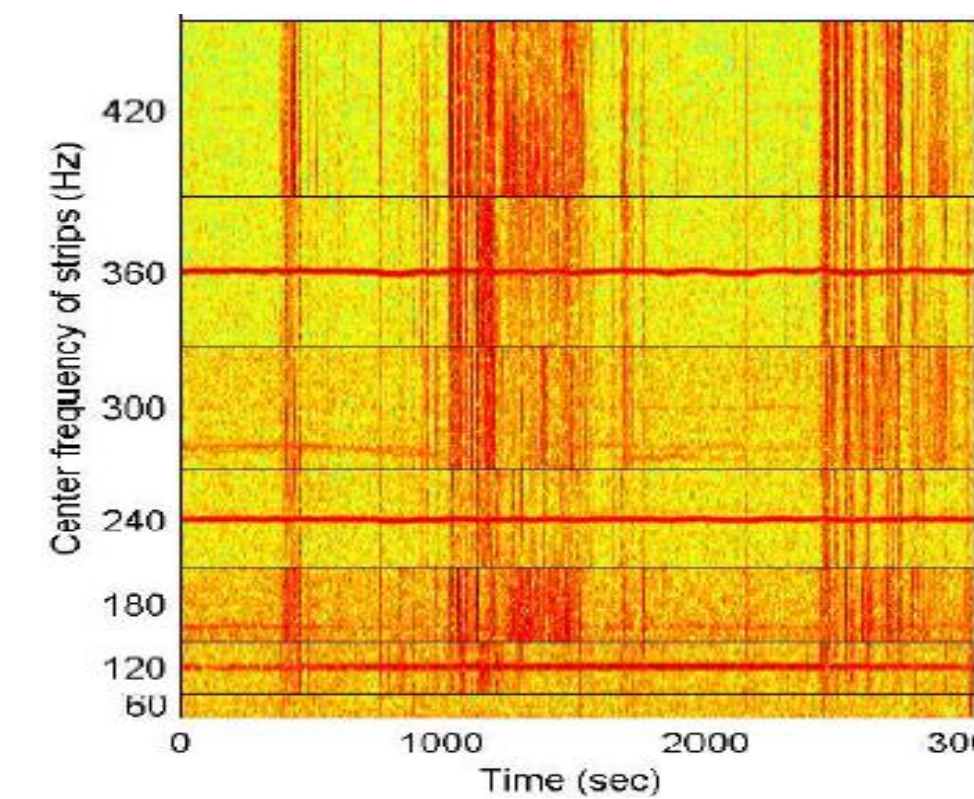
ENF in Video Recordings

- Optical sensors capture lighting fluctuations (Photodiodes and CCD/CMOS).
- Light intensity follows a power law with electric current => ENF in video appears at 100/120Hz.
- Aliasing can occur due to the lower frame-per-sec rate (24-30fps).
- ENF appears at aliased frequencies, depending on the nominal ENF and camera sampling rate.

Sampling by video camera   fs=29.97 Hz   Bandwidth of ENF harmonics spread out than base ENF
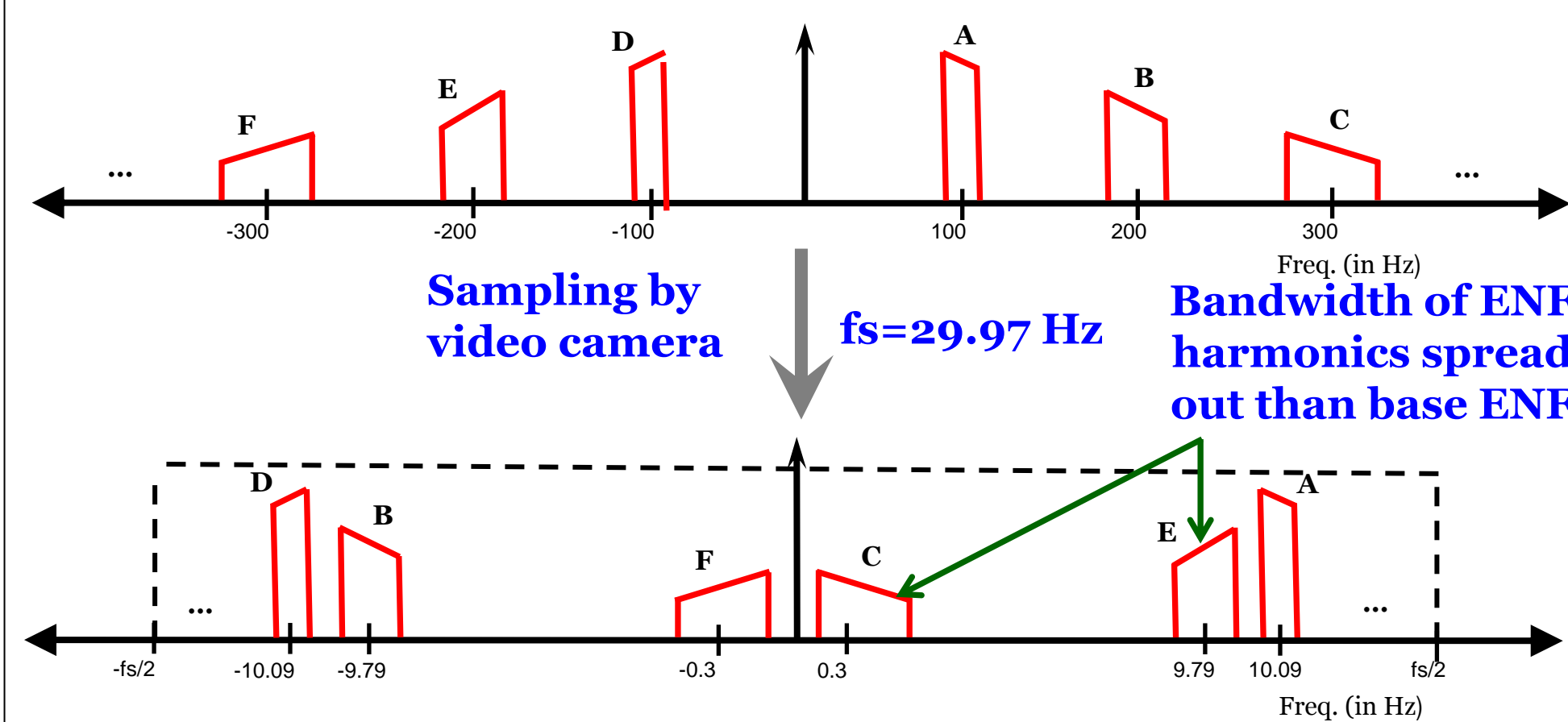
ENF nominal (Hz)	Video frame rate (fps)	Aliased base ENF (Hz)	2nd harmonic aliased (Hz)
60	29.97	0.12	0.24
60	30	0	0
50	29.97	10.09	9.79
50	30	10	10

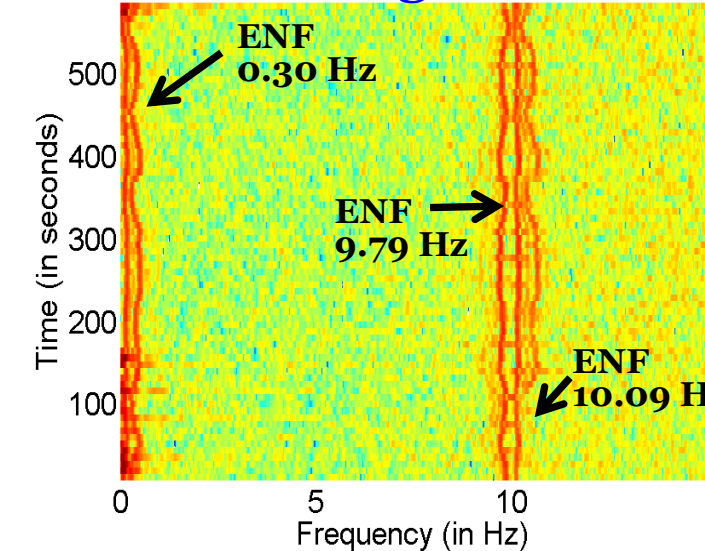## Robust ENF Estimation

- ENF can appear at different harmonics of nominal freq.
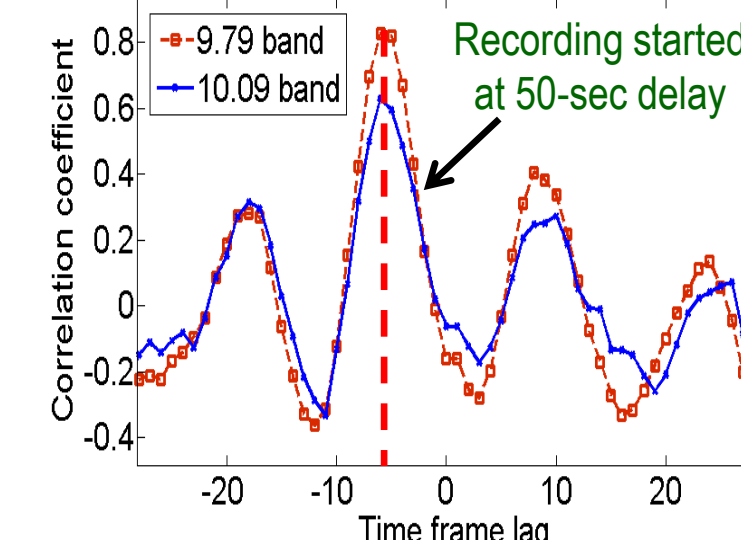- Can strategically combine different spectrogram strips to achieve more accurate estimates of the ENF.

Application 1: Time of Recording

ENF in video signal from China

Experiment in China

Recording started at 50-sec delay

- Compare the ENF fluctuations from reference power-ENF with the media ENF.
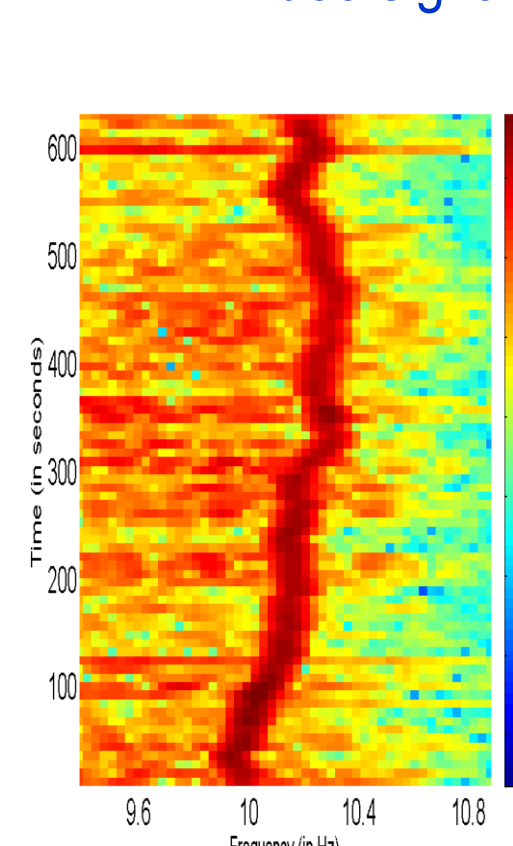- Highest correlation between two sets of ENFs corresponds to recording time.

Application 2: Audio-Visual Binding

- Is the audio track in the video recording original or superimposed later?
- ENF from audio track should match with ENF from visual track.
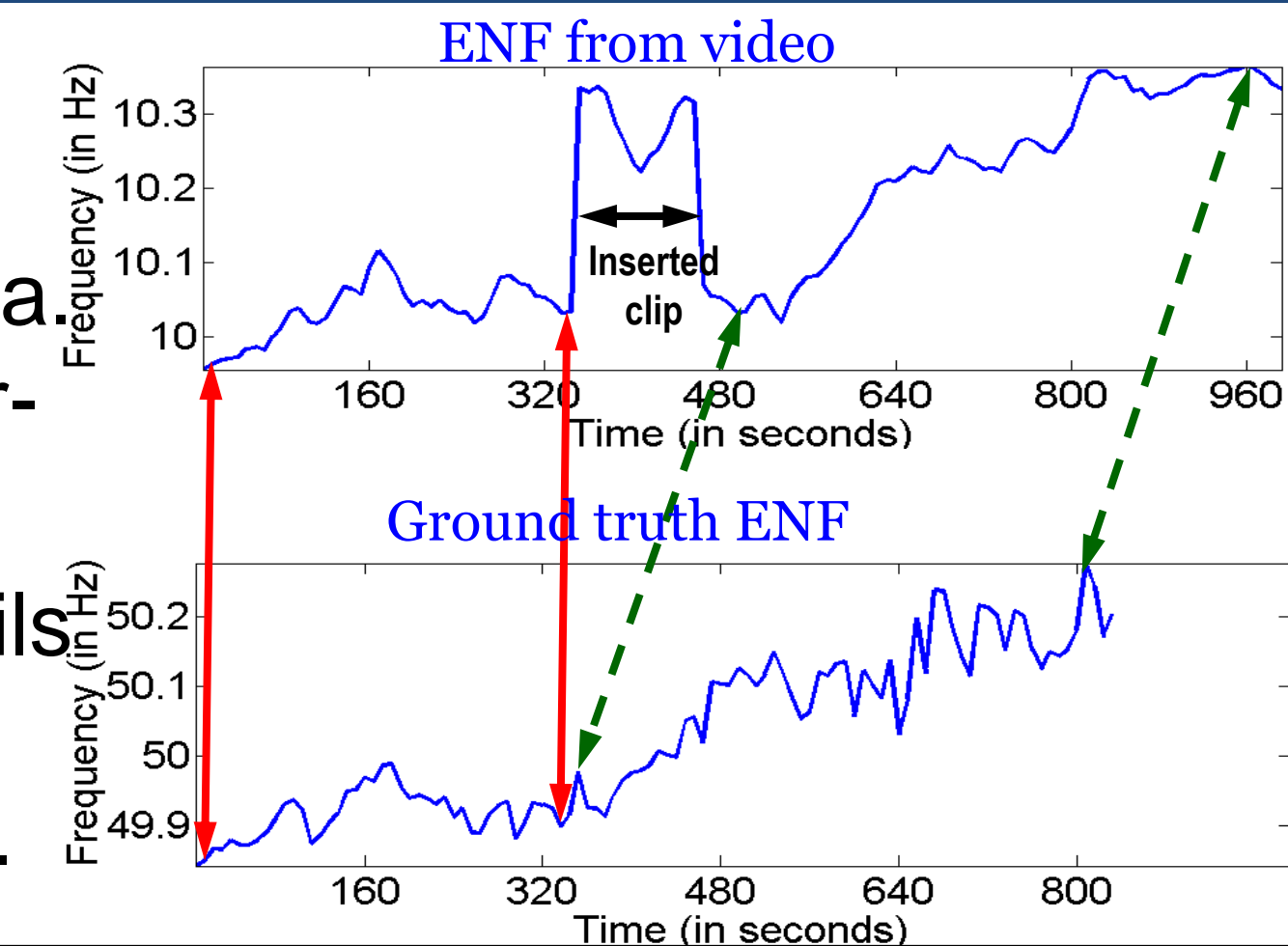 - ❖ Knowledge of reference power-ENF not required.
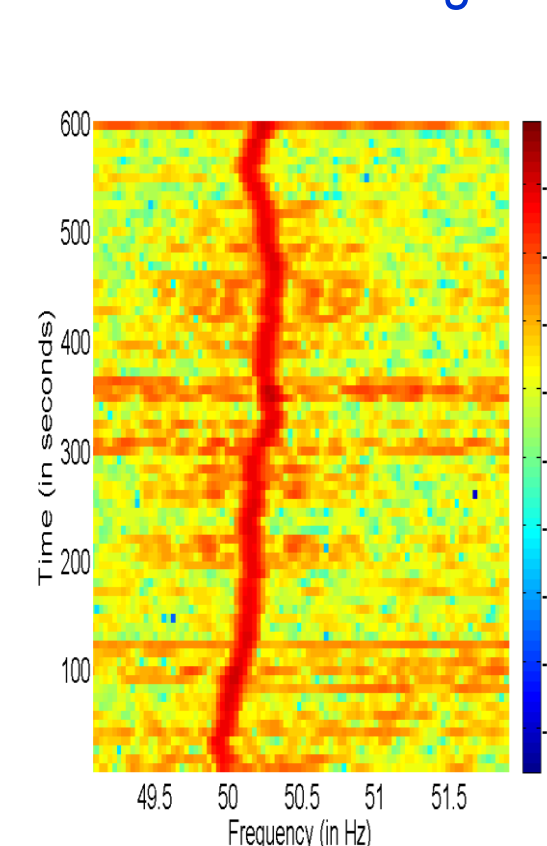
ENF in audio signal   ENF in video signal

## Application 3: Detect Tampering

- Tampering leads to discontinuity in ENF signal from media data.
  - ❖ No reference power-ENF required.
- Obtain forensics details by comparing with reference power-ENF.

ENF from video

Inserted clip

Ground truth ENF

Application 4: Localization

- Main ENF fluctuation trends are similar across a power grid.
- High-pass details of ENF can help locating the origin of a signal within a power grid.
- ENF from different grids can have different statistical properties.
  => Can help estimate the grid-of-origin through machine learning, with no concurrent reference ENF.

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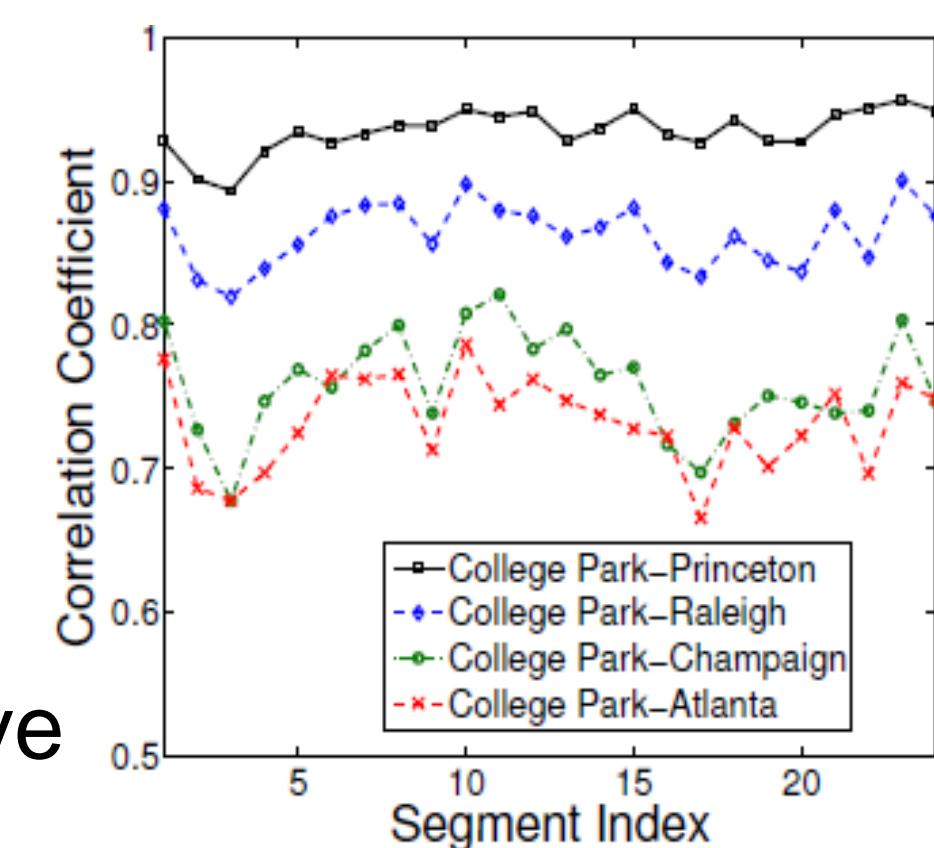
Application 5: Historical Alignment

- Two ENFs can appear in digitized historical recordings: original ENF and ENF at time of digitization.
- Can create a historical ENF "database" and timestamp old recordings for archival and forensic purposes.

Digitized Kennedy White House 1962 recording

Original Recording Turned off