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ENF Background & Motivation

- Electric Network Frequency (ENF): Supply frequency of a power grid. Nominal value: 60 Hz in Americas, 50 Hz most other places.
- The ENF fluctuates around the nominal due to the real-time (im)balance between power consumption and generation.
- Random; Unique in time & grid; Similar in locations of same grid.
- Applications: time & location authentication, tampering detection.
- How to extract? STFT; Subspace methods, e.g., MUSIC, ESPRIT.
- **May** be embedded in multimedia recordings via sensing acoustic vibrations or interfering electromagnetically in sensing circuits.
- Sample of factors affecting the capture of ENF traces in audio recordings made by battery-powered recorders:

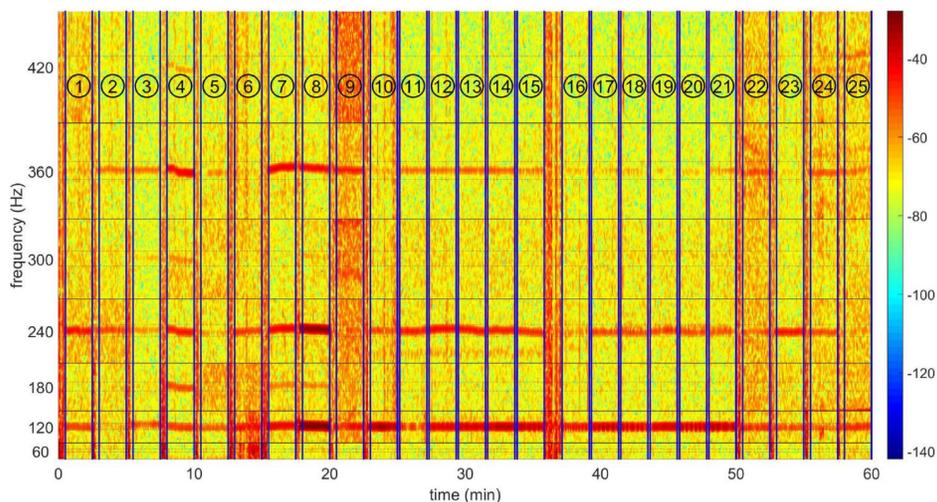
	Factors	Effect
Environmental	Electromagnetic (EM) fields	Promote ENF capture in recordings made by <i>dynamic</i> microphones but not in those made by <i>electret</i> microphones.
	Acoustic mains hum	Promotes ENF capture; sources include fans, power adaptors, lights, and fridges.
	Electric cables in vicinity	Not sufficient for ENF capture.
Device-related	Microphone type	Different types have different reactions to the same sources, e.g., to EM fields.
	Frequency band of recorders	Recorder may be incapable of recording low frequencies, e.g., around 50/60 Hz.
	Recorder internal compression	Strong compression, e.g., Adaptive Multi-Rate, can limit ENF capturing.

Main Contribution & Key Results

- Analyzed impact of i) audio recorders, ii) recording environment and manner on how ENF signals are embedded in recordings.
- May help to understand applicability of ENF-based forensic tools.
- Key results:
 - Moving recorder → ENF quality ↓ due to Doppler effect.
 - Recording environment, location, microphone unit/type → affect ENF traces' strengths and harmonic locations.

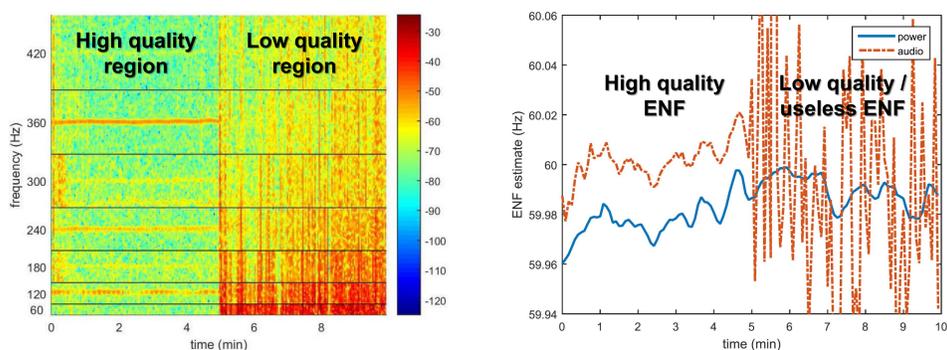
Factor: Recording Environment & Location

- 1-hour recording, 25 locations, ~2 mins per location.
- Takeaway: recording environment and the specific → affect **strengths** and **harmonic locations** of captured ENF traces.

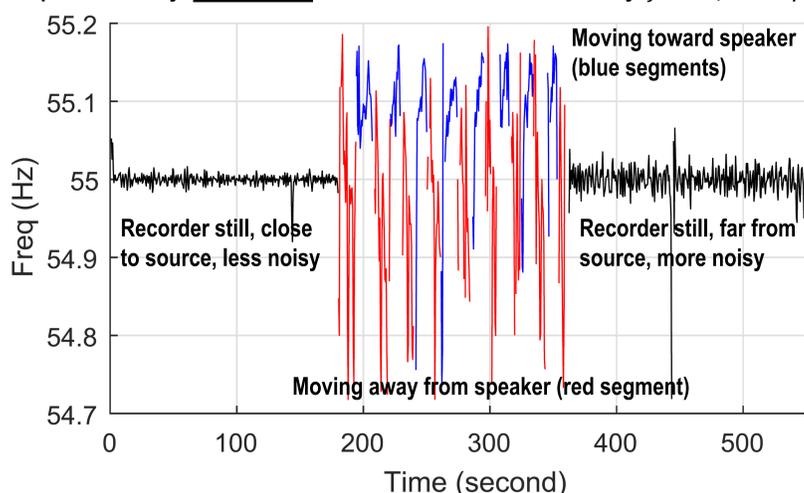


Factor: Moving Audio Recorder

- **Casual Walk:**
 - Olympus recorder stationary in 1st half and moving in 2nd half.
 - Moved around by hand in a random manner while casually walking around in a room.
 - Takeaway: **moving** recorder can affect **quality** of captured ENF.

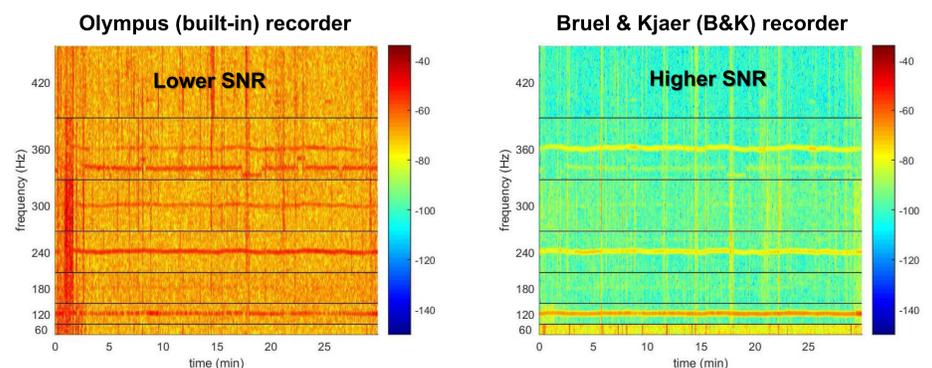


- **Controlled Movement:**
 - Synthetic source: constant frequency at $f_0 = 55$ Hz.
 - A person held the recorder walking at a constant speed toward and away from the source.
 - Takeaway: substantial part of frequency change can be explained by **Doppler** effect characterized by $f = (1 + v_r/c)f_0$.



Factor: Recorder Type

- Takeaway: recording devices can affect **SNR** of ENF traces.



- Takeaway: recording devices can determine the ENF **harmonics** around which the traces can appear.

