Applications of ENF Criterion in Forensic Audio, Video, Computer and Telecommunication Analysis

Catalin GRIGORAS, PhD, Forensic Examiner
forensicav@techemail.com

AES SC-03-12 Working Group on Forensic Audio
T19 Topics in Audio Forensics
May 23rd 2006
Authentication

Audio Tapes

- AES Standards:
- Criterions, articles, books, etc.

Digital Audio (Video) Recordings
Digital audio/video recordings (DR) can be classified on several ways:

- compressed vs non-compressed,
- long-play vs short-play,
- recording medium: recording on digital audio/video tape (DAT, DV) vs memory or hard-disk,
- outdoor vs indoor recording,
- phone vs surveillance, etc.
The proposed criterion for DR authentication:

- Digital Recording
  - With 50/60 Hz frequency (and harmonics)
  - Without 50/60 Hz frequency
The waveform (a), spectrum (b), waterfall (c) and spectrogram (d) of an **IDEAL** 50 Hz signal
The waveform (a), spectrum (b), waterfall (c) and spectrogram (d) of a **REAL** 50 Hz signal
Methods to extract and analyse ENF

1. Time/Frequency domain (spectrograms)

2. Frequency domain (FFT over time windows)

3. Time domain (zero crosses)
ENF examples

1. Electric Network(s)  
   220Vac/50Hz

2. UPS  
   220Vac/50Hz

3. Inverters  
   12Vdc to 220Vac/50Hz
ENF tests across Romania, 1998-2000

Bucharest vs different locations: Brasov, Cluj-Napoca, Constanta, Craiova, Iasi, Oradea, Rm Valcea, Timisoara s.a.
ENF example test across Romania, 1998-2000:
Cluj-Napoca, Iasi, **Bucharest**
ENF example tests across Europe, 2000-2006

Bucharest vs:
- Athens, Greece
- Krakow, Poland (2)
- Hague, Netherlands
- Madrid, Spain (3)
- Rome, Milan, Italy
- Paris, France
- Budapest, Hungary
and others.
ENF example tests across Europe, 2000-2006

2005-06-13, 786 Km

Bucharest, Romania

Kracow, Poland
ENF example tests across Europe, 2000-2006

2005-07-05, 734 Km

Bucharest, Romania

Athens, Greece
ENF example tests across Europe, 2000-2006

2006-01-05, 1133 Km

Bucharest, Romania

Rome, Italy
ENF example tests across Europe, 2000-2006

2006-01-23, 2476 Km

Bucharest, Romania

Madrid, Spain
ENF example test, 2005-12-01, 10:00 - 14:00 GMT

Bucharest, Romania

Rm Valcea, Romania

Hague, Netherlands

Madrid, Spain
ENF example test, 2005-12-01, 10:00 - 14:00 GMT
ENF analysis during one week

1:00  2:00  3:00  4:00  5:00  6:00  7:00 AM
Conclusion

- no periodicity was found in the short term variation of ENF (samples longer than 1 minute),

- there is a *random* fluctuation of ENF around 50 Hz,

- the presence of some valleys and peaks *around* specific moments of a day can be predicted, but their values and shapes not,

- the entire EN carries *almost* the same frequency,

- DC removal and 50 Hz Band Pass Filters are requested in order to minimize analysis errors.
Case Work Audio Example 1

Evidence: audio file on a CD, WAV PCM format, mono, 16 bit, 8 KHz, containing a three hours conversation
Case Work Audio Example 1

date and time claimed by B (LEA informer)

“A” reference / date and time claimed by A
Examiner’s Opinion:

- The digital audio recording I analyzed is not authentic and doesn’t represent a duplicate of an authentic recording.

- The original recording has been created on DD/MM/YYYY and then several segments have been digital deleted. The evidence I analyzed represents the results of these technical interventions on original or duplicate material.
Case Work Video Example

The expert opinion was:

the questioned digital video recording had been digitized on the claimed date.
TIME DOMAIN ANALYSIS

Figure 11. The result of a link between two different signals containing ENF
TIME DOMAIN ANALYSIS

Figure 10. Three consecutive zero-crosses corresponding to two different semi-periods $D_{6,7}$ and $D_{7,8}$
DIGITAL AUDIO RECORDINGS ANALYSIS
The Electric Network Frequency Criterion

TIME DOMAIN ANALYSIS

Rec.1
(10 sec)
DIGITAL AUDIO RECORDINGS ANALYSIS
The Electric Network Frequency Criterion

TIME DOMAIN ANALYSIS

Rec.2
(10 sec)
DIGITAL AUDIO RECORDINGS ANALYSIS
The Electric Network Frequency Criterion

TIME DOMAIN ANALYSIS

Rec.3
(10 sec)
DIGITAL AUDIO RECORDINGS ANALYSIS
The Electric Network Frequency Criterion

TIME DOMAIN ANALYSIS

ENF Analysis

Rec.1

Rec.2

Rec.3
ENF Database

The space necessary to save the ENF reference as WAV PCM, mono, 16 bit, 120 Hz

<table>
<thead>
<tr>
<th>Days</th>
<th>Seconds</th>
<th>Capacity [MB]</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>86400</td>
<td>20.232</td>
</tr>
<tr>
<td>7</td>
<td>604800</td>
<td>141.624</td>
</tr>
<tr>
<td>31</td>
<td>2678400</td>
<td>627.192</td>
</tr>
</tbody>
</table>
DIGITAL AUDIO RECORDINGS ANALYSIS
The Electric Network Frequency Criterion

Reference ENF database

Digital audio evidence (to analyze)

Downsample 120 Hz and band-pass filter 49-51 Hz

ENF shape

Compare ENF shape of the evidence with the ENF database

Decision

The digital evidence has been recorded on the claimed date and time

The digital evidence has not been recorded on the claimed date and time

Try to locate the real date and time when the evidence has been recorded
APPLICABILITY OF THE ENF CRITERION

Sony DAT Walkman vs Digital Video Recording
APPLICABILITY OF THE ENF CRITERION

CONCLUSIONS

- The ENF Criterion and Methodology can be used to verify and/or identify the date/moments when a digital recording was created;

- I recommend to use the ENF Criterion in conjunction with other techniques and methods (e.g. classical audio/video authentication methods, impulse response of a room, IT investigations etc.).
Many thanks to:

- Peter French, J. P. French Associates, UK,
- Alan Cooper, Metropolitan Police Service, Department of Information, London, UK;
- Andrea Paoloni, Fondazione Ugo Bordoni, Rome, Italy;
- Jos Bouten, Netherlands Forensic Institute, Ministry of Justice;
- Joaquin Gonzalez Rodriguez and Francisco Javier Simon del Monte, Universidad Autonoma de Madrid, Spain;
- Jose Juan Molina, Guardia Civil, Madrid, Spain;
- Carlos Delgado, Comisaria General de Policia Cientifica, Madrid, Spain;
- John D. Makris, Hellenic Police, Forensic Sciences Division, Athens, Greece;
- Mateusz Kajstura, Institute of Forensic Research, Cracow, Poland

and many other friends of mine for their suggestions, comments and/or entering the inter-laboratory tests of ENF Criterion.

Thank you too and... keep in touch!