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Working Group for Forensic Speech & Audio Analysis

FORENSIC SPEECH AND AUDIO ANALYSIS WORKING GROUP BEST PRACTICE GUIDELINES FOR ENF ANALYSIS IN FORENSIC AUTHENTICATION OF DIGITAL EVIDENCE			
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The purpose of this document is to provide the Forensic Speech and Audio Analysis Working Group (FSAAWG) members, guidelines for ENF analysis in the area of forensic authentication of digital audio and audio/video recordings.

ENF analysis is one of a number of techniques that may be applied to a digital audio/video recording in order to assist in determining its authenticity.

REVISION HISTORY
Version 1 of this document was edited and concluded by Catalin GRIGORAS, Ph.D., Alan COOPER, Ph.D. and Marcin MICHAŁEK, Ph.D.
It was agreed by the ENFSI FSAAWG Steering Committee on June 2nd, 2009

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1 AIMS

1.1 To provide guidance to the Forensic Speech and Audio Analysis Working Group (FSAAWG) members and other forensic laboratories relating to:

a) The use of the ENF criterion in forensic authentication examinations of digital audio and audio/video recordings, in order to successfully present their reports or testimonies to requesting parties and in a court of law;

b) Establishing and maintaining good working practices in the field of forensic audio and ENF analysis that will assist in delivering reliable results, maximise the quality of information obtained and produce robust evidence;

c) The encouragement of a robust and consistent ENF methodology with the benefit of producing results that are comparable, thus facilitating interchange of ENF data between individual laboratories.

1.2 To promote ENF analysis as a major part of the digital audio and audio/video recording authentication process.

2 SCOPE

2.1 The document is not intended to be a training manual and does not prescribe or discuss any specific bespoke or commercial software or hardware that may be used for ENF analysis.

The document is limited to specific aspects of forensic audio analysis that encompass the ENF criterion. General laboratory and forensic practices, documentation, training, proficiency testing, accommodation, evidence presentation, health and safety etc, are not covered unless there are specific requirements to be taken into account when conducting ENF examination.

2.2 The following are typical casework requirements / deliverables for ENF analysis:
a) Detect the presence or absence of ENF fundamentals i.e. 50/60 Hz and their harmonics and sub-harmonics (see 5.1.1).
b) Detect the number and relative amplitudes of ENF components.
c) Detect the type of ENF components (mains, uninterruptible power supplies, etc.).
d) Detect the grid(s) that generated the ENF components (eg.: continental Europe, UK, USA, etc.).
e) Identify the date and time of an ENF component.
f) Verify the date and time of an ENF component.
g) Verify the likelihood that the digital recorder under examination can pick up ENF components in different environments, with or without battery power.

3 QUALITY ASSURANCE

3.1 Introduction

3.1.1 The ENFSI Board encourages implementation of best practice guidelines/manuals and quality assurance standards.

3.2 Definitions

The following definitions have been used throughout this document:
Audio – Sound that is capable of being heard.
Client –May include, investigating police officers, prosecuting authorities and the courts.
ENF – Electric Network Frequency.
FFT – Fast Fourier Transform.
Proficiency Test - Inter-laboratory comparison designed and operated to assure laboratory performance in specified areas of testing, measurement or calibration. Requires a known expected outcome.
Quality Assurance - All the planned and systematic activities implemented within the Quality Management System, and demonstrated as needed, to provide adequate confidence that an entity will fulfil the requirements for quality.
Validation - Confirmation by examination and provision of objective evidence that the particular requirement for a specific intended use are fulfilled.

3.3 Requirements for a 'Technical Specialist' dealing with ENF analysis

3.3.1 Due to variations in the size of different laboratories and variability within different laboratory systems, absolute standardization cannot be achieved. Individuals may be responsible for more than one area of expertise within his/her lab. A person whose specialisms may include ENF analysis could have a title such as Forensic Scientist, Forensic Engineer, Researcher, Technical Officer etc; in this document the generic title Technical Specialist will be used. The key skills recognised for a Technical Specialist whose specialisms incorporate ENF analysis will include:

> a) Has achieved appropriate levels of technical competency for audio and ENF analysis.
> b) Is familiar with current evidential practices regarding evidence handling procedures, documentation, exhibit labelling etc.

c) Is able to write reports and statements containing methodologies, findings and conclusions on audio and ENF analysis.
d) Can reliably maintain all evidential records and documentation.
e) Can provide both factual and opinion based testimony in court.

This person will have authority to conduct audio and ENF casework analysis, with responsibility for the overall technical quality.

3.3.2 In the event that no personnel within the laboratory are competent to be the Technical Specialist on a specific case or specific technical aspects relating to ENF, arrangements should be made for a qualified and competent consultant/contractor to be utilised from outside the laboratory to perform these duties. The external consultant/contractor should have the same technical authority and responsibility for ENF analysis as an in-house Technical Specialist.

3.4 Validation

3.4.1 The laboratory should only use properly evaluated techniques and procedures for the forensic examination of digital audio recordings including ENF analysis.

3.4.2 Validation requires as a minimum that:

a) The critical aspects of the ENF analysis have been identified and the limitations defined.
b) The methods, equipment and software used have been demonstrated to be fit for ENF analysis, as described in section 4 and section 5.
c) The ENF analysis is fully documented.
d) The ENF results obtained are reliable and reproducible. Any limitations of the results must be clearly indicated in the analysis notes and final report/statement.
e) The ENF technique or procedure has been subjected to independent assessment and, where novel, peer review.
f) The individuals using the ENF technique or procedure have demonstrated that they are competent to do so.

3.4.3 Where the ENF techniques or procedures have been validated elsewhere, the laboratory should demonstrate that it can achieve the same quality of results.

3.4.4 Software testing processes should involve the identification of ENF key functions and formulating a test procedure to ensure that it fully meets these requirements. All software testing should be fully documented.

3.5 Software (Forensic Analysis)

3.5.1 There are commercial signal analysis software packages that are capable of analysing ENF signals. In addition, individual forensic laboratories and scientists may have produced bespoke ENF analysis software that is not commercially available. Both types have been discussed in the scientific literature (section 7). For software tools that can be configured in a variety of ways and/or uses a number of different parameters, it is particularly important to document the set-up and individual parameter values in order to produce a process that can be repeated (e.g. sampling frequency, FFT size, overlap, span, window type, zero padding factor etc).

3.5.2 Suitable backup procedures for ENF data originating from ENF database software must be maintained.

3.5.3 Software used for ENF analysis can be broadly divided into two categories: Manual Analysis Software and Automated Analysis Software.

3.5.3.1 Manual Analysis Software
Manual analysis software allows a Technical Specialist to check the presence or absence of ENF, determine the type of ENF and verify the date and time of a questioned recording using a one-to-one comparison between the questioned ENF data and an ENF database.

3.5.3.2 Automated Analysis Software
To establish or verify the date and time of a recordings production. Automated Analysis Software allows a Technical Specialist to perform an automated comparison between the questioned ENF data and an ENF database.

3.5.4 For all other types of software tools, in order to ascertain both suitability and reliability for each application, their use should be defined and a regime of testing established.

3.6 Equipment/environment

3.6.1 Equipment and working environment for audio and ENF analysis should be designed/laid out with the following considerations:

a) Equipment housings, equipment, cabling etc should be properly screened.
b) Equipment connected together for recording and analysis purposes should be done so in a way that avoids earth loops that would give rise to induced local ENF.
c) Safeguards should be in place to avoid radio frequency interference (RFI) from mobile phones etc which could bleed into recording and analysis equipment.

3.6.2 Calibration/measurement should be routinely carried out on the database clock source used in the digitisation process of the ENF. A correction factor to the database ENF estimates would need to be applied for data that had been collated using a soundcard that had a bias in its sampling frequency. Ideally, to reduce bias to negligible levels a high quality external clock reference should be used in conjunction with a professional soundcard.

3.6.3 In order to maintain reliable date and time accuracy, a computer system used to record ENF data directly from the electrical network may be synchronised to an external date/time source.

4 CASE ASSESSMENT

4.1 Introduction

4.1.1 Before starting work on any case the Technical Specialist should carry out an assessment of all the information available and the items provided for examination in light of the agreed client requirements. From this assessment the Technical Specialist should clarify or re-define the requirements with the client if necessary. Client requirements should be documented and referred to in the final report and or witness statement.

4.1.2 Where interpretation is required the Technical Specialist should consider to what extent the proposition/s put forward by the client can be tested and should assess whether ENF could be present due to other circumstances e.g. copying.

4.1.3 The Technical Specialist should consider what evidence is likely to be found if each proposition was correct and should make an assessment of the potential evidential value of the anticipated findings (e.g. consideration of the types of data or files involved, the potential for other ENF contamination etc).

4.2 Information requirements

4.2.1 In order to be able to determine the cause of anomalies found during a recording such as discontinuities or establish the likelihood of accidental ENF contamination, comprehensive details are required about the recorder and recordings alleged history. The following information may be material in establishing the authenticity/integrity of the recorded evidence:

a) Is the recording original i.e. is the submitted exhibit the first media on which the recording was made; not a copy, clone or the result of a file transfer of any description?

b) At the time of the recording's production was the recorder battery powered or connected to the electrical network (mains)?

c) Is the tape/disc/memory card/solid state device new or has it been used before?

d) How has the recorder been used? Examples: *built in microphone, external microphone, connection to radio receiver, direct or indirect connection to a telephone line or mobile phone etc.*

e) What were the recorder's settings? Examples: high (HQ) / medium (MQ) / low (LQ) quality, long-play (LP) / short-play (SP), sound filter on/off, voice operated recording facility on/off, etc.

f) How was the recording equipment switched on at the start and off at the end of each recording? Was the recorder switched on or off during the recording, if so by what means? Examples: *stop and record buttons, remote switch, pause button, mains power switch or by any other method.*

g) Has the recording been played back, transcribed or copied? If so, what equipment and methodologies have been used?

h) Dates and times of any events relating to the recording's history.

i) The person(s) responsible for, and the sequence and timing of events in, the questioned recording.

j) Have any modifications or repairs been carried out before or after the questioned recording has been produced?

4.3 The Chance of Detection and Recovery of ENF

4.3.1 The opportunity for the detection and recovery of ENF data will depend on many factors, including:

a) The type of power supply used by the recorder during the capture of events.

b) The technical specifications of the recorder, including:

b1) Format of digital evidence (e.g. WAV, AVI, MPEG, etc).

b2) Compression algorithms (e.g. MP3, WMA, DSS, DMR etc).

c) ENF signal to noise ratio.

d) Location of recorder.
e) Age and condition of the digital media submitted.
f) The level of any security features applied by the user.

4.4 The Potential Significance of ENF

4.4.1 Given favourable conditions it is possible to recover ENF and provide details about:
a) The number of ENF components.
b) The ENF type (mains, uninterruptible power supplies, etc).
c) The geographical area that the ENF corresponds to (e.g. continental Europe).
d) The date and time the ENF corresponds to.
e) Original or copied status of the recording.
f) The continuity of the recording (stopped/started, edited etc).

5 LABORATORY EXAMINATION

In addition to any specific ENF analysis and protocols described, normal evidence handling procedures must be complied with. Any anti-contamination precautions or requirements of the particular case (e.g. presence of ENF generators) must be considered before any examination proceeds and the appropriate precautions necessary are identified and implemented.

As applicable to the requirements of all forensic analysis work, the analysis and recovery of ENF data should be fully documented at all stages. The equipment and software settings (e.g. FFT size, overlap etc) must be recorded in the contemporaneous notes made during the analysis and stated in the written report. Any limitations of the processes applied or in the results obtained should be clearly documented.

5.1 Analysis Protocols

The ENF analysis that is carried out in individual cases should be determined by the requirements of the case and will depend on the value of any other particularities (e.g. recording length) or evidence which may be available. A systematic approach should always be adopted to ensure consistency of delivered services.

5.1.1 Recommended signal conditioning processes prior to the ENF analysis:
a) To assist subsequent signal processing, remove any DC component on the signal.
b) To remove signals outside of the required ENF analysis bandwidth, a band pass filter must be applied to the questioned recording which is set somewhere between +/- 0.5 Hz to +/- 1 Hz either side of the ENF centre frequency (band passing will also automatically remove any DC component on the signal).
c) When analysing the ENF component, (either the fundamental or a harmonic of the fundamental) use the following as a ‘rule of thumb’ relating to the choice of downsampling frequency: Two times the ENF centre frequency of interest plus 20% (ENF x 2.4).
So for example an ENF of 50Hz would be decimated to 120 Hz and an ENF of 60 Hz would be decimated to 144 Hz.

5.1.2 Changes in ENF frequency may be small (typically +/- 50 mHz) requiring the implimentation of a relatively high resolution spectral analysis. Recommended methods to calculate and visualise the ENF components of a questioned recording are**:**

a) Compute a high order spectrogram (e.g. FFT size = 4096 or 8192, Hamming window, overlapping 50%), make a zoom around 49-51 Hz or narrower.

b) Use an FFT in conjunction with an interpolation scheme. This method allows good frequency resolution to be obtained with minimal frame overlap.

c) Compute the zero crossings and calculate the frequency.

Technical/scientific details regarding the above recommended analysis methods can be found in the various papers listed at the end of this document.

5.1.3 Recommended methods to setup and maintain an ENF database:

a) ENF acquisition to be uncompressed (e.g. linear PCM).

b) Use uninterruptible power supplies (UPS) to avoid desktop PC shut downs and ENF database disturbances.

c) In general, because of the lower power consumption, use laptops in conjunction with UPS's to avoid system shutdowns when the mains power is lost for extended periods.

d) Make regular ENF database backups.

e) Maintain two separate databases in different locations in order to minimize the risks of local electric network failure or PC crashes.

f) Check periodically the database/PC system date and time setting and manually make the necessary corrections/adjustments. Alternatively, synchronise the system via an external date/time source for automated updating.

g) Isolate the system (either physically or via software security) from personnel not authorised to access the database.

5.1.4 Recommendations relating to automated matching of extracted data to a database of ENF estimate include:

a) ENF database information should be stored in a simplified format in order to minimise signal processing overheads and allow simple search criteria to be applied. ENF estimates should therefore be stored after the application of a peak picking algorithm i.e. only the peaks of the data are stored rather than all of the transform points of an FFT.

b) ENF sampling rate (how often an ENF estimate is taken) should be identical for the database and the data extracted from the questioned recording.

c) A simple search algorithm needs to be applied i.e. an algorithm that searches for the questioned recording's ENF pattern in the archived ENF data. The process would involve overlaying two length N vectors and computing a metric that determines the degree to which the two vectors match. The metric used could be based on the mean squared error (MSE) or on the correlation coefficient. It may be beneficial to use both methodologies in order to verify the results of one method with that of the other. All methods used must be validated.

6. EVALUATION AND INTERPRETATION

6.1 For evaluation and interpretation purposes, the ENF data extracted from the questioned recording needs to be compatible with the ENF data collated by the database. For example if the ENF database audio storage format consists of a single channel WAV file, having a 120 Hz sampling rate and a bit depth of 16 bits, it is recommended that the questioned signal be converted to the same format.

6.2 Evaluation and interpretation of the ENF findings will require consideration of:

a) The background information available about the case.

b) The original expectations formulated during the case assessment.

c) Other possible forensic analysis techniques (e.g. header and file structure analysis, acoustic analysis, etc).

6.3 The influence of these factors can be assessed by using the Bayesian approach in which at least two competing hypotheses are considered:

Hp = favouring the prosecution allegation

Hd = favouring a defence position

for example:

'*what is the chance of finding the evidence if the suspect carried out a particular set of actions (Hp)*'

against:

'*what is the chance of finding the evidence if the suspect is not the person who carried out the particular actions (Hd)*'

By applying best estimates to each of the relevant factors considered, numerical values can be obtained for each of the hypotheses and from these two values the 'Likelihood Ratio' (LR) can be calculated.

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