

ORIGINAL RESEARCH

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Forensic audio authentication analysis technique of first or higher generation copies of analog magnetic audio tapes

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Abstract

In forensic audio examination, standard listening and visual sound spectrogram analysis methods often lead to incorrect conclusions due to the losses in data when the tape is copied. Furthermore, conducting the standard examinations on audio files which are digitally edited and re-recorded on the tapes, leaving very little trace behind, also result in incorrect decisions made by forensic experts. In this study, a novel and a very simple technique was developed, where the electronic edit traces on an electronically edited tape become easily detectable on copy generation tapes. Thus, regardless of the duplication speed, copied tapes can be analyzed for their originality and integrity with this technique and digital changes on them can be determined. The technique is based on increasing the tape playback speed by modifying the playback system of a player device. This essentially alters the time base of the signal and expands the low frequency scale of the recording in the frequency domain, and makes manipulation marks easily observable. It can be applied to most analog magnetic tape recorder devices. Edit marks can be precisely detected with minimal loss of time by using specially modified nonstandard devices rather than available conventional standard devices.

Keywords: Forensic audio, copy generation tapes, analogue audio tape editing, authentication, tampering

Introduction

At the present time, magnetic tapes are no longer common. However, they are still presented to courts as evidence that provides information about the activities of organized crime groups with a long history, and communication between such organizations and crimes against government.

In forensic cases, analog audio cassettes are examined for transcription, speaker identification and authenticity by order of the court. Rather than the originals, usually, copy generations of the tapes are procured. Many of the institutions around the world require possession of the original tapes and even possession of the used recording devices as a condition of approval for admissibility as evidence. This condition is rarely fulfilled, and many findings that prove a crime and should be considered as evidence are ignored due to non-compliance with the regulations because of the technical limitations in this area.

In the pre-digital era, audio tape manipulations were done on analog equipment from a player to a recorder device using the available play/pause/record keys. This type of start/stop process

causes abrupt signal interruptions and magnetic recording process discontinuities that leave strong magnetic traces on the tape. Such recordings may be recopied onto another tape; each copy after the original is termed a copy generation. For example, a tape submitted as evidence may be a 4th generation tape but the manipulations might have been done on the 1st and 2nd generations. A submitted tape may be duplicated for distribution in the judiciary system for analysis by different bureaus. Although this process is not a “manipulation” and is legal, nevertheless the distributed copies will carry new traces and suffer losses due to duplication. The magnetic marks on tapes may be blocked by player bandpass filters, and/or masked by noise during listening. Alleged alterations on original tapes can be observed by physical or magneto optical examination, but that method is inadequate in the analysis of copy generation tapes [1,2,3]. In tape to tape copies, audio signal loss and noise increase is unavoidable. Signal loss is primarily due to used equipment signal path filtering and the nonlinearities of magnetic heads. Noise is due to the circuit noise of the used equipment, switching signal transients, and the used magnetic tape. At every generation copy, losses and noise increase. Low frequency noise may not look very meaningful to the analyst; however it carries very useful clues due to tape print-through. Such traces get weaker with every generation. For this reason, copy generation tapes are not acceptable for use as evidence. Hence it is important to identify if the tape is a copy generation.

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Traditional methods of critical listening, visual waveform analysis, spectrographic analysis, and optical magnetic visual analysis are possible on the originally recorded analog audio cassettes only by some forensic audio laboratories. Information obtained through the entire investigative procedures results in a decision. Unfortunately, the procedures that form the background of these decisions are still incomplete [1,6,7,8]

With the advent of digital techniques and equipment, audio manipulations are performed on digitized audio signals on computers using software. The manipulated final result is often recorded on an analog tape to give the impression of authentic evidence. The work of revealing manipulations concentrate on three primary techniques of editing: mechanical editing, electronic editing, and digital editing. In some cases, it is very important if an audio cassette is analog edited and copied, or computer edited and recopied to analog media. The determination of alterations and manipulations done after digitizing the sound signals recorded on a tape in the computer and re-recording from the computer edited file again on to a tape is the most difficult one [4,5,6]. A digitally manipulated signal recorded on analog tape will be clean under any physical or magneto optical examination, yet the presence of any acoustic traces will lead to the classification of the evidence as “digitally manipulated and copied to analog”.

Spectrographic analysis of analog tapes is done on the digital audio signal obtained by digitizing the playback output of a conventional player device.

Very High Speed Technique (VHST) was developed and has been used as a solution for copy generation tapes, at the Istanbul University Institute of Forensic Sciences [4]. This method has increased the reliability of the decisions on the determination of manipulations on every type of copy generation tapes.

For this study, normal bias compact cassettes have been chosen for testing VHST, however it can be similarly applied to other types of magnetic tapes as well. VHST is based on increasing the rotation speed of the tape player. As a result, signal strength and frequency increases proportionally. Due to this speed increase, very low frequency signals also go over the low frequency cutoffs of audio bandpass filters and NAB equalizing filters of cassette players. Consequently all of the very low frequency signals, which occur due to magnetic deformations, tape print-through, stray magnetic fields, and electronic switching noises, electric network signal remains can easily be observed and determined by spectral analysis. Such signals are not generated by the human auditory system.. Because of the high frequency signal losses during copying in analog tapes, low frequency analyses are very important. The low frequencies may also carry characteristic magnetic signatures arising from the local mains voltage or recording device [9]. Another advantage of this technique is the ability to observe the low frequency signals on a wider frequency range of the spectrogram with the expanded frequency scale.

Material and Method

More than 100 different brand, model and type analog audio tapes, and more than 30 audio tape recorders (micro cassette, compact cassette, reel to reel) have been tested since 1993 for developing VHST and have been applied to real cases. For this study, normal

bias compact cassettes have been chosen to apply VHST to establish the technique applicable to other analog magnetic tapes as well. Copy generation tapes were produced using a Sony TC-WE 805s double cassette deck. Computers with sound cards were used, and the software to examine the signals was Adobe Audition V 3.01 [10]. A modified tape speed cassette player for applying VHST have been made and used. The only disadvantage of the modified cassette player with a variable tape speed is not exactly knowing the set tape speed, however this issue is resolved in the frequency domain by observing a sinusoidal signal with a known frequency on a tape, i.e., if a 1 kHz signal on tape is observed at 14 kHz in the frequency domain, the speed up factor is 14 times, and the real time values in the time domain waveform will be calculated through multiplying the observed time with 14. The said cassette player with variable rotational speed is a first in literature and a patent application has been made. In this research, the particular modified player starts at a linear tape speed of 14x and speeds up to about 29x towards the end of the tape in the cassette; this requires a simple modification on the device. The rotational (angular) hub speed is actually varied by the operator but stays constant at the set value. A variable constant linear tape speed playback, i.e., where the operator set speed remains the same throughout playback, is also possible but the modification is somewhat more complex. The simple modification was found to be sufficient for our purposes, and is used in this paper. The effect of the varying speed on audio pitch may be compensated by software during the analysis as illustrated later in Fig. 3b. Test signal tapes and real case tapes were used for exemplifying results on spectrogram.

Analog recorders possess an erase head and a record head. An erase head is generally made of a piece of permanent magnet, or a coiled head electromagnet that is magnetized by a high frequency signal obtained from a “bias oscillator”. Erase heads produce approximately three times stronger magnetic fields than the recorded audio signal tape magnetic coercivity (~300 Oe) for erasing the recorded signals [11]. Low amplitude bias signals are also sent to the record head to cover up hysteresis loss. These make magnetic imprints on tape. Traces of such magnetic imprints occur on tapes together with the recorded signal. These types of strong imprints and recorded signals also interfere up and down the base layers of the tapes on cassette hubs causing “print thru” (or print through) [11,12]. During the examination, these magnetic marks and signs can be observed, but because of the attenuation by band-pass filter and NAB equalizing filter, not all of the signs can be detected clearly with standard player devices [13].

Generally, the tape readout sensitivity is related to playback heads, tape speed, NAB equalizing filter, and band-pass filters. These also effect noise and distortion as well as magnetic playback losses from tapes especially at high frequencies, and are the major causes of signal loss in magnetic tapes and determine the equipment’s limitations.

VHST is based on increasing the tape speed of the cassette player by 14-29 times. Tape speeds are increased as high as 14 times at the beginning of the cassette and reach 29 times or higher at the end. Hence, low frequency signals’ output strength and frequency are increased by 14-29 or more times. Due to this speed increase, extremely low frequency signals strengthen and increase in frequency and jump over the band-pass filters of the cassette player [14]

Results

Technological advances in the field of radiology have had significant impact on the detection of very low frequency signals, which occur due to magnetic deformations, print-through, stray magnetic fields, electrical network frequency signals and electronic noise signals can easily be observed and determined by spectral analysis using VHST. The electronically edited area generates a unique and recognizable discontinuity which can be seen as a spectral glitch in the visual spectral signals. Example cases are illustrated in Figs. 1 to 4. This technique is useful in differentiating analog and digital editing, and in differentiating some electromagnetic interference signals as in Fig. 2 that look like an editing trace. Because of high frequency signal loss in analog tapes, very low frequency analyses are quite important. Another advantage in using this technique is the ability to observe extremely low frequency signals on an expanded frequency scale spectrogram.

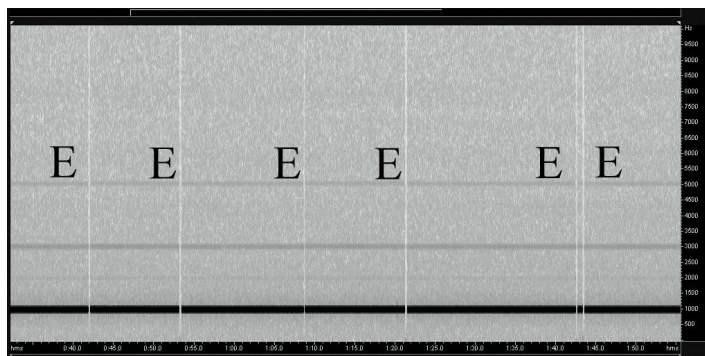


Figure 1. The spectrogram of a fourth generation normal tape speed copy of a compact cassette tape with six distinct electronically edited areas (marked E) and with a 1 kHz recorded sinusoidal signal

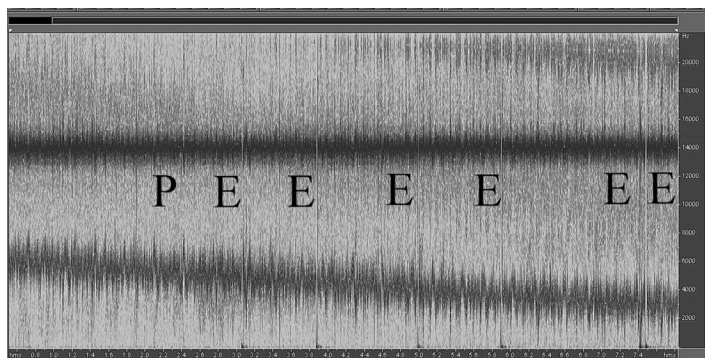


Figure 2. The VHST spectrogram of the same cassette described in Fig. 1 at a tape speed of 14x. This spectrogram is also pitch compensated. An interference signal (P) invisible in Fig. 1 can easily be differentiated at the 14x increased tape speed with VHST. (E) marks are edited areas. Note the changes in the time base instances due to the tape speed increase

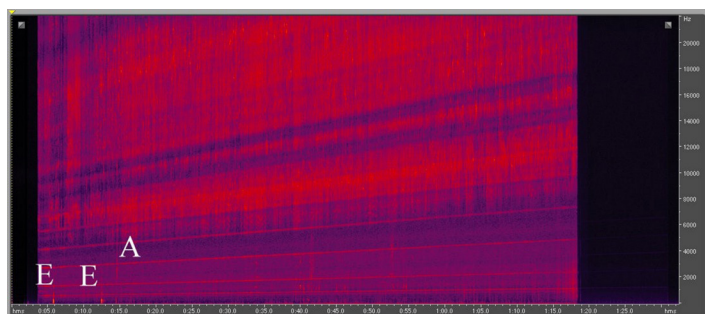


Figure 3a. Full spectrogram of a 30-minute third generation copy tape, time-compressed to ~90 seconds using VHST. Tape speed average was ~22x (14-29). This tape is a real forensic case. Tape-to-tape copies have been made at standard speed. (E) are electronic editing marks. (A) is a very low frequency acoustic action sound trace

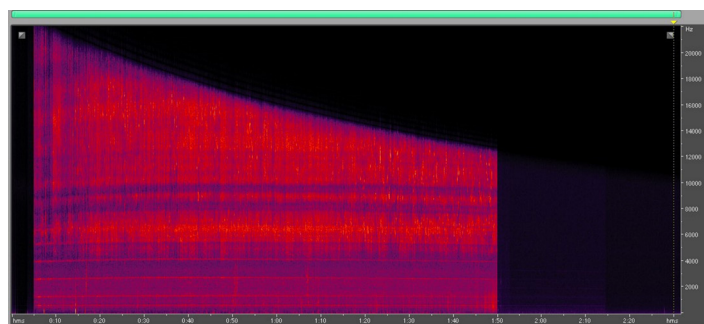


Figure 3b. The spectrum of Fig. 3a processed by "pitch bender" (pitch correction) software to compensate for pitch modification due to tape speed increase

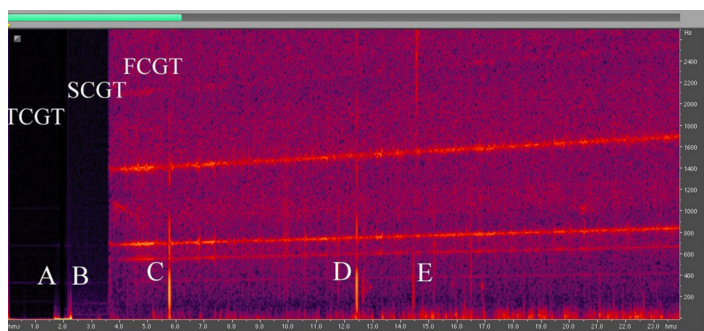


Figure 4. The spectrogram of the beginning of the tape of Fig. 3a with VHST. Tape speed average was ~22x (14-29)

In Figure 4 TCGT is a third generation copy tape leading "blank" part. SCGT is a second generation copy tape leading "blank" part. FCGT is a first generation copy tape leading "blank" part (A) is the magnetic deformation sign of TCGT, observed at 5 Hz. (B) is magnetic deformation sign of SCGT observed at 10 Hz. C and D are magnetic deformation signs of FCGT observed at 250 Hz. (E) is very low frequency acoustic sound trace observed at 350 Hz.

Discussion

Analog audio tapes always have background noise signals which increase with tape copying every generation. These increasing noise signals can be observed with traditional methods. However it is sometimes very difficult or impossible to observe and to determine at which generation the editing has taken place based on the differences in noise signal layers. Using VHST, there may be a possibility to find at which copy generation the editing has taken place in the copy tape under investigation.

Detection of magnetic deformation marks on original tapes is traditional in visual magneto optic analyses. However, visual magnetic analysis methods may not be employed with copy tapes.

Generally analog electronic edits are made with standard audio equipment and presume target listening and criminal analyses with standard listening devices [1,7]

VHST is not a standard playback technique. Therefore many signals can be observed which cannot be detected using standard methods and equipment. When examining copy generation tapes with VHST, very clear differentiating signs on analogue tapes due to analog editing, digital editing, and random electromagnetic interference signals can be detected and evaluated. Some random electromagnetic interference signals and signal distortion can occur during the recording and playback processes when digitizing the

analog audio to the computer, and these may look like manipulation signals during the analysis, however the VHST technique can also help discriminate them and prevent misinterpretation.

In general, even if some editing traces are determined, it is hard to disprove the authenticity of the tape. Pause and stops during the original recording, VOR type recordings, etc. also create edit marks on tape, but the tape may be authentic. Edits that change the meaning of the words, sentences, and content of the conversation within the audio must be confirmed through other standard examinations.

Audio work, which includes studio music work, is always mentally exhausting. This can result in unrecoverable errors in forensic audio examinations. VHST is helpful in that aspect especially due to the time-efficiency. It determines the exact locations of the stop, record, pause, voice operated recording, and erase activities at ~20 times or higher tape speeds, and is followed by the analysis of those specific locations through other methods. The faster location of suspicious audio points enables a faster overall analysis and reduces analyst fatigue.

A first generation copy tape was played more than 130 times using VHST but it didn't physically deform very much under high speed playback stress.

The level of very low frequency noises are observed to increase in standard listening especially at the beginning and ending segments of the cassettes, producing periodic low frequency pulse sounds due to print-through with every copy generation. However in the observations using VHST, these sounds signals can be observed better in every location on the tape, and all of the print-through traces can be visible and monitored on spectrogram. This makes the potential edits on the previous generation tape visible. It is important for the determination of originality or integrity [1,15].

Conclusion

The intentional manipulations of the cassettes are defined as "effective manipulation" in this study [14]. If effective manipulation of a cassette can be revealed, it will not be admissible in court. Therefore, authentication is important for the acceptability of an evidence item. Suspicious manipulations on original tapes can be observed by magneto optical examinations, but these methods cannot be employable with copy tapes. VHST, which is reported for the first time in this study, can detect the effective manipulations in the copy generation tapes fast and easily, and is helpful in that aspect especially due to the time-efficiency. Many signals undetectable in traditional examination techniques and methods become visible in VHST. It determines the exact locations of the stop, record, pause, voice operated recording and erase activities at tape playback speeds of ~20 times or higher, and allows for the validation of those locations through other methods. These applications could be preceded with this simple technique, and is proposed for the first time in literature, and is suggested to be used in the courts with confidence. Although this technique is explained for compact cassette audio tapes in this study, it can be applied to almost all analogue magnetic tape recorder device recordings such as micro cassettes, reel to reel tapes, and audio tracks of video tapes. VHST has increased the reliability of the decision on the

manipulation of every type of copy generation tapes. A patent application for the very high constant tape speed cassette player used in this technique has been made, and is currently in process.

Competing interests

The authors declare that they have no competing interest.

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