INFLUENCE OF THE AZIMUTH MISALIGNMENT ON ANALOGUE TAPE AUTHENTICATION IN FORENSIC TASKS

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ABSTRACT

Authentication of analogue tape recordings is one of the most important problems for the forensic laboratories. It is necessary to prove whether a specific tape was recorded with a given tape recorder. For that reason, a comparison between marks left by both tape recorder heads in the original tape and in a new recording must be done. An important time interval between both recordings may exist in which an azimuth head deviation may occur.

In the present work the influence of the head misalignment in the reproduction of the marks is discussed.

INTRODUCTION

Despite the evolution of digital technologies, analogue audio tape recordings are still been used as evidences in judicial fact-finding proceedings. The reason of this fact lies on the difficulties found by experts when trying to decide the validity of digital material, and finding out if any manipulation has been made within the recording. Imperfections inherent to analogue recordings can be used as clues in its forensic analysis. However, a universal solution for the problem of tape authentication has not been found yet.

Several standard procedures have been established stating the criteria for analogue tape authentication, with the aim of providing scientific methods for expert analysts ensuring result repeatability. Nevertheless, the results obtained after their application cannot guarantee an error-free correct conclusion [1].

One of the most detailed procedures may be the one developed by the AES Working Group on Forensic Audio leaded by A. Pellicano [2], setting a comprehensive examination of both recorder device and tape recording to decide if the second is original. The whole process consists of three main steps: critical listening of the recording, waveform examination and photo-microscopic analysis of tape magnetic coating, all three trying to find out anomalies due to tape manipulation. AES procedure not only attempts to prove that the tape has not been modified, but also that the tape provided as evidence was made with the recorder that must be deliver together with the tape. At this stage, the main study consists on comparing the marks (signatures) the recording device leaves in a test tape with the analogous signatures found in the evidence tape. Recorder transport functions generate electric transients that can be recorded together with the audio material. If that marks are device dependent, they can be used to assess relationship between recorder and recording.

SIGNATURE COMPARATION

Pellicano's report describes the procedure of getting a set of marks of the supplied recorder, generating them into a test tape. The series must contain a minimum of ten signatures of all the transport functions available on the apparatus (start, stop, stop-start, pause, voice activation, and any other the examiner may consider). The test marks are then digitised into a computer-based system able to display their waveform.

After searching for signatures in the evidence tape in a similar way, a comparison with the test marks is used to formulate an opinion about the matter. Obviously, the designated original recording and the test one must be reproduced with the recording device employed in the evidence take to ensure similar degradations of the marks in both tapes. This method seems quite simple and clear to perform, but some considerations must been taken into account to avoid undesirable wrong decisions.

In first place, signature waveforms (fig. 1), exhibit a transient look-like, and although some of them are really stable, two equivalent ones never look exactly the same, even if they are produced with the same device and in the same tape, but in different moments. So, a criterion to characterise and compare marks must be clearly established.

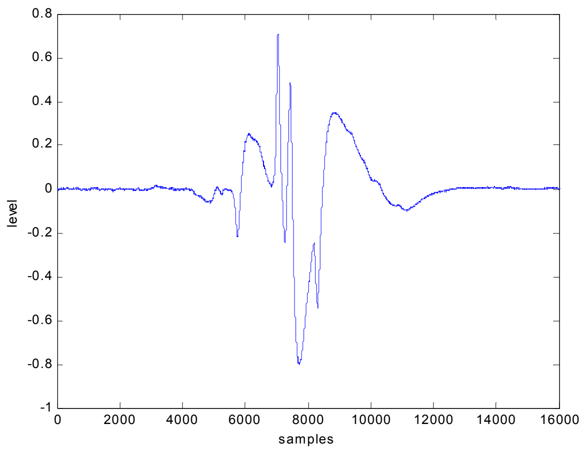

Figure 1. *General look of analogue tape recording signatures*.

In this sense, the Image and Acoustics Laboratory of the Spanish Civil Guard proposes the generation of a feature vector of the signature [1], by selecting a set of characteristic points in the waveform. That solution has provided good results but a great amount of mark information is not used, so other feature extraction must be tested considering the full length signature.

On the other hand, in civil, criminal or other fact-finding proceedings, a considerable lapse of time may pass between the evidence procurement and the analysis of the material in the forensic laboratory. If any feature of the tape or the recorder changes in this time affecting the signatures, wrong conclusion could be derived form the analysis, denoting as not original a tape recording that does.

One of such variations, not difficult to produce, is write-read head azimuth misalignment, resulting in different head position between the original recording and the test time. The only stress affecting write-read heads in their physical displacement produced by start and stop transport functions can derive in such azimuth variations. If that variation affects the reproduction of the marks, invalid results can be delivered. So, the effect of head azimuth variation must be analysed trying to find out a correlation between head position and signature degradation.

MATERIAL AND PROCEDURE

Several tape recorders and radio cassettes of common use are the equipment under test. Although they are not the ones mostly used in forensic applications, the results obtained with their study can be easily extrapolated to any model. They are:

JVC UX-P3R, MX-K5R, MX-K1R.
MX-Onda MX-MCP825.
Panasonic RX-D12.
Philips AZ-1050, AZ-1060, AZ-1018, MC-30.
Sanyo M-1060C, M-1118, M-1560F.
Sony CMT-EP30, TK-KE240.

The marks corresponding to start, pause, release pause and stop are obtained in this order for each one, generating mark series. Type I tape, according to ICE classification, is used because is the only type that can be employed with every recording device.

Each mark series is reproduced with the same tape recorder that generated it, digitised and saved in a computer, according to the main guidelines described in AES document. This operation is repeated modifying the read-write head azimuth, using all its available position range. Notwithstanding the position of the head must be precisely known to correlate it with the resulting mark, at this moment it is not necessary to know exactly how the amount of deviation is done for each recording. Moreover, in a first approach, it is unknown in forensic situations, so these tests provide results with direct application to real cases.

A sound card is used as A/D converter, with 16 bits of lineal quantization and a sample frequency of 48 kHz. As the overall information of the mark is contained in the low frequency range, the sampling frequency has denoted not to be a critical parameter.

The testing procedure consists on generating a mark series with the head in its “unknown” original position. The series is digitised ten times, with the original head position, with the maximum azimuth deviation in both extremes and in seven additional intermediate positions. Since the stop signatures are the most stable and representative of a tape recorder [1], they are the only studied in this paper of both erase and write-read heads. A comparison test is performed between the original and the rest of the marks with the aim to study the ability of the system in recognizing the signatures assignating them to the device employed in their obtention.

To use all the available information contained in a signature waveform, the comparison between two marks must be redefined. The method proposed consists on obtaining an error function with the deviation between the whole marks, instead of using a discrete feature vector. If this error function remains under a given threshold, the compared marks are assumed to be made with the same tape recorder. By using this criteria in the comparison of marks, very good results in previous works has been provided, as related in [3].

It is necessary to temporally align both mark waveforms to obtain the error function, in order to avoid invalid functions due to bad origin selection. To achieve this with maximum accuracy, and in an operator-independent manner, cross-correlation between both waveforms (1) must be done.

$$C_{xy}(t) = \int_{-\infty}^{+\infty} x(t+T)\,y(t)\,dt \qquad (1)$$

Being x(t) and y(t) the mark waveforms under assay.

The time instant where both marks are best superimposed is represented by the cross-correlation maximum value, and is used to generate the error function. In other words, the error in this point reaches its lowest possible value. This method is commonly used in maximum length sequence (MLS) measurements [5], known as subtraction technique.

Once the marks are aligned, the error signal is computed subtracting one waveform from the other, and then squaring to ensure positive values of the error function. The key point of the method relies in the great magnitude difference between the error functions when comparing signatures from same and different devices (figure 2). The maximum of the error function e, defined as (2), will be the error value used in the decision step:

$$e = \max\left[(x(t) - y(t))^2\right] \tag{2}$$

Finally, e value will be used as distance measure between the marks. Its relation with the threshold will determine the acceptance or rejection of the mark source. Prior tests have been performed to fix the optimum threshold value. The threshold level finally used is equal to 0.16.

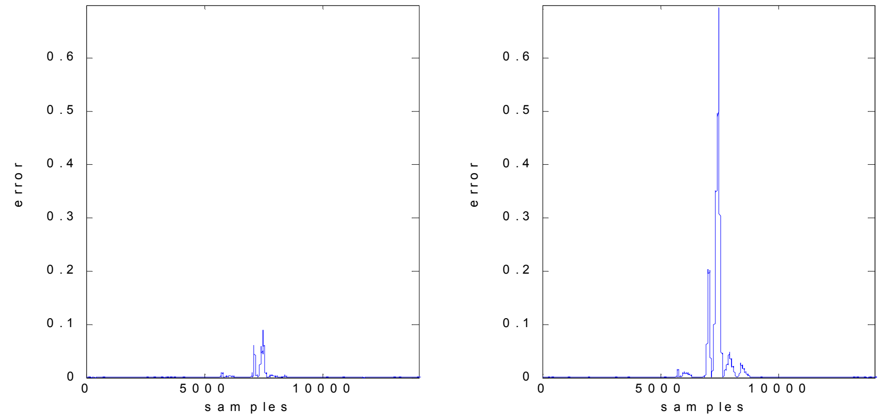

Figure 2. *Two error functions, obtained comparing signatures form same and distinct equipment respectively.*

It is known that the erase head stop mark is the most stable and error-free signature [1]. At first stage, this is the mark used. Although the write-read head is the unique head displaced, the erase head signature could be altered. According to the AES procedure [2], the tape must be reproduced with the original tape recorder. Thus, in a real forensic analysis, the digitised copy of the waveform may be taken with azimuth deviation or perhaps not. If the procedure works, despite of the differences between the marks resulting with variation of azimuth angle (figure 3), the corresponding distance e may rely under the decision threshold.

Finally all the process is repeated with the stop mark of the write-read head with the goal of obtaining qualitative comparison employing signatures generating previously known worse results.

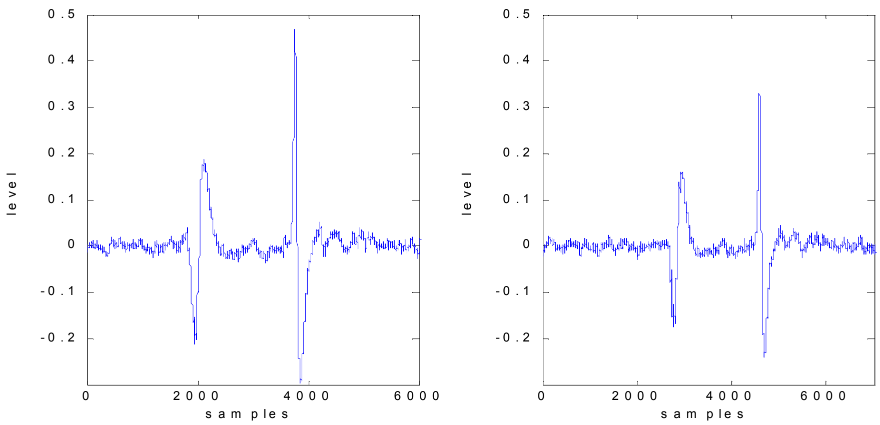

Figure 3. *Differences between same erase head marks obtained without and with azimuth deviation respectively.*

RESULTS

The results must be analysed separately considering the head employed. First, with the erase head, the waveform of the reproduced marks is slightly different from one to another, depending on the azimuth deviation incurred. As the overall shape of the error function is similar, the proposed method of identification has failed in no one of the cases under study.

With the write-read head, the waveform of the reproduced marks is again slightly different but this time, the method of classification has failed an intolerable 70% of the cases. As is described in [1], the stop mark of the write-read head is rather unstable. The latter combined with the azimuth deviation, cause that this mark is totally useless to characterise a tape recorder.

In the graphs presented in figure 4, it can be seen the effect of the azimuth deviation on the error classification of both heads. The azimuth alignment is arbitrary varying from both extremes (1, 10), value 5 corresponding to none deviation at all.

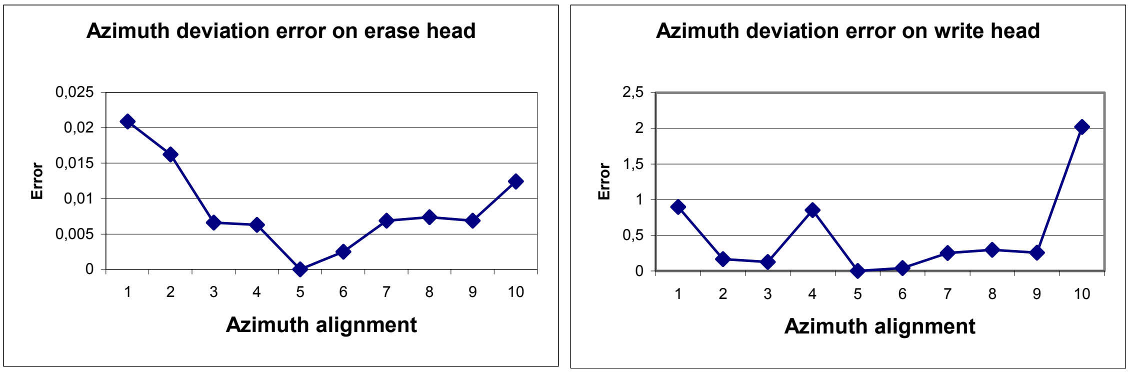

Figure 5. Error value (*e*) versus azimuth position for erase head (left) and write-read head (right)

It is clearly noticeable the magnitude differences in the distances obtained when working with record and write-read heads. The maximum error generated by erase head results slightly superior of 0.02, while in the second case maximum levels as great as 2.0 are produced with a similar head position with total displacement.

CONCLUSIONS AND FUTURE DIRECTIONS

As expected, azimuth misalignment affects recording signatures, originating visually noticeable differences for different read head positions. Those differences are not taken into account in the standard methods proposed to decide authentication of analogue tape recordings.

The stop mark of the erase head has proved to be the best signature to identify a tape recorder. The azimuth deviation alteration can be eliminated via the error function proposed. It is extremely interesting that the function error presents its absolute minimum when there is no azimuth deviation. This feature can be used in real forensic tasks to restore the original azimuth position of the head as a previous alignment prior to the test procedure.

The stop mark of the write-read head is useless unless there is no azimuth deviation. The non-stability of these marks together with misalignment problem must be considered, and reformulation of standard procedures is proposed to avoid wrong decisions derived from the use of these signatures.

The problem of identifying by means of head signatures is still open. Both head marks reproduction varies with the azimuth deviation. The classification method works very well with the marks leaved by the erase head, the most stables, but it does not works with the write-read head marks. This may originate problems, for instance, a mark could be considered false when it is from the original tape recorder.

Future directions are to find a correlation between marks and position of the head, to determine if two marks apparently different may have been done by the same equipment, detecting the problem source. Similarities within different marks or their corresponding error functions obtained with the same apparatus must be analysed trying to obtain a set of clues in this line.

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