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TAPE-CUT EDITING OF A STERO PCM TAPE DECK EMPLOYING STATIONARY HEADS

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TAPE-CUT EDITING OF A STEREO PCM TAPE DECK EMPLOYING STATIONARY HEADS

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1. Abstract

The PCM tape recorder should perform the traditional function of recording for practical use in studios. Along with electronic editing, tape-cut editing will also play an important role in studio work. Avantages of tape-cut editing are:

(1) Editing time can be minimized if splice points are not numerous.
(2) Editing can be performed with only one PCM deck without expensive electronic equipment.

This paper describes signal processing and performance of digital tape-cut editing.

2. A Comparison Between Tape-Cut and Electronic Editing

The ultimate quality of reproduction achieved by a complete audio system, from microphone to speaker, was largely dictated by the recording and playback equipment. It is well known that PCM recording techniques are being introduced into recording and playback equipment to bring about significant improvements to this situation. When a PCM tape recorder is used professionally in a studio, however, in addition to the need for the highest quality of reproduction, there are also calls for the functions required of professional equipment: e.g., editing, location of the start of an item, and the supply of advance signals, etc.

A consideration of the system to be adopted for a PCM-based recording studio indicates that it should, like a conventional analogue studio, comprise multichannel recording, mix-down, master recording, and cutting, as the route for the production of the disc. The editing functions called for, therefore appear to be the punch-in and punch-out for the multichannel recorder, and the editing with the master recorder. As the means of editing with the PCM master recorder, there are both the tape-cut editing used with conventional analogue equipment, and electronic editing. Electronic editing enables a copy to be made selectively from the original, and was first made possible by the introduction of the PCM recorder. While it has the advantage that editing can be performed without physically cutting the tape, it does suffer the disadvantage that a copy of the complete tape, from beginning to end, must be made when editing a single point in the middle of the tape. On the other hand, tape-cut editing, although it necessarily involves the physical cutting of the tape, has the advantages listed below, which justify its continued use in parallel with electronic editing. The advantages of tape-cut editing include:

(1) As previously mentioned, provided the number of splices to be made on a reel is small, the fast-forward speed can be used to get from point to point, making splices only where needed, and considerably reducing the time taken.

(2) For electronic editing, at least two PCM recorders are necessary, whereas tape-cut editing can be performed with only one. This is an extremely important consideration at the present time, when PCM recorders are not yet widely distributed, and they must be used with the greatest possible efficiency.

(3) In order further to increase the efficiency of PCM recorder usage, once the place to be edited has been marked on the PCM recorder, editing can be performed by using only the tape-transport function of the analogue recorder, leaving until later a check with the PCM recorder.

(4) Apart from a few points which require care, editing procedures are almost identical with conventional analogue techiques. There is thus no need for special education of the operators, so that full use of the PCM recorder can be made from the moment it is introduced.

3. Kinds of PCM Tape Recorder

PCM recorders can be broadly divided into those using fixed heads and those using rotary heads, with the latter subdivided into helical and transverse scanning types. From the point of view of tape-cut editing, the slant angle of less than 10° with helical scanning makes it a practical impossibility. On the other hand, with transverse scanning, tape-cut and splice editing is possible, as with conventional VTRs. However, the need to avoid splicing at a recorded track entails continual inspection of the image, with corresponding difficulties in operating and in causing damage to the tape. With stationary head PCM recorders, on the other hand, the tape can be cut anywhere at will, thus enabling editing in much the same way as with conventional analogue recorders.

The stationary head PCM tape recorder that we have developed features editing performed in the following way: First the tape is wound at high speed to the vicinity of the place to be edited, then, in the stop mode, the reels are moved slowly backwards and forwards using both hands, listening to find the required point. Then the back of the tape is marked, and an editor and splicing tape are used to splice the tape. The procedure is virtually identical with that used for conventional tape-cut editing.

4. Problems Arising with Tape-Cut Editing on Stationary Head PCM Tape Recorders

The following problems, not encountered with tape-cut editing of conventional analogue tape recorders, must be solved before it is possible to perform tape-cut editing on stationary head PCM recorders.

(1) The design of the PCM recorder incorporates phase-locked servo control of the capstan drive. When the tape is spliced after having been cut, the servo pulses cannot be expected to retain the correct spacing. While it would be possible, as with transverse scanning videotape recorders, to 'develop' the control track and make the splice in accordance with the pulses, this would considerably complicate the editing procedure.

(2) At the splice, although for a very small time, a very large number of coding errors will be generated, too many for the normal correcting code to deal with.

(3) If the audio signal immediately before the square-cut tape join is not in phase with the audio signal on the PCM tape recorder after the join, click noise will be generated.

Each of these problems has been solved, as detailed in the following section, in the PCM recorder we are marketing now.

5. Solutions to the Problems at the Splice

5-1 Dealing with disturbance of the servo control

The phase-locked capstan servo-control system compares the playback pulses from the tape with internally generated standard pulses, and controls capstan rotation on the basis of phase differences between them. Therefore, if the phase changes discontinuously at the splice, the servo-lock will be broken, and in the worst case could take as long as 1sec to get back in synchronism, posing a threat to correct demodulation for that time. However, in this recorder, a number of sub-servo-pulses with staggered phases, as shown in Fig. 1, are derived from the playback servo-pulses. Normally just one series of pulses from among them is selected and used as the controlling servo-pulse. By selecting the sub-series closest to the servo-pulses immediately before the splice, and adopting it as the new servo-pulse series, the servo-control after the splice can continue without any disruption of phase-locked control.

5-2 Error signals at the splice

A signal drop-out of the order of several msec, associated with the cutting of the tape, cannot be avoided at the tape splice. Although the special error-correcting capability built into the PCM recorder is capable of dealing with the error signals due to normal drop-outs caused by dirt, etc., the circuits are overloaded by the very large volume of errors at the splice.

We have therefore incorporated a memory, in which the playback signal is delayed for a certain time during normal playback. When the signal drops out, the length of time spent in the memory is reduced, and the signal immediately before the splice is joined smoothly with the normal signal immediately after the drop-out. As shown in Fig. 2, the portion of the signal drop-out is cut out, equivalent to joining the normal signals immediately before and after the splice. The blank which arises in the memory due to cutting out the drop-out portion of the signal is eliminated by briefly raising the tape speed. However, even under these circumstances the signal is read out from the memory in synchronism with clock pulses from the internal quartz-crystal oscillator, so that the playback signal is completely free from wow and flutter.

5-3 Discontinuities in the audio signal level at the splice

With conventional analogue recorders using tape-cut editing, a smooth transition between the signals before and after the splice is achieved by a diagonal tape cut. With PCM recording, on the other hand, the way in which the signal is distributed over the tape requires that the tape should be cut square. The need therefore arises for some kind of processing of the signal to eliminate the click noise which would otherwise result from the discontinuity in the level of the audio signal before and after the splice, Fig. 3a. Two possible methods for relieving this problem present themselves.

(1) The step in the playback sound level at the splice can be eliminated by fade-in and fade-out before and after the splice point, as in Fig. 3b.

(2) The actual joining of the signals can be performed by waiting until the signal level after the splice reaches the same level as that immediately before it, see Fig. 3c. This method involves the detection of points at which the signals can be joined.

6. Results of Tests

We evaluated the various methods suggested above for dealing with discontinuities in levels in terms of their suitability with reference to different kinds of signals. Fig. 4 shows the waveforms for a 1kHz sine wave. It proved quite impossible to detect splices made for jazz or vocals, and we give here only the results for orchestral music. The work concerned was Mahler's "Titan" symphony: the output waveforms are shown in Fig. 5. We chose the places to be spliced at random, and performed subjective assessments by the eight research workers in our laboratory on a five-point scale. The five basic assessment standards were:

(1) Clearly detectable, completely impractical.

(2) Readily detectable, not suitable for practical use.

(3) Can be detected to some extent, but may be just practicable under certain circumstances.

(4) Difficult to detect, presenting no problems for practical use.

(5) Completely undetectable.

The results of these subjective assessments are given in Fig. 6. The mains reasons for the '1' and '2' assessments were the primitive method of 'editing,' resulting in musical discontinuities.

7. Embodiment in the Recorder

An introduction to the stationary head PCM tape recorder that we have developed follows here as an example of the embodiment of the signal-processing techniques mentioned above. T is equipment was developed for use as a master recorder, and its external appearance is shown in Fig. 7. The recording pattern is shown in Fig. 8, and consists of two analogue tracks carrying the same content as the PCM signal. They are used to give the advance signal and the playback signal used to locate the point to be edited. The specification is given below.

Item	Specification
No. of channels	2-ch PCM 2-ch analogue
Tape width	6.3mm (¼")
Tape speed	38cm/sec (15ips)
Emphasis	T = 75μsec, X = 14dB switch on/off type
Soft clamp	Switch on/off type
Dither	Switch on/off type
Mute	Switch on/off type, generating the digital equivalent of a fixed 0V DC signal in the recording mode.
Preview head	Optional

8. Conclusion

We investigated the various problems which can arise when tape-cut editing is used with PCM tape recorders. The results established that PCM recorders, too, can be used without difficulty for tape-cut editing. This should help accelerate the widespread adoption of PCM recorders.

9. Acknowledgements

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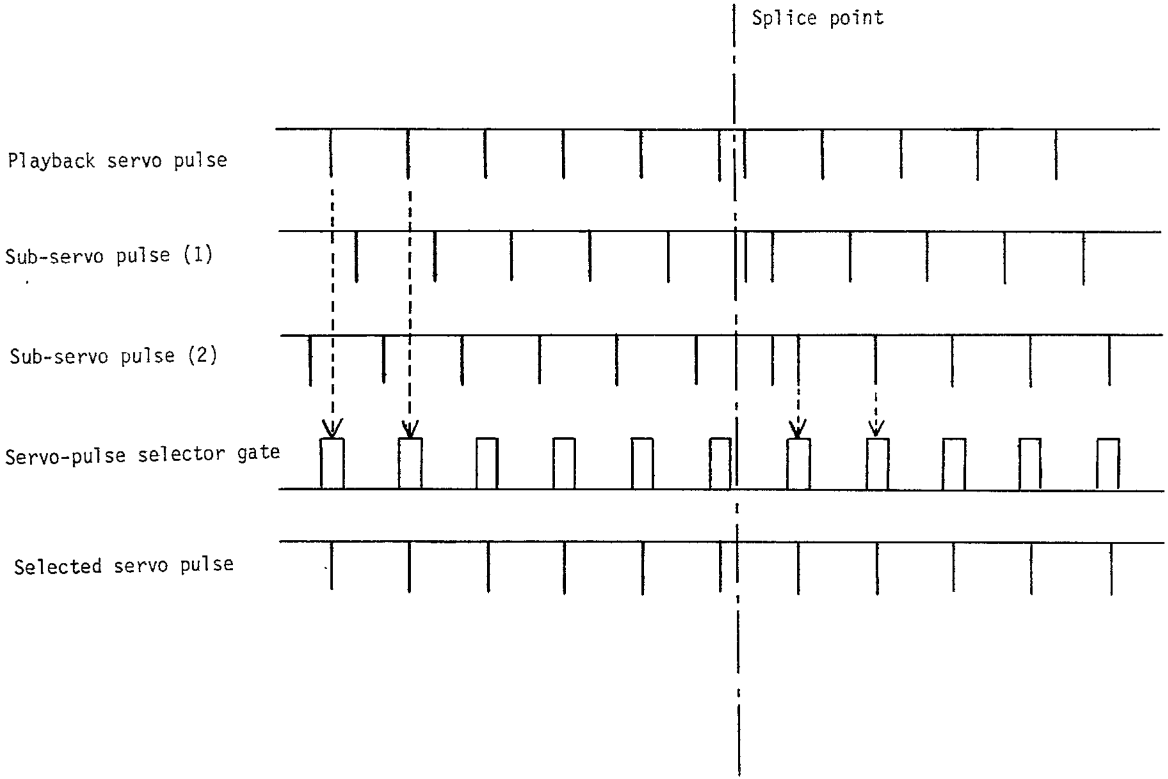


Fig. 1 Selection of the sub-servo pulse

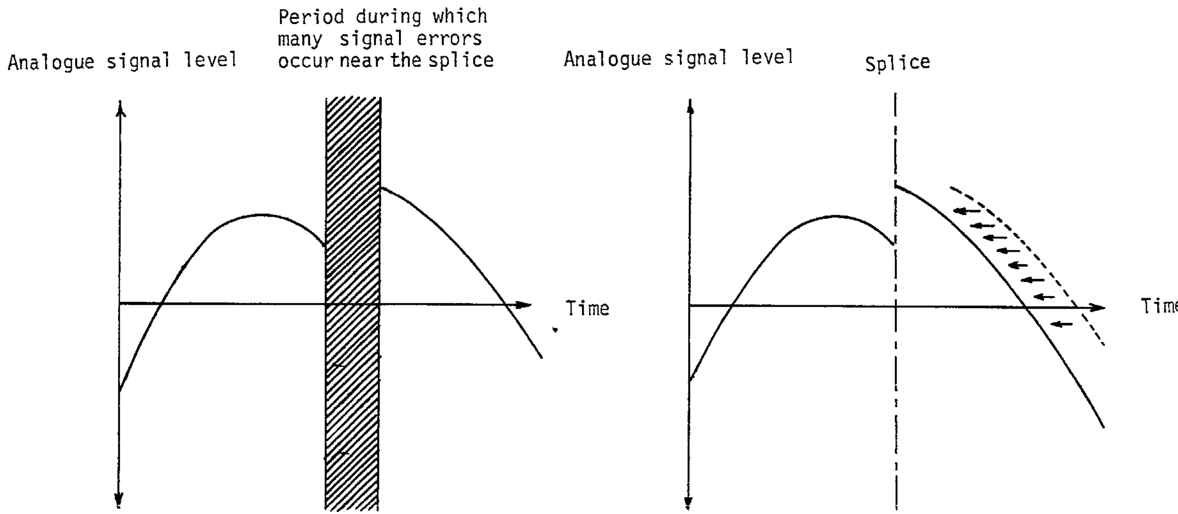


Fig. 2 'Closing up' of the digital signal in the memory at the splice

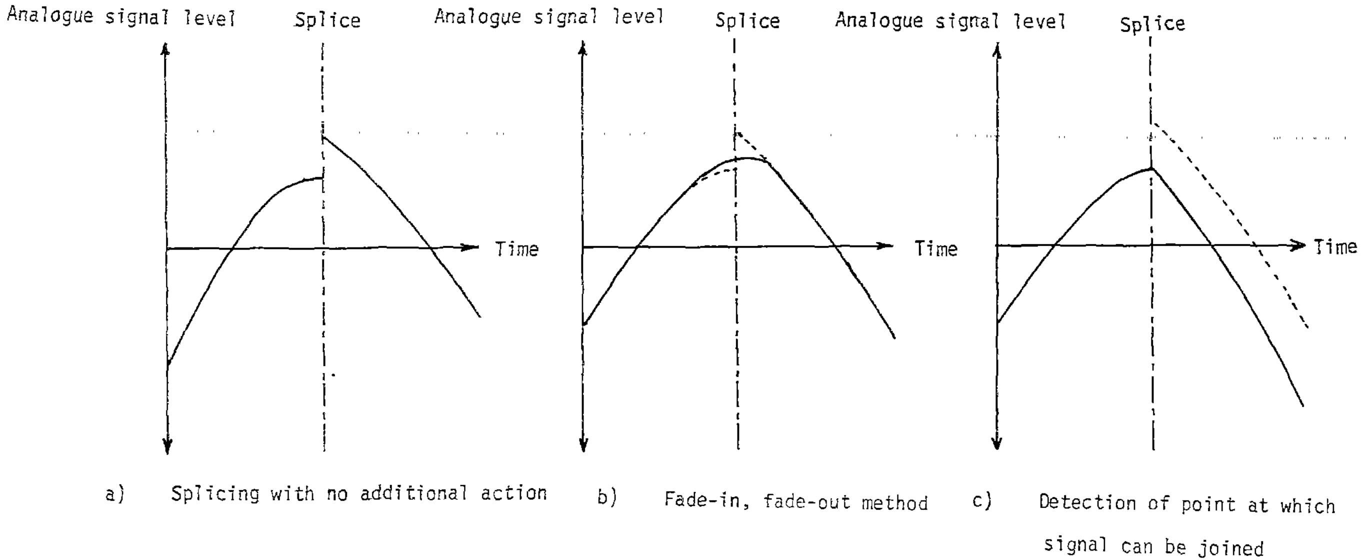
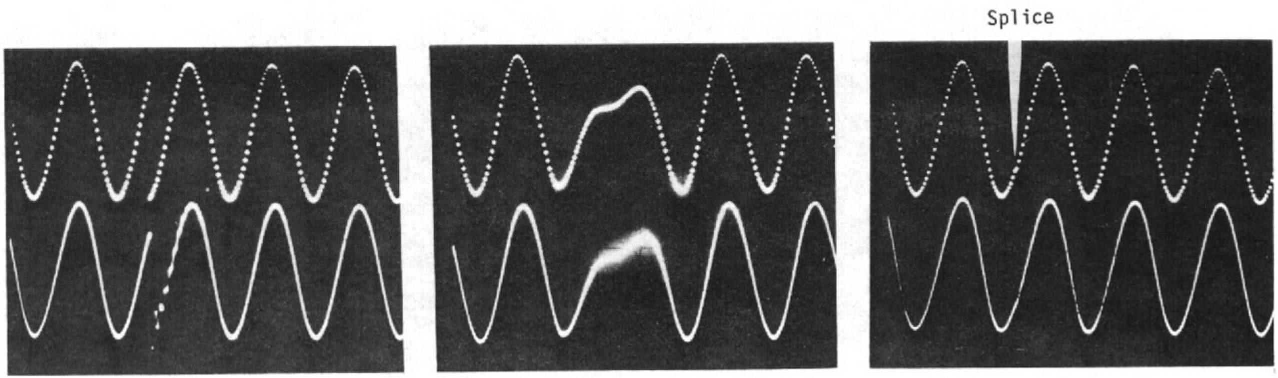


Fig. 3 Measures to deal with analogue signal-level discontinuities at the splice



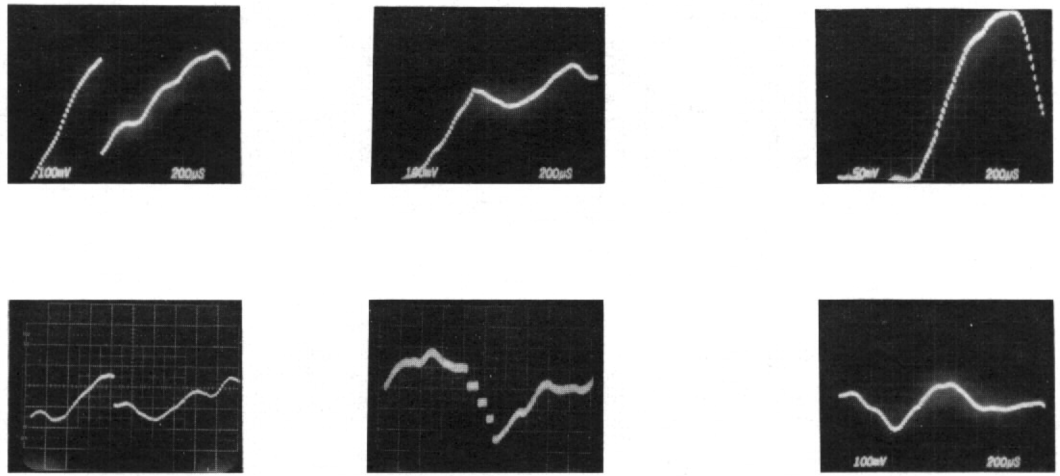
a) When no action is taken

b) Fade-in, fade-out

c) Detection of point at which signal can be joined

Note: The upper waveform is the D/A converter output, the lower waveform is the low-pass filter output.

Fig. 4 Signal joining for sine waves

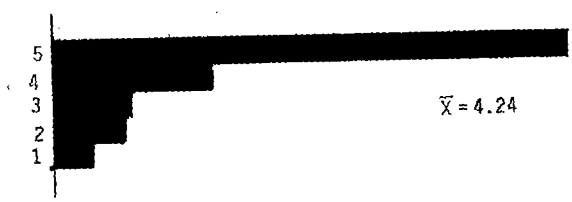


a) When no action is taken b) Fade-in, fade-out c) Detection of point at which signal can be joined

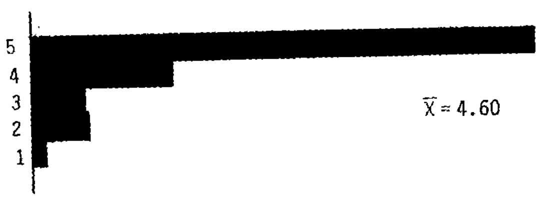
Note: The work was Mahler's "Titan" symphony

Fig. 5 Signal joining for an orchestral work

a) When no action is taken



b) Fade-in, fade-out



c) Detection of point at which signal can be joined

Note: The work was Mahler's "Titan" symphony

Fig. 6 Subjective assessments of the signal-joining method

Fig. 7 External view of the 2-channel PCM tape recorder

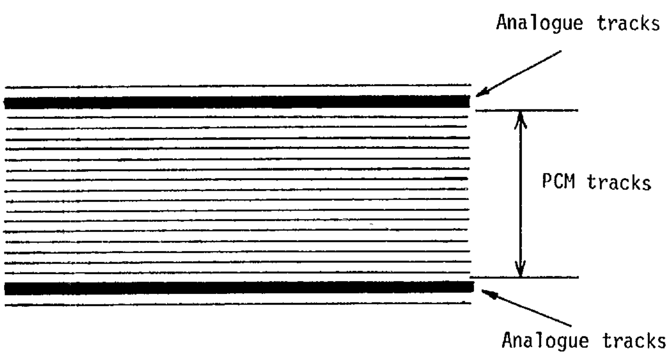


Fig. 8 Recording pattern on the tape