A DIGITAL-AUDIO CONTACT PRINTING TECHNIQUE

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Toshiharu Kobayashi
Toshio Shirai
Makoto Ando
Shinji Amari
Sony Corporation
Tokyo, Japan

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Toshiharu Kobayashi , Toshio Shirai , Makoto Ando , Shinji Amari

Advanced Engineering Division Development Center

Sony Corporation

Abstract

This paper describes a newly developed high-speed contact printing system to produce pre-recorded tapes for DATs (Digital Audio Taperecorders).

Employing a magnetic contact printing technique and using an advanced metal high-Hc mother tape, new barium-ferrite copy tape, high-quality and high-speed duplication was achieved.

Introduction

The DAT uses a helical-scan recording method similar to that of a VCR and thus the high-speed duplication technique used for audio compact cassettes is not applicable. A suitable high-speed duplication technique for use with a helical-scan recording systems is contact printing.

It is for this reason that the pre-recorded DAT tape format has a wide track-pitch mode (1.5 times as wide as the normal mode) for contact printing.

Format of Pre-recorded DAT tape

(1) Sampling frequency and track pitch

Table I shows the sampling frequencies and track-pitches used. 44.1KHz, the same sampling frequency as that of the compact disk, is used only for playing back pre-recorded tapes.

Track Pitch / Fs(KHz)	NORMAL (for head recording)	WIDE (for contact printing)	Remarks
48	recording and playback possible	not used	standard
44.1	playback only	playback only	only used for pre-recorded tape
32	recording and playback posssible	not used	optional

Table I Sampling Frequencies (Fs) and Track Pitches

(2) Specifications of DAT pre-recorded tape

Table shows the specifications of the DAT pre-recorded tape.
The DAT format has two different track-pitches: 13μm(normal)and 20μm(wide).
The 50% Difference in track pitch gives a 3.5dB margin in playback output level at a sacrifice of playing times.

Track pitch	NORMAL (13.59 μm)	WIDE (20.4 μm)
Number of channels	2	
Sampling frequency	44.1 KHz	
Quantization	16 - bit linear	
Tape speed	8.15 mm/s	12.225 mm/s
Playing time	120 min.	80 min.
Remarks	for head recording	for contact printing

Table Specifications of DAT pre-recorded tape

The tracking method used in the DAT is the area-divided ATF (Auto-matic Track Finding) method.

As can be seen in Fig.1 the ATF pattern is slightly modified in the wide track pitch format to maintain playback compatibility of the ATF circuit between the normal mode and the wide track-pitch mode.

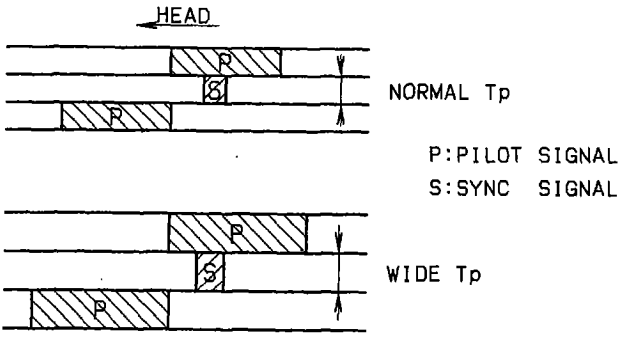

Fig.1 ATF Pattern for Wide Tp

Magnetic contact printing technique

Magnetic contact printing is a technique in which the magnetic surfaces of a pre-recorded mother tape and a copy tape are put into contact with each other and a magnetic bias field is applied to the contact area. This printing process can be called the ideal anhysteretic magnetizing process.

We will describe below the new technology involved.

1) Method of tape contact

We adopted the air-pressure contact method which has been used for some time to duplicate half-inch video tapes.

Air under pressure is directed around the bias head, as can be seen in Fig.2, so the mother and copy tape can run rapidly by each other while keeping contact without slipping.

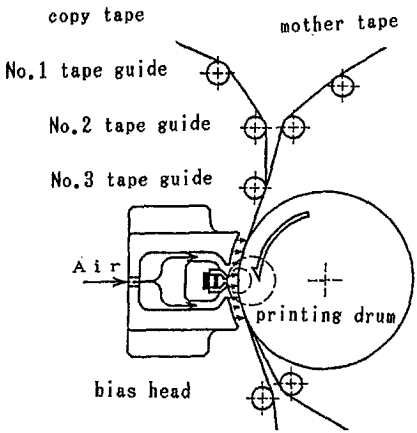

Fig.2 Method of tape contact

2) Tape transport

The printing drum rotates and drives the mother and copy tapes. The tapes are pressed to the printing drum by air under presure.

During printing process, the tention on the mother and copy tapes around the the printing drum is carefully regulated.

The transport path of the mother and copy tapes is restricted by the three guide pins shown in fig.3.

AS can be seen in Fig.2 and 3, the two No.2 tape guides guide the upper edge of the tape so the lower edge is properly fed to No.3 tape guide.

In this way the vertical slippage between the two tapes is eliminated by the proper adjustment of the two No.2 tape guides.

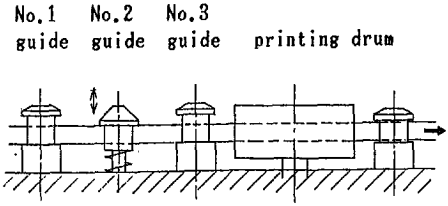

Fig.3 Tape transport

3) Tapes

In magnetic contact printing, the coercivity (Hc) of the mother tape has to be at least three times that of the copy tape.
But the highest value of Hc which we can use at this point is about 2000 Oe. And the present writing heads are only able to magnetize mother tapes which have similar coercivity. Therefore it is impossible in magnetic contact printing to use metal copy tape which has coercivity of 1400 Oe.

This is why we adopted as the copy tape balium-ferrite tape which has been recently developed and has high output characteristics in high-frequency range with a lowcoercivity.

4) Method of applying the bias magnetic field

At the beginning of our work, we used a ring head to apply the bias magnetic field parallel to the length of the tape. We found, however, that when we used barium-ferrite tape as the copy tape, in spite of this tape's low coercivity, a high bias magnetic field was required, resulting in demagnetization of the mother tape and a printed tape with a low output level.

Our solution was to apply the bias magnetic field perpendicular to the surface of the tape in order to reduce the demagnetization of the mother tape. In addition, we used soft magnetic iron for the printing drum in order to increase the perpendicular component of the bias magnetic field. Fig.4 shows the difference in bias magnetic field obtained using a conventional printing drum and a soft magnetic iron printing drum, as obtained by the finite element method. Fig.5 shows the significant improvement in demagnetization of the mother tape and the increase in output of the printed tape as brought about by the adoption of the new printing drum. Fig.6 shows the improvement in demagnetization of the mother tape with repeated printings.

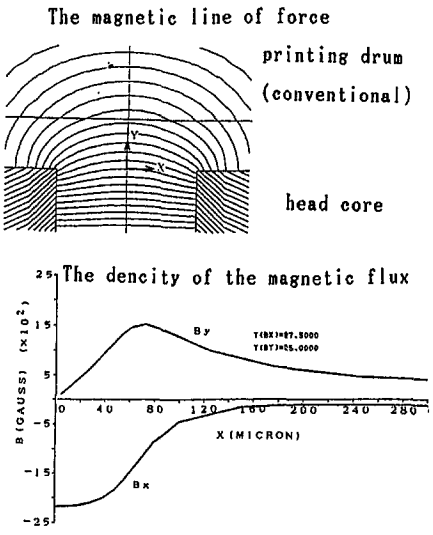

Fig.4-1 Using a conventional printing drum

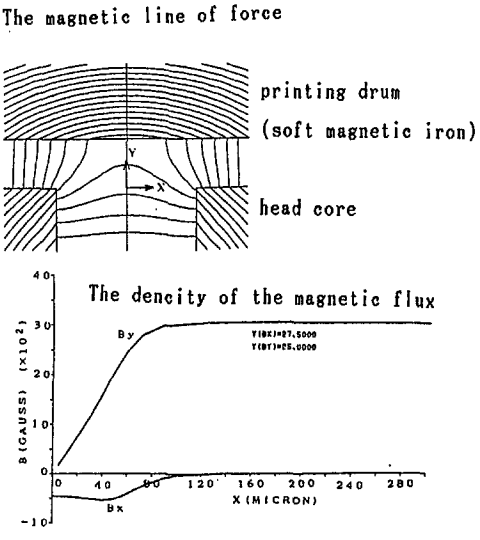

Fig.4-2 Using a soft magnetic iron printing drum

Fig.4 The bias magnetic field obtained by F.E.M.

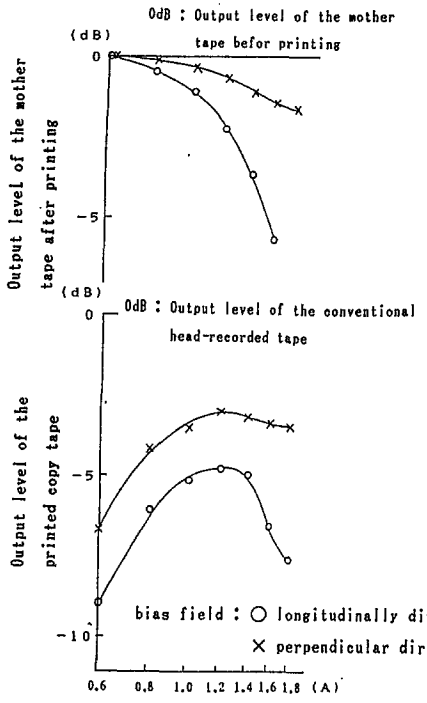

Fig.5 demagnetization of the mother tape and output level of the printed copy tape. ($\lambda = 0.67\mu m$)

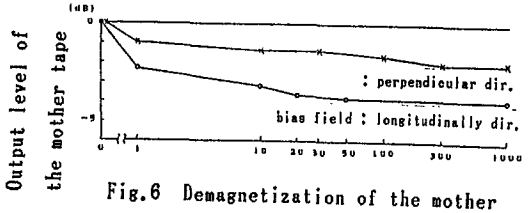

Fig.6 Demagnetization of the mother tape with repeated printing

5) Printing performance

Next, we show the performance of our contact printing system.

○Signal output level of the printed tape

Table Ⅲ shows the characteristics of the newly developed mother and copy tape.

	Hc (Oe)	Bm (G)	material
mother	2000	3500	metal powder
copy	620	1500	barium ferrite

Table Ⅲ Mother and Copy Tape Characteristics

Using those new tapes the output at the short wavelength of 0.67μm is 3.5dB lower than that of conventional head-recorded copy tape.
This is not a problem, because the pre-recorded format of the DAT has a wide track-pitch mode with a 3.5dB margin.

The playback characteristics of contact-printed tape and head-recorded tape are different. The ATF signal of contact-printed barium-ferrite tape is weak because the ATF signal is very low frequency (130KHz). Because of this the ATF signal of the mother tape must be emphasized.

○Error rate of printed tape

The average block-error rate before correction is less than 10^{-3} and the reproduced signal is fully corrected and stable.

○Envelope fluctuation of printed tape

Envelope fluctuation of signal output was 1.5dB p-p, a little larger than that of conventional head-recorded copy tape, but this difference is not significant in practical use.

○Track pattern linearity of printed tape

The track linearity of printed tape was less than 3 μm p-p .
This is sufficient for practical use.

○Specifications of the printer

Basic specifications of our printer are shown in Table Ⅳ.

Tape Width	3.81 (mm)
Bias Head	Ferrite Ring Head
Frequency of Bias Field	200 (KHz)
Contact Pressure	4 (Kg/cm)
Printing Speed	4 (m/s)
Rewinding Speed of Mother Tape	6 (m/s)

Table Ⅳ Basic Specifications of the Printer

System Construction

Following components are needed when making pre-recorded tapes using the present method: PCM source, signal processor, mother recorder, printer, and cassette loader.

We are now developing a signal processor, mother recorder and printer --- a complete DAT Contact Print System.

The PCM source playbacks audio PCM signals.
The signal processor translates the PCM signal of the source into the PCM signal of the DAT, inserts the sub-code of the DAT into the PCM signal, generates the ATF signal for the wide track-pitch mode, controls the function of the source, and can control multiple mother recorders.

The mother recorder records the mirror pattern of the DAT format on high-Hc metal tape. Its head drum has the opposite gradient of the usual DAT, and we use Sendust as the writing-head material because of its high Bs. The mother recorder records the cue signal for printer and cassette loader use. The mother recorder indicates the error rate during recording, so the quality of the recording can be monitored.

Fig.7 shows the connection of PCM source, signal processor and mother recorders .

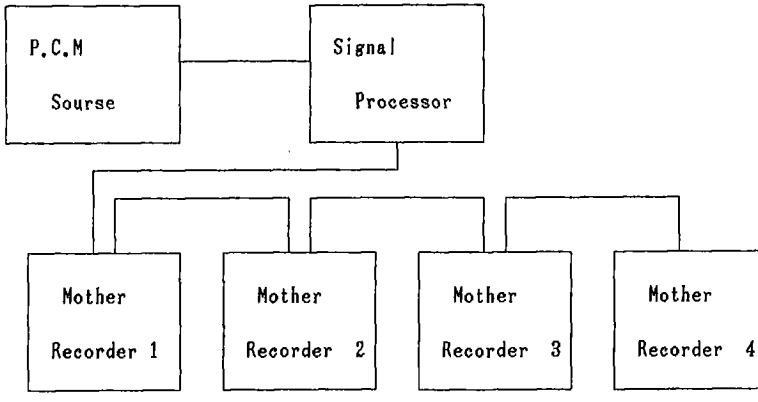

Fig.7 Connection of recording.

Fig.8 shows the printer.
This is similar to Sony's half inch VCR printer.
The printer prints pre-recorded tape 150 times as fast as conventional head-recording even considering loss time such that required for rewinding of the mother tape and shifting of the printing drum, in order to permitt rewinding. The mother tape can be used more than 3000 times.

The cassete loader winds the printed tape onto cassettes.

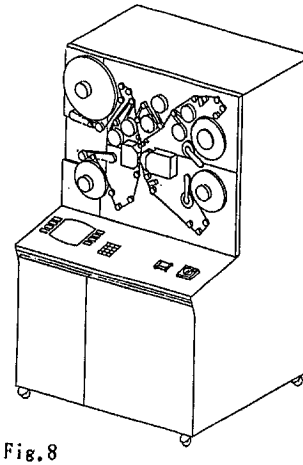

Fig.8

Acknowledgement

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References

1. T.Nagaki et al, "Magnetic contact duplication for R-DAT with Barium Ferrite media",HR-06 Inter Mag.1986.
2. K.Odaka et al, "Format of pre recorded R-DAT tape and results of high speed duplication", I.E.E.E I.C.C 1986.