ON THE SYSTEM DESIGN AND THE SIGNAL PROCESSING OF A ROTARY HEAD DAT

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ABSTRACT

A rotary head direct digital recording method is known to be able to achieve very high packing density in principle by almost ten times over stationary head recording.
The authors have developed a proto-type model of a Rotary-head Digital Audio Tape recorder (R-DAT) using a small size cassette based on experimental specification of DAT conference. The proto-type model has been designed conforming to the currently used three major sampling rates: 48/44.1/32 KHz, and also providing recording/reproducing capability for sub-code data consisting of item number of music pieces,elapsed time,and so on.
This paper mainly describes the system design and the signal processing of the developed R-DAT system.

1. INTRODUCTION

Compact Disc(CD) players with only a playback function have been widely used as consumer use digital audio equipment. Moreover, a Digital Audio Tape recorder (DAT), which uses a small cassette as a recording medium, is expected to replace the conventional compact cassette tape recorder, and a DAT conference was formed in June, 1983 to establish its specifications.
About 80 domestic and overseas makers have discussed and examined a standard format for over 1 year, and the experimental specifications both for a rotary head DAT (R-DAT) using the helical scanning method, and for a stationary head DAT (S-DAT) using the multi-track recording method, were decided upon in August, 1984.
The authors have developed a proto-type model of R-DAT based on this specification, and this report describes the outline of its system design and signal processing.

2. OUTLINE OF R-DAT SYSTEM

The R-DAT system is highly regarded, not only for high quality audio characteristics, but also for its small size, light weight, facility of use, and the many additional functions for which it can be used, giving applications from general audio to hi-fi audio.
Table 1 shows an outline of the system, Fig.1 shows the track format.

Features of R-DAT are as follows.

(a) High recording density(129 $MBPI^2$) is obtained by a narrow track and guardbandless recording method.

(b) 30ϕmm drum diameter and 90° wrap angle are great advantages in making the equipment compact, permitting a rapid access music search system, keeping the tape in contact with the drum.

(c) System parameters are selected conforming to the three major sampling rates, currently used in the world : 48/44.1/32KHz.(44.1 KHz mode is used for playback only)

(d) After-recording of the PCM signal and the sub-code signal, one before or after the other, is possible by recording the PCM signal, sub-code signal, and ATF signal for tracking, on independent areas of a track.

(e) Many functions can be added by using the sub-code signals which have a capacity of 273 KBPS (about 4.6 times a CD sub-code capacity).

(f) The cassette is about half of the conventional compact cassette size, and can record 2 hours of information.

3. SYSTEM DESIGN AND SIGNAL PROCESSING

3-1 OUTLINE OF SYSTEM CONSTRUCTION

Fig.2 shows the system construction of a proto-type model.

The 2-channel audio signal is processed through a low pass filter (LPF), analog to digital converter, encoder, and modulator. Then an ATF signal is added, and the final signals are recorded on the tape through the recording amp, and rotary transformer.

In the playback mode, the reproduced signal from the head is processed through the playback amp, equalizer, signal detector, demodulator, decoder, digital to analog converter, LPF, and output as a 2-channel analog signal.

Memory is used for interleaving and companding the time base. The servo block controls head tracking using reproduced ATF signal and revolution of both reel motor and drum motor.
The system control circuit controls the system operation, time display, and rapid access music search system by using a micro-computer which uses key input and sub-code information.

3-2 MODULATION, DEMODULATION

The modulation method for the system shoud have the following characteristics:

(a) The DC component should be excluded for recording and reproducing through the rotary transformer.

(b) Tmax/Tmin should be as small as possible for overwrite erasing.

(c) Tmax should be as small as possible for clock recovering.

As a method which has these characteristics, an 8-10 modulation method is employed in the R-DAT.
In this method, successive data bits are divided into groups of 8 bits, and each group is converted into 10 channel bits based on the algorithm so as to suppress the DC component, and Tmin and Tmax are 1 and 4 channel bits, respectively.
At demodulation, each channel data unit of 10 bits is converted into an 8-bit data unit through a conversion table.
Fig.3 shows the eye pattern of the reproduced signal modulated by this modulation method.

3-3 ERROR CONTROL METHOD

As an error correction method, this system employs the doubly encoded Reed Solomon code, which has powerful error correction capabilities, and two-track completed interleaving, which has strong interpolating capabilities.

3-3-1 INTERLEAVING

As shown in Fig.4, the L and R channel data samples are divided into even samples and odd samples, and the data for one channel is disposed diagonally across the track.
By employing this interleaving, high reliability of reproduced data can be obtained, as either even or odd samples will be correct, even if all samples recorded in a track are lost by head clogging, or all samples recorded in the area between tape edge and center of tape are lost.

3-3-2 CODE CONSTRUCTION

Fig.5 shows the code construction in a track, where the symbol means an 8-bit unit of data which is generated by dividing a sample of 16-bit data into upper and lower units.
As shown in Fig.5, data recorded on a track consists of four planes, and each plane is doubly encoded by C1 code and C2 code.
C1 code is constructed by (32,28,5) Reed Solomon code over $GF(2^8)$, and C2 code is constructed by (32,26,7) Reed Solomon code over $GF(2^8)$.

3-3-3 DECODING ALGORITHM AND ITS PERFORMANCE

Generally, a decoding algorithm has several variations. The authors employ an algorithm which has correction capability superior to that of a CD.
C1 decoder corrects up to two errors, and sets the C1 flag when over 2 errors occur.
C2 decoder corrects up to 6 erasures detected by C1 flags as shown in Fig.6.

Fig.7 shows random error correction capability.
Fig.8 shows burst error correction capability.

Measured block error rate was about 10^{-3} ,and correction was complete, with nocompensation for normal playback.

3-4 TRACKING METHOD

The tracking method of R-DAT is the ATF (Automatic Track Finding) method. The tracking error signal is generated from the difference of the crosstalk portions of the pilot signals which are recorded on the adjacent tracks on both sides; it controls the capstan motor rotation speed to bring the tracking error close to zero. With this system, the tracking error is within $\pm\mu m$.

3-5 RAPID ACCESS MUSIC SEARCH

Rapid access music search can be done by reading the data for music search from the reproduced signal, while keeping the tape in contact with the drum and running at high speed. In this system the drum motor rotation speed and tape running speed are controlled so that the relative velocity between the rotary head and the tape is constant, and it is possible to find the music search data with the tape running at about 200 times normal speed.

4. CONCLUSION

To sum up, the authors have described the outline of system design and signal processing of a proto-type model of the R-DAT.
R-DAT is far superior to the conventional compact cassette tape

recorder, due to its highly advanced performance, multi-function capabilities, easy operation, and smaller cassette size. For these reasons, we expect that the R-DAT will be used not only for audio signal recording but also for data recording with a large size memory (DAT-RAM).
The authors believe that the R-DAT is destined to take a leading position in the field of a newly emerging digital audio equipment.

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Table. 1. Outline of R-DAT system (Tentative)

Item		Contents
Tape Width	(mm)	3.81
Tape Speed	(mm/s)	7.200
Track Length	(mm)	23.508
Track Pitch	(μm)	12.0
Track Angle (Still)	(deg)	6°22′
Drum Diameter	(mm)	30
Drum Revolution Speed	(rpm)	2000
Writing Speed	(m/s)	3.134
Wrap Angle	(deg)	90.0
Number of Audio Channels		2
Sampling Frequency	(KHz)	48.0
Quantization	(bits)	16
Linear Recording Density	(KBPI)	61.0
Sub-code capacity	(KBPS)	273
Error Correcting Code		Doubly-Encoded RSC
Modulation Scheme		8-10
Trackig Method		ATF (area divided)
Cassette Size	(mm)	73x53x10.5

ATF : Automatic Track Finding
RSC : Reed Solomon Code

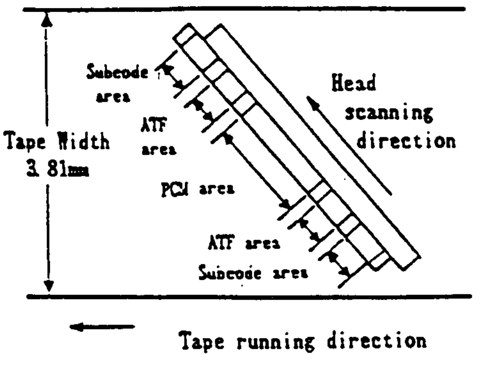


Fig. 1. Track format of R-DAT system

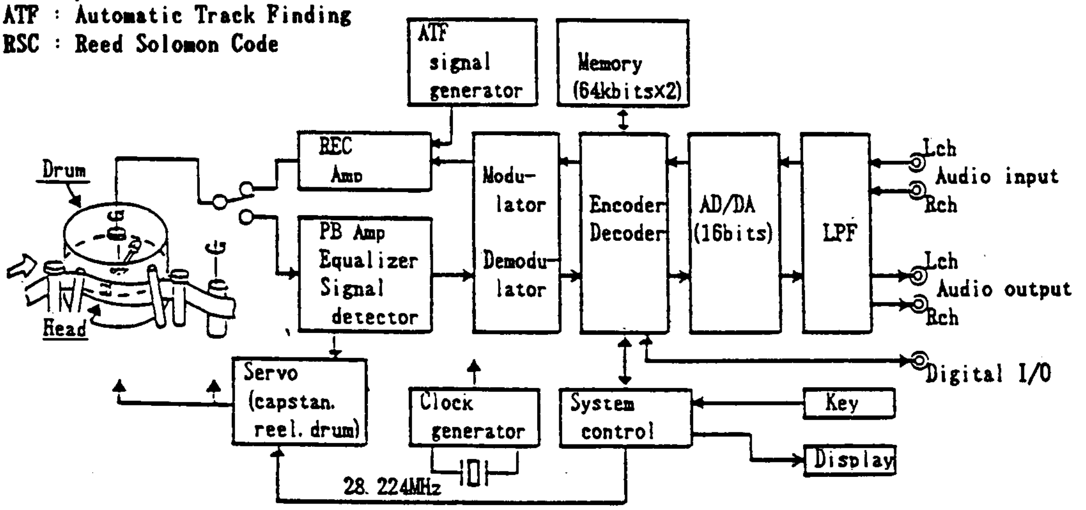


Fig. 2 Block diagram of R-DAT system

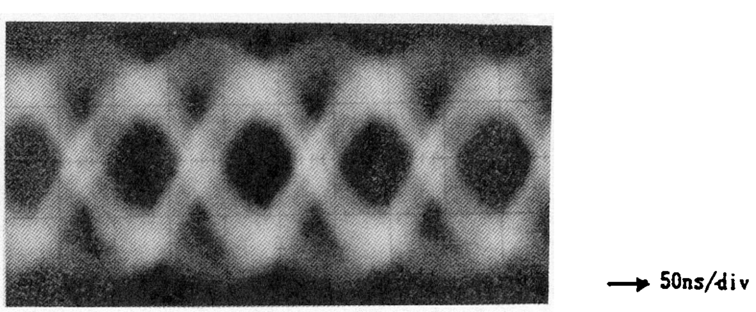


Fig. 3 Eye pattern

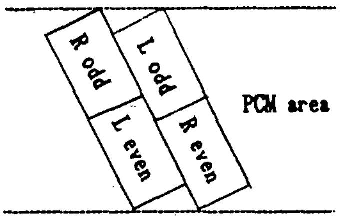


Fig. 4 Schematic representation of interleaving

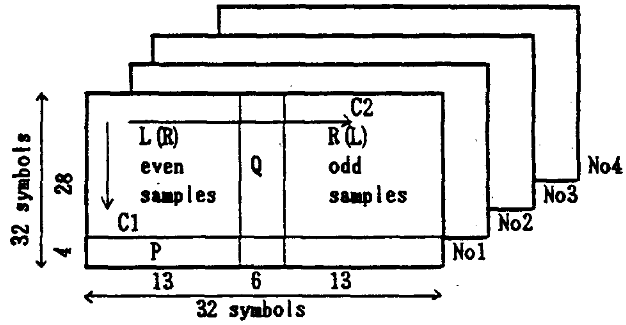
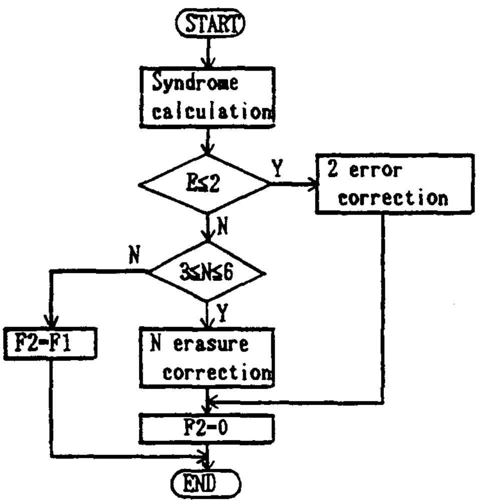


Fig. 5 Construction of code



where E : number of errors
N : number of C1 flags
F1 : C1 flag
F2 : C2 flag

Fig. 6. Decoding algorithm

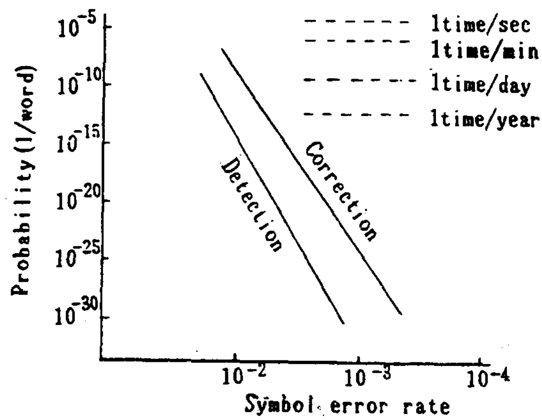


Fig. 7 Capability of random error correction

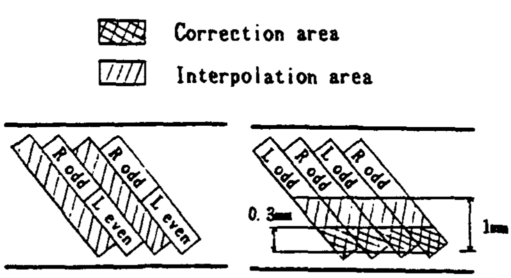


Fig 8. Interpolation and correction capability for burst error

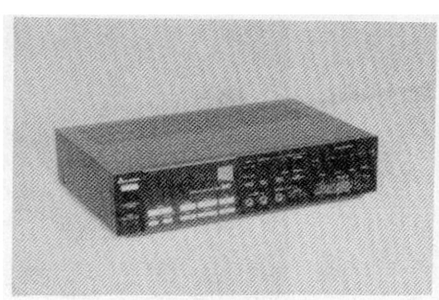


Fig. 9. Appearance of a prototype model