DIGITAL EQUALIZATION ON THE STATIONARY HEAD TYPE DAT

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Abstract

On the DAT, recording data are around 2.4MBPS as L and R channel signals at a 44.1kHz sampling rate. This is attained not only by dividing data into 20 tracks but also doing high density recording, 64KBPI. In this high density recording, equalization must be provided to the reproduced signals because of their intersymbol interference. We investigated the equalizer with digital signal processing. This equalizer is constructed using a transversal filter. In designing this equalizer we applied the mean-square error method to decide tap coefficients, assuming that the superposition of magnetic transition on tape is satisfied. First, details of this equalizer circuit and its decision method are mentioned. Then the experimental results are reported. As a result, superposition of impulse response is well satisfied and it is able to design the digital equalizer easily.

1. Introduction

On the stationary head type DAT, 20 tracks are provided as data tracks and a high density recording of 64KBPI of linear density is attained to record around 2.4MBPS PCM signal. Under these conditions there is much intersymbol interference in reproduced signals, so equalizaion of recording and reproducing characteristics is required to alleviate interference. We studied the equalizer using digital signal processing as shown in FIG.1. Digitalization has many advantages such as stability of characteristics, simplicity of setting parameters, and reduction of circuit scale by time-multiplex technique. To make the most of these advantages it is necessary to examine equalizing characteristics quantitatively, and here we report the results.

2. Recording and Reproducing Characteristics

FIG.2 shows frequency characteristics with a thin film head which is under development. PCM signals actually to be recorded are modulated by 8-10 codes. 8-10 codes are DC-free and run length-limited [(1) timing-window Tw=0.8T, (2) minimum runlength Tmin=Tw, (3) maximum runlength Tmax=5Tw as "T" means PCM data period before modulation]. While the track bit rate is 120KBPS (T=8.33μs), there is much intersymbol interference in reproduced signals (see FIG.3). To detect PCM data correctly, interference must be reduced so equalization must be provided in both amplitude and phase properties including characteristics of recording and reproducing head amplifiers.

3. Definition of Ideal Characteristics and Calculation of Tap Coefficients

Evaluation of the equalizer requires an investigation of the eye pattern at the equalizer output. We examined the shape of the eye pattern from the impulse response waveform based on Nyquist's criteria. First as Nyqyist's 1st criterion, FIG.4(a) shows the spectrum of impulse response of cosine roll-off characteristics Sa(f), and secondly, as Nyquist's 2nd criterion, FIG.4(b) shows that of impulse response defined by cubic function. Then we examined the spectrum using the following formulas (when $f1=1/2Tw$):

$$Sb(f)=\begin{cases}\cos\dfrac{\pi f}{2f_1}+S_2(f) & \text{for } 0\leqq f<f_1\\ S_1(f) & \text{for } f_1\leqq f<(1+K_0)f_1\\ 0 & \text{for } (1+K_0)f_1\leqq f\end{cases}$$

$$S_2(f)=\begin{cases}A_3(f_1-f)^3+A_2(f_1-f)^2+A_1(f_1-f)+A_0 & \text{for } (1-K_0)f_1\leqq f<f_1\\ 0 & \text{for } 0\leqq f<(1-K_0)f_1,\ f\leqq f_1\end{cases}$$

$$S_1(f)=\begin{cases}A_3(f-f_1)^3+A_2(f-f_1)^2+A_1(f-f_1)+A_0 & \text{for } f_1\leqq f<(1+K_0)f_1\\ 0 & \text{for } 0\leqq f<f_1,\ (1+K_0)f_1\leqq f\end{cases}$$

$$A_3=\frac{2A_0}{(K_0f_1)^3}-\frac{\pi}{4f_1(K_0f_1)^2},\quad A_2=-\frac{3A_0}{(K_0f_1)^2}+\frac{\pi}{2K_0f_1^2},\quad A_1=-\frac{\pi}{4f_1}$$

FIG.5 shows examples of impulse response waveforms and FIG.6 shows examples of eye patterns provided as in FIG.5 above. Comparing the provided impulse response with the actual impulse response equalized by the FIR filter shown in FIG.1, we calculated each tap coefficent using the following procedure so as to minimize the mean square error (when Td in FIG.1 is equal to Tw.):

(step 1) Sampling of both the positive and negative impulse responses 16 times during the sampling period, Tw/24[sec] and calculating their mean additive value in order to reduce noise.

(step 2) Reduction of DC offset of measured impulse response by calculating DC level of pulse edges. Processing of the impulse response with window function.

(step 3) Decision of tap coefficients which correspond with each parameter(K_0,A_0) according to the ideal impulse response.

4. Experiment Results

FIG.7 shows examples of impulse response and FIG.8 shows examples of eye patterns. FIG.9 shows the relation of K_0 vs. symbol error rate equalized in Nyquist's 1st criterion. FIG.8 shows that we were able to get good results.

5. Conclusion

We considered equalization and investigated to decide the tap coefficients by minimizing the mean square error between ideal impulse response on Nyquist´s criteria and actual impulse response. From the results of experiments, superposition of impulse response is well satisfied and quantitative investigation of equalizing characteristics is possible on the stationary head type DAT.

References

(1) W.R.Benett et al. "Data Communication", McGraw-Hill
(2) M. Tachibana et al. "Equalizaion in Digital Magnetic Recording", IECE, MR73-7, 1973
(3) J. Sugita et al. "A Data Detection Method for a Stationary Head Digital Tape Recorder", IECE, EA82-59,1982

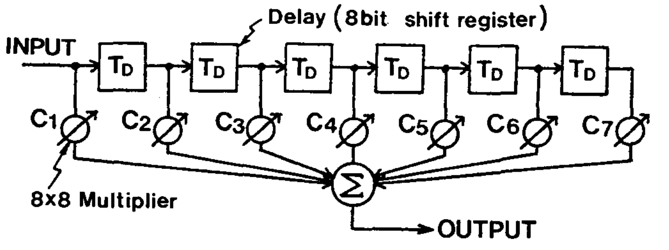


FIG.1 Block Diagram of Equalizer

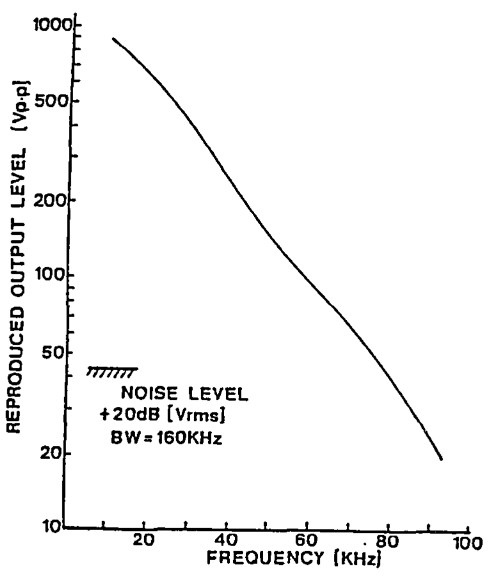


FIG.2 Frequency Characteristics

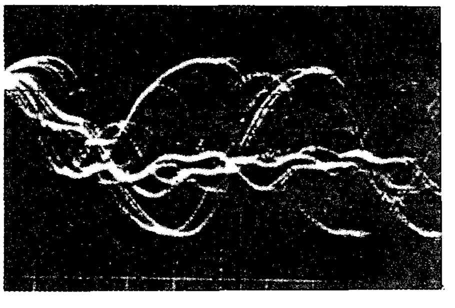
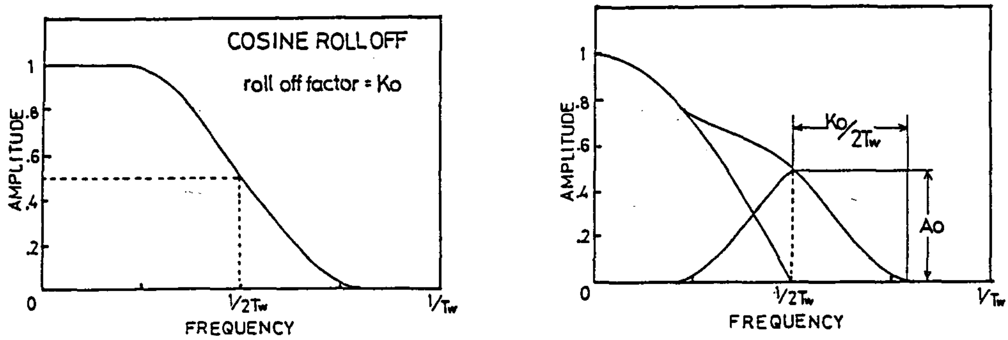


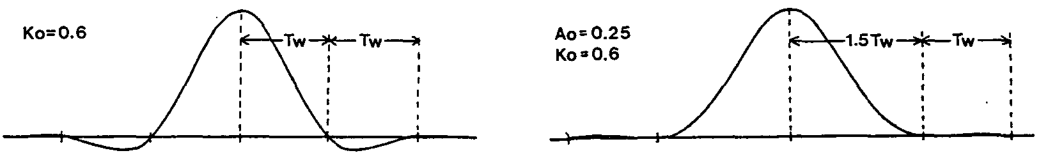
FIG.3 Reproduced Signal



(a) Nyquist's 1st Criterion

(b) Nyquist's 2nd Criterion

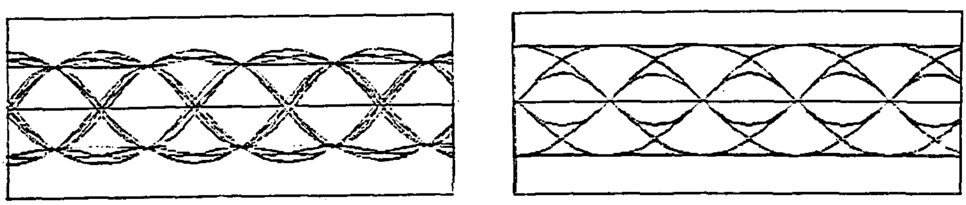
FIG.4 Spectrum of Impulse Response



(a) Nyquist's 1st

(b) Nyquist's 2nd

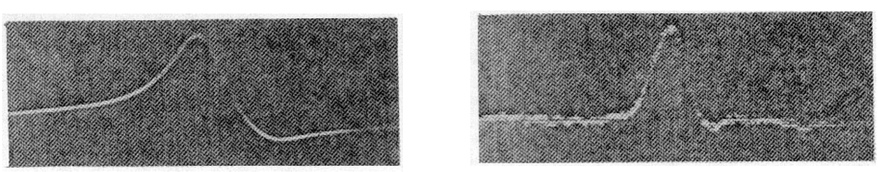
FIG.5 Impulse Response



(a) Nyquist's 1st K_0=0.6

(b) Nyquist's 2nd A_0=0.25 , K_0=0.6

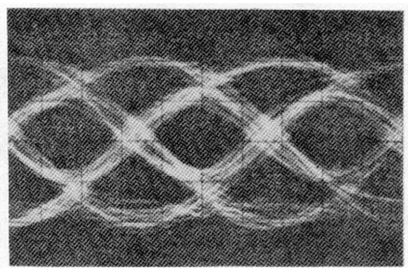
FIG.6 Eye Pattern

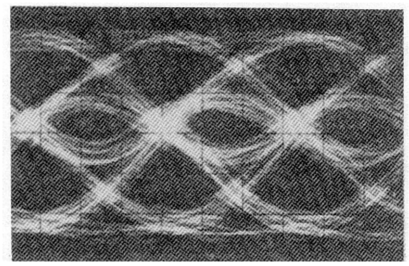


(a) Reproduced

(b) Equalizea

FIG.7 Measured Impulse Response





(a) Nyquist's 1st $K_0=0.6$ (b) Nyquist's 2nd $A_0=0.25$, $K_0=0.6$

FIG.8 Measured Eye Pattern

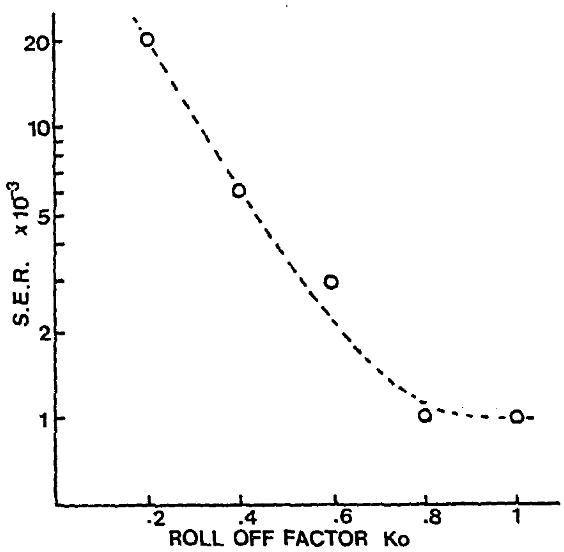


FIG.9 S.E.R. of Nyquist's 1st