CORRELATION BETWEEN TAPE DROPOUTS AND DATA QUALITY

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ABSTRACT

This paper will present the results of a study to correlate tape dropouts and data quality. A tape dropout is defined in the Telemetry Standards[1] as "a reproduced signal of abnormally low amplitude caused by tape imperfections severe enough to produce a data error" Bit errors were chosen as the measure of data quality. Signals were recorded on several tracks of a wideband analog instrumentation magnetic tape recorder. The tape tracks were 50 mils wide. The signal characteristics were analyzed when bit errors or low reproduce amplitudes were detected.

TEST SETUP

A block diagram of the dropout test setup is shown in figure 1. The digital oscilloscope was triggered when bit errors occurred or when the signal level dropped to a predetermined level. The digitized waveform was then stored on a floppy disk. Tests were performed with bi-phase level, noisy video, and predetection signals.

The bi-phase level signal was chosen because it has no DC component and at least one transition every bit. A bi-phase level signal consists of a series of pulses of width equal to either the bit period or one-half the bit period. When a bi-phase level signal is recorded and reproduced, a series of half-sine waves results (see figure 2). Therefore, the same signal can be used to measure bit errors and signal attenuation at upper bandedge (UBE) and one-half UBE.

A 500 kb/s bi-phase level signal was recorded at a tape speed of 30 inches per second (ips). The average signal amplitude per bit during the dropouts was measured for both the UBE/2 and UBE bit patterns. One interesting result was that the signal reduction at UBE/2 and UBE was nearly the same for the dropouts analyzed. This result is illustrated in

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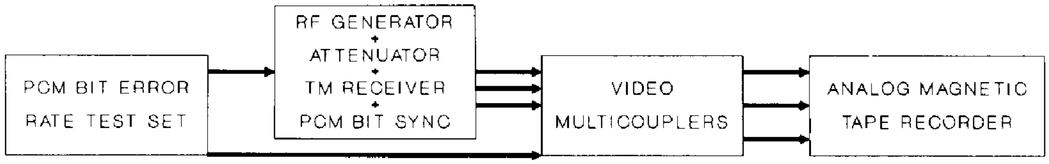
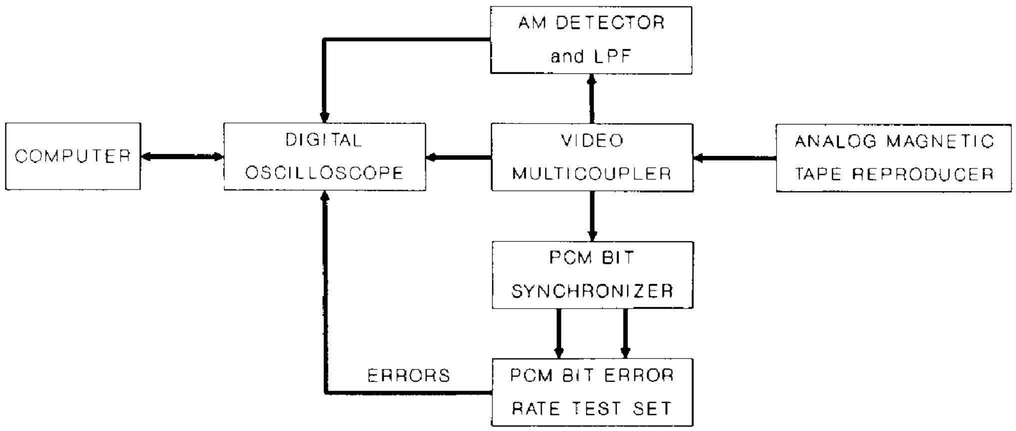


PCM DATA RECORDING



PCM DATA PLAYBACK

Figure 1. Tape Dropout Test Setup.

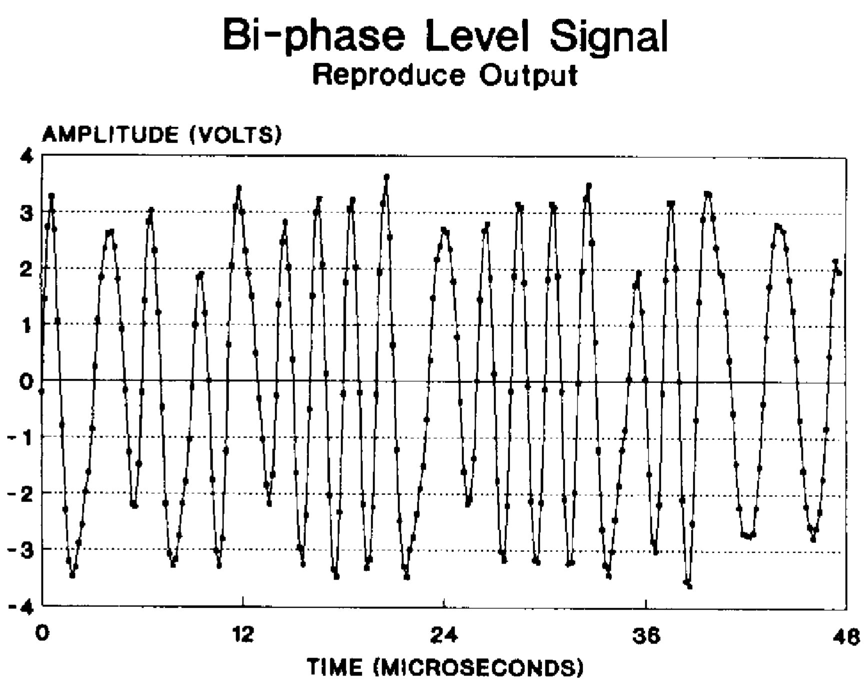


Figure 2. Bi-phase Level Signal.

figure 3. Wallace[2] found that the signal reduction due to effective head-to-tape separation during the reproduce process is 54.6 dB/wavelength. The empirical record loss factor[3] has been found to be about 45 dB/wavelength. Therefore, if the signal reduction at UBE/2 is 14 dB, the reduction at UBE should be 28 dB. In figure 3, when the amplitude of the UBE/2 bit pattern was reduced by ≈14 dB, the amplitude of the UBE bit pattern was reduced by only 15 to 17 dB. All of the dropouts detected in this portion of the study had nearly the same attenuation at UBE/2 and UBE. The variation of dropout depth versus wavelength was explored in more detail by recording the sum of three sine waves with very different frequencies.

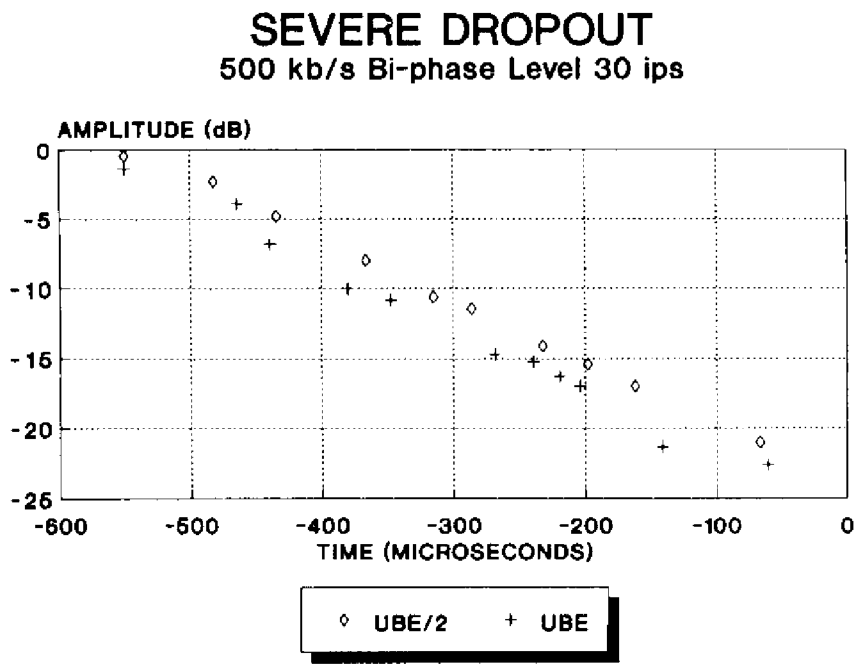


Figure 3. Attenuation for UBE/2 and UBE Bit Patterns.

SINE WAVE TEST RESULTS

The sine waves (39.1, 195, and 480 kHz) were recorded on several tracks of the recorder at a tape speed of 30 ips. The frequencies were picked so an integral number of cycles occurred in each 51.2 microsecond interval. The amplitudes of the two highest frequency signals were equal. The amplitude of the 39.1 kHz signal was one-tenth the amplitude of the other two frequencies. The reproduce output was connected to both an amplitude modulation (AM) detector and a digital oscilloscope. The AM detector output was used to trigger the digital oscilloscope when the reproduce level decreased to a predetermined level.

The signal amplitude changes during the dropout were measured by performing a series of 256-point fast Fourier transforms (FFTs). The FFT results were normalized by dividing the power in each time slot for each frequency by the average power of the same frequency before the dropout. This normalization eliminated differences due to imperfect amplitude equalization. These tests were performed with 2 dB over-bias and with no bias. The record level was slightly below saturation for the no bias tests. Typical results are shown in figures 4 and 5. The attenuation was nearly the same for all frequencies (slightly greater at higher frequencies). The dropout durations were longer (time below a given dB level) for the shorter wavelengths.

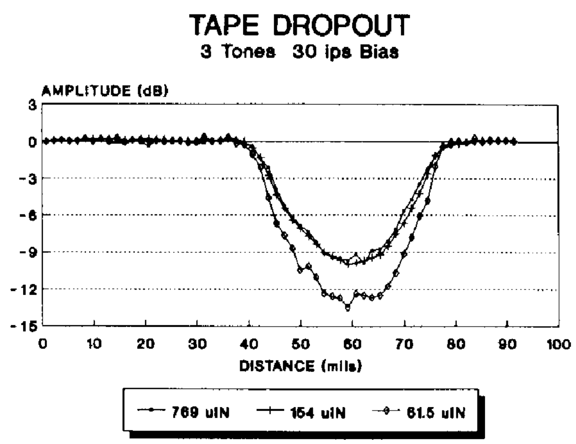


Figure 4. Attenuation for Three Wavelengths (+2 dB Bias).

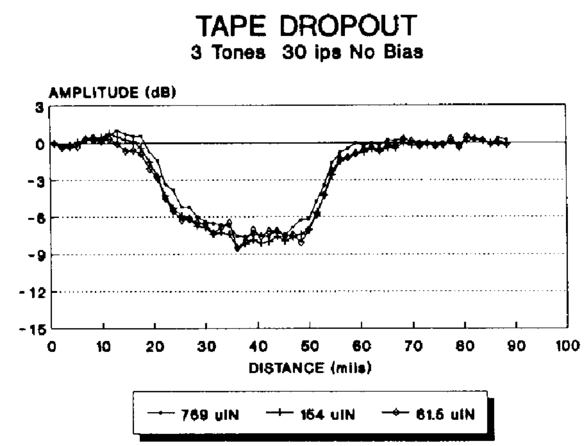


Figure 5. Attenuation for Three Wavelengths (No Bias).

If the tape is physically lifted off the reproduce head, the attenuation is much greater at the higher frequencies than at the lower frequencies. This effect is illustrated in figure 6. The data in figure 6 agree with the separation loss theory better than the data in figures 4 and 5 do.

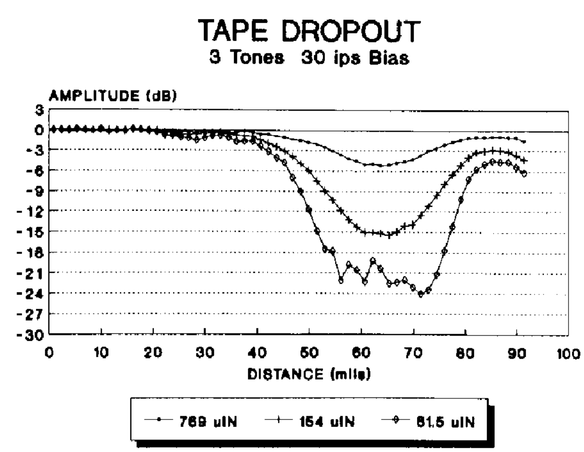


Figure 6. Attenuation for Three Wavelengths (Tape Lifted).

BI-PHASE LEVEL TEST RESULTS

Additional dropout tests were then conducted using 500 kb/s bi-phase level signals at a tape speed of 30 inches per second. The tapes were relatively new Ampex 795 tapes from the Defense Logistics Agency (DLA). Dropouts that cause bit errors only occurred every few thousand feet of tape. Most of these dropouts had a duration of 20 to 30 mils. The signals were digitized during the dropouts and the rms values were calculated every 8 microseconds (4 bits). A severe dropout is shown in figure 7. The locations of the first six bit errors are marked. The first bit error did not occur until the signal was attenuated by ≈18 dB in this example.

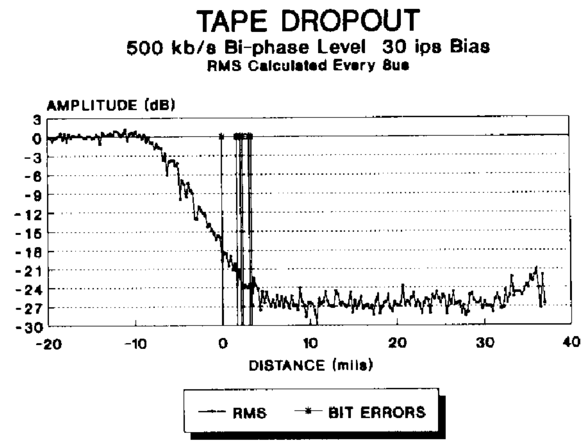


Figure 7. Amplitude and Bit Error Locations During Dropout.

TEST RESULTS WITH NOISY VIDEO AND PREDETECTION SIGNALS

Tests were then conducted with a pseudo-noise non-return-to-zero level (NRZ-L) pulse code modulation (PCM)/frequency modulation (FM) radio frequency (RF) link added to the test setup. The RF signal level was varied until between 1 and 10 errors occurred per million bits. The predetection carrier, receiver video, and bit synchronizer outputs were recorded on magnetic tape. The pseudo-noise pattern was nearly DC free (1024 ones and 1023 zeros every 2047 bits) and never had more than 11 bits between transitions. A circuit was built to trigger the digital oscilloscope whenever four bit errors occurred during a 256-bit window.

No error bursts were detected on the predetection tracks. The average bit error rate was approximately one-tenth of the error rate on the bi-phase level tracks. The reason for the lower error rate was that the playback intermediate frequency (IF) bandwidth was one-half of the pre-recording IF bandwidth. I estimate that a dropout depth of greater than 25 dB would have been required to cause a burst of errors on the predetection tracks. Severe dropouts do occur but fortunately they are rare.

The receiver video tracks had many burst errors. Figures 8, 9, and 10 show a dropout which caused 35 bit errors on a receiver video track. Figure 8 shows the variation in the peak-to-peak amplitude during this dropout. The peak-to-peak value over a 14-bit interval was used instead of the rms value because peak-to-peak is more accurate for NRZ-L signals. The first errors occurred when the amplitude was decreased by ≈6 dB.

Figure 9 shows the maximum, minimum, and average of maximum and minimum for each 14-bit interval. The variation in the average of maximum and minimum represents the baseline variation. The bit synchronizer has to track this variation accurately to properly decide ones from zeros. The baseline variation was at least as large during the dropout as before the dropout even though the peak-to-peak amplitude was reduced by a factor of three during the dropout.

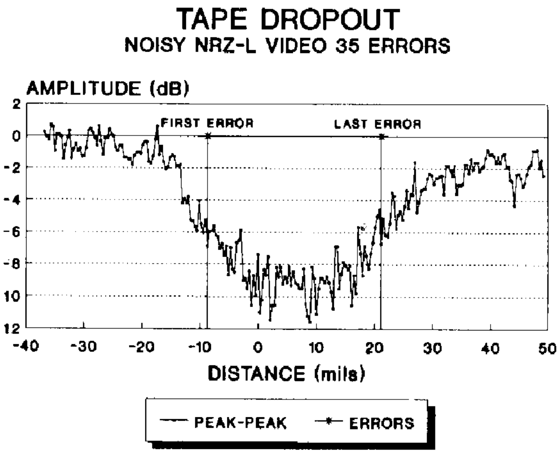


Figure 8. NRZ-L Video Tape Dropout.

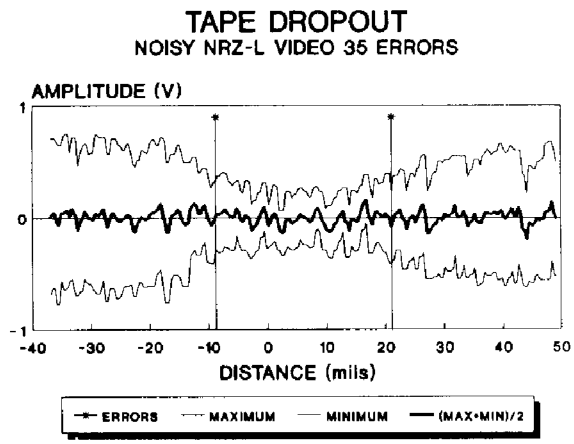


Figure 9. Maximum, Minimum and Average Signal Levels During Tape Dropout.

Figure 10 shows 200 bits during this dropout. Notice the baseline variation. Some bits do not make it to mid-scale (the nominal decision point between ones and zeros). Figures 9 and 10 show that the biggest cause of errors in this dropout was baseline variation. The bits could have all been detected correctly if the decision point was chosen properly for each bit interval. The nominal playback bit error rate for the noisy video was twice the bit error rate of the signal which had been detected and converted to bi-phase before recording.

CONCLUSIONS

All bit error bursts detected during this study occurred during tape dropouts (signal reduced by at least 6 dB). However, not all tape dropouts caused bit errors. Predetection recording had the greatest immunity to tape dropouts. However, the packing density was only one-half of the packing density with the other recording methods. The bi-phase level signals were also quite immune to tape dropouts. The noisy NRZ-L video signals were adversely affected by baseline variations which occurred during the dropouts. Noisy NRZ-L video signals are not usually a good choice for recording[1]. The dropout depth and duration were greater for short wavelengths than for long wavelengths. The dropout depth that will cause data errors depends on many variables including:

type of signal being recorded
recorded bit packing density

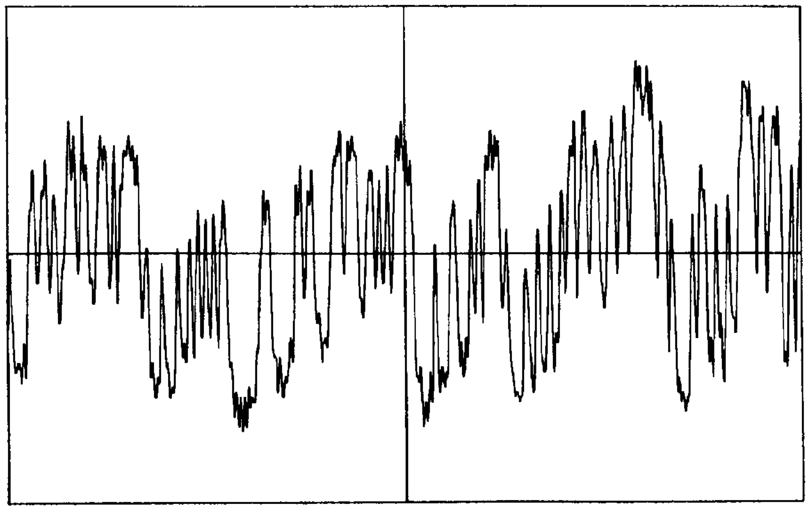


Figure 10. NRZ-L Video During Dropout.

quality of record and reproduce machines
accuracy of playback azimuth and equalizer adjustments.

Tape dropouts can be caused by several problems. The usual assumption is that most dropouts are caused by debris which create a physical separation between the head and the tape. The signal attenuation in decibels should be inversely proportional to the wavelength. The data measured in this study do not fit this model. Dropouts could also be caused by a lack of magnetic particles in a small region of the tape. I believe the loss could be nearly the same at all frequencies in this case.

REFERENCES

1. Range Commanders Council (RCC) Telemetry Group, Telemetry Standards RCC Document 106-86, Chapter 7, September 1989.

2. Wallace, R. L., "The Reproduction of Magnetically Recorded Signals," Bell Systems Technical Journal, 30, 1145 (1951).

3. Bertram, H. N., and R. Niedermeyer, "The Effect of Spacing in Magnetic Recording," IEEE Transactions on Magnetics MAG-18, 1206 (1982).