

FREQUENCY RESPONSE OF TAPE TRANSPORT SERVO SYSTEMS

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Summary. A method of measuring the frequency response of the tape servo system of analog magnetic tape recorder/reproducers is presented. The servo responses of three tape machines were measured using this method. The results of these measurements are shown to be in good agreement with the difference (in decibels, (dB)) between the flutter spectra in tachometer and tape servo modes. It is also shown that all three servo systems amplified some flutter components. Therefore if the flutter spectrum of the record machine is known, the total flutter can be reduced by carefully choosing the reproduce machine.

Introduction. The difficult conditions (spacecraft, ships, etc.) under which much data recording is done often makes the use of tape servo off recorded reference signals necessary, because the recording machine was either not running at a constant speed or not running at the correct speed. Since many tape servo systems amplify rather than attenuate certain frequencies of flutter¹, it is important to be able to measure the servo response of a tape recorder/reproducer. This paper presents a method for making this measurement. The results of this measurement are also compared to the difference (in dB) between the flutter spectra in tachometer and tape servo modes.

Test Methods and Results. The frequency response of the tape transport servo system was measured using a method proposed in an informal memorandum by Dr. M. H. Nichols*. Figure 1 is a block diagram of this method. A 100 kilohertz (kHz) signal is frequency modulated by a sinusoid of known amplitude and frequency. This creates a deterministic flutter component whose amplitude can be easily measured using a discriminator and a spectrum analyzer or wave analyzer. The usual flutter components of the tape recorder/reproducer will also be present at the discriminator output. Therefore, a narrow band filter must be used to measure the amplitude of the artificially induced component. The ratio of the output in tape servo mode to the output in tachometer mode is the measure of how well the servo system performs at that frequency of flutter. The

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measured servo responses of three tape recorder/reproducers are presented in figures 2, 3, and 4. All three servo systems are shown to have regions of flutter frequency where the servo system amplifies the modulating frequency.

The choice of the peak deviation of the simulated reference signal is very important. Reference 1 showed that laboratory analog tape recorders have many individual flutter components which cause deviations of between 1 hertz (Hz) and 50 Hz. The best choice of deviation is the largest one that is expected to be seen in practice, if this deviation is within the linear region of the servo system. The test can be run with the largest expected deviation and then repeated with a smaller deviation. If the servo response is approximately the same for the two tests, both deviations are within the linear region. If the responses are not the same at the frequencies where the large flutter components are expected, the servo system should be readjusted or a different reproducer used. Care should be taken to minimize the spurious modulation components (mostly multiples of 60 Hz). This test can also be performed using a flutter meter with a built-in wave analyzer (such as the MICOM 8300W) instead of the discriminator and spectrum analyzer.

In this study, the peak deviation of the 100 kHz voltage controlled oscillator VCO was 50 Hz with the exception that a 2.5 Hz deviation was used for recorder 1 for simulated flutter frequencies between 100 Hz and 300 Hz. At a peak deviation of 200 Hz, the servo loops of all three recorders were unstable over some band of modulation frequencies. Figure 5 is a plot of the flutter spectrum of recorder 1 with a 150 Hz modulating frequency and a peak deviation of only 50 Hz. This recorder was unstable at this combination of modulating frequency and deviation. This caused the large low frequency components. A comparison with figure 6 shows that these components were amplified by approximately 55 dB with respect to their normal level in tape servo mode. Therefore, a smaller deviation had to be used to get a valid measure of the servo response of recorder 1 at frequencies between 100 Hz and 300 Hz.

Reference 1 shows that even laboratory analog tape recorders can have individual flutter components which deviate the carrier by up to 50 Hz (recorder D of that study had such components at 165 Hz and 180 Hz). When a tape was recorded on recorder D and reproduced in tape servo mode on recorder 1, the servo system could not achieve proper lock. This caused the peak-to-peak (2σ) flutter to rise to 3% in a 10 kHz bandwidth (it was 0.3% in tachometer mode). Therefore, the tape servo mode should be used cautiously or else servo systems with large amplifications should be readjusted for more damping.

Tests were then conducted to check the validity of using the servo response (measured by the preceding technique) to predict the flutter spectra in tape servo mode. The flutter spectra of the three recorder/reproducers were measured in both tachometer and tape servo modes using a MICOM 8300W flutter meter in conjunction with an Electro-Mechanical

Research (EMR) 1510 spectrum analyzer. The differences (in dB) between the flutter spectra in the two modes were determined for several discrete flutter components and are plotted in figures 2, 3, and 4. These values agree quite well with the measured servo responses. Figure 2 also shows good agreement for a tape recorded on machine 2 and reproduced on machine 1. This verifies that the results of the proposed measurement method can be used to predict the flutter spectrum in tape servo mode. The departures at low frequencies are due to a combination of background noise and interchannel time displacement error. Since some flutter components are not stationary, care must be taken to choose spectral components which give consistent results for the flutter comparison.

Figure 6 is a plot of the flutter spectrum of recorder 1 in tape servo mode overlaid on its flutter spectrum in tachometer mode. The peak-to-peak (2σ) flutter in a 10 kHz bandwidth was 0.19% in tachometer mode and 0.20% in tape servo mode. However, the time base error was reduced in tape servo mode because the low frequency components are dominant in time base error. (Time base error is proportional to the integral of flutter.)

Conclusions. This study has shown that the flutter spectrum in tape servo mode can be predicted with reasonable accuracy if the servo frequency response and the flutter spectrum in tachometer mode are both known. This can be used to minimize flutter by reproducing a tape on a machine that does not amplify the main flutter components of the tape.

It was also shown that the servo systems of all three recorders used in this study amplified some frequencies of flutter. The servo system with the largest amplification was unstable when a tape recorded on another laboratory recorder was reproduced on it in tape servo mode. Therefore, the servo systems of tape recorder/reproducers with large amplification at some frequencies should be readjusted for more damping because they tend to be unstable in tape servo mode and cause an increase in total flutter.

Reference.

- 1) Law, E. L., "Analysis of the Power Spectral Density of Tape Recorder Flutter," Pacific Missile Test Center, Point Mugu, California, TP-76-7, 26 March 1976.

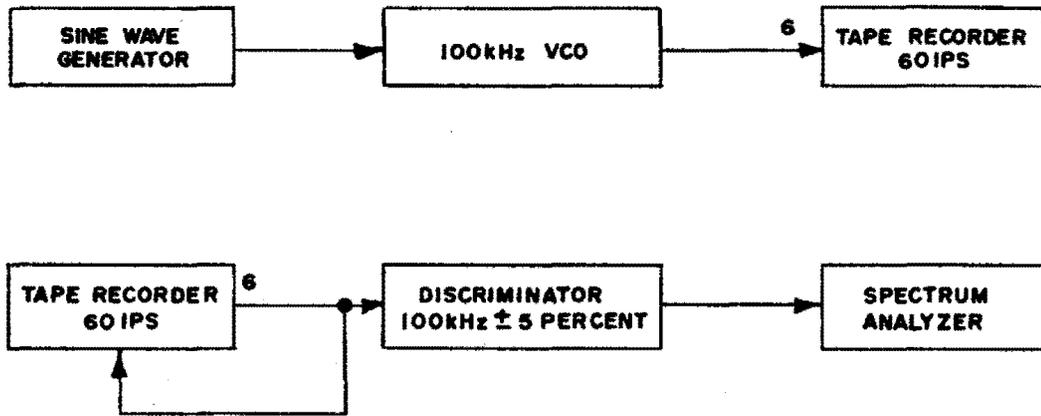


FIGURE 1 SETUP FOR SERVO RESPONSE TEST

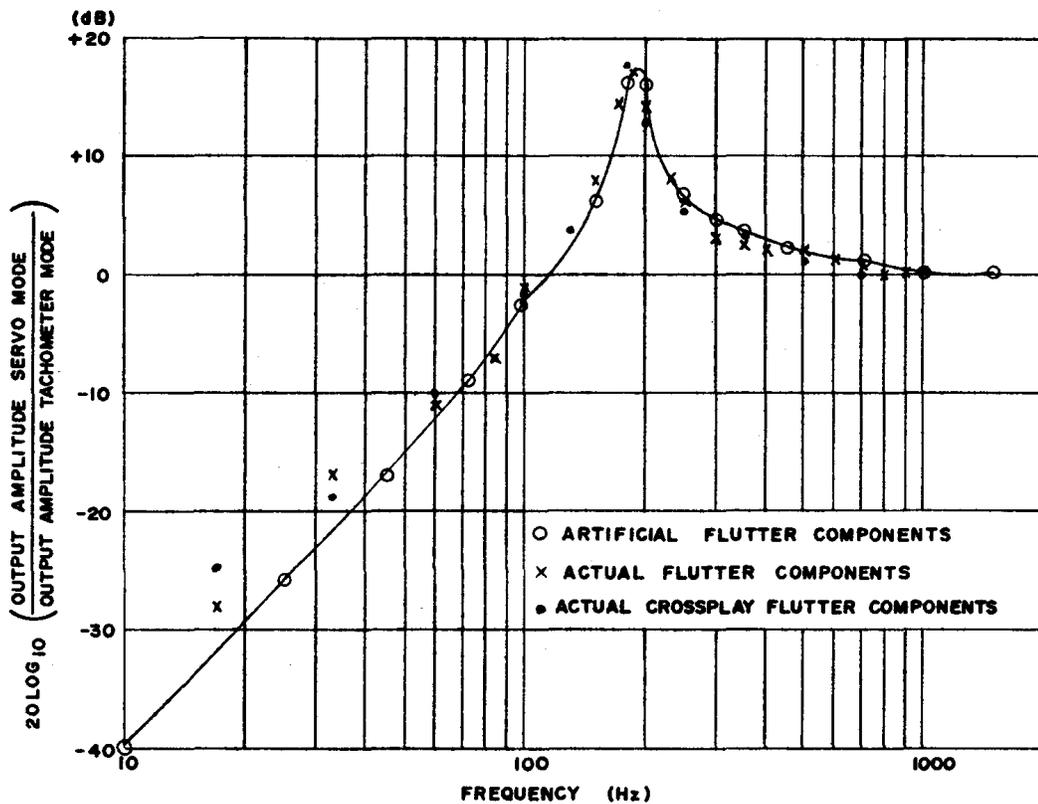


FIGURE 2 SERVO RESPONSE OF RECORDER/REPRODUCER 1.

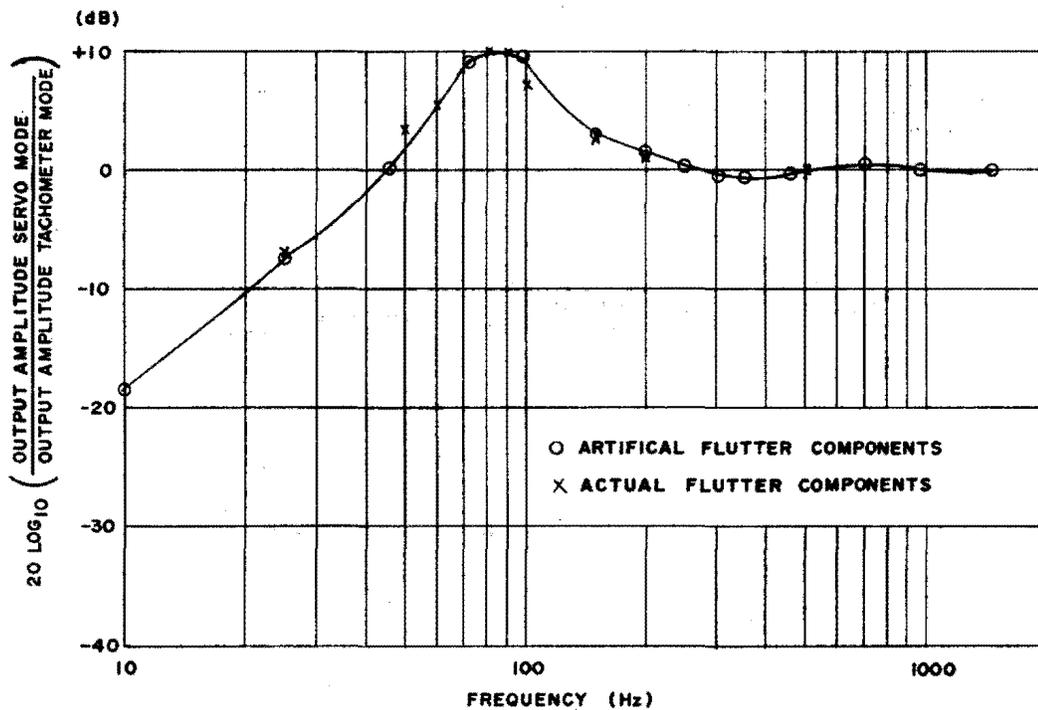


FIGURE 3 SERVO RESPONSE/ REPRODUCER 2.

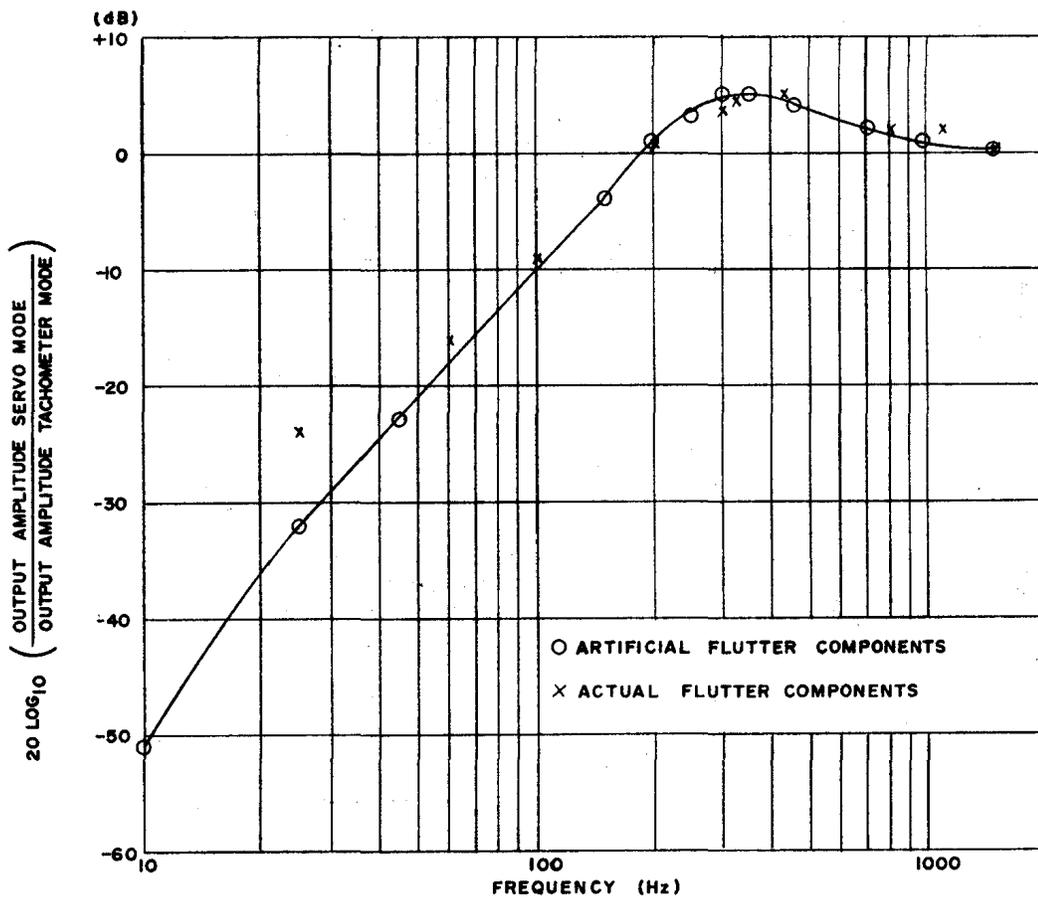


FIGURE 4 SERVO RESPONSE OF RECORDER/REPRODUCER 3.

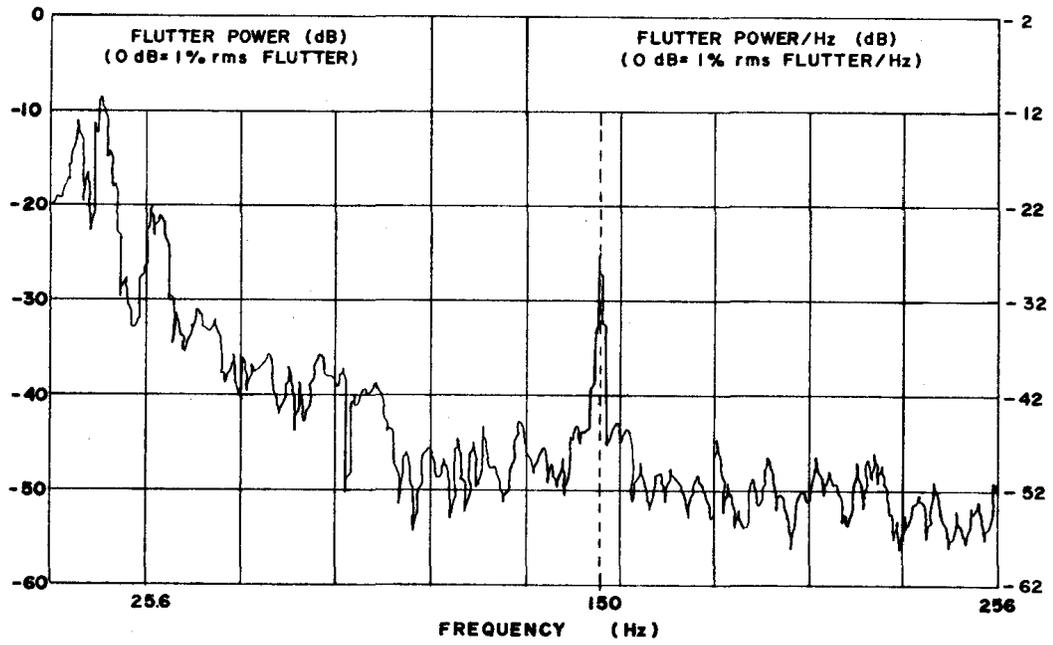


FIGURE 5 FLUTTER SPECTRUM OF RECORDER/REPRODUCER 1 IN TAPE SERVO MODE (UNSTABLE)

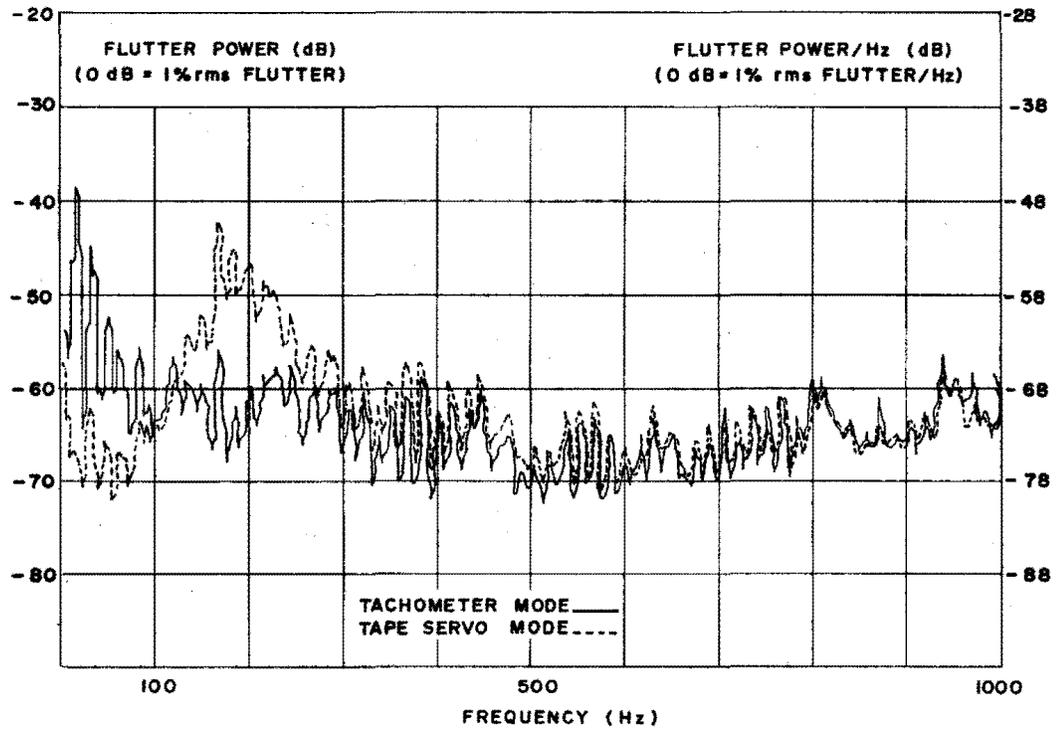


FIGURE 6 FLUTTER SPECTRA RECORDER/REPRODUCER 1.