DOUBLE DENSITY RECORDING ACQUISITION AND PLAYBACK

by

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SCOPE

This paper discusses signal performance of longitudinal Double Density acquisition recordings made an flight recorders and reproduced on a single laboratory ground station recorder. it includes comparisons with standard bandwidth recording signal performance.

INTRODUCTION

The technology for Double Density recording has been available to the user community of longitudinal instrumentation recorders since 1984. The impact of the technology an the user is the ability to either double mission time or double data rate capability. However, questions of reliability and compatibility between acquisition and ground station systems, plus the expectation of rotary class recorders, have been factors in the limited use of this technology. Advancements in head manufacturing quality and experience along with improvements in signal electronics have answered these questions.

GOAL

This paper is a report on the test results from an evaluation run on the signal performance of MARS and M14 longitudinal acquisition recorders when reproduced on a 3700J ground station or laboratory recorder. Our intent was

to establish an understanding of compatibility in Double Density recordings made with flight recorders and their ground station counter-parts.

We will first review some of the definitions of terms used in Double Density recording followed by an overview of our approach. The equipment used will be described along with a review of the test procedure. Test results will be shown in graphic form.

DEFINITIONS

Standard Bandwidth--33 kilobits/inch (kbpi) maximum packing density at up to 120 ips as defined by IRIG for Wideband data.

Double Density--a generic name for double the standard bandwidth (Wideband) packing density or 66 kbpi maximum packing density at up to 120 ips.

Half-speed--66 kbpi maximum packing density at one-half the standard bandwidth speed for an IRIG. data frequency range.

ex.1--the standard bandwidth MARS acquisition recorder has a top speed and frequency of 1 MHZ @ 60 ips. The half-speed version of this and the one used in this paper is 1 MHZ @ 30 ips.

ex.2--any standard IRIG recorder with a top speed and frequency of 2 MHZ @ 120 ips would have a half-speed version that would be 2 MHZ @ 60 ips.

Double Bandwidth--66 kbpi maximum packing density or double the IRIG frequency range at any of the standard bandwidth speeds.

ex.3--the MARS recorder in ex.1 above would have a double bandwidth version of 2 MHZ @ 60 ips. This is the double bandwidth acquisition recorder used in this paper.

ex.4--any standard IRIG recorder with a top speed and frequency of 2 MHZ @ 120 ips would have a double bandwidth version of 4 MHZ @ 120 ips.

Note: the 3700J recorder/reproducer used in the tests reported, herein, can be used for either double bandwidth or half-speed when configured in a Double Density made.

SNR (This Paper)--for the discussions in this paper SNR is the RMS signal to the RMS noise UNFILTERED. The purpose for this is to avoid confusion over different methods of filtering.

IN-LINE Double Density--the odd channels only of a 28 channel system.

APPROACH

Using a computer aided test system developed by DATATAPE engineering for frequency response and signal-to-noise evaluation, recordings were made on the acquisition recorders and played back on a baseline tested ground station recorder/reproducer. The results were plotted and compared without equalization adjustments. A second comparison was made after equalization was optimized for the acquisition recordings. Some additional comparisons were performed between standard bandwidth and Double Density recordings.

EQUIPMENT and TEST PROCEDURE OVERVIEW

Three different acquisition recorders were used to acquire the data with all tapes reproduced on one ground station recorder/reproducer. The recorders used are listed below:

Acquisition Recorders

- **MARS 1400LT-3B, 28 channel double bandwidth recorder**
- **MARS 1400LT-3B, In-line half-speed recorder**
- **M14ER, 28 channel standard bandwidth recorder**

Ground Station Recorder

- **3700J re-configured by head changes to support all of the acquisition recorders used.**

The computer aided test system used as the controller consists of a DATATAPE developed menu driven program with an HP 300 series CPU, color monitor, a 9153B disk drive, and a 7474A platter. The program allows for either read-while-write or reproduce only frequency response data which can be previewed on screen prior to either plotting or storing to disk.

In addition to the tape recorder/reproducers and the computer controller, some special test equipment was required. Below is a list of that equipment with brief descriptions:

Equipment Name/Number	Description
HP-3325A Synthesizer Function Generator frequency response.	Digital display signal generator for record signal
HP-3586C Selective Level Meter	Digital display signal level measuring meter.
Tektranics 7603 Oscilloscope	

The test procedure followed normal recorder alignment practices per IRIG 118-89. Some specific items of interest are:

- **All data was from direct bias recordings;**
  - **2% third harmonic distortion for all acquisition recordings.**
  - **1% third harmonic distortion for ground station baseline.**
- **All data is playback on the ground station reproducer from channels 5, 9, and 11 as they were the only channels configured the same on all recorders.**

- **Reproduce equalization is adjusted for flat frequency response with upper bandedge set intentionally at 2 dB below the 1 Volt rms system output level.**

- **Noise response data is time phased measurements in a 50 Hz to 40 MHZ bandwidth (effectively UNFILTERED). Time phased measurements are noise data taken in the same time interval it took to gather frequency response signal data. In other words multiple measurements over time. In the graphic presentations these measurements results in a straight line noise plot that represents unfiltered SNR.**

- **Two sets of reproduce amplifier cards of the same configuration were used, one set for standard bandwidth recordings and one set for Double Density recordings. The purpose was to keep the number of adjustments to a minimum.**

- **The same record cards were used in the ground station recorder for all baseline alignments regardless of bandwidth.**

- **All data was screen previewed and then stored on disk for later analysis and comparison.**

PERFORMANCE RESULTS and SPECIAL COMPARISONS

The first tests performed were baselining the ground station recorder/reproducer. This was done for standard bandwidth 14 track and 28 track system configurations. The data was only taken for system frequency response at 120 ips and 60 ips (2 MHZ and 1 MHZ top frequencies respectively). Results of the 14 track (50 mil track width) standard bandwidth performance yielded SNR ranging from 29 dB to 31 dB for both 120 ips and 60 ips tape speeds. Frequency response was well within IRIG ± 3 dB of 1/10 bandedge signal for all tracks at both speeds. The 28 track SNR results ranged from 26 dB to 28 dB at 120 ips and 27 dB to 29 dB at 60 ips. Frequency response was also well within IRIG specification for the 28 track configuration.

Figures 1 through 4 on the following pages show the complete standard bandwidth results graphically.

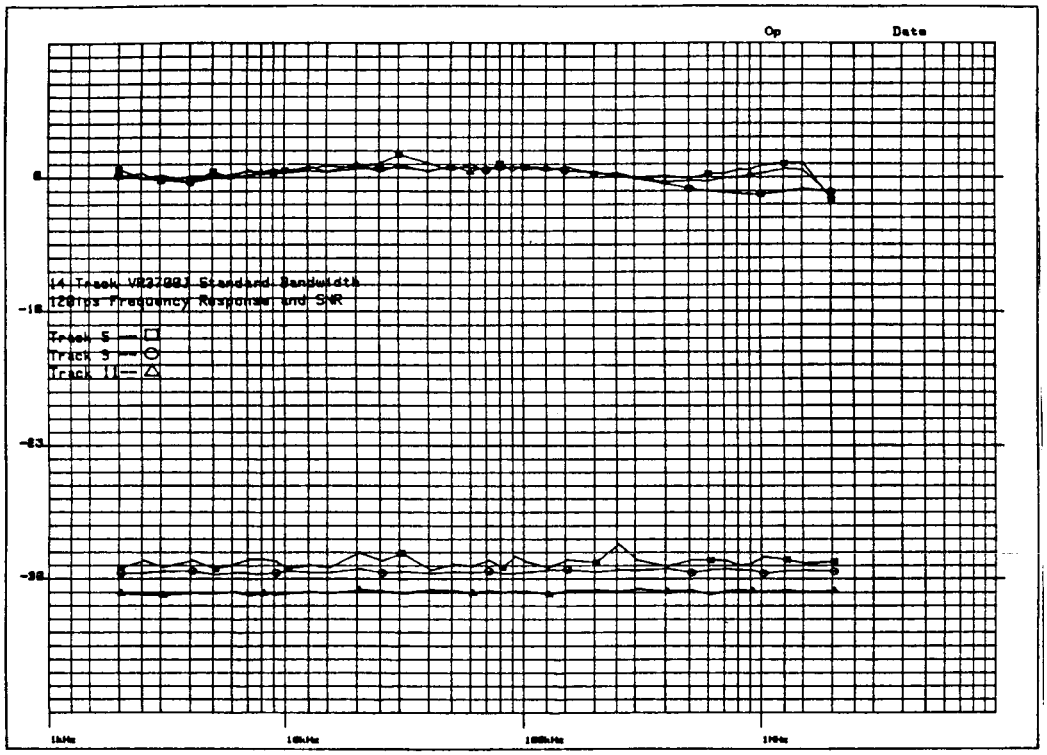

FIGURE-1. 14 Tk Ground Station Baseline 2 MHZ @ 120 ips

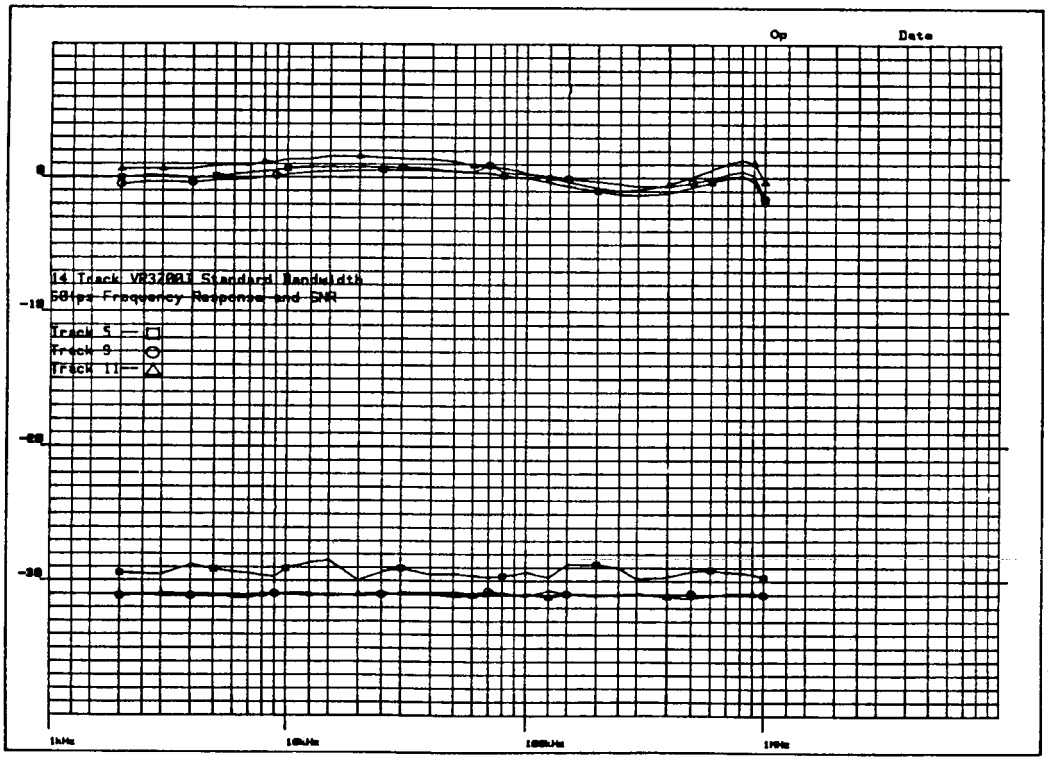

FIGURE-2. 14 Tk Ground Station Baseline 1 MHZ @ 60 ips

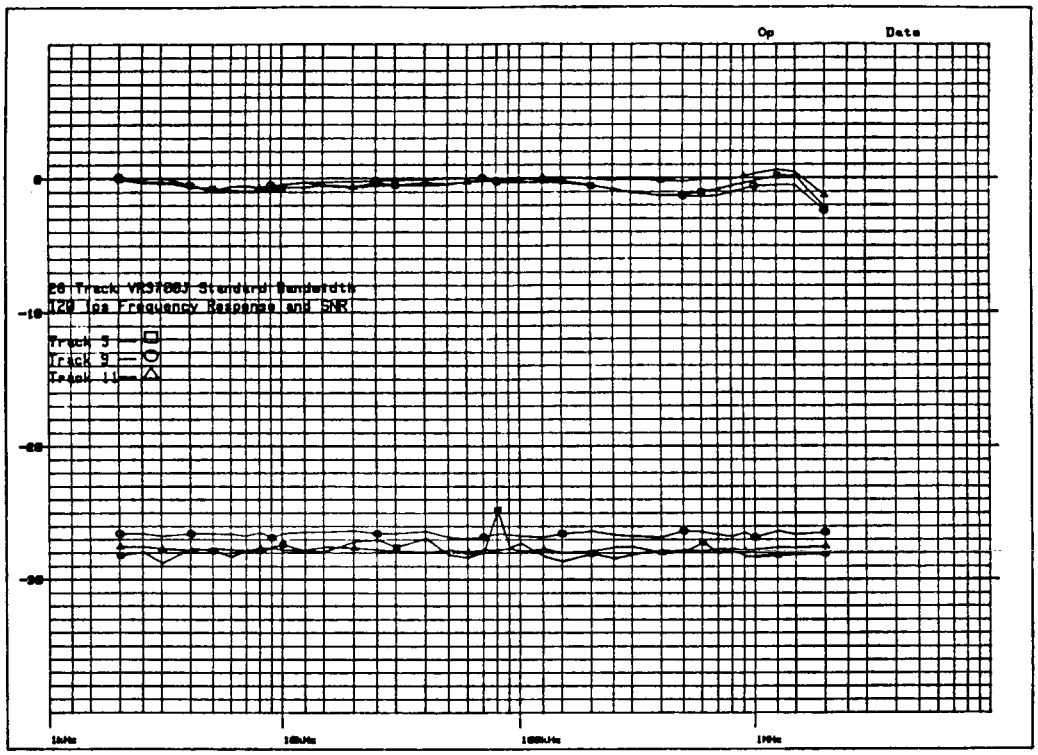

FIGURE-3. 28 Tk Ground Station Baseline 2 MHZ @ 120 ips

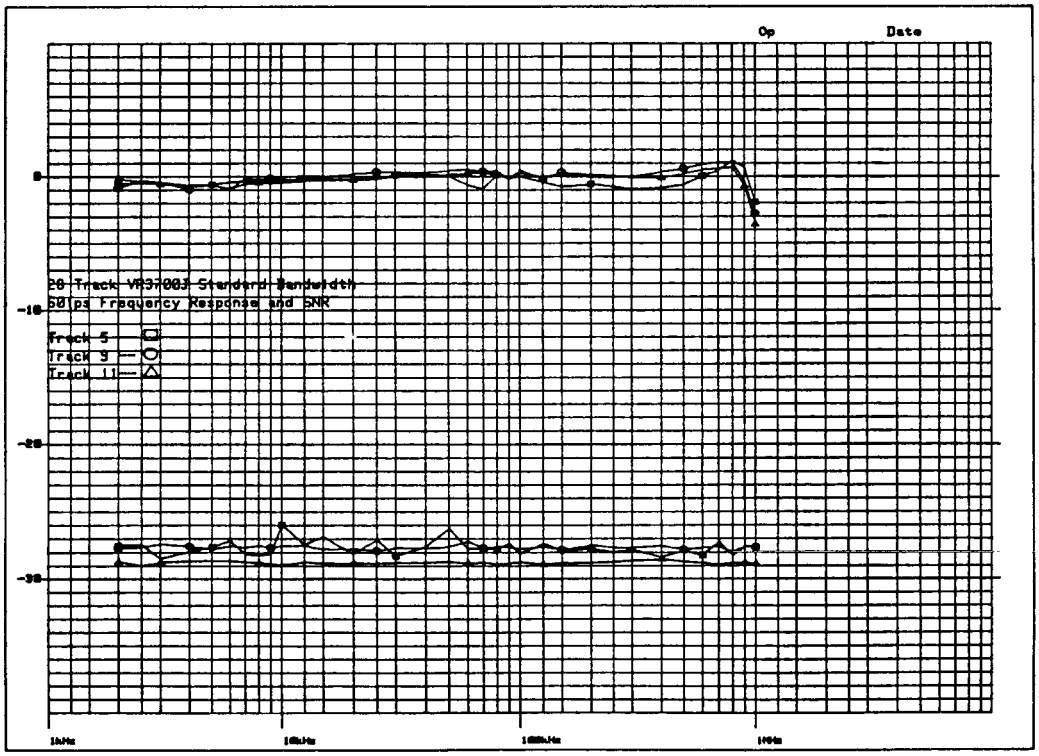

FIGURE-4. 28 Tk Ground Station Baseline 1 MHZ @ 60 ips

Baseline alignments were then made to the ground station system in Double Density mode. In this Configuration the frequency response and SNR data was taken for 60 ips and 30 ips (2 MHZ and 1 MHZ top frequencies respectively). With what will later be referred to double bandwidth (2 MHZ @ 60 ips acquisition), the SNR results ranged from 21 dB to 26 dB with frequency response well within IRIG requirements. One of the tracks appeared to have higher noise than the others. Because of time constraints we were unable to determine the cause. The data was, therefore, not excluded from this report. The half-speed (1 MHZ @ 30 ips acquisition) SNR results ranged from 23 dB to 26 dB with again the frequency response well within IRIG requirements. Figures 5 and 6 contain the detailed results.

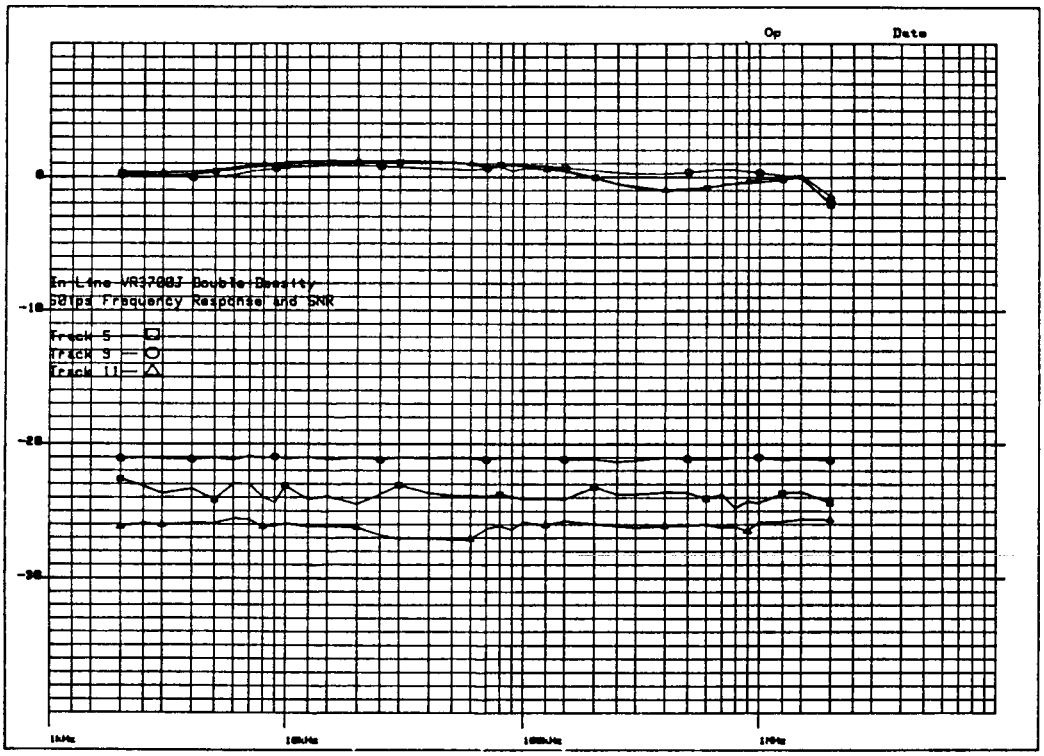

FIGURE-5. 28 Tk Ground Station Baseline 2 MHZ @ 60 ips

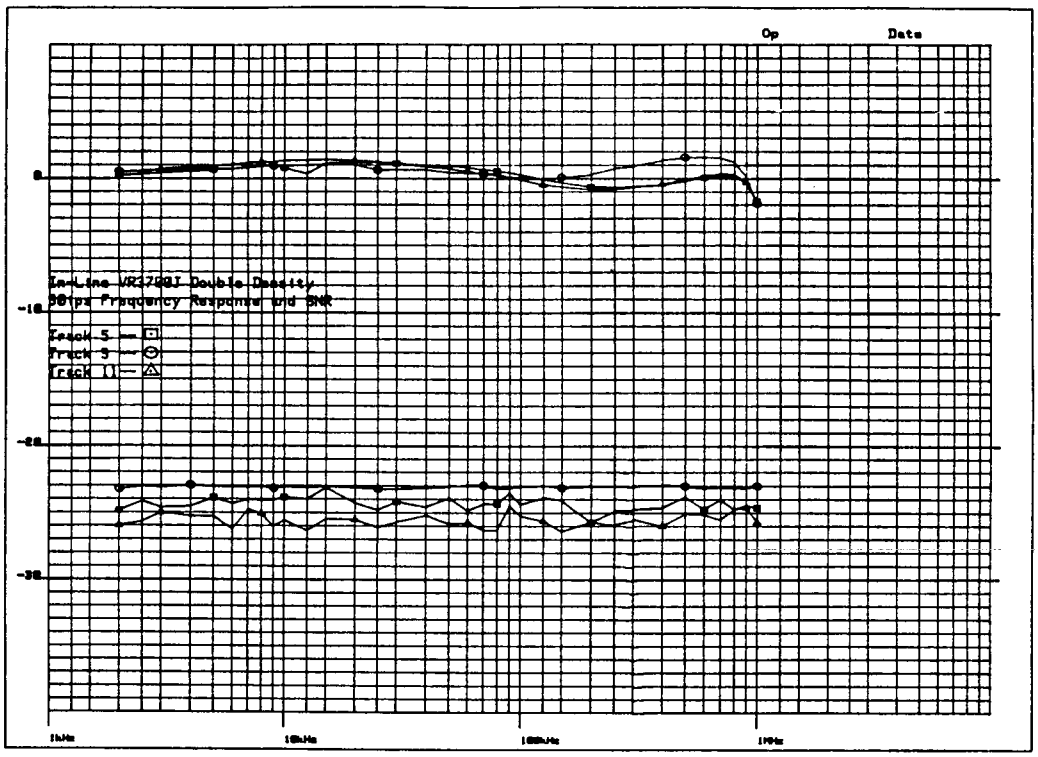

FIGURE-6. 28 Tk Ground Station Baseline 1 MHZ Z 30 ips

Upon completing the ground station performance baseline effort, we began the Double Density acquisition recording effort. The in-line half-speed acquisition recording was made first. Without rewinding the tape, it was removed from the recorder and put on the double bandwidth acquisition recorder. In order to determine compatibility with the ground station system, the recordings were first reproduced without any equalization adjustments. Figures 7 and 8 on the next page show that these recordings have low end response well above the nominal 1 Volt system output. The response begins to dip at 1/10 bandedge and then level out towards upper bandedge. This less than flat response is not unexpected. The 2% record level produces the higher output while differences in the record pre-emphasis between acquisition recorders and the ground station produce the difference in the response curve shape. It should be noted that the noise level is the same as it was for the baseline ground station alignment which is to be expected.

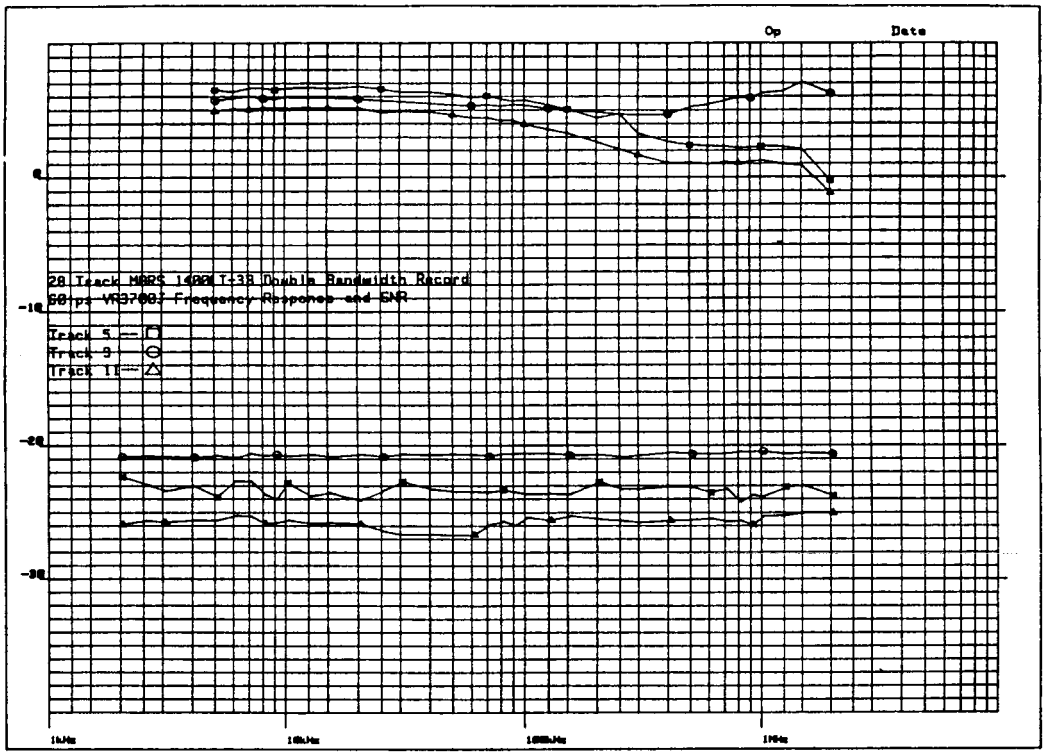

FIGURE-7. 28 Tk Acquisition 2 MHZ @ 60 ips-No Rep Adjustments

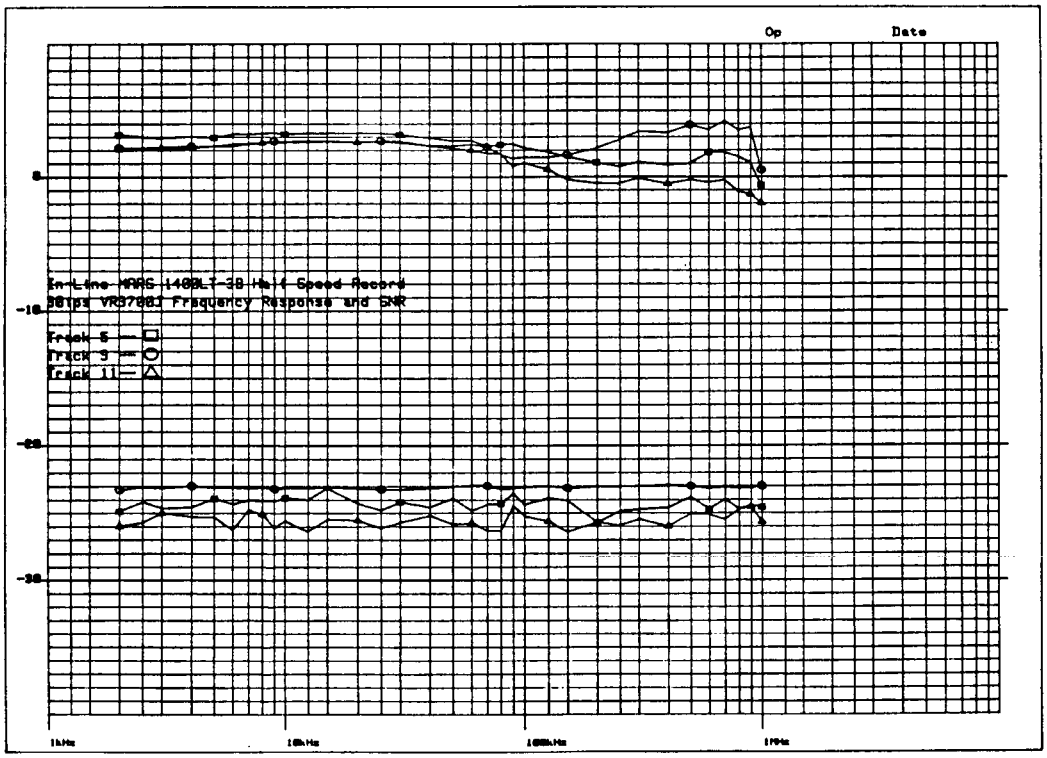

FIGURE-8. Inline Acquisition 1 MHZ @ 30 ips-No Rep Adjustments

However, when the tape was rewound and the equalization adjusted, the response curves were well within IRIG specification. The SNR fell in a range of 27 dB to 29 dB for double bandwidth and 26 dB to 28 dB for half-speed as shown in Figures 9 and 10.

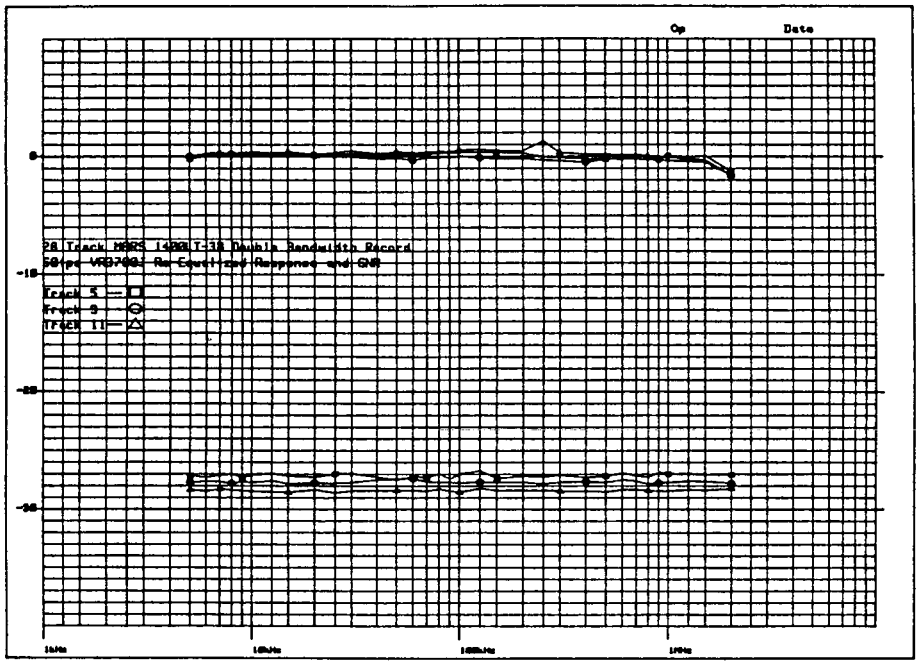

FIGURE-9. 28 Tk Acquisition 2 MHZ @ 60 ips-With Rep Adjustments

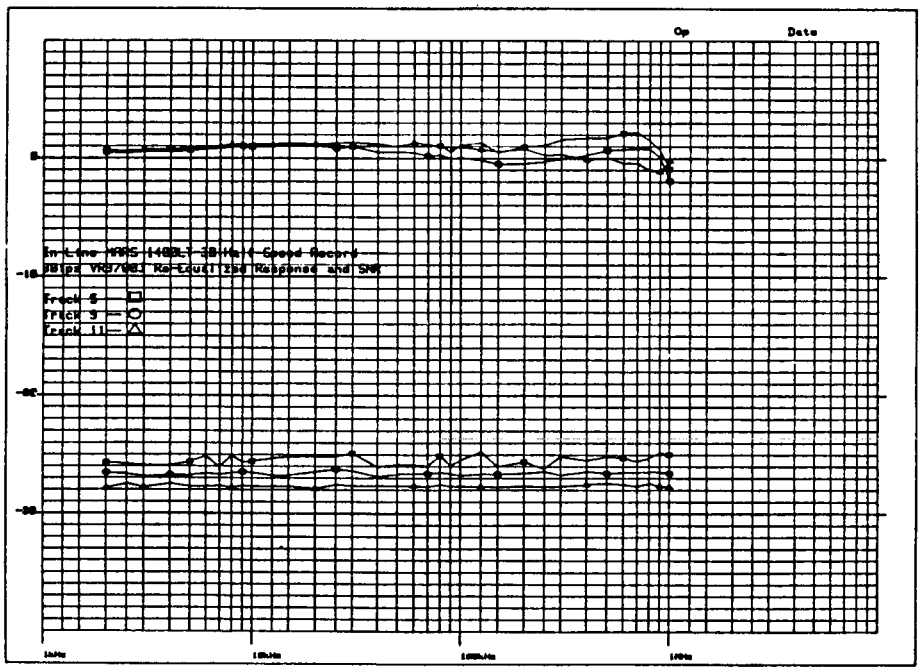

FIGURE-10. Inline Acquisition 1 MHZ @ 30 ips-With Rep Adjustments

The ground station standard bandwidth performance was compared to the acquisition recordings Double Density performance. In these comparisons, however, an aggregate track was used instead of all three tracks. This was done to simplify the graphic presentation and eliminate confusion. Figure 11 compares the acquisition double bandwidth recording (2 MHZ at 60 ips) to the ground station standard bandwidth (2 MHZ at 120 ips) results. The three curves are the acquisition recording before equalization adjustment, after adjustment, and the ground station response. It can be seen in this figure how the acquisition noise level improved when the equalization was adjusted. Effectively no difference in frequency response can be seen between the two recordings after adjustment of the double bandwidth levels. Only a 1 dB difference in SNR was seen after adjustment.

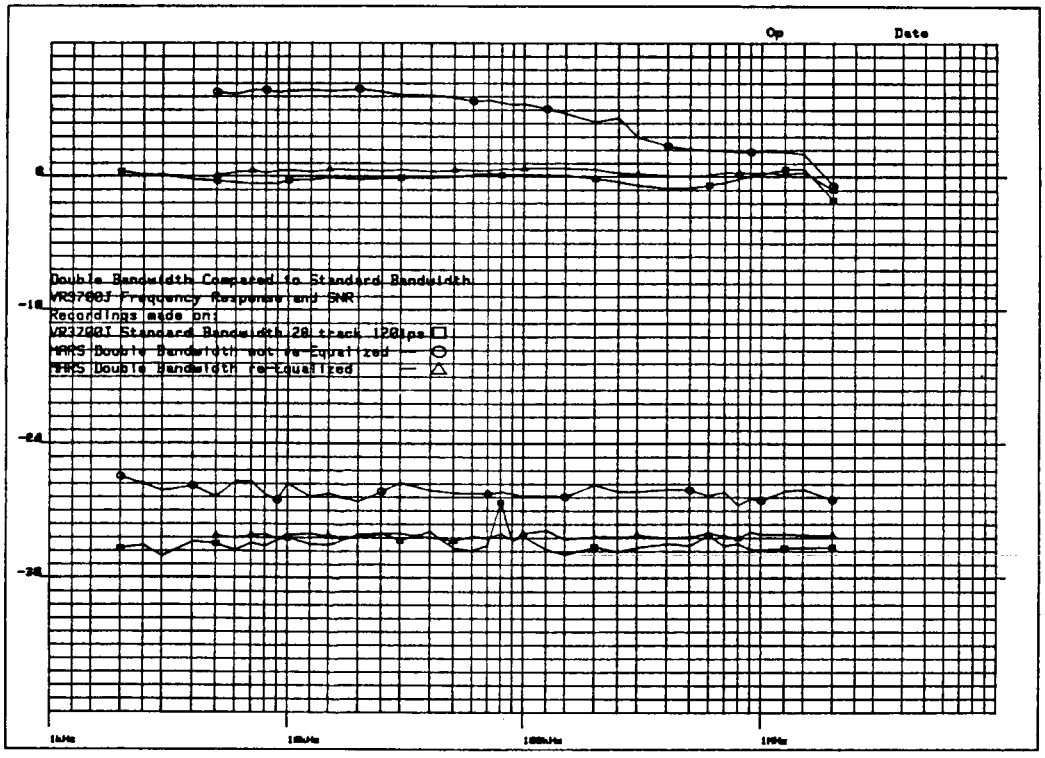

FIGURE-11. 28 Tk Acquisition 2 MHZ @ 60 ips Before and After Rep Adjustments Compared to 28 Tk Ground Station 2 MHZ @ 120 ips

Figure 12 compares the half-speed acquisition recording (1 MHZ at 30 ips) to the ground station standard bandwidth (1 MHZ at 60 ips) results. Once again the response before adjustment vs after adjustment can be compared to the standard bandwidth result. Although some difference is evident, it is not significant. The half-speed SNR is approximately 2 dB less than the standard bandwidth recording, but very respectable at 26 dB.

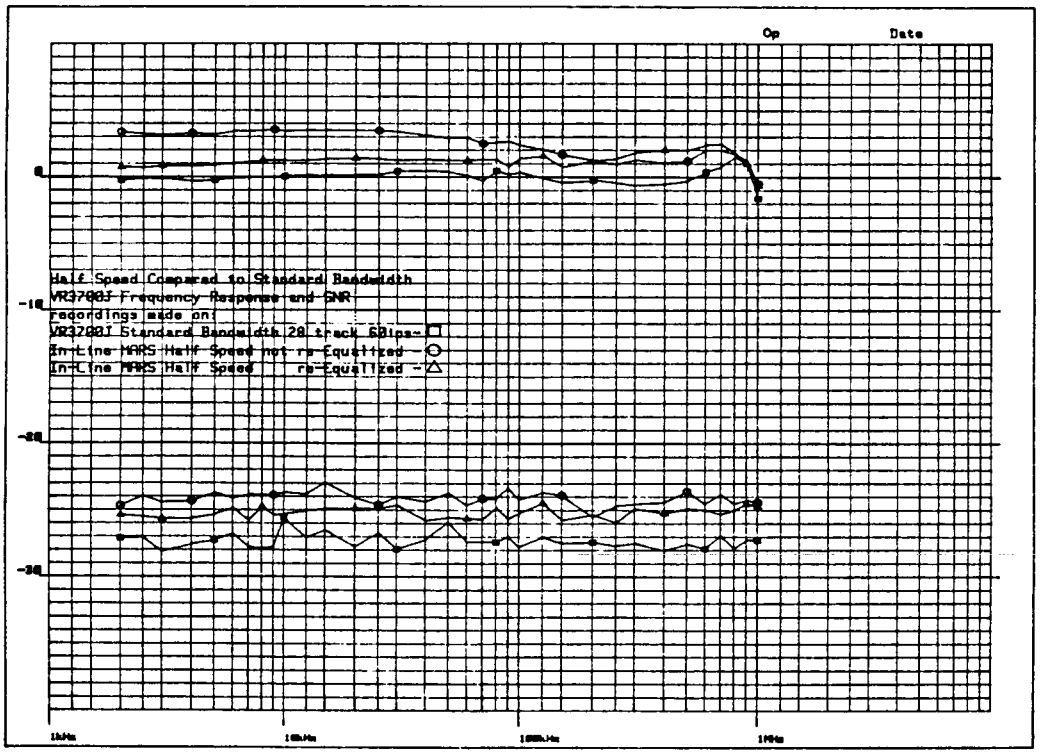

FIGURE-12. Inline Acquisition 1 MHZ @ 30 ips Before and After Rep Adjustments Compared to 28 Tk Ground Station 1 MHZ @ 60 ips

As we progressed in our testing, a standard bandwidth acquisition recorder became available. Figure 13 compares this recorder's 2 MHZ at 120 ips performance with the double bandwidth 2 MHZ at 60 ips performance. The frequency response was again virtually identical while the standard bandwidth SNR was better by approximately 1 dB.

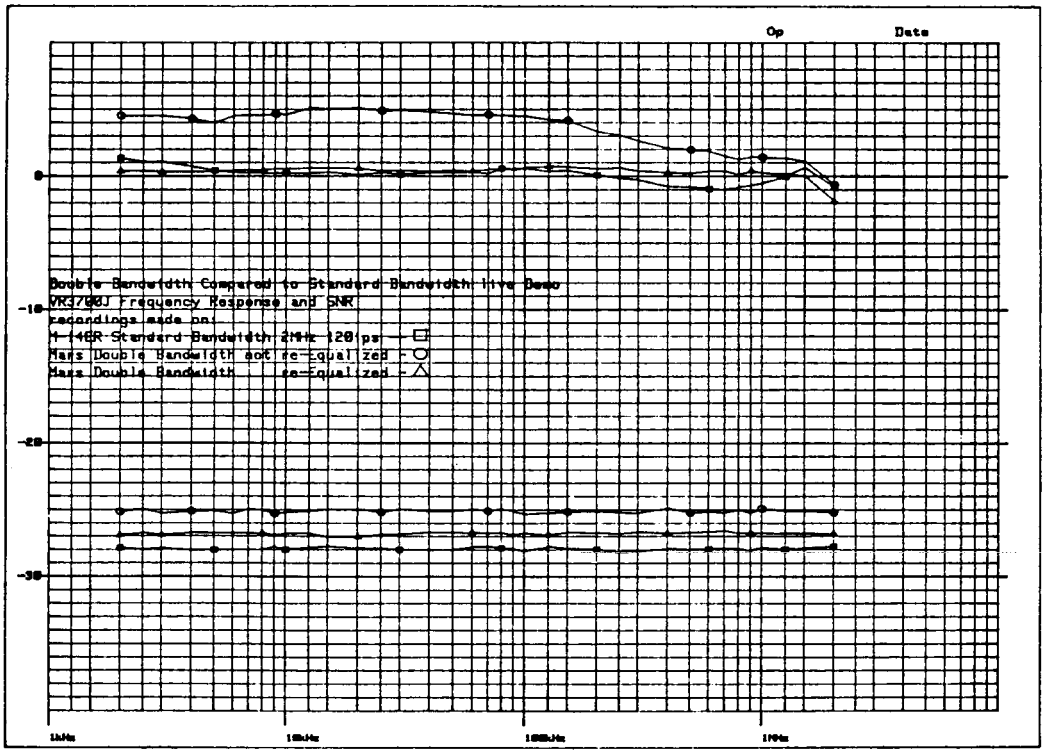

FIGURE-13. 28 Tk Acquisition 2 MHZ @ 60 ips Before and After Rep Adjustments Compared to 28 Tk Standard Bandwidth Acquisition 2 MHZ @ 120 ips

Two final comparisons were performed. A lot of discussion has taken place related to 50 mil vs 25 mil track widths for Double Density performance. These last two comparisons look at 25 mil double bandwidth and half-speed performance from acquisition recorders to the 50 mil standard bandwidth ground station performance. Figure 14 shows the response with adjusted equalization of a double bandwidth 25 mil track to a ground station 50 mil track (2 MHZ at 60 ips vs 2 MHZ at 120 ips). No difference in frequency response resulted. The double bandwidth SNR was only 4 dB less than the standard bandwidth SNR (27 dB vs 31 dB).

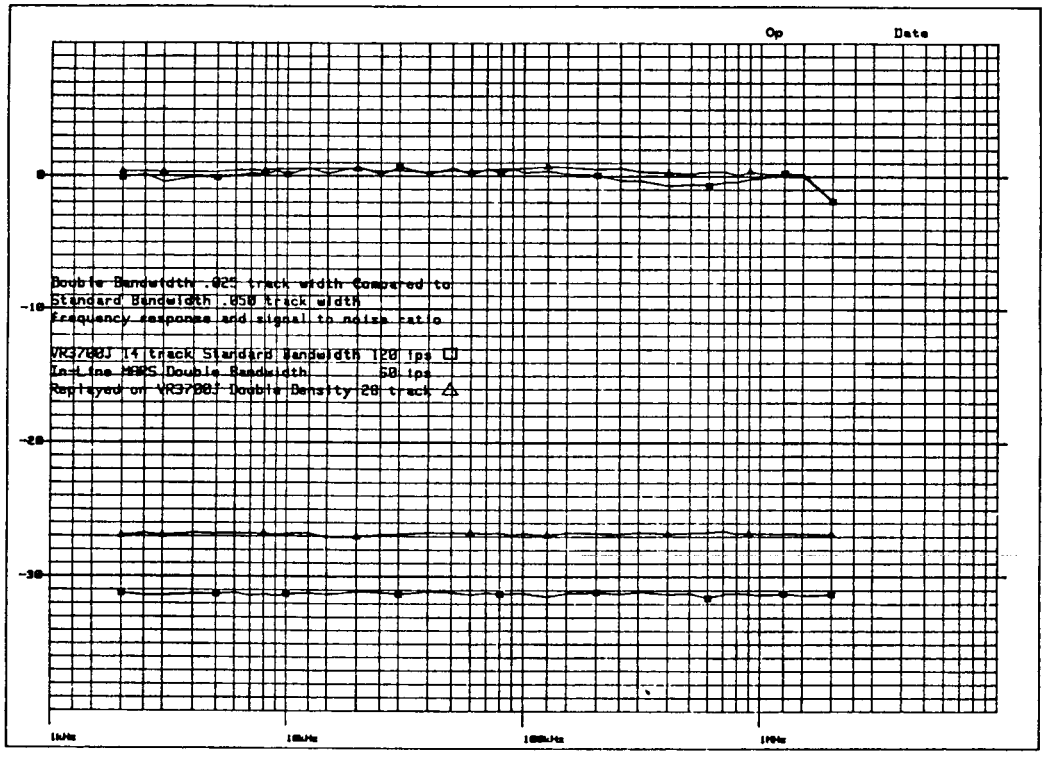

FIGURE-14. 28 Tk (25 mil) Acquisition 2 MHZ @ 60 ips, After Rep adjustments Compared to 14 Tk (50 mil) Ground Station 2 MHZ @ 120 ips

Figure 15 shows the response with adjusted equalization of a half-speed 25 mil track to a ground station 50 mil track (1 MHZ at 30 ips vs 1 MHZ at 60 ips). Again little difference in frequency response resulted. The half-speed SNR was 28 dB while the standard bandwidth SNR was 31 dB.

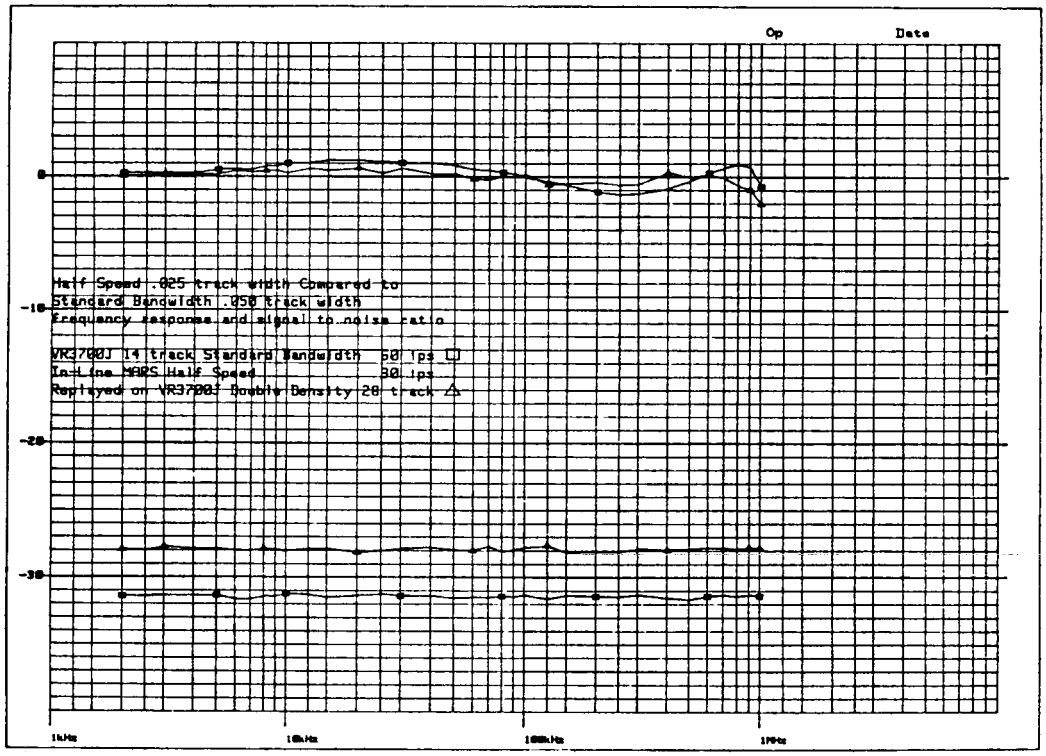

FIGURE-15. Inline (25 mil) Acquisition I MHZ @ 30 ips After Rep Adjustments Compared to 14 Tk (50 mil) Ground Station 1 MHZ @ 60 ips

SUMMARY

Graphic presentation of tests performed for 28 track standard bandwidth direct ground station performance was compared to direct Double Density acquisition performance. The test results of the direct recordings yielded the following:

- **Acquisition double bandwidth 2 MHZ-60 ips recording vs ground station standard bandwidth 2 MHZ 120 ips-- Result 27 dB SNR vs 28 dB SNR**

- **Acquisition half-speed 1 MHZ-30 ips recording vs ground station standard bandwidth 1 MHZ-60 ips--**
  Result 26 dB SNR vs 28 dB SNR

Additional comparisons of standard bandwidth 50 mil track performance vs Double Density 25 mil track performance were made. These test results yielded the following:

- **Acquisition double bandwidth (25 mil) 2 MHZ-60ips recording vs standard bandwidth (50 mil) 2 MHZ-120 ips-**
  Result ≃ 4 dB SNR degradation but > 25 dB SNR

- **Acquisition half-speed (25 mil) 1 MHZ-30 ips recording vs standard bandwidth (50 mil) 1 MHZ-60 ips--**
  Result ≃ 3.5 dB SNR degradation but > 25 dB SNR

CONCLUSION

In every case tested the acquisition recorder Double Density frequency response compared favorably to the standard bandwidth ground station system response yielding full compatibility. In a comparison with a standard bandwidth acquisition recording very little performance difference was found. Although a small degradation in SNR does occur from the ground station standard bandwidth recordings the acquisition Double Density recordings are compatible with ground station reproduce systems. In every case the results showed very respectable SNR.