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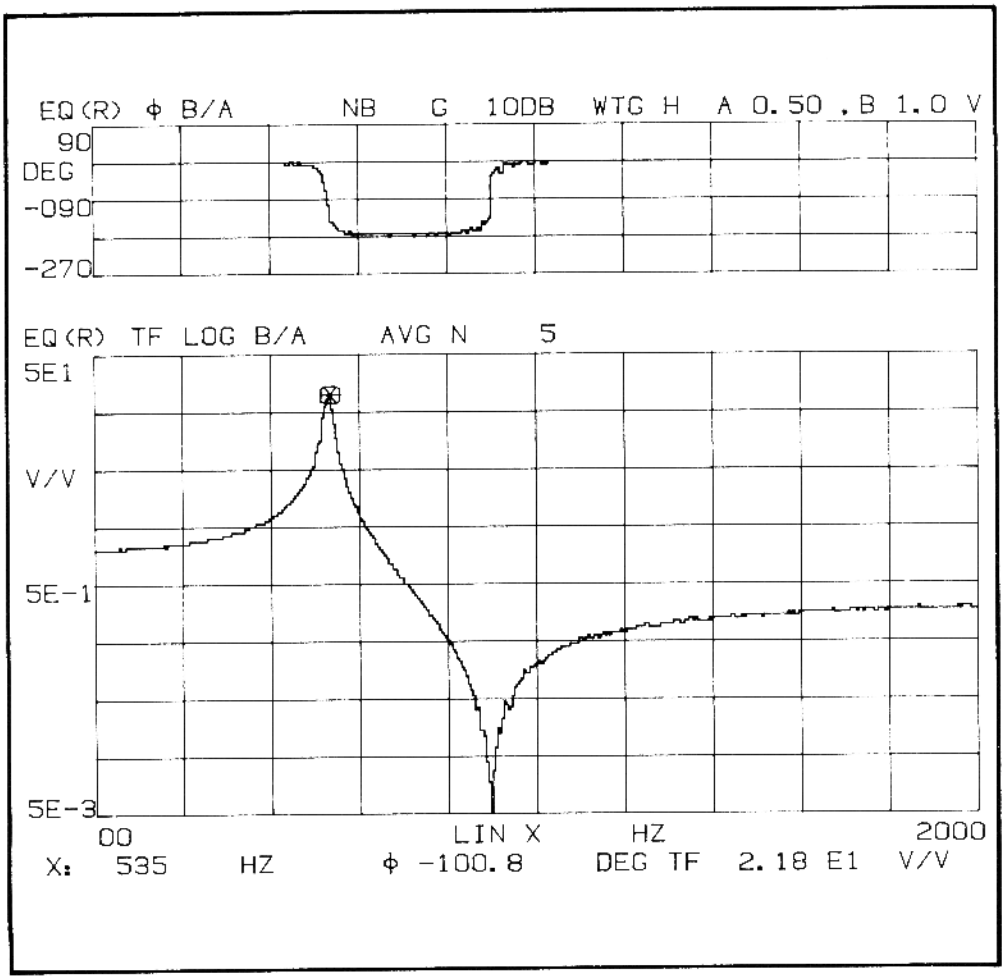


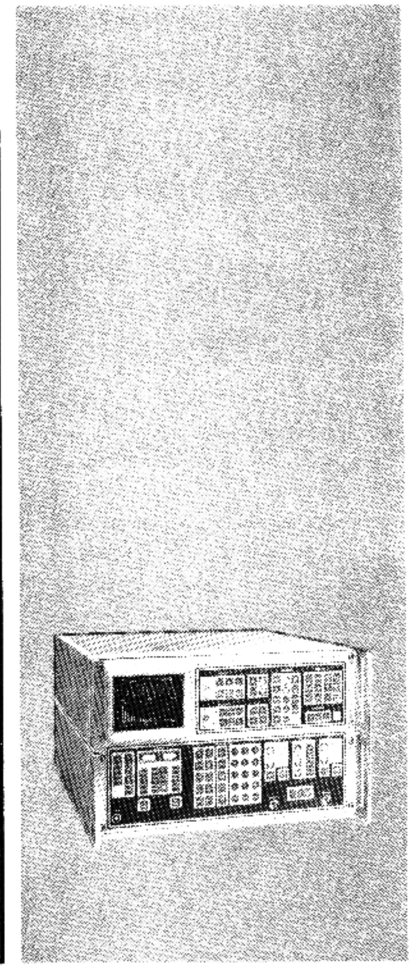

# The How and Why of Equalized Transfer Function and Phase

## Key SD375 Features:

- Amplitude Correction
- Phase Correction
- Continuous Correction with Exponential Average

**Scientific Atlanta**
Spectral Dynamics Division

# Applications for Equalized Transfer Function and Phase

## 1. Definition

Equalized ratio is the ratio of two transfer functions.

This is expressed as follows:

$$ER = \frac{M1}{M2}$$

where ER is equalized ratio; M1 is Memory 1, which is data with incorporated frequency response errors; and M2 is Memory 2, which is the reference signal with incorporated error.

When measuring mechanical system transfer functions, the excitation (force) and response (acceleration) signals must pass through various types of electronics prior to viewing and processing the data or making a hard copy. Frequency response problems can exist in one or more channels of charge amplifiers, voltage amplifiers, cabling, tape recorders, or even in the analyzer itself. Equalized ratio is a method of compensating for these frequency response problems and makes corrections in both amplitude and phase.

## 2. Problem Solving using Equalized Ratio

Let's take a look at a situation in which a tape recorder has frequency response problems. We will be recording the input force information on Channel 1 and the acceleration response information on Channel 2 of the recorder. Figure 1 shows the raw time domain information of the transient force and acceleration signals at the input of the tape recorder. Figure 2 shows the frequency content of each of these signals and Figures 3a and 3b display the transfer function and phase information. Figure 4 shows that we have good coherence, except, as expected, at the anti-resonance points.

Now let's look at the same data after it has been recorded and played back from a faulty tape recorder. Figure 5 depicts the same force and acceleration signals, but the signals have changed because of the frequency response problems with the tape recorder. This is apparent when comparing Figures 1 and 5. The frequency response problem shows up even more drastically on the spectrum plot in Figure 6. The overall effect can be seen in comparing the desired transfer function (Figures 3a and 3b) to the transfer function analyzed from the tape in Figures 7a and 7b. Large errors in phase and amplitude can be seen. The coherence function in Figure 8 is not as good as the one taken prior to the data being recorded but, at the resonant frequencies, it is high enough to provide us with reasonable confidence in the data. It should be noted that, if the response of the tape recorder is bad enough to greatly degrade the data to a point of low

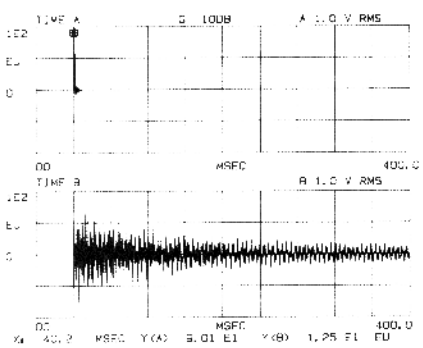

**Figure 1. Time Trace Input Force and Output Response**

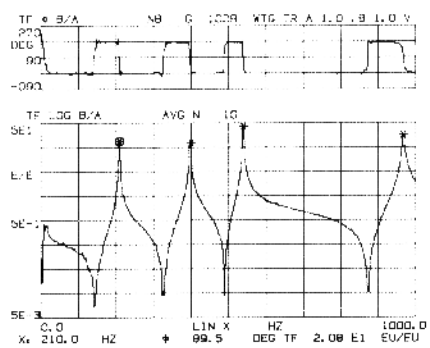

**Figure 3a. Transfer Function of Signals from Figure 2**

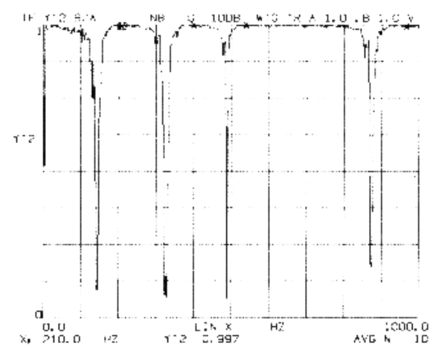

**Figure 4. Coherence Plot of Data Signals**

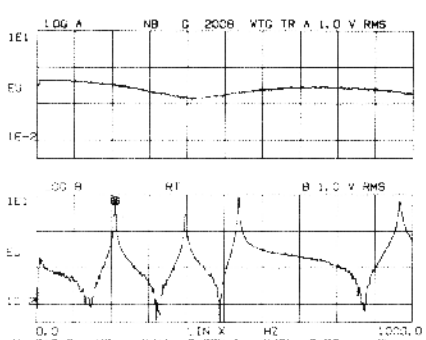

**Figure 2. Frequency Content of Time Traces in Figure 1**

1. TF & Φ

ID 00000

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | X: | 210.0 | HZ | Φ | 89.5 | DEG TF | 2.08 E1 | EU/EU |
| 2 | X: | 400.0 | HZ | Φ | 51.6 | DEG TF | 1.95 E1 | EU/EU |
| 3 | X: | 540.0 | HZ | Φ | 99.3 | DEG TF | 4.11 E1 | EU/EU |
| 4 | X: | 970.0 | HZ | Φ | 60.2 | DEG TF | 2.79 E1 | EU/EU |
| 5 | | | | | | | | |
| 6 | | | | | | | | |
| 7 | | | | | | | | |
| 8 | | | | | | | | |

**Figure 3b. Digital Readout on the Four Resonant Frequencies and Their Phase Relationship from Figure 3a**

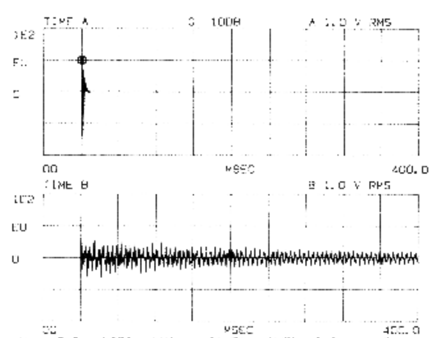

**Figure 5. Trace of Same Signal as Figure 1, but Showing the Effect of Recorder Frequency Response Problems**

coherence values, the transfer function cannot be fully corrected by equalized ratio.

Now that we know what the data should look like and how the frequency response problem has affected the data, how do we use equalized ratio to correct the transfer function? First, we can assume that we do not know what the ideal transfer function looks like. Second, we can see from Figure 7b that our phase angles at resonance are not close to 90 degrees, even though we were making a driving point accelerance measurement. Let's examine the tape recorder.

We start by recording an identical (from the same source) broad band random noise signal on both channels of the tape recorder simultaneously. The frequency response of this signal is shown in Figure 9. Looking at the playback signal from the tape recorder, we see in the time traces of Figure 10 and the spectrum plots of Figure 11, that the frequency response is not flat. In fact, it is different for both Channels 1 and 2. The transfer function between Channels 1 and 2 of the tape recorder is shown in Figure 12. If there had been no problems with the frequency response of the tape recorder, the transfer function would be a straight line at unity with zero phase at all frequencies. Since that is not the case, the transfer function and phase information shown in Figure 12 becomes our correction information and this data is stored in Memory 2 of the SD375. The force and acceleration signals are then played back from the tape and their transfer function is stored in Memory 1 (Figure 7) of the SD375.

The data stored in Memory 1 carries the same errors as the data stored in Memory 2. If we divide Memory 1 by Memory 2 by calling up line 5 of the transfer function menu (equalized ratio), we obtain Figures 13a and 13b. In the corrected transfer function, by comparing Figures 13a and 13b with 3a and 3b, we see a great similarity in amplitude and phase. In fact, they are almost identical. This shows that our correction factor has brought our data back to the original configuration that we saw prior to recording the signals.

## 3. How to Perform an Equalized Ratio Measurement with the SD375

### 3.1 Assumptions

Let's assume we have a tape recording of a force and acceleration signal which we would like to use for transfer function measurement. Let's also assume that the play-back electronics of the recording have some frequency response problems. How do we compensate for the error?

### 3.2 Initial Equipment Set-Up

a. Press PANEL O RCL on the SD375.

b. Connect tape recorder to SD375 (force signal to Channel A and response signal to Channel B)

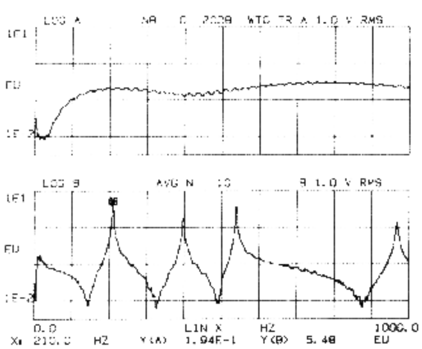

**Figure 6. Effect of Frequency Response Problems on Data Signals**

1, TF & Φ

ID 00000

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | X: 210.0 | HZ | Φ | 053.7 | DEG | TF | 2.82 E1 | EU/EU |
| 2 | X: 400.0 | HZ | Φ | 264.4 | DEG | TF | 1.50 E1 | EU/EU |
| 3 | X: 540.0 | HZ | Φ | -049.1 | DEG | TF | 1.98 E1 | EU/EU |
| 4 | X: 970.0 | HZ | Φ | 223.8 | DEG | TF | 5.48 | EU/EU |
| 5 | | | | | | | | |
| 6 | | | | | | | | |
| 7 | | | | | | | | |
| 8 | | | | | | | | |

**Figure 7b. Digital Readout of Incorporated Error from Tape Recorder**

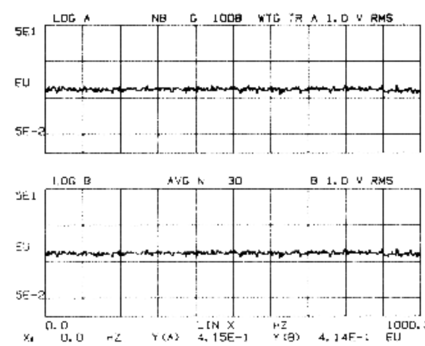

**Figure 9. Frequency Content of White Noise Reference Signal**

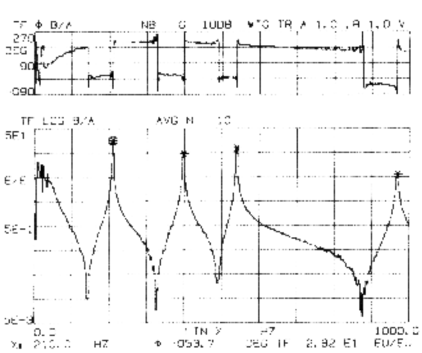

**Figure 7a. Transfer Function of Incorporated Error from Tape Recorder**

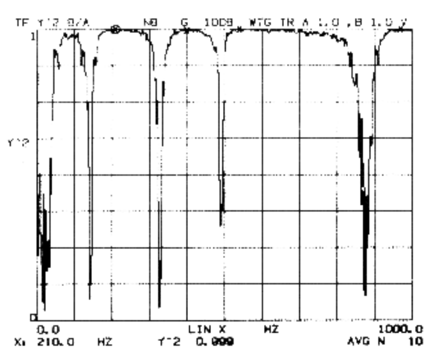

**Figure 8. Coherence of Signal with Incorporated Error**

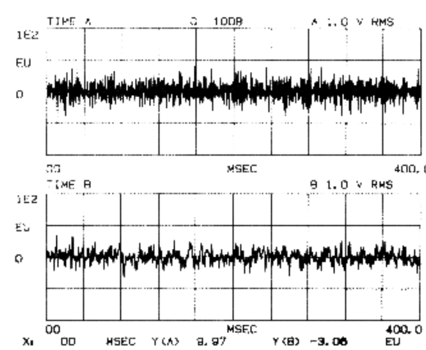

**Figure 10. Time Traces Showing Effect of Tape Recording on Signal in Figure 9**

c. Select the desired frequency range for analysis.

d. Turn on tape recorder and adjust SD375 input for maximum sensitivity with no overload.

e. Record white noise signal on tape. (Use SSG output of SD375, if equipped with -4 option.) Adjust level of noise signal so that no overload is seen on either the tape recorder or the SD375. The gains of the tape recorder should be set the same as they were when the data was recorded.

**3.3 Storing the Correction Data**

a. Select a sufficient number of averages on the SD375 for a smooth response.

b. Press function TF.

c. Press MENU.

d. Select Line #1, TF, and phase.

e. Press OPERATE.

f. Start tape recorder and play white noise signals into SD375.

g. Press average ERASE, and START.

h. Press XFR M1→M2.

**3.4. Storing the Data Signals (Transient Data)**

a. Put data tape on recorder.

b. Set Channels A and B for 10% threshold at -10% delay.

c. Press weighting function SPCL.

d. Select a reasonable amount of averages.

e. Press STOP, ERASE, TRANS AUTO, START.

f. Start tape recorder.

g. Press average STOP when data looks reasonable.

**3.5. Display Equalized Ratio**

a. Press function TF MENU.

b. Select Line 5, equalized, TF, and phase.

c. Press OPERATE.

The result is the equalized transfer function with the corrected amplitude and phase.

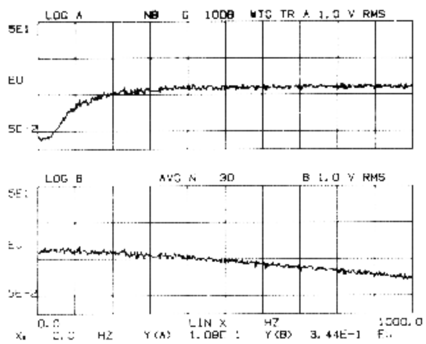

**Figure 11. Frequency Content of Calibration Signal Through Tape Recorder**

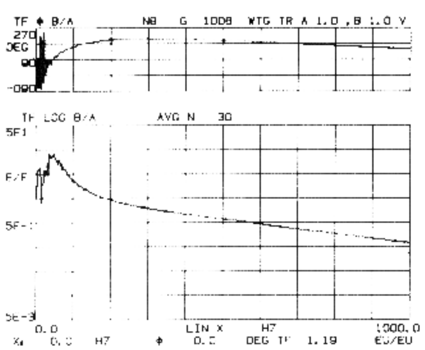

**Figure 12. Transfer Function of Tape Recorder**

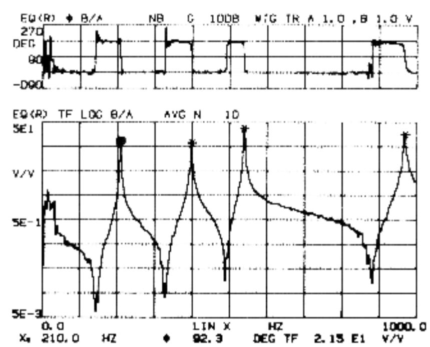

**Figure 13a. Corrected Transfer Function**

5. EQUALIZED TF & ♦

ID 00000

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | X: 210.0 | HZ | ♦ | 92.3 | DEG | TF | 2.15 E1 | V/V |
| 2 | X: 400.0 | HZ | ♦ | 53.2 | DEG | TF | 1.87 E1 | V/V |
| 3 | X: 540.0 | HZ | ♦ | 103.1 | DEG | TF | 3.81 E1 | V/V |
| 4 | X: 970.0 | HZ | ♦ | 66.8 | DEG | TF | 2.77 E1 | V/V |
| 5 | | | | | | | | |
| 6 | | | | | | | | |
| 7 | | | | | | | | |
| 8 | | | | | | | | |

**Figure 13b. Digital Readout of Corrected Transfer Function**

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