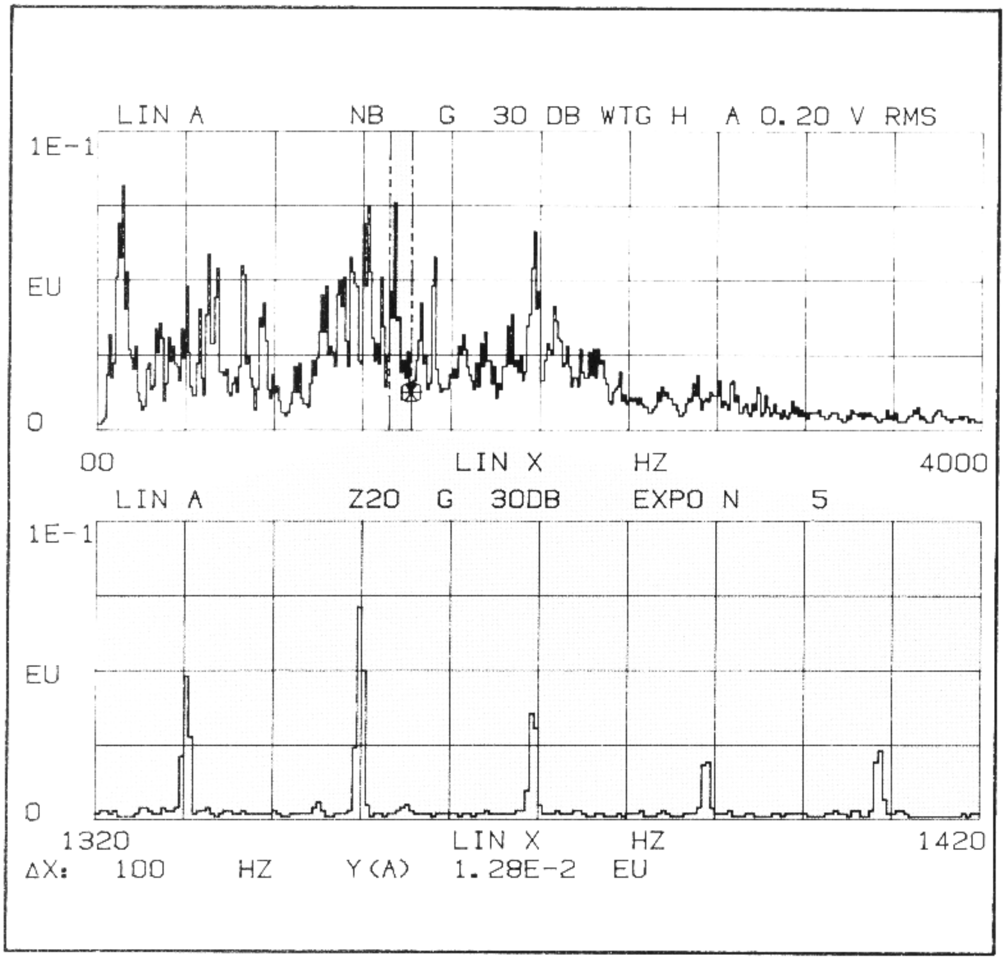

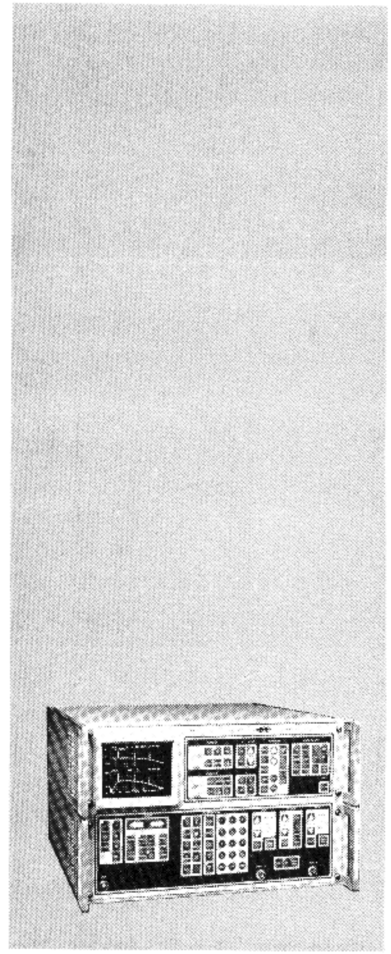

The How and Why of Zoom

Key SD375 Features

- Simultaneous broadband and zoom display in RT or AVG mode
- Aliasing protection for ultra low frequency analysis
- Digital implementation with flexible zoom selection
- Six zoom factors; 2, 5, 10, 20, 50 and 100
- Zoom about the cursor — set the cursor and expand
- Post-zoom, pre-analysis gain, for optimum use of available signal strength
- Continuous high resolution cursor readout of expanded frequency values

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Applications For Zoom

1. Definition

Zoom does for the data analyst what a telephoto lens does for the photographer. It allows him to move in and concentrate the analytical power of the analyzer on a selected band of frequencies. Zoom processing of data incorporates two important results; greater resolution, and improved signal to noise ratio. The one drawback is that, in most cases, zoom increases the time needed to acquire and process the data.

There are two types of zoom widely used in analyzers today; post zoom, and real time zoom. The post zoom method collects and stores a long time sample record. This time record can then be converted through the FFT process into a standard frequency spectrum or a zoomed spectrum. Normally, this method is limited in the magnification factors of zoom. It may also be limited to specific frequency ranges and, in some cases, cannot be viewed in real time or simultaneously with broadband information.

The real time zoom technique limitation is that it cannot zoom on stored data. However, the advantages heavily outweigh this, in that there are many selectable zoom factors. In the case of the SD375, there are six zoom or magnification factors. These include 2, 5, 10, 20, 50, and 100.

The SD375 zoom operates on all 21 baseband frequency ranges. Real time and averaged zoom (up to 2,048 ensembles) can be selected for single or dual channel spectrum displays. Most importantly, a simultaneous baseband and zoom display is standard to observe spectrum detail in the zoom window yet maintain visibility outside the zoom window (see cover).

2. Problem Solving Using Zoom

2.1 Improved Resolution

The resolution of a real time analyzer is normally defined as the full scale frequency divided by the number of lines or cells making up the spectrum display. For the SD375, this would be full scale divided by 400. This says, if we analyze a transducer signal on the SD375 using the 4 kHz range, the resolution would be 4,000 divided by 400 or 10 Hz. Any signals, regardless of their source, cannot be effectively separated if they are within 10 Hz of each other anywhere on the 0 to 4,000 Hz band. Figure 1 shows a chart of frequency ranges versus resolution for all of the baseband ranges, plus zoom, for the SD375.

The most important use of zoom is to separate signals which are so near the same frequency that they cannot be resolved with standard narrowband analysis. Figure 2 is the spectrum of an acceleration signal from a

		Zoom Factor					
Frequency Range	Base 0	2	5	10	20	50	100
1	0.0025	0.00125	0.0005	0.00025	0.000125	0.00005	0.000025
2	0.005	0.0025	0.001	0.0005	0.00025	0.0001	0.00005
4	0.01	0.005	0.002	0.001	0.0005	0.0002	0.0001
5	0.0125	0.00625	0.0025	0.00125	0.000625	0.00025	0.000125
10	0.025	0.0125	0.005	0.0025	0.00125	0.0005	0.00025
20	0.05	0.025	0.01	0.005	0.0025	0.001	0.0005
40	0.1	0.05	0.02	0.01	0.005	0.002	0.001
50	0.125	0.0625	0.025	0.0.125	0.00625	0.0025	0.00125
100	0.25	0.125	0.05	0.025	0.0125	0.005	0.0025
200	0.5	0.25	0.1	0.05	0.025	0.01	0.005
400	1	0.5	0.2	0.1	0.05	0.02	0.01
500	1.25	0.625	0.25	0.125	0.0625	0.025	0.0125
1K	2.5	1.25	0.5	0.25	0.125	0.05	0.025
2K	5	2.5	1	0.5	0.25	0.1	0.05
4K	10	5	2	1	0.5	0.2	0.1
5K	12.5	6.25	2.5	1.25	0.625	0.25	0.125
10K	25	12.5	5	2.5	1.25	0.5	0.25
20K	50	25	10	5	2.5	1	0.5
40K	100	50	20	10	5	2	1
50K	125	62.5	25	12.5	6.25	2.5	1.25
100K	250	125	50	25	12.5	5	2.5

Figure 1. Frequency Resolution Chart

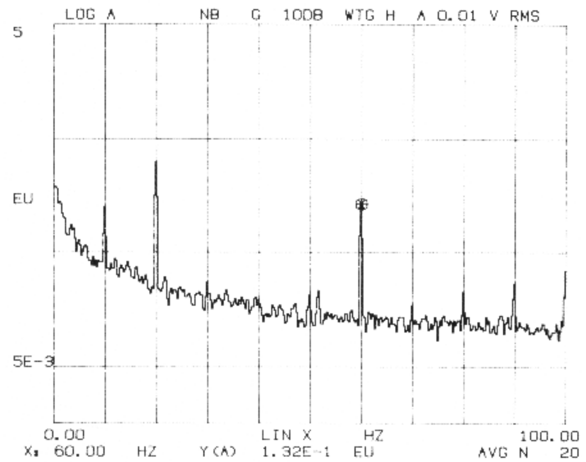
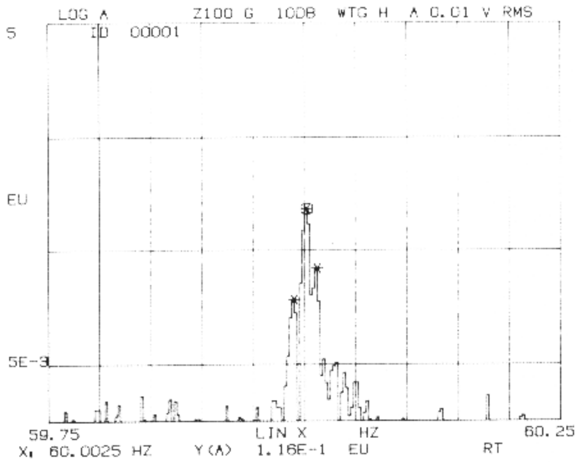


Figure 2. Panel Vibration Signals, Broadband

vibrating panel on which three motors were mounted. These motors each drive a separate gear box and operate at 3,600 rpm (60 Hz). Figure 2 displays the vibration amplitude for all signal components from 0 to 100 Hz. By zooming in on the 60 Hz component with a zoom factor of 100 and concentrating the analysis power of the SD375 on all frequencies between 59.75 and 60.25 (a 0.5 Hz spread) we can see the individual frequencies and acceleration levels of each motor along with their listings in Figure 3.

There is a price to be paid for high resolution. That price is time. The time to make one complete analysis for each level of zoom is given in Figure 4.




```
1.    SPECT A & B

      ID 00001

1 X: 59.9900 HZ    Y(A)   1.82E-2   EU     RT
2 X: 60.0025 HZ    Y(A)   1.16E-1   EU     RT
3 X: 60.0125 HZ    Y(A)   3.41E-2   EU     RT
4
5
6
7
8
```

Figure 3. Panel Vibration Signals, Zoom with Frequency Listings

Baseband		Zoom Factor 2		5		10		20		50		100	
Frequency Range	Memory Period Sec.	Frequency Band	Memory Period	Frequency Band	Memory Period	Frequency Band	Memory Period	Frequency Band	Memory Period	Frequency Band	Memory Period	Frequency Band	Memory Period
1	400	0.25	800	0.1	2K	0.05	4K	0.025	8K	0.01	20K	0.005	40K
2	200	0.5	400	0.2	1K	0.1	2K	0.05	4K	0.02	10K	0.01	20K
4	100	1	200	0.4	500	0.2	1K	0.1	2K	0.04	5K	0.02	10K
5	80	1.25	160	0.5	400	0.25	800	0.125	1.6K	0.05	4K	0.025	8K
10	40	2.5	80	1	200	0.5	400	0.25	800	0.1	2K	0.05	4K
20	20	5	40	2	100	1	200	0.5	400	0.2	1K	0.1	2K
40	10	10	20	4	50	2	100	1	200	0.4	500	0.2	1K
50	8	12.5	16	5	40	2.5	80	1.25	160	0.5	400	0.25	800
100	4	25	8	10	20	5	40	2.5	80	1	200	0.5	400
200	2	50	4	20	10	10	20	5	40	2	100	1	200
400	1	100	2	40	5	20	10	10	20	4	50	2	100
500	0.8	125	1	50	4	25	8	12.5	16	5	40	2.5	80
1K	0.4	250	0.8	100	2	50	4	25	8	10	20	5	40
2K	0.2	500	0.4	200	1	100	2	50	4	20	10	10	20
4K	0.1	1K	0.2	400	0.5	200	1	100	2	40	5	20	10
5K	0.08	1.25K	0.1	500	0.4	250	0.8	0.25	1.6	50	4	25	8
10K	0.04	2.5K	0.08	1K	12	500	0.4	250	0.8	100	2	50	4
20K	0.02	5K	0.04	2K	0.1	1K	0.2	500	0.4	200	1	100	2
40K	0.01	10K	0.02	4K	0.05	2K	0.1	1K	0.2	400	0.5	200	1
50K	0.008	12.5K	0.01	5K	0.04	2.5K	0.08	1.25K	0.16	500	0.4	250	0.8
100K	0.004	25K	0.008	10K	0.02	5K	0.04	2.5K	0.08	1K	0.2	500	0.4

Frequencies in Hz

Memory Period in Seconds

Figure 4. Memory Period and Analysis Band for Each Zoom Factor for Every Base Band Frequency Range

2.2 Improved Signal to Noise Enhancement

When processing periodic signals in the presence of extremely high background noise, it may be necessary to lower the background noise in order to detect the presence of a periodic signal. To perform an analysis of this type, considerable time can be saved if the operator knows where to look for the signal of interest.

Let's assume we are looking for a known signal with a frequency of approximately 85,500 Hz. Let's also assume that the amplitude of the signal is less than that of the background noise. Figure 5 is the instantaneous or real time analysis of the spectrum from 0 – 100 kHz. By taking the average of this spectrum, as shown in Figure 6, we see that no periodic component exists at 85.5 kHz, or at least it is not visible under the present measurement conditions.

Let's zoom in on 85.5 kHz and bring the signal out of the noise. We must first understand what causes the noise to be higher than the periodic signal. The amplitude of a periodic sinusoidal signal is completely independent of the filter width used to analyze it. Even if the amplitude is read with a voltmeter with no frequency limitations, the same amplitude would be measured. This is not the case for the broadband noise. The wider the analysis filter, the higher the measured noise amplitude. Consequently, the narrower the filter, the lower the amplitude. The wider filter will allow more noise energy through than the narrow filter. For the 100 kHz range using Hanning weighting, the filter bandwidth is 1.5 times the filter spacing (BW = 100,000 ÷ 400 × 1.5 = 375 Hz). By increasing the resolution using zoom, the bandwidth can be reduced, thus reducing the measured noise level yet not effecting the amplitude of the periodic. Figure 7 is a series which shows the measured noise level dropping as the zoom factor is increased. The filter bandwidth used for analysis decreases from 375 Hz to 3.75 Hz. The periodic signal can be seen more clearly with each level of zoom. With a zoom

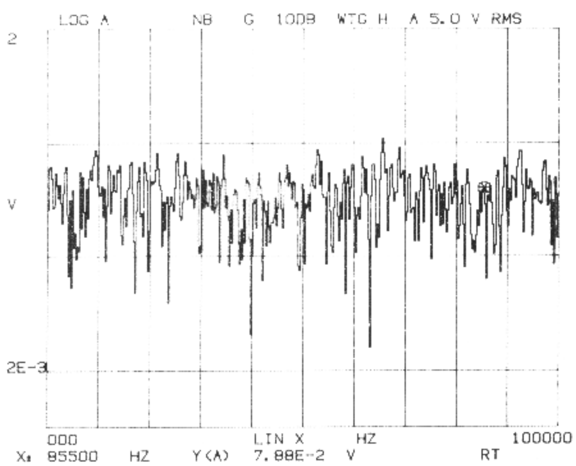


Figure 5. Instantaneous Broadband Spectrum, No Averaging

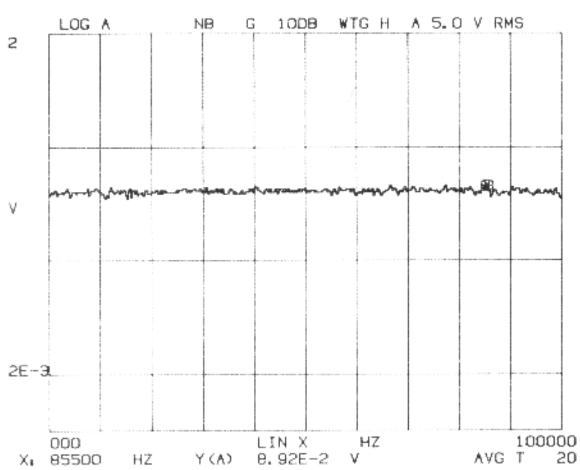


Figure 6. Broadband Spectrum Average

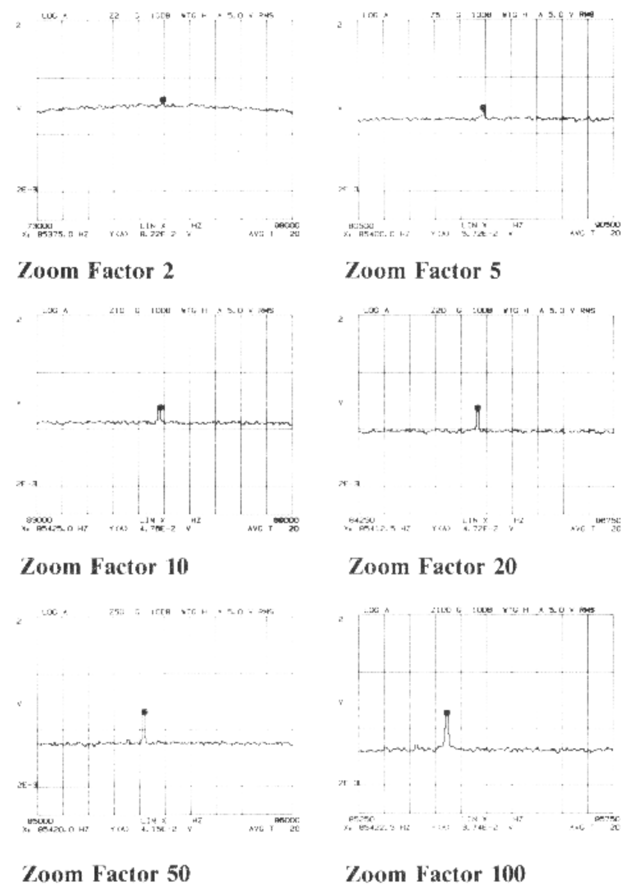


Figure 7. Zoom Data Series Centered on 85,500 Hz, Depicting a Steady Decrease in the Noise Signal as the Zoom Factor is Increased from 2–100

factor of 100, the signal can be detected without averaging (Figure 8).

3. Transfer Functions and Zoom

Increasing resolution of measured transfer functions with zoom provides us with answers to problems that might not be available any other way. Let's look at the following problems: isolating a mode, determining resonant frequencies, and calculating damping.

3.1 Mode Isolation

When measuring a transfer function on a given structure, normally there are many modes of vibration. In theory, this number could be infinite. Practically, however, there is some upper frequency of interest which limits the number of modes displayed. Figure 9 shows a transfer function measured on a structure excited using the impact technique. If this information is to be used for modal analysis purposes, a best circle fit algorithm might be employed using the Nyquist diagram. The six modes can be seen in the Nyquist, but the circles are not well defined because of the lack of resolution. The circles look more like triangles. Let's increase our analysis resolution with respect to the 965 Hz mode using zoom.

To perform a zoom function on data gathered with the impact technique, delay of Channels A and B must be used. Normally a delay of − 10% is used (assuming special/transient weighting and transient auto are implemented). To calculate the proper delay for any zoom factor, the following equation is used: % Delay equals (zoom factor times 100) minus 110. A chart for all zoom factors is shown in Figure 11. If we

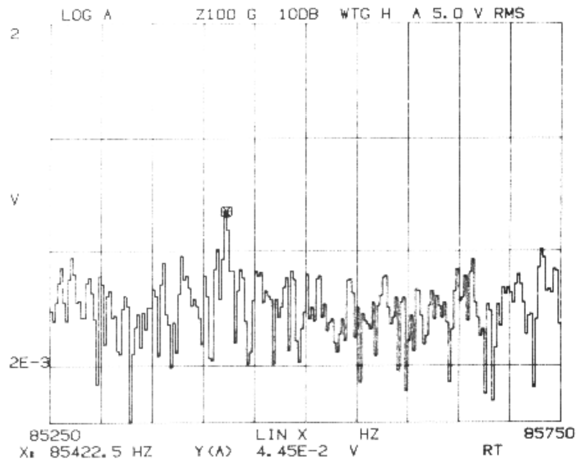


Figure 8. Instantaneous Look at Periodic Buried in Noise with No Averaging (Enhancement of Figure 5)

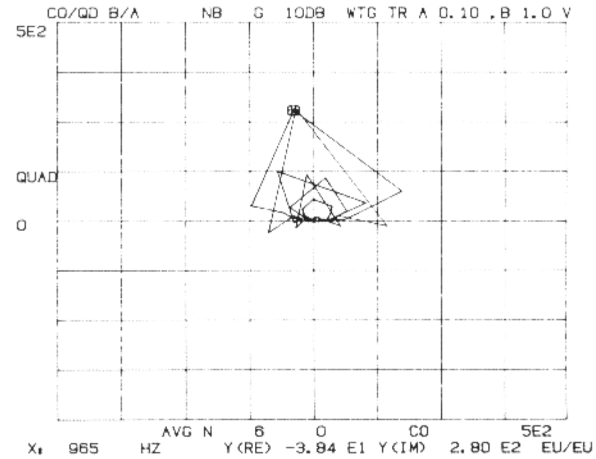


Figure 10. Nyquist Plot of Transfer Function (Figure 9)

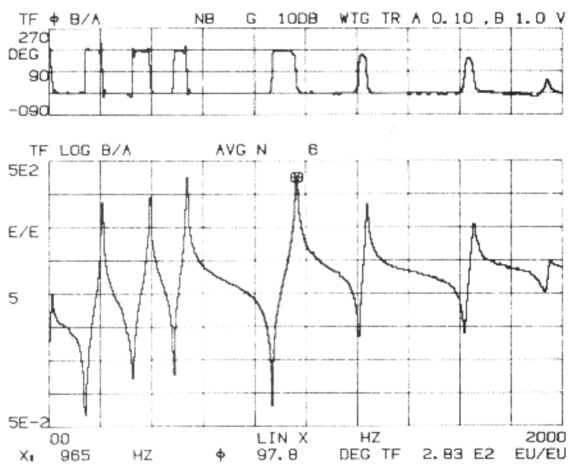


Figure 9. Transfer Function, Magnitude and Base Plot Before Zoom

Zoom Factor	% Delay
2	+90
5	+390
10	+890
20	+1890
50	+4890
100	+9890

Figure 11. Zoom Factor Delay Chart for Proper Positioning of Impact Data for Special Weighting

zoom on the center frequency of 965 Hz with a zoom factor of 10, we get the transfer function measurement of Figure 12. The Nyquist plot in Figure 13 shows we have good mode isolation and many points on the Nyquist curve.

An alternate technique is available for measuring transfer functions using the impact technique and zoom with the SD375. This involves expo-averaging, the use of overlap processing and either Hanning or Flat Top weighting. Either technique can produce good results but generally the TRANS AUTO, delay technique is less operator-dependent.

3.2 Determining Resonant Frequencies

There are methods of finding the resonant frequencies of a structure that are more accurate than reading the peaks of the transfer function.

a. The phase angle between input force and output acceleration will be 90° at resonance. Looking at Figure 14, we see modes of vibration with a listing of frequency, phase angle, and amplitude. All the measured phase angles should approach 90° but, because of the lack of frequency resolution, they do not. The mode at 395 Hz shows a phase angle of 117.4°. This is a 27.4° error. By increasing the resolution with a zoom factor of 10, the measured phase angle changes to 87.3° and displays a more accurate frequency of 396.5 Hz, as shown in Figure 15.

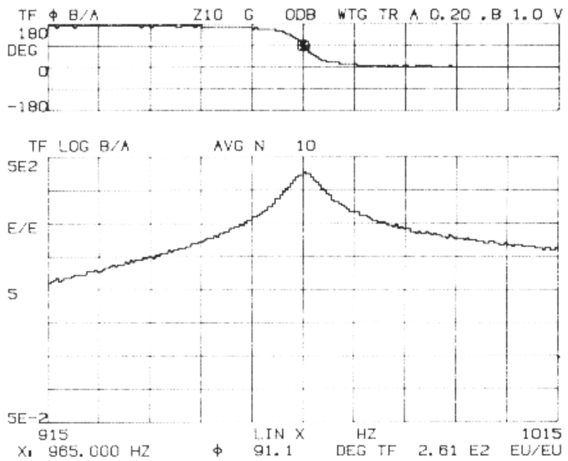


Figure 12. One Mode Segment from Figure 9 Using Zoom

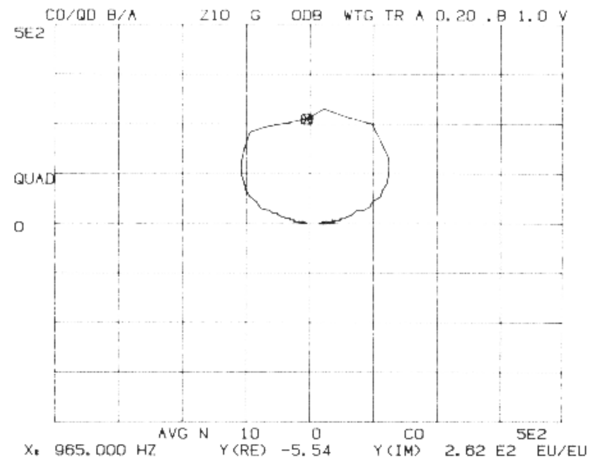
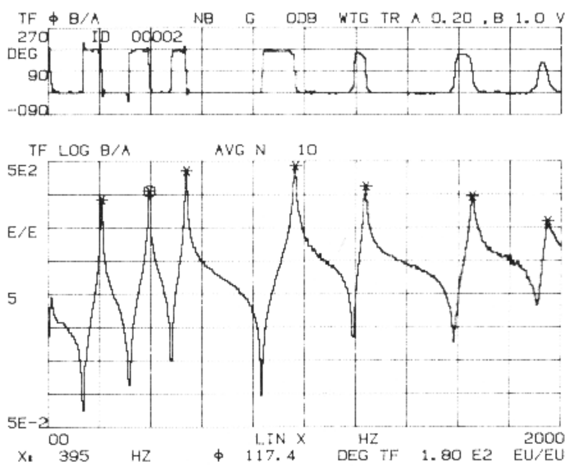


Figure 13. Nyquist Diagram of Isolated Mode



1. TF & Φ

ID 00002

1	X:	210	HZ	Φ	96.0	DEG TF	1.34	E2	EU/EU
2	X:	395	HZ	Φ	117.4	DEG TF	1.80	E2	EU/EU
3	X:	540	HZ	Φ	93.6	DEG TF	3.55	E2	EU/EU
4	X:	965	HZ	Φ	89.5	DEG TF	4.30	E2	EU/EU
5	X:	1240	HZ	Φ	76.9	DEG TF	2.14	E2	EU/EU
6	X:	1655	HZ	Φ	86.8	DEG TF	1.52	E2	EU/EU
7	X:	1950	HZ	Φ	74.4	DEG TF	6.09	E1	EU/EU
8									

Figure 14. Transfer Function with Magnitude and Phase Listings for each Mode of Vibration

b. In the real (RE) and imaginary (IM) transfer function display, the same problem, lack of frequency resolution, exists with the real component that we had with the phase angle measurement. Figure 16 shows a transfer function with a mode at 209 Hz. The real component is shown in Figure 17. Note how rapidly the real value passes through zero. By using zoom to increase resolution, we get more data points as the real value goes from its most negative point to its most positive point. Figure 18 shows the higher resolution with a zoom factor of 10 and the true resonant point at the 0 crossing is 209.4 Hz. The real component of a simple transfer function will be zero at resonance if the input and output signals from the structure are force and acceleration respectively.

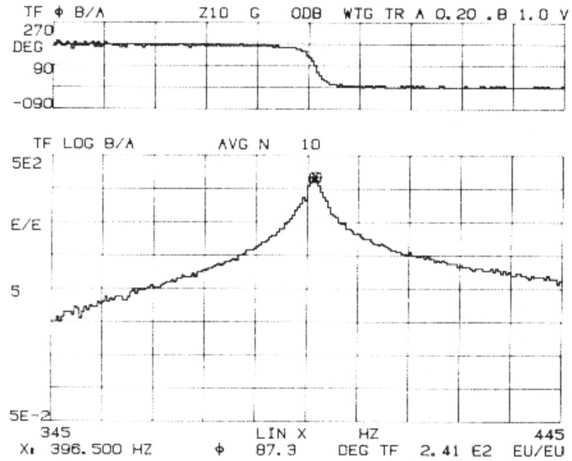


Figure 15. Zoom Data from Figure 14 Centered at 396.5 Hz

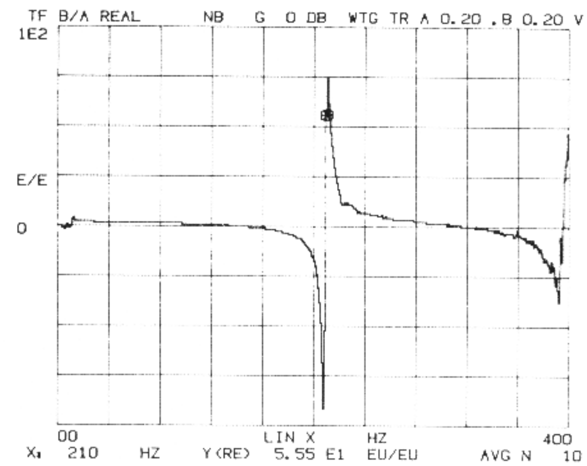


Figure 17. Real Components of the Transfer Function in Figure 16

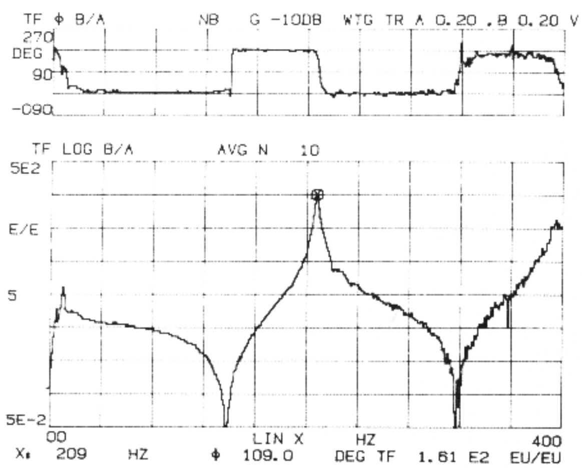


Figure 16. Transfer Function Magnitude and Phase

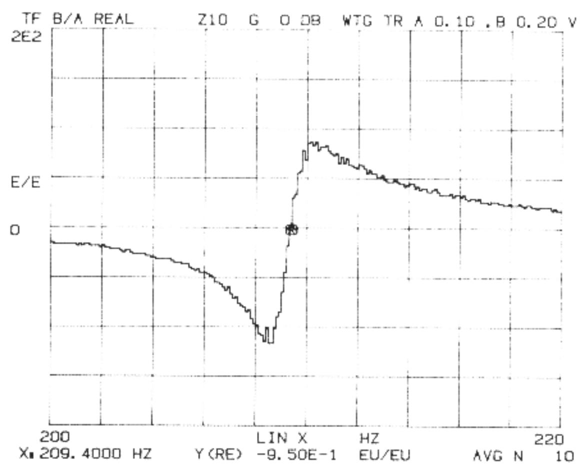


Figure 18. Real Components of the 209 Hz Mode, Zoomed by a Factor of 10

3.3 Calculating The Damping Coefficient

One method of performing a damping calculation on a simple system is to use the real component shown in Figure 17. However, when the most negative point and positive point of this signal get very close together (this occurs in lightly and moderately damped systems) there is not enough measurement resolution to perform the calculation with confidence. The formula for calculating the damping coefficient is:

$$\zeta = \frac{(F1/F2)^2 - 1}{(F1/F2)^2 + 1}$$

where ζ = damping coefficient; F1 = higher frequency; F2 lower frequency. In Figure 19 a zoom factor of 20 has been used to expand the most negative and most positive points of the real component. The frequencies have been entered through text entry in Figure 19. We see the total separation between the two frequencies of interest is only 1.5 Hz, but after zoom, there is a readout resolution of 0.05 Hz.

Substituting into the above equation, we have:

$$\zeta = \frac{(210.35/208.85)^2 - 1}{(210.35/208.85^2 + 1} = 0.007$$

There is still some uncertainty in this value because, when the negative and positive peaks of the transfer function real components are expanded through zoom, the peaks become very broad and it is difficult to exactly define the maximum amplitude point for identifying the precise frequencies; however, the zoom result is closer to the true value for ζ than could be obtained without zoom.

4. When and How Can Zoom Be Used?

4.1 Zoom Feature

The zoom feature can be activated on either Channel A, Channel B, or both simultaneously by pressing the Translator ON button during the following types of analysis:

a. Spectrum Menu, Lines 1 through 7 and 13

b. Transfer Function Menu, Lines 1 through 5

c. Power Menu, Lines 1 through 8

The zoom feature is automatically activated when using Spectrum Menu, Lines 8 and 9.

4.2 Zoom Spectrum

The zoom spectrum can be amplified an extra 6 or 12 dB with zoom Y-gain. Any overload indications will show up on the input CH A or CH B overload.

4.3 Cursor Y-Gain

The cursor control plays a double function in the zoom mode. When the center frequency set (CF set) is off, the cursor control will slide the zoom window through the entire baseband spectrum and read out the center of the zoom window. Activating center frequency set, the cursor control operates just as it does in baseband mode, but it selects and reads out the frequencies being displayed in the zoom window with the improved zoom resolution.

4.4 Anti-aliasing Protection

One important feature of zoom is that is provides anti-aliasing protection for ultra-low frequency ranges. The SD375 uses the 10 Hz anti-aliasing filter for the 1, 2, 4, 5 and 10 Hz frequency ranges, so it is possible to encounter aliasing problem on the 1, 2, 4, and 5 Hz ranges. However a 1 Hz alias-free range can be created, for example, by selecting the 200 Hz baseband range and zooming around 0.5 Hz with a zoom of 100. For other synthesized ranges, refer to Figure 4. All (zoom developed) frequency ranges have anti-aliasing protection and do not have to start at 0 frequency.

4.5 Faster Analysis Times With Zoom

When analyzing data on low frequency ranges, sometimes the analysis time is extremely long. For example, on the 1 Hz range, it takes 400 seconds to load just one memory period. Combine this with a number of averages and the time gets even longer. By creating a 1 Hz range with zoom as discussed in 4.4, the memory period is cut in half. This can be achieved because the analyzer is now operating with only 200 lines of resolution instead of 400. This holds true for any frequency range created using the zoom function. This allows the operator a choice of 400 lines of resolution and maximum processing time or only 200 lines of resolution with decreased processing time. This technique has no effect on the upper real time speed of the analyzer.

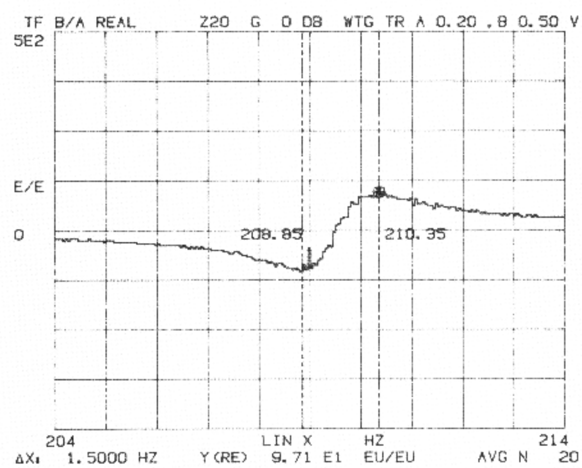


Figure 19. Real Components of the 209 Hz Mode, Zoomed by a Factor of 20

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