

## Analysis of GBT Accelerometer Data from the May 19 Elevation Rotation

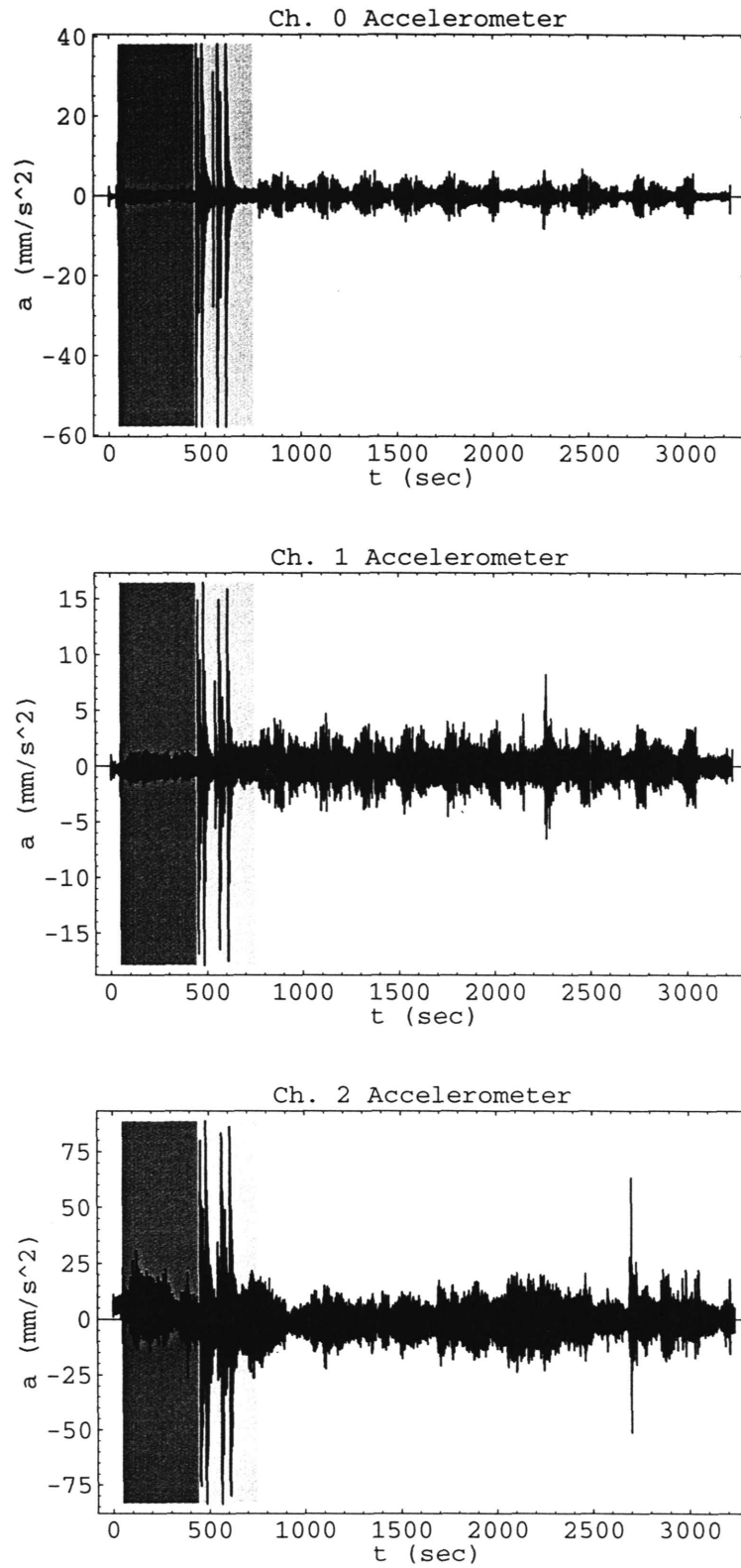
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**Abstract.** On May 19<sup>th</sup> of this year the GBT tipping structure was moved  $\sim 12^\circ$  in elevation (from  $65^\circ 77'$  to  $77^\circ 67'$ ). During the move, data were acquired from four accelerometers in order to characterize the structural vibrations. Two accelerometers were mounted near an elevation bearing, and two were at the outboard end of the horizontal feed arm. The time series of accelerometer data were previously presented in a memorandum by John Ford (GBT Archive Memo. No. S0098, dated May 20, 1999). In this memorandum I describe power spectra derived from the vibration data.

On May 19<sup>th</sup> of this year, the GBT tipping structure was moved  $\sim 12^\circ$  in elevation (from  $65^\circ 77'$  to  $77^\circ 67'$ ). The tipping structure had not been moved in elevation during the period of the past year or so, because of the rework which was required on the backup structure (BUS) permanent supports. John Ford arranged to have accelerometer data recorded during, and immediately following, the elevation move. Two accelerometers (Ch. 0 and Ch. 1) were mounted on the alidade structure, near one of the elevation bearings, and two (Ch. 2 and Ch. 3) were mounted at the end of the horizontal feed arm. The Channel 1 accelerometer was aligned to be sensitive to acceleration in the direction along the elevation axle, and the Channel 0 one to acceleration perpendicular to the axle (and in the horizontal plane). The Channel 2 accelerometer was aligned to measure side-to-side acceleration of the feed arm, and Channel 3 to measure acceleration along the horizontal section of the feed arm. A description of the data acquisition, and plots of the raw observations, have previously been presented by John Ford in GBT Archive Memo. No. S0098, [1].

Figure 1 shows the full, fifty-four minute times series recorded by three of the accelerometers. The Channel 3 accelerometer data were off scale during all but four minutes of the observation period, so data from that accelerometer will be ignored. The gain factors quoted by John Ford in GBT Archive Memo. S0098 were used to convert the voltage output of the accelerometers into units of acceleration. Also, the mean value, computed over the fifty-four minute duration of each time series, has been subtracted out. The peak accelerations shown for the Channel 0 accelerometer exhibit a positive/negative asymmetry, because the strongest positive peaks saturated the A/D converter. The colored background hues correspond to three regimes of activity: Data from the time period of the continuous motion in elevation, which had a duration of about five minutes, are shown against a blue background. Data in the pink-shaded region correspond to small, incremental adjustments in elevation angle needed to complete the move. It will be interesting, in particular, to look in detail at the final "decay" event in the pink-shaded region. Data in the yellow region are from the time period (of approximately forty minutes duration) following the elevation motion, when construction activity resumed. The long-period, quasi-periodic components



**Figure 1.** Fifty-four minute times series of acceleration measurements recorded by three of the accelerometers. Data from the time period of the continuous motion in elevation are shown against a blue background. Data in the pink shaded region correspond to small, incremental adjustments in elevation. Data in the yellow region are from the time period following the elevation motion, when construction activity resumed.

which are evident, especially, in the Channel 0 data are likely due to repeated ascent and descent of the elevator on the alidade structure following the move.

Figure 2 shows, in detail, the interesting “decay” events from the pink-shaded region of Figure 1. The final decay event is the most interesting of these, because it is uninterrupted. Figure 3 shows the final event alone. The modulated nature of the decay curves suggests the presence of multiple modes. The envelope of the decay is obvious to one’s eye up to perhaps sixty or eighty seconds beyond the onset of the impulsive excitation event.

A similar picture emerges if one computes the autocorrelation of the long (39-minute duration) segment of the time series following the decay “events”—i.e., the parts of the time series shown in the yellow-shaded regions of Figure 1. During this time, the excitations were not due to extreme impulsive events, but rather were due to random events. (Earlier, in GBT Memo. 167, results on structural damping of the alidade derived from wind-gust vibratory excitation were compared with results from the “shaker” test, reported on in Memo. 159, and led to similar conclusions.) Plots of the autocorrelation functions derived from the final thirty-nine minutes of the time series are shown in Figure 4. The qualitative nature of the decay is similar to what is seen in Figure 3, but it appears that a somewhat different mixture of modes must have been excited by the impulsive events than by the random excitations, because the patterns differ a bit in detail. This is confirmed if we look at power spectrum estimates derived from the two different segments of the time series.

Figure 5 shows power spectra derived from 120-second duration time series records of the “decay” event shown in Figure 3 (the segment begins as soon as the Ch. 0 A/D converter stops saturating), and Figure 6 shows spectra derived from the final thirty-nine minutes of data. An  $\sim 1$ -Hz mode is shown to be more strongly excited in the Channel 1 and Channel 2 data of Figure 5 than it is in Figure 6 (in Fig. 6, in fact, this mode is essentially entirely absent from the Ch. 1 data).

The Figure 6 spectra, indeed, appear to be “cleaner” than those of Figure 5. My feeling is that better estimates of structural damping can be derived from long-duration—e.g., one-hour long—observations during which the excitation is of a random nature (due to wind gusts, say) than from short duration observations following extreme impulsive events.

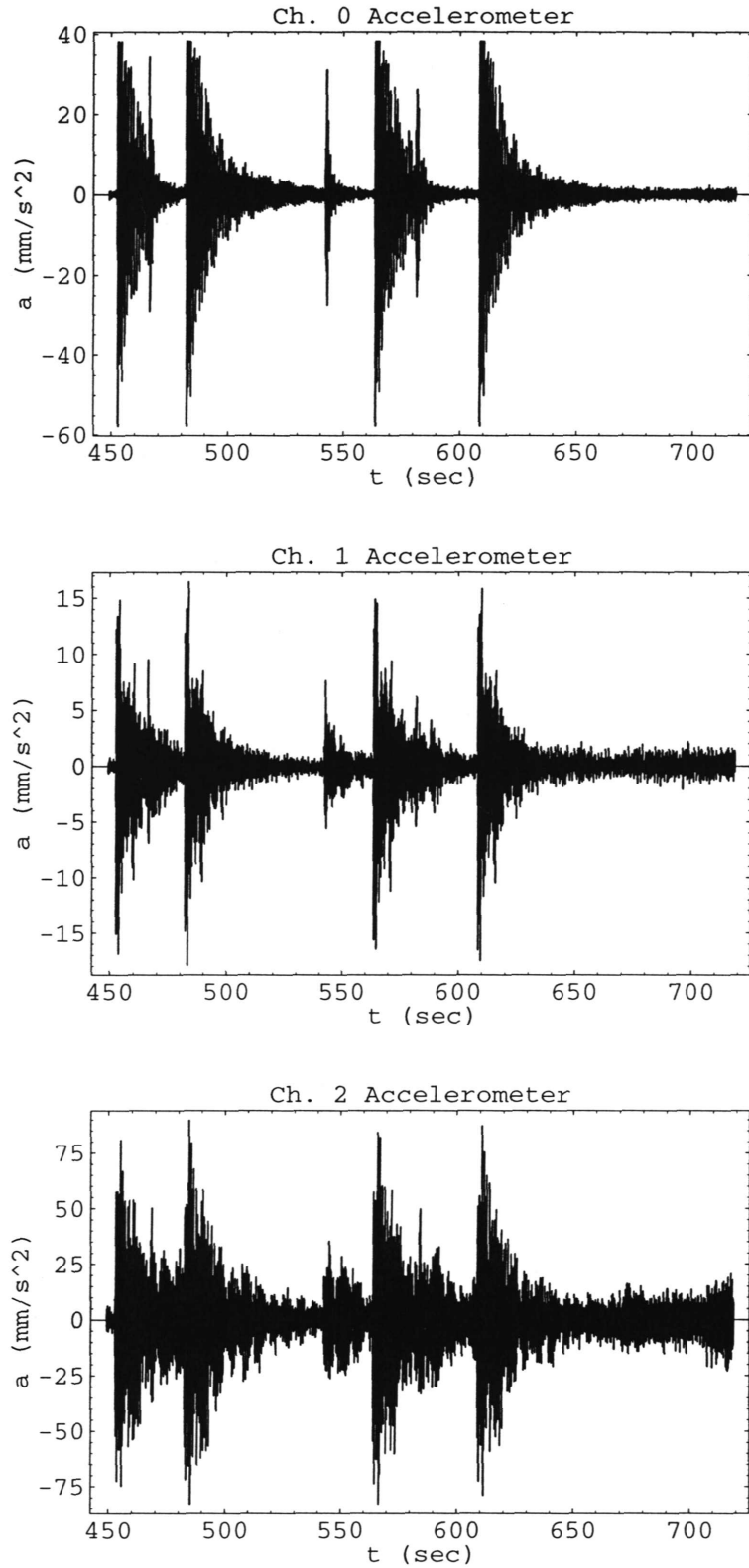
Figure 7 shows high-resolution plots of the 1-Hz modal resonance line in the Channel 0 spectrum and of the modal resonance lines near 0.7 Hz in the Channel 1 and Channel 2 spectra. The 1-Hz resonance is a narrow line (0.006 Hz to 0.010 Hz full-width at half-maximum (FWHM)), corresponding to a 0.3% to 0.4% coefficient of viscous damping. The 0.7 Hz line is split into a pair of components at 0.70 Hz and 0.74 Hz. The features at 0.70 Hz in the Channel 1 and Channel 2 spectra have FWHMs of  $\sim 0.013$  Hz, corresponding to a damping coefficient of 0.9%. These features themselves appear as though they might be the superposition of features of about half this width. The fine detail in the two spectra might indeed be noise bumps, but I do not know what would cause the noise in Channels 1 and 2 to be correlated—so maybe they are to be believed.

Asymmetries in the load paths and the weight distribution on the structure might indeed lead to mode splitting. I believe that, as of May 19<sup>th</sup>, some of the seventeen BUS temporary supports had been removed and some had not. Also, work was underway to repair the 21 bent and bowed members of the BUS that had been damaged a few weeks before. Today—in August ’99—all of the load has been transferred to the permanent supports, the temporary support beams have all been removed, and all the primary modules of the vertical feed arm have been assembled. (But main-surface panel installation has not yet begun.) Thus, the next set of accelerometer data should be a good deal more representative of the behavior of the completed antenna. In particular, it will be interesting to record some data at the tip of the feed arm.

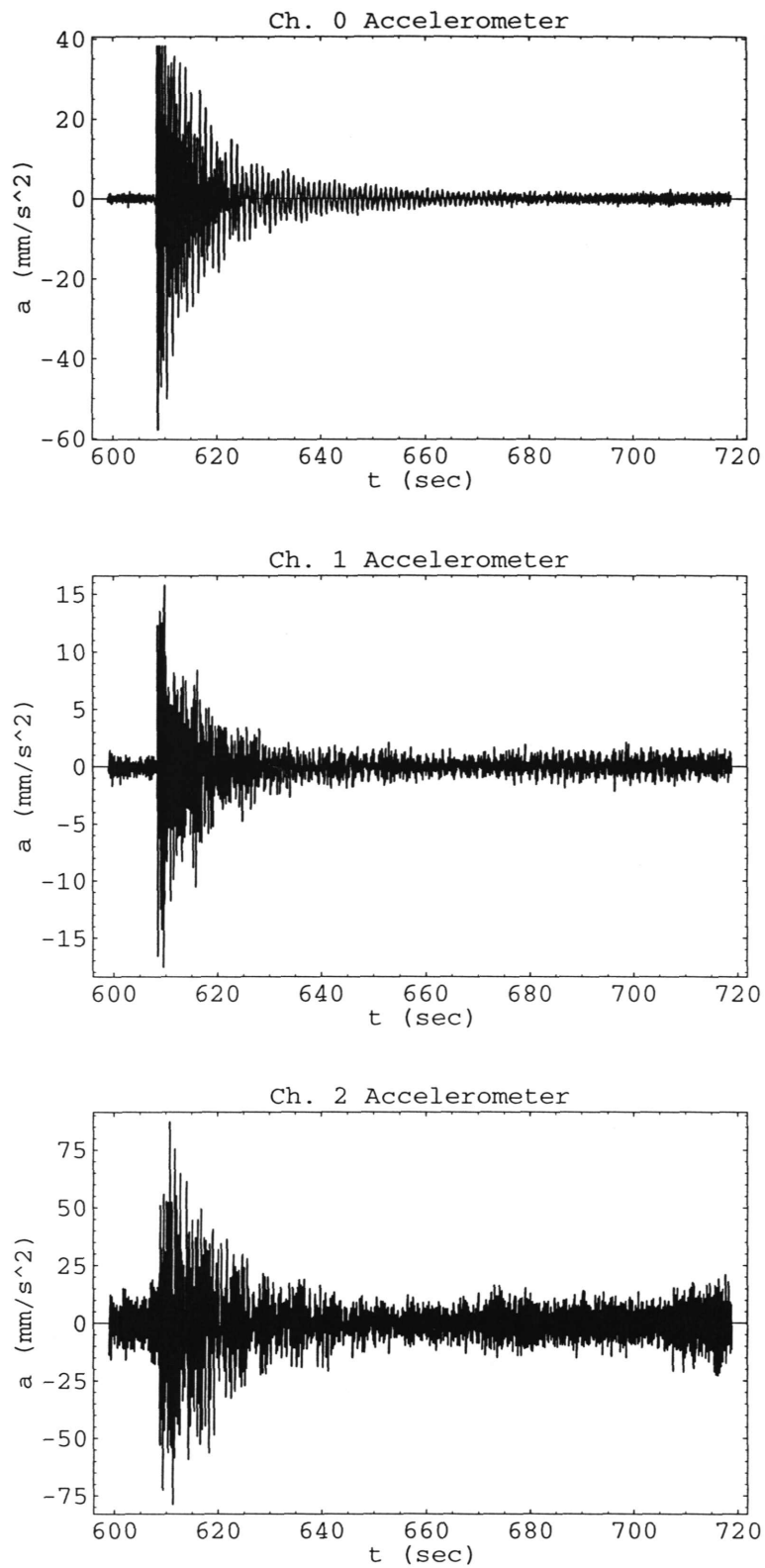
Finally, I thought it might be interesting to twice numerically integrate some of the accelerometer data, to obtain velocity and position. I did this with two ten-second segments of the Channel 2 accelerometer data, one from the time of the final “decay” event shown in Figure 3 and one from the quiescent period. The results are shown in Figures 8 and 9. During the decay event the peak-to-peak amplitude of the oscillatory motion is typically  $\sim 0.7$  mm, whereas during the quiescent period the peak-to-peak amplitude is typically around 50 microns.

#### REFERENCES

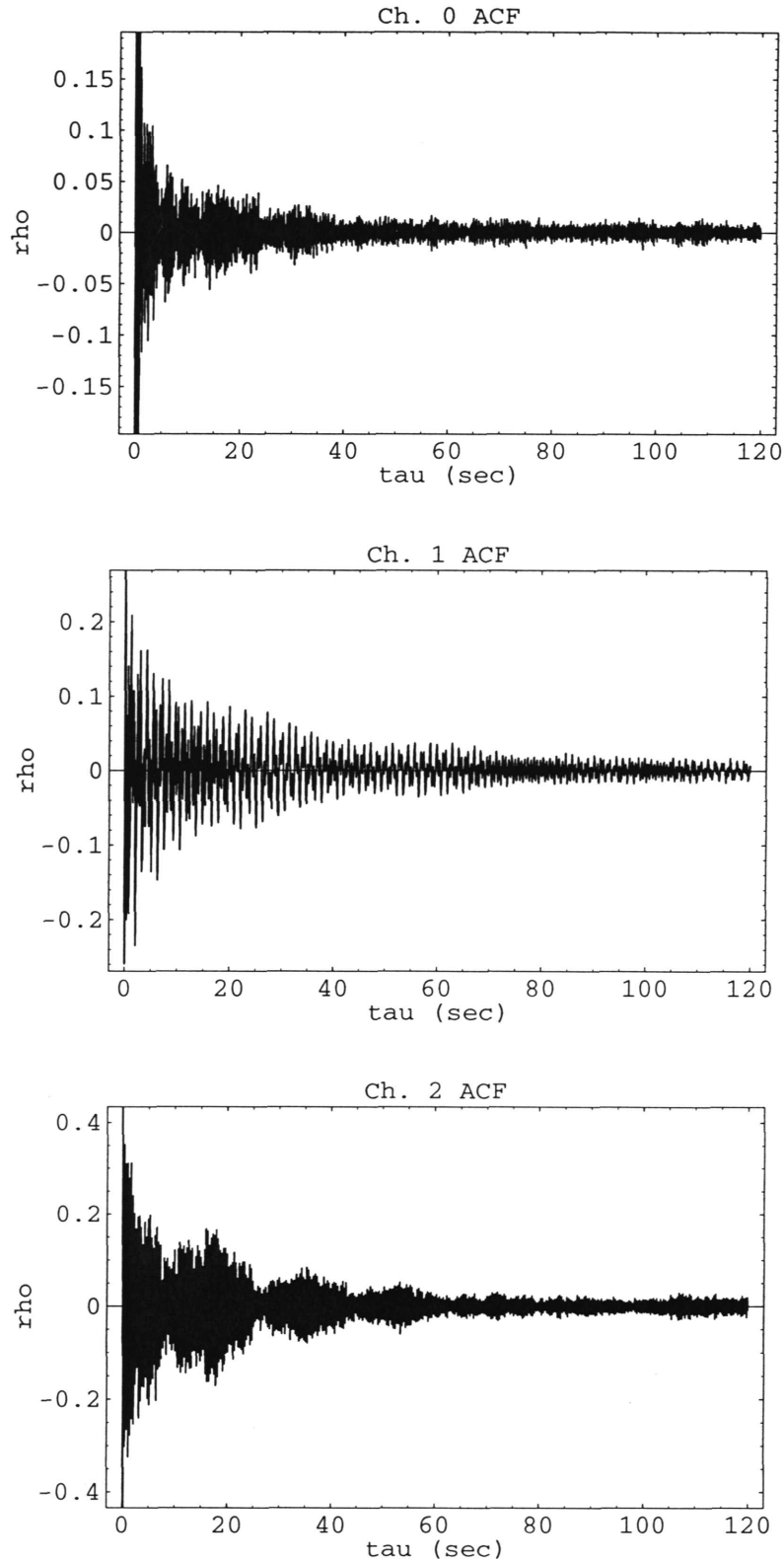
- [1] J. Ford, “GBT Accelerometer Data for the Recent Elevation Rotation”, GBT Archive Memo. No. S0098, May 20, 1999.
- [2] J. M. Payne, D. Schiebel, and F. R. Schwab, “Dynamic Tests on the GBT”, GBT Memo. No. 159, October 24, 1996.
- [3] F. R. Schwab, J. M. Payne, and D. Schiebel, “Dynamic Tests on the GBT”, GBT Memo. No. 167, June 7, 1997.



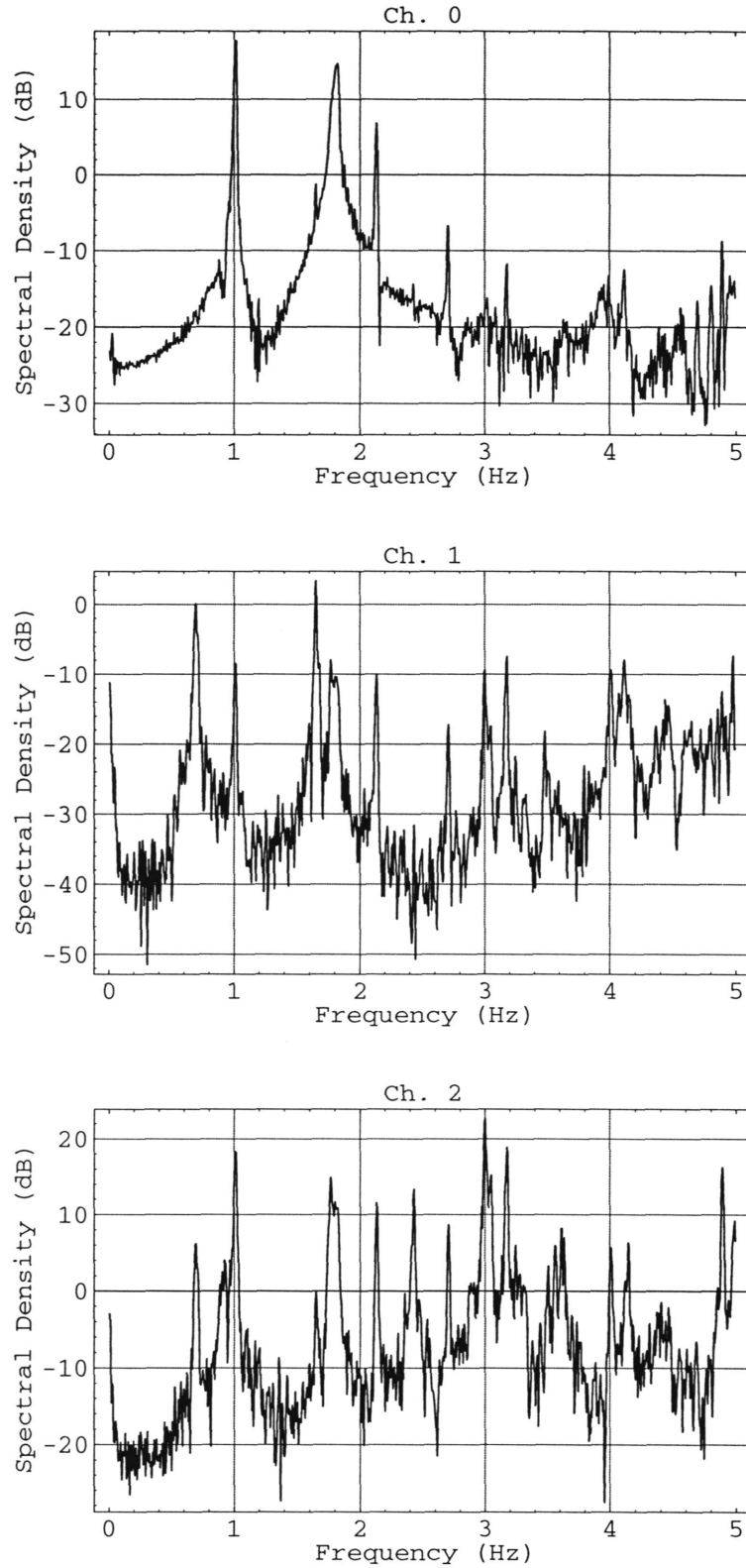
**Figure 2.** This figure shows, in detail, the “decay” events (shown in pink in Figure 1) arising from the final, incremental adjustments in elevation at the end of the move.



**Figure 3.** The final “decay” event, shown separately.

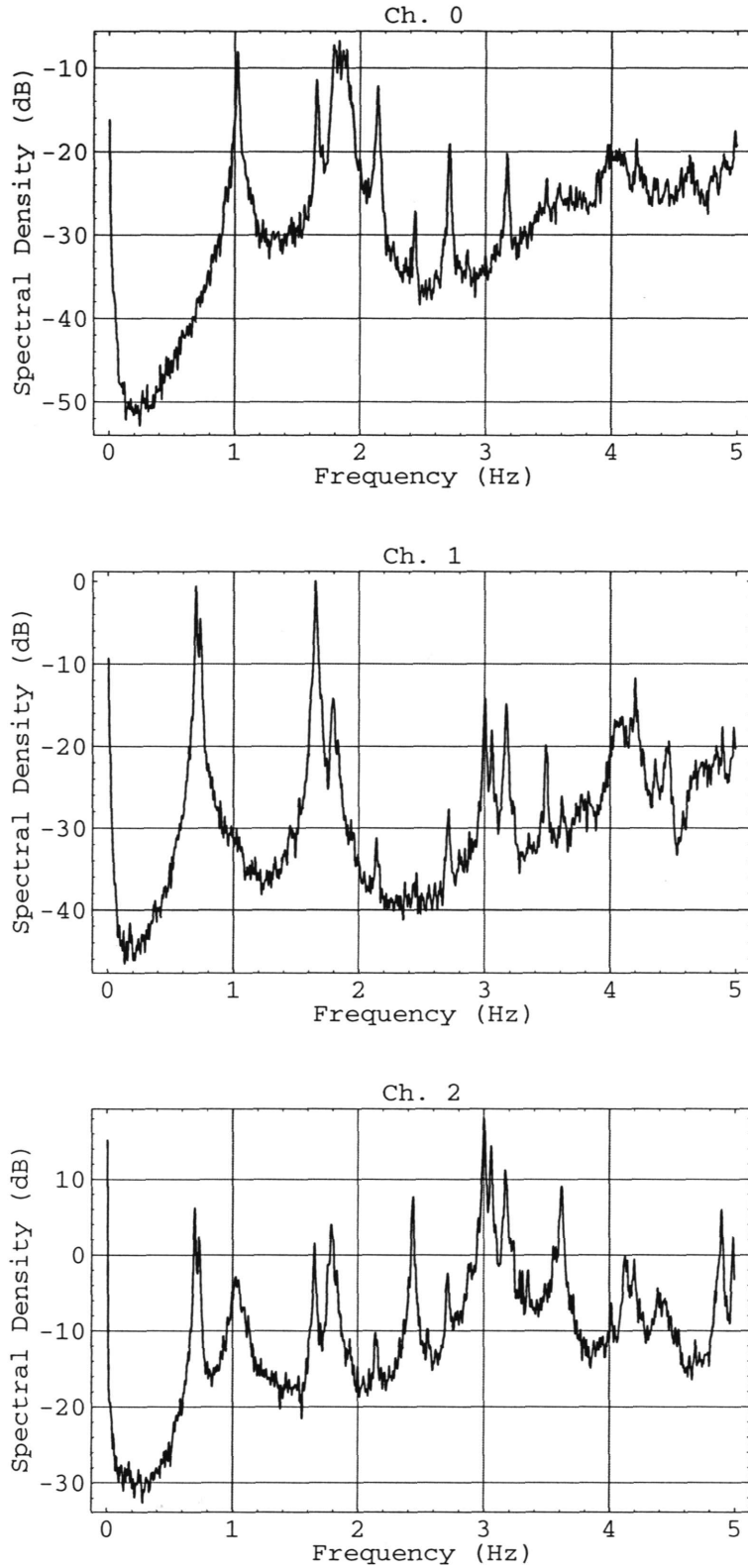


**Figure 4.** Autocorrelation functions computed from the final thirty-nine minutes of data (shown in yellow in Fig. 1) during which the excitations of the structure were not of the extreme impulsive variety, but rather random in nature. Compare with the “decay” event shown in the preceding figure.

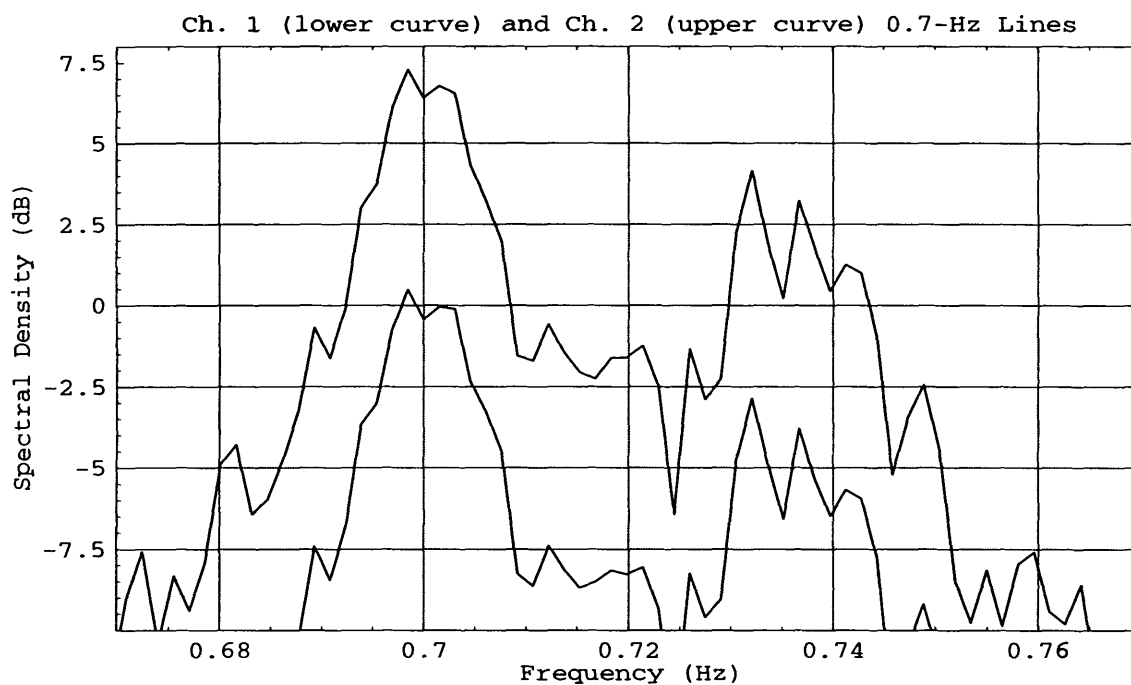
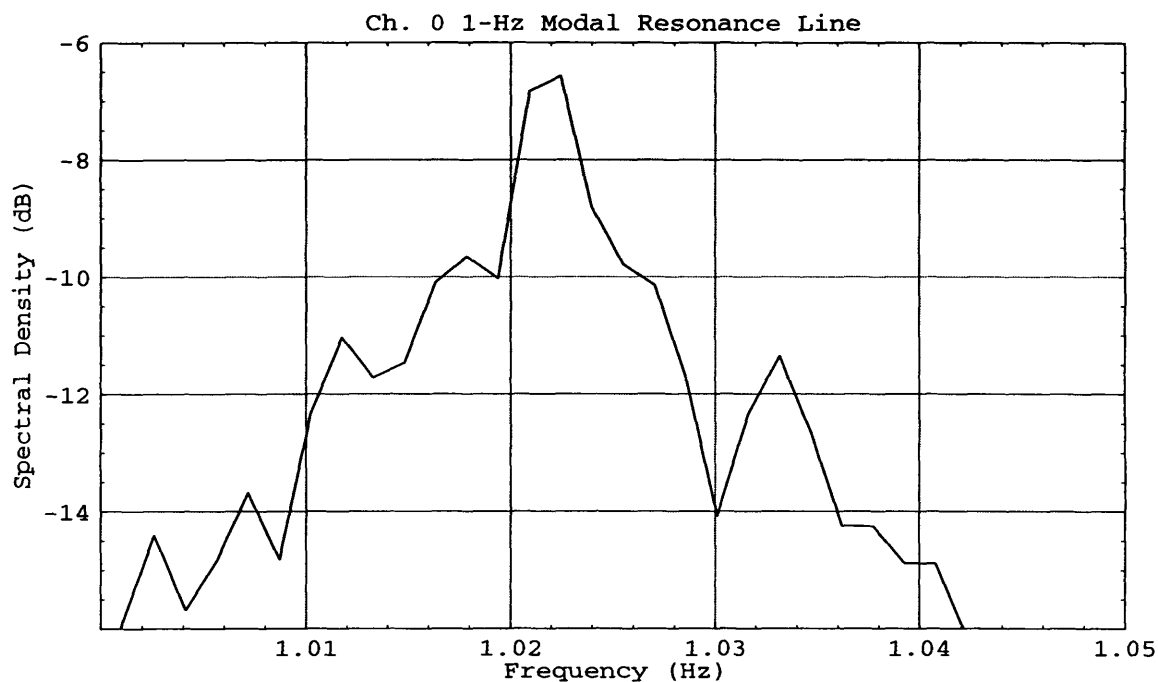


**Figure 5.** Power spectra computed from the 120-second time series records of the “decay” event shown in Figure 3. The spectra were computed using a 8192-point sliding data window, 62.5% overlap, and a  $\pi$  prolate spheroidal wave function taper applied in the time domain. The spectral features are artificially broadened, because of the tapering and because of the short duration of the time series.

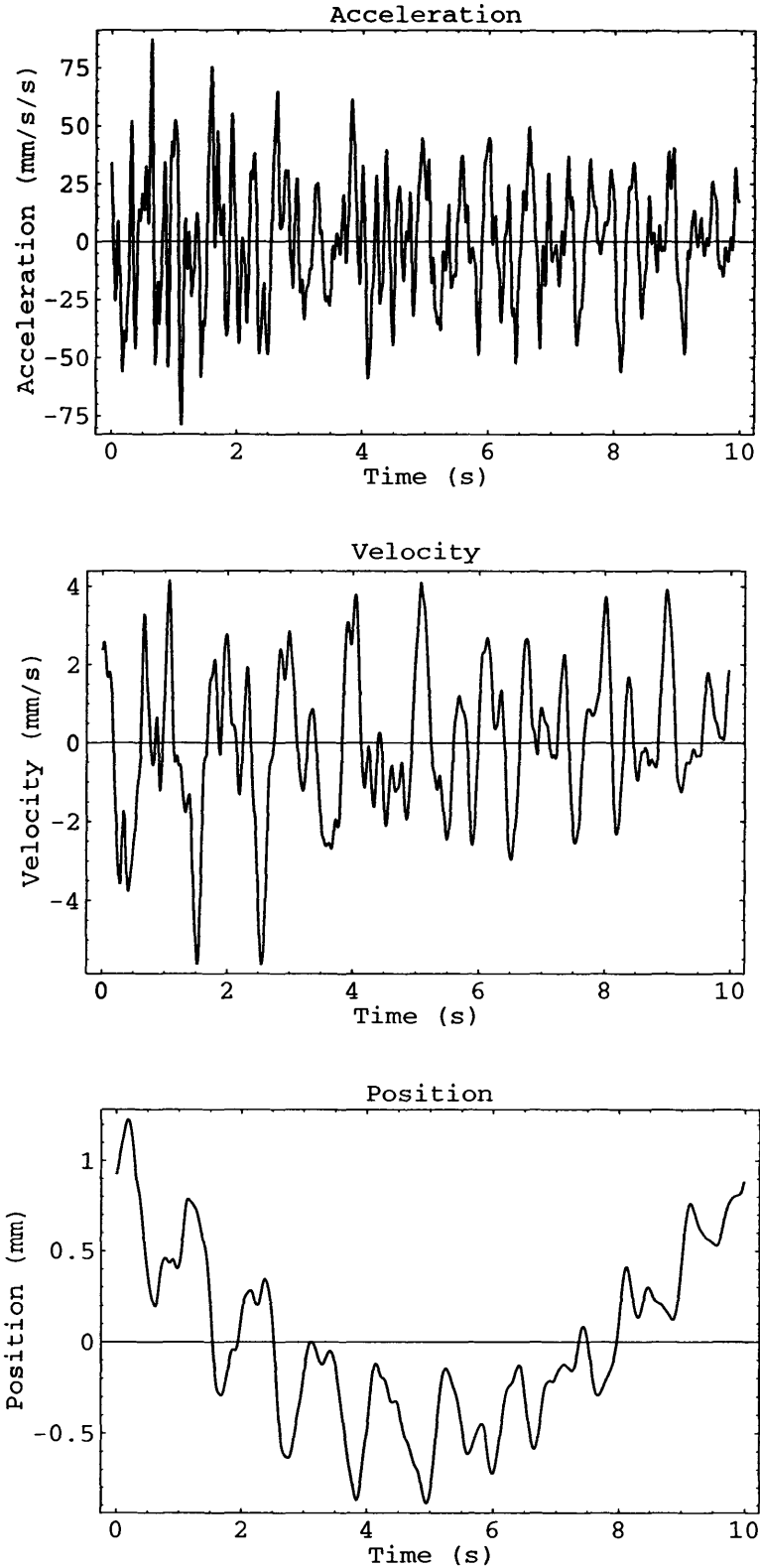




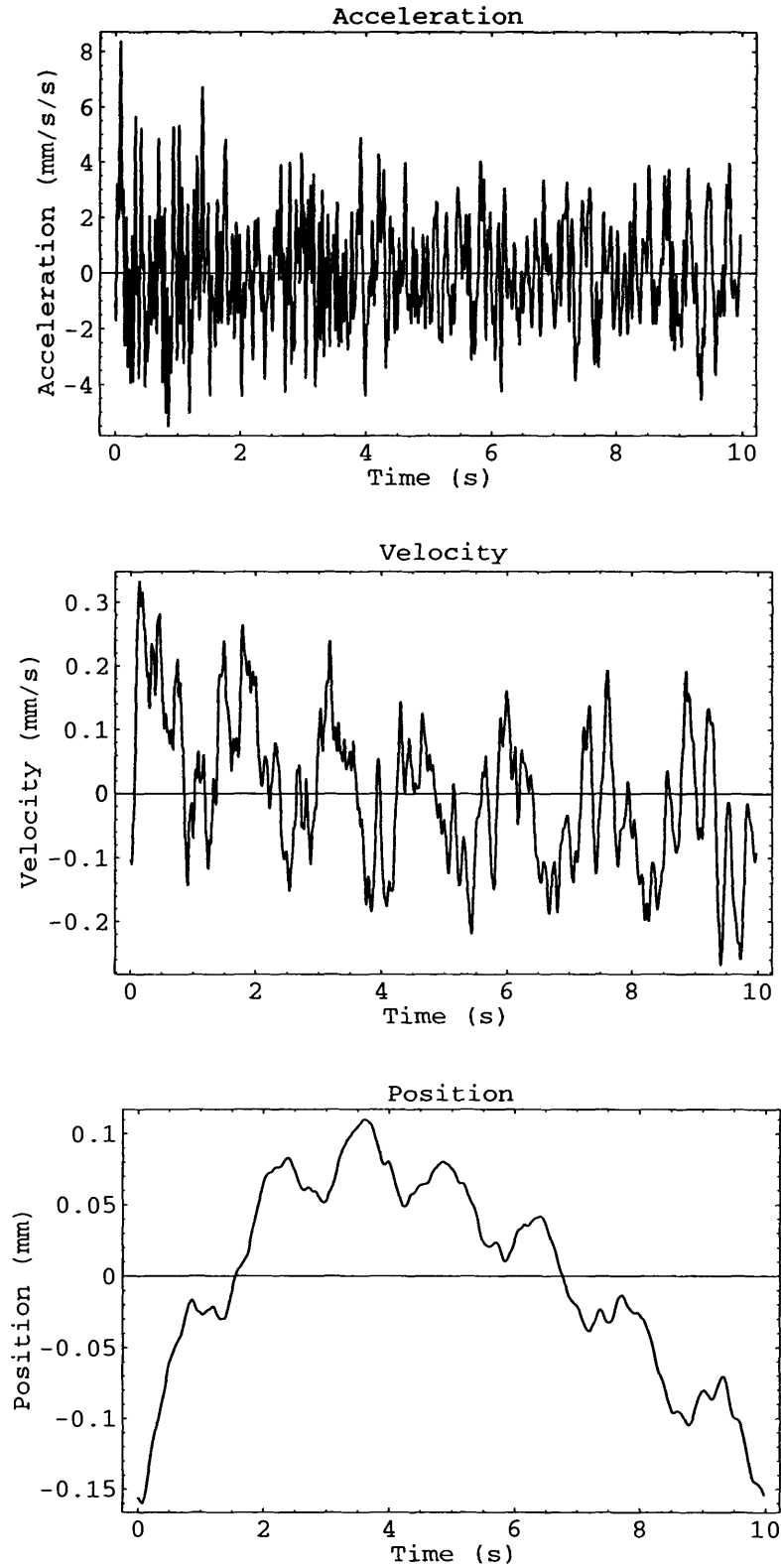
**Figure 6.** Power spectra computed from the final thirty-nine minutes of the time series. The spectra were computed using a 16,384-point sliding data window, 62.5% overlap, and a  $3\pi/2$  prolate spheroidal wave function taper applied in the time domain.



**Figure 7.** (Top) High-resolution plot of the Channel 0 1-Hz modal resonance line. This is a narrow (0.006 Hz to 0.010 Hz 3-dB width) line, corresponding to a 0.3% to 0.5% coefficient of viscous damping. (Bottom) Plots of the Channel 1 and Channel 2 modal resonance lines in the neighborhood of 0.7 Hz. The features at 0.70 Hz have full-widths at half-maximum of  $\sim 0.013$  Hz, corresponding to a damping coefficient of 0.9%. But they appear as if they could correspond to the superposition of two lines, each with  $\sim 0.5\%$  damping. Note the similarity, between the two channels, of the many “bumps” in the spectra—which suggests that the fine structure may be real. In order to achieve high spectral resolution, these spectra were computed using a uniform taper and 50% overlap.



**Figure 8.** (*Top*) Ten seconds of acceleration measurements from the Channel 2 accelerometer, taken from the onset of the “decay” event shown in Figure 3. (*Middle*) A plot of the inferred velocity, obtained by numerically integrating the acceleration. (*Bottom*) Inferred position, obtained by numerically integrating the velocity. The long-time-scale position drift likely is due to instrumental drift and is not to be believed. However, the mean oscillation about this trend—which has a peak-to-peak amplitude of, typically,  $\sim 0.7$  mm—is indeed credible.



**Figure 9.** (*Top*) Ten seconds of acceleration measurements from the Channel 2 accelerometer, taken after the elevation move (900 seconds into the time series shown in Fig. 1). (*Middle*) The inferred velocity, obtained by numerically integrating the acceleration. (*Bottom*) The inferred position, obtained by numerically integrating the velocity. In this case the mean oscillation has a peak-to-peak amplitude of  $\sim 50$  microns.