GBT MEMO 204

GBT Feed-arm Analysis using Laser Ranging and Accelerometers

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Abstract

Differential displacement measurements using the laser rangefinders and the accelerometers at the top of the feed-arm are discussed. Parametric plots of the differential displacement indicate motions of the feed-arm on the order of $1-2$ mm over time intervals of a few minutes, consistent with previous results [Par99]. Power spectra produced from both the rangefinder and accelerometer data are consistent.

1 Observations

On 15 October 1999, an experiment was performed using 5 ground laser rangefinders and accelerometers to measure the motions of the top of the feed-arm. [Par99] describes the experimental setup and some results of these differential measurements. Briefly, the telescope azimuth was such that the tip of the feed-arm was almost directly north; hence the directions of the accelerometer axes were oriented along the ground coordinate system axes. Five rangefinders were used to measure targets on the tip of the feed-arm. Rangefinders zy101, zy102, and zy103 were pointed at target ZEG41040L, zy110 at ZEG41040R, and zy112 at ZEG41080. Data were taken at a rate of 5 Hz. Because zy103 was not synchronized with the other rangefinders, data taken from zy101, zy102, and zy110 were used the calculate the differential motions of the top of the feed-arm. The equations derived by [Gol99] were used to calculate the differential positions with time.

The data discussed here were taken at a different time than the results discussed in [Par99]. We have chosen a time range where both rangefinder data and accelerometer data existed—between UTC 20:56:15 and 21:04:03. Note that because of an error in the IRIG clock the rangefinder time stamps are off by $\sim$ 1 hour.

Both the rangefinder and accelerometer data were analyzed using Mathematica. The rangefinder data were reformatted and edited before any analysis using a Perl script. Only return amplitudes greater than 20 mV were selected and any phase ambiguities were adjusted.

2 Results and Discussion

2.1 Laser Rangefinder Data

The range data from zy101, zy102, and zy110 are shown in Figure 1. The raw ranges are plotted as a function of time in minutes after UTC 00:00:00. Note that there are several ranges which are clearly unphysical, where the range varies by one or two mm in a small fraction of a second. These data were not edited and remain in the current analysis.

Figure 2 shows the calculated displacements as a function of time. Here x, y, and z correspond to the ground coordinate directions of east, north, and zenith. Variations in the displacement are detected on the order of $1-2$ mm for the x and y directions over 8 minutes of time. The dz displacement is fairly constant with a slow drift of about 0.5 mm over a period of 8 minutes.

Parametric plots of the displacement are shown in Figures 3, 4, and 5 for the $dy-dx$, $dz-dx$, and $dz-dy$ planes, respectively. The largest motions are in the $x-y$ plane. The feed-arm seems to dwell in a particular location with variations of $\sim 0.25-0.50$ mm while slowly drifting to new locations about 1 mm away.

Power spectra were produced from the calculated displacements using code developed by Fred Schwab [SPS97, Sch99]. Welch's method is employed where the time series is divided into overlapped weighted segments which are then averaged together [Wel98, PW93]. To increase the signal-to-noise ratio a tapered window is used to select sections over a period of 100 sec (500 points). A spheroidal function is used to taper the window. Also, the windows are overlapped by half the window size and averaged together.

The power spectra are shown in Figures 6, 7, and 8 for displacements dx, dy, and dz, respectively. For the dx displacement the power spectrum indicates the three lowest frequency modes at $\sim$ 0.7, 0.9, and 1.25 Hz. In the dy displacement the lowest mode is at $\sim$ 0.8 Hz. Note that the two lowest modes for the dx direction are not present. The higher frequency mode at 1.25 Hz does exist, however. The lowest frequency mode for the dz direction is at 1.25 Hz and the amplitude is down by about 5–10 dB.

2.2 Accelerometer Data

On 13 October 1999, two accelerometers were moved from the base of the feed-arm to the top of the feed-arm. During the 15 October 1999 experiment the channel 2 accelerometer was aligned *almost* exactly in the x-direction, while the channel 3 accelerometer was aligned in the y-direction. The accelerometers were sampling at a rate of 100 Hz. The power spectra analysis used for the accelerometer data is identical to that of the rangefinder data except that the window size is 3600 samples.

Figures 9 and 10 show the power spectra for the accelerometer data for channels 2 and 3, respectively. Note that the low frequency modes in channel 2 correspond to the same modes in the rangefinder dx spectrum, while the modes in channel 3 correspond to the modes in

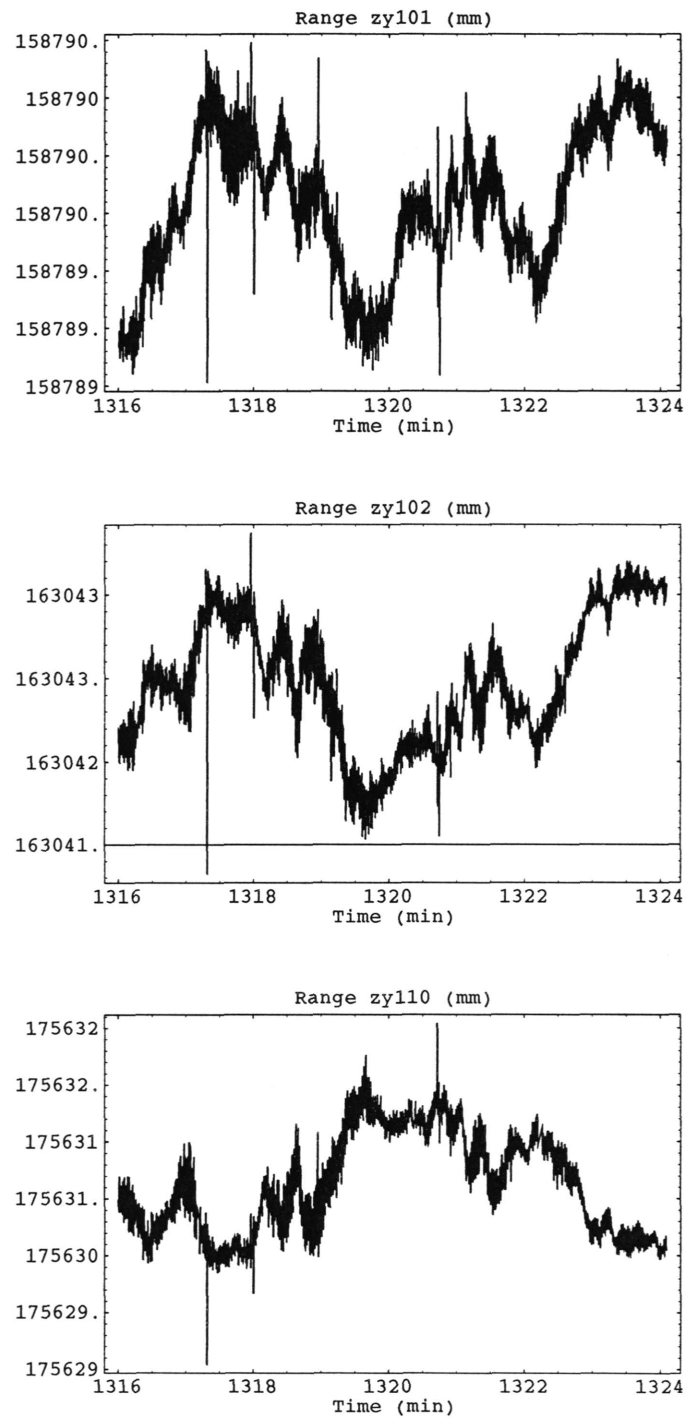

Figure 1: Ranges for each rangefinder plotted versus time.

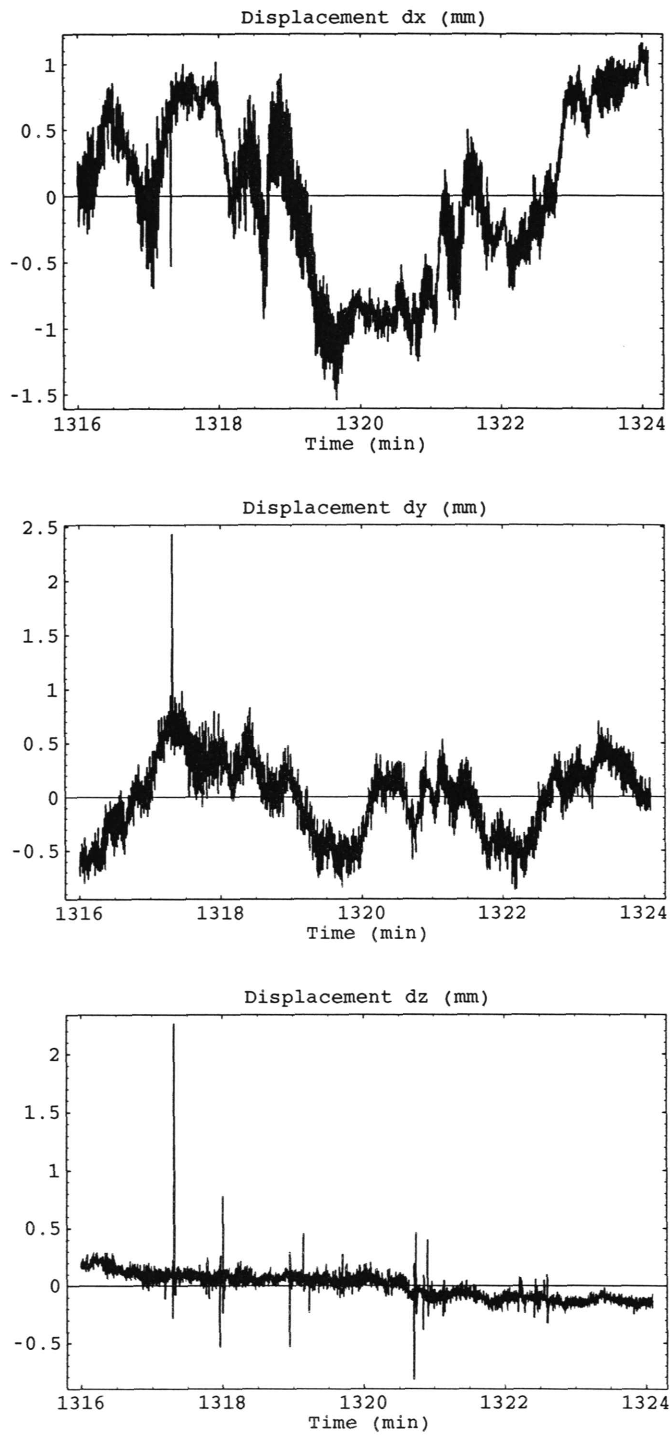

Figure 2: Calculated rangefinder displacements for dx, dy, and dz plotted versus time.

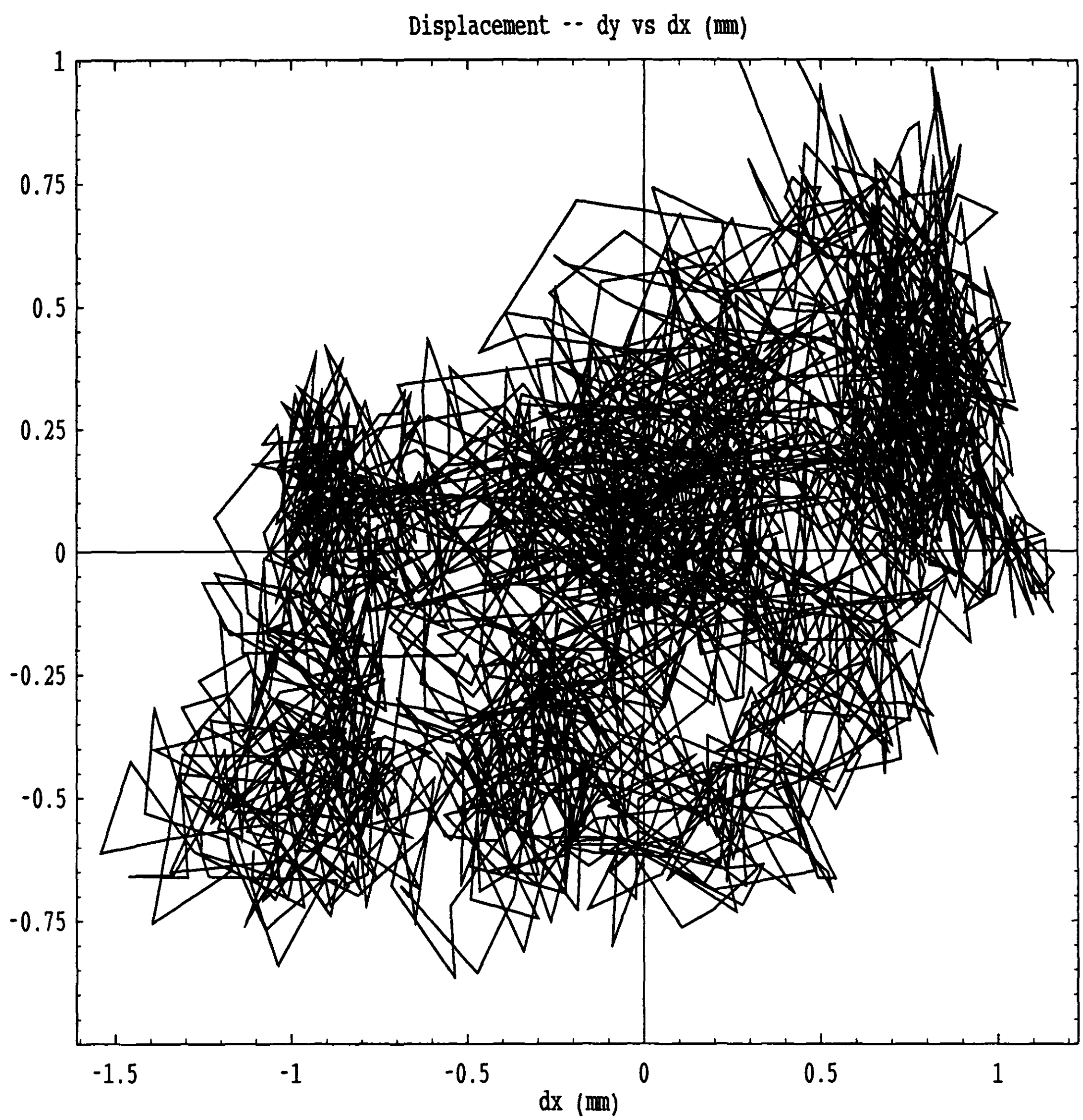

Figure 3: Parametric plot of rangefinder displacements $dy - dx$.

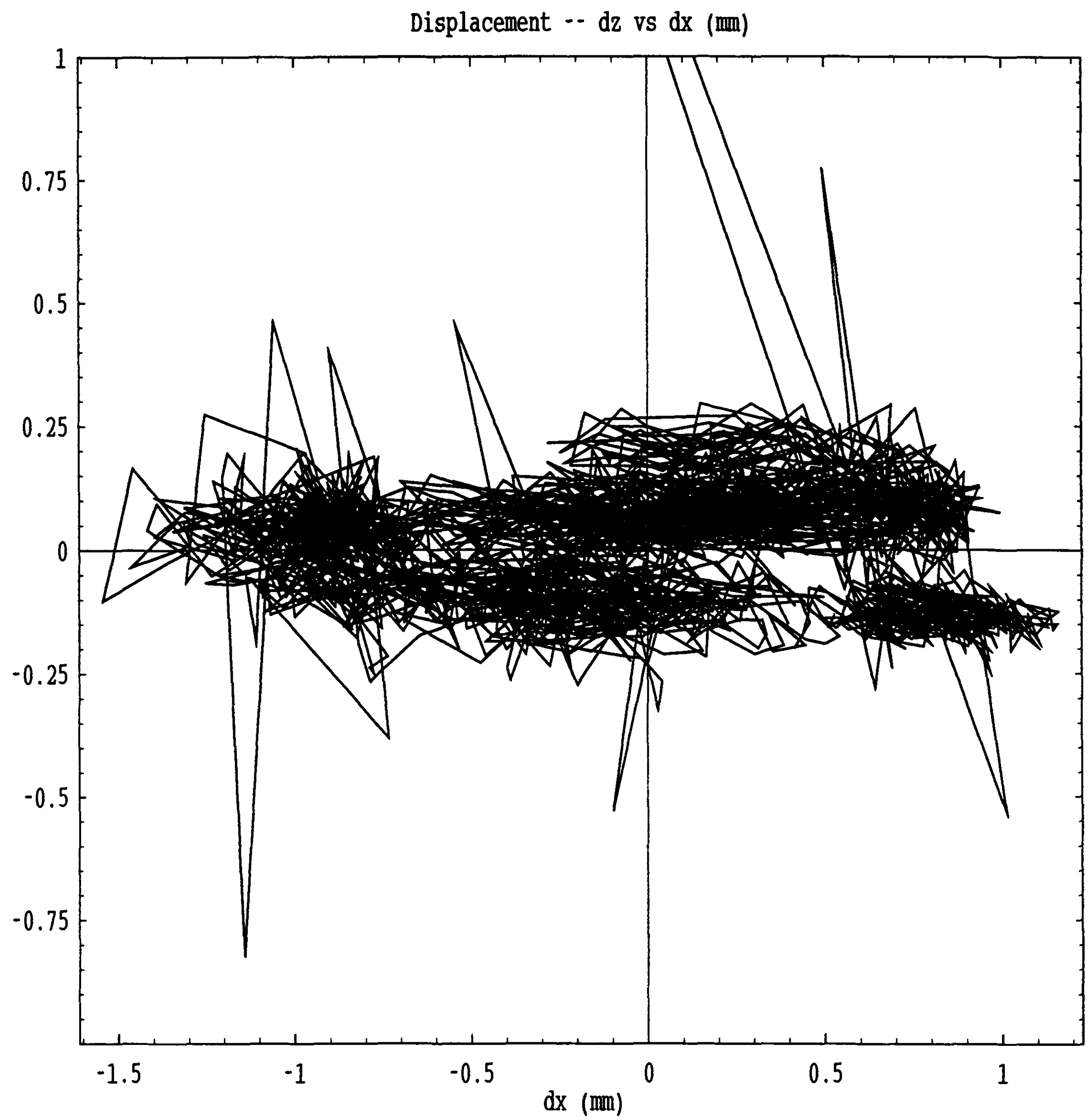

Figure 4: Parametric plot of rangefinder displacements $dz - dx$.

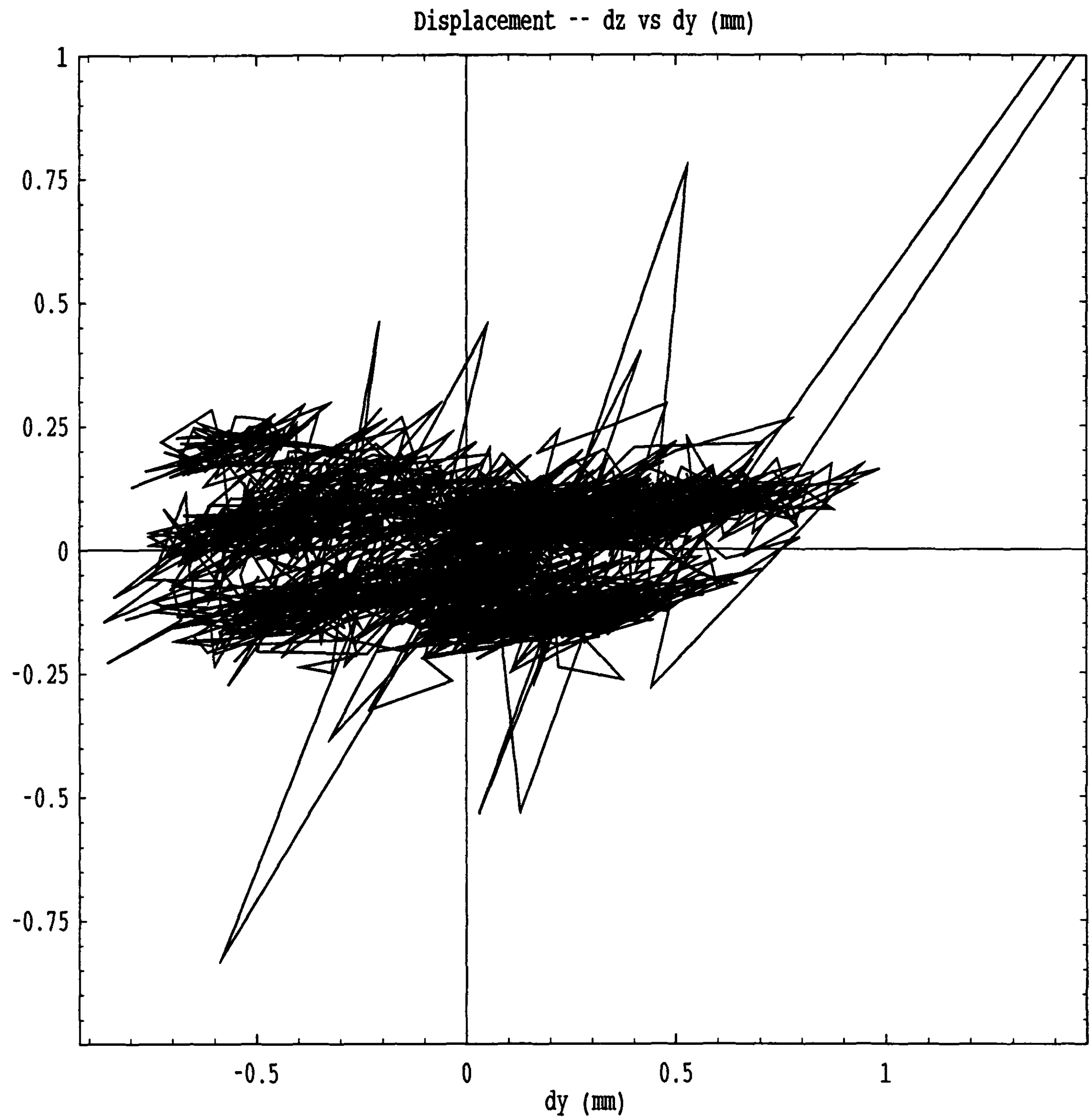

Figure 5: Parametric plot of rangefinder displacements $dz - dy$.

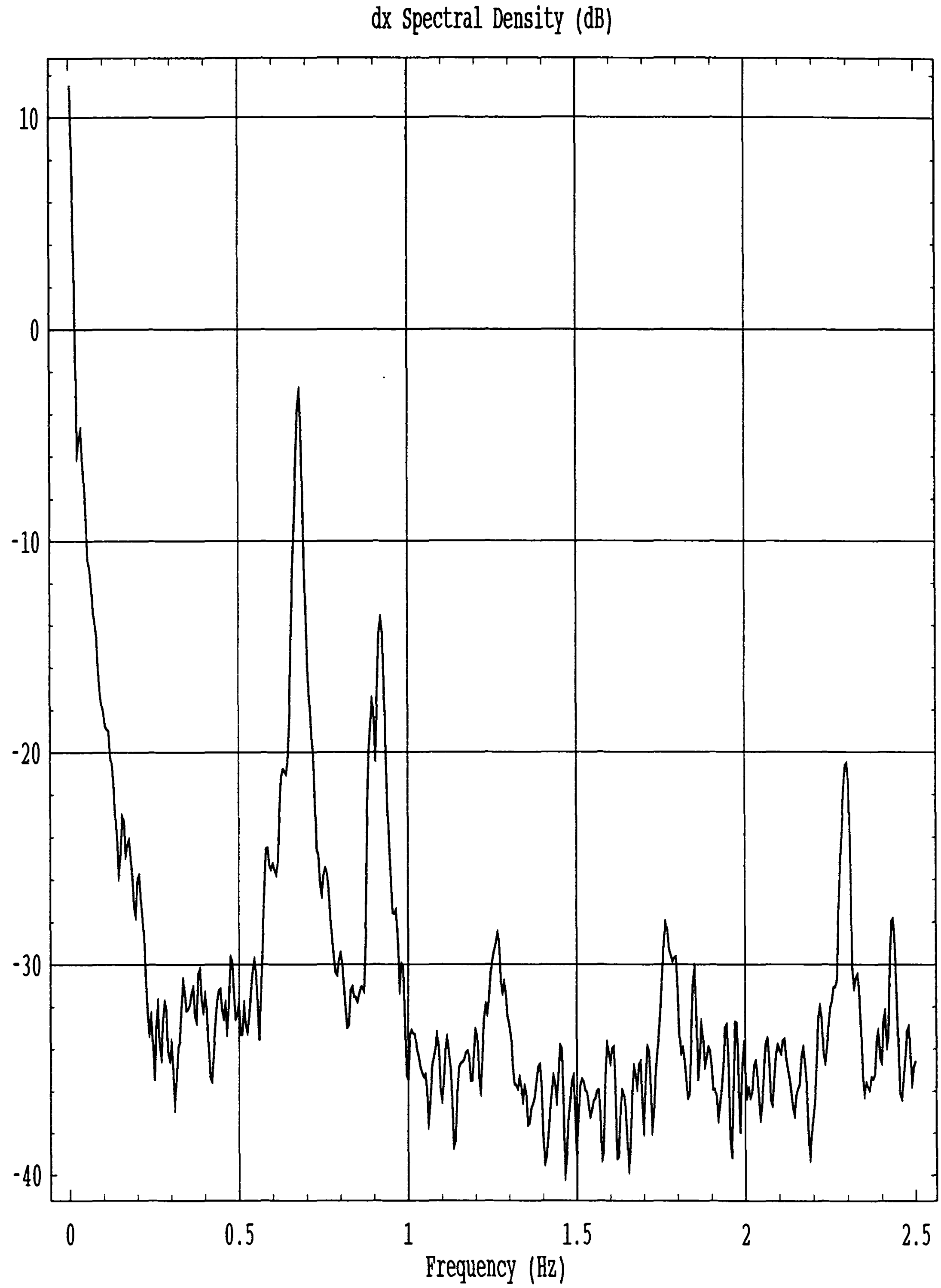

Figure 6: Power spectra for rangefinder displacement dx.

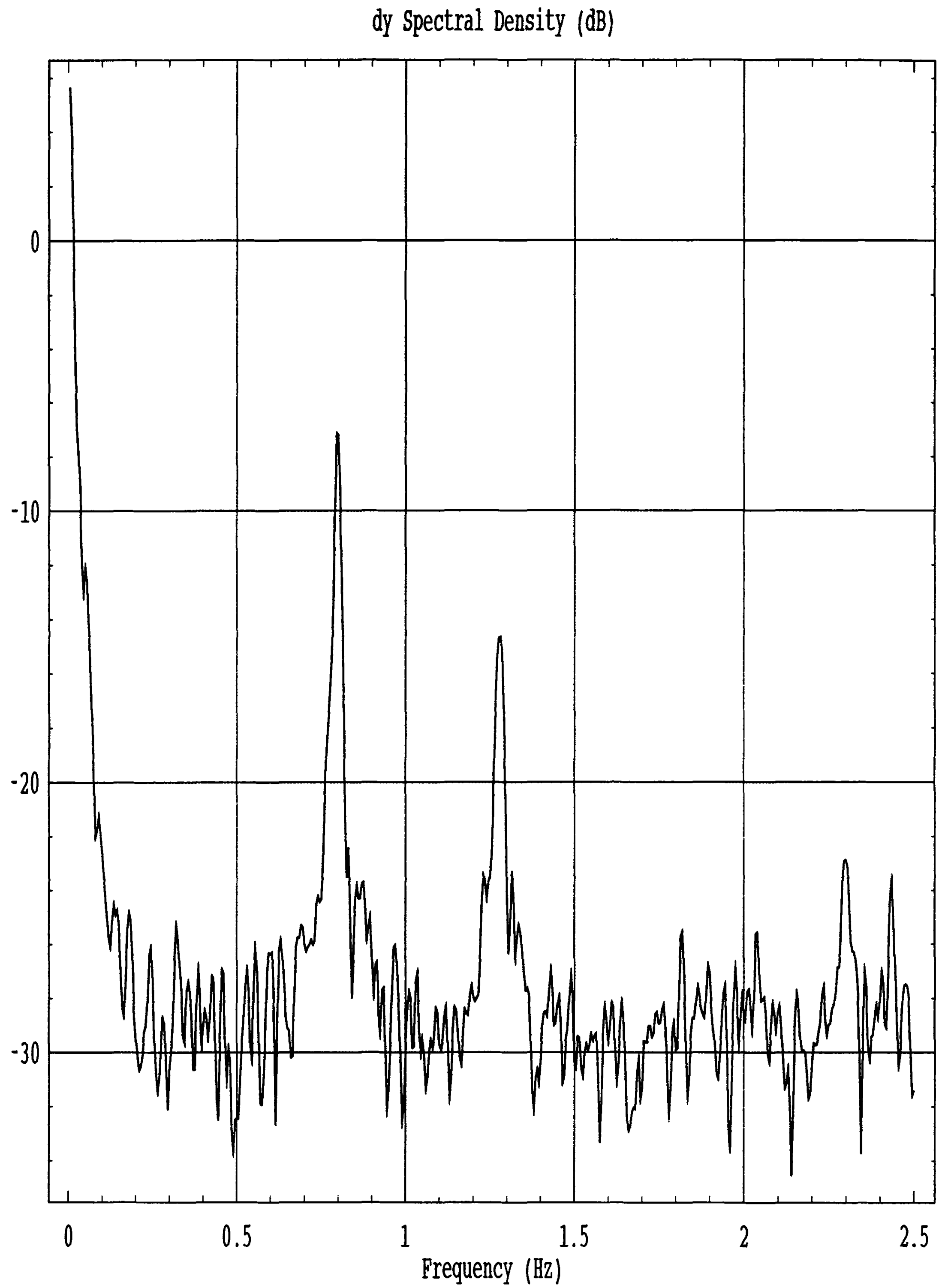

Figure 7: Power spectra for rangefinder displacement dy.

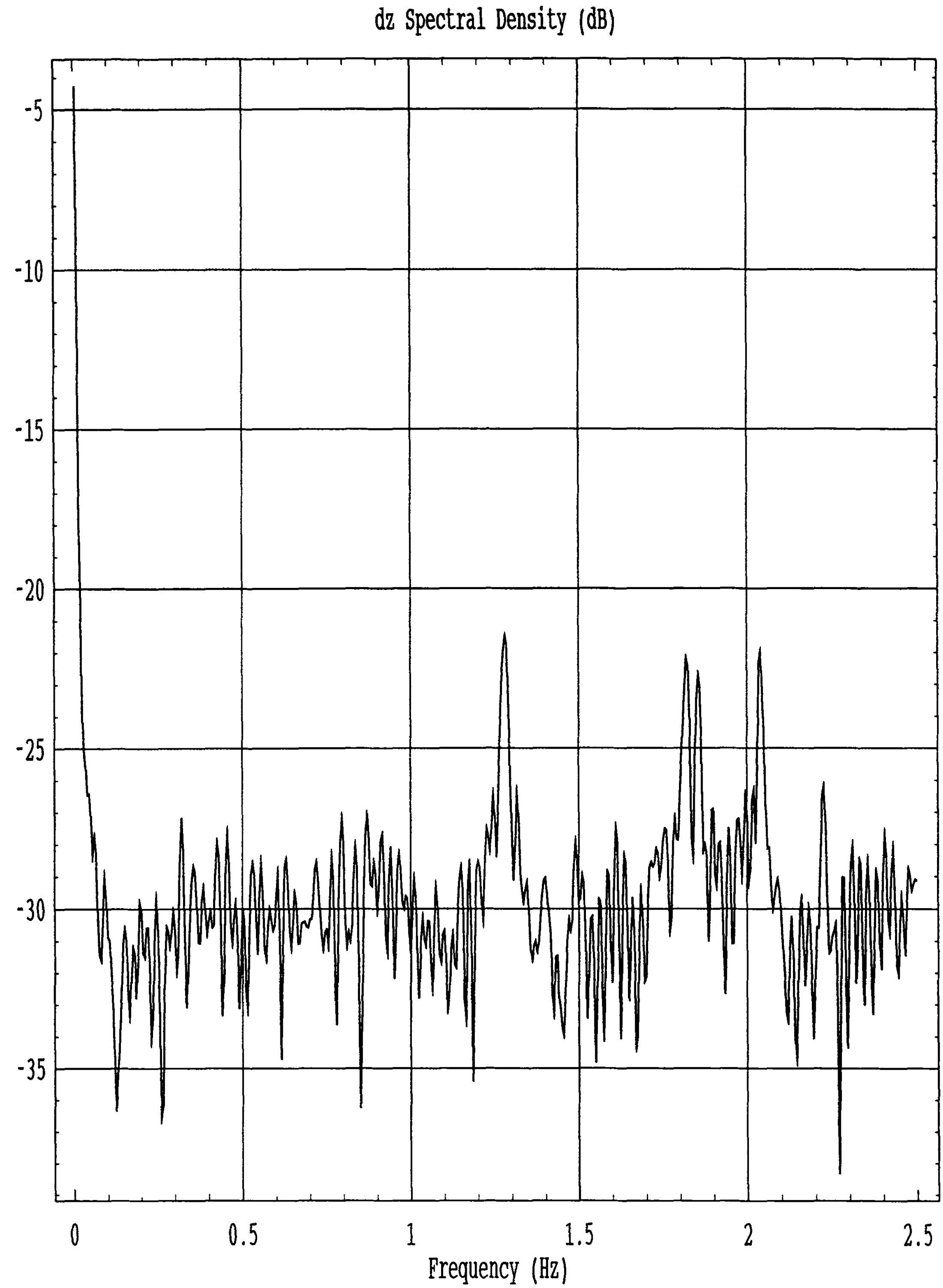

Figure 8: Power spectra for rangefinder displacement dz.

the *dy* spectrum.

Overall it appears that the rangefinder data and the accelerometer data are consistent. Notice, however, that there is considerable power in the higher frequency modes in the accelerometer data. This observation is counter intuitive upon first inspection of these plots. For example, consider that the feed-arm is vibrating with amplitude A and frequency w, or $x = Asin(wt)$. Upon differentiation the acceleration is $a = -Aw^2sin(wt)$. Thus the power goes as w^4 and care must be taken when comparing the amplitudes of rangefinder "positional" spectra versus the accelerometer spectra.

References

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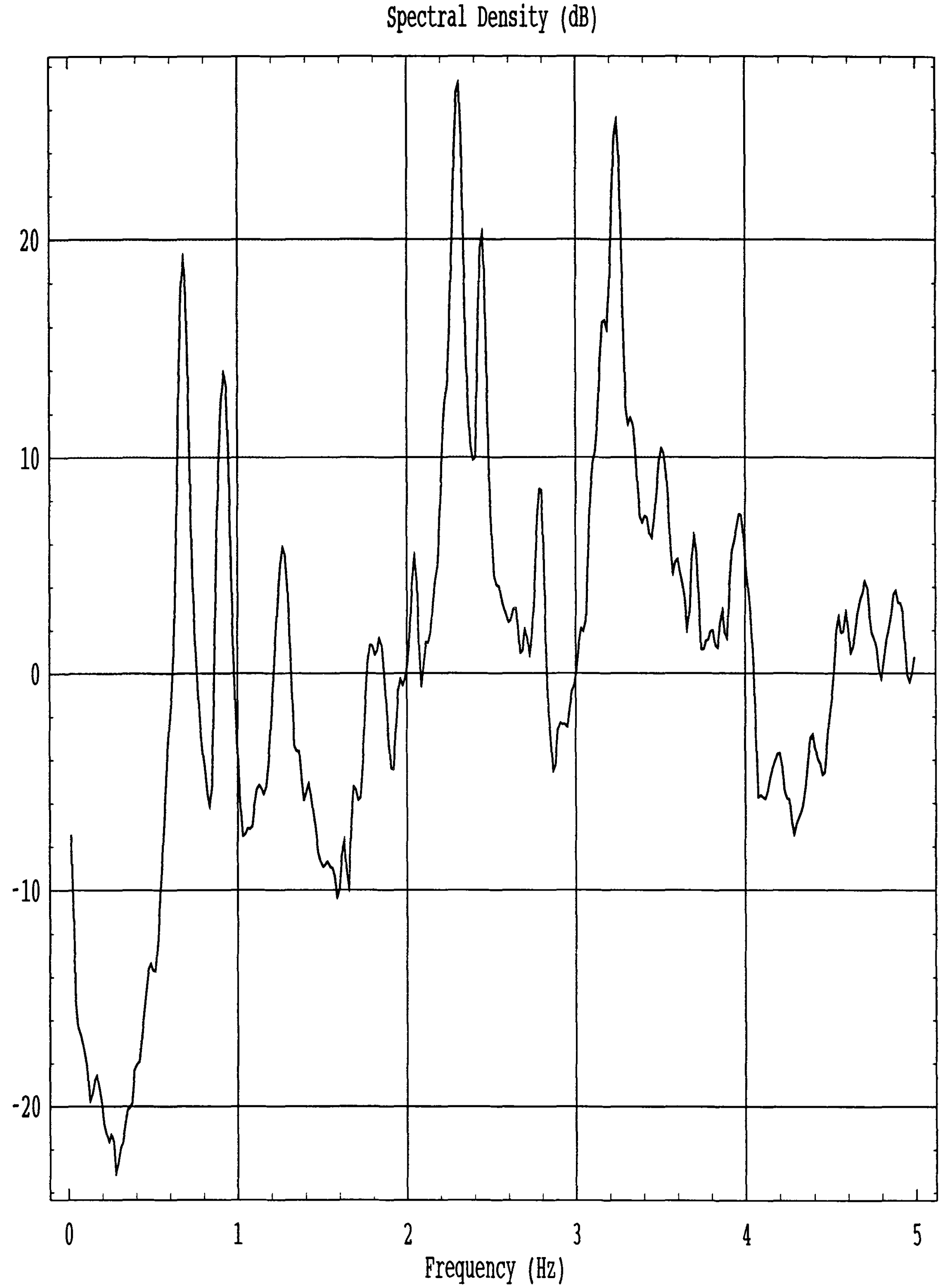

Figure 9: Power spectra for accelerometer channel 2.

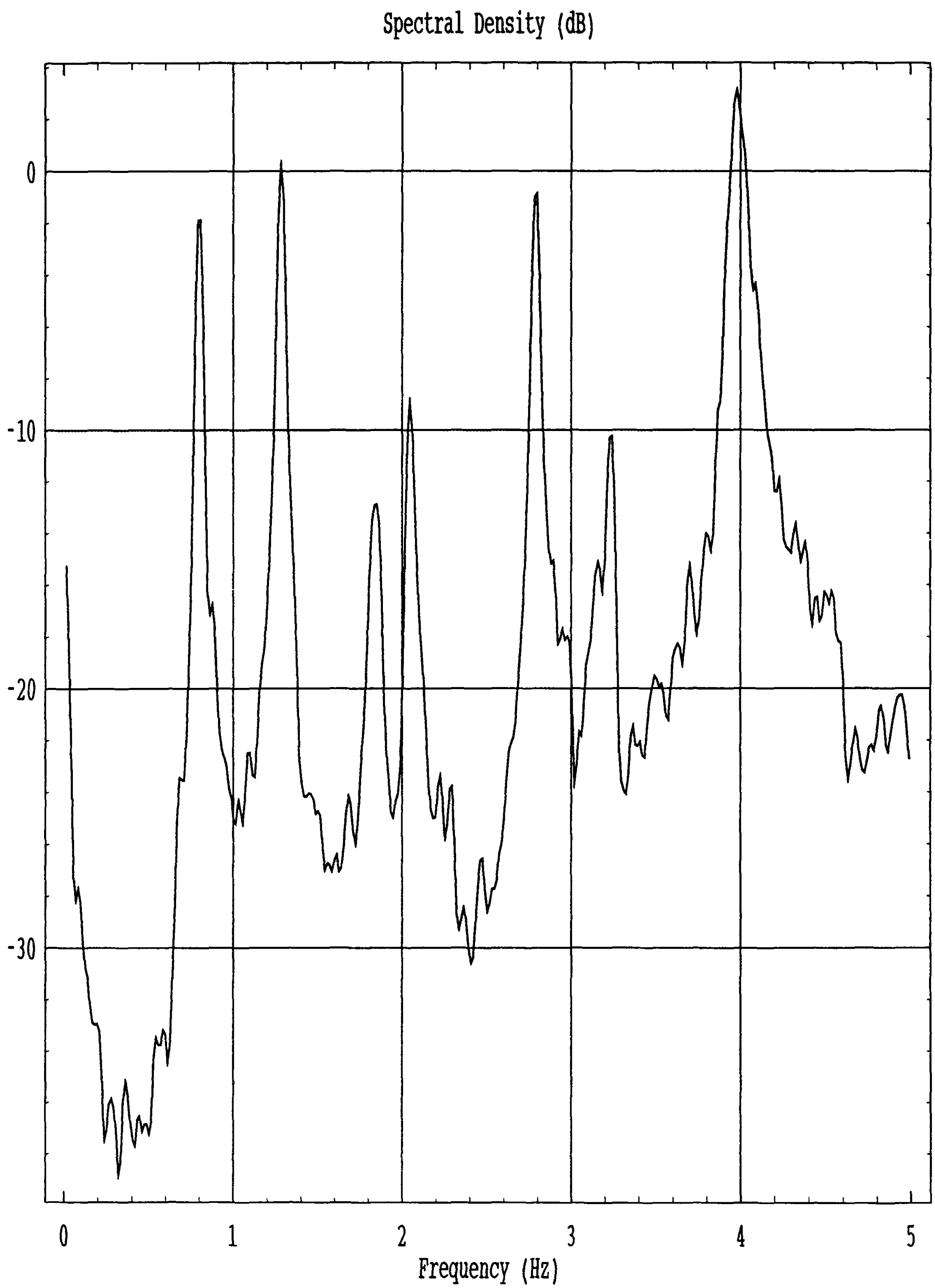

Figure 10: Power spectra for accelerometer channel 3.