Analysis of Longitudinal Phase Monitor Signal during Store #4004 Including Beam Blow-up

Bob Webber, February 27, 2005

This note investigates the frequency spectrum of data from the Tevatron beam phase monitor, T:LPM001, prior to and during longitudinal blowup of the proton bunches in the first four hours of Tevatron Collider Store #4004, Friday, February 25, 2005. During this store, the phase monitor was timed to monitor the phase of proton bunch #1. The data analyzed here is from the phase monitor electronics via MADC channel T:LPM001 as recorded by a 15 Hz data logger.

Figure 1 shows the phase monitor data along with SBD bunch width measurement and longitudinal damper gain setting during that time. The damper gain was reduced near the end of this time following blow-up of the bunch width.

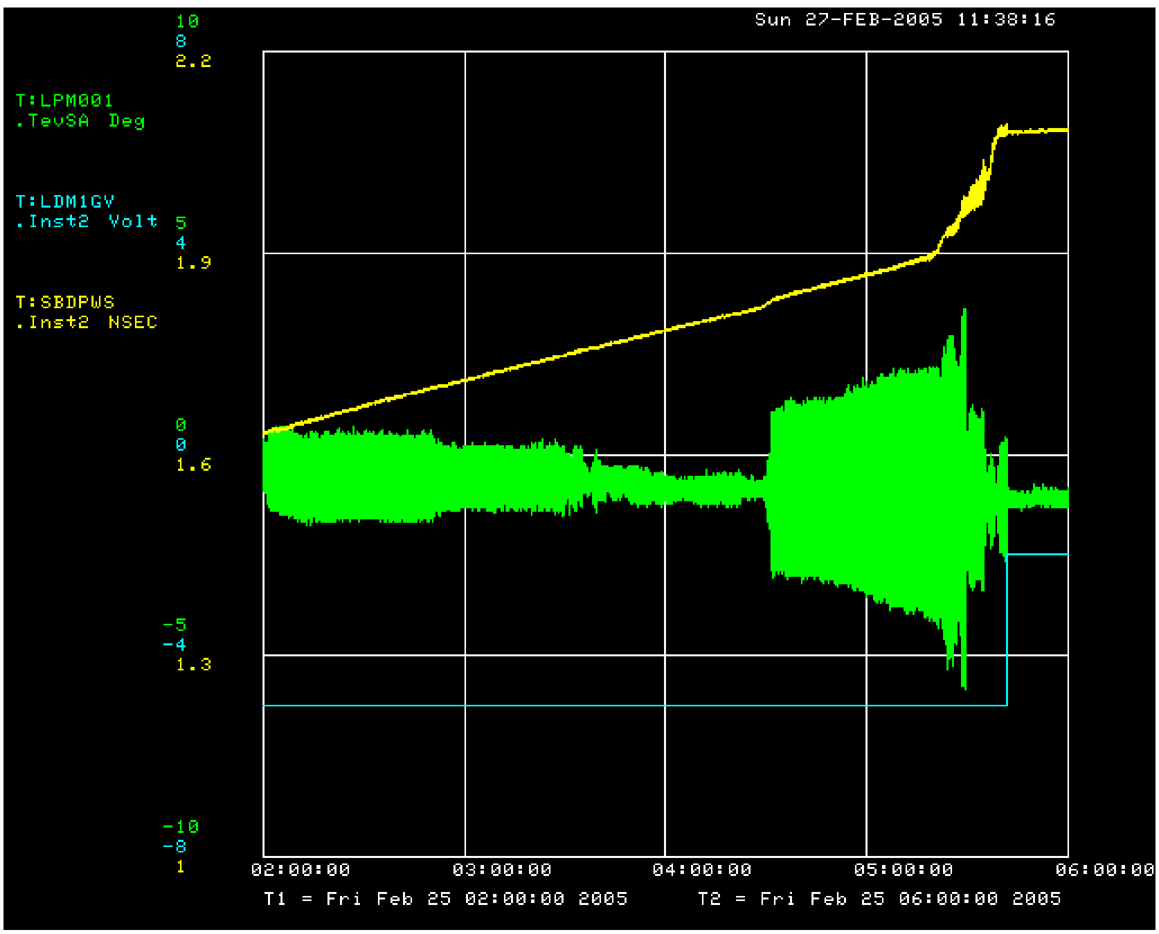

Figure 1. Phase monitor, longitudinal damper gain, and SBD bunch width during first four hours of Store #4004.

The available data during this interval of time is only that recorded by the TevSA 15Hz data logger, whereas the interesting beam dynamics effects are almost certainly occurring at higher frequencies. This means that the beam frequencies are aliased into a 7.5 Hz band by the sampling frequency of the logger.

Earlier observations have shown that the phase monitor signal in its full bandwidth clearly sees the 10.0 Hz proton/antiproton RF frequency difference during cogging. The 15 Hz logger data and analysis of its frequency content during collision cogging of this store is shown in Figure 2. The 10 Hz cogging signal, aliased to 5 Hz, is clearly recoverable from the logger data. This expected result forms a basis of credibility for the observations that follow.

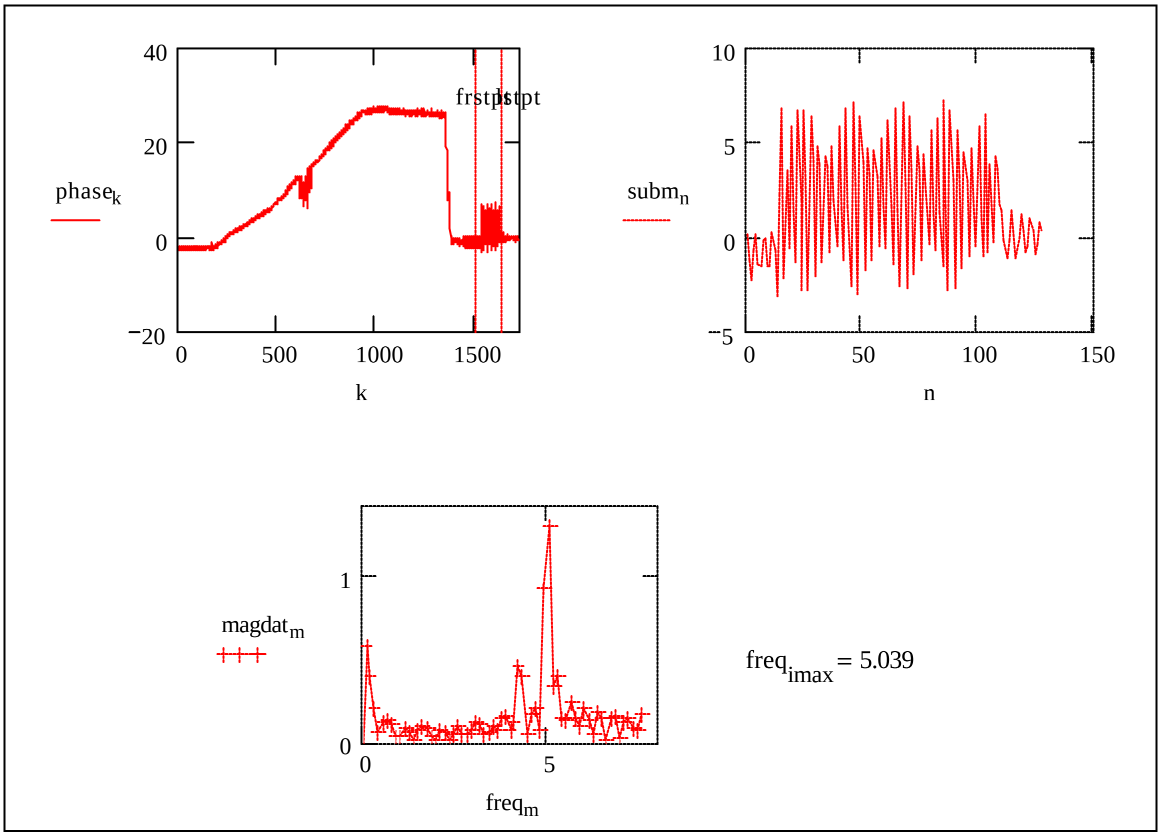

Figure 2. A) Phase monitor data during acceleration and collision cogging, B) Zoom of 128 data points windowed in A during cogging and C) FFT of windowed data clearly showing aliased 10 Hz cogging frequency. Horizontal scale of A and B is 15 Hz sample point number and horizontal scale of C is frequency in Hz.

Figure 3A is a plot of the ~200,000 data points from the logger used in the analysis. This stream of data was separated into 49 sequential 4096-point segments and the frequency content of each segment was computed. Figure 3B shows the frequency of the largest amplitude spectral component for each segment (excluding the dc component). The main signal frequency is fairly constant at 4.2 Hz until the large amplitude phase variations begin when the frequency drops to 3.8 Hz and then decreases steadily down to about 3.5 Hz. As the bunch width growth accelerates, there is a large frequency change and a splitting of what had been like a single line. When the damper gain is reduced and the "event" ends no discernable frequency is apparent in the spectrum of the small amplitude phase monitor signal. Figures 4-12 show the details and evolution of these signals.

Figures 4-8 show:

1) There is a clearly distinguishable and rather narrow frequency content in the signal at 4.2 Hz until about point 170,000.
2) The frequency rapidly changes to about 3.8 Hz when the large amplitude phase variations begin around point 130,000 and drops to about 3.5 Hz just before rapid bunch length growth begins.

Figures 9-11 show that as the rapid bunch length growth occurs:

1) The frequency makes a sudden and large change to about 2.7 Hz.
2) What had been a like a single frequency drops to below 2 Hz and splits into multiple lines.
3) Finally a single frequency reappears at about 2.8 Hz.

Figure 12 shows that when things settle down, no discernable frequency remains in the small amplitude phase signal variations.

Little attempt is be made to interpret these results beyond commenting on where to expect certain aliased frequencies. The synchrotron frequency at 980 GeV is known to be in the 30-40 Hz range. Given the 15 Hz logger sampling, 35 Hz will alias to 5 Hz, 36 to 6, 37 to 7, 38 (now above 2.5 times 15) to 7, 39 to 6, 40 to 5, etc.

It might be reasonable to interpret the 4.2 Hz signal before the blow-up as due to 34.2 Hz synchrotron motion. The line splitting as the blow-up is in full bloom might be due to development of and cross-talk between coupled bunch modes. If due to simple change in RF voltage, the possible ~1% change synchrotron frequency from 34.2 to 33.8 Hz would require a ~2% reduction in RF amplitude. A quick glance at the data logged RFUM value does shows no change approaching that magnitude. On the other hand, the aliased signals might be due to effects happening at frequencies far from the synchrotron frequency if for instance the longitudinal damper is driving the system at some arbitrary frequency.

Conclusion – curious effects are observed, but not explained.

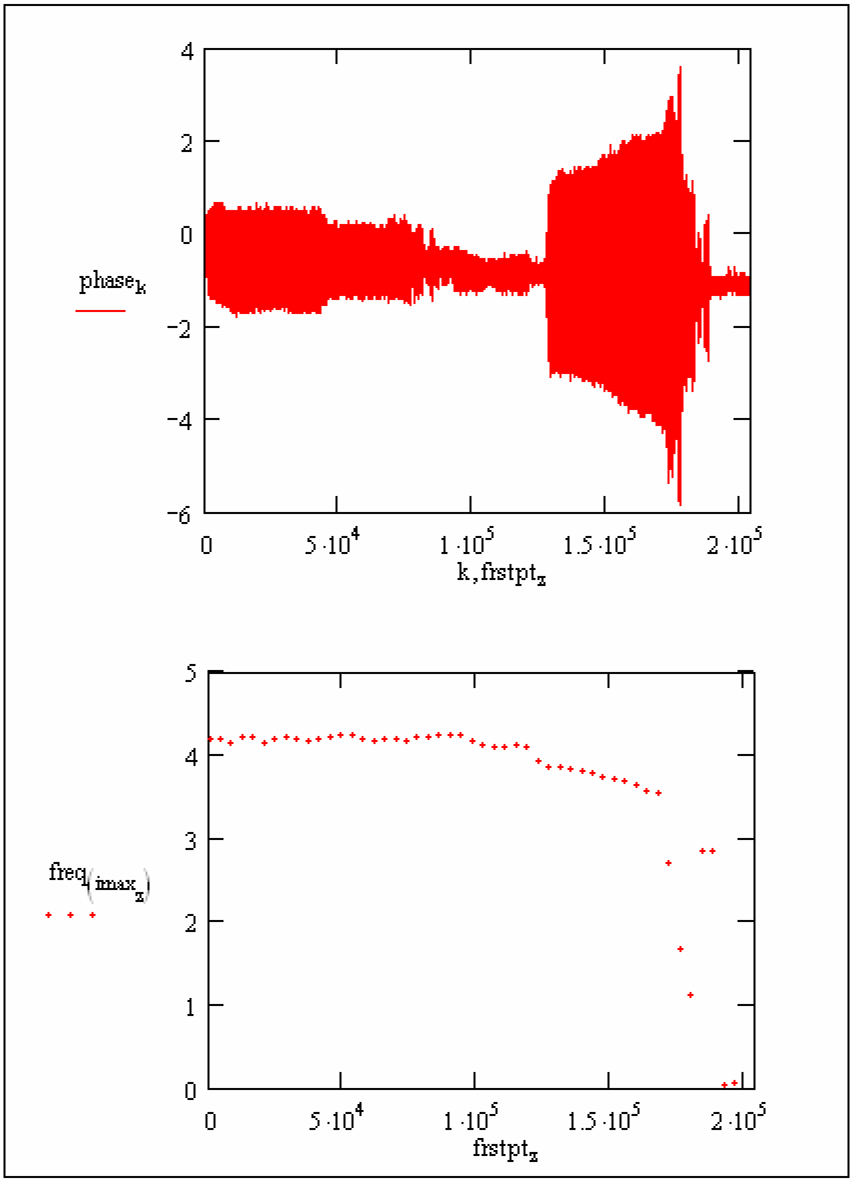

Figure 3. A) Phase monitor data plotted by sample number, B) frequency of largest amplitude spectral component for each of 49 sequential 4096-point segments of the data.

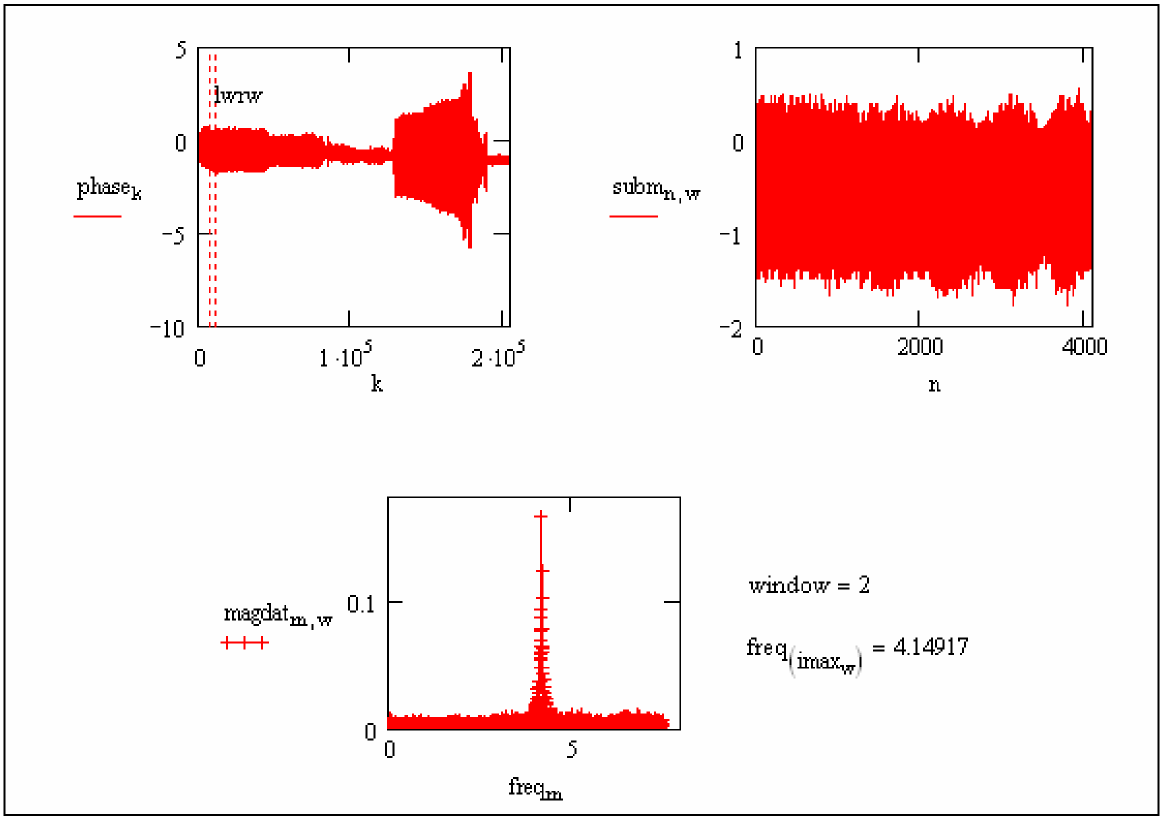

Figure 4. Data segment #2.

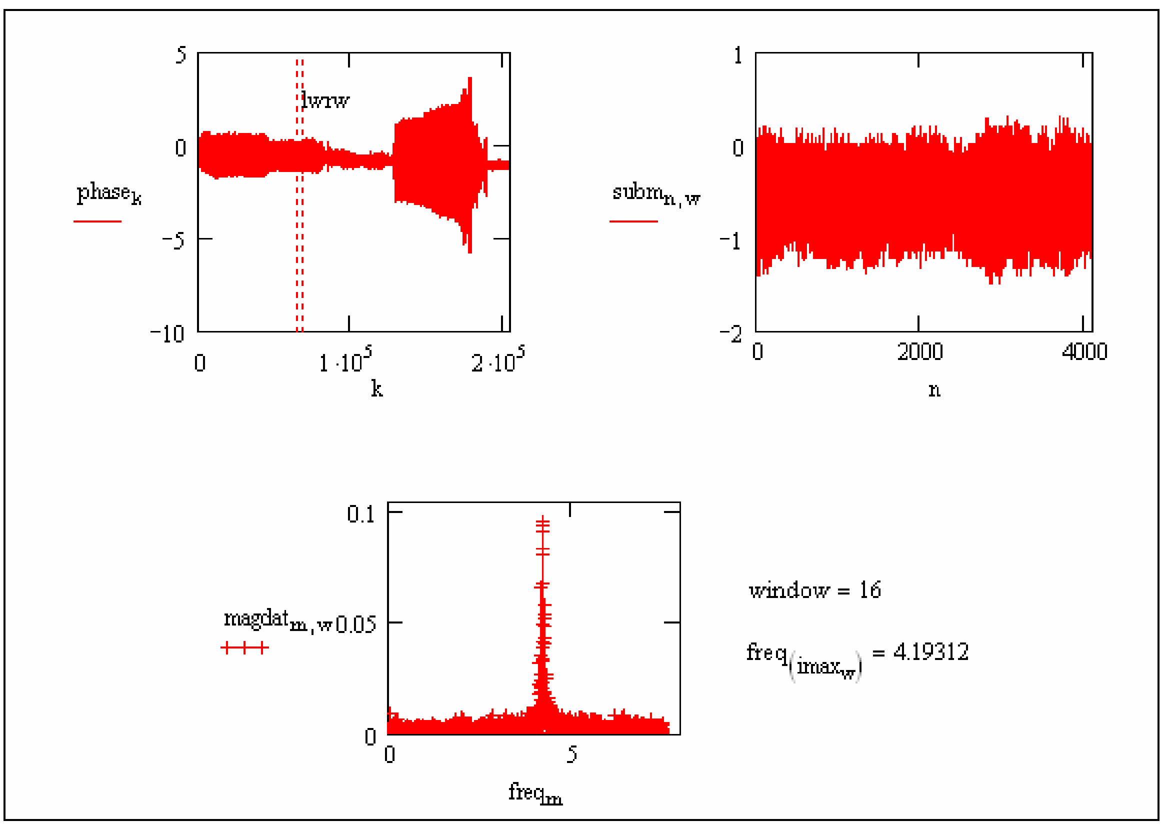

Figure 5. Data segment #16.

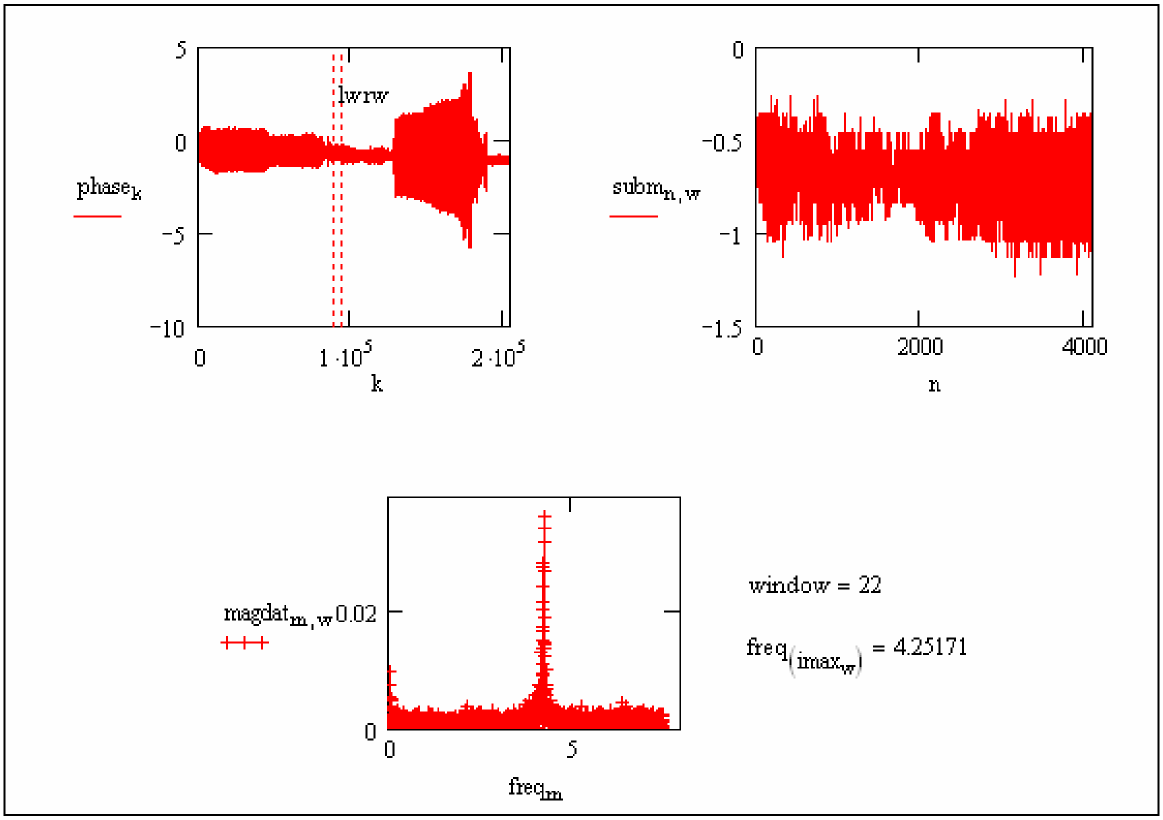

Figure 6. Data segment #22.

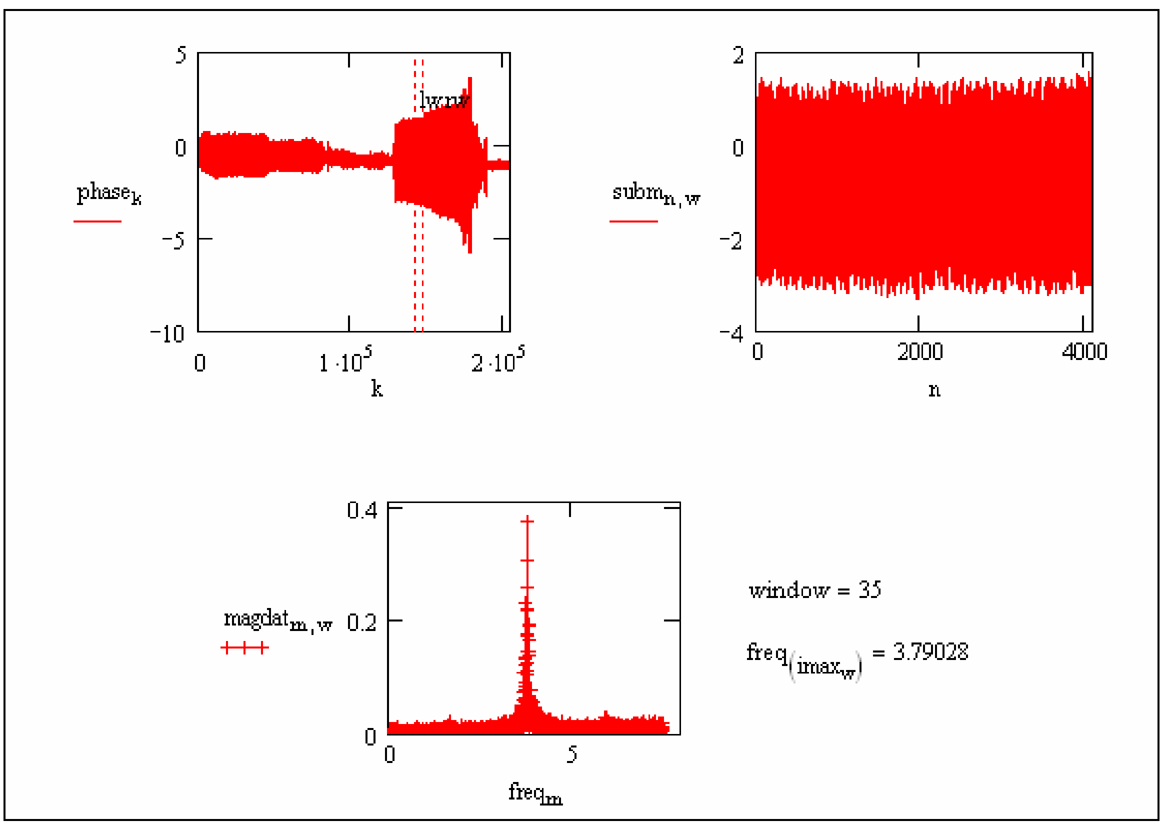

Figure 7. Data segment #35.

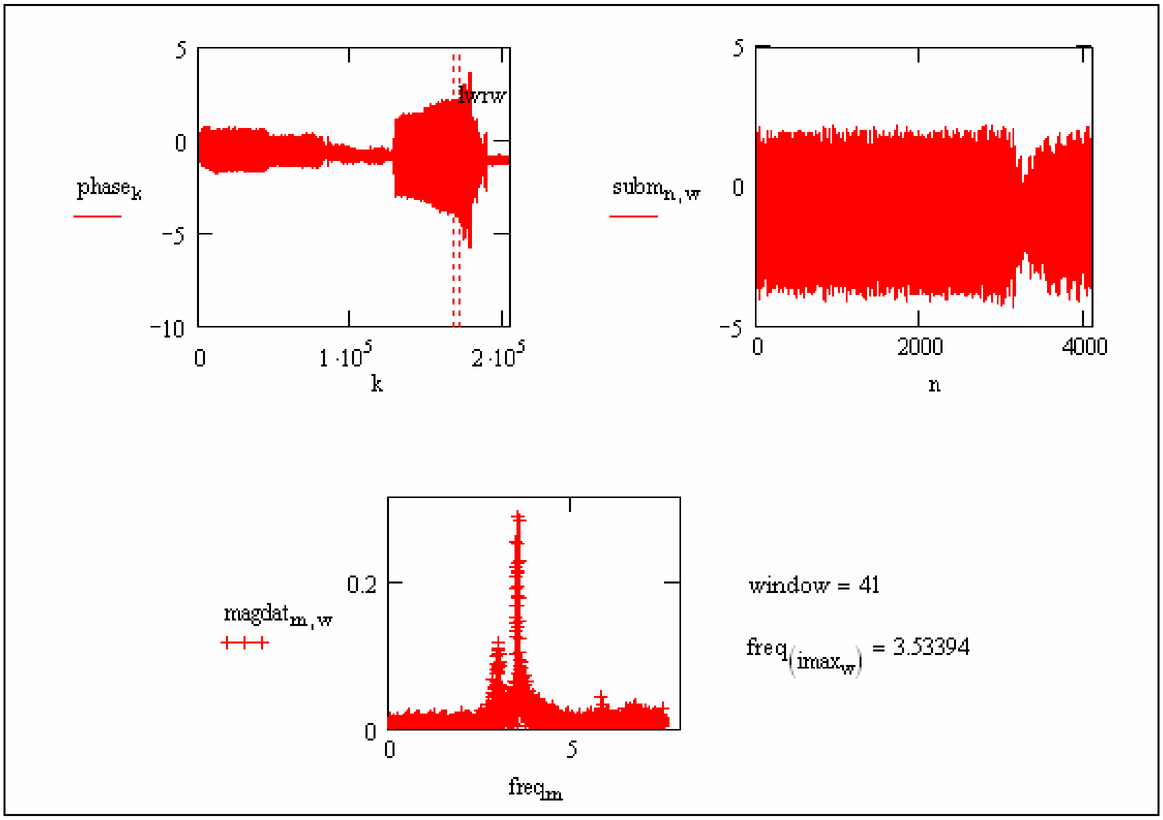

Figure 8. Data segment #41.

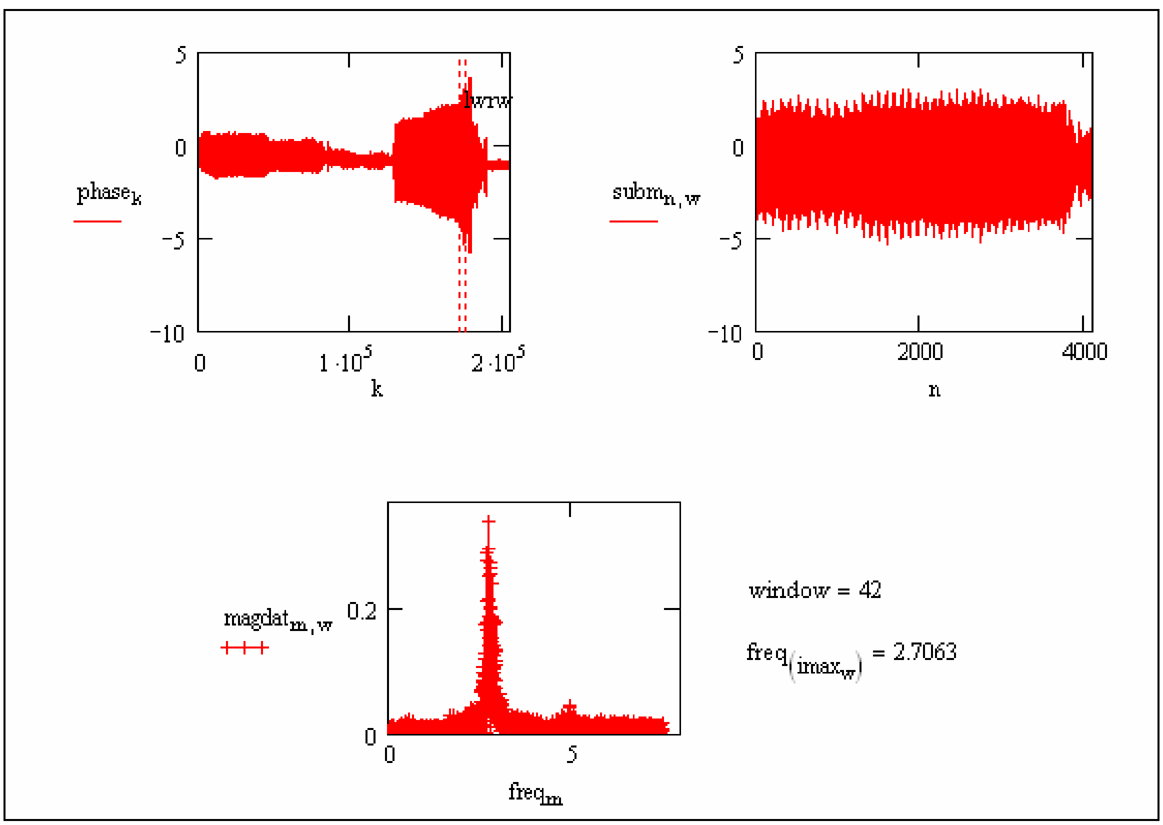

Figure 9. Data segment #42.

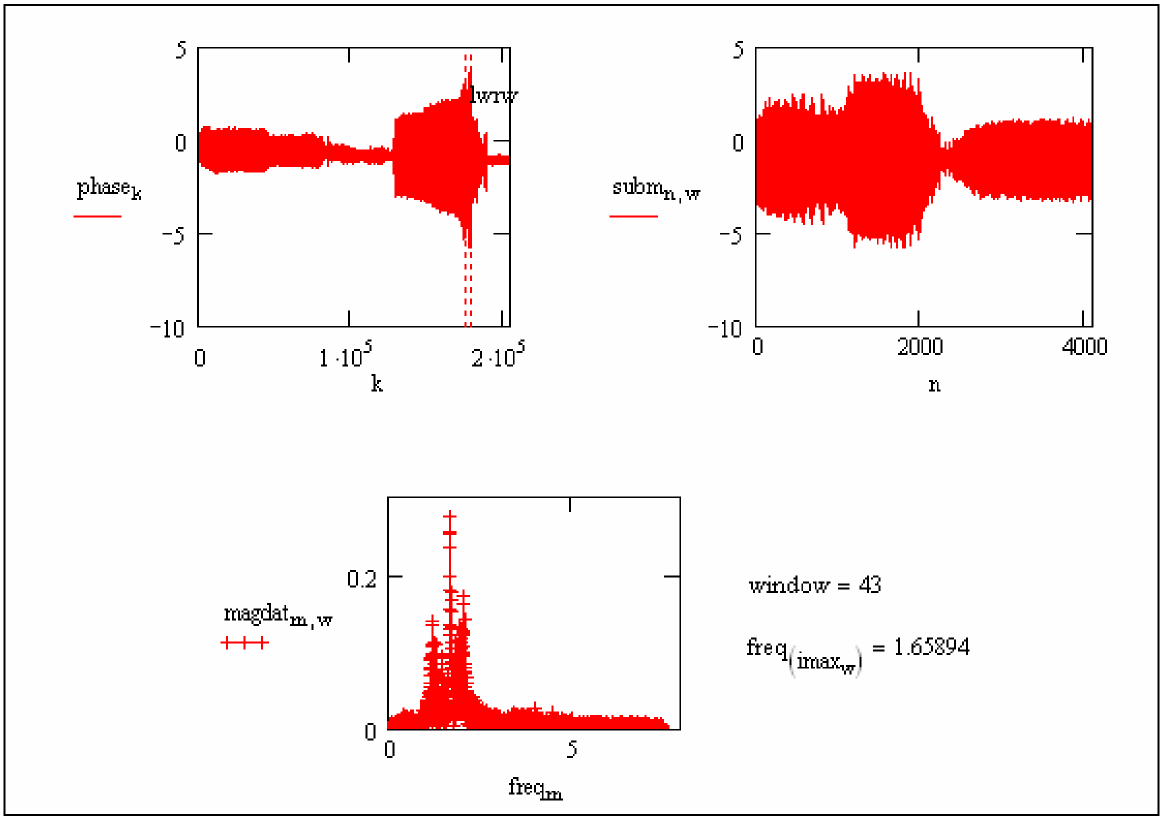

Figure 10. Data segment #43.

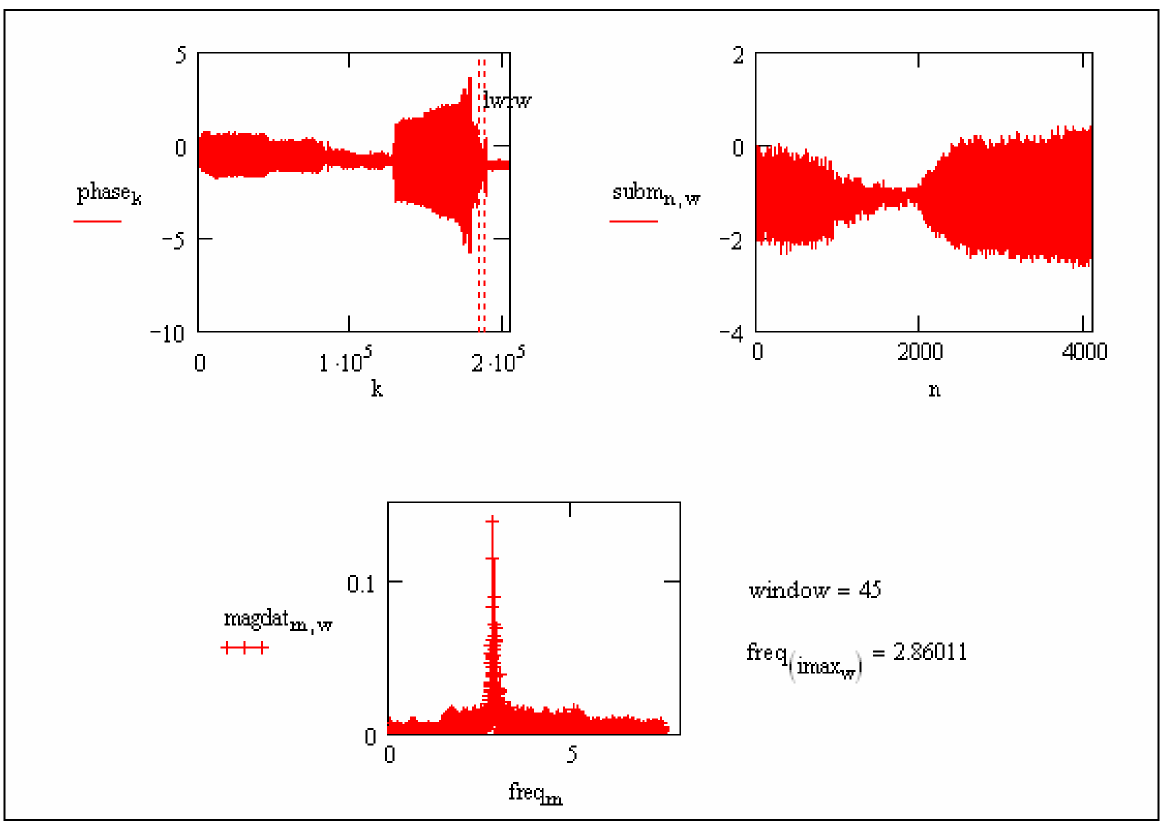

Figure 11. Data segment #45.

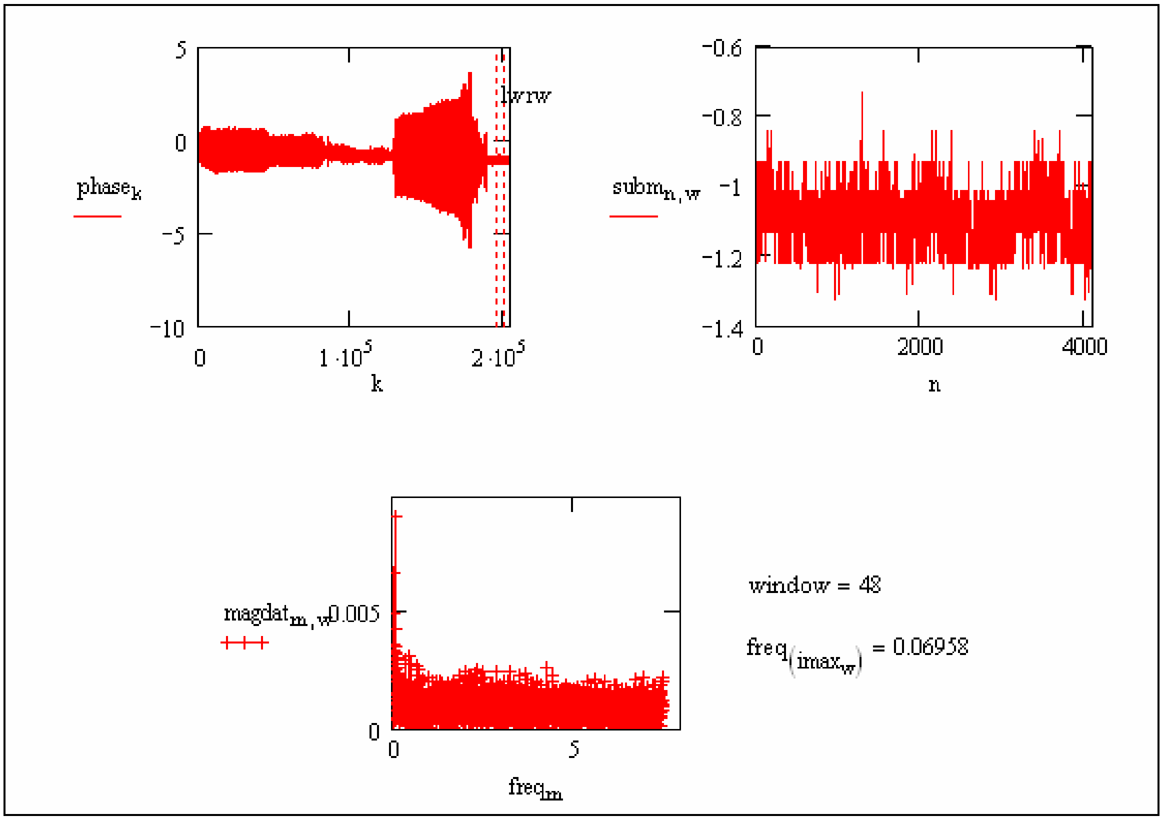

Figure 12. Data segment #48.