A MEAN FILTER METHOD FOR REMOVING SATURATION FROM PYROTECHNIC SHOCK PULSES

By Tom Irvine
Email: tomirvine@aol.com

March 18, 2008

Background

Numerous problems can affect the quality of accelerometer data during pyrotechnic shock events. A baseline shift, or zero shift, in the acceleration time history is perhaps the most common error source.

Chu notes in Reference 1 that this shift can be of either polarity and of unpredictable amplitude and duration. He has identified six causes of zero shift:

1. Overstressing of sensing elements
2. Physical movement of sensor parts
3. Cable noise
4. Base strain induced errors
5. Inadequate low-frequency response
6. Overloading of signal conditioner

A piezoelectric accelerometer may have its amplification factor Q well above 30 dB at resonance. This resonance may be excited by high-frequency pyrotechnic shock energy. Resonant ringing causes higher element stresses than expected.

Accelerometer resonant ringing is a special example of the first cause. This is a particular problem if the accelerometer has a piezoelectric crystal as its sensing element.

Chu notes that this may cause the signal conditioner to overload, as follows

> When a signal conditioner attempts to process this signal, one of its stages is driven into saturation. Not only does this clipping distort the in-band signals momentarily, but the overload can partially discharge capacitors in the amplifier, causing a long time-constant transient.

This overload causes zero shift in the acceleration time history. This shift distorts the low-frequency portion of the shock response spectrum.

The risk can be reduced by using an accelerometer with a built-in mechanical lowpass filter. This is especially needed for near-field shock measurements.

Symptoms

The baseline shift is often apparent in the acceleration time history.

The effect becomes even more apparent as the velocity is integrated from the acceleration trace. Assume that the accelerometer mounting location has zero net velocity change. The velocity signal may nevertheless have a “ski slope” effect whereby it diverges to some completely unrealistic level.

Furthermore, the positive and negative SRS curves may diverge from one another, particularly at low natural frequencies. One of these curves may also flatten out to some unrealistically high level as the natural frequency approaches zero.

The overall slope of the SRS should be approximately 6 dB/octave in the low frequency domain. There may be local peaks and dips, but any sustained divergence in slope from 6 dB/octave could be due to saturation.

Data Surgery

There are numerous possible “surgical” techniques for removing saturation from a pyrotechnic shock pulse. None is perfect.

One method is simply to ignore the corresponding shock response spectrum below 100 Hz.

Another method is to modify the signal to force the net velocity to zero.

Various methods of high-pass filtering and piecewise trend-removal may also be used.

Any modification of the original time history may cause phase distortion or may introduce other errors. Furthermore, any of the methods may fail to completely remove the saturation effects.

Mean Filtering Method, Objectives

Again, there is no perfect method for trend removal, but shock data is too precious to discard.

A proposed method is “mean filtering with optimization.” This method uses trial-and-error to select the filtering parameters which yield a time history which best meets the following criteria:

1. Agreement between positive and negative SRS curves.
2. A slope of 6 dB/octave for each of the SRS curves over the lower frequency domain.

The first criteria assumes that the true acceleration pulse is “reasonably symmetric” about the zero baseline.

Furthermore, fulfillment of the criteria should yield a corresponding velocity time history with nearly zero net velocity.

The mean filter is a simple type of lowpass filter. An intermediate goal is to synthesize a mean filtered signal which is assumed to represent the saturation. The mean filtered signal is then subtracted from the raw acceleration time history. The resulted is the “cleaned” time history.

Mean Filtering Method, Parameters

The mean filter is characterized by its window size and the number of passes.

A mean value is calculated for each window. The windows are overlapped, with an increment of 1 data point for each following window. This process is repeated for each of the passes.

The window size and the number of passes are varied randomly in order to a find the “cleaned” time history which bests meets the objectives given in the previous section.

An example is given in Appendix A.

References

1. Anthony Chu, “Zero Shift of Piezoelectric Accelerometers in Pyroshock Measurements,” Paper presented at the 57th Shock and Vibration Symposium, 1986.

APPENDIX A

<u>Example</u>

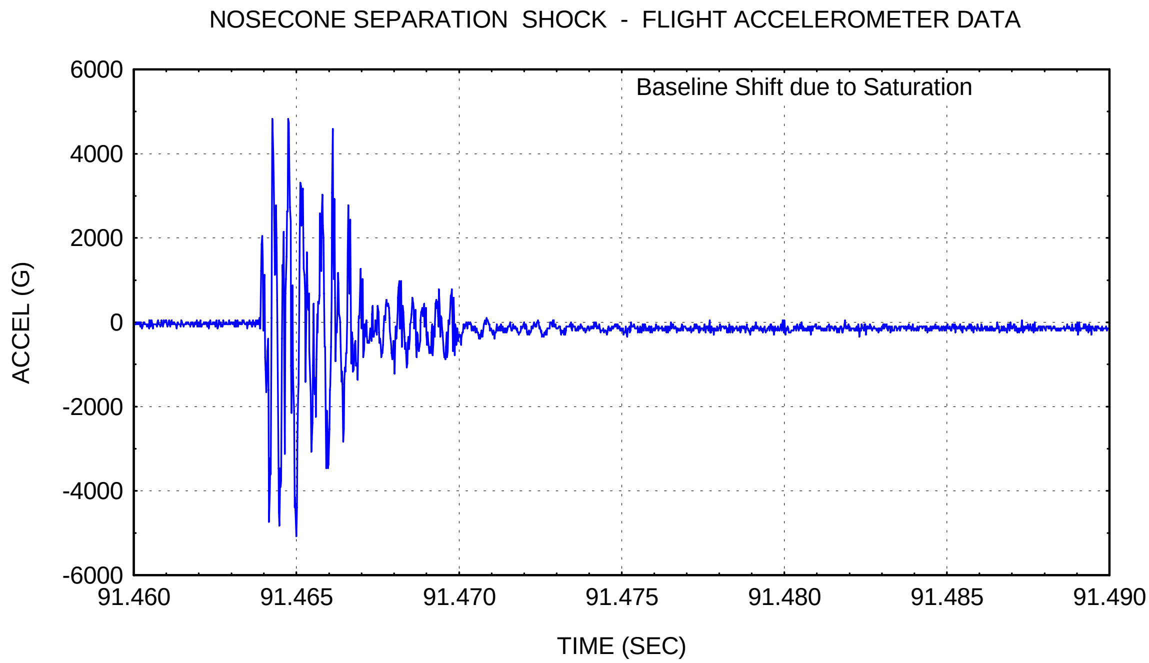


Figure A-1.

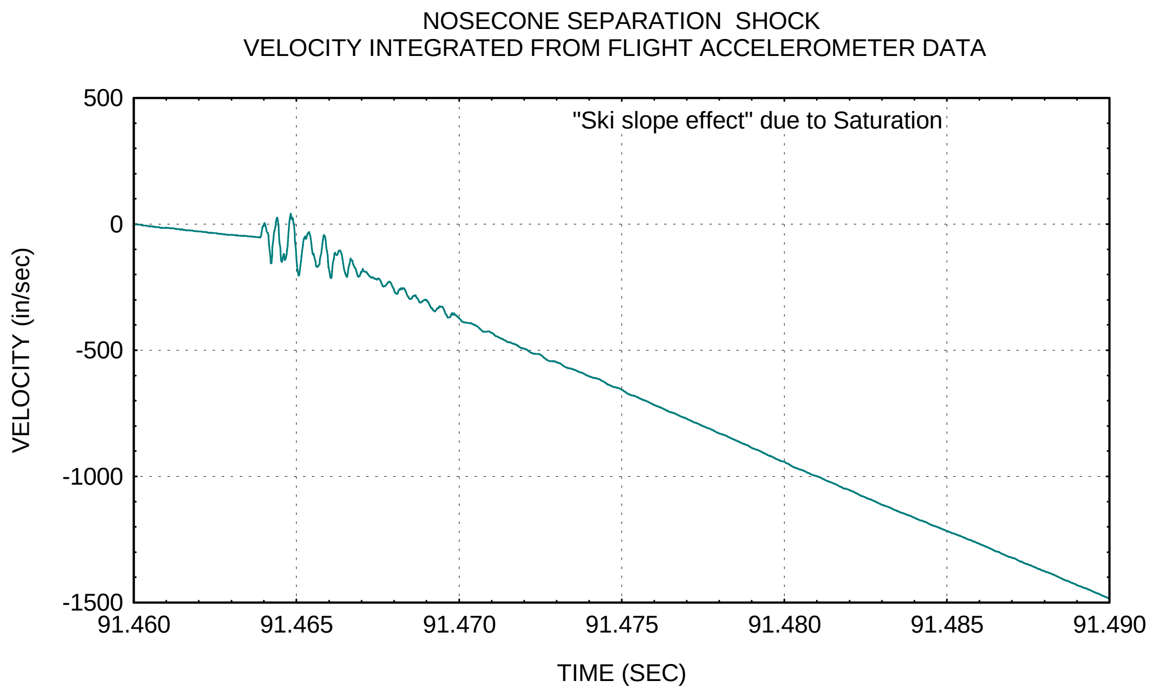


Figure A-2.

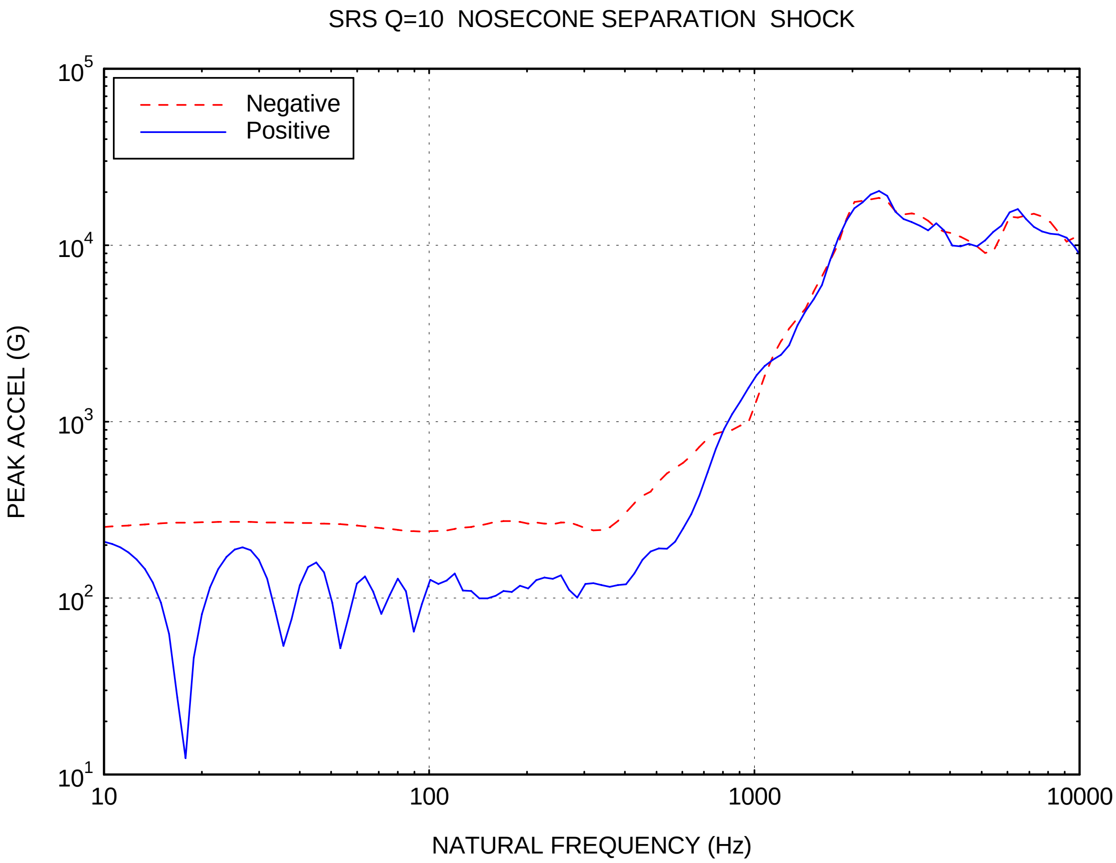


Figure A-3.

The time history in Figure A-1 has a baseline shift due to saturation.

This causes each of the SRS curves to be artificially high at the lower natural frequencies, as shown in Figure A-3.

The difference between the two curves is 26.7 dB at 17.8 Hz. This is a large difference which is another symptom of the saturation effect.

The data is "cleaned" using the mean filter method, as shown in Figures A-4 through A-7.

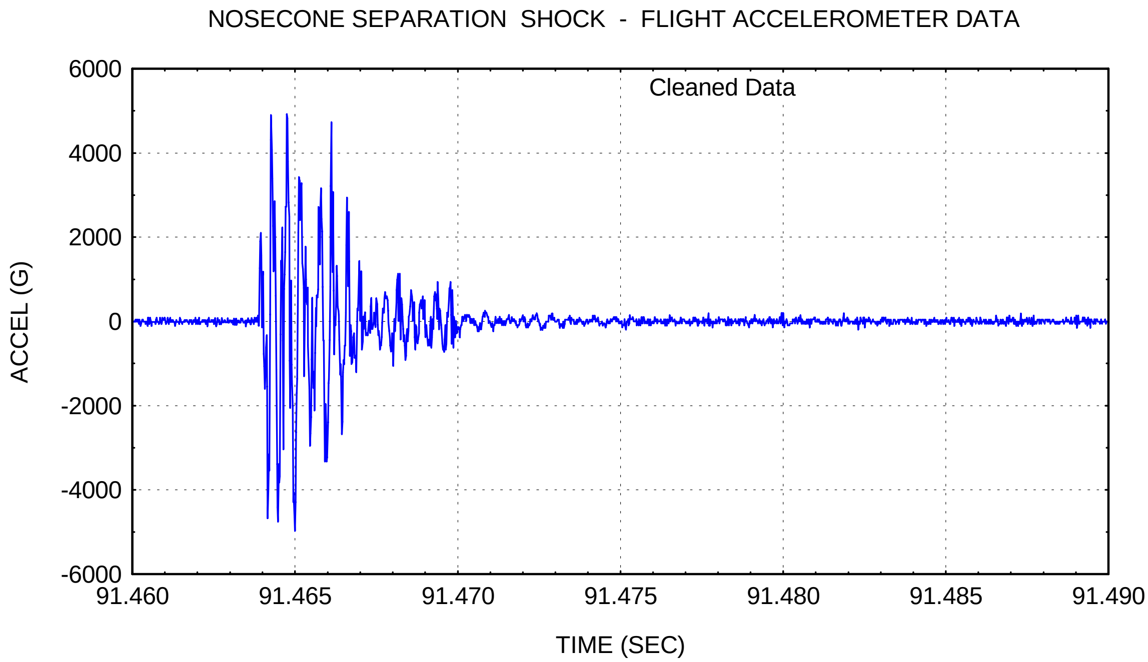


Figure A-4.

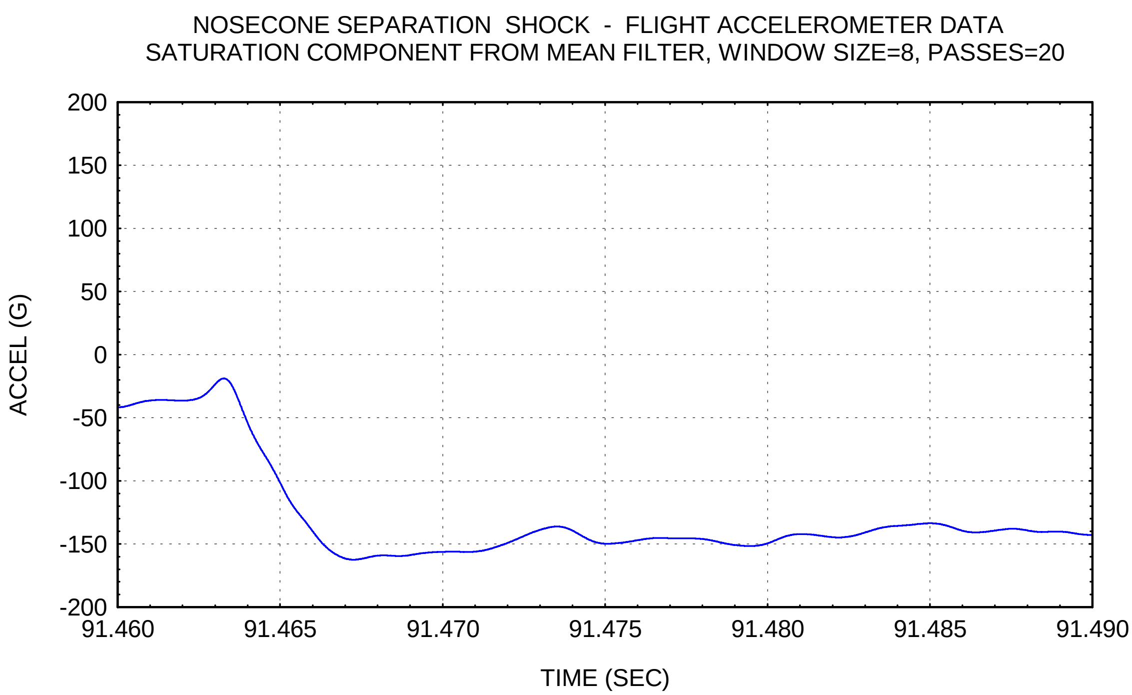


Figure A-5.

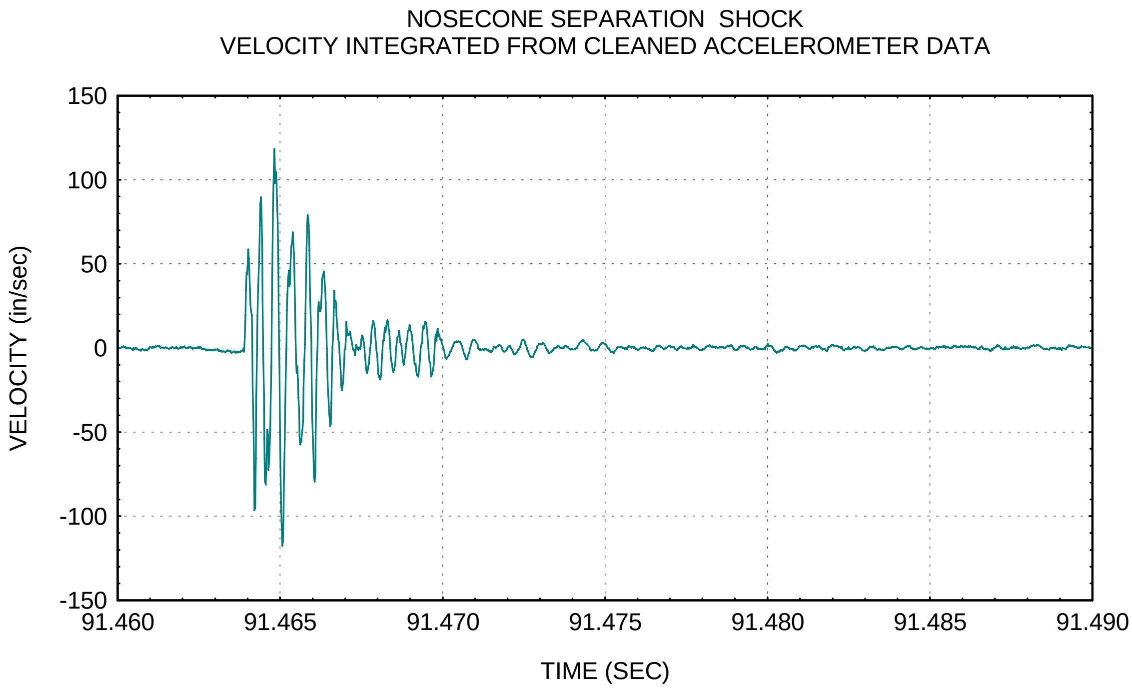

NOSECONE SEPARATION SHOCK
VELOCITY INTEGRATED FROM CLEANED ACCELEROMETER DATA
150
100
50
0
-50
-100
-150
VELOCITY (in/sec)
91.460
91.465
91.470
91.475
91.480
91.485
91.490
TIME (SEC)

Figure A-6.

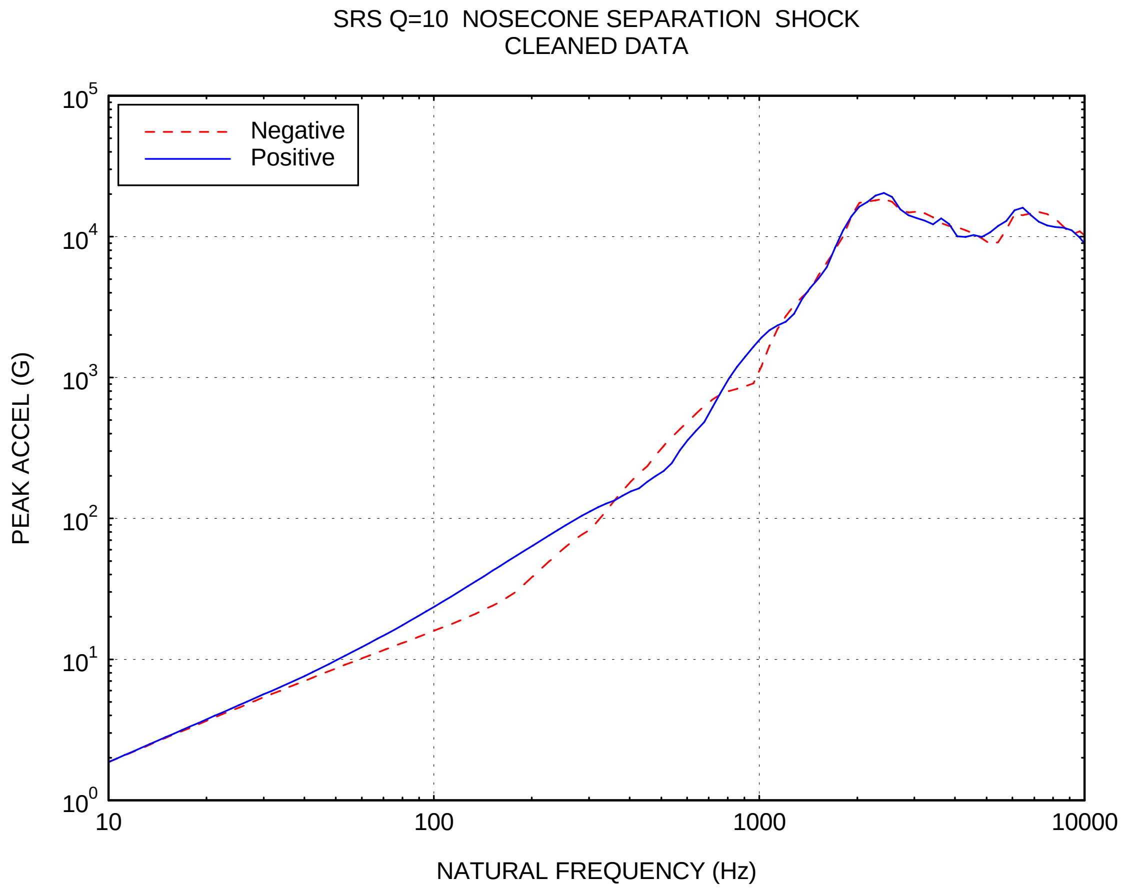
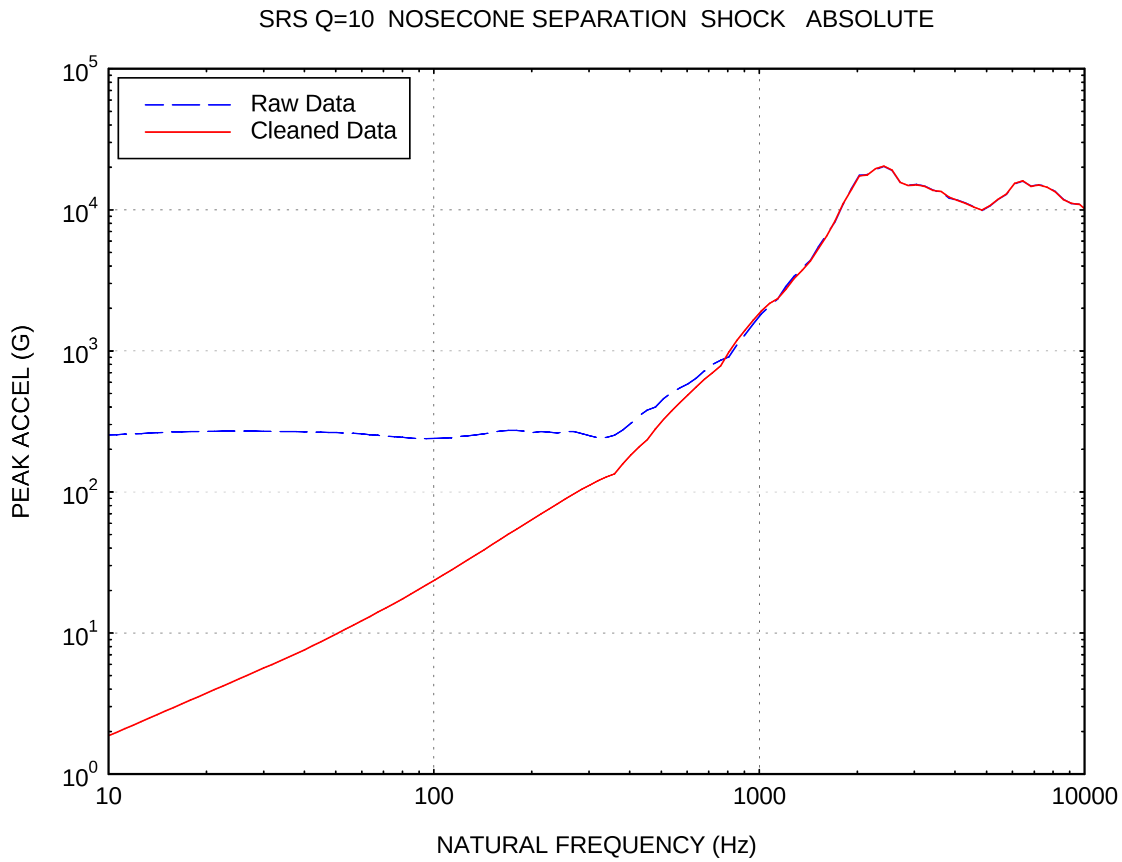


Figure A-7.

The slope at the low frequency end is about 6.7 dB/octave.

The resulting SRS is plausible. There is no means to judge whether it is “exact,” however.



SRS Q=10 NOSECONE SEPARATION SHOCK ABSOLUTE
Raw Data
Cleaned Data
PEAK ACCEL (G)
10^5
10^4
10^3
10^2
10^1
10^0
10
100
1000
10000
NATURAL FREQUENCY (Hz)

Figure A-8.