Shock Response Spectra

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Innovation
Do the Right Thing
Collaboration
Capable & Competant
Strong & Driven Work Ethic
Accountable & Responsible
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Overview

SRS History

SRS Theory

SRS Applications

Creating an SRS Test

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Introduction to SRS

- A graphical representation of a shock, or other transient acceleration, in terms of how a single degree of freedom (SDOF) system (like a mass on a spring) would respond to that input
- A calculated function based on the acceleration time history. It applies an acceleration time history as a base excitation to an array of SDOF systems (Irvine, 2012).
- The maximum response of a series of SDOF system having the same damping to a given transient signal (Alexander, 2009)

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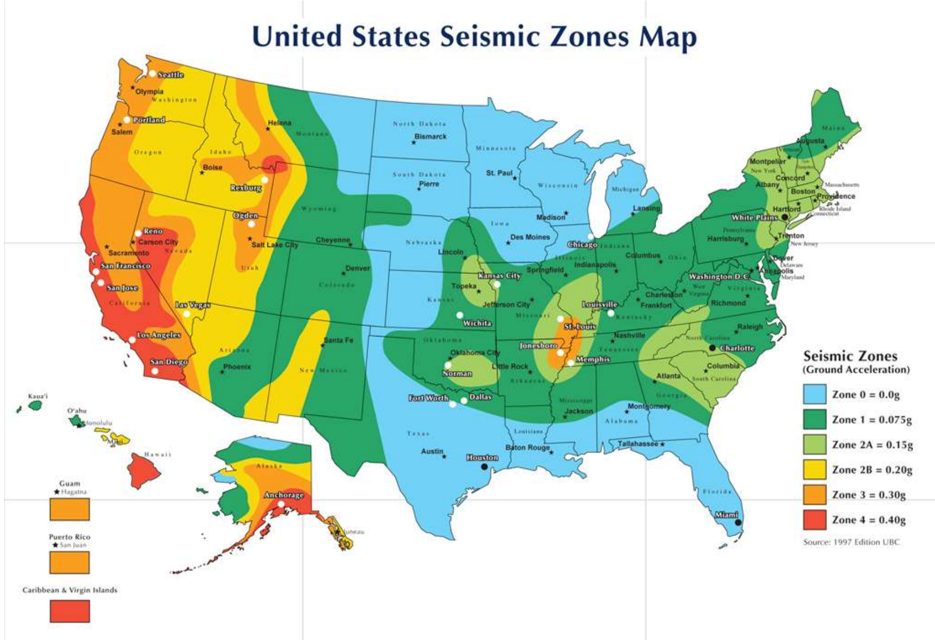
Introduction to SRS

- First presented in 1933 by Dr. Maurice Biot
  - Primary study was concerning building response to earthquakes
- Seismic Industry
- Military/Defense and Aerospace



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SRS Applications

- SRS was adopted by the military after Biot/MIT utilized SRS algorithms to develop qualification tests for Navy equipment
    - Electronics and systems were more widely used and were negatively affected by things like bombs and torpedo’s.
- Since then, SRS has been used for qualifying products that would be exposed to complex shock events!

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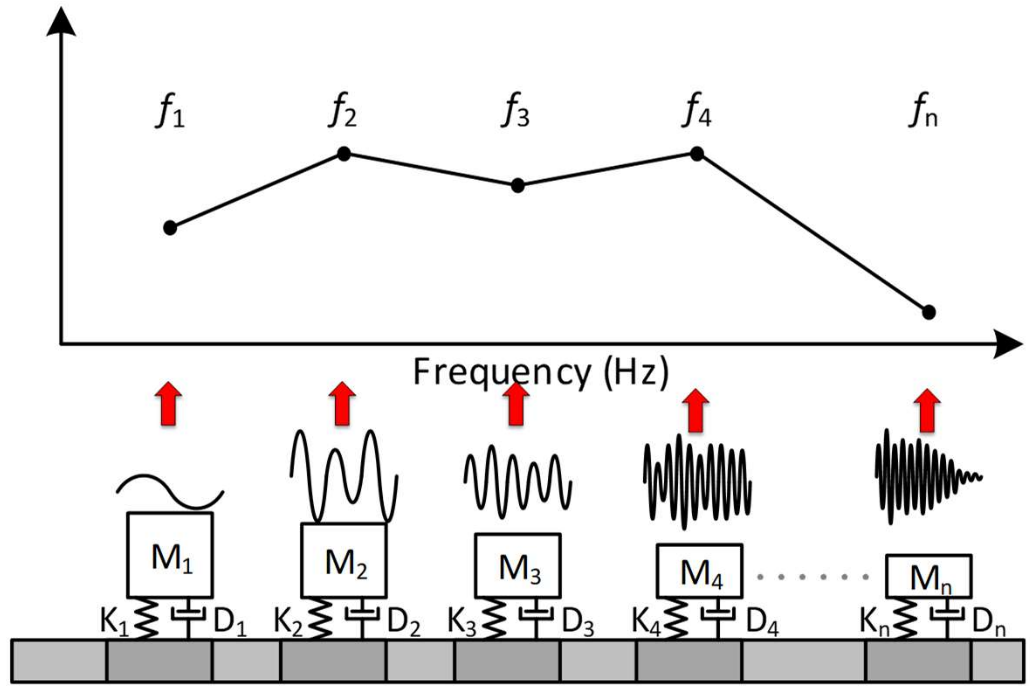
SRS Simplified

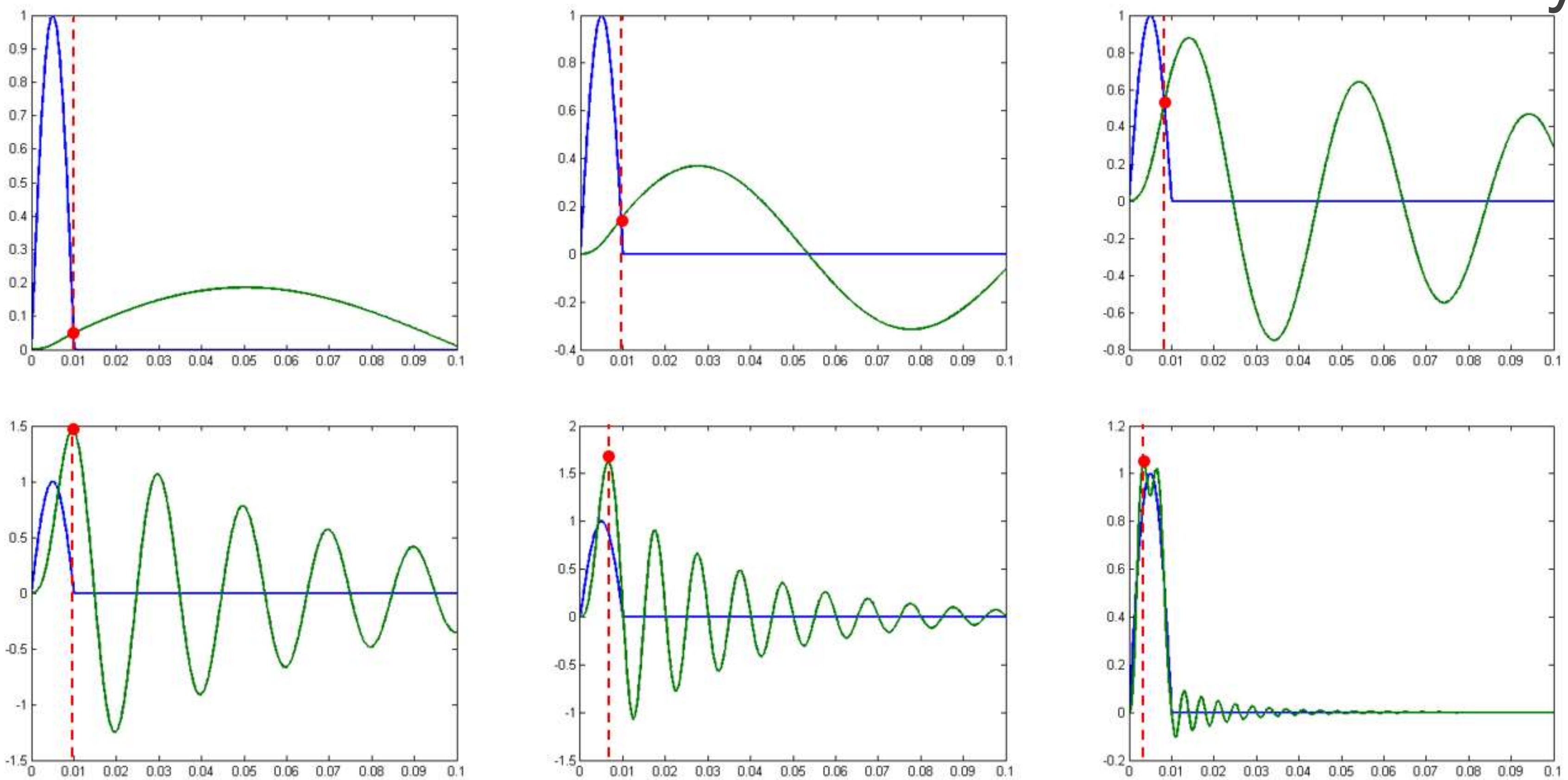
- SRS is a theoretical SDOF, mass-damper-spring oscillator that are excited by a base motion.
  - Each having a unique **natural resonant frequency** logarithmically spaced at integer fractions of an octave
  - Each having the same critical damping factor (ζ)or resonant gain (Q)
- EXAMPLE: 1G, 10mS Half Sine



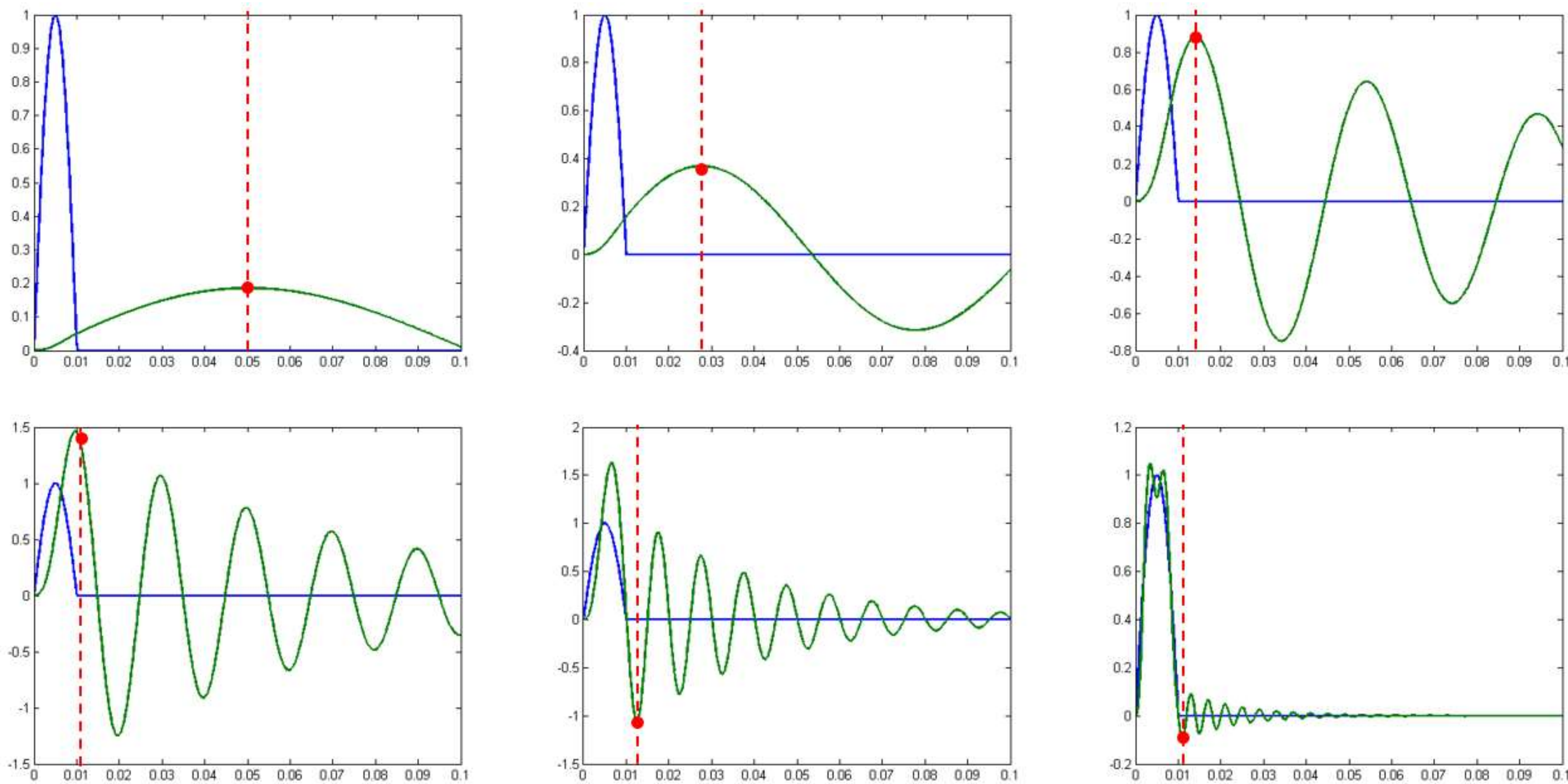
Common SRS Terms

- Pseudo-Velocity
- Primary SRS/Initial SRS
- Residual SRS
- Negative SRS
- Positive SRS
- Maximax SRS
- Response Spectrum
- Required Response Spectrum (RRS)
- Test Response Spectrum (TRS)
- Zero Period Acceleration

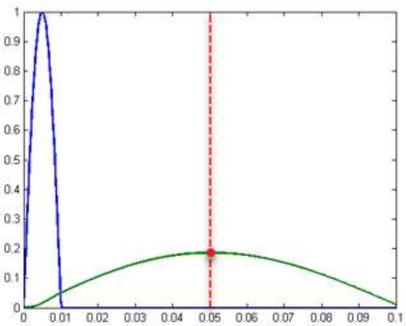
Primary SRS



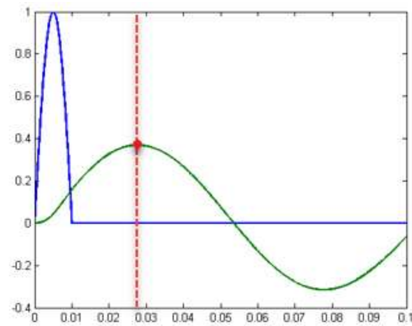
Residual SRS



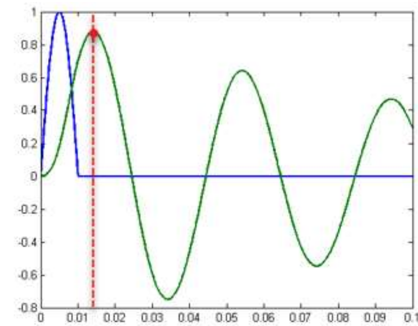
MaxiMax SRS



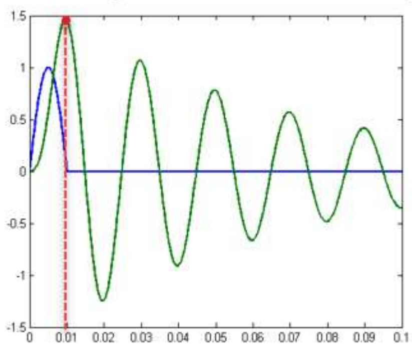
5 Hz Oscillator
Max Response = 0.1858 Gpk



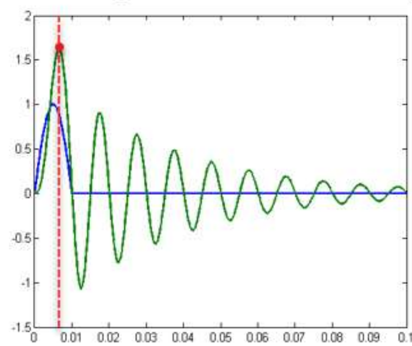
10 Hz Oscillator
Max Response = 0.3690 Gpk



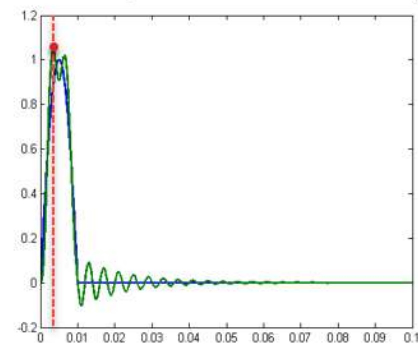
25 Hz Oscillator
Max Response = 0.8780 Gpk



50 Hz Oscillator
Max Response = 1.4628 Gpk

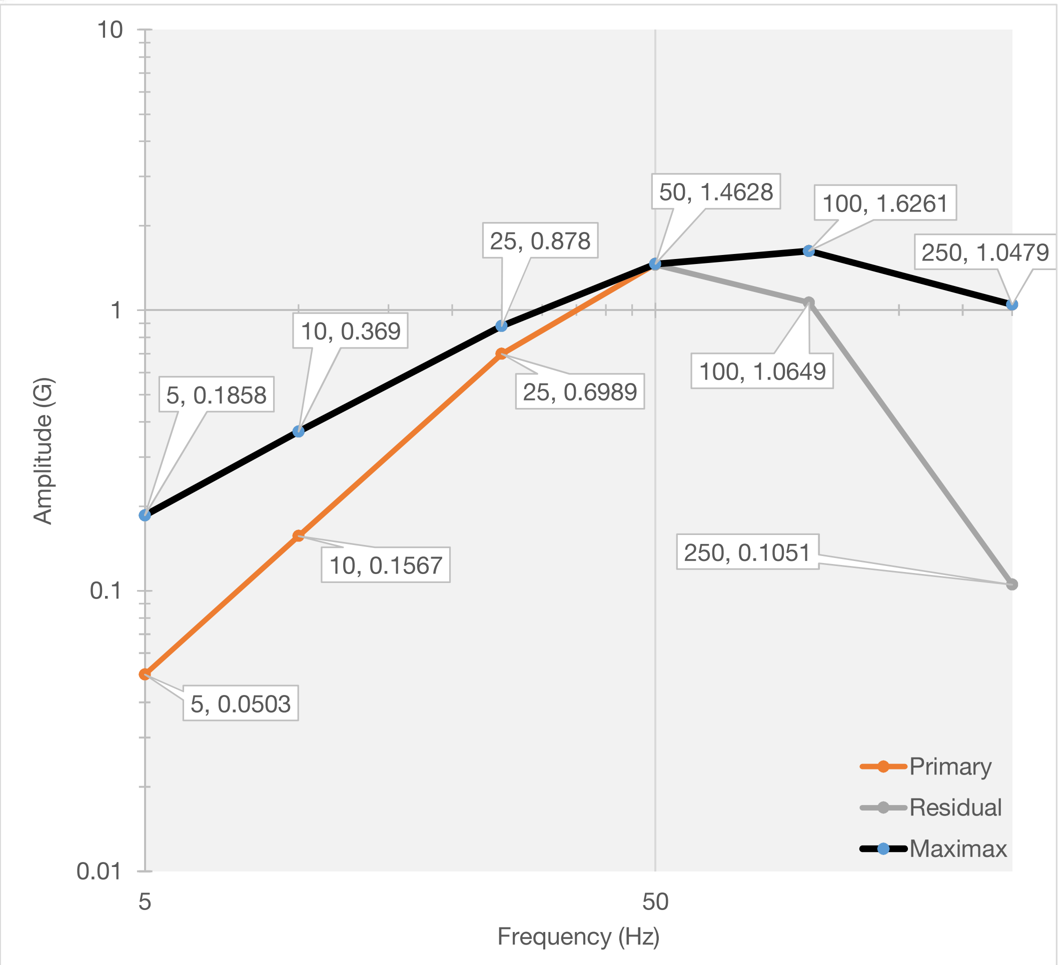


100 Hz Oscillator
Max Response = 1.6261 Gpk



250 Hz Oscillator
Max Response = 1.0479 Gpk

SRS Comparison



- Maximax is equal to residual before crossover
- Maximax is equal to primary after crossover

SRS Shortfalls

- Waveforms with different amplitudes, frequency content and time lengths can all generate similar/identical SRS's.
- No time or phase information
- Not a measure of the actual response of the device under test

SRS Test Definition

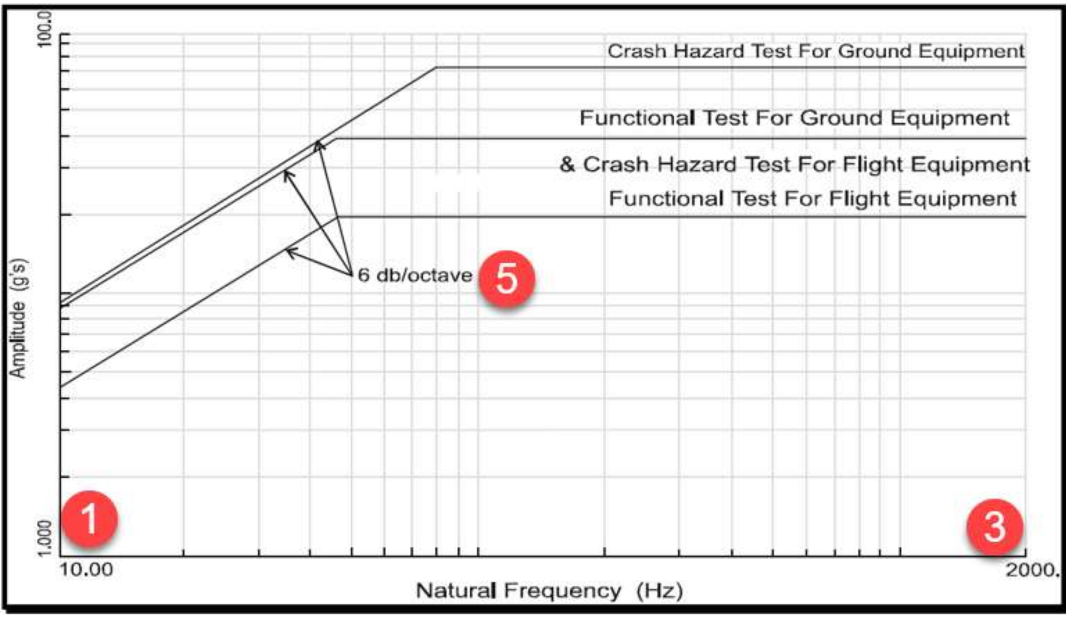
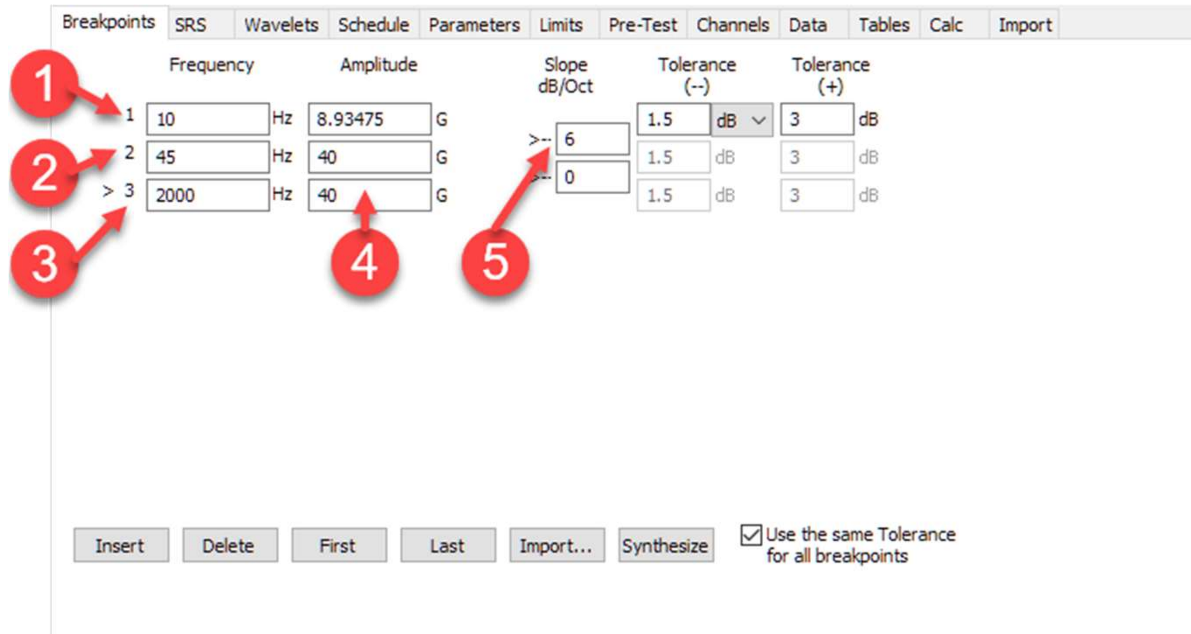


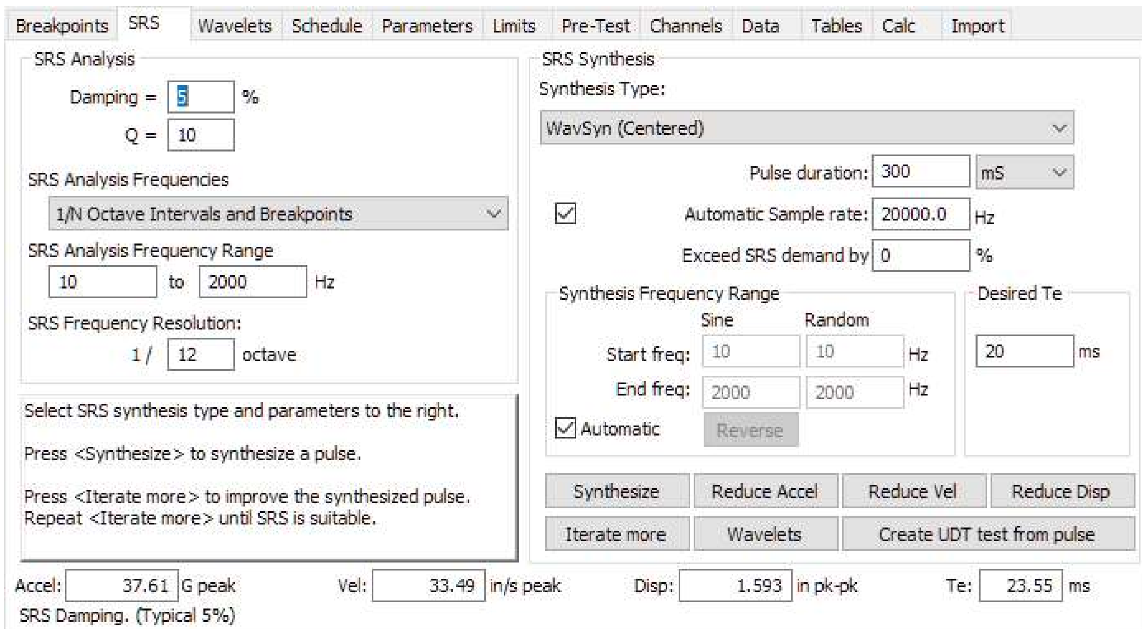
Figure 516.6-8. Test SRS for use if measured data are not available (for Procedure I - Functional Shock, & Procedure V - Crash Hazard Shock Test).

Test Category	Peak Acceleration (g's)	T_e (ms) [/1]	Cross-over Frequency (Hz)
Functional Test for Flight Equipment	20	15-23	45
Functional Test for Ground Equipment	40 4	15-23	45 2
Crash Hazard Shock Test for Flight Equipment	40	15-23	45
Crash Hazard Shock Test for Ground Equipment	75	8-13	80

Breakpoints Tab

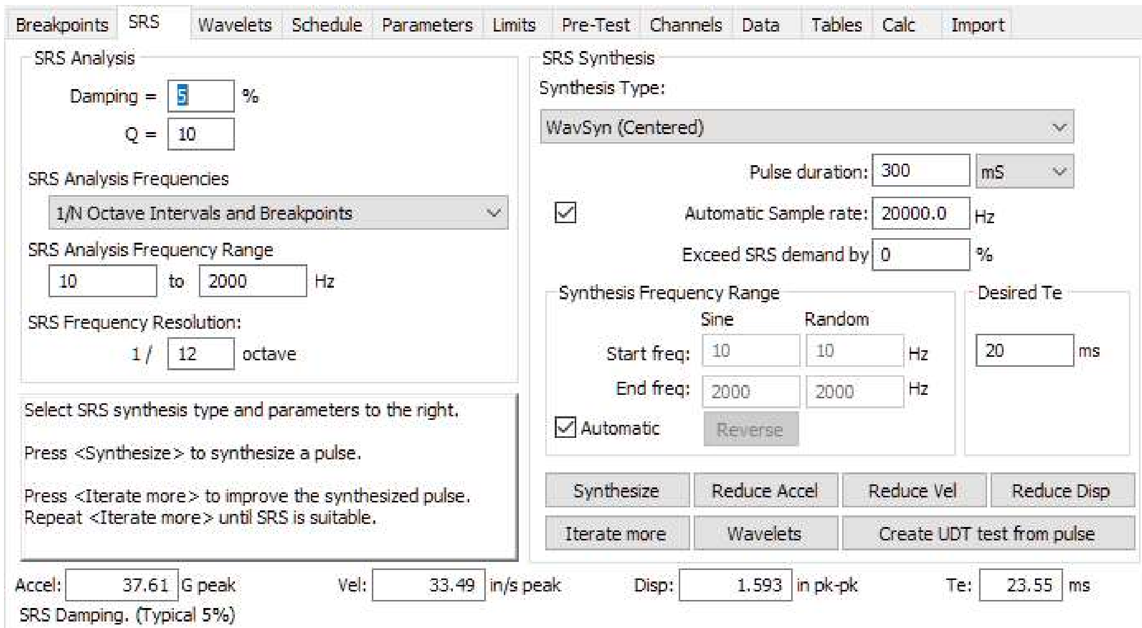


SRS Tab


Breakpoints
SRS
Wavelets
Schedule
Parameters
Limits
Pre-Test
Channels
Data
Tables
Calc
Import
SRS Analysis
Damping = 5 %
Q = 10
SRS Analysis Frequencies
1/N Octave Intervals and Breakpoints
SRS Analysis Frequency Range
10 to 2000 Hz
SRS Frequency Resolution:
1 / 12 octave
Select SRS synthesis type and parameters to the right.
Press <Synthesize> to synthesize a pulse.
Press <Iterate more> to improve the synthesized pulse.
Repeat <Iterate more> until SRS is suitable.
SRS Synthesis
Synthesis Type:
WavSyn (Centered)
Pulse duration: 300 mS
Automatic Sample rate: 20000.0 Hz
Exceed SRS demand by 0 %
Synthesis Frequency Range
Sine
Random
Start freq: 10 10 Hz
End freq: 2000 2000 Hz
Automatic
Reverse
Desired Te
20 ms
Synthesize
Reduce Accel
Reduce Vel
Reduce Disp
Iterate more
Wavelets
Create UDT test from pulse
Accel: 37.61 G peak
Vel: 33.49 in/s peak
Disp: 1.593 in pk-pk
Te: 23.55 ms
SRS Damping. (Typical 5%)

Parameters Tab

Analysis Frequency vs. Synthesis Frequency vs. Control Frequency



SRS Synthesis Types

- Linear Chirp
- Exponential Chirp
- WavSyn
- Burst Random
- Linear Chirp on Burst Random
- Exponential Chirp on Burst Random
- From User Waveform
- Enveloped Burst Random
- Damped Sine Waves

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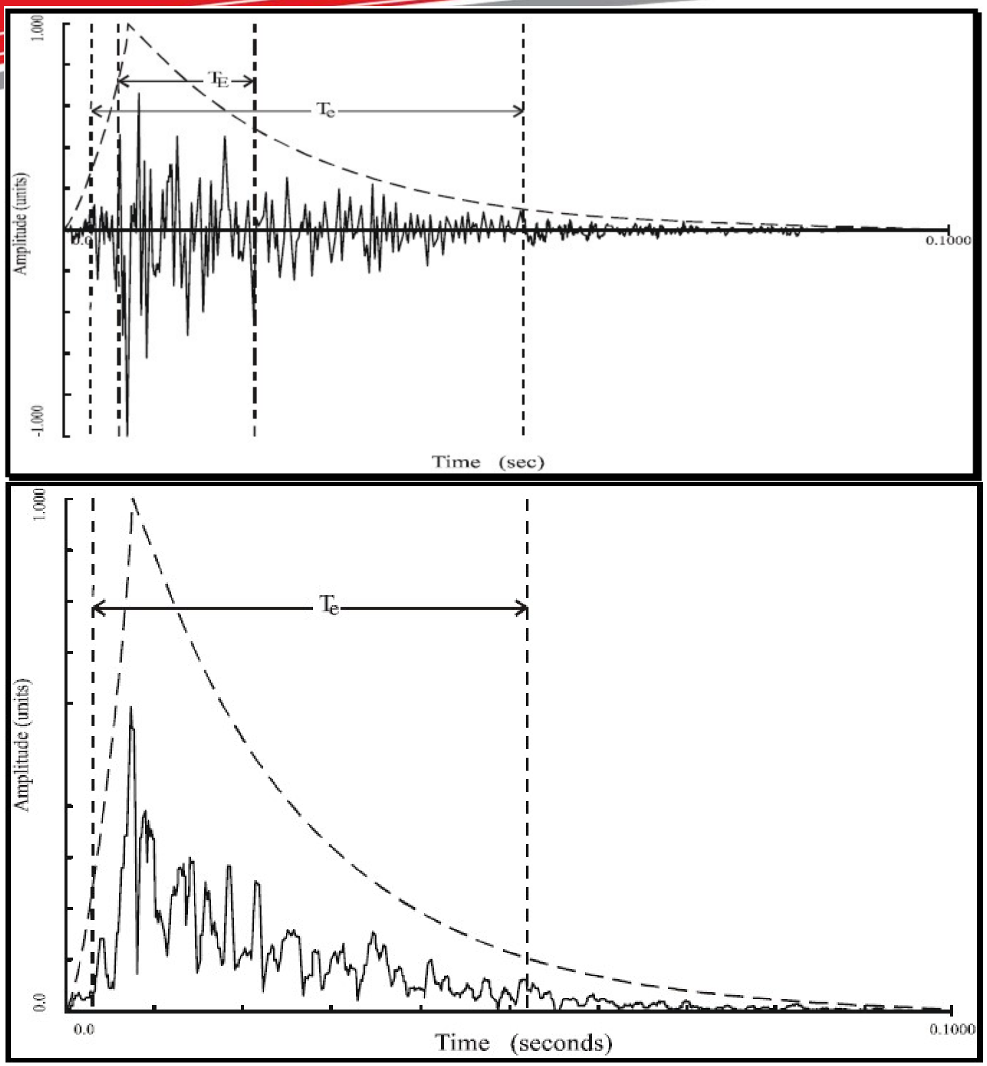
SRS Test Definition



- MIL-STD-810G Method 516.6
- T_e replaces T_E
- T_E vs. T_e
  - T_E is the “minimum length of time that contains all data magnitudes exceeding 1/3 of the peak magnitude associated with the time event”
  - T_e is the minimum length of time that contains at least 90% of the RMS time history amplitudes exceeding in value 10% of the peak RMS magnitude associated with the shock event

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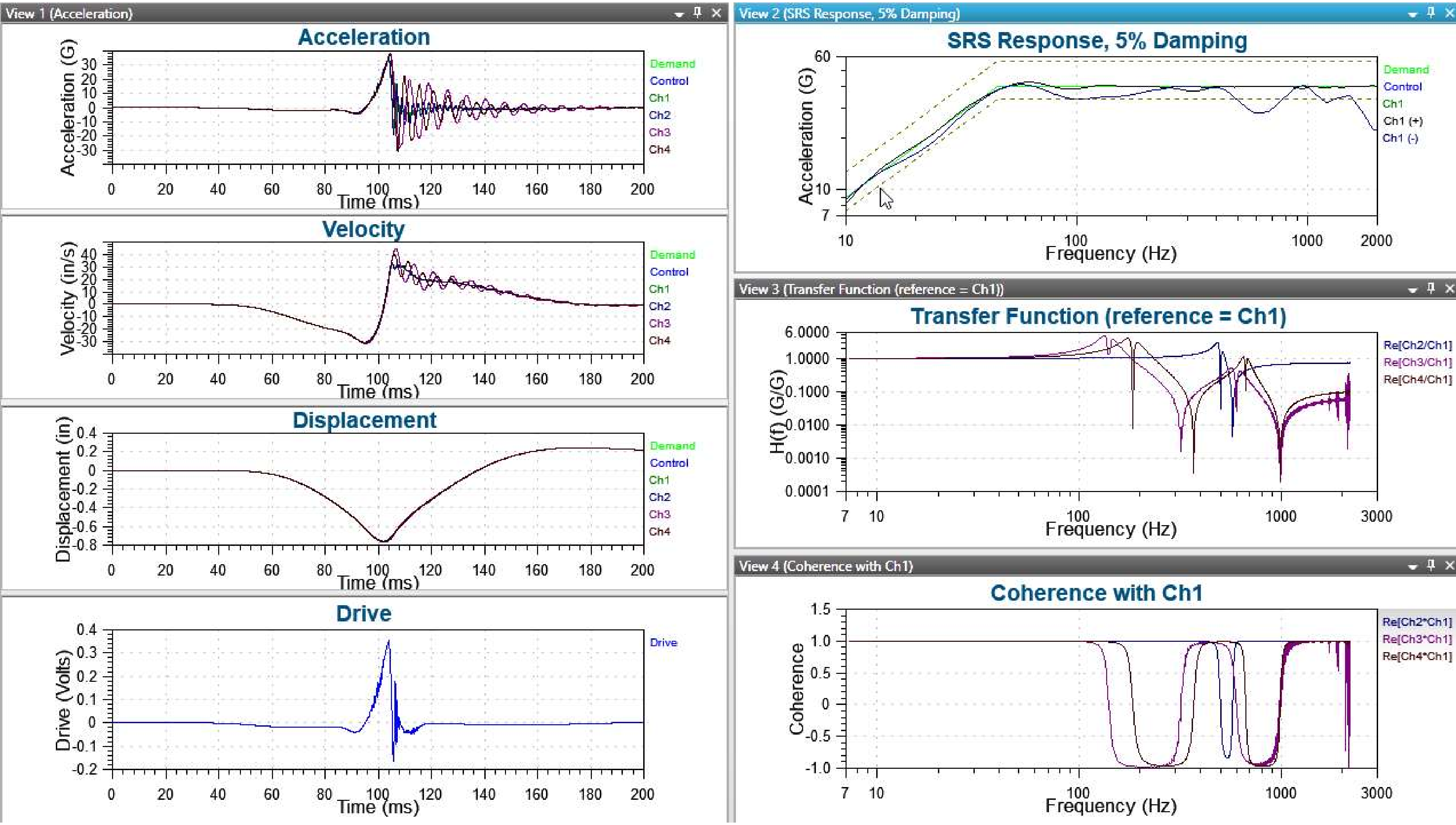
View 1 (Acceleration)
Acceleration
Acceleration (G)
Time (ms)
Demand
Control
Ch1
Ch2
Ch3
Ch4
Velocity
Velocity (in/s)
Time (ms)
Displacement
Displacement (in)
Time (ms)
Drive
Drive (Volts)
Time (ms)
View 2 (SRS Response, 5% Damping)
SRS Response, 5% Damping
Acceleration (G)
Frequency (Hz)
Ch1 (+)
Ch1 (-)
View 3 (Transfer Function (reference = Ch1))
Transfer Function (reference = Ch1)
H(f) (G/G)
Frequency (Hz)
Re[Ch2/Ch1]
Re[Ch3/Ch1]
Re[Ch4/Ch1]
View 4 (Coherence with Ch1)
Coherence with Ch1
Coherence
Frequency (Hz)
Re[Ch2*Ch1]
Re[Ch3*Ch1]
Re[Ch4*Ch1]

Common SRS Test Control Problems

- Initial Pulse Overshoots → Check Max Output on Limits Tab
- Pulse/Test Never Reaches Full Level → exceed demand by x%
- Pulse/Test never reaches Full Level → Enter "Minus Tolerance"
- Test Resonance cause SRS to exceed Tolerance → Wavelets

Meeting SRS Requirements

- There is no unique synthesized complex transient pulse satisfying a given SRS
  - When synthesizing a complex transient pulse from a given SRS and the pulse and it doesn’t meet requirements, what can I do?
    - Exceeds system limits (usually shock or displacement)
    - The duration of the pulse is > 20% than Te

DO NOT decompose SRS to low frequency and high frequency components

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Meeting SRS Requirements

- IF the DUT has no significant low frequency modal response
  - It may be acceptable to allow the low frequency portion of the SRS to fall out of tolerance to satisfy the high frequency portion
    - HF portion must begin at least one octave below natural frequency of DUT
- IF the DUT has low frequency modal response
  - It many be acceptable to allow the duration of the pulse to fall out of tolerance
  - Not to exceed $Te + 1/(2f_{min})$
  - F_{min} = lowest frequency of interest in SRS analysis

Post Test – Report Generation

- Typical items included in Test Report
  - Duration of each exposure
  - Number of exposures
  - Status of test item after each visual examination
  - Response time histories and information processed
    - Absolute MaxiMax SRS
    - Pseudo-velocity SRS
    - Optional (ESD, Frequency Spectrum)
  - Test item modal analysis data
  - Any deviations from test plan

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Unique VibrationVIEW SRS Features

- Adaptive SRS Control
  - No need to modify wavelet table to compensate for structural resonance
- Modify a Field/User Waveform to meet a desired SRS Demand

SRS Resources

- Irvine, T. (2012, July 9). An Introduction to the Shock Response Spectrum. http://www.vibrationdata.com/tutorials2/srs_intr.pdf
- Ferebee, R., Clayton, J., Alldredge, D., & Irvine, T. (2008, April). An Alternative Method of Specifying Shock Test Criteria. Retrieved from https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20080025729.pdf
- Biot, M. (1932). Transient Oscillations in Elastic Systems. California Institute of Technology.
- Alexander, J. (2009). Shock Response Spectrum – A Primer. Sound and Vibration Magazine, pp6 -14

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Any Questions?

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