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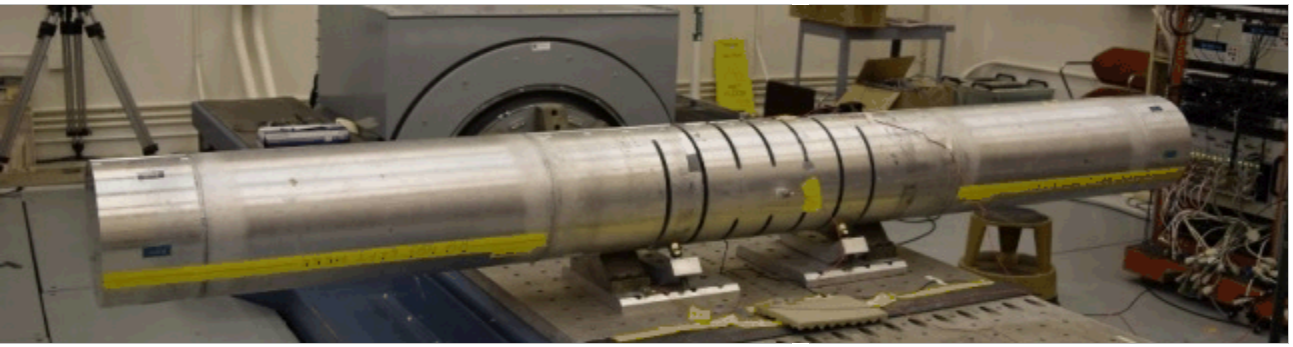

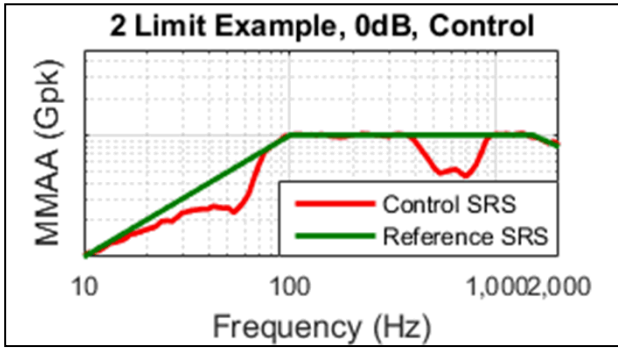

Response Limited Shaker Shock Testing

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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Background

- Limiting is an accepted practice for random vibration tests
  - Protect test hardware from excessive responses
  - Counteract boundary condition differences
  - Better representation of environment
- Response limited shaker shock
  - Built into TSHAKER which is a Sandia developed shock control program
  - Controlled dynamic transient simulations on electrodynamic or electrohydraulic shaker test systems
  - Works on many different waveform types
    - Sums of decayed sines
    - WaveSyn
    - Supplied shock time histories

The Control Process

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- Algorithm derived from the SRS Correction algorithm in TSHAKER
- Modification of the drive pulse to correct SRS error due to non-linear response
- Drive pulse modified by updating the FRF used to compute the drive pulse
  - Error corrections only applied to the magnitude of the FRF
- Test operator selects parameters used for error correction.
  - Frequency Range
  - Correction Factor
  - Amplify Only, Attenuate Only, or Both

Test and Control Setup

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- Required instrumentation
  - Control location
  - Response limit locations
- Required shock spectra
  - Input control SRS reference profile
  - Response limit SRS reference profiles
  - Interpolated to same frequency spacing as the FRF from the control system
- Limit control options
  - Amplify only
  - Attenuate only
  - Attenuate and amplify

Control Scheme

- Low level unlimited run (e.g. -12 dB)
  - To obtain FRF
- Error calculation at control input and response locations
  - Error=achieved SRS/reference SRS
  - Only consider error>1 for response locations
- FRF Update
  - Based on largest error source for each frequency line
  - Weighted to something less than 100% (discussed on next slide)
    - Manual selection based on current results
- Increasing test level (e.g. 3dB)
  - With new computed input pulse
- Repeat with updated error correction
- Increase to full level test

Error Update Weighting

- Weighting helps with several issues
  - Structural nonlinearities
    - Damping increases with level
    - Weighting helps make sure the control doesn't overshoot
  - Nonlinearities in the SRS
    - Changing lower frequency amplitude will change amplitude at higher frequencies
    - Weighting helps make sure the control doesn't overshoot input in frequencies above limiting band
- Manual weight selection
- Consistent weight for all frequencies

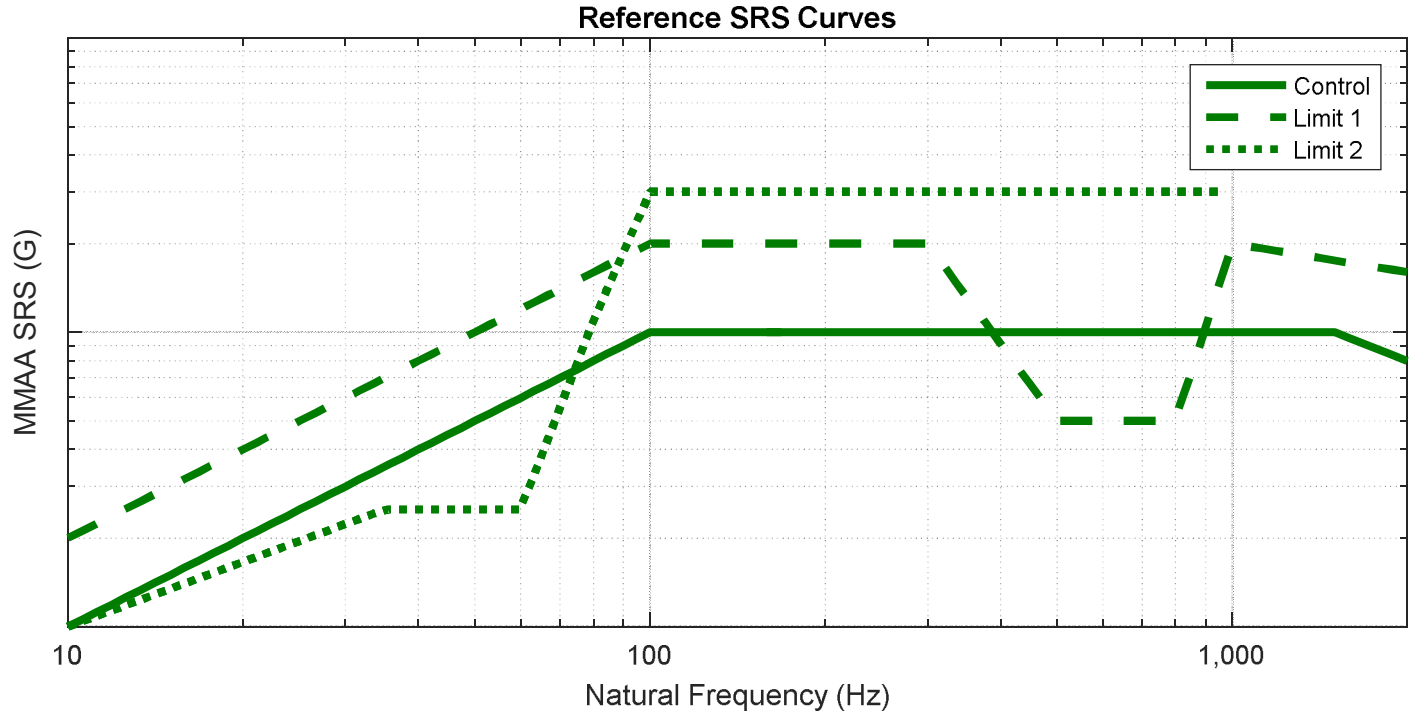
- May need to iterate weighting without increasing test level to dial it in
- Weighting historically never reaches 100%

Typical weighting

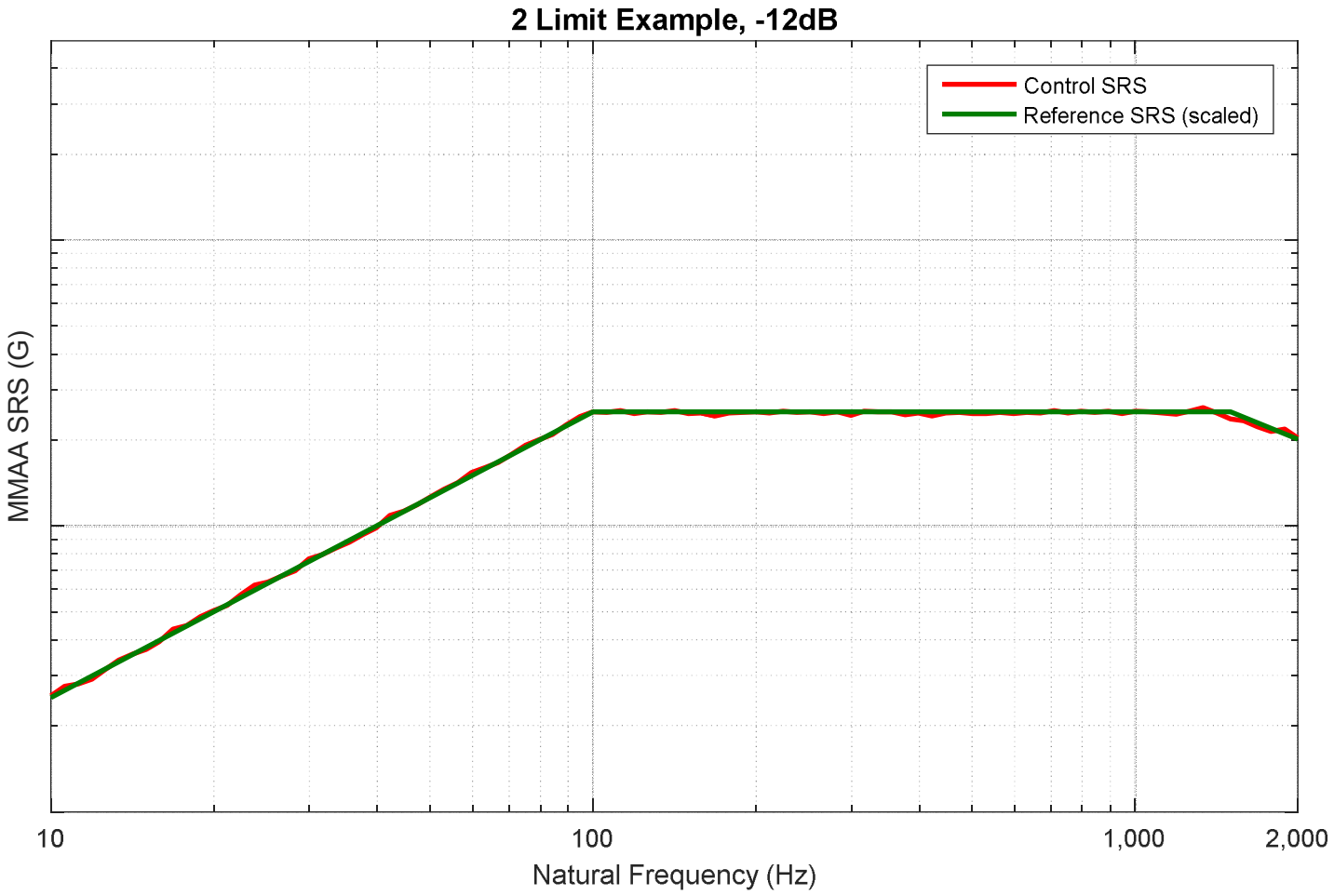
Test Level (dB)	Weight (%)
-12	50
-9	70-75
-6	80-85
-3	80-90
0	80-90

Example with Two Limit Channels

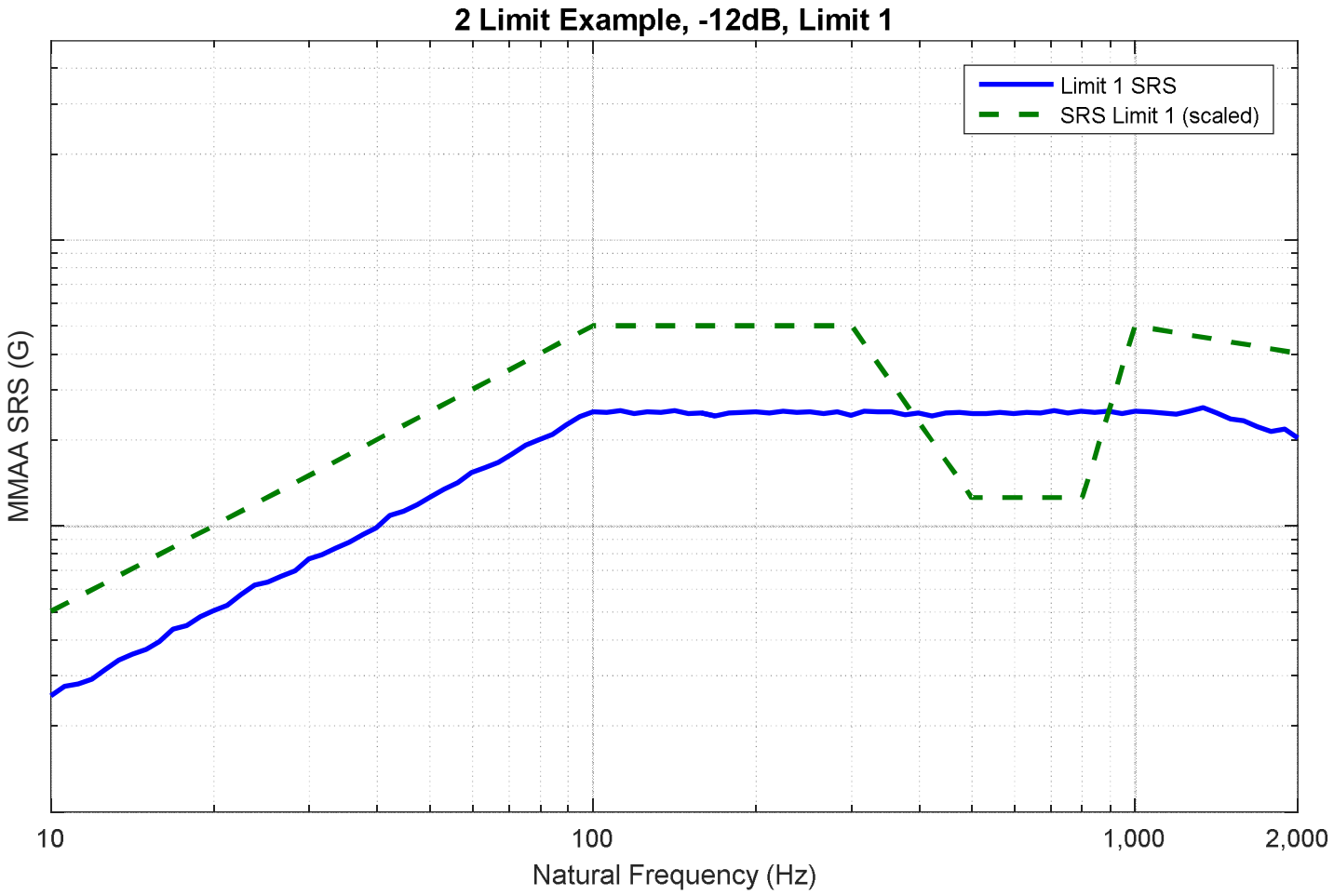
- Closed loop
- 2 limit channels with different limit SRS
- Control, Lim 1, and Lim 2 connected directly to output drive.



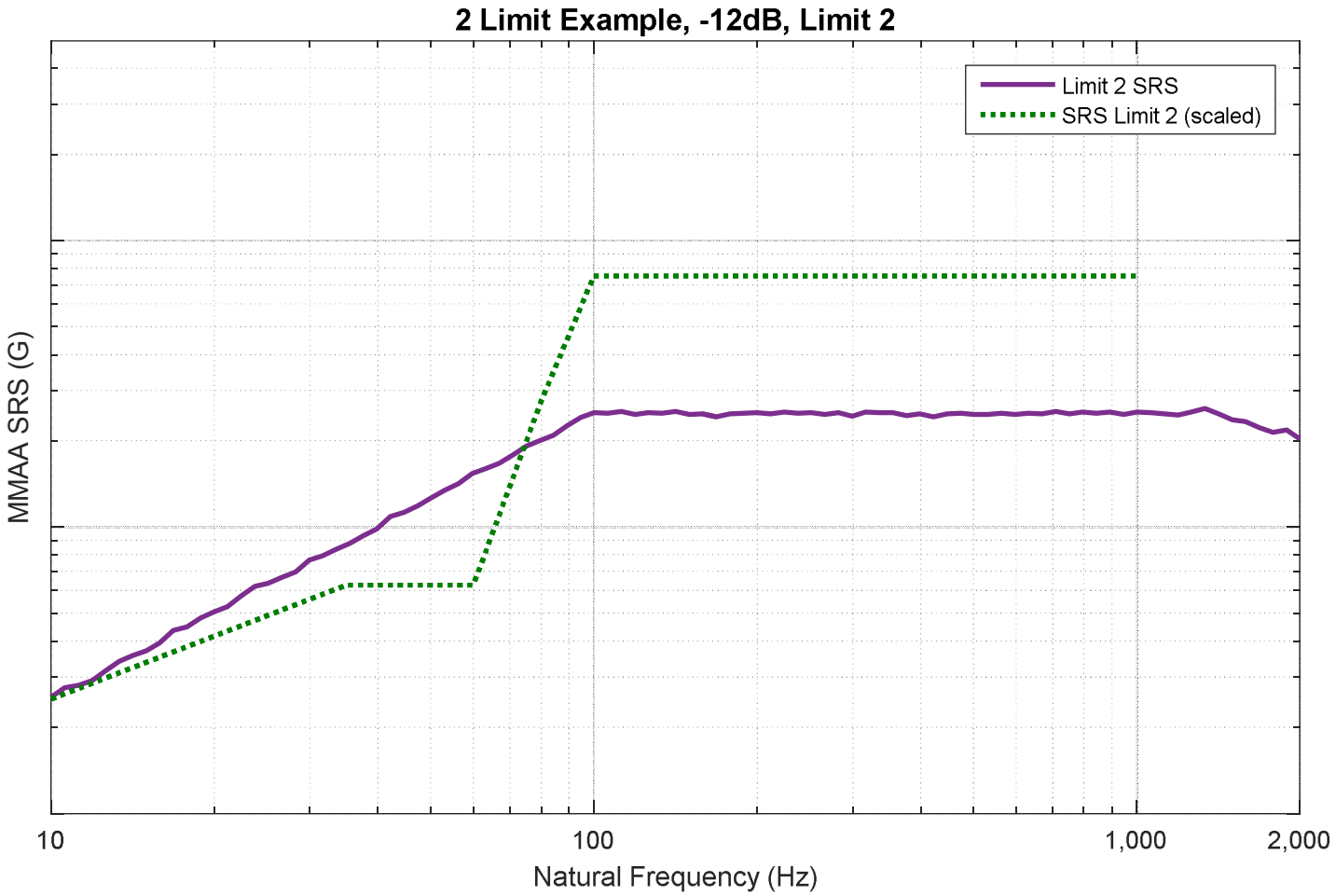
Unlimited Run: Control Channel



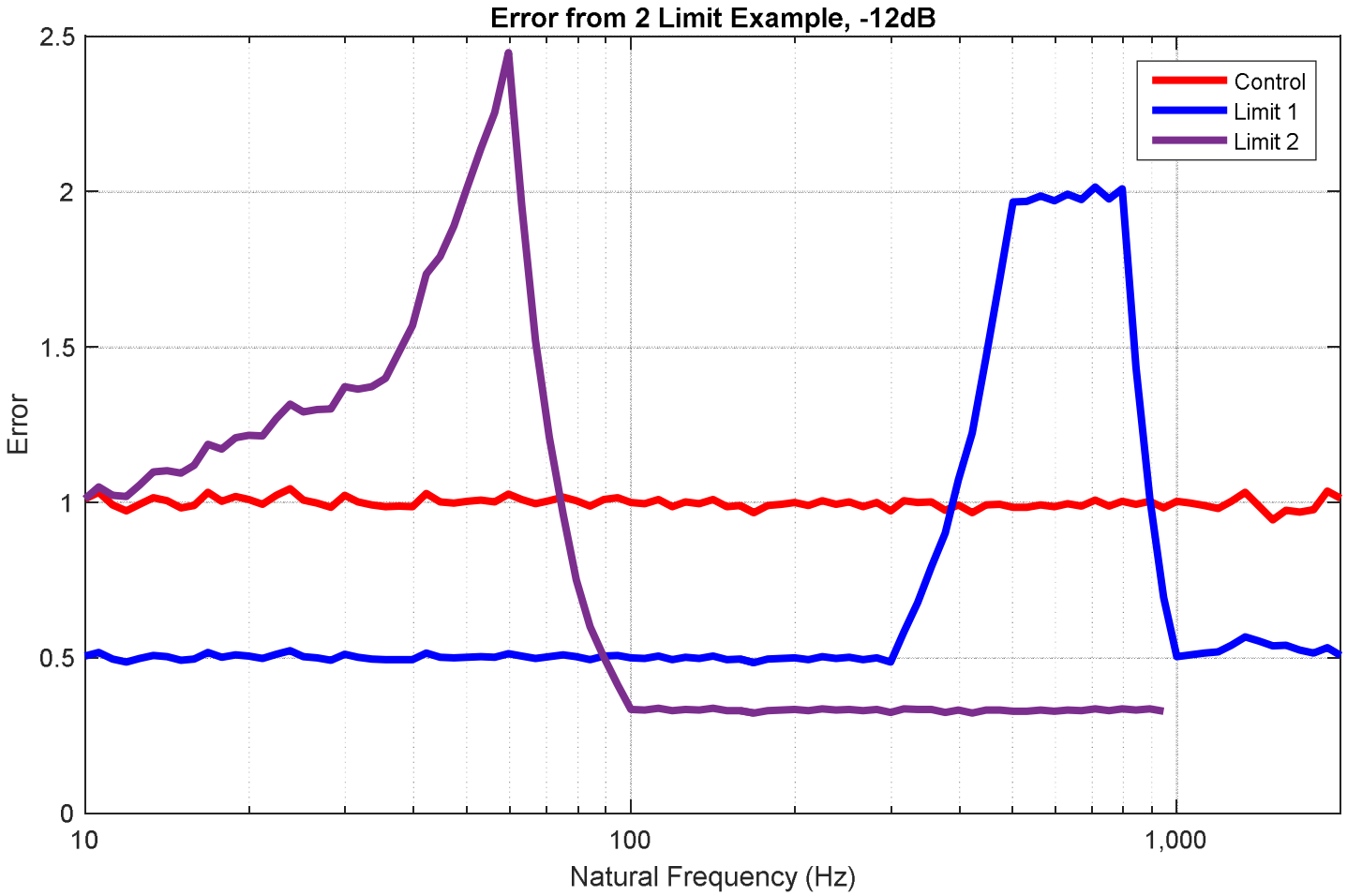
Unlimited Run: Limit Channel 1



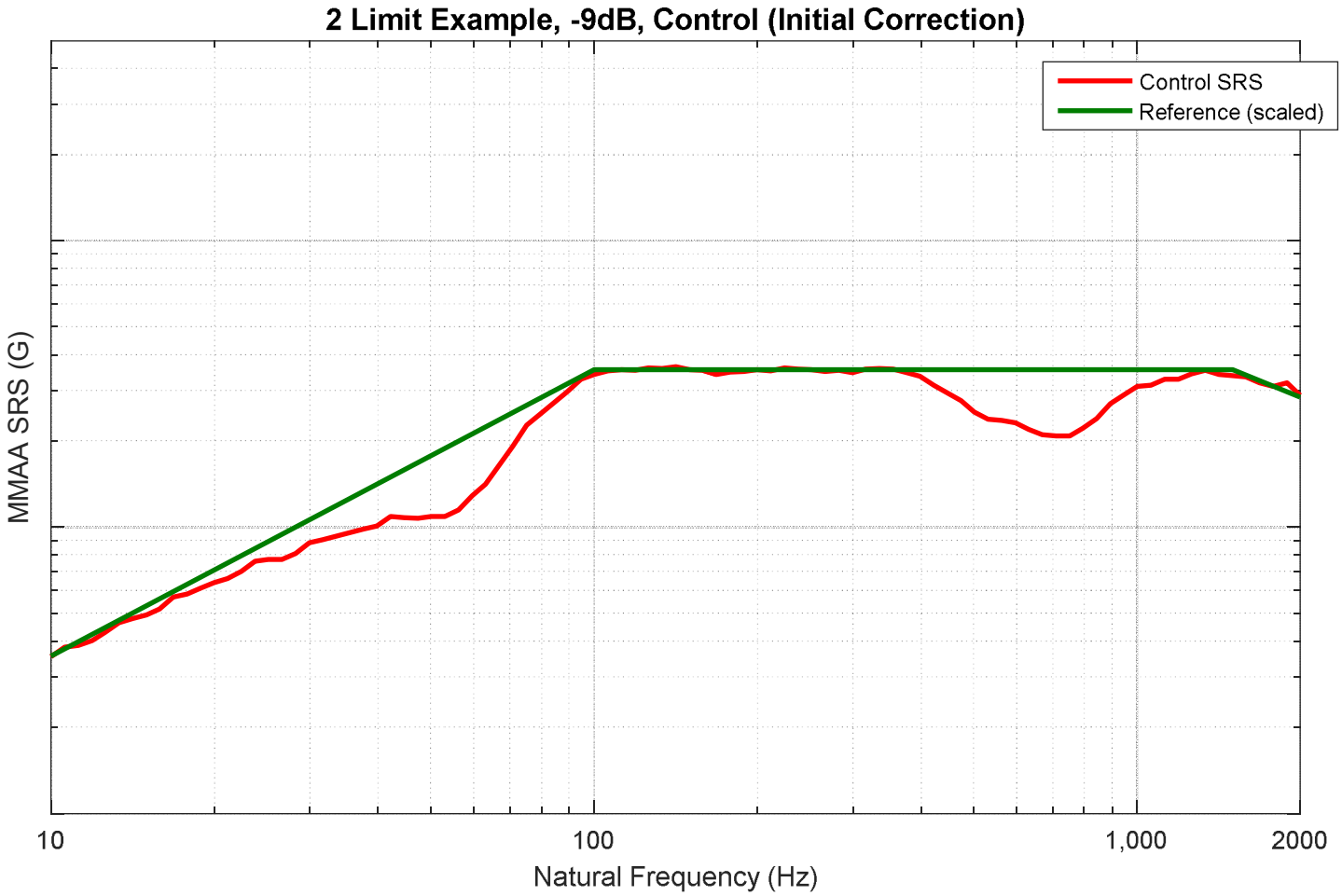
Unlimited Run: Limit Channel 2



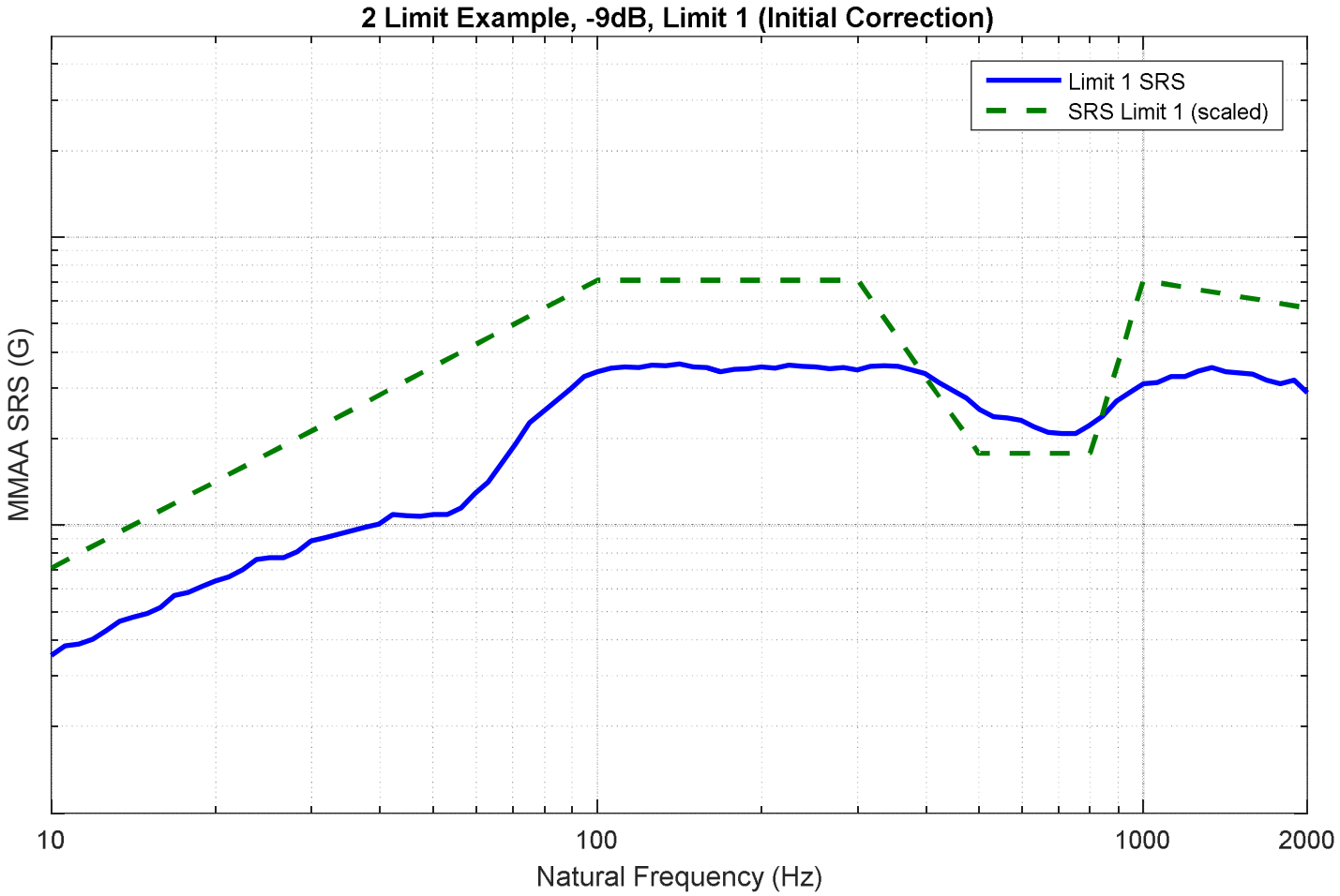
Unlimited Run: Error



Initial Correction: Control Channel



Initial Correction: Limit Channel 1



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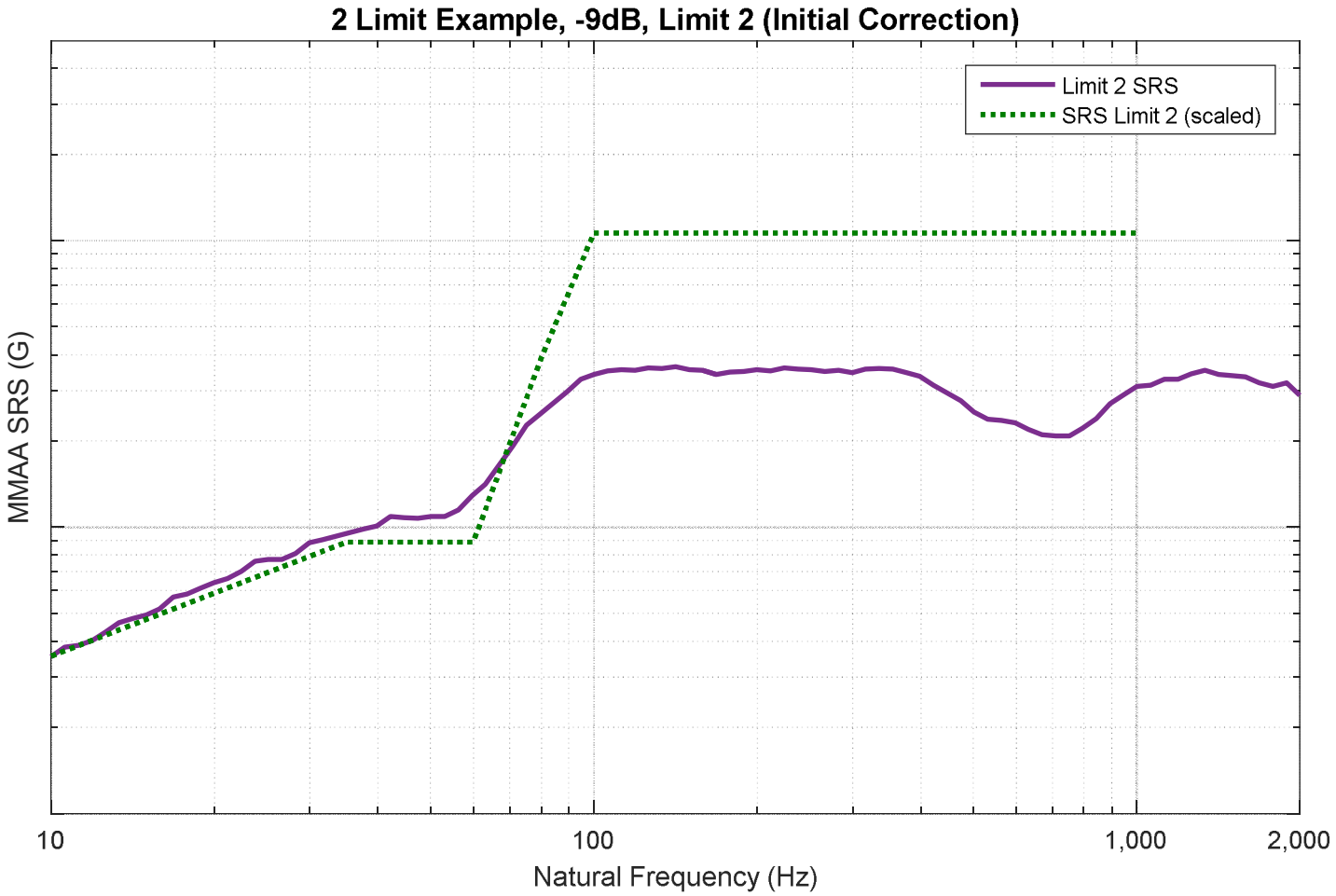
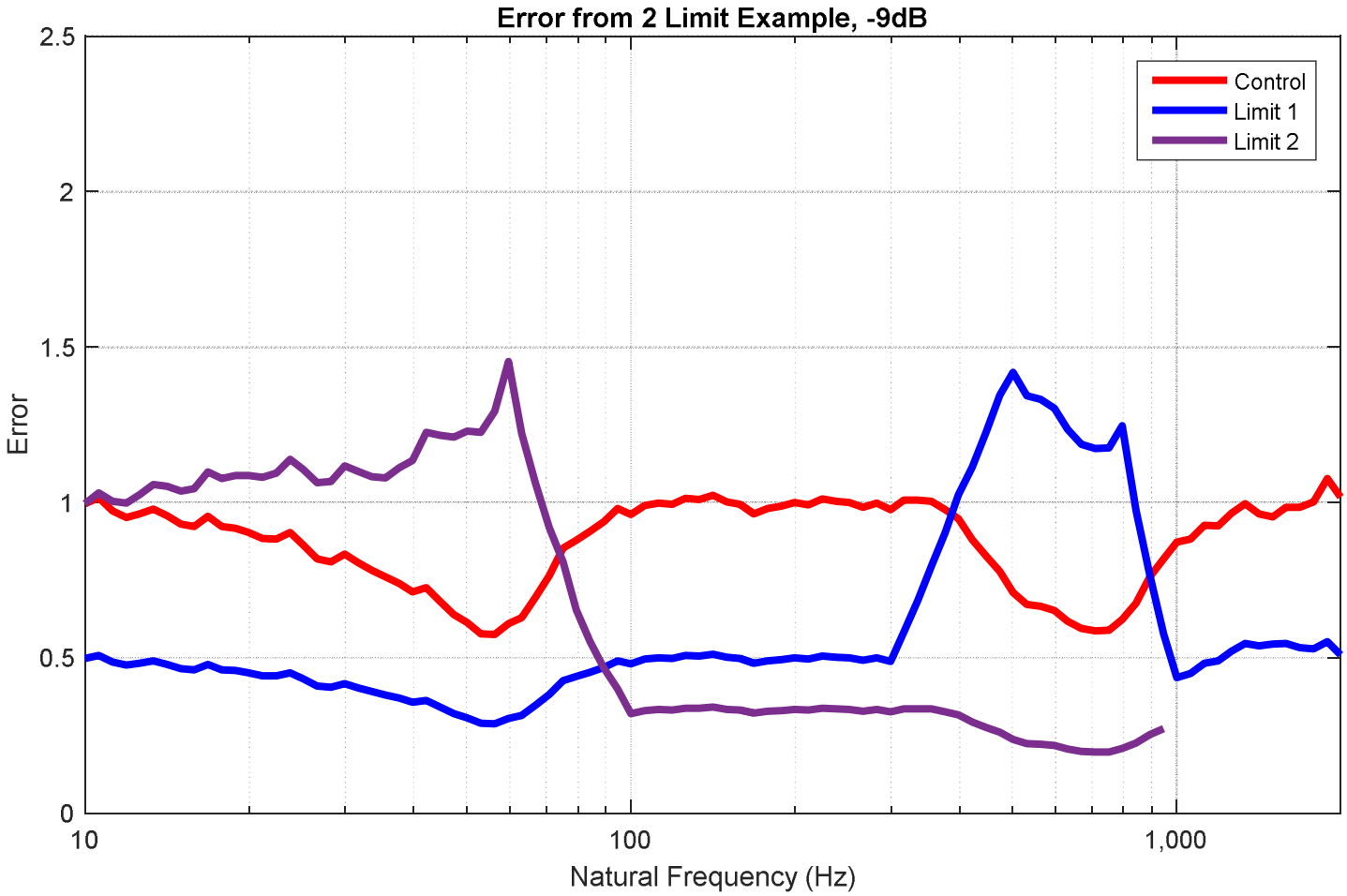
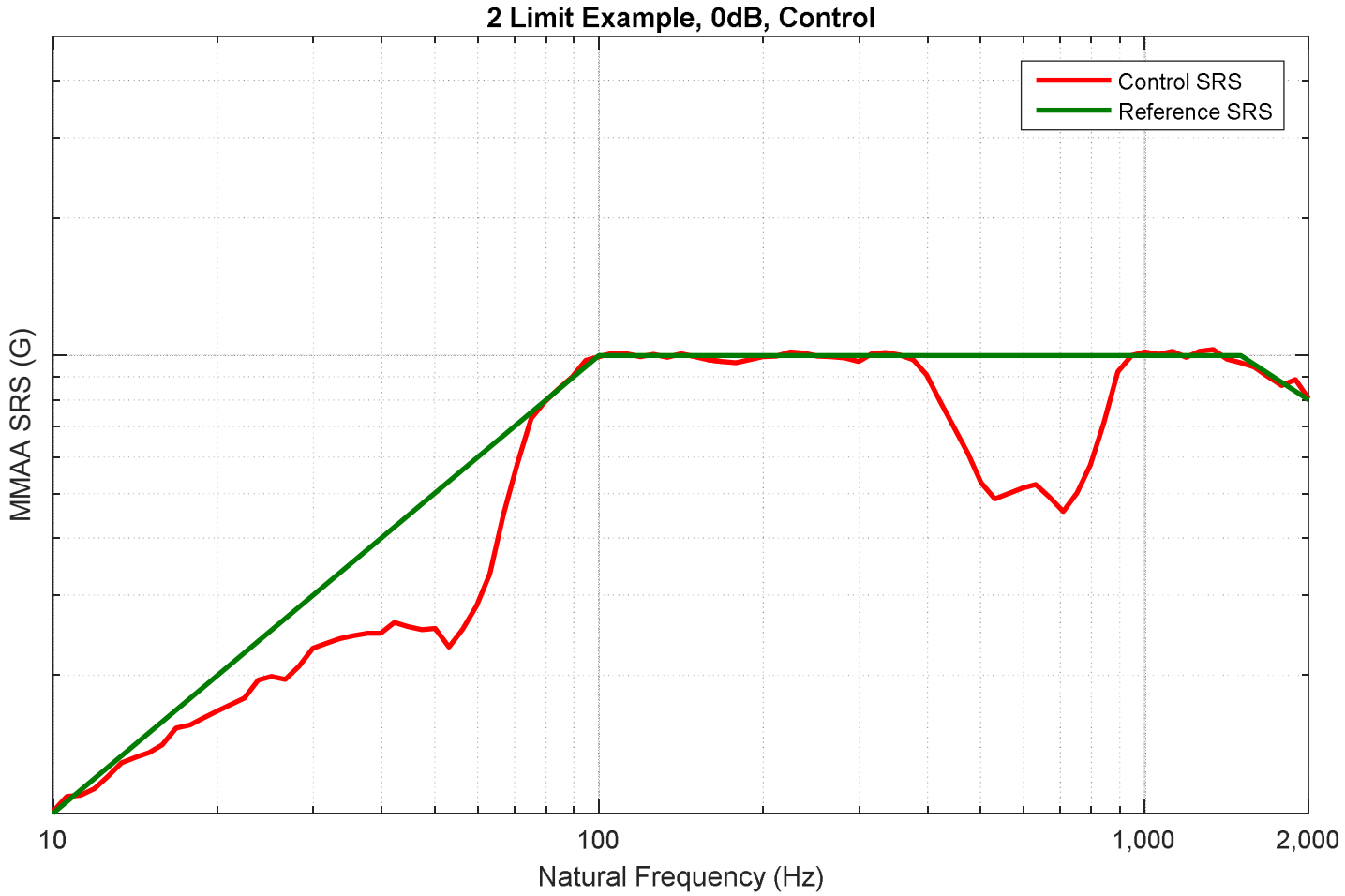


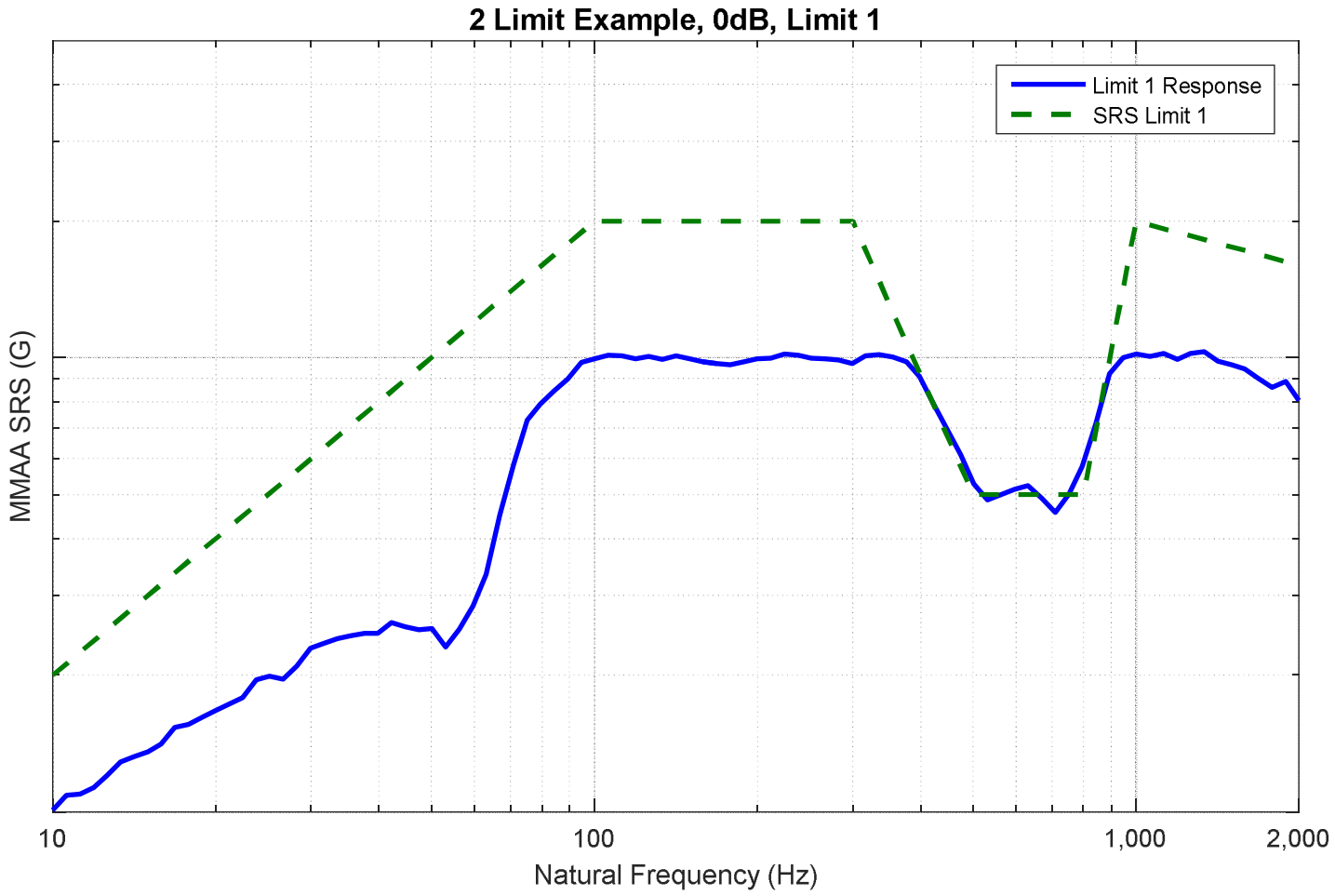
Initial Correction: Error



Final Correction: Control Channel



Final Correction: Limit Channel 1



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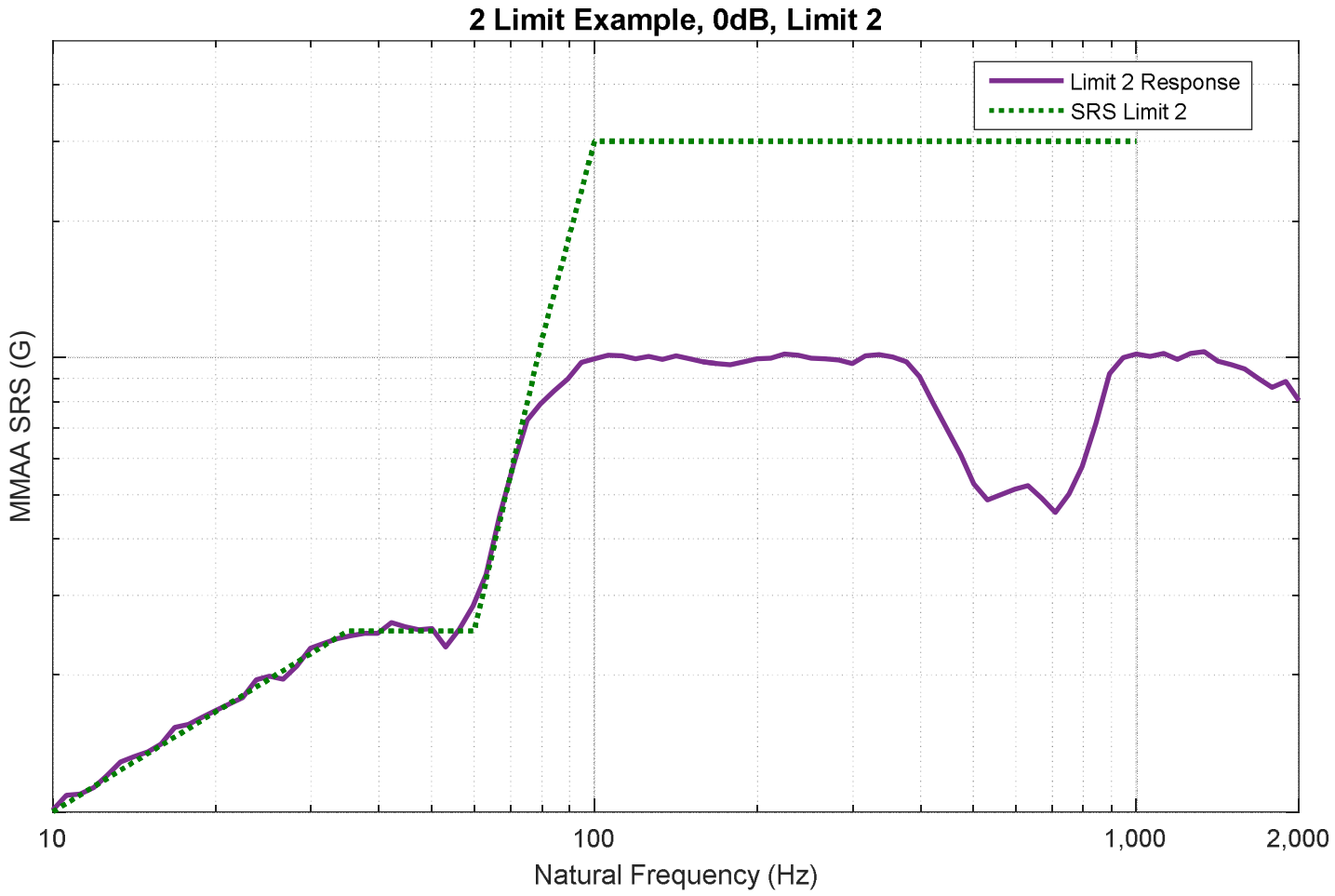
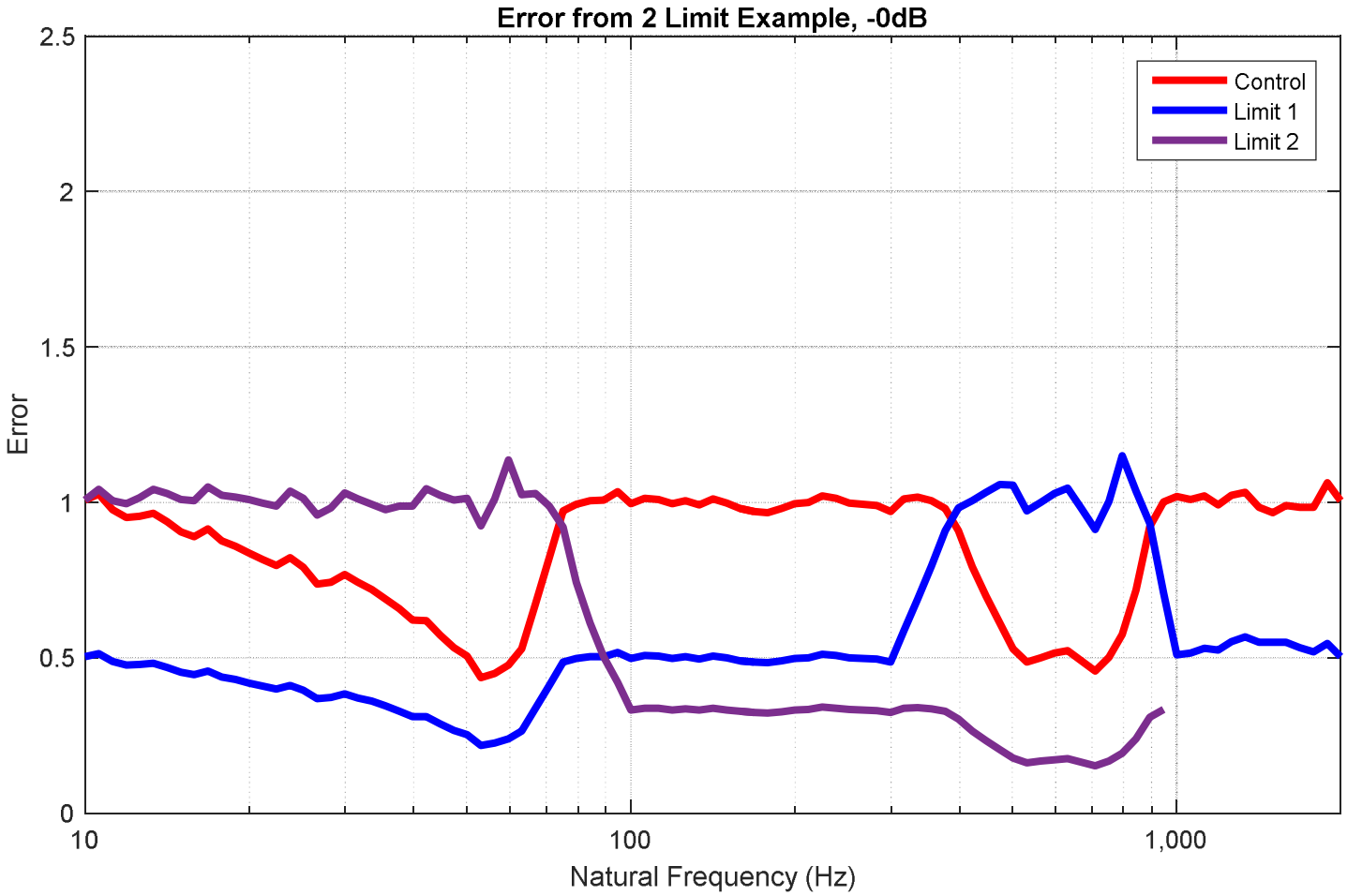
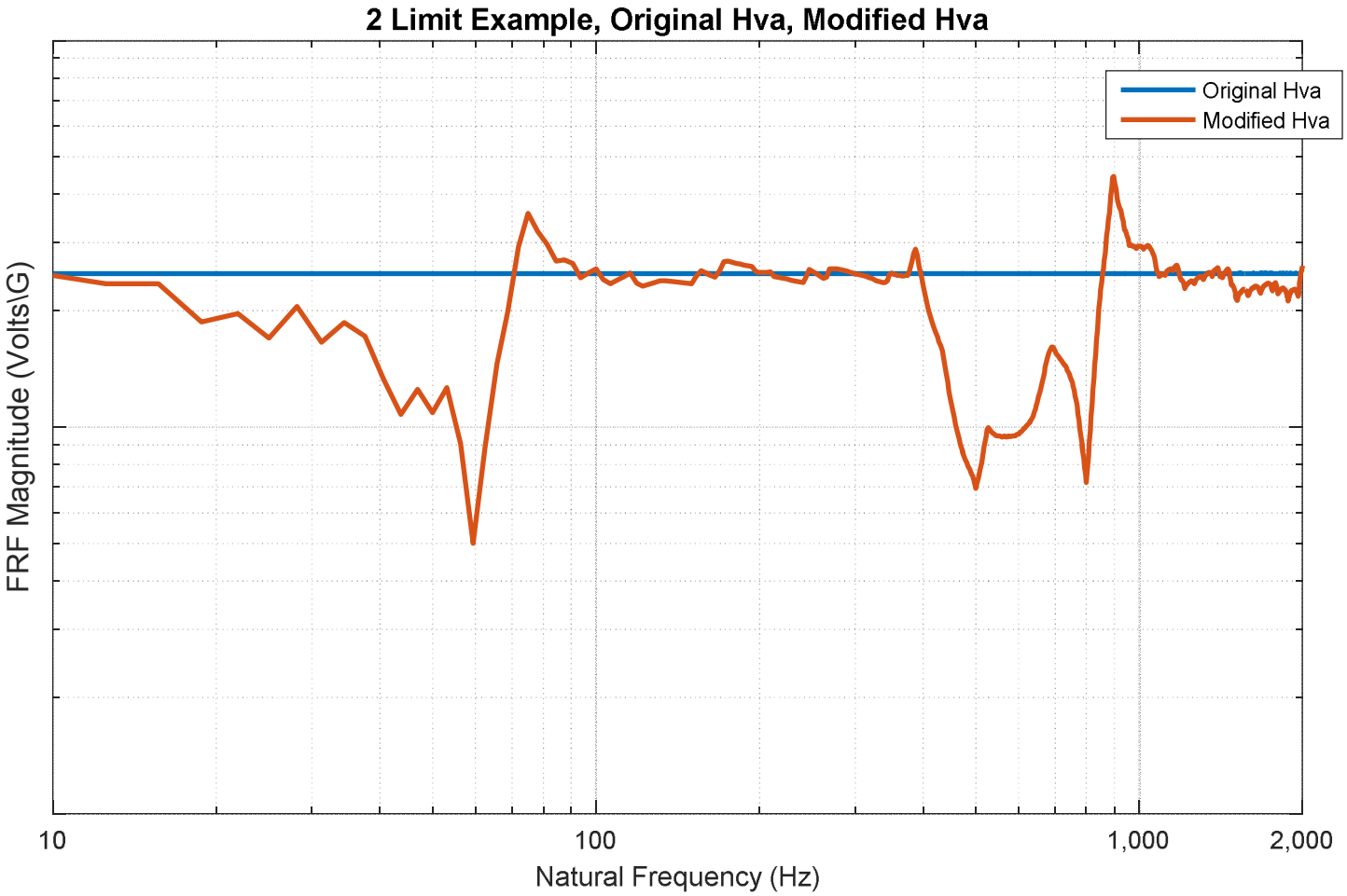


Final Correction: Error

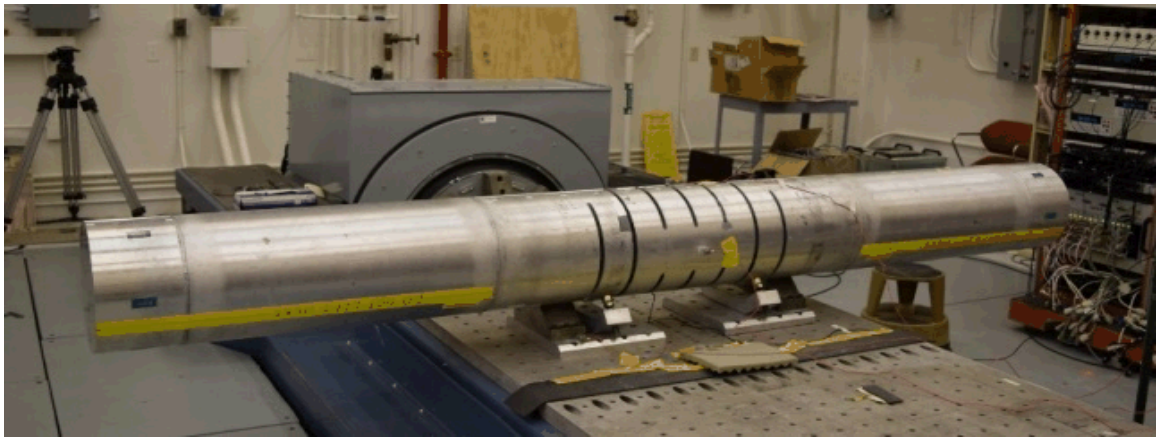


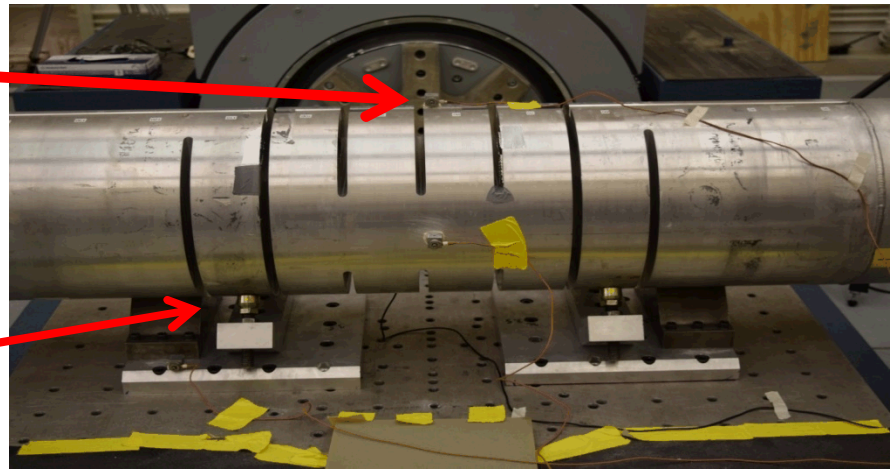
FRF Comparison



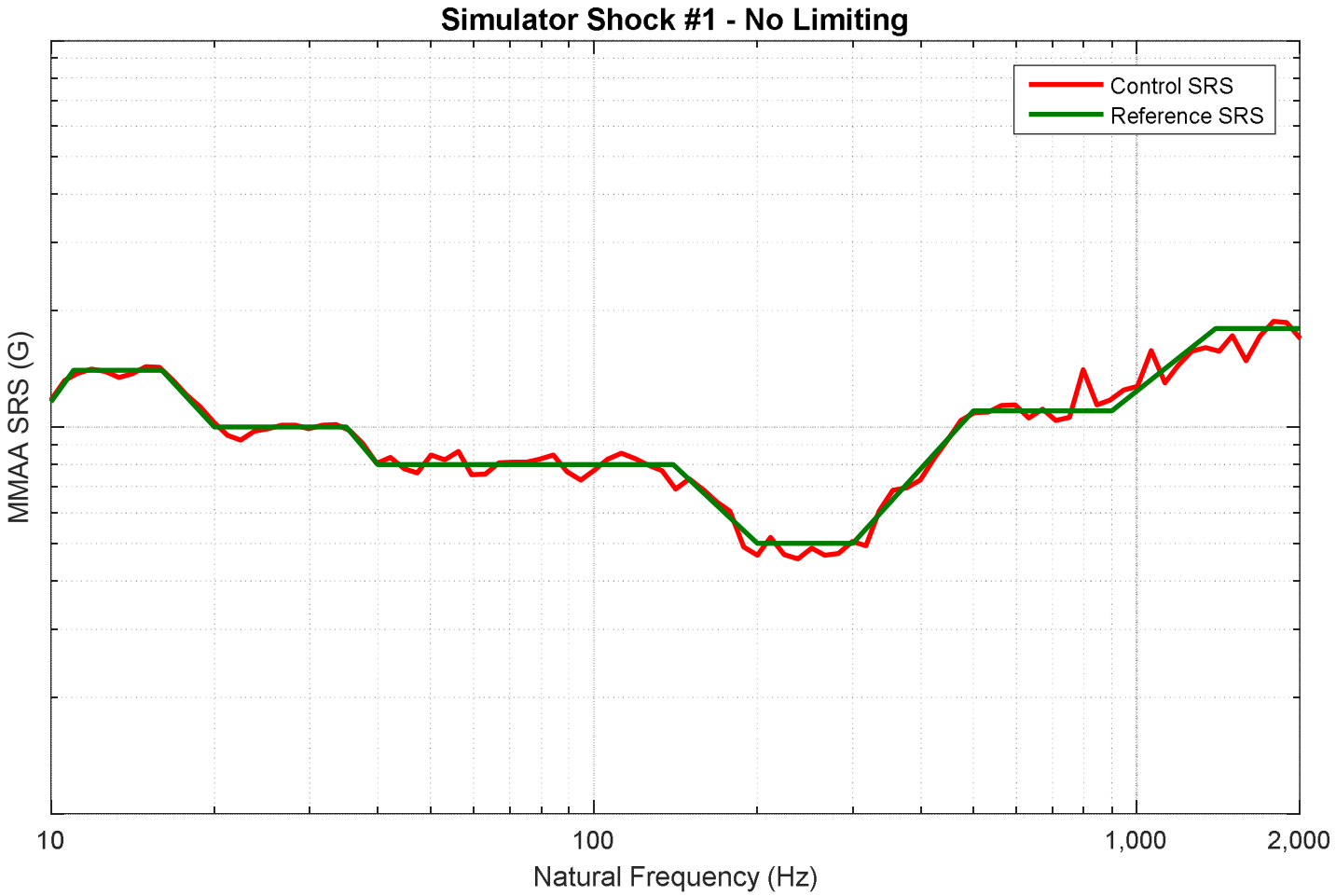
Example with Test Article

- Full level shock test
- High in axis response on test article
- Single point response limit
- Reference limit is +6dB of input

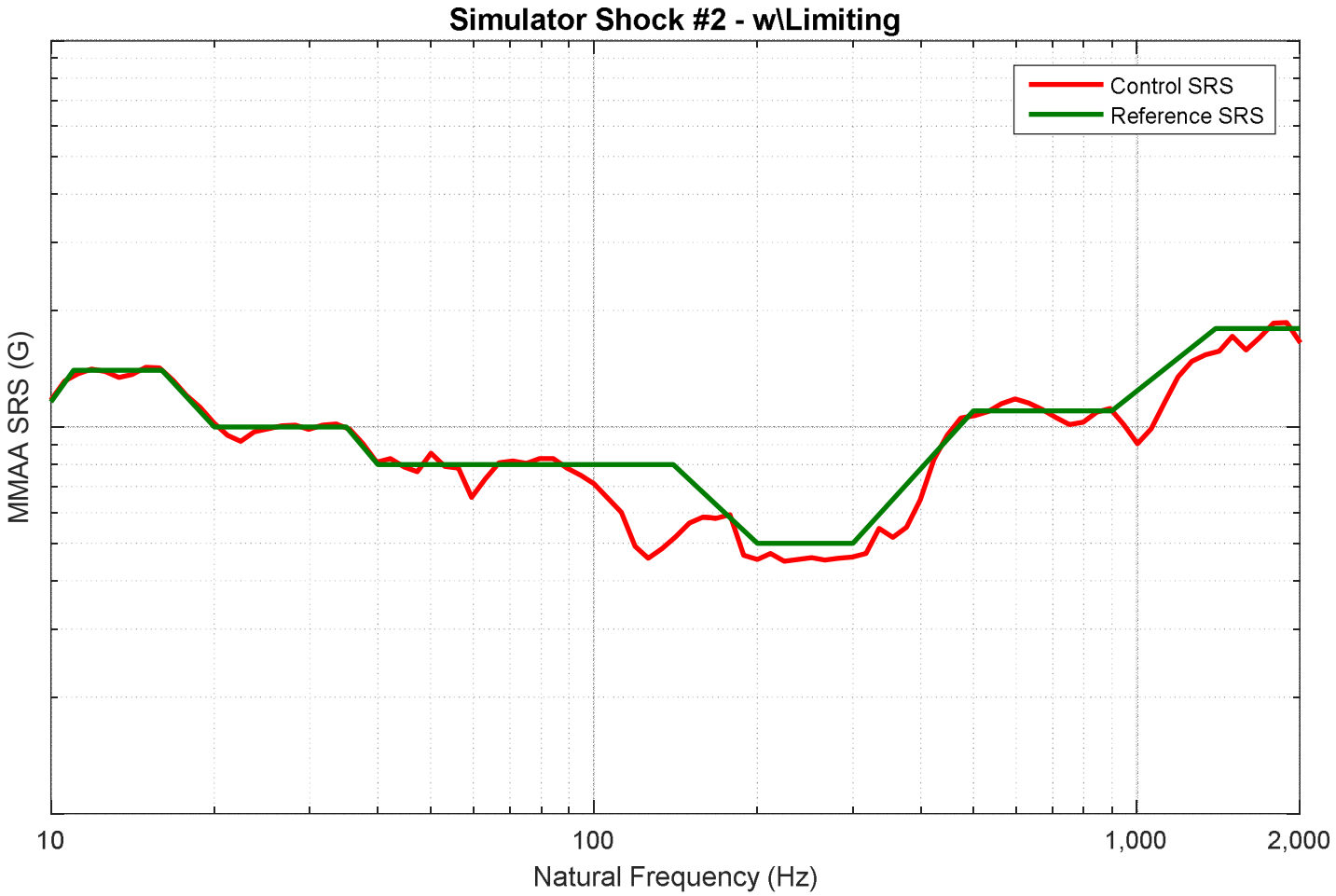




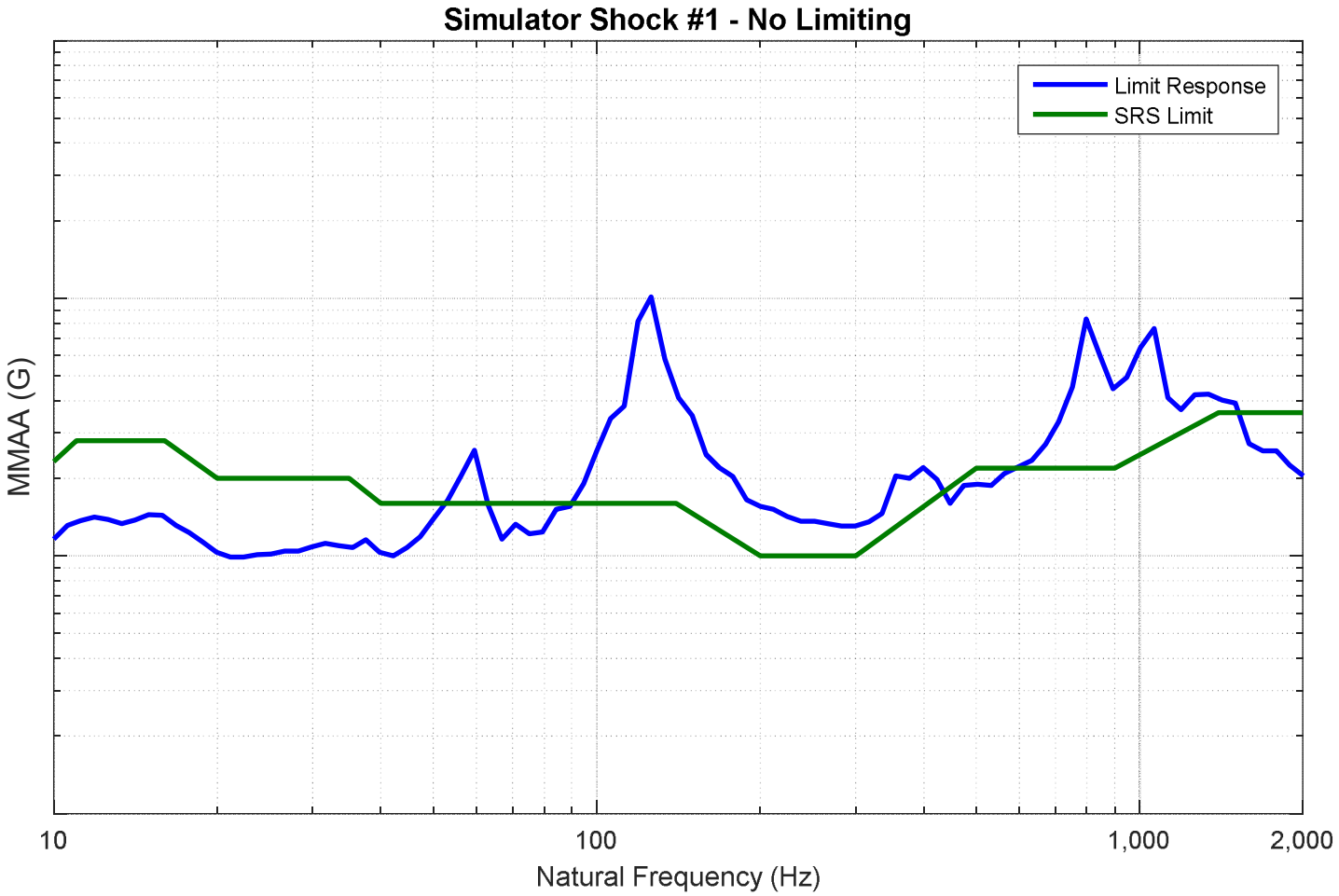
Full Level Control No Limiting



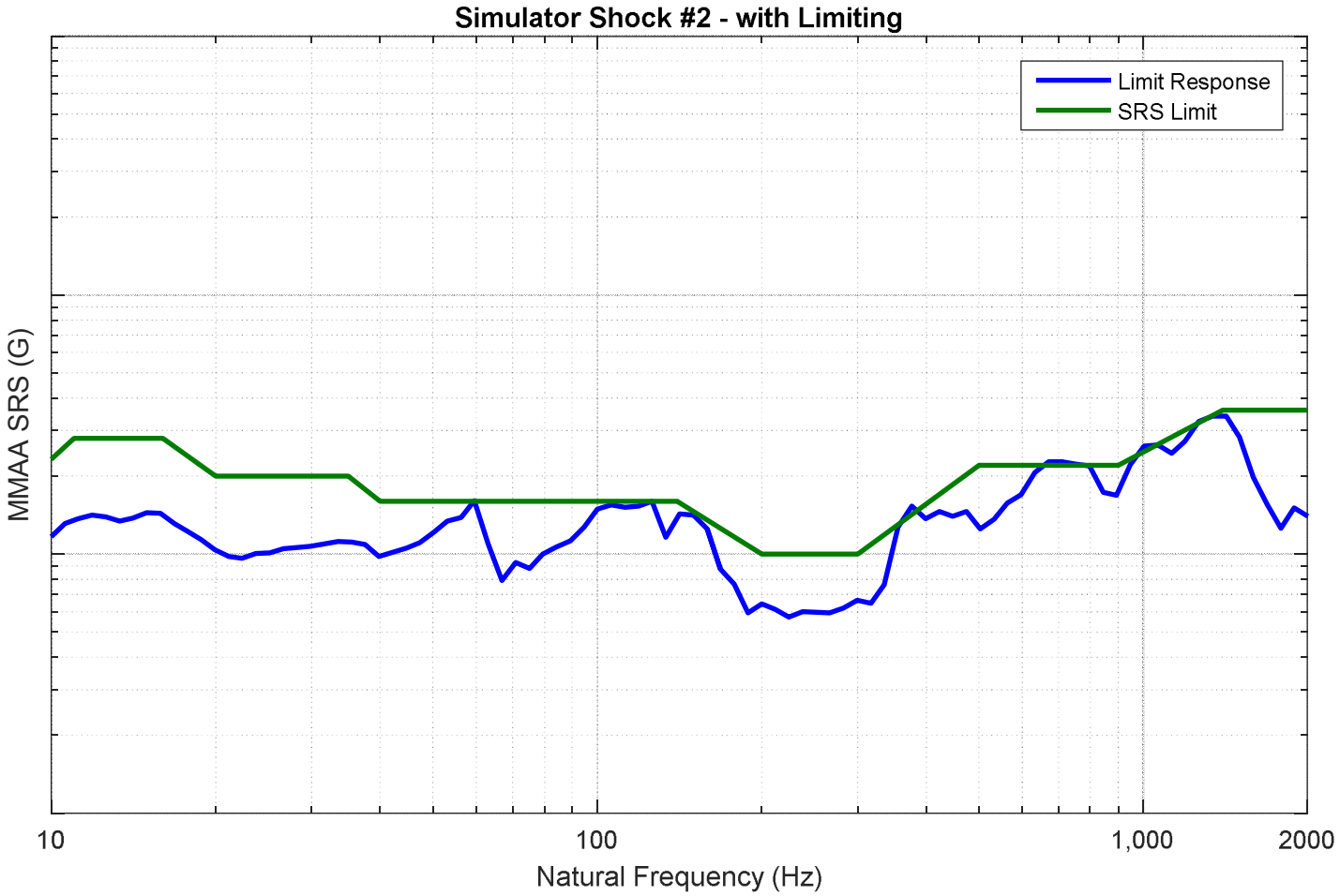
Full Level Control With Limiting



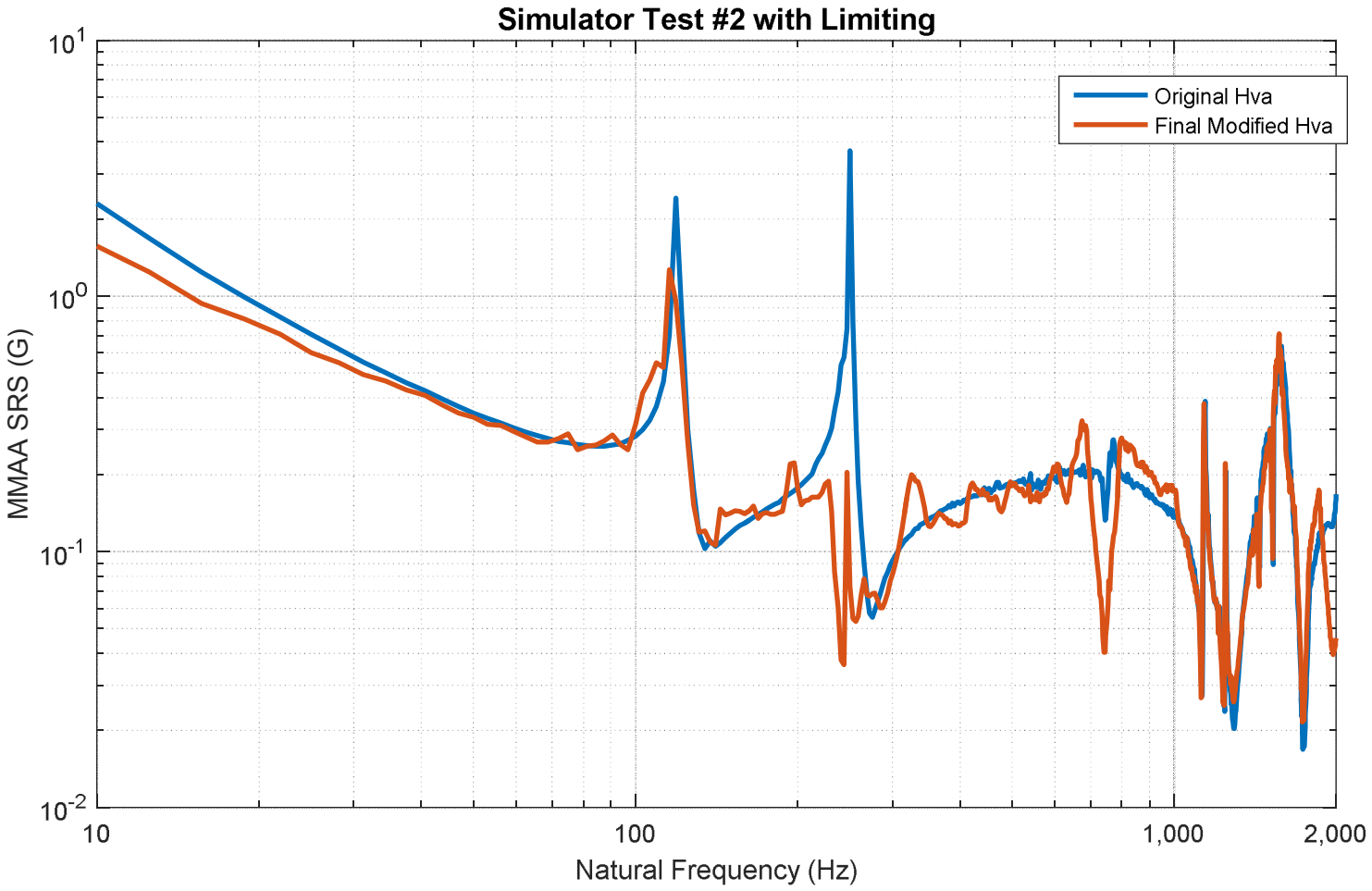
Full Level Response No Limiting



Full Level Response With Limiting



FRF Comparison



Conclusions and Future Work

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- A method has been developed for conducting response limited shaker shock testing
  - Prevent over testing for shock
  - Multiple response channels can be limited
- It is comparable to well accepted response limited random vibration testing

- Weighting curve rather than same for all frequencies