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# The Derivation of System Responses for a Mil-Standard Road*

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# Outline

- Background
- Measurement of Road Environment
- Derivation of Mil Std Inputs and Responses
- Derivation of Shaker Test Specifications
- Summary

# Background

- The Mil Std 810 (MS810) truck transportation vibration specifications [1] have historically been implemented as a set of three single axis vibration tests applied to the store at the base of its shipping configuration (i.e., the truck bed)
  - Force limited vibration theory indicates that such an approach is overly conservative
- The purpose of this study is twofold
  - To generate realistic worst case Multi-Degree-of-Freedom (MDOF) inputs and responses consistent with MS810
  - To develop a set of multi-point response limit test control spectra based on those inputs

# Measurement of Road Environment

- The key to defining realistic test specifications is to measure the true field environment
- A series of road tests were performed to measure responses for the following configurations
  - A 5-ton uni-body flatbed and a flatbed tractor trailer
  - Interstate, rural highway, city streets, and dirt roads
- As one might expect the measured responses were well below MS810 levels
  - Hard to find worst case road



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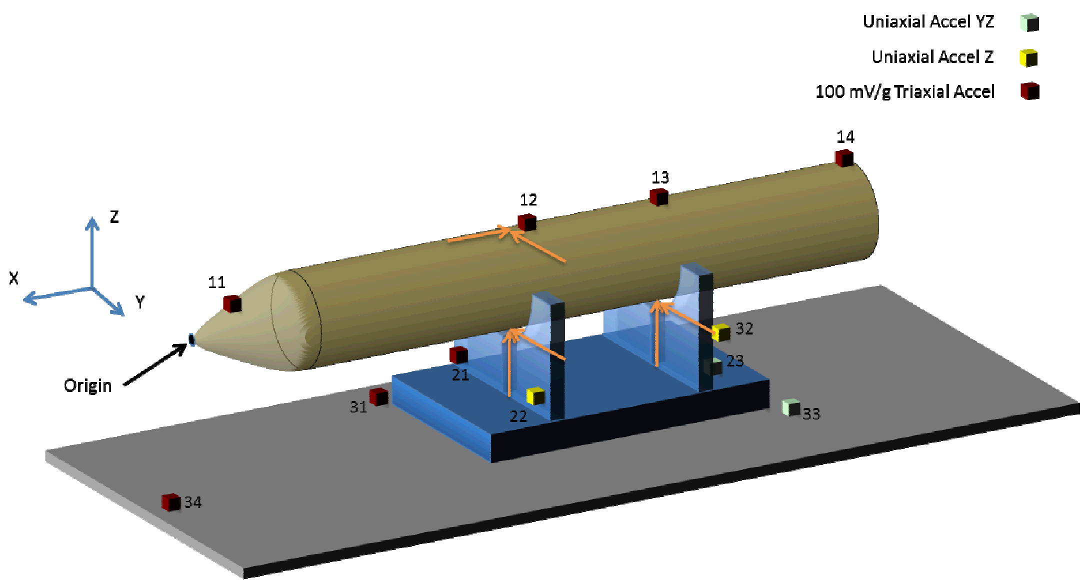
# Measurement of Road Environment

Simulator on 5-ton Flatbed

Instrumentation Layout for Simulator




Note that the H-Gear is resting on wooden chocks

Responses were measured on the truck bed, the H-Gear deck, and the exterior of the simulator

# Derivation of Mil Std Inputs and Responses

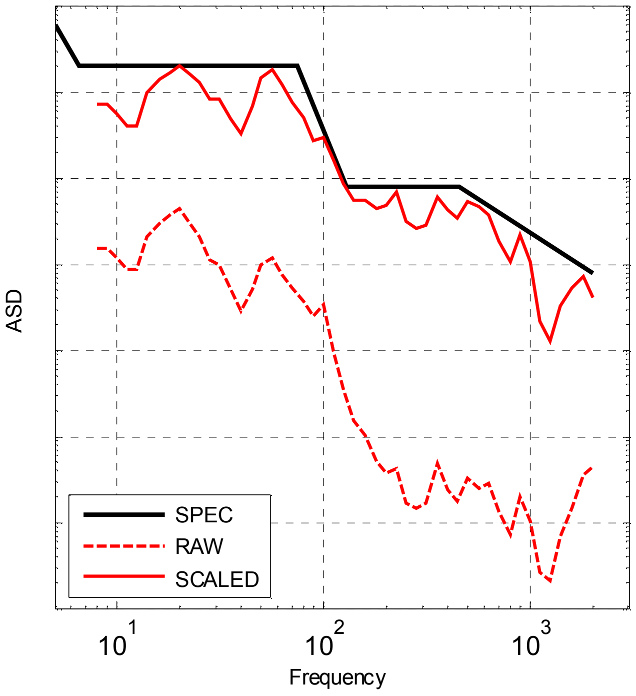
- **Must scale responses up to MS810 levels**
- **The responses were grouped into Spectral Density Matrices (SDMs)**
  - **Truck bed (input), H-Gear, and simulator**
  - **Multiple-Input-Multiple-Output (MIMO) Transmissibility Response Functions (TRFs) were generated between the input SDM and the two response SDMs**
- **Two issues had to be resolved**
  - **The appropriate method for scaling the amplitude**
  - **Method for preserving the phase and coherence between the inputs**

# Magnitude Scaling of Responses

- When scaling the field response amplitudes up to MS810 levels, it would certainly be conservative to scale the responses frequency-by-frequency
  - However, if one considers how specifications are typically derived, the straight line segment specifications tend to hug the peaks and fill in the valleys
  - It is the filling in of the valleys in the input specifications that tend to over drive the store responses
- Two types of scaling were considered
  - Peak Scaling
  - Grms scaling

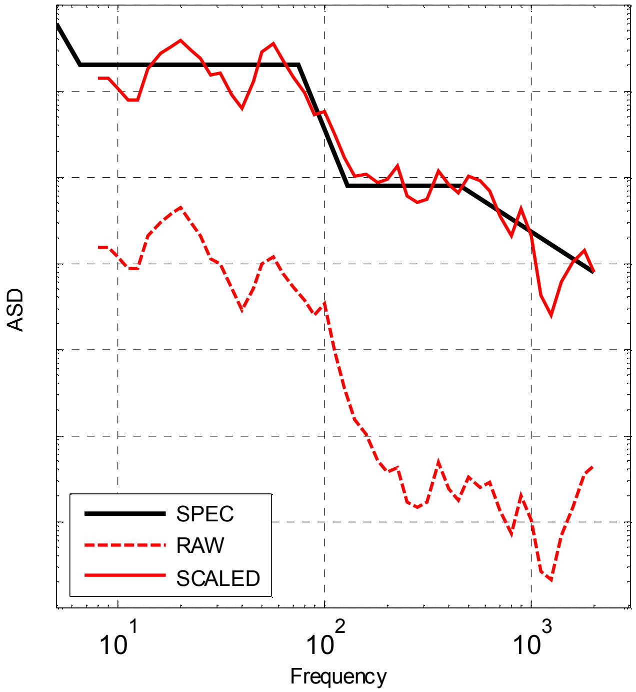
# Peak Scaling

- **An algorithm was developed to scale the peaks in the raw field data until they touch the specification and to let the valleys be scaled as a linear function of the scale factors for the peaks on either side**



# Grrms Scaling

- The original MS810 specifications were based on VIBRAN spectra using extremely coarse analysis bands
- Therefore, it makes sense to adjust the peak scaled ASD to match the Grms of the MS810 spectra in each analysis band



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# Phase and Coherence

- **When scaling the road responses to MS810 levels it is crucial that we preserve the "true" phase and coherence between the inputs**
  - **Normalize the raw input SDM, $S_{IJR}$, by dividing each term in that SDM by the square root of the adjacent diagonal terms**

$$S_{IJN}=S_{IJR}/sqrt(S_{IIR}S_{JJR})$$

  - **Multiply the terms in the normalized SDM, $S_{IJN}$ by the desired peak or Grms scaled ASDs to produce a scaled SDM having the same phase and coherence as the raw SDM**

$$S_{IJS}=S_{IJN}sqrt(S_{IIS}S_{JJS})$$



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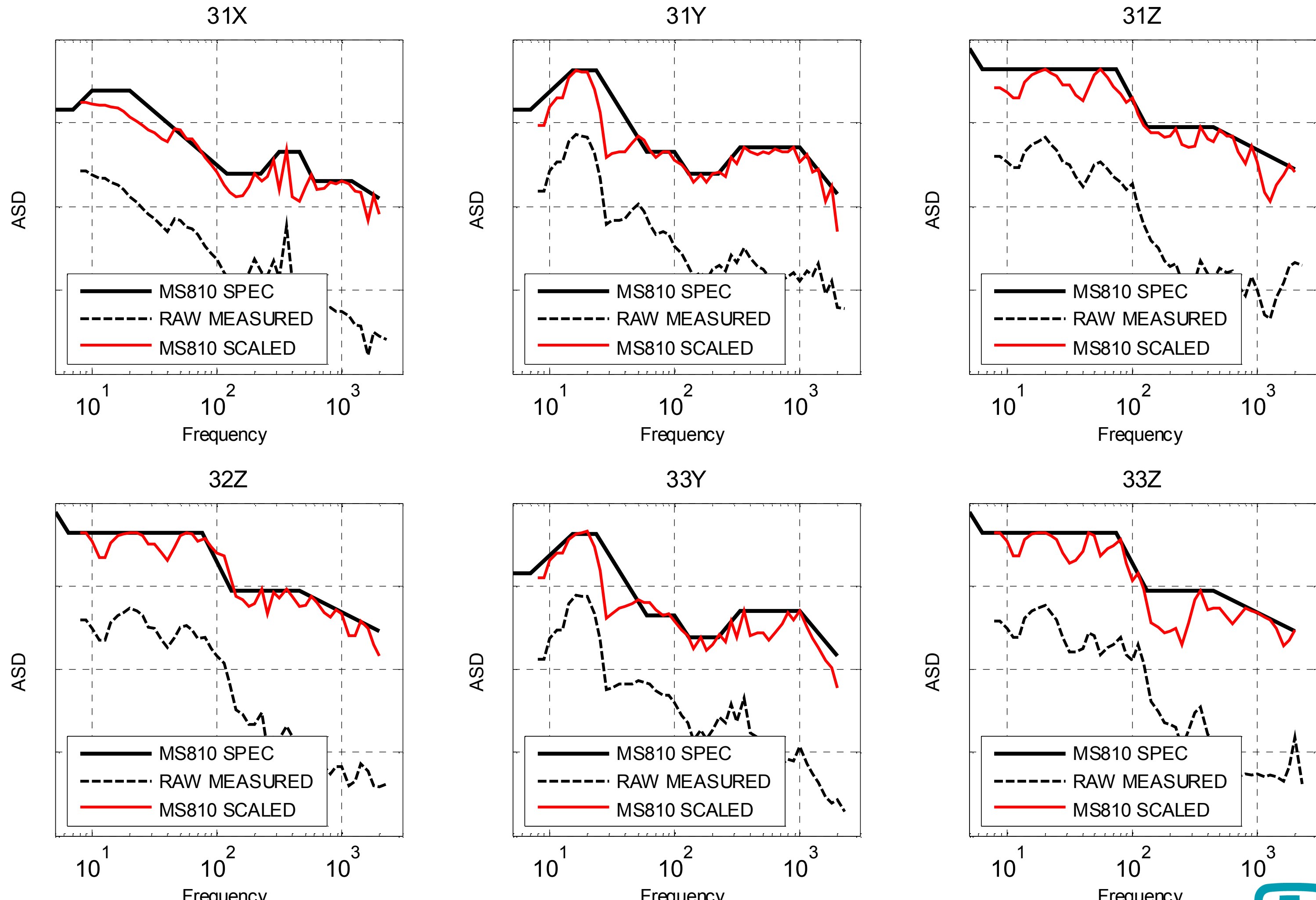
# Scaled Inputs (Peak Scaling)



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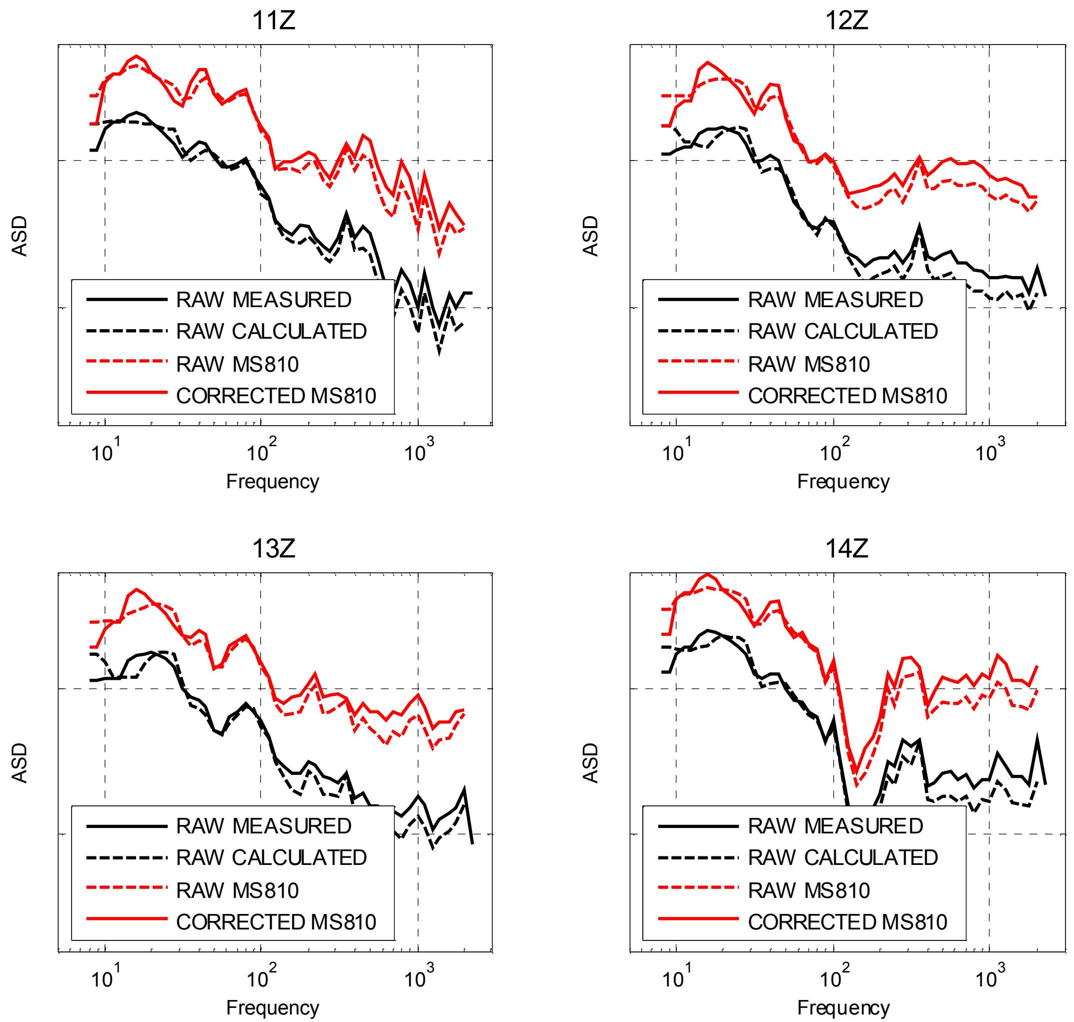
# Derivation of Realistic Mil Std 810 Responses

- The response SDM, $S_{RSP}$, is computed using the scaled input SDM, $S_{INP}$, and the TRFs, $H$

$$S_{RSP} = S_{INP} H S'_{INP}$$

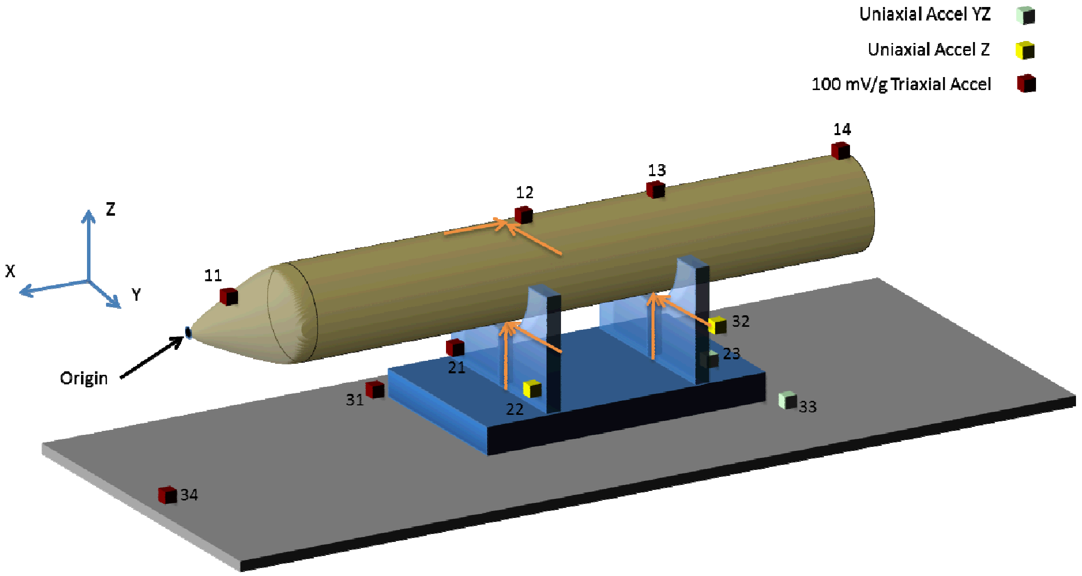
- The TRFs do not account for the incoherent portion of the response so the values of $S_{RSP}$ are under predicted when the coherence is less than 1
  - The under prediction can be estimated by computing the response to the raw input
  - The diagonal terms in $S_{RSP}$ were then multiplied by the ratio of the measured and synthesized raw response ASDs

# Example of Scaled Responses



# Derivation of Shaker Inputs

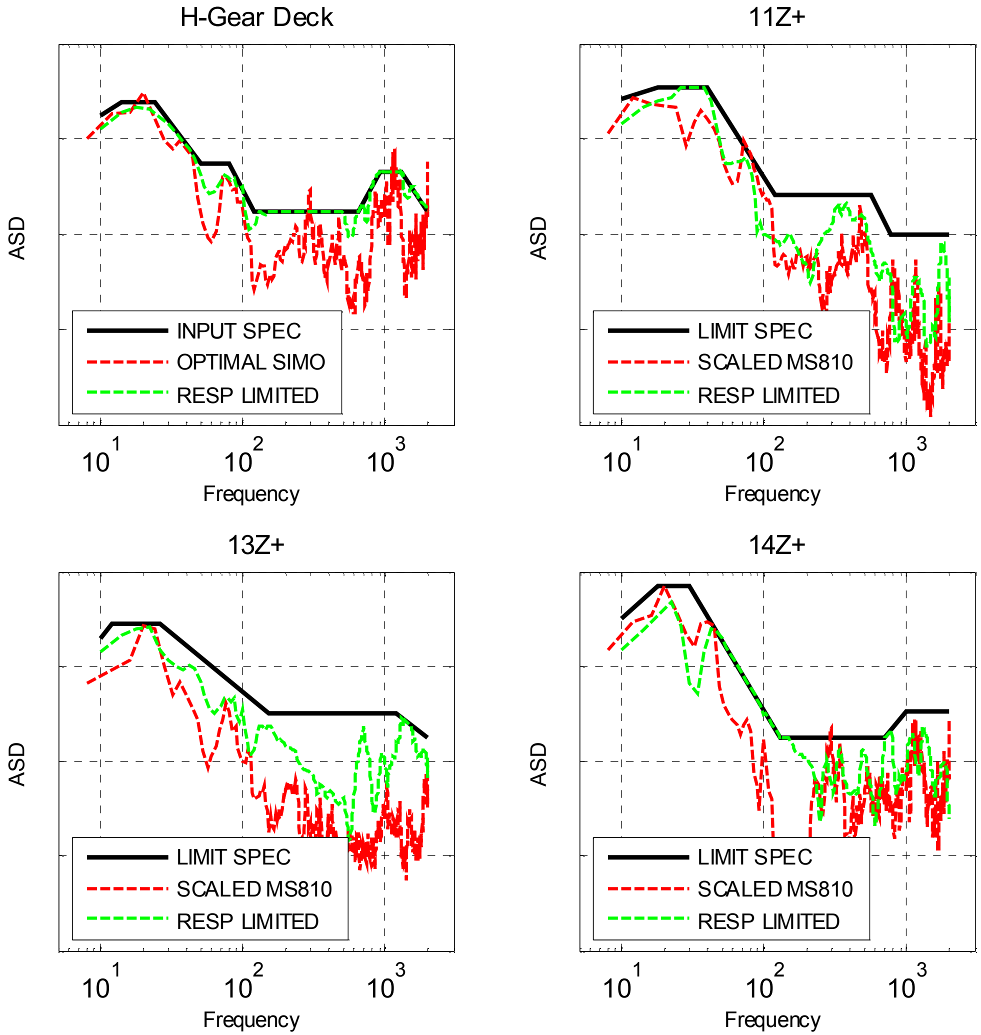
- A single axis shaker test can only match one response location exactly
- Therefore, the decision was made to derive an input that reproduced the response at the four simulator response points in a least squares sense



# Derivation of Shaker Test Specifications

- **A single input / multiple output (SIMO) model was used to derive the optimum least squares input to the H-gear [2]**
  - The actual input specification is the straight line segment envelope of the optimal SIMO input
- **Response limits were developed for the four external locations on the simulator**
  - The response limits were primarily defined so as to prevent overdriving of the unit in frequency bands where the input spectra filled in valleys in the SIMO spectra
  - Good limit spectra should allow for frequency shifts associated with unit-to-unit variability while keeping the lab test responses in line with the scaled MS810 responses

# Example of Response Limiting Test Specifications




In a perfect test the "Resp Limited" spectra should slightly exceed the "Scaled Response"

# Summary

- **This methodology provides a greater degree of realism than the traditional single axis base input control scheme**



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# References


- [1] MIL-STD-810E; "Environmental Test Methods and Engineering Guidelines.“
- [2] Cap, J. S., C’ de Baca, M. K., and Smallwood, D. O.; “A Technique for the Identification of the Optimum Inputs for a Vibration or Acoustic Test”; Proceedings of the 76th Shock & Vibration Symposium; October 31st – November 3rd, 2005; Destin, FL.




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