Mass Loaded Support Structures Random Vibration Predictions

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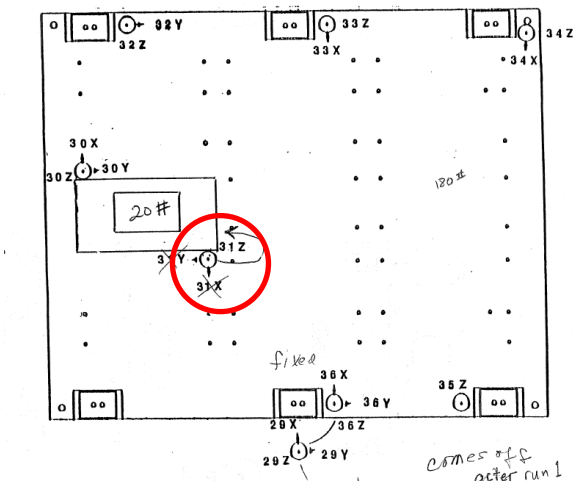
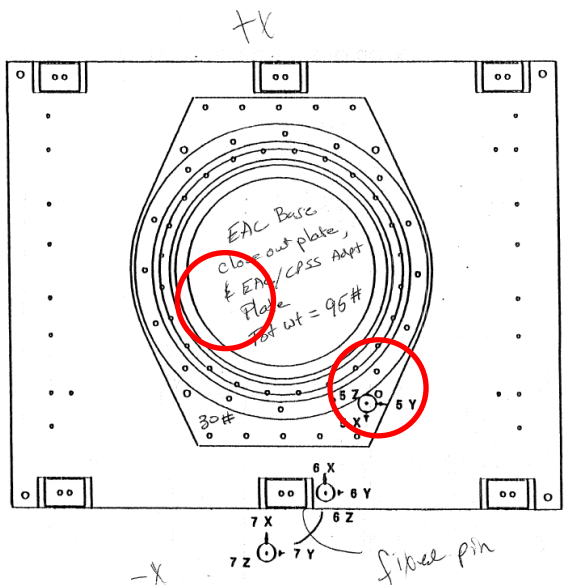
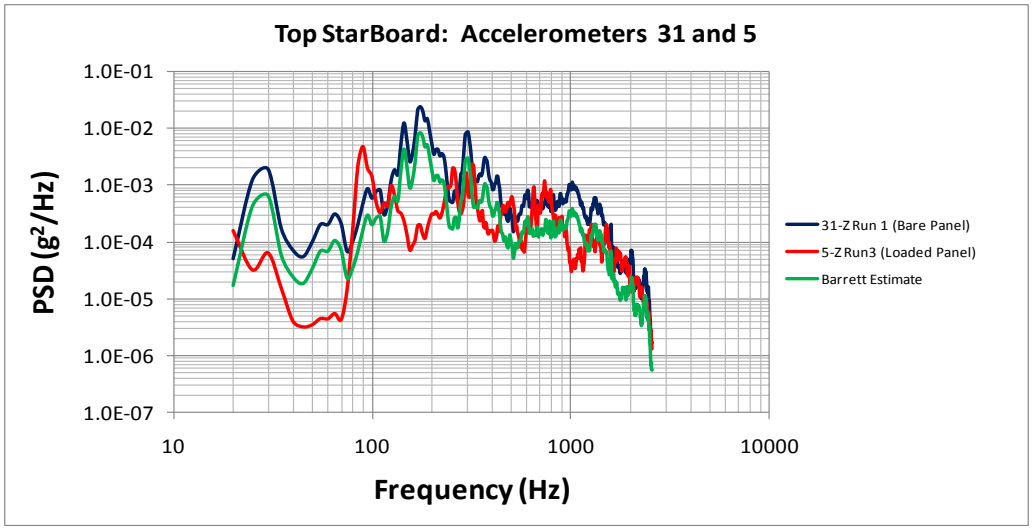
Overview

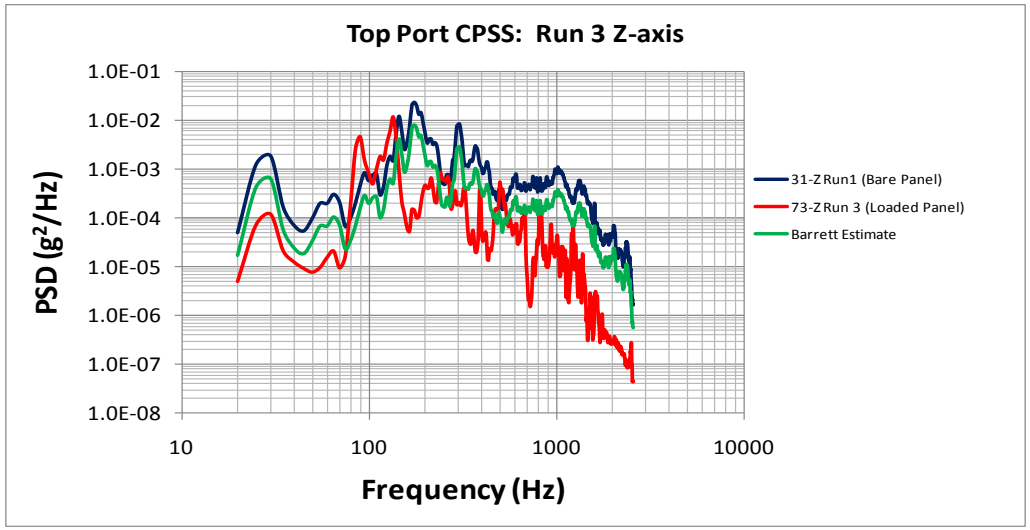
- Random vibrations at component/vehicle structure interfaces can be greatly attenuated by the mass of heavy components.
- Historically, knock down factors applied to the unloaded structure vibration predictions have been used to account for the attenuation due to the component masses.
  - *The most common approach has been the Barrett method*
- To improve mass loaded prediction methodologies acoustic experiments using panels and electronic boxes were performed
- In this presentation the results from this effort are discussed
  - *Recommendations on using different methods at the various flight hardware design stages are PROVIDED. In particular the following methods are discussed:*
  - *Modified Barrett,*
  - *Impedance, and*
  - *FEM/BEM*

MPESS Loaded and Unloaded Panels









Support Structure: 180 lbs

Components and Support Structures: 525 lbs

Special Thanks to MSFC

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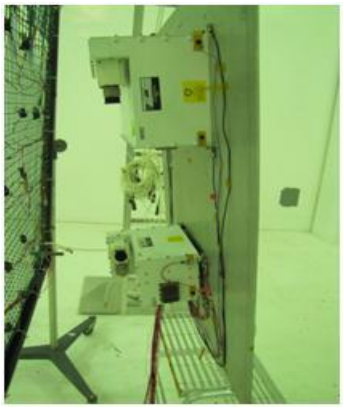
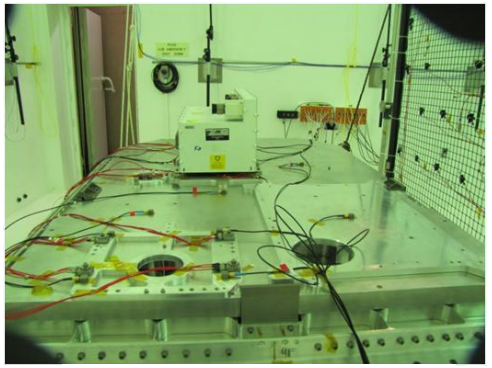
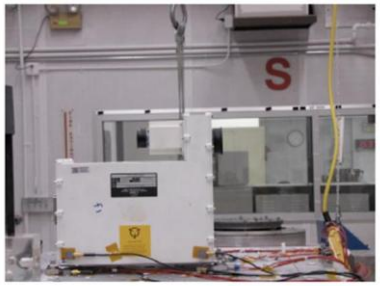
JPL Acoustic Test Configurations

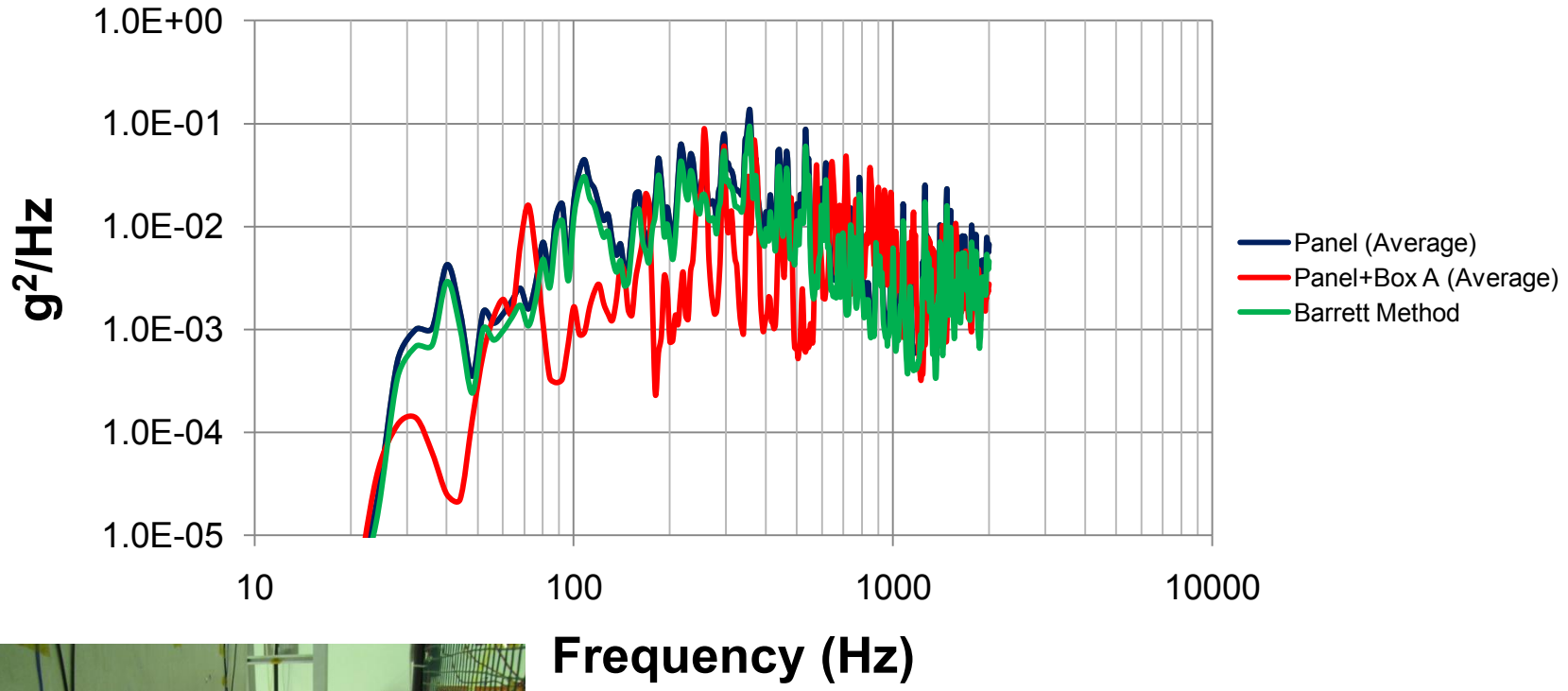
- A simple Aluminum Panel with flight-like electronic boxes
  - *Several different configurations tested*
  - *Panel suspended (free-free boundary condition)*
  - *Detailed measurements using sound pressure levels, acceleration and force responses were made*
  - *Tap tests with calibrated hammer and force gages used to measure detailed impedances at each component interfaces*
- MSL Rover Deck and Electronic Boxes (flight-like Structures)
  - *Several different configurations tested*
  - *Panel attached to a frame (fixed boundary condition)*
  - *Detailed measurements using sound pressure levels, acceleration and force responses were made*
  - *Tap tests with calibrated hammer and force gages used to measure detailed impedances at each component interfaces*
- Force-limited random vibration tests using two electronic boxes

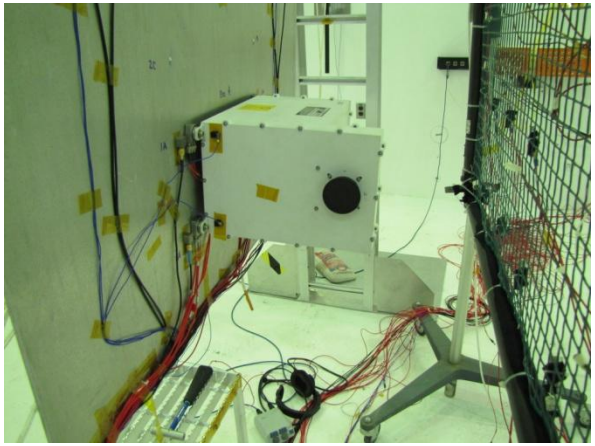






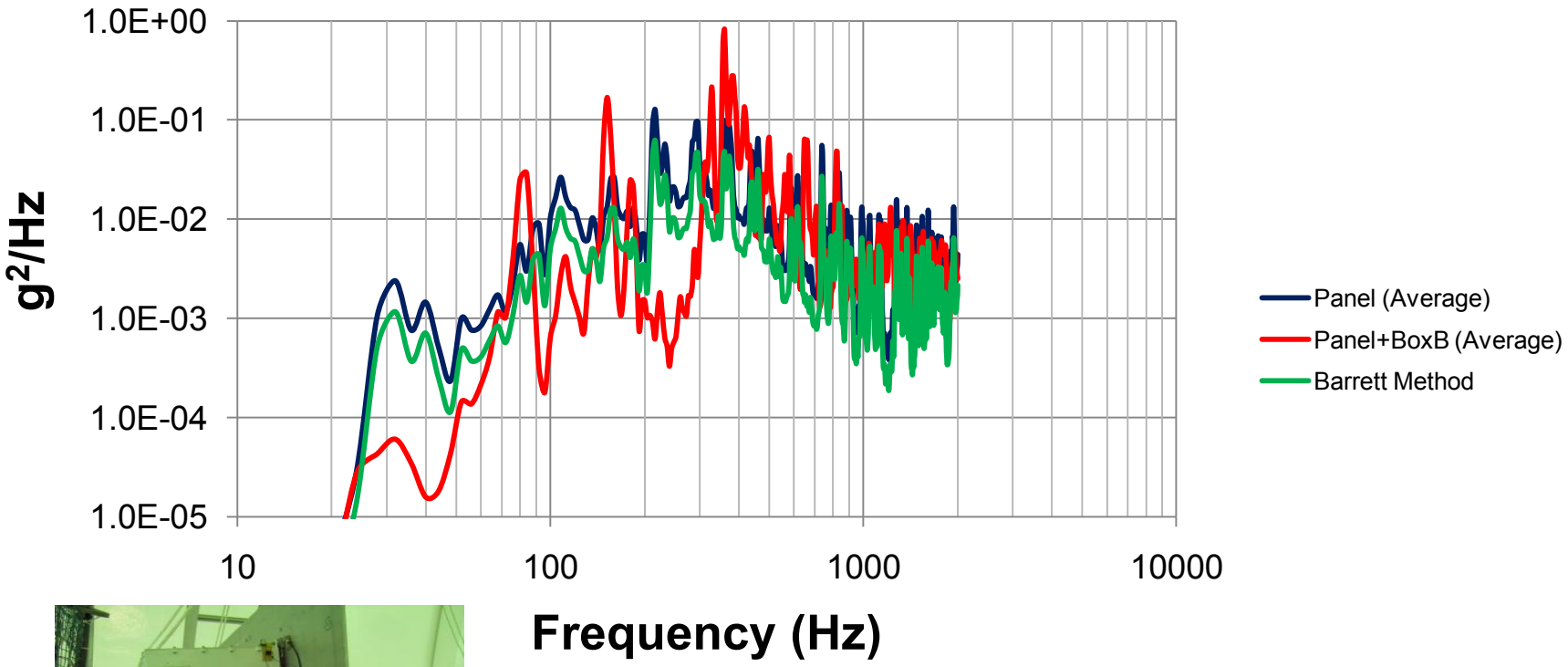
AL Panel +Box A IF Acceleration Responses (Acoustic Test)

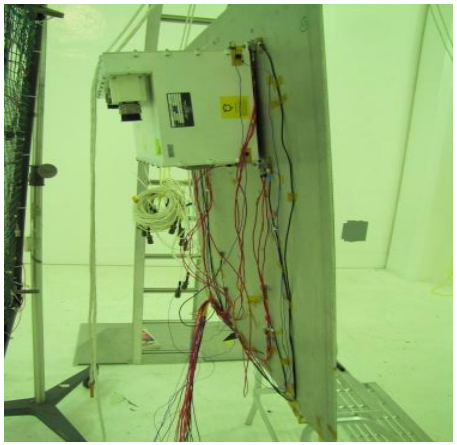




Support Structure: 42.6 lbs
Component and Support Structure: 60 lbs

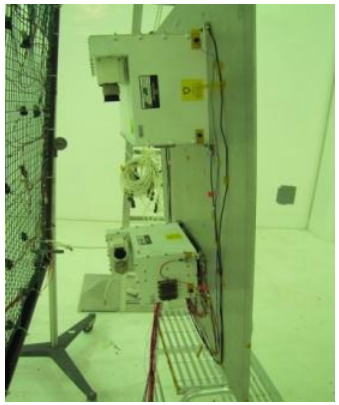
AL Panel +Box B IF Acceleration Responses (Acoustic Test)

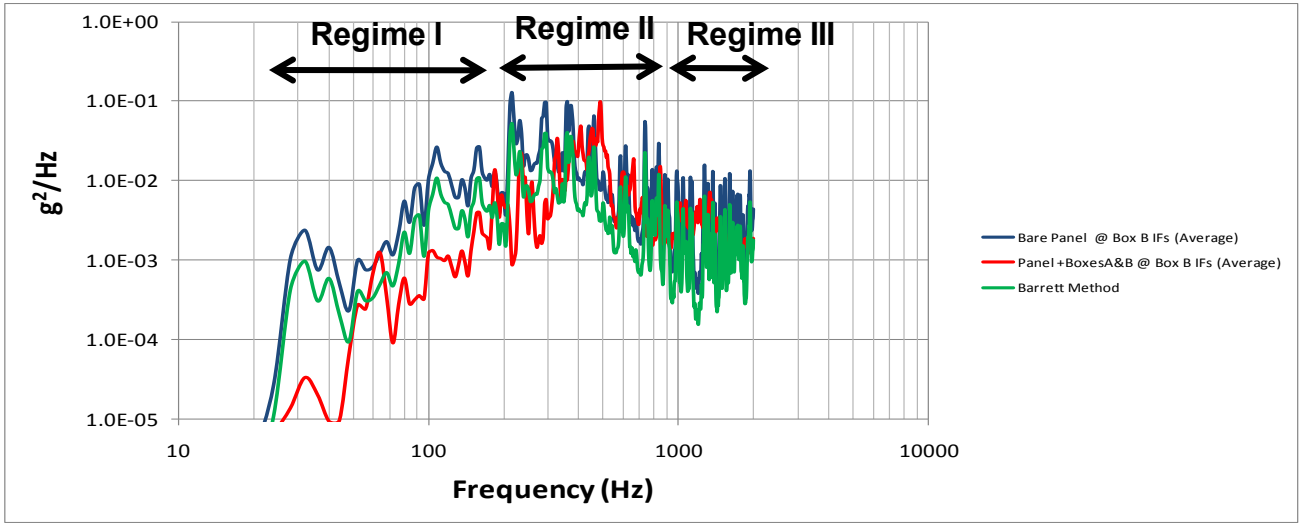


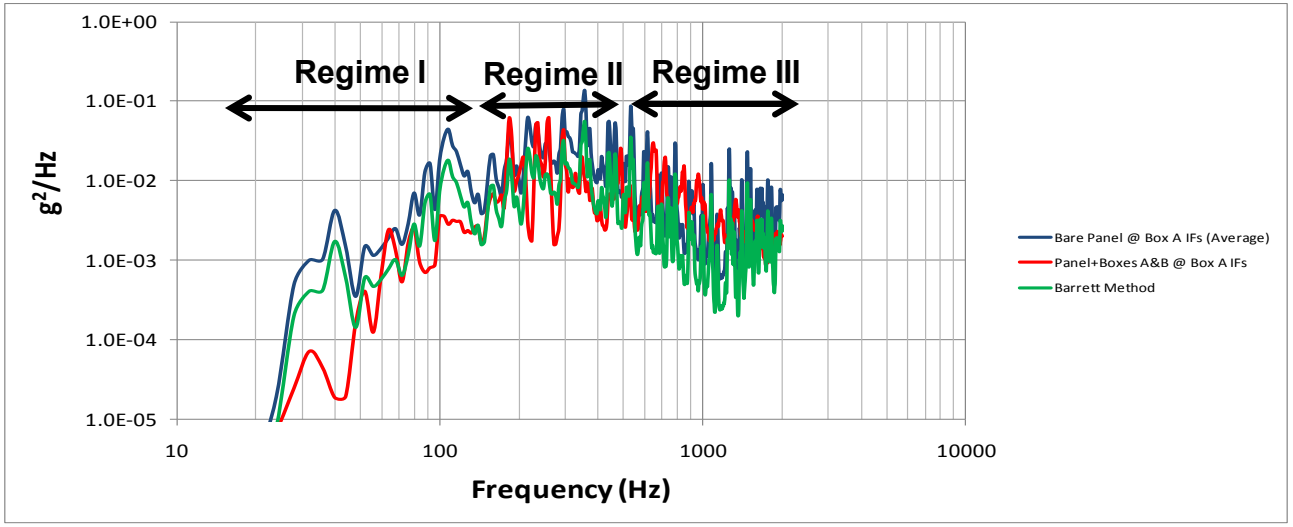


Support Structure: 42.6 lbs
Component and Support Structure: 87 lbs

AL Panel + Boxes A and B IF Acceleration Responses (Acoustic Test)

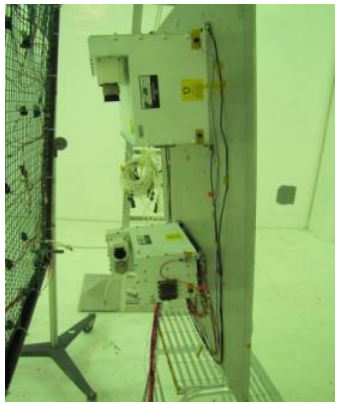


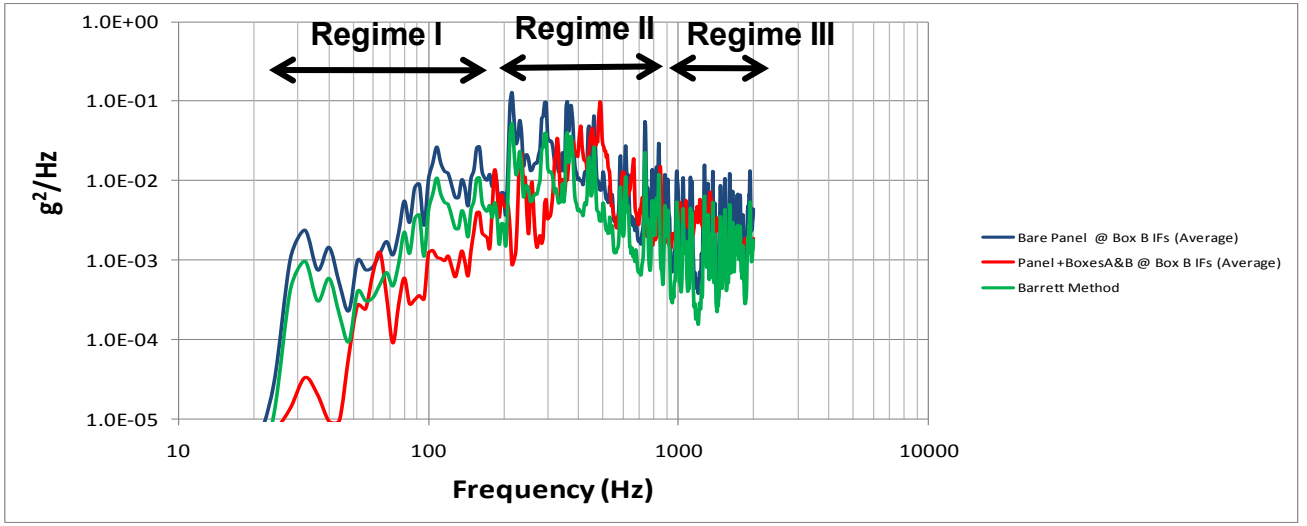


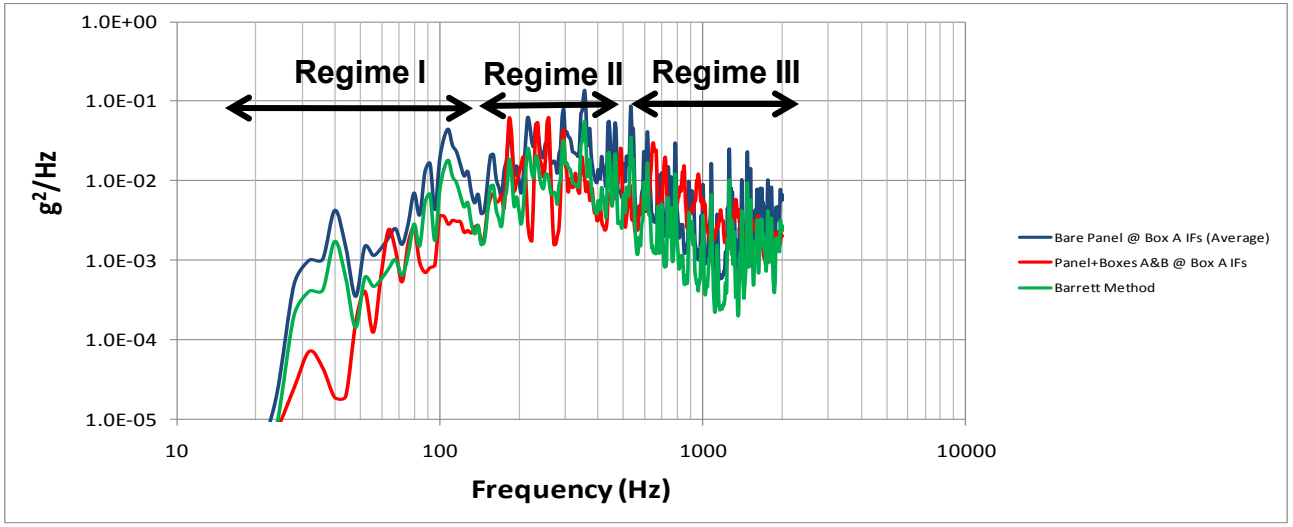


- **Significant Attenuation below a few tens of Hz (regime I)**
- **Attenuation and amplification in mid-frequency (regime II),**
- **No Changes at higher frequencies (regime III).**

AL Panel + Boxes A and B IF Acceleration Responses (Acoustic Test)

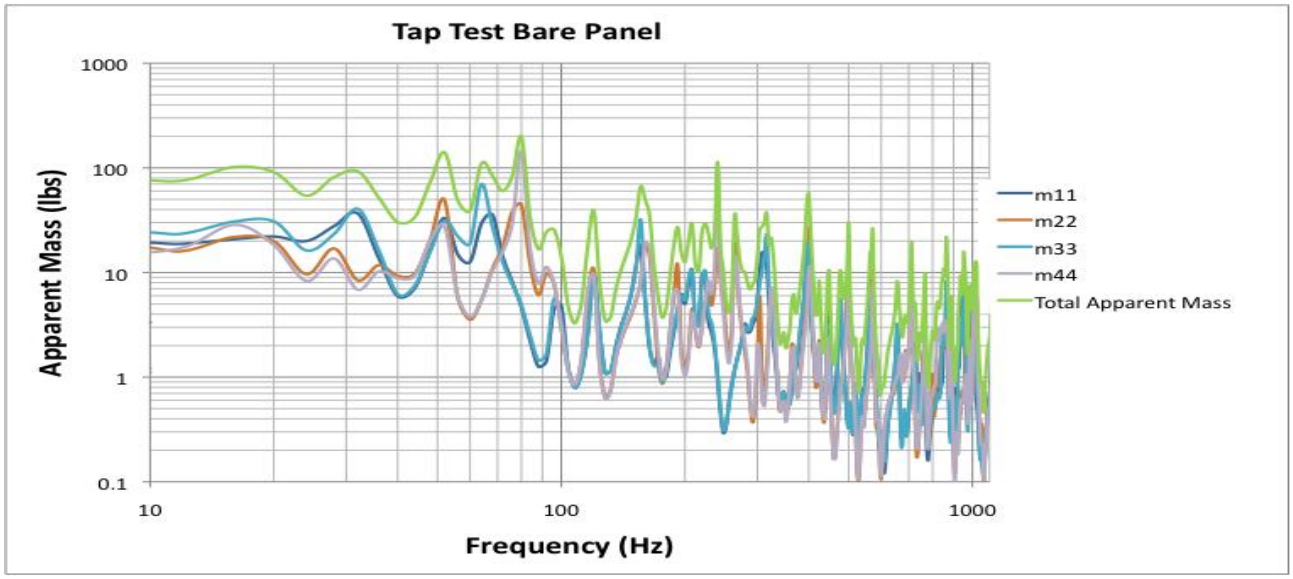


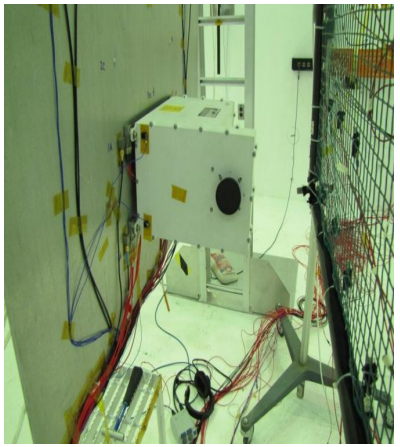


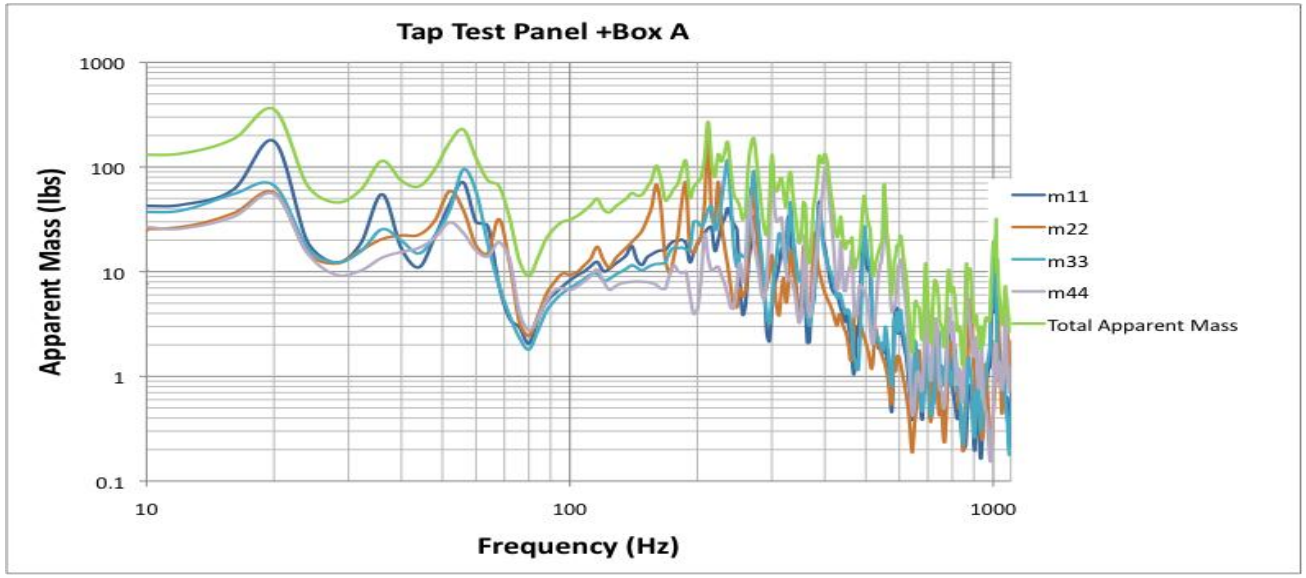


- **Significant Attenuation below a few tens of Hz (regime I)**
- **Attenuation and amplification in mid-frequency (regime II),**
- **No Changes at higher frequencies (regime III).**

Measured Apparent Mass of Al Panel (42.6 lb) with Box A (17.4 lb) (Tap Test)

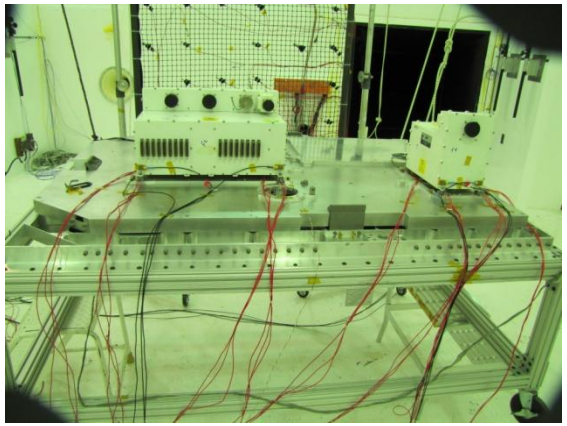


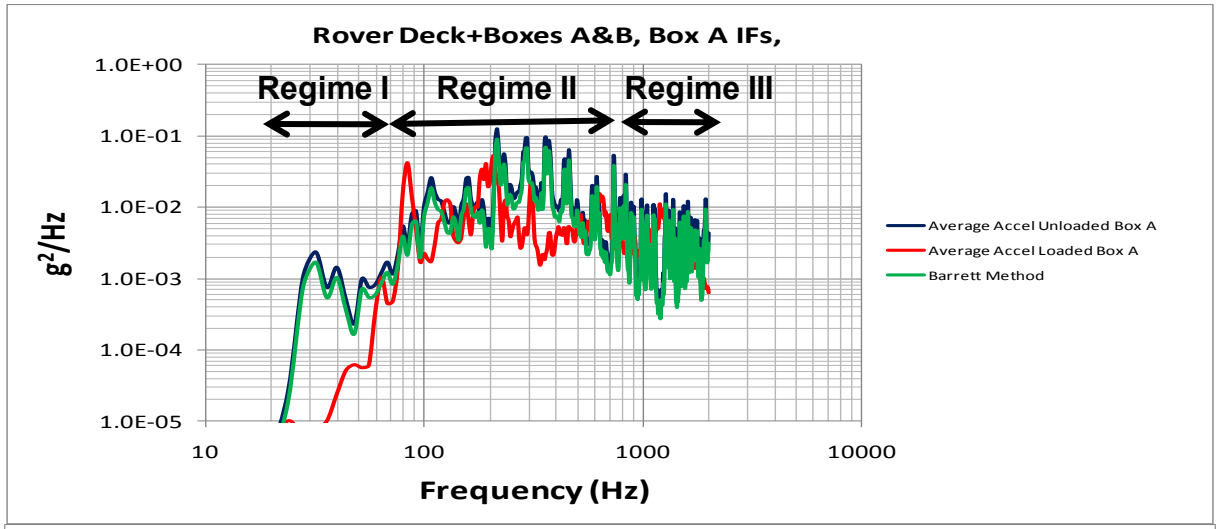


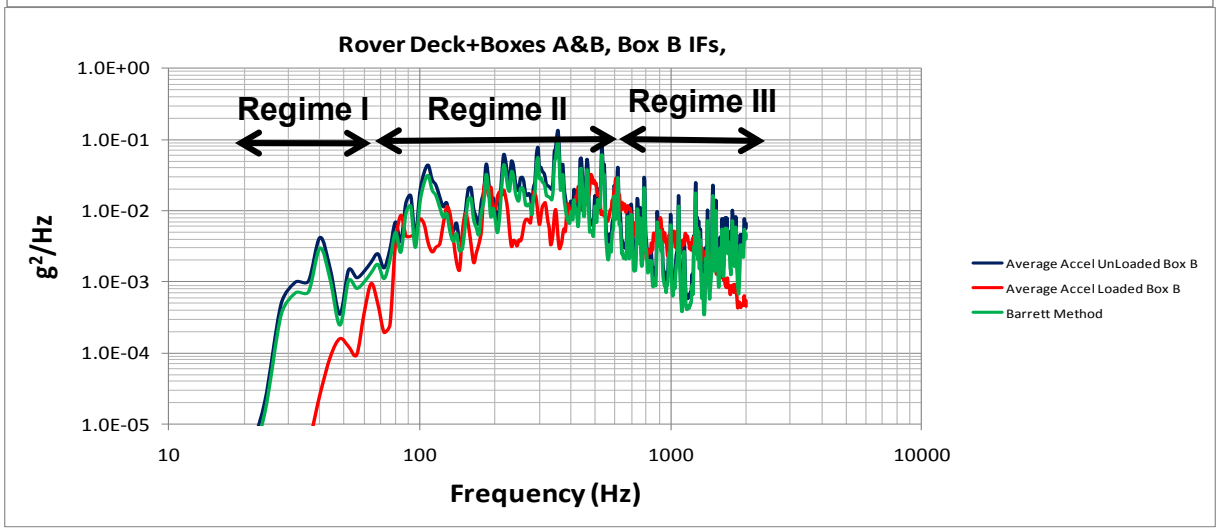


The apparent masses defined as the acceleration at point i when a force is applied at point j, and the forces at the other interface points are zero.

Rover Deck +Boxes A+B IF Acceleration Responses (Acoustic Test)





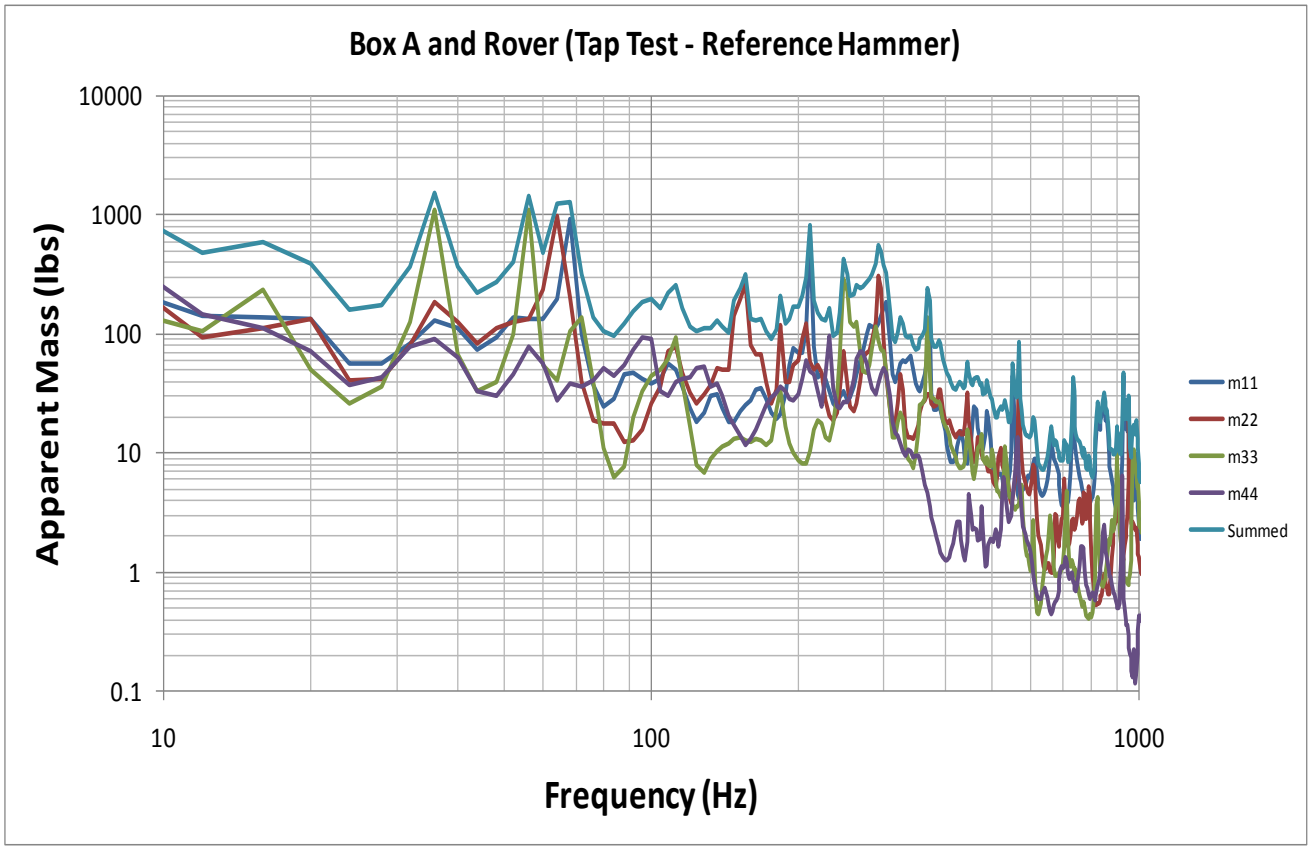


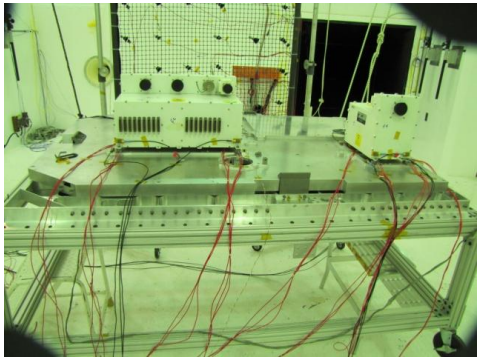
- **Significant Attenuation below a few tens of Hz (regime I)**
- **Attenuation and amplification in mid-frequency (regime II),**
- **No Changes at higher frequencies (regime III)**

Support Structure: ~156 lbs

Components and Support Structures: 219 lbs

Measured Apparent Mass of Rover Deck (156 lb) with Boxes A&B (62.3 lb), Box A IFs (Tap Test)

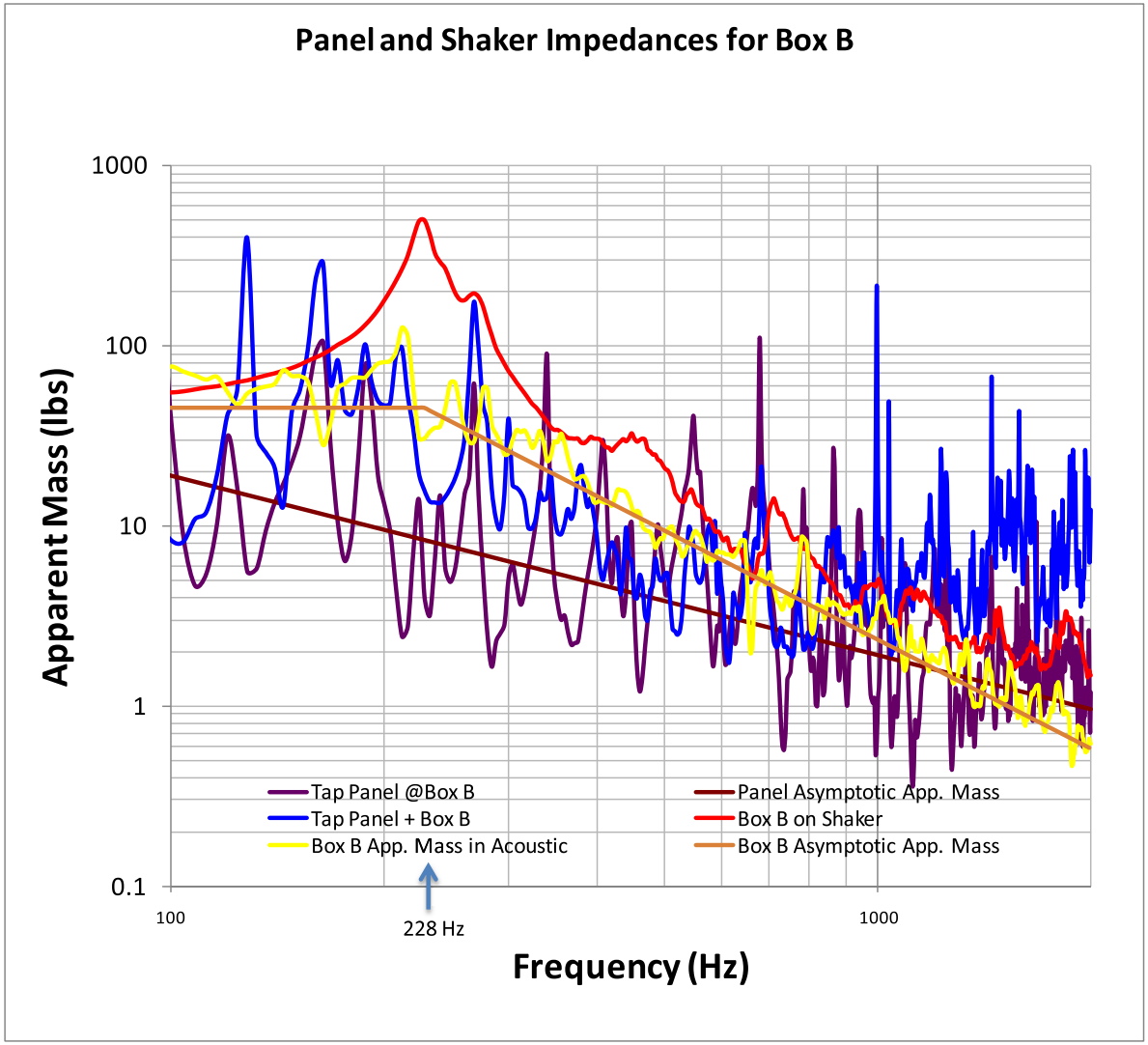




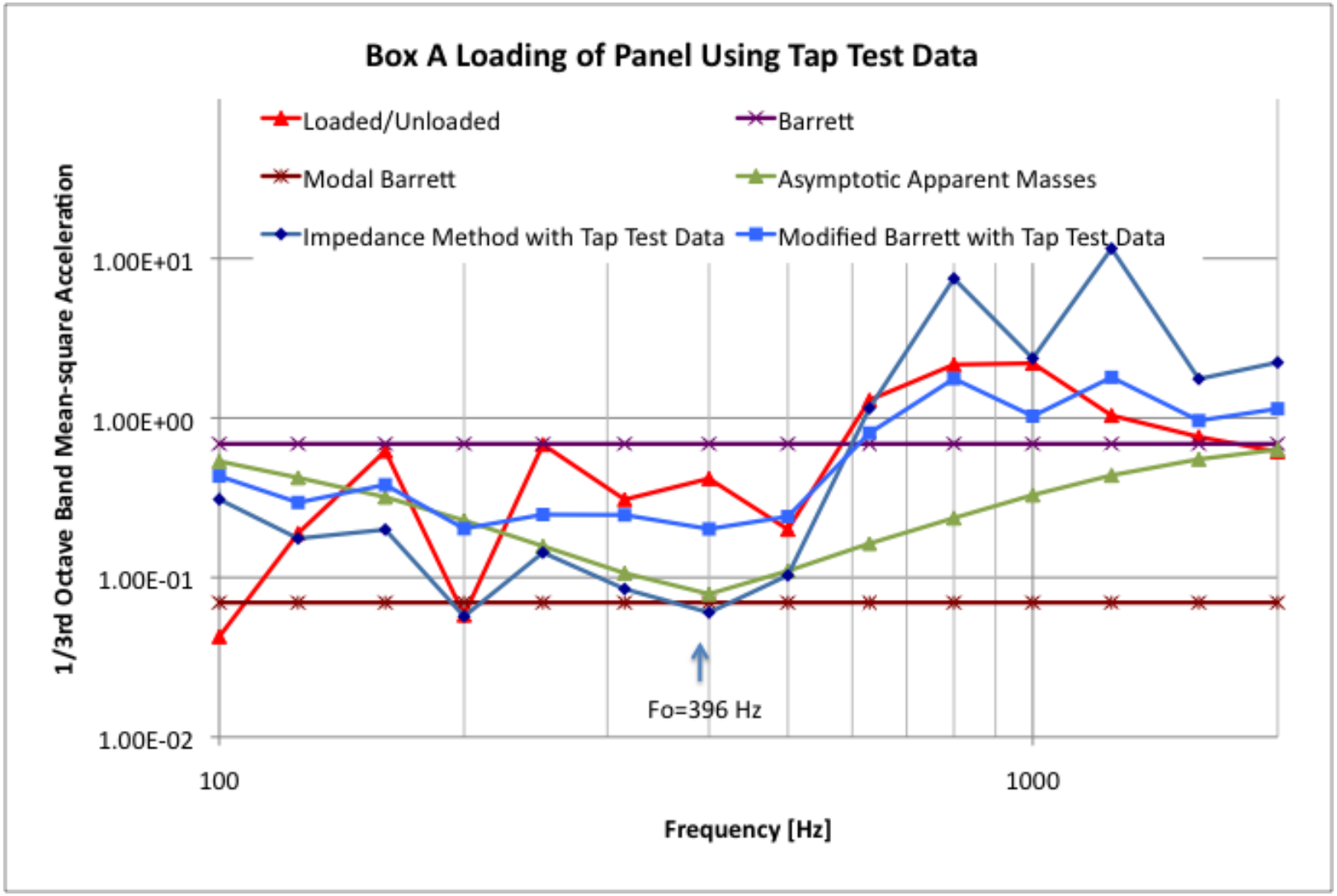
The apparent masses defined as the force at point i when an acceleration is applied at point j, and the accelerations at the other interface points are zero.

Panel Apparent Masses
AL Panel+ Box B

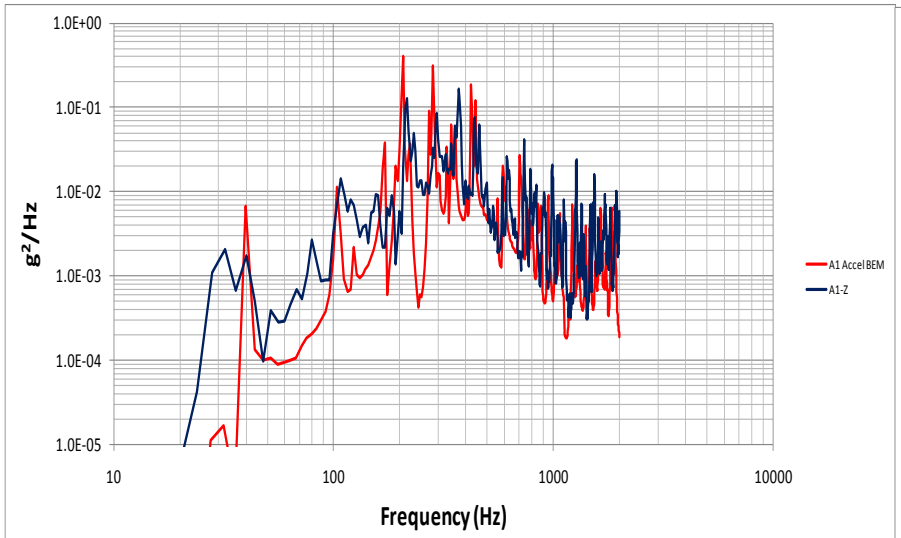
- Apparent Masses obtained using:
  - *Tap test of the bare panel*
  - *Tap test of the loaded panel*
  - *Acoustic test of loaded panel*
  - *Shaker test,*
- Sum of the diagonal apparent masses are shown,
- Panel asymptotic apparent mass is calculated (using backbone or critically damped value of the apparent mass)
  - *$M = 8\rho c \kappa cl/2\pi f$ (Multiplied by 4 to account for four lfs)*

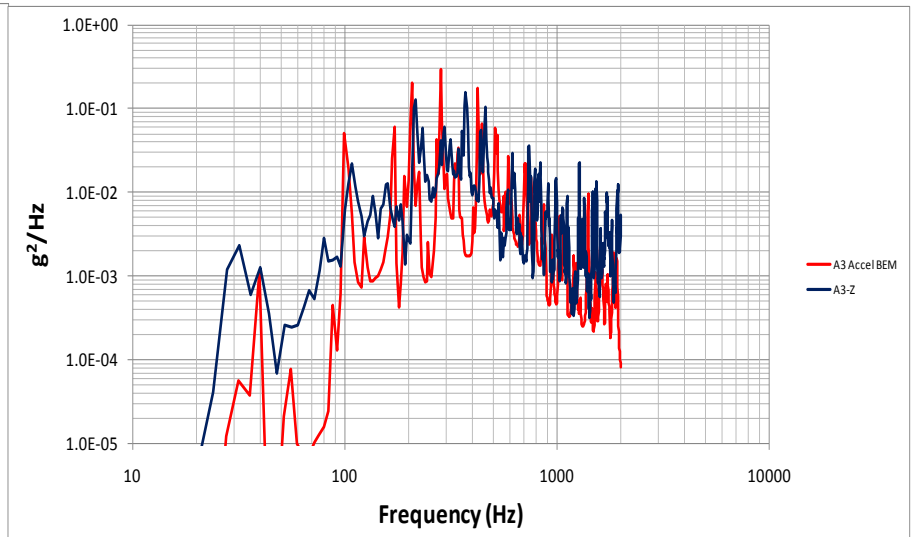


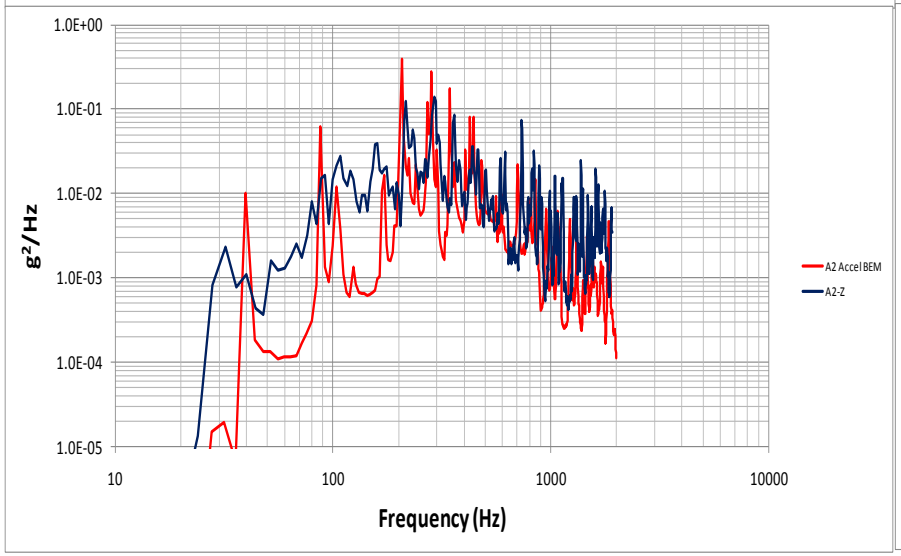
Impedance and Modified Barrett Methods

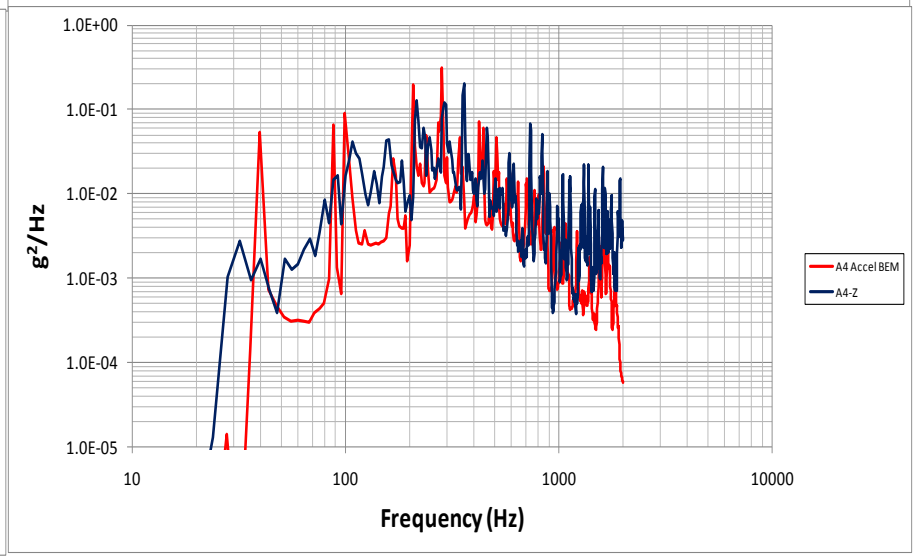


FEM/BEM: Acceleration Responses of Bare AL Panel @ Box B IFs (Correlated w/ measured data)

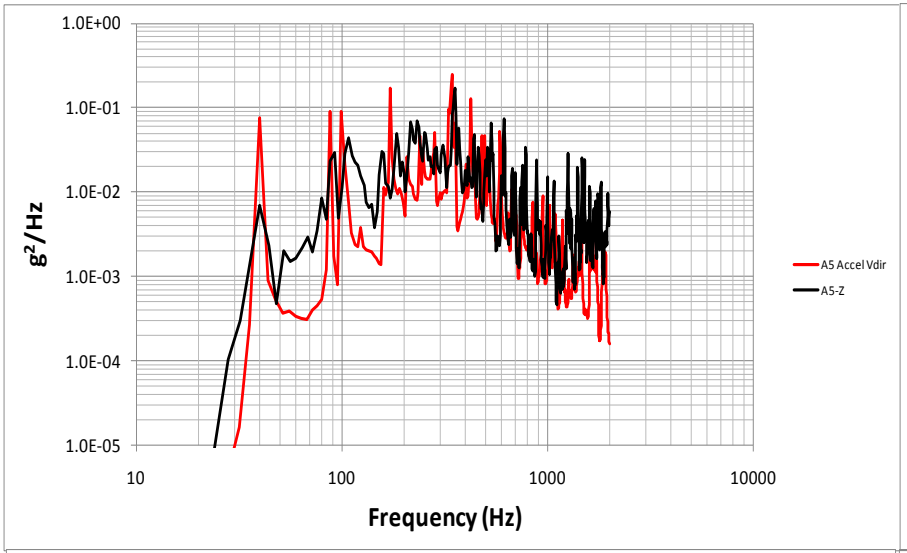


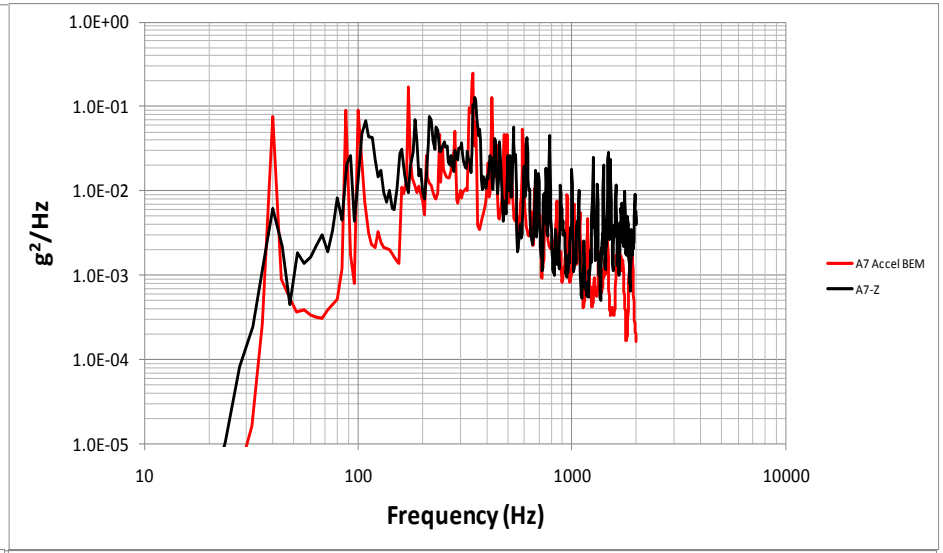


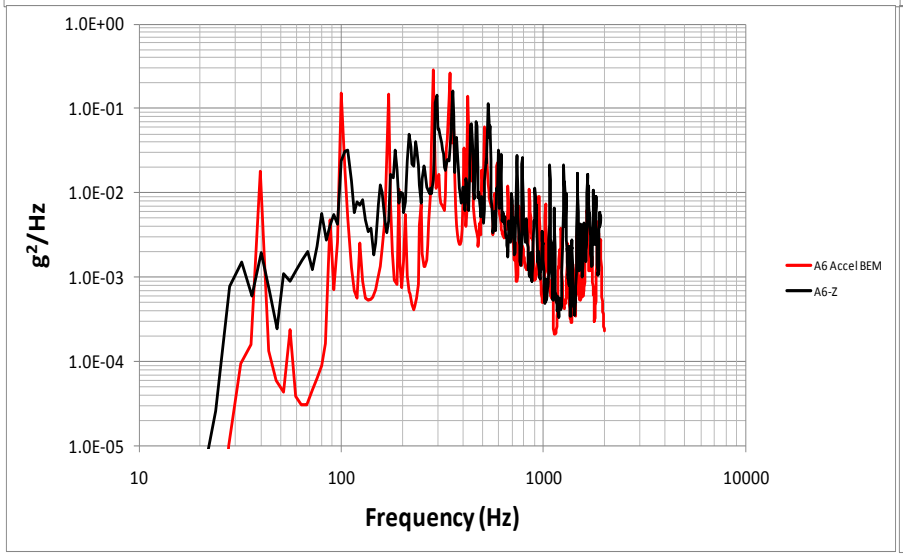


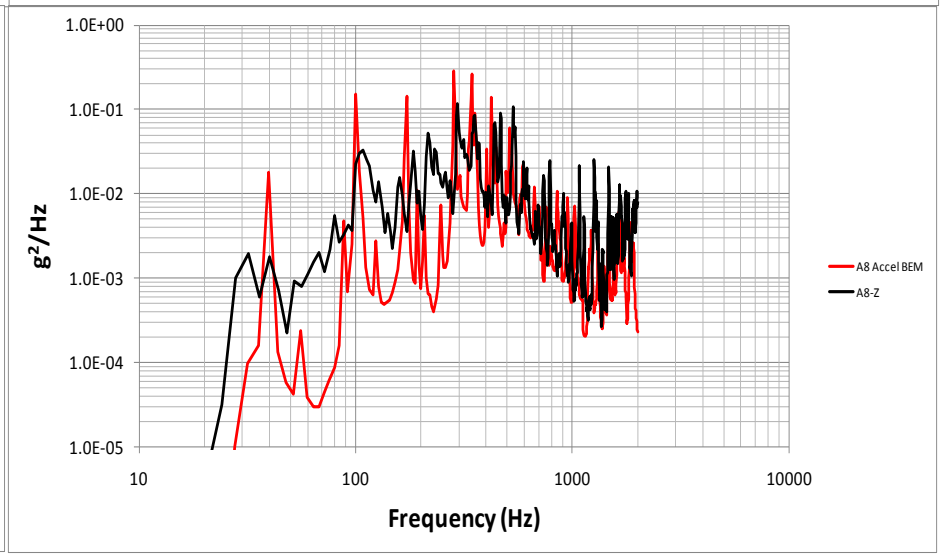


FEM/BEM: Acceleration Responses of Al Panel+Box A @ Box A IFs (Correlated w/ measured data)









Summary

- The classical Barrett method with a knock down factor used to derive component RV environments not adequate
- *For low-density equipment mass loaded panels three regions are identified: Region I with significant attenuation, Region II with amplification and attenuation, and region III with minimal changes*
- Based on the high-fidelity acoustic tests performed using a few loaded panel configurations, the following approaches are recommended for "Component Mass Attenuated" random vibration predictions:
  - *Modified Barrett methods (at early stages of project where the details of the source structure and equipment not available)*
  - *Asymptotic approach (at early stages of project where the details of the source structure and equipment not available)*
  - *Impedance approach (knowledge of the transfer functions of the loaded and unloaded structures become available)*
  - *Boundary element method approach (when FEM models become available)*
    - A crude model may suffice; should be modified when a high-fidelity models emerge, or
    - Use a few exiting FEMs that are representative of the new loaded structure at the early stages of projects, estimate acceleration responses at the equipment interfaces using BEM and statistically derive RV environments
      - *update when a high-fidelity model becomes available*

Thank you

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