

Acoustic Investigation / Rail Roughness and Noise, Sound Transit Central Link

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Definitions

- **Potential noise sources**

- Rolling noise
- Squeal from slip-stick interaction on rail head, flange/gauge face contact, restraining rail or guard rail contact
- Impacts at frogs, joints, bad welds, wheel flats

- **Roughness**

- Random roughness plus periodic roughness (corrugation)
- Rolling noise is proportional to sum of wheel and rail roughness

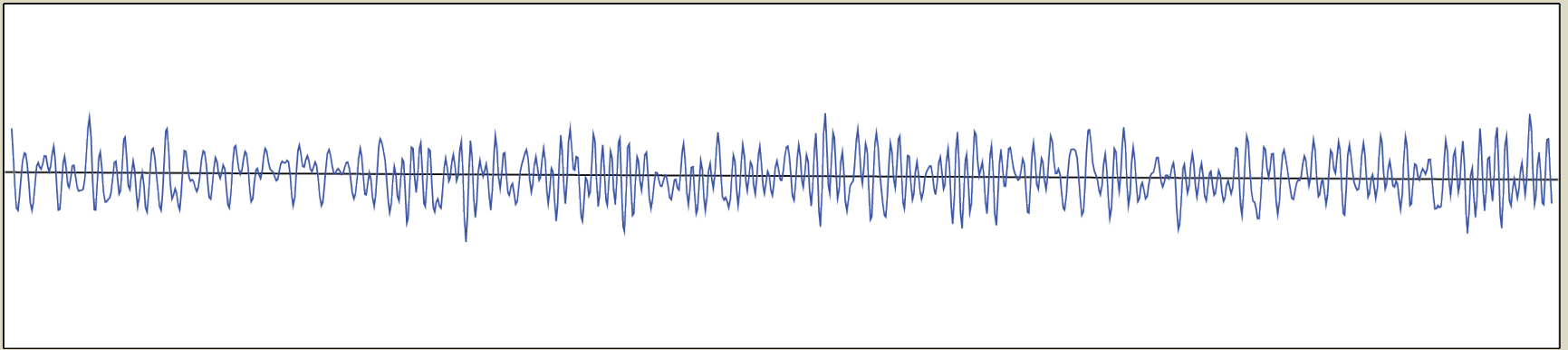
- **Noise (A-weighted sound level, dBA)**

- Frequency weighted to approximate human hearing

"Roughness"

Any longitudinal irregularity in rail surface:

Random Roughness

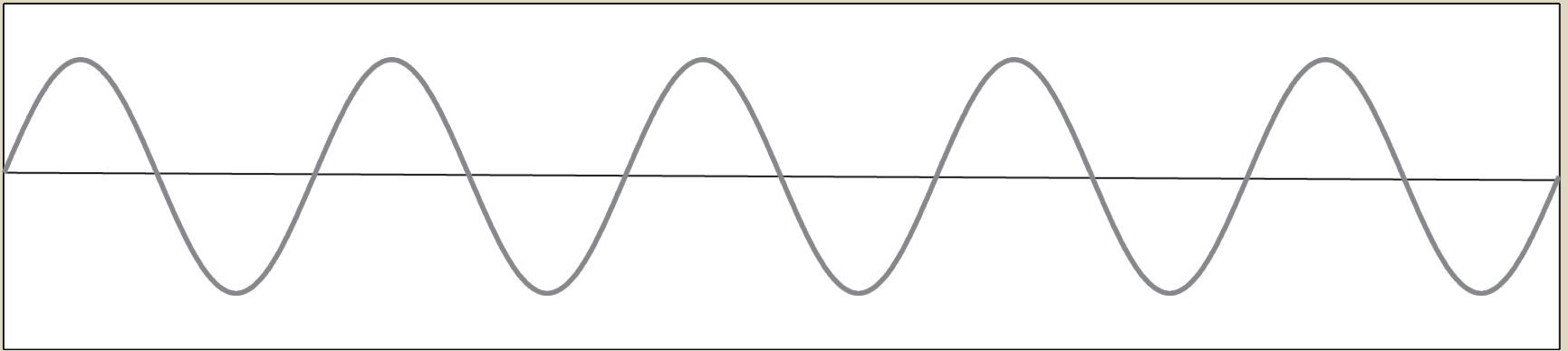


$$\begin{aligned} f &= \frac{\text{speed}}{\text{wavelength}} \\ &= 447 \times \frac{\text{speed}(\text{mph})}{\text{wavelength}(\text{mm})} \\ &= 18.8 \times \frac{\text{speed}(\text{mph})}{\text{wavelength}(\text{in.})} \end{aligned}$$

"Roughness"

Any longitudinal irregularity in rail surface:

Corrugation



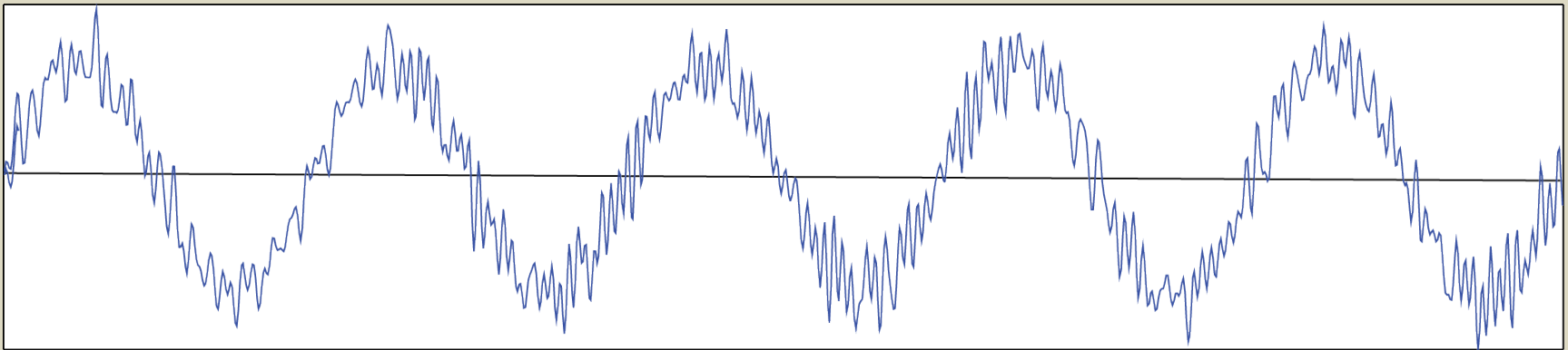
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"Roughness"

Any longitudinal irregularity in rail surface:

Combined Roughness

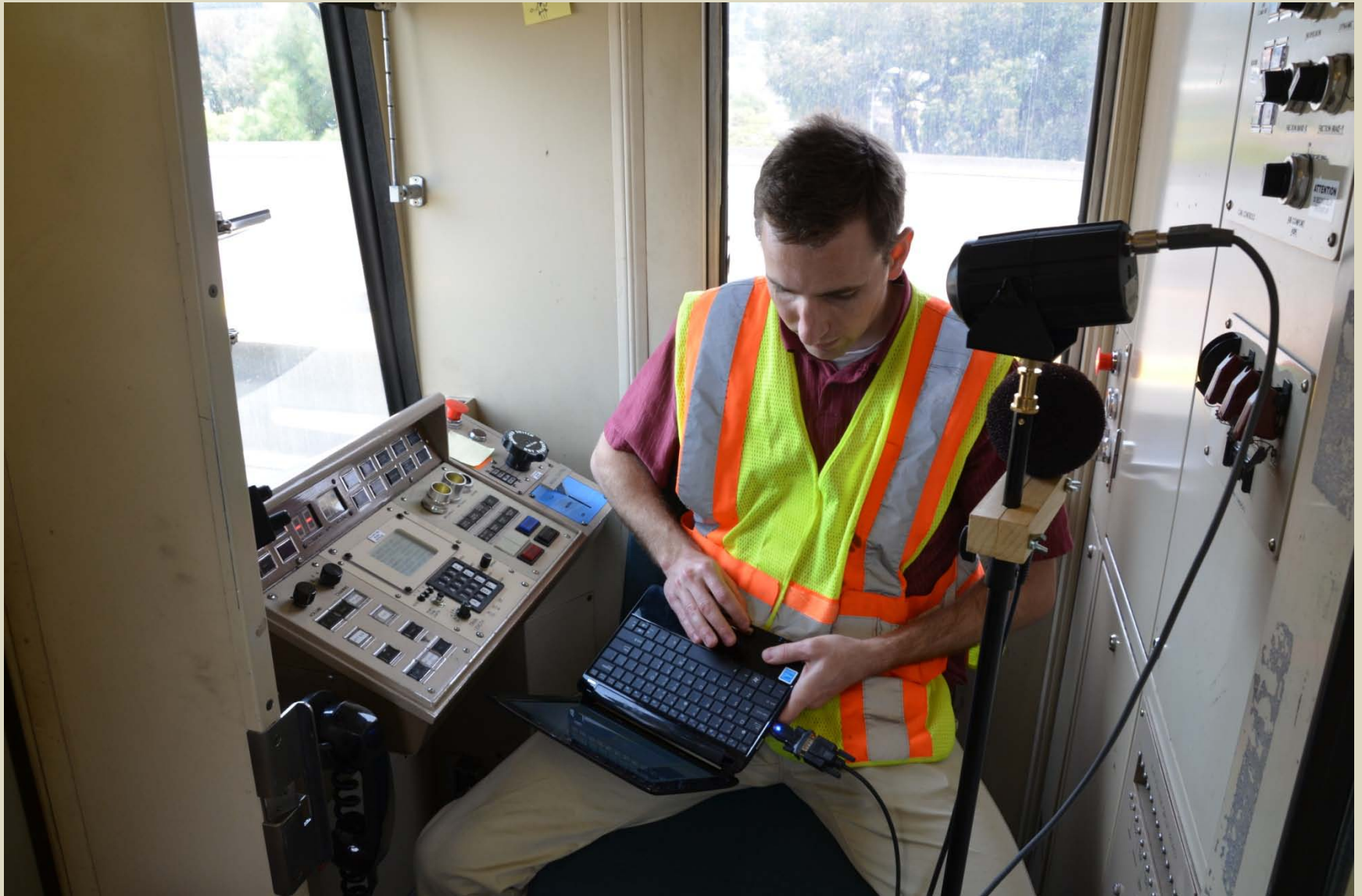


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Sound Transit Acoustic Test Program

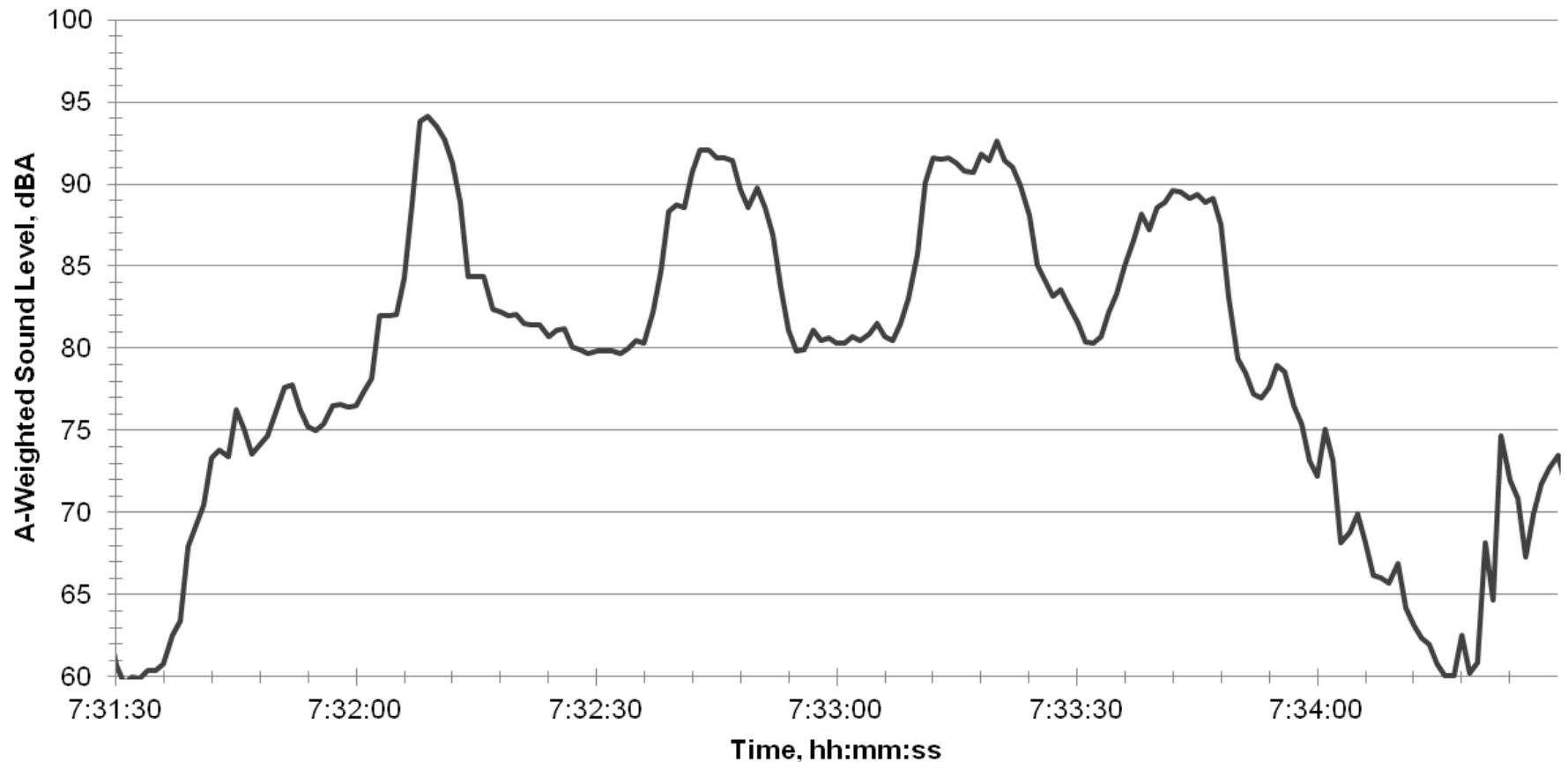
- On-board noise levels to identify problem areas
- Selected five sites for detailed measurements
 - Selected based on complaint history and results of on-board measurements
 - Two on embedded track in the middle of MLK Jr. Blvd.
 - Three on Tukwila aerial structure
- Measurements at test sites
 - Noise at 1m from near rail, 2.4m from far rail
 - Rail roughness
 - Rail vibration decay rate

Onboard Noise Measurement

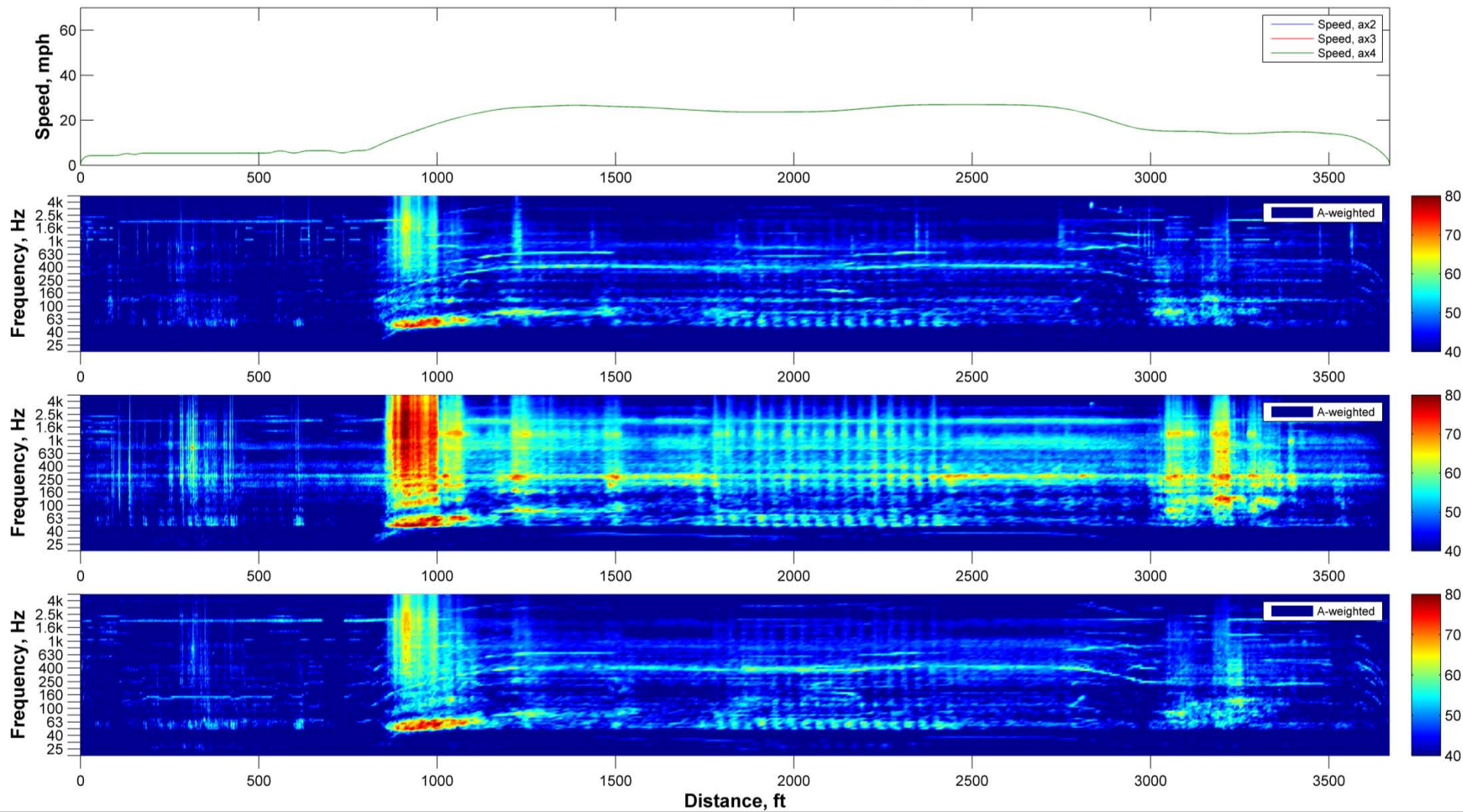


In-Car Noise Measurement, 2003

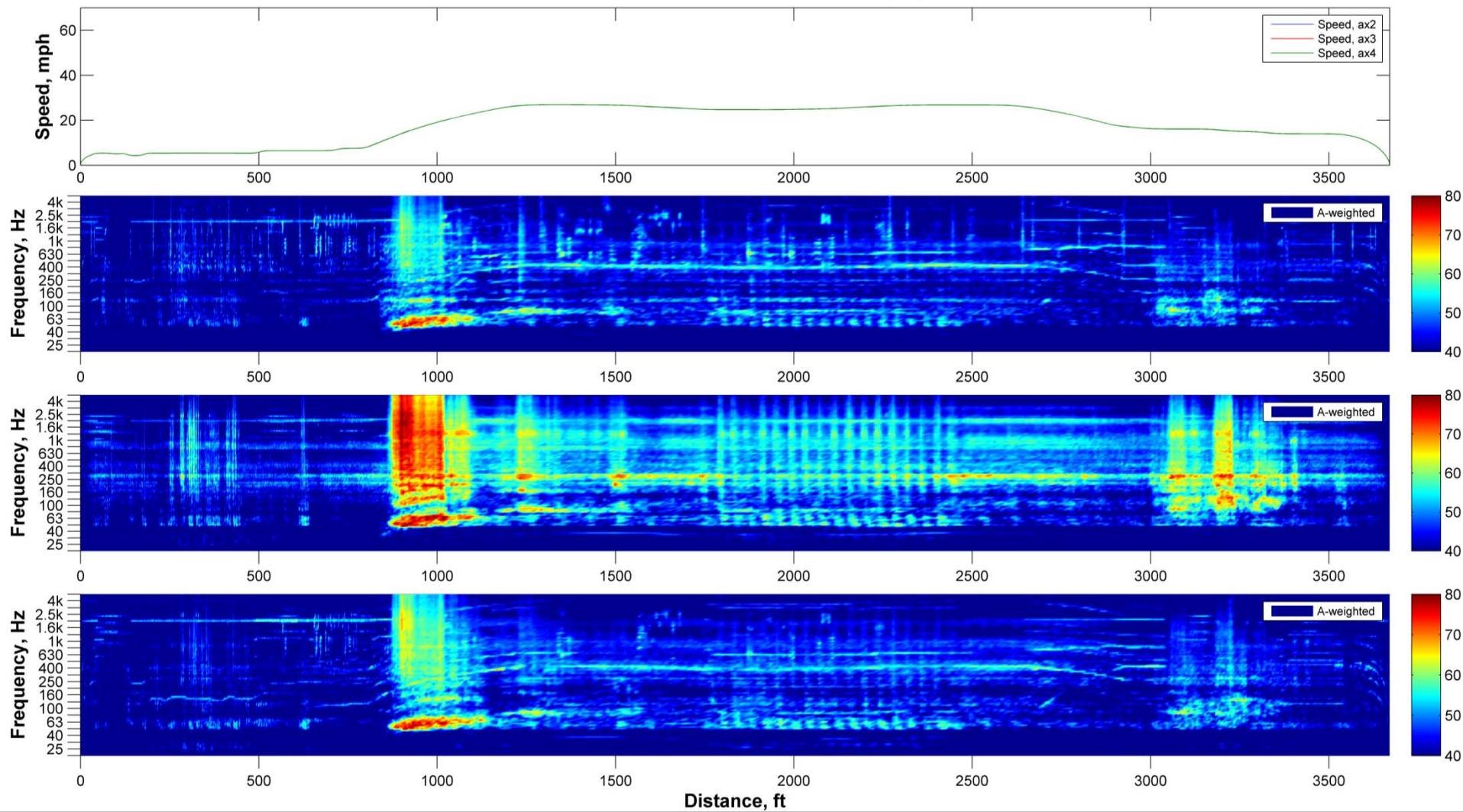
In-Car Noise, San Bruno to South San Francisco



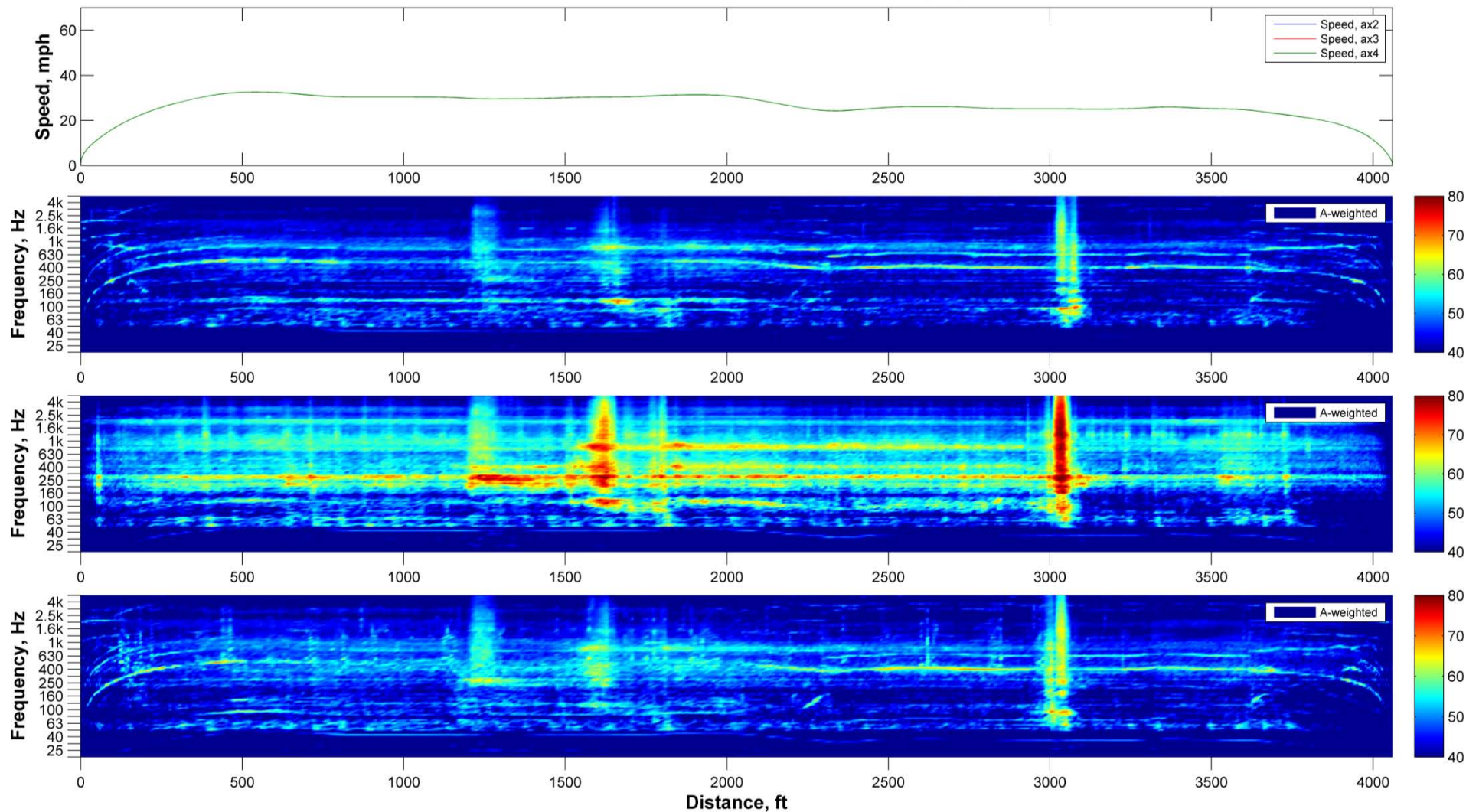
Example On-Board Spectrogram (1)



Example On-Board Spectrogram (2)



Example On-Board Spectrogram (3)

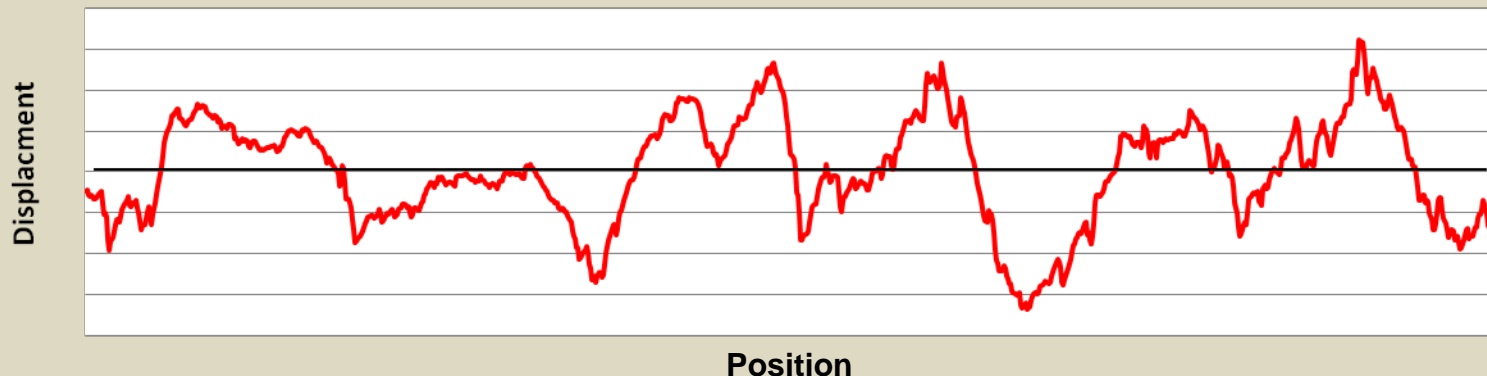


Noise Measurements 1m from Rail



Rail Roughness Measurements

Measure vertical displacement in rail over a small track section (typically 100 to 300m)



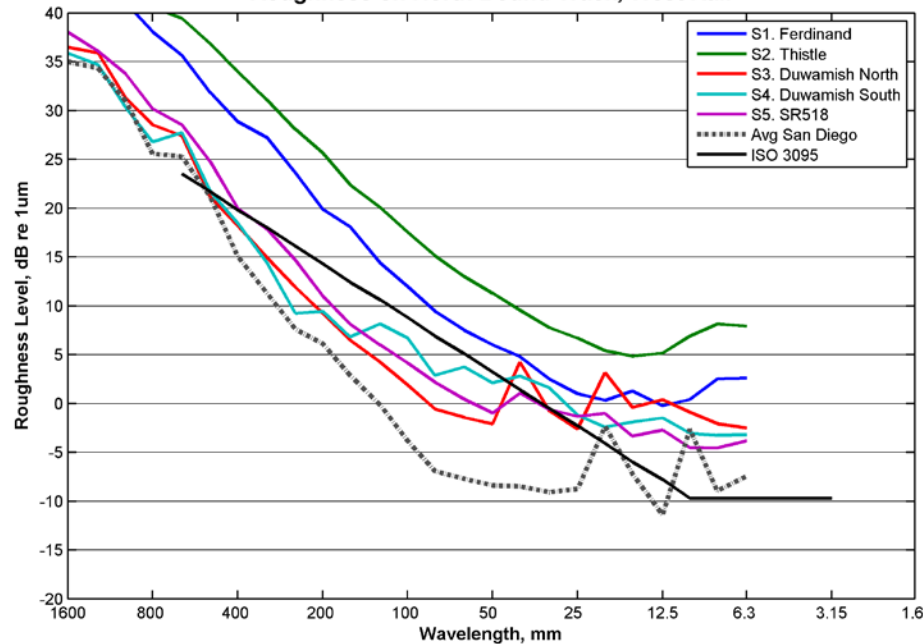
Vibration Decay Rate Measurement



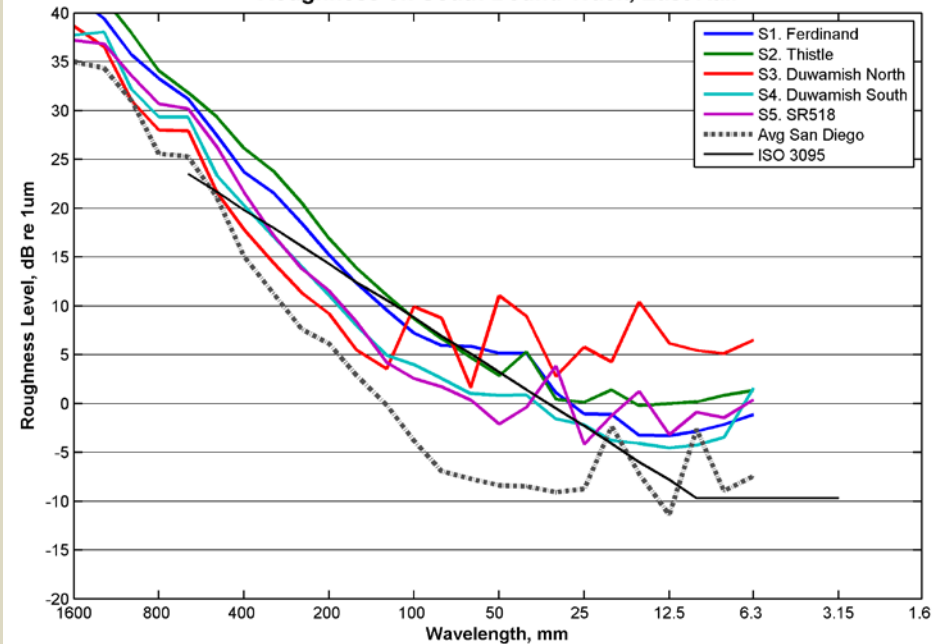
Rail Roughness Results

Average Roughness, 1/3 Octave Band Spectra

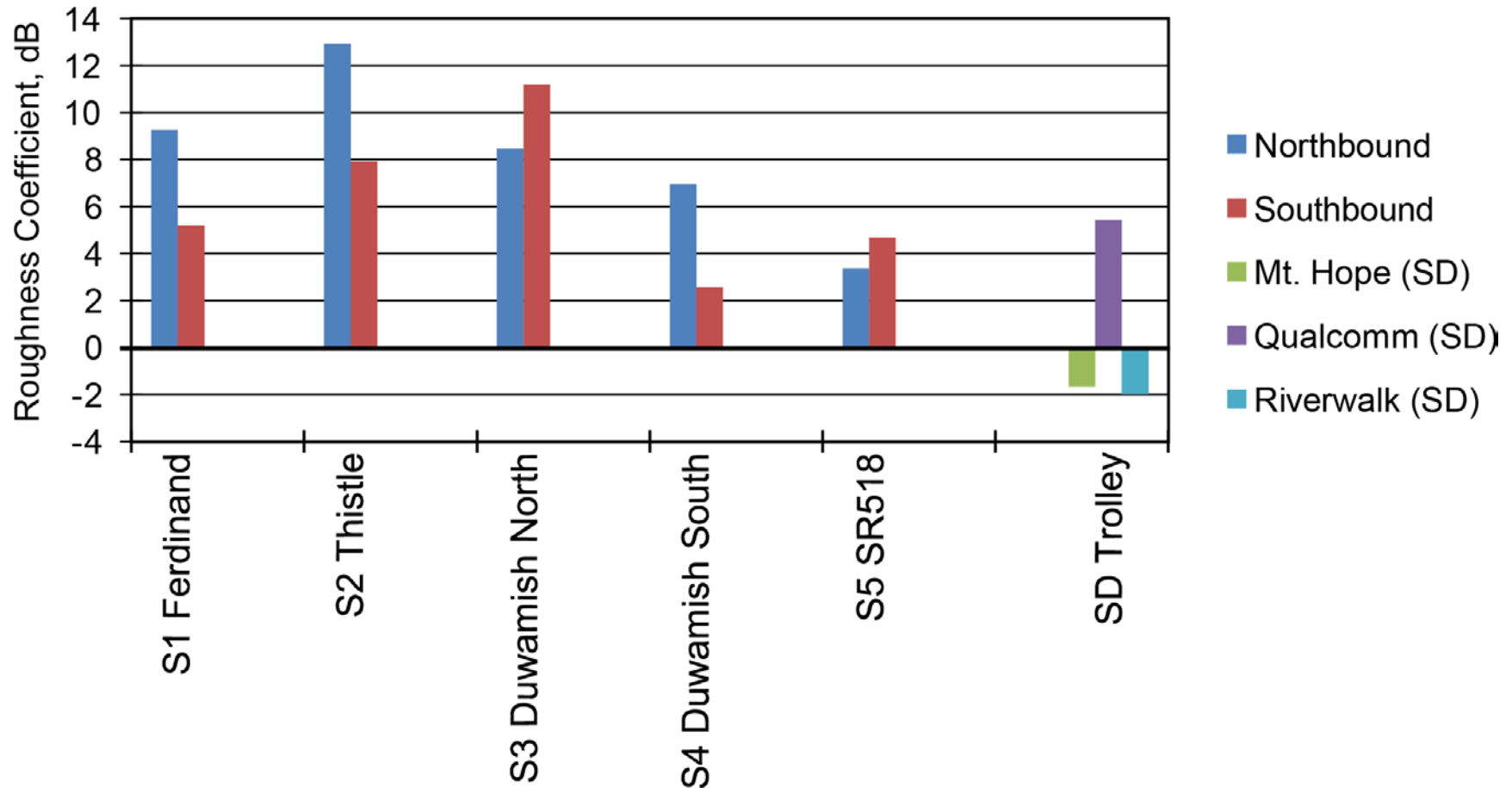
Roughness on North Bound Track, West Rail



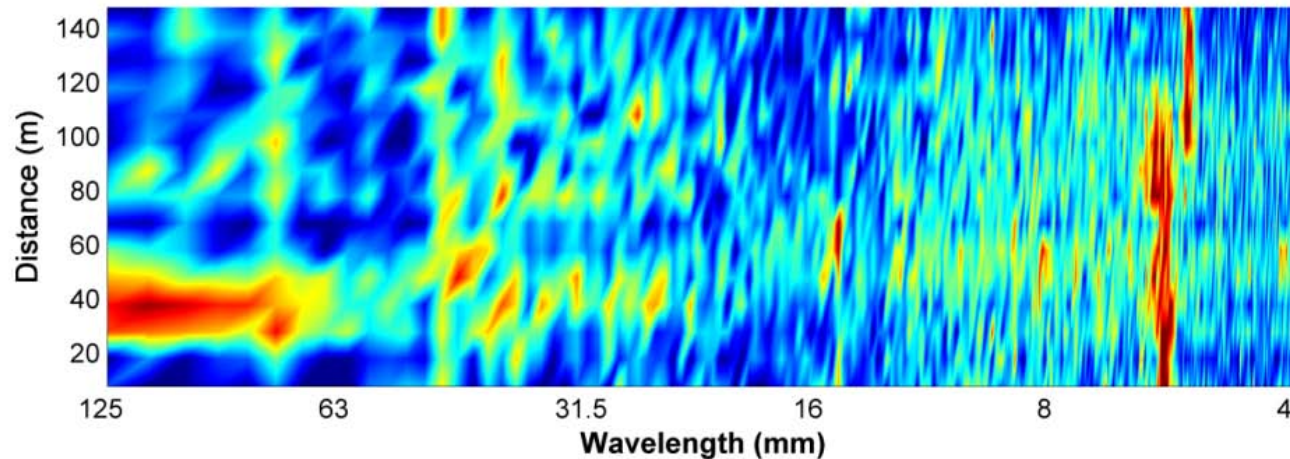
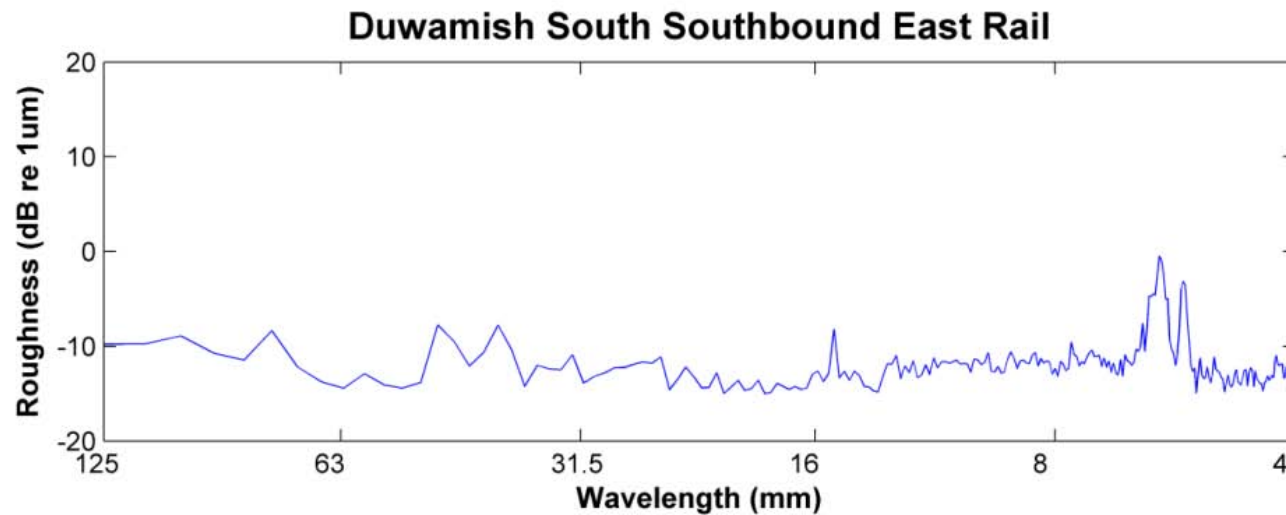
Roughness on South Bound Track, East Rail



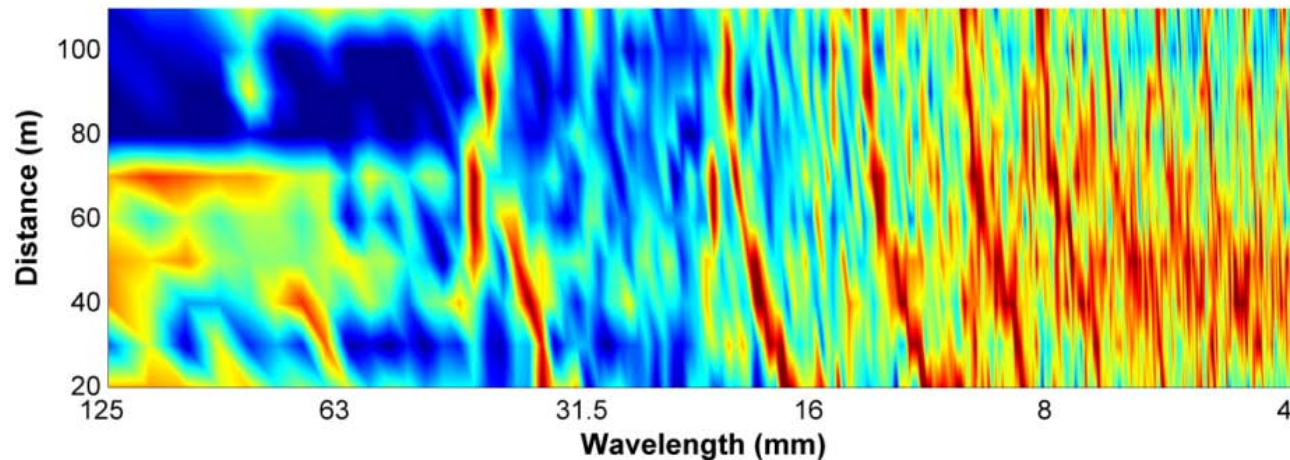
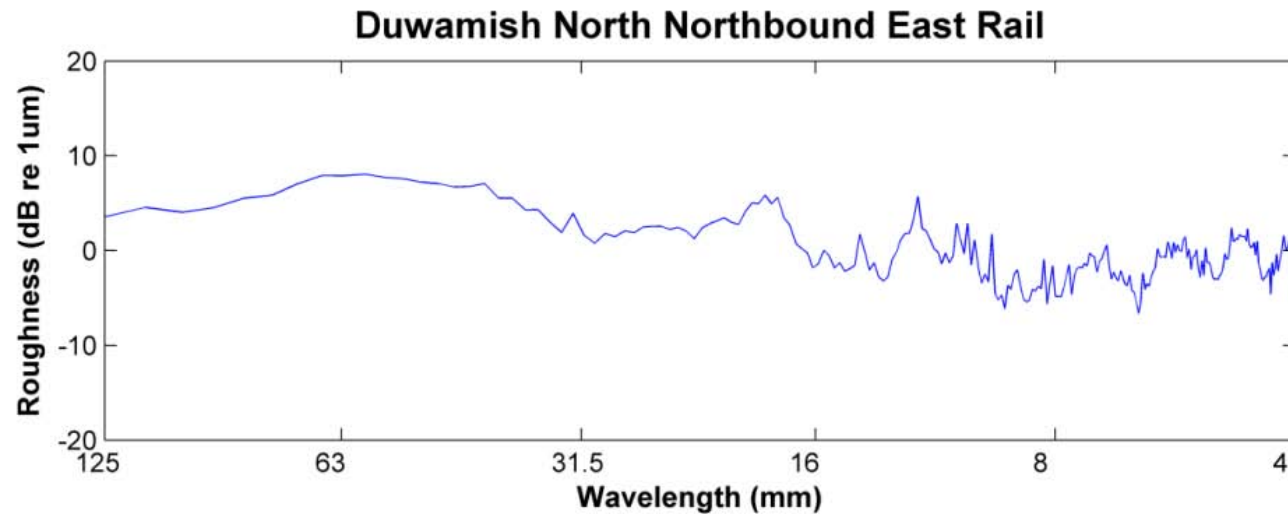
Derived Roughness "Coefficient"



Roughness Spectrogram, Site 4

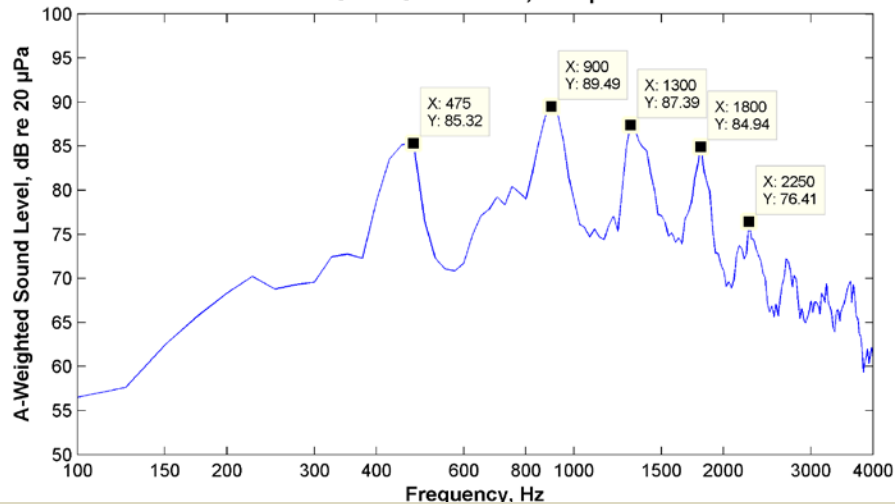


Roughness Spectrogram, Site 3

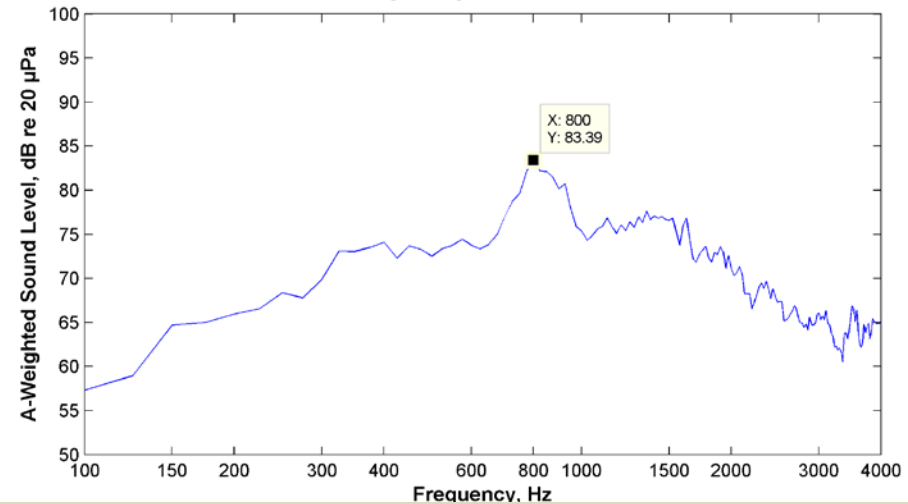


Typical Noise Spectra, Site 3 and Site 4

Site 3 SB Event 48, 38 mph

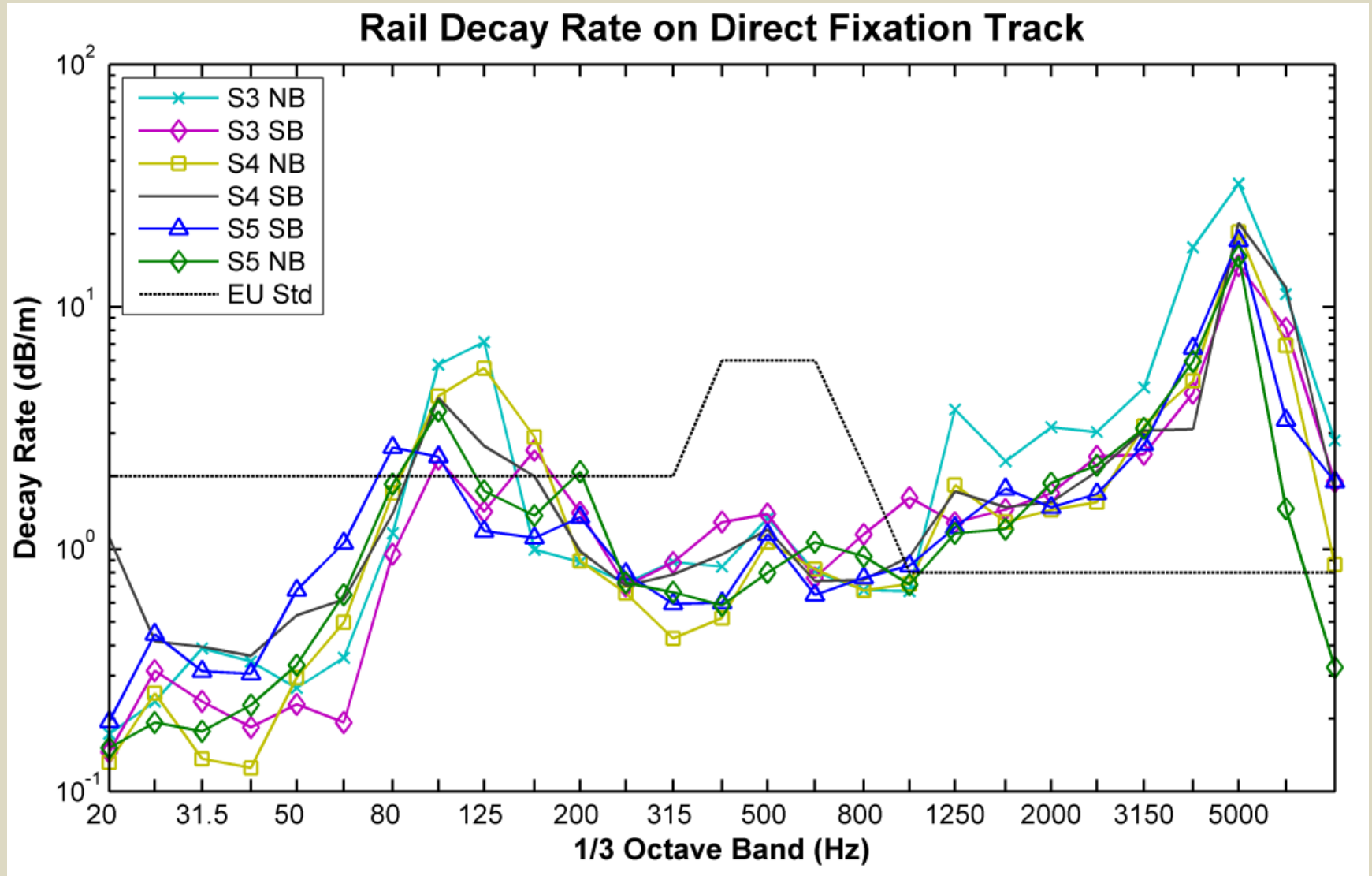


Site 4 SB Event 18

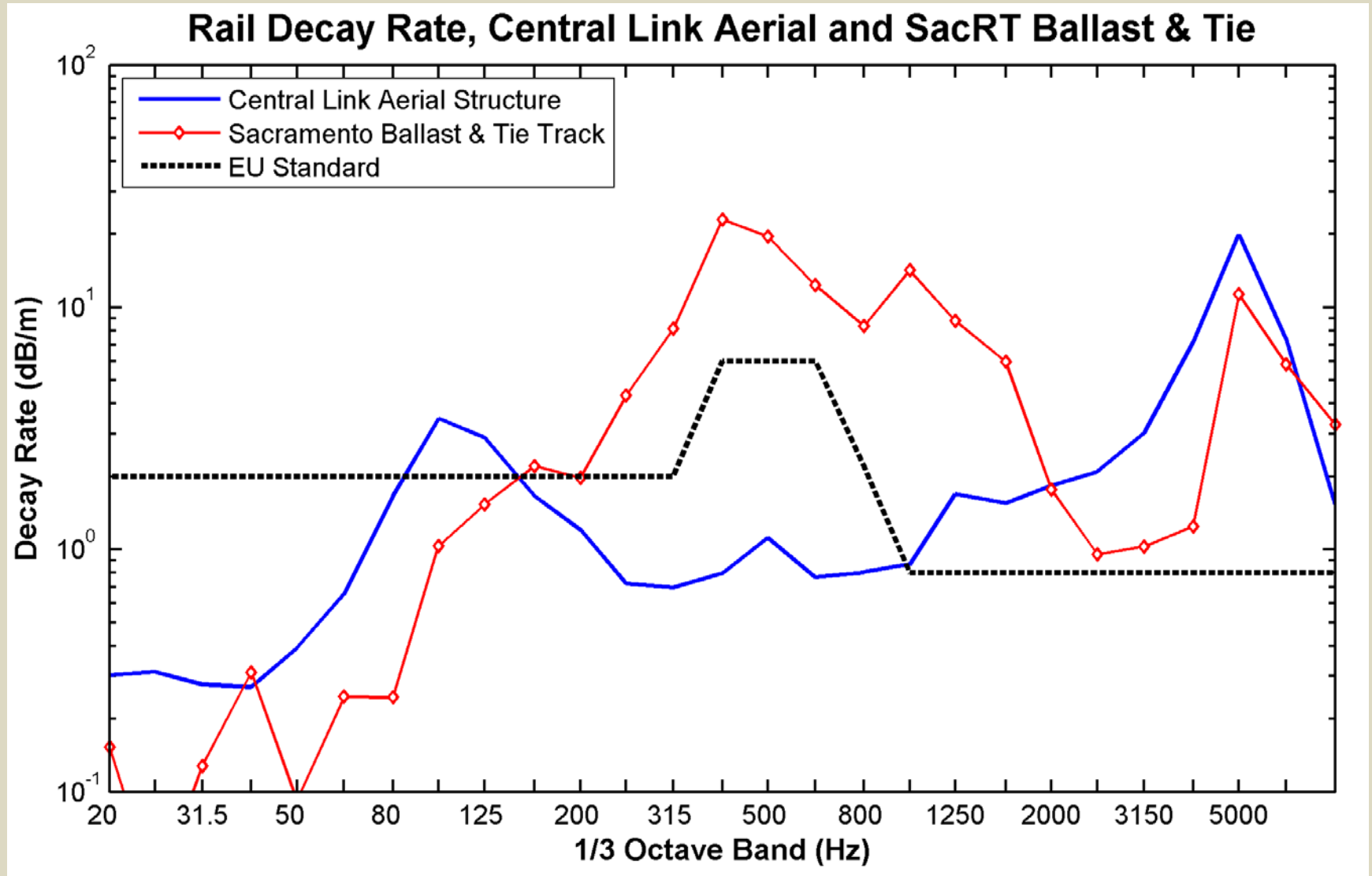


Rail Vibration Decay Results

Rail Vibration Decay Rate

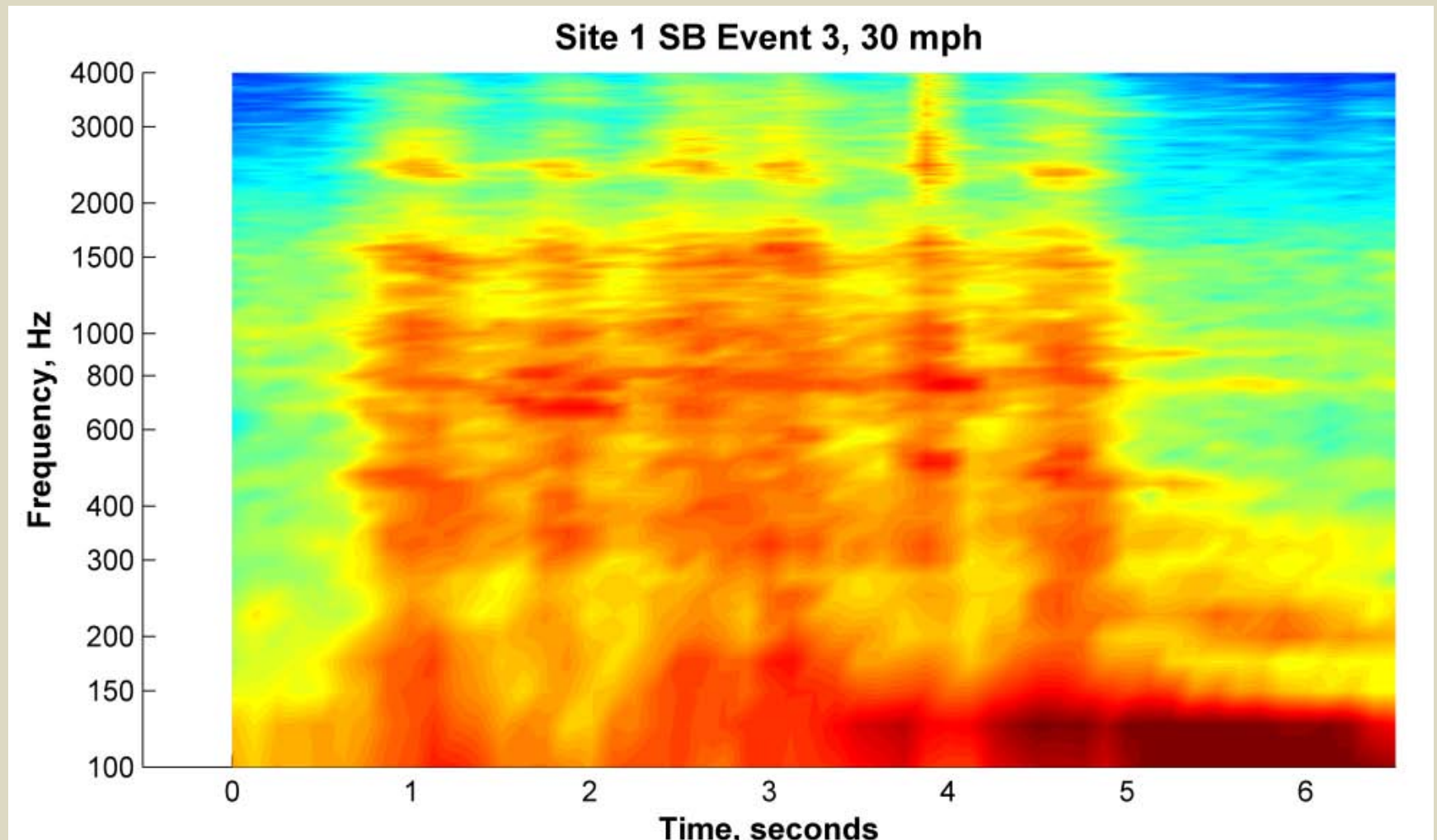


Average Rail Vibration Decay Rate

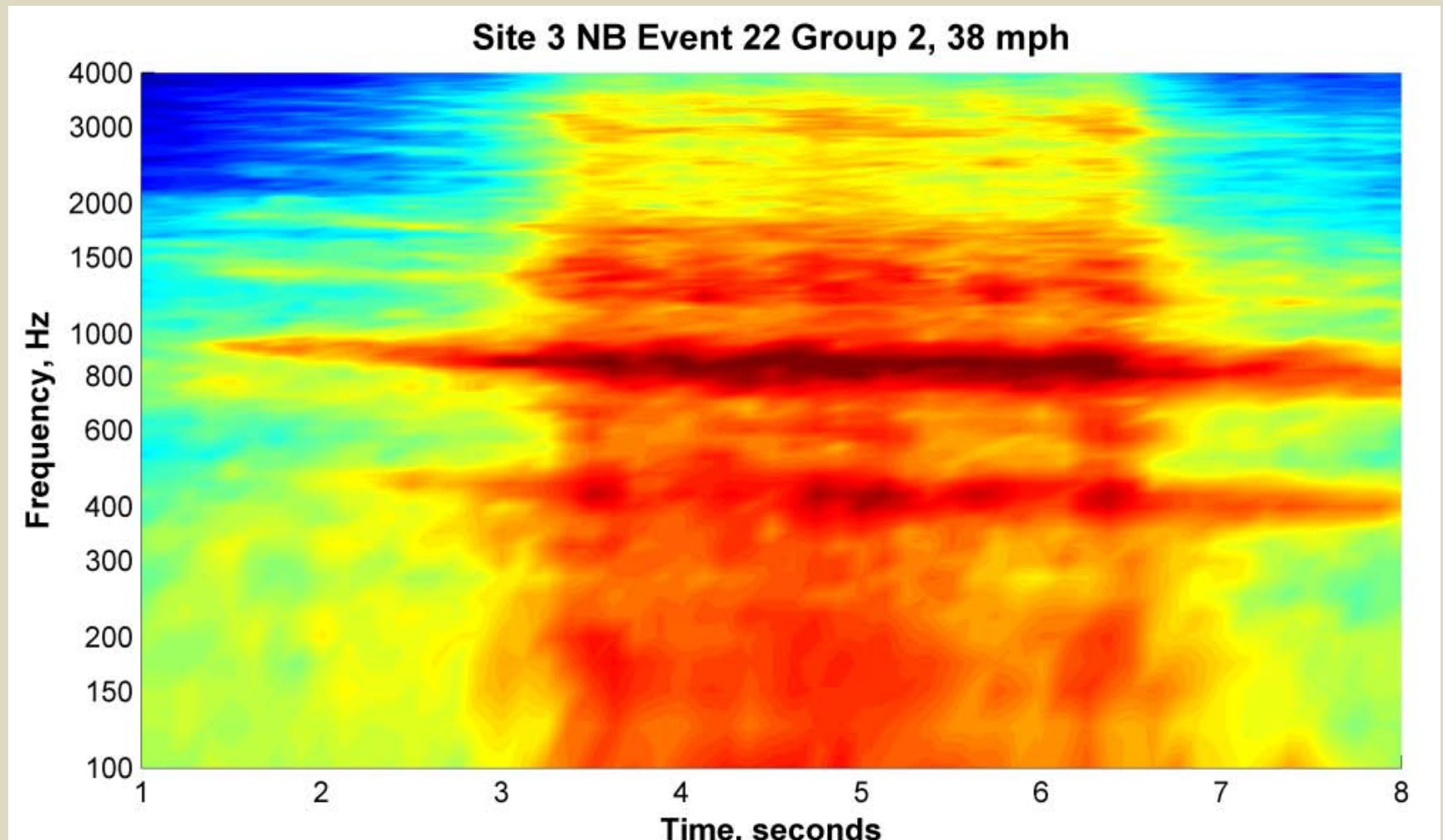


Noise Source, Wheel or Rail or Both?

Is Noise from Wheel or Rail?



Is Noise from Wheel or Rail?



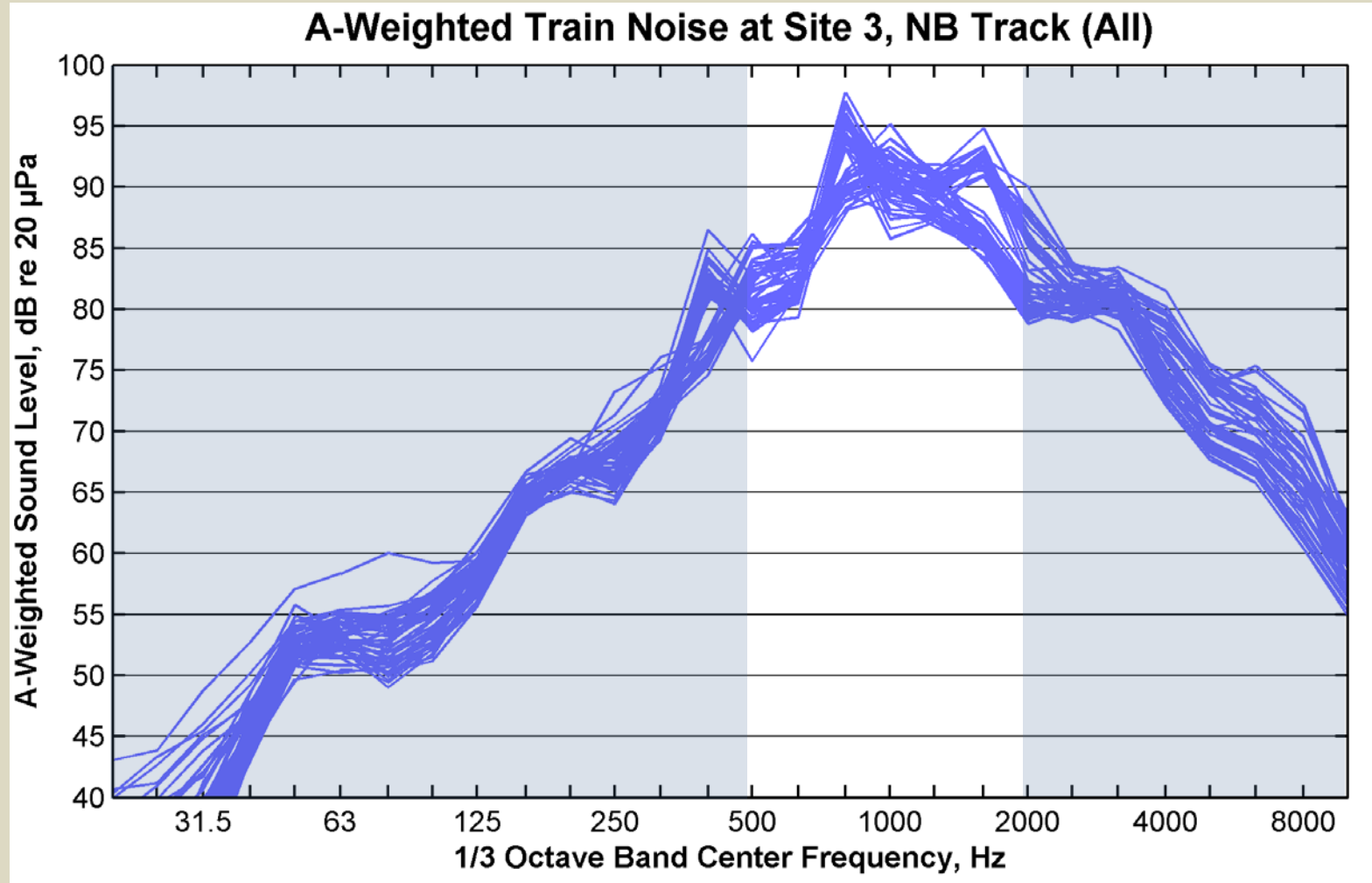
Conclusion:

- Embedded track noise is dominated by wheel
- Aerial structure noise is dominated by rail vibration
- This result along with rail decay rate suggests that rail dampers would be an effective measure to reduce noise on aerial structure

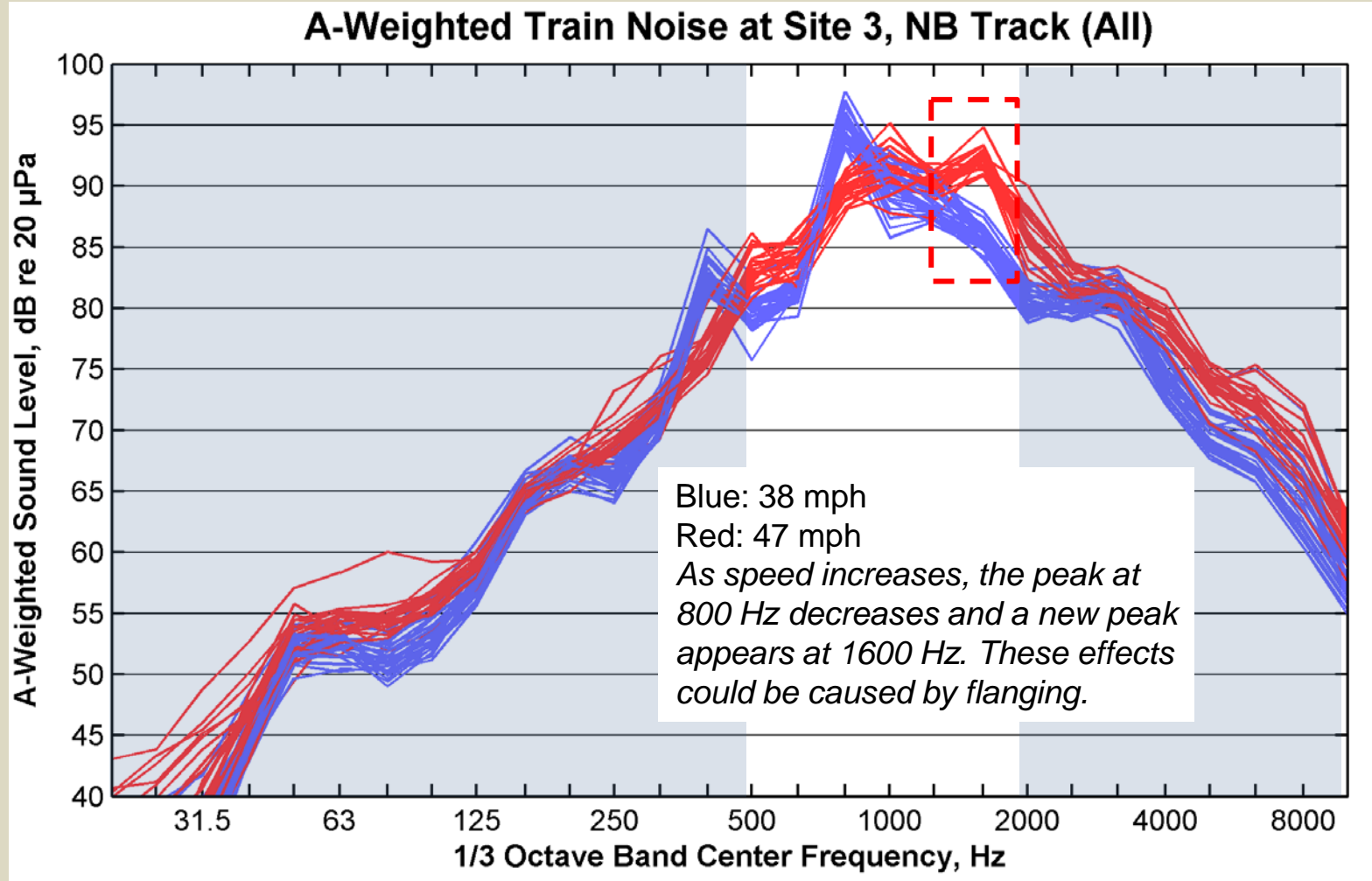


Noise that is NOT Correlated with Roughness

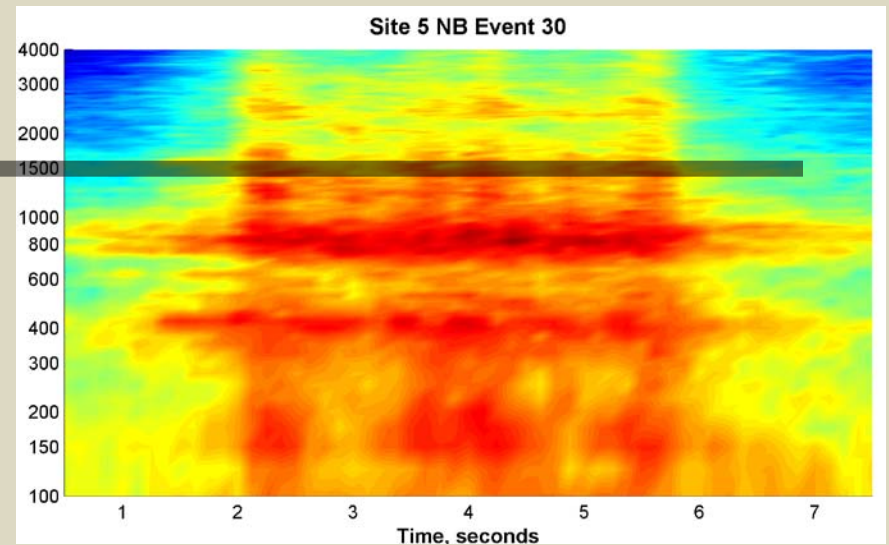
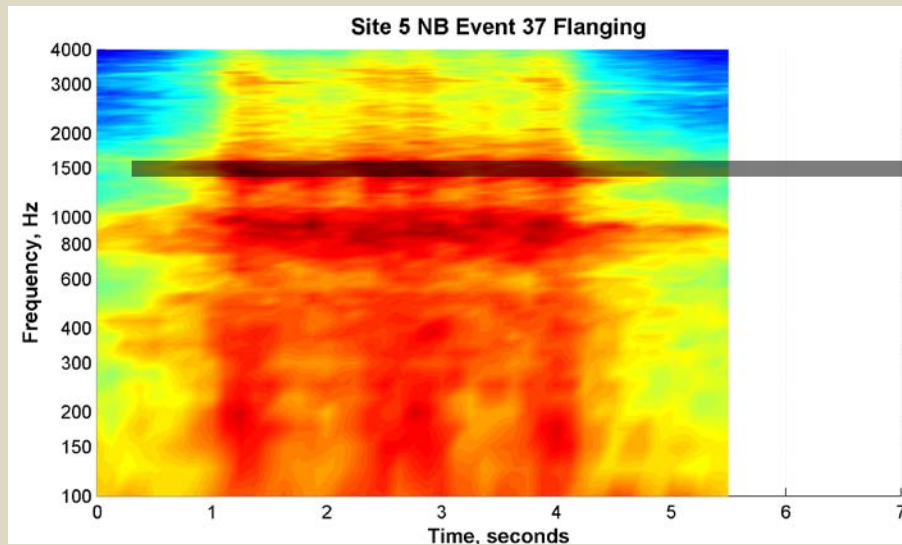
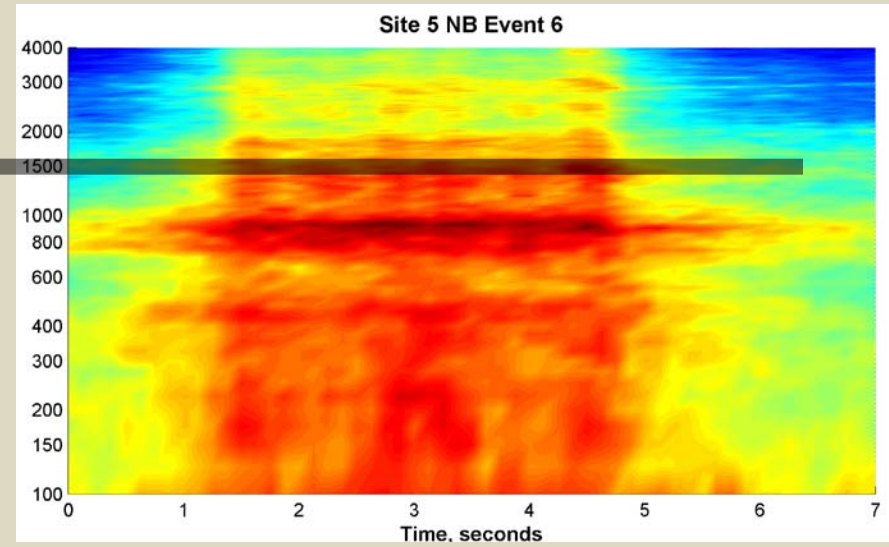
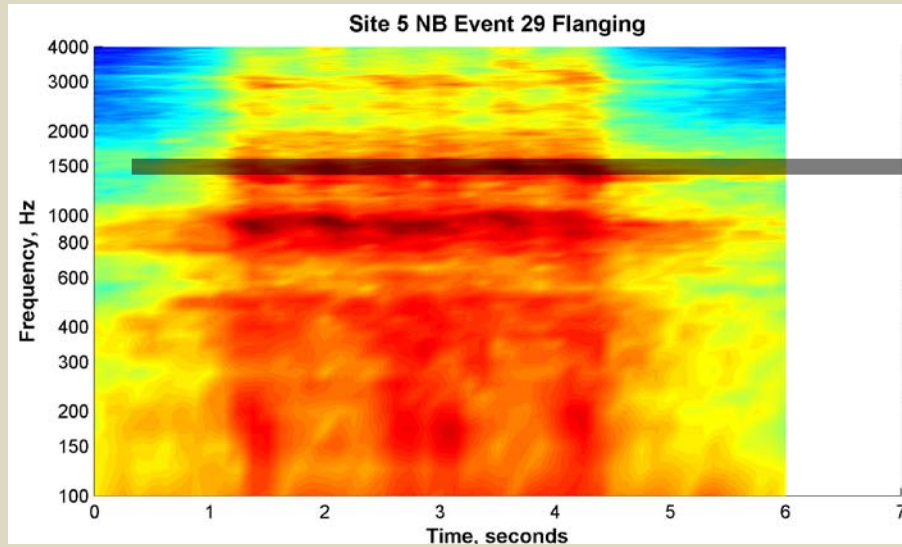
All Trains, at Site 3, Duwamish NB (Sound Transit)



All Trains, at Site 3, Duwamish NB (Sound Transit)



Example Noise Spectrograms, Sit 5



Inference

- Noise not correlated to roughness occurred at 4 of 5 sites
- Did not occur with all trains
- At two locations where trains were in two speed groups: “Extra” noise occurred at one speed and not at the other
- Suggests that noise is not caused by roughness in center of wear band.
- Possible sources:
 1. Intermittent contact between wheel flange and gauge face of rail.
 2. Wheels not tracking in wear band.

CONCLUSIONS

- Substantial noise reduction could be achieved with smoother track
- Future rail grinding should meet roughness tolerances (Suggest ISO 3085 limits as starting point)
- There are other noise sources that must be addressed to achieve maximum noise reduction
- Rail and wheel dampers are a potential noise mitigation measure