

# 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

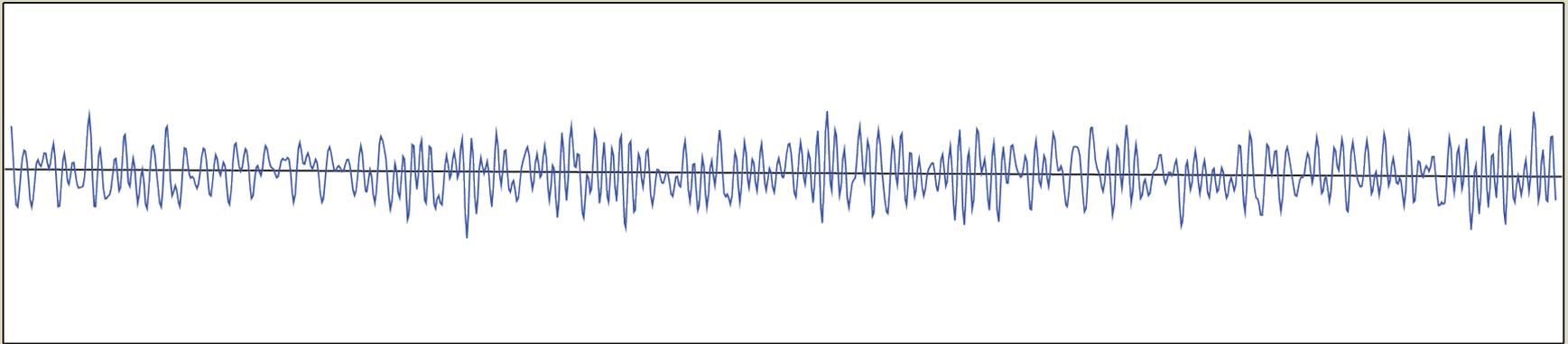
- **Noise (A-weighted sound level, dBA)**

- Frequency weighted to approximate human hearing

# "Roughness"

Any longitudinal irregularity in rail surface:

## *Random Roughness*

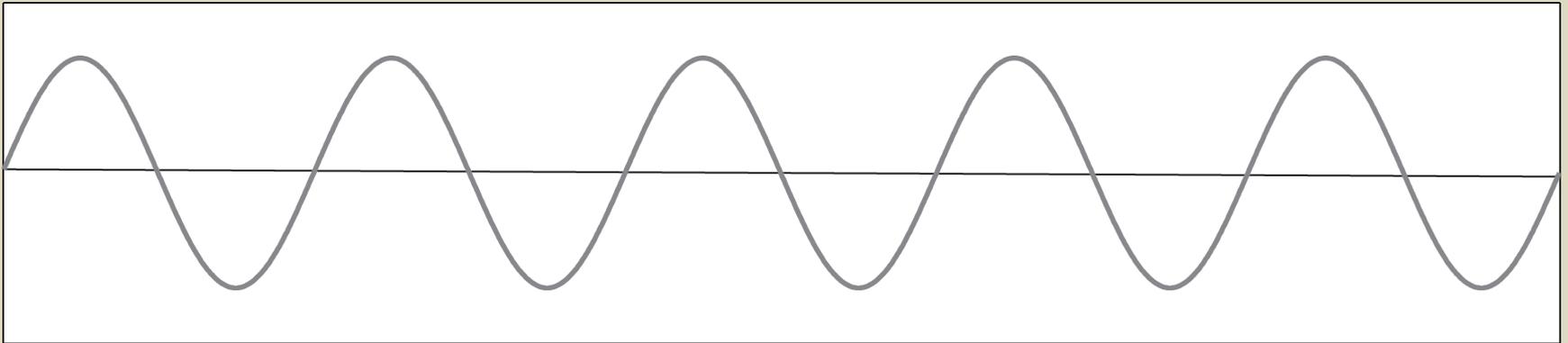


$$\begin{aligned} f &= \frac{\textit{speed}}{\textit{wavelength}} \\ &= 447 \times \frac{\textit{speed (mph)}}{\textit{wavelength (mm)}} \\ &= 18.8 \times \frac{\textit{speed (mph)}}{\textit{wavelength (in.)}} \end{aligned}$$

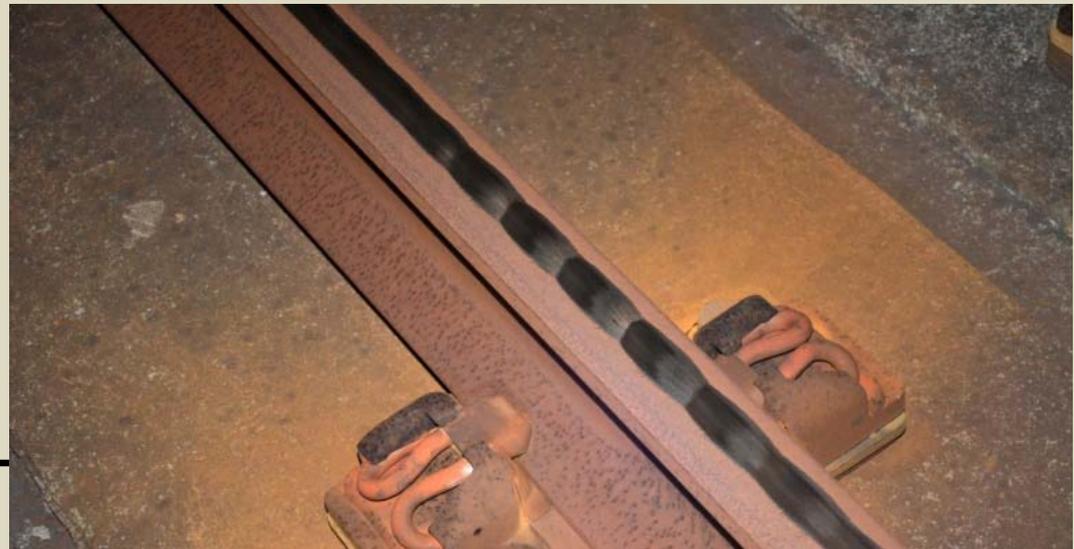
# "Roughness"

Any longitudinal irregularity in rail surface:

**Corrugation**



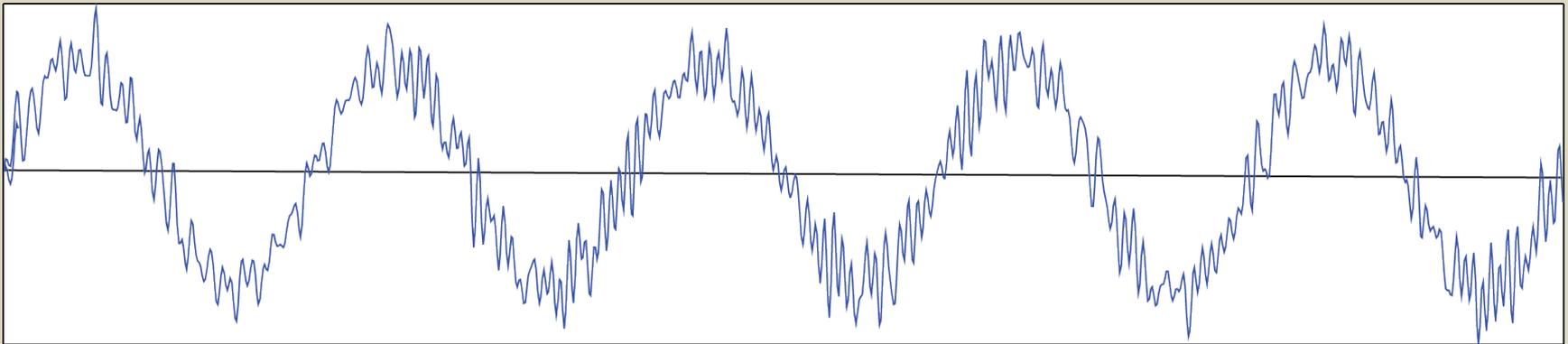
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# "Roughness"

Any longitudinal irregularity in rail surface:

## **Combined Roughness**



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

# Sound Transit Acoustic Test Program

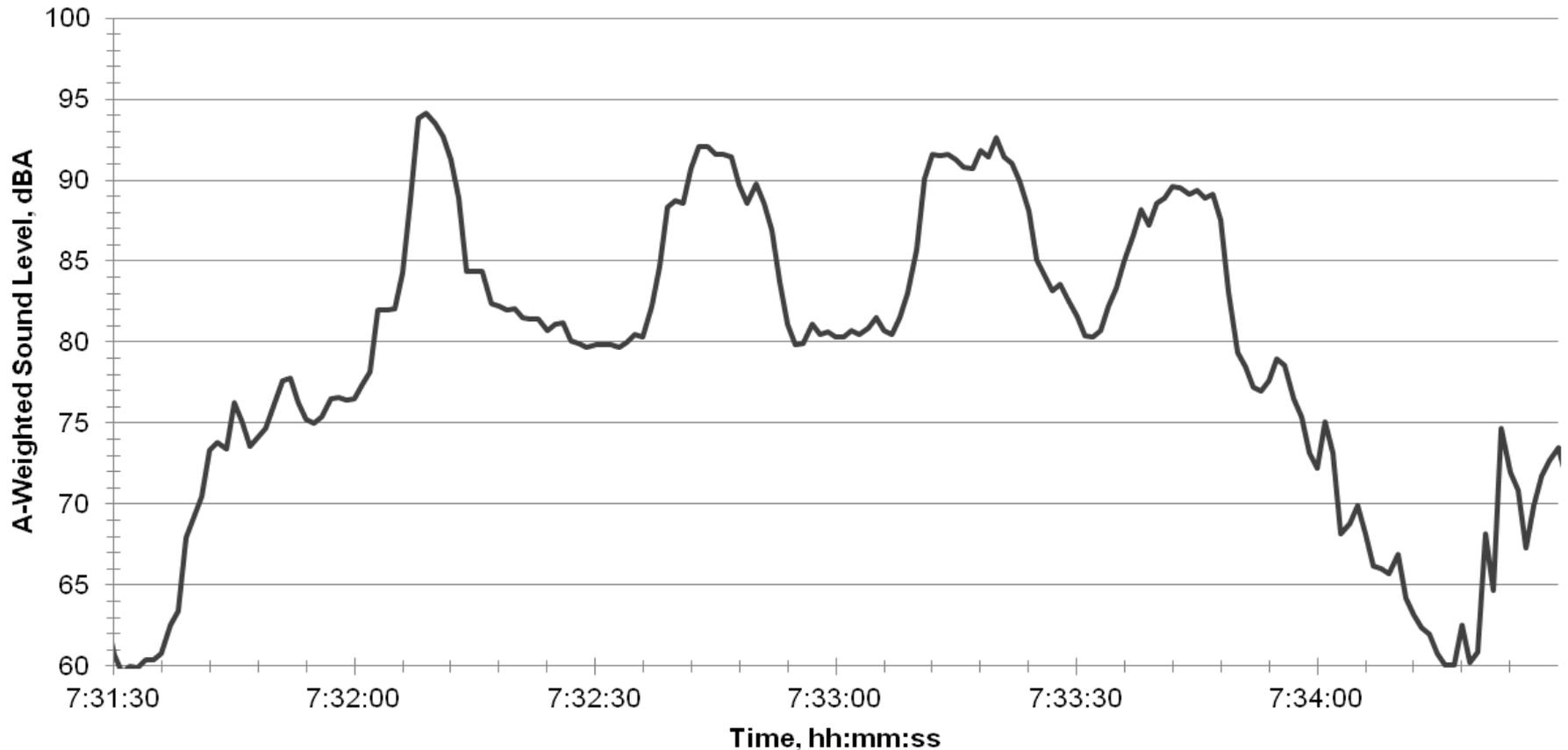
- On-board noise levels to identify problem areas
- Selected five sites for detailed measurements
  - Selected based on complaint history and results of on-board measurements
  - Two on embedded track in the middle of MLK Jr. Blvd.
  - Three on Tukwila aerial structure
- Measurements at test sites
 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

# Onboard Noise Measurement

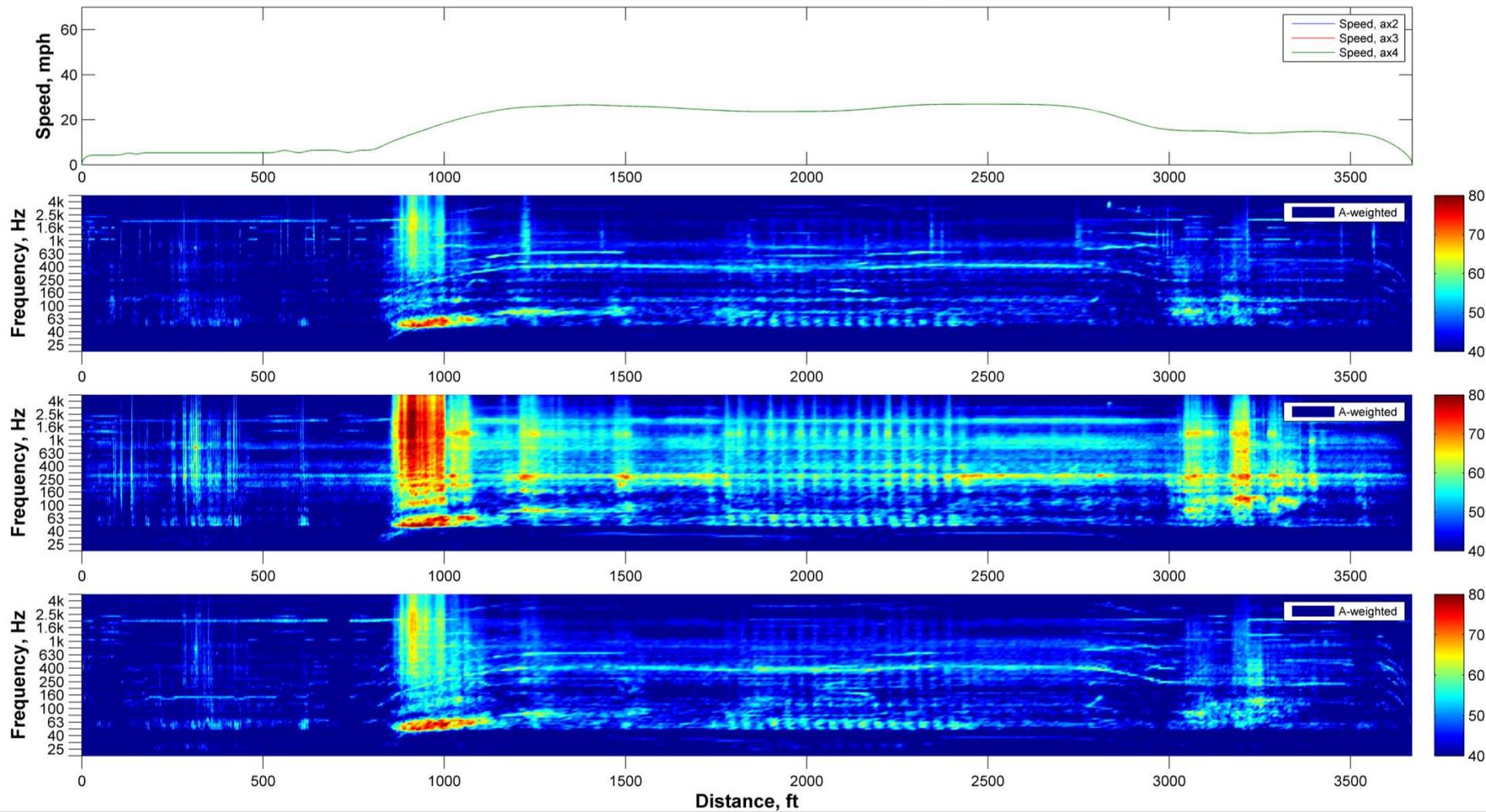


# In-Car Noise Measurement, 2003

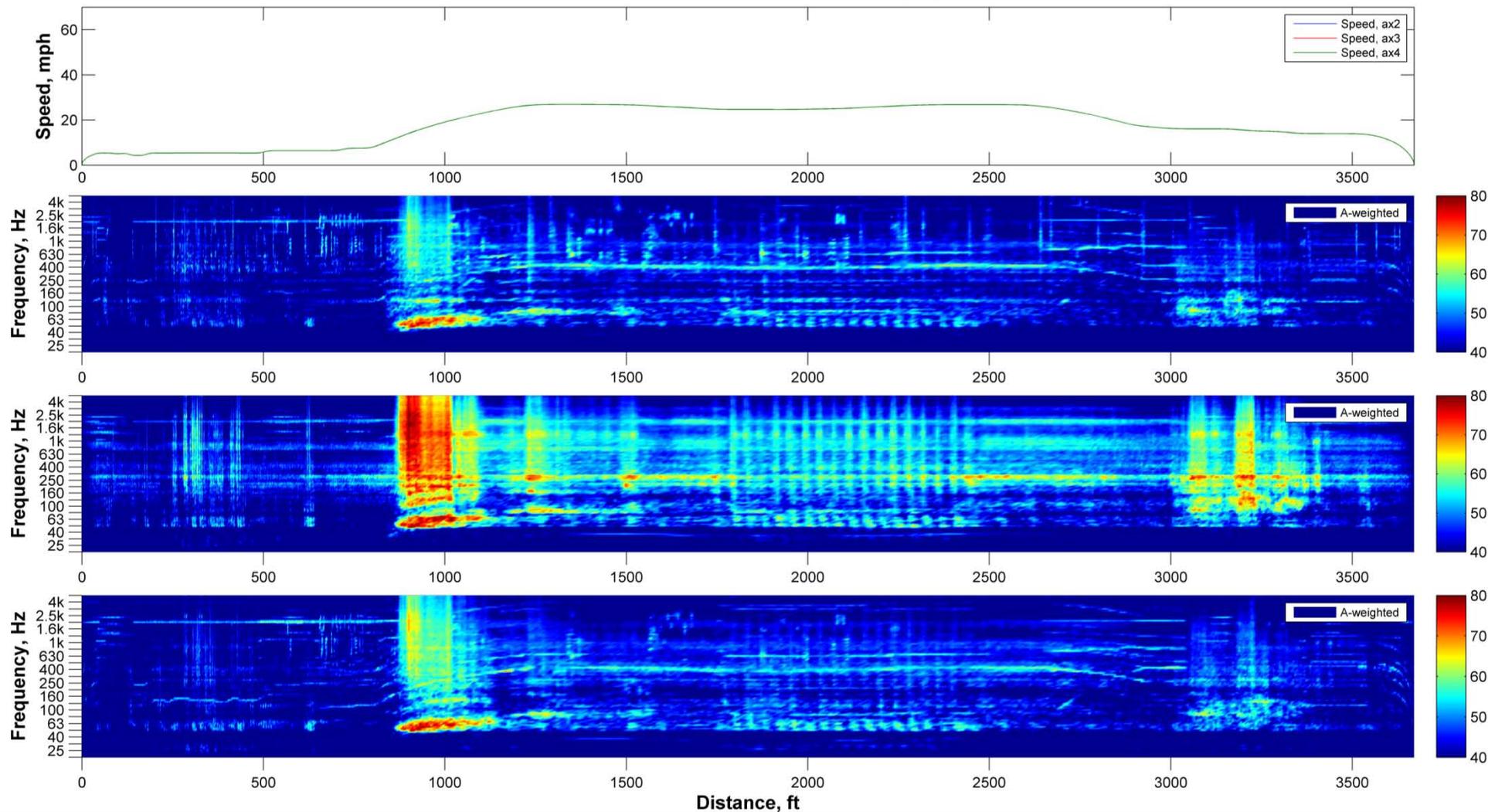
## In-Car Noise, San Bruno to South San Francisco



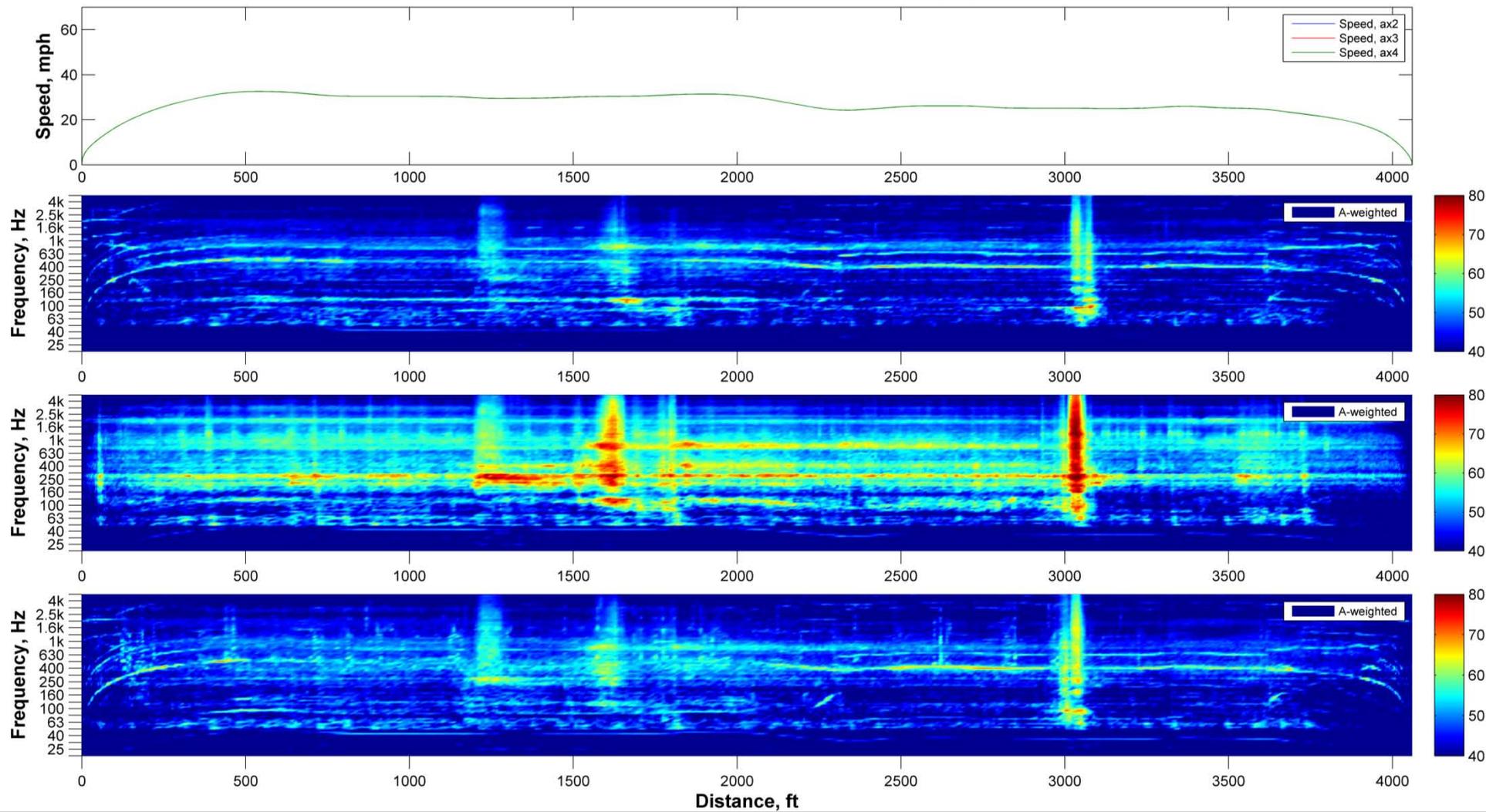
# Example On-Board Spectrogram (1)



# 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)



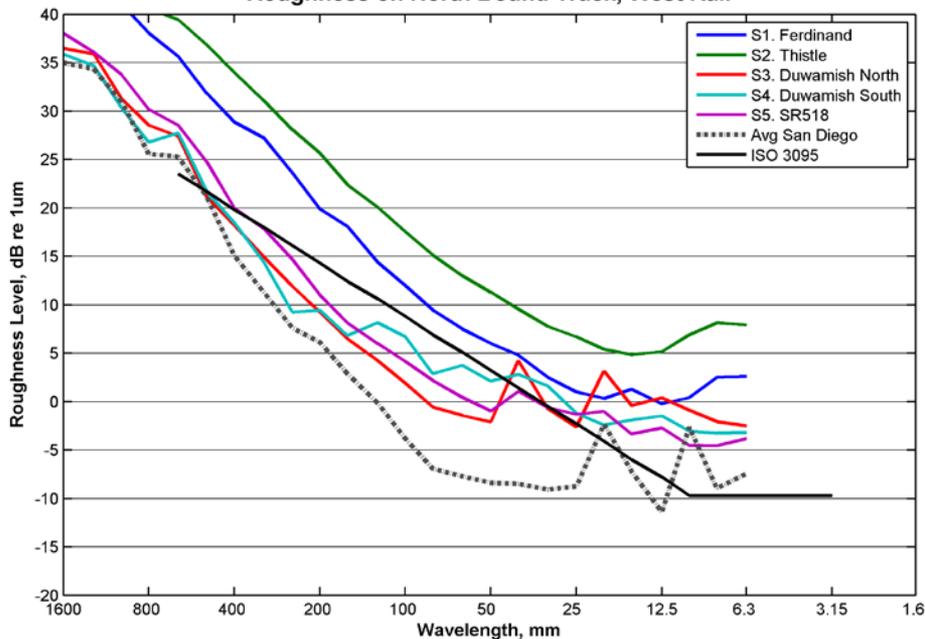
# Vibration Decay Rate Measurement



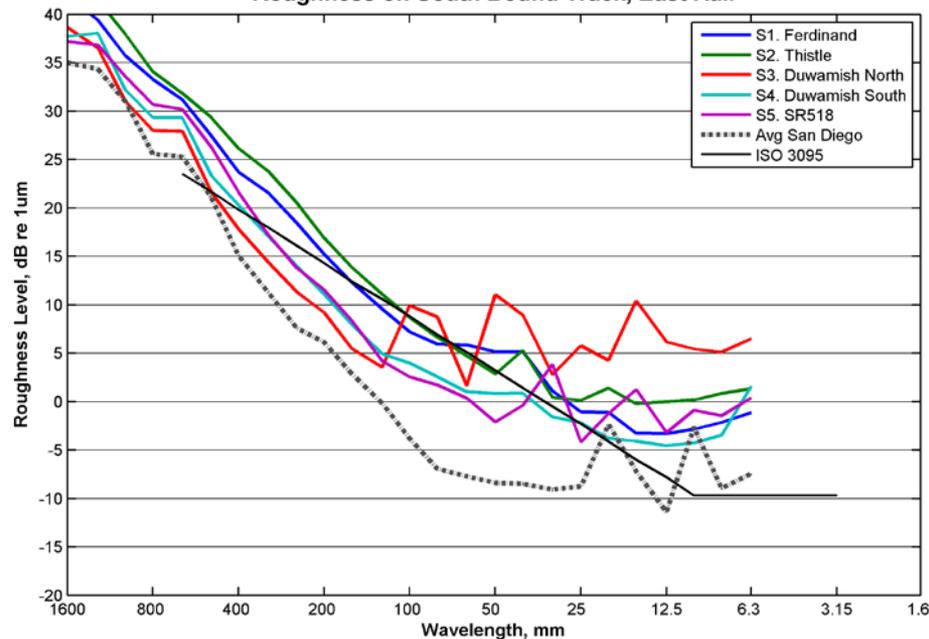
# Rail Roughness Results

# Average Roughness, 1/3 Octave Band Spectra

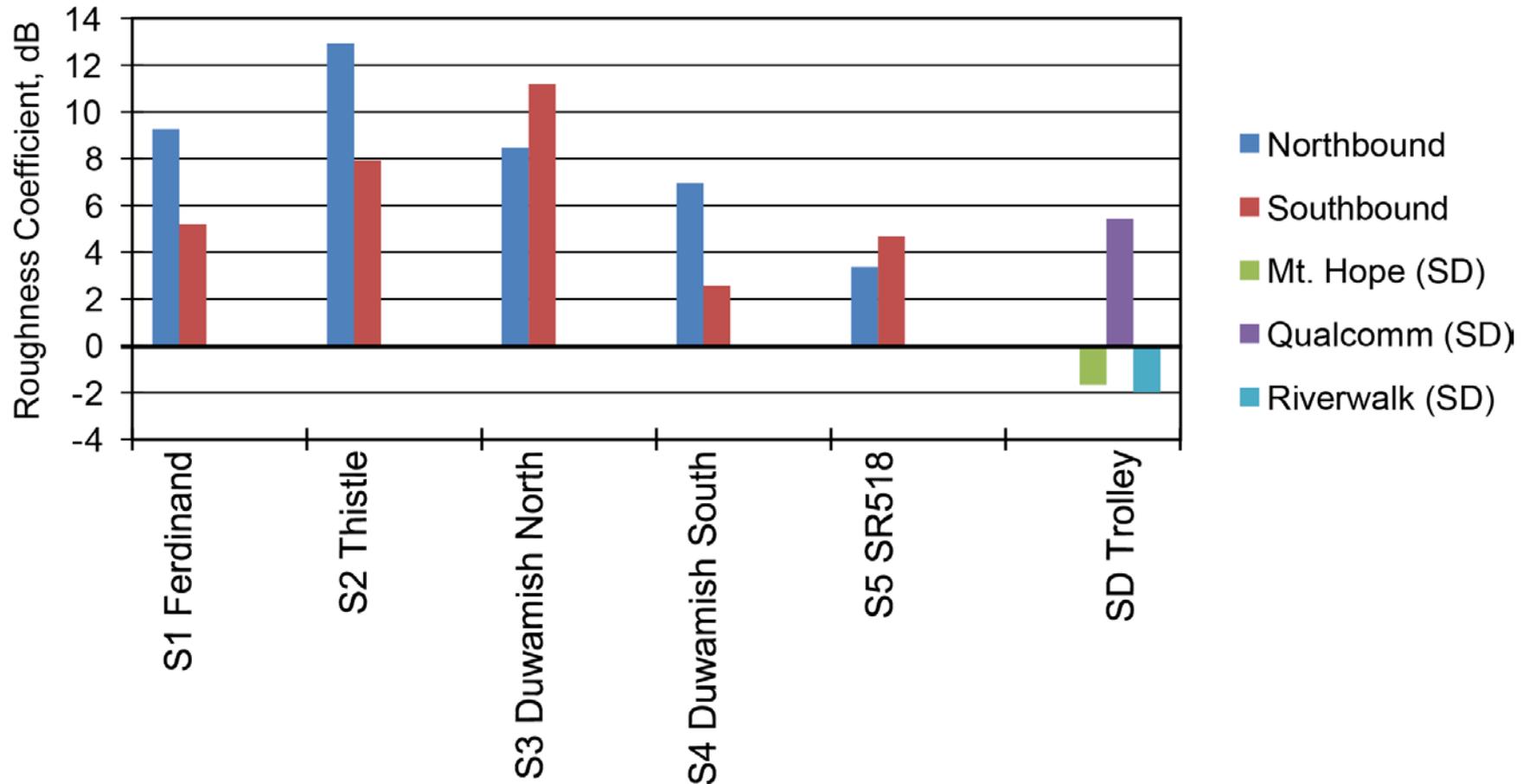
Roughness on North Bound Track, West Rail



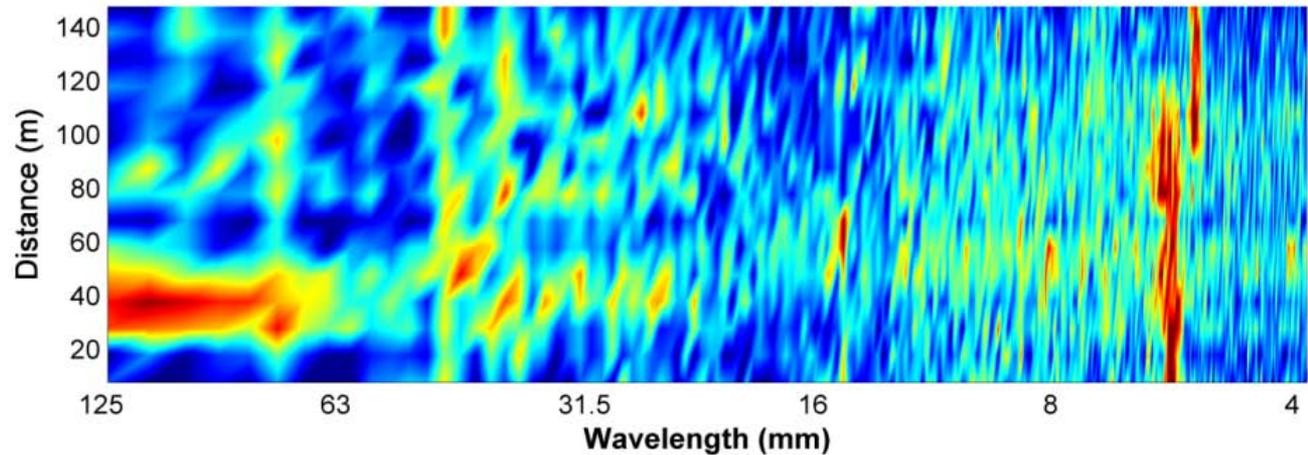
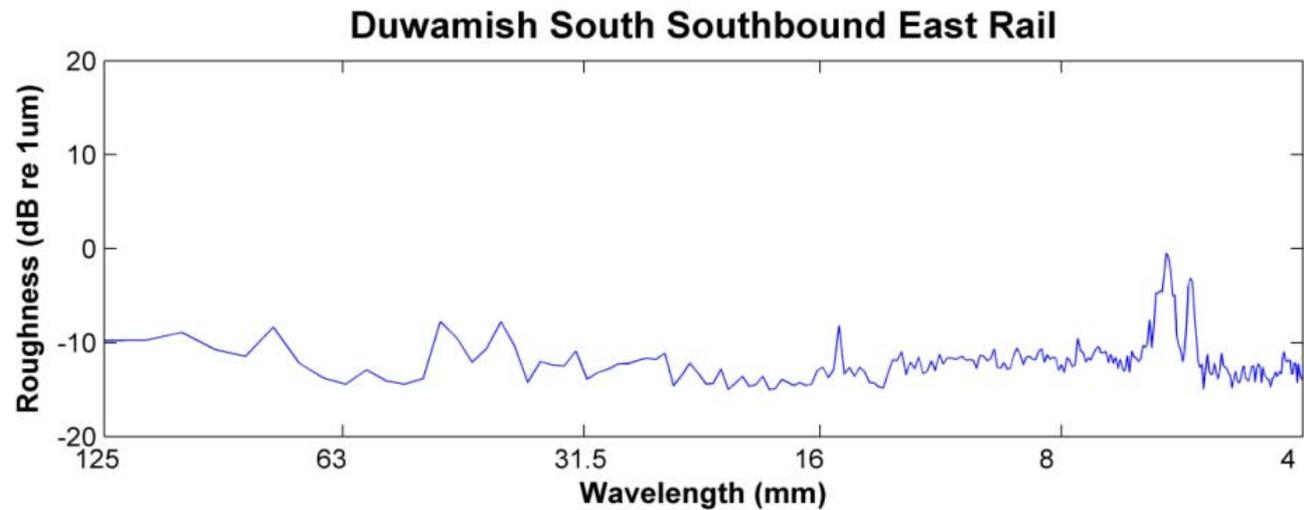
Roughness on South Bound Track, East Rail



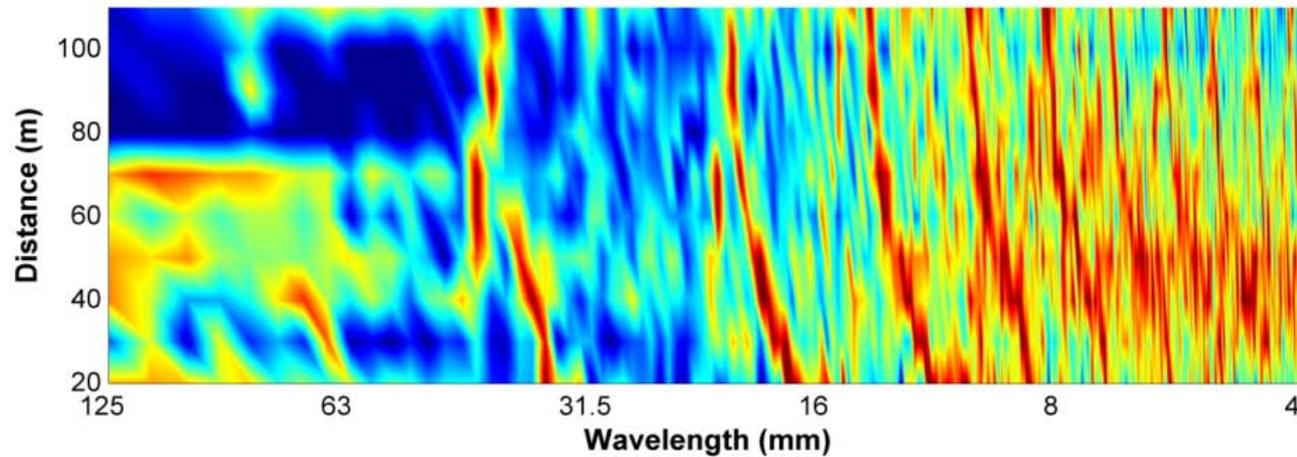
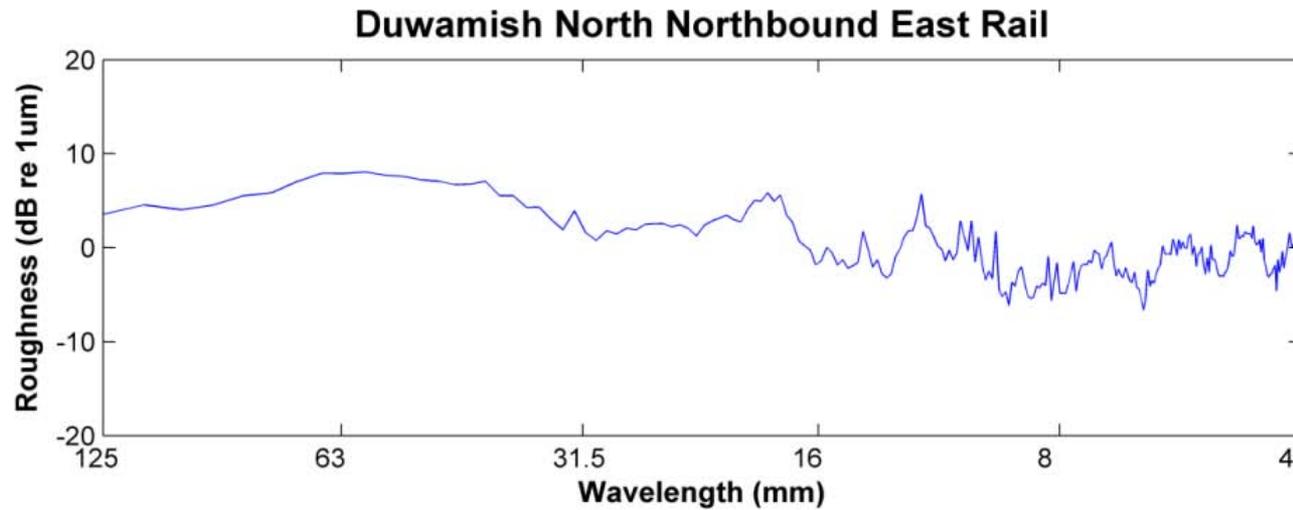
# Derived Roughness "Coefficient"



# Roughness Spectrogram, Site 4

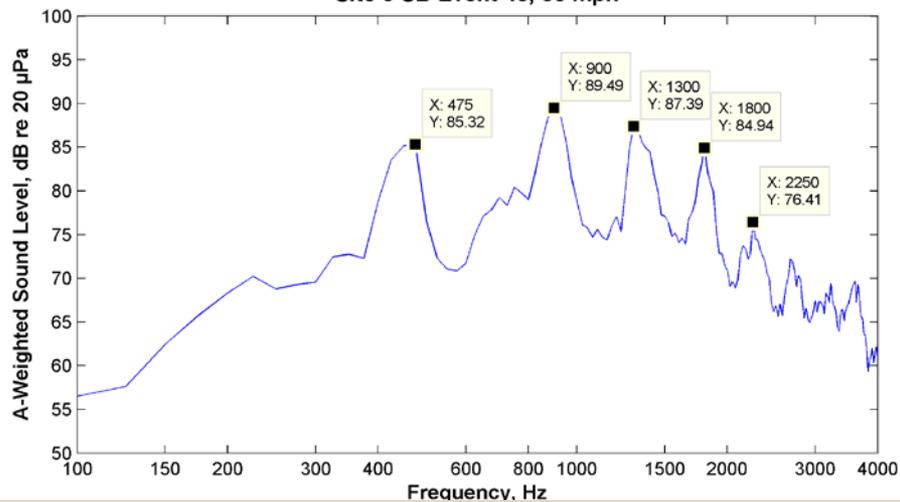


# Roughness Spectrogram, Site 3

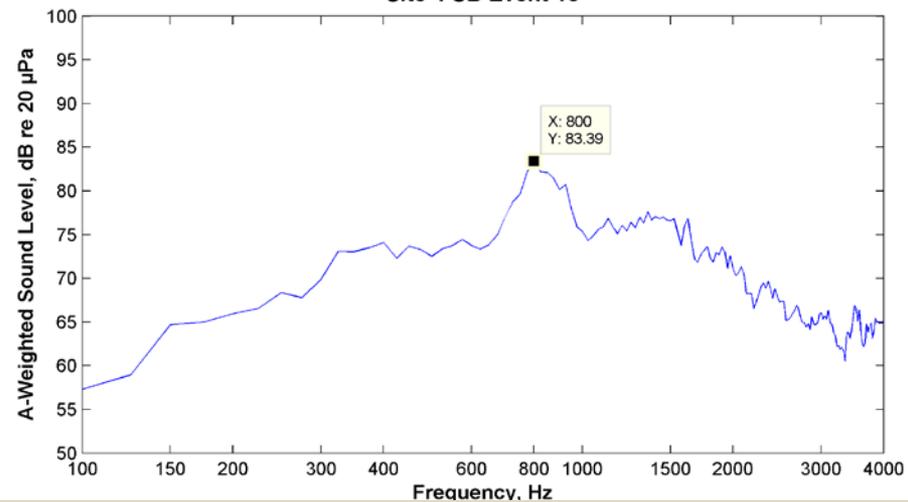


# Typical Noise Spectra, Site 3 and Site 4

Site 3 SB Event 48, 38 mph

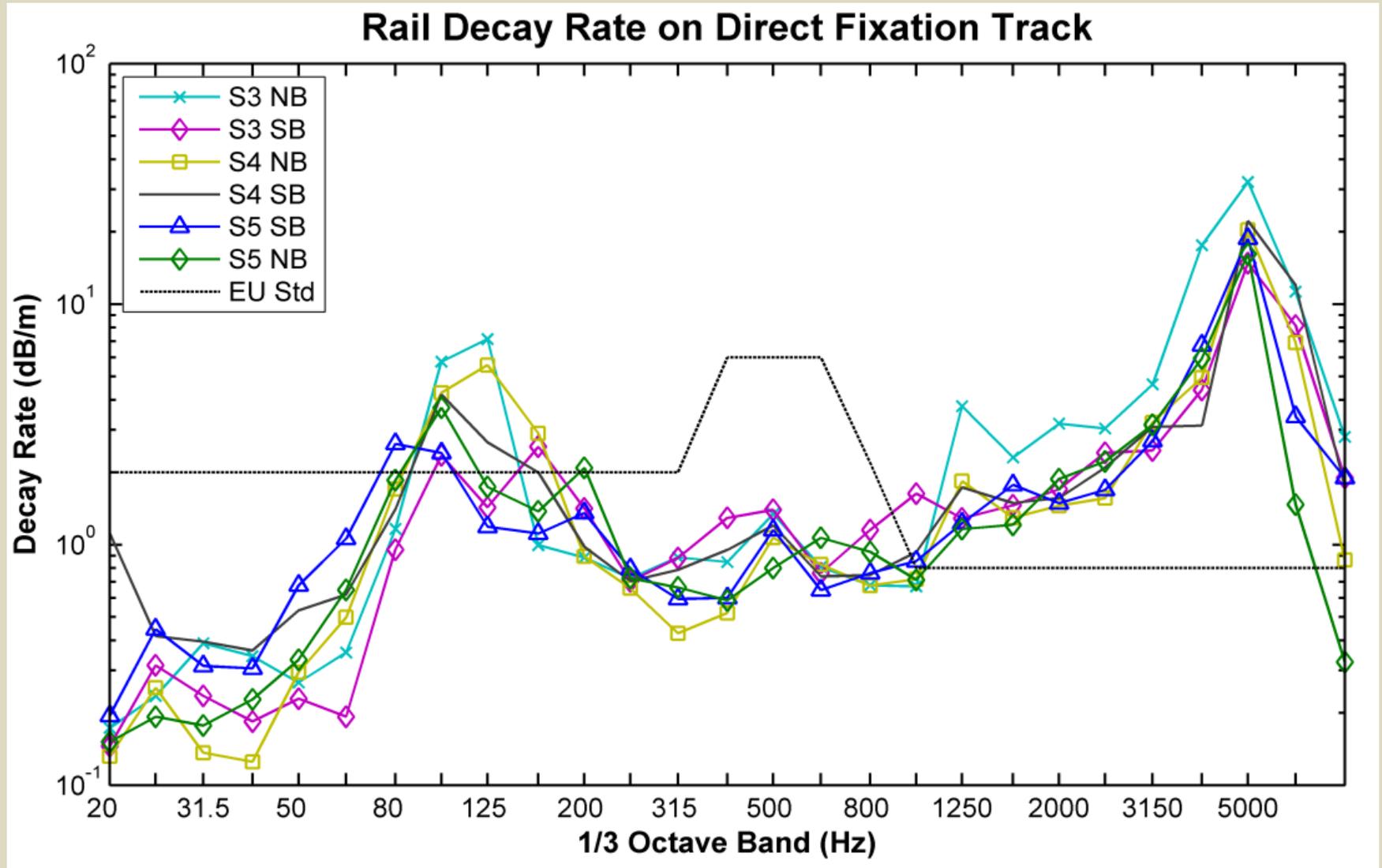


Site 4 SB Event 18

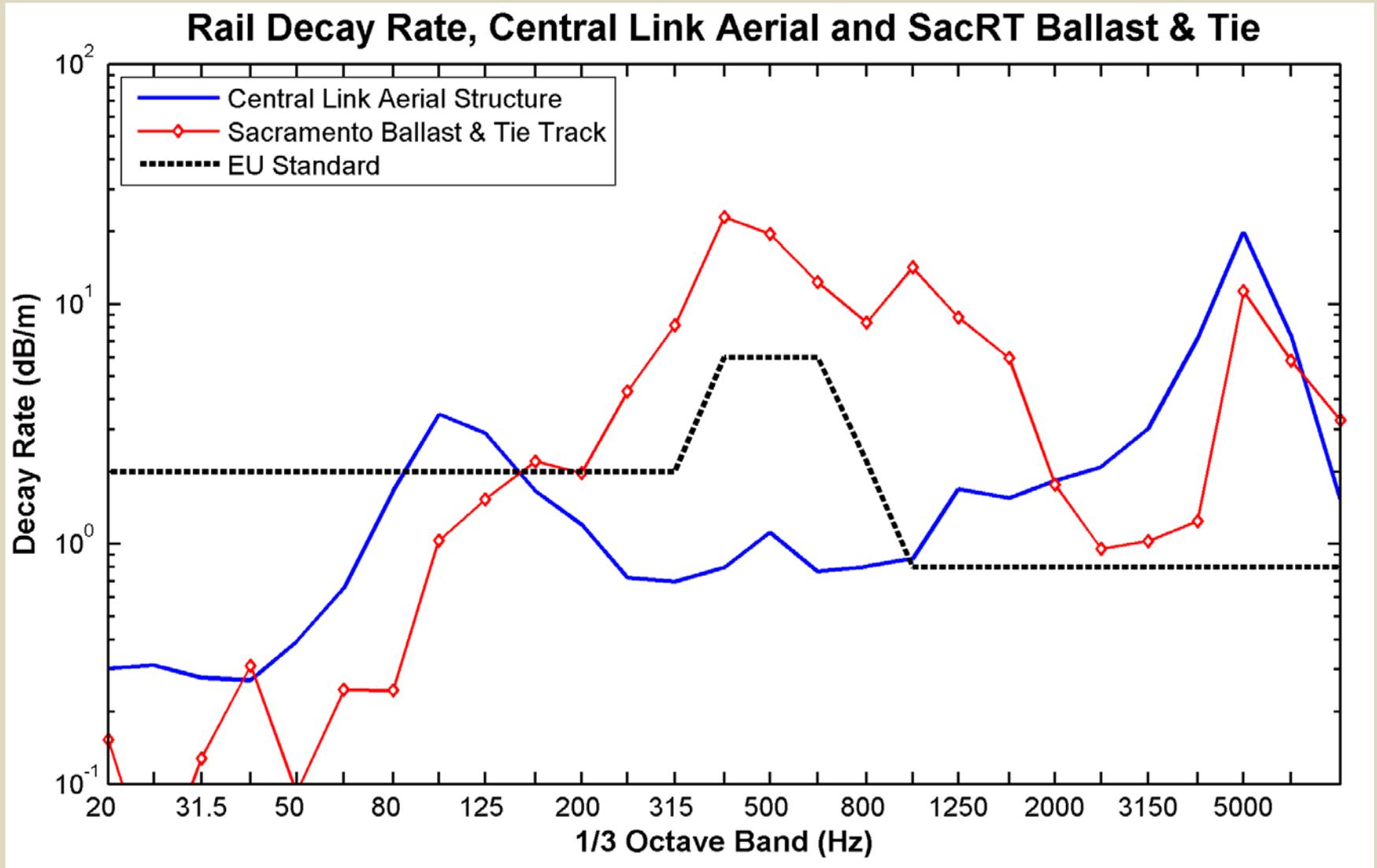


# Rail Vibration Decay Results

# Rail Vibration Decay Rate

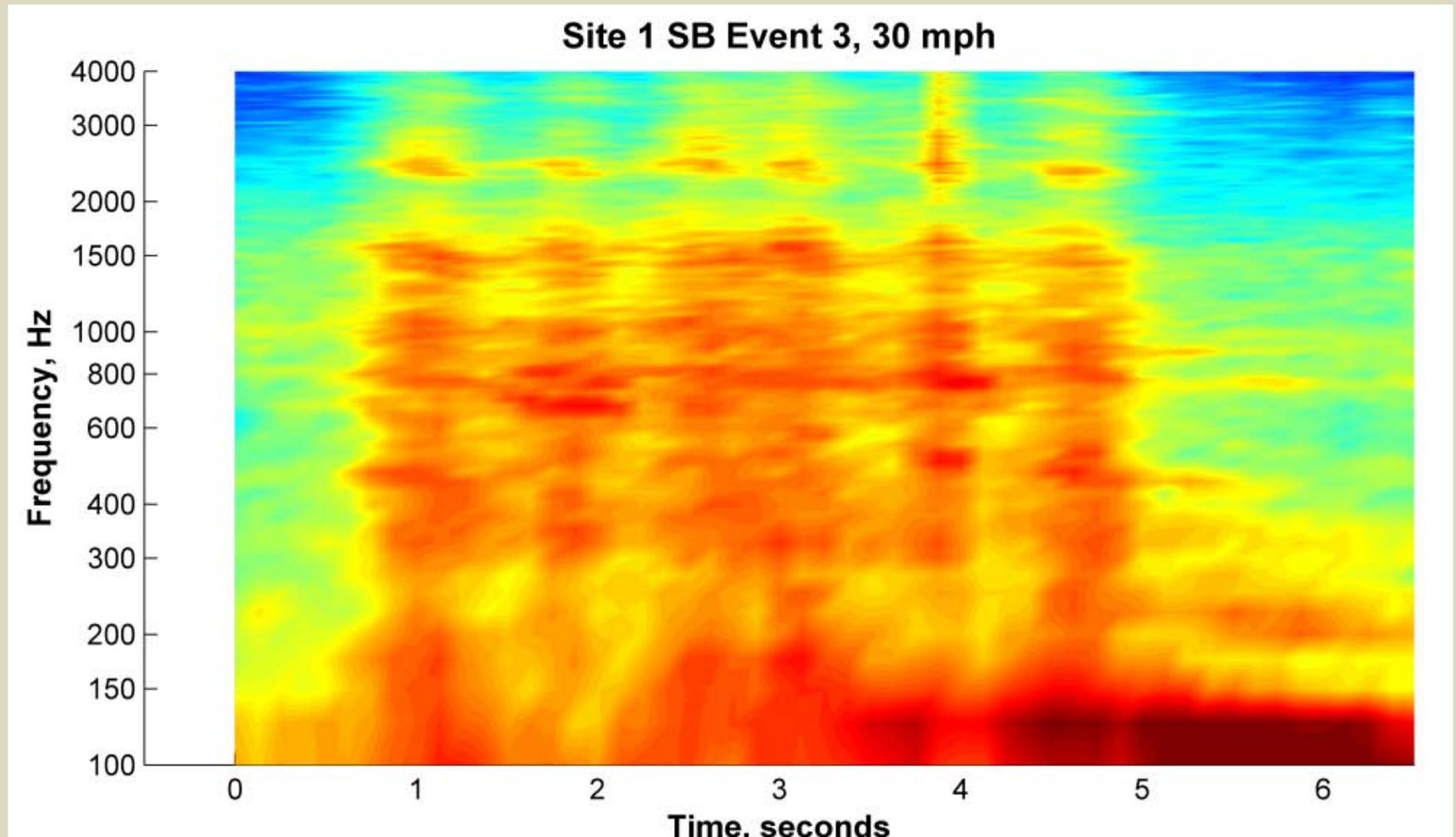


# Average Rail Vibration Decay Rate

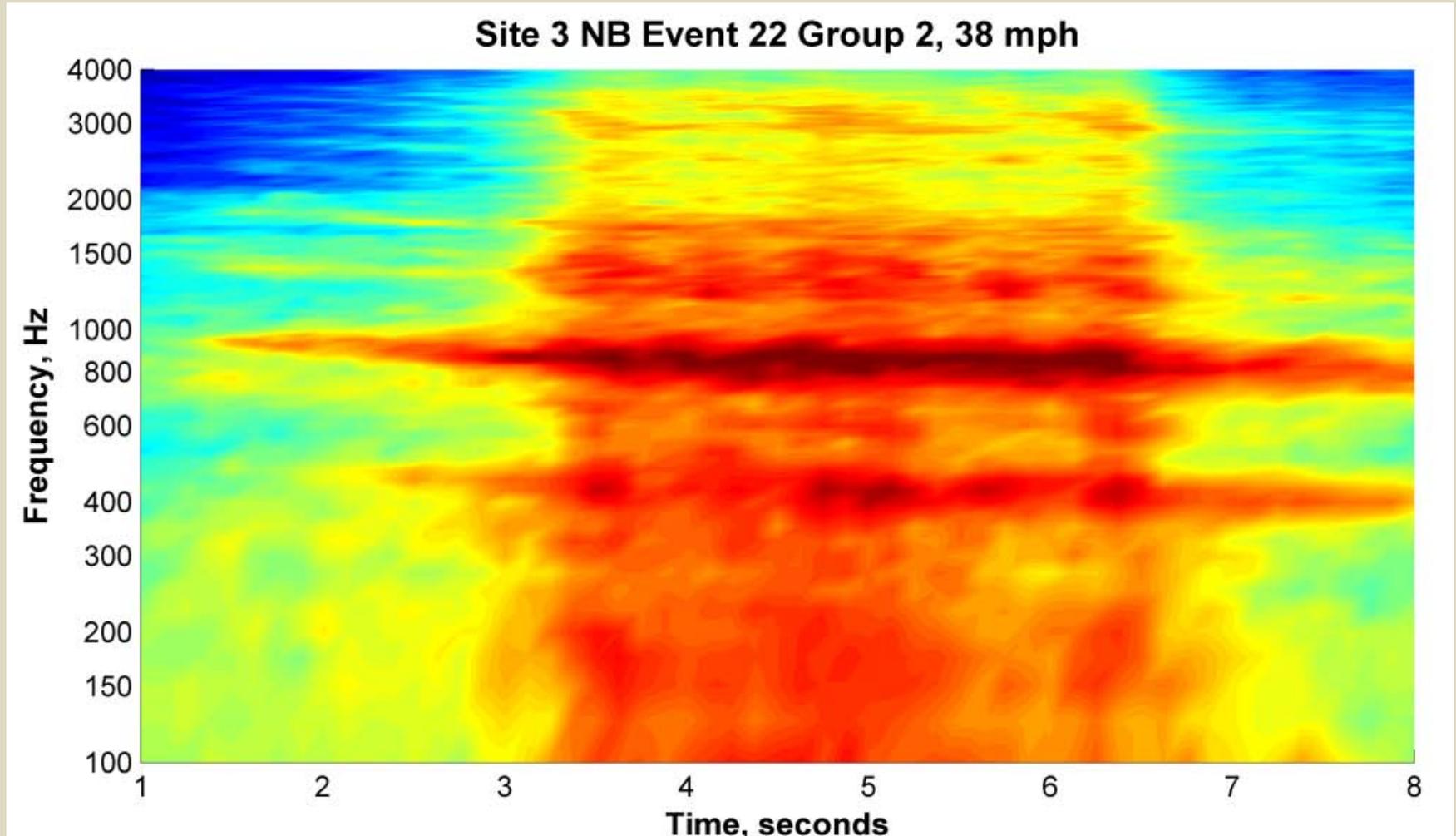


# Noise Source, Wheel or Rail or Both?

# Is Noise from Wheel or Rail?



# Is Noise from Wheel or Rail?



# Conclusion:

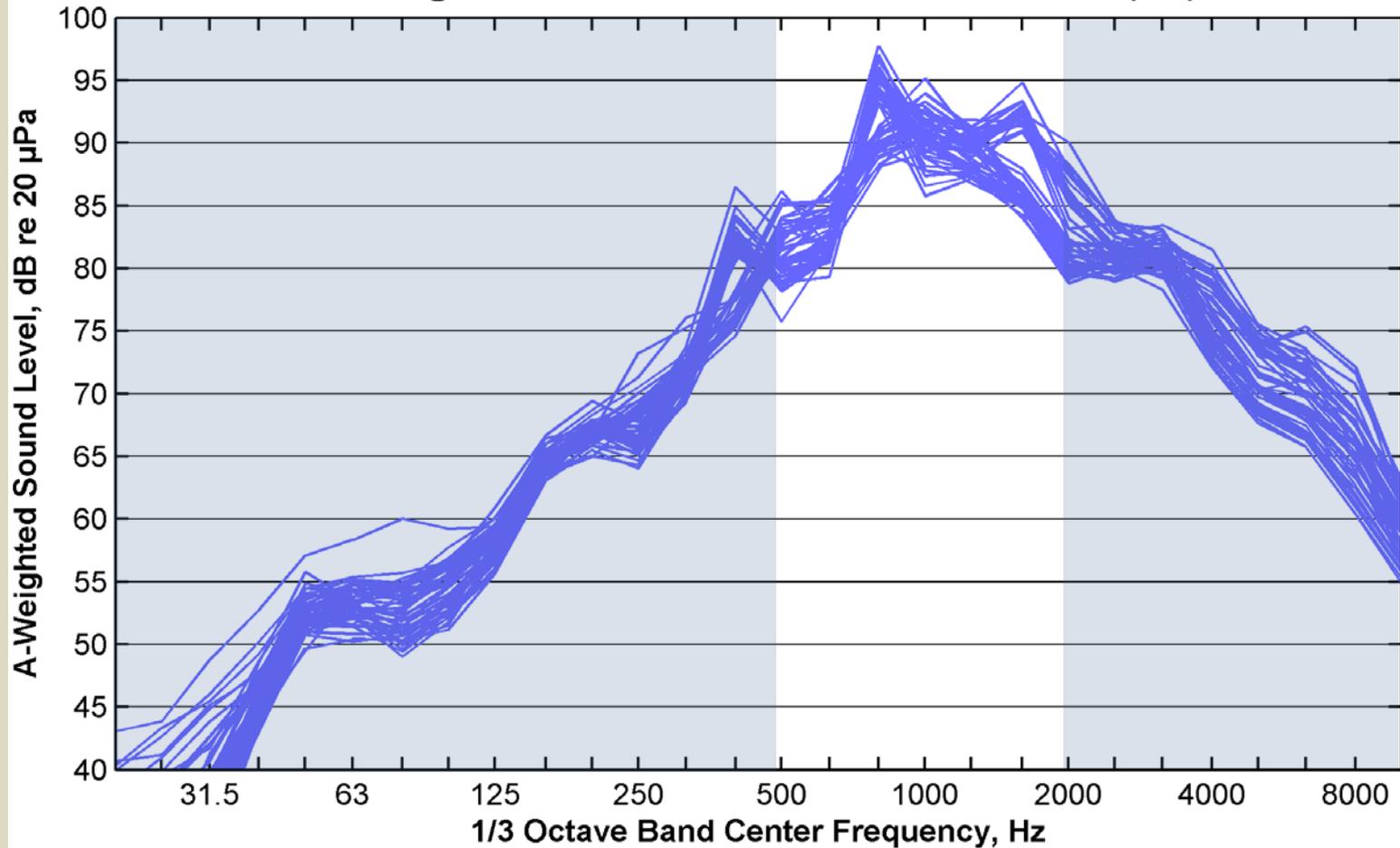
- Embedded track noise is dominated by wheel
- Aerial structure noise is dominated by rail vibration
- This result along with rail decay rate suggests that rail dampers would be an effective measure to reduce noise on aerial structure



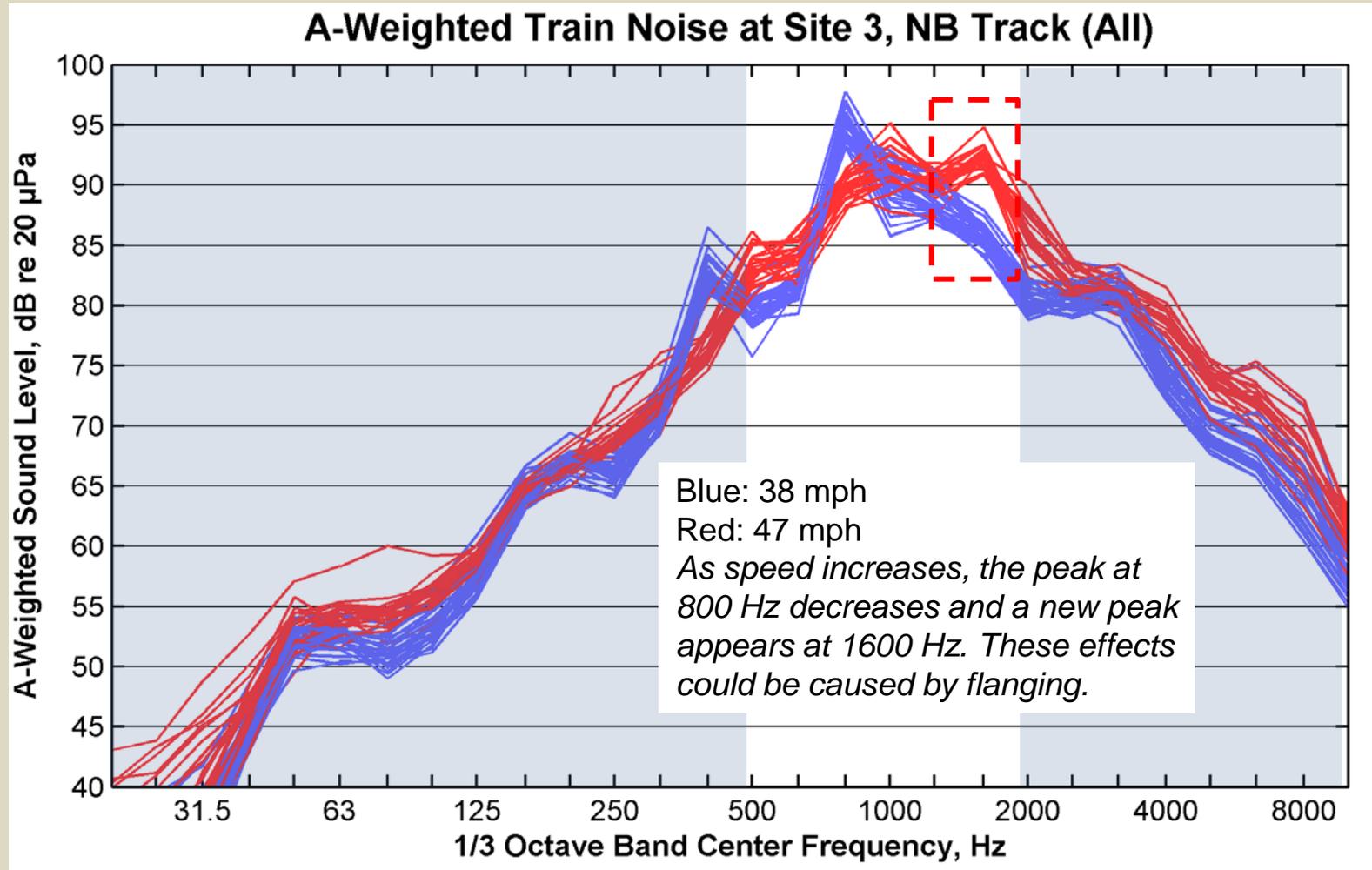
# Noise that is NOT Correlated with Roughness

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

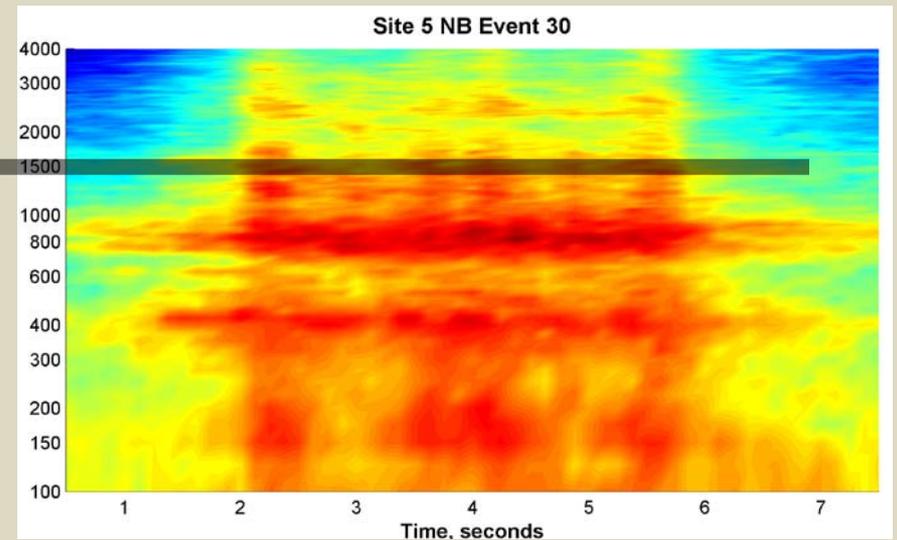
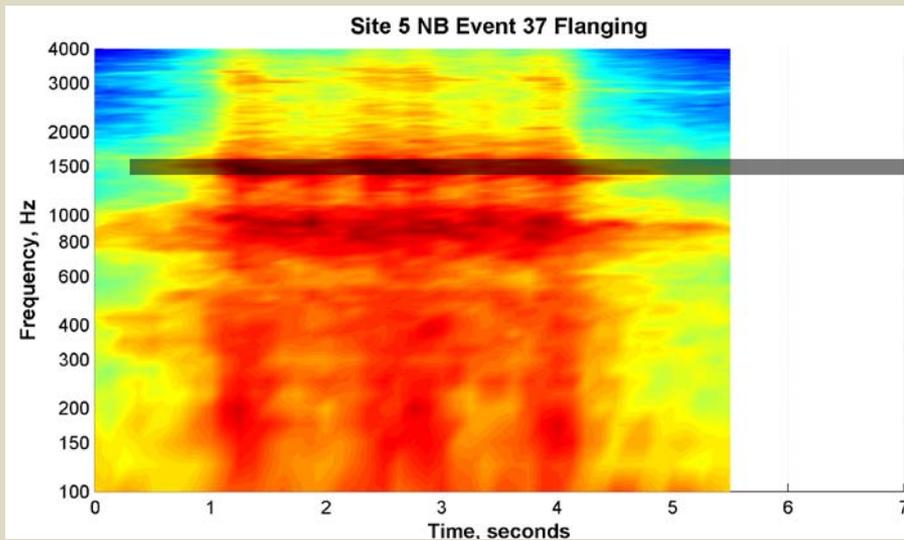
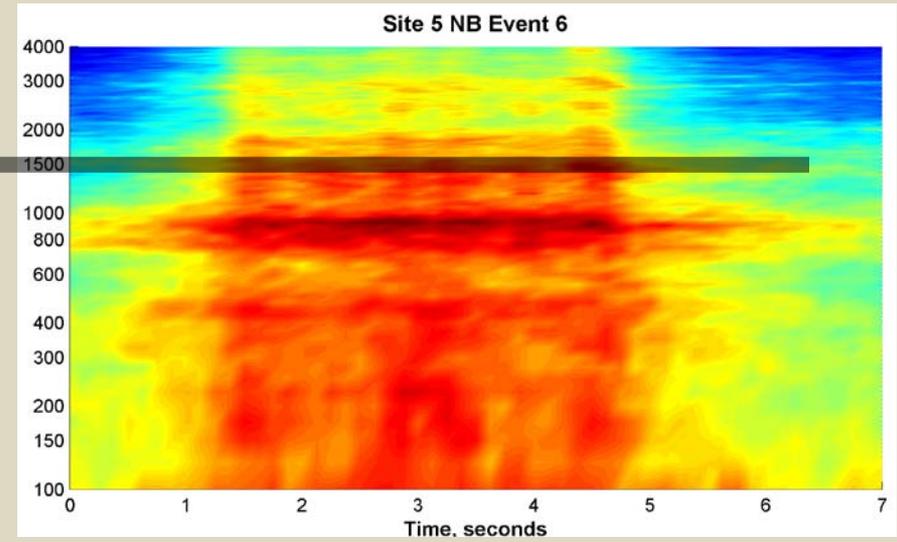
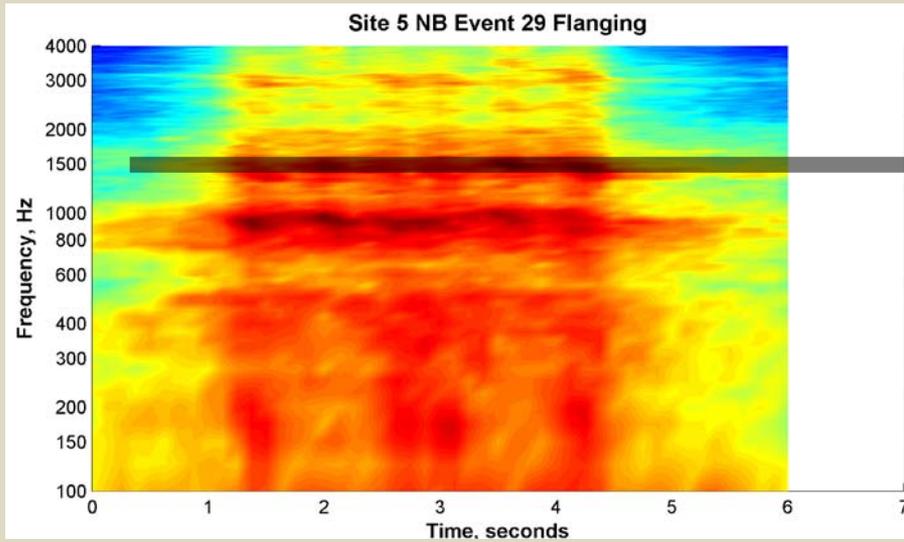
**A-Weighted Train Noise at Site 3, NB Track (All)**



# 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