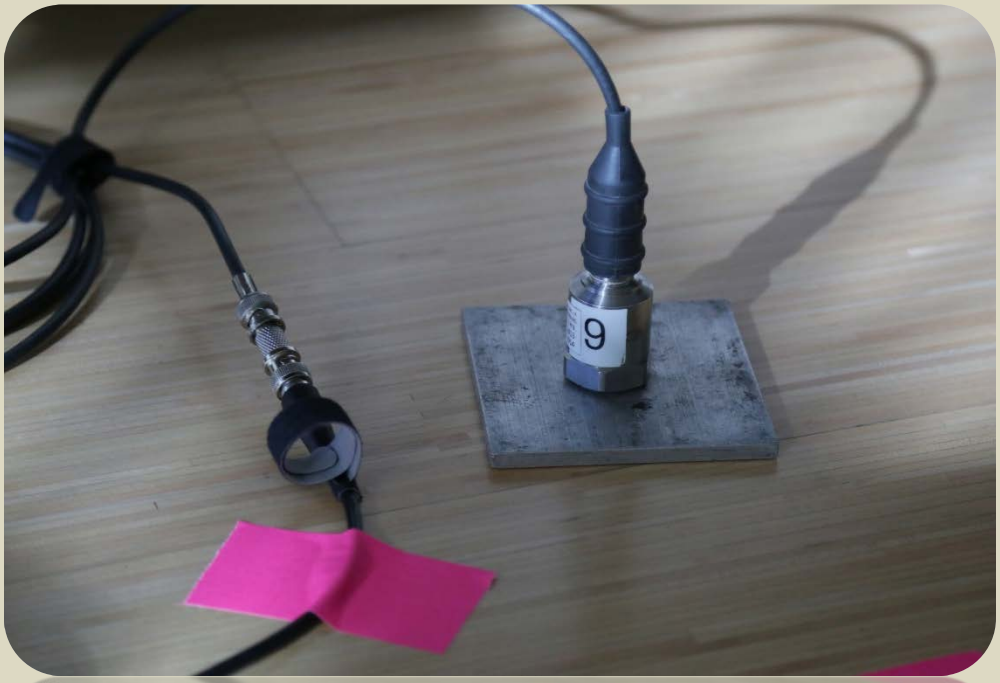
Ground-borne Noise
Evaluations and Considerations



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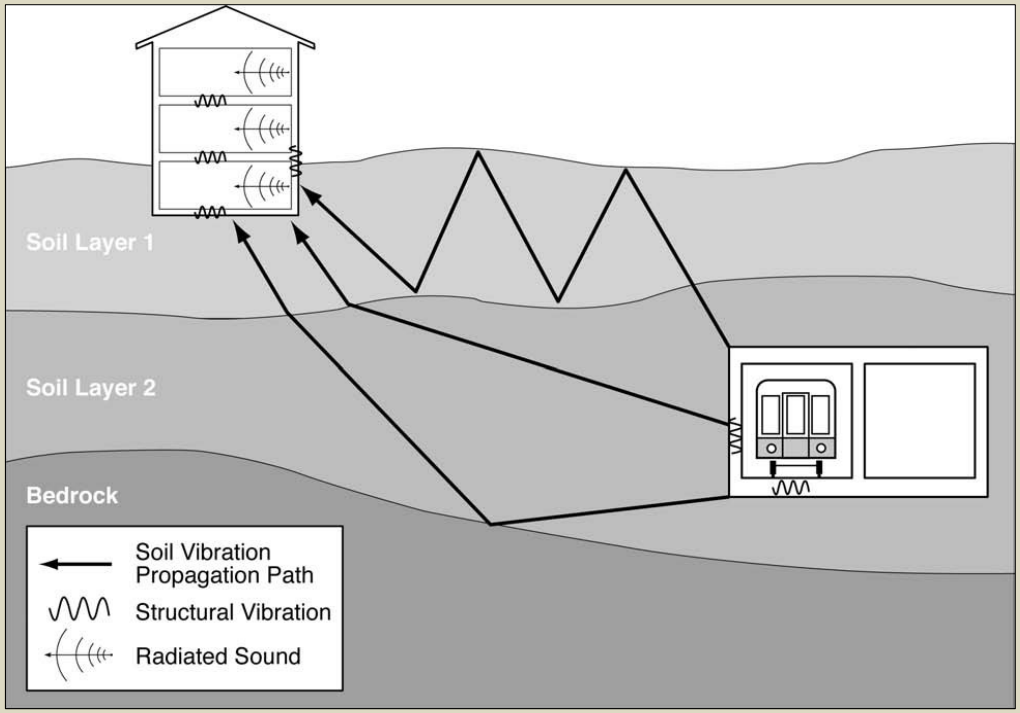
Light rail projects

- Projects require examination of potential vibration impacts to residences or other sensitive buildings

- Vibration from trains propagates away from tracks and into foundations of nearby buildings

- Potential effects:
  - feelable movement
  - rattling of windows
  - shaking of items on shelves or walls
  - rumbling sounds



Source: FTA Guidance

Ground-borne noise (GBN)

- Vibration of room surfaces radiate sound pressure waves much like giant loudspeakers … can be perceived as low-frequency rumble noise

- Vibration is not just a rail project phenomenon!
  - Highway construction
  - Roads with discontinuities (e.g., changes in pavement type or cracks), especially with heavy trucks and buses
  - Bridges

Ground-borne noise (GBN)

- How big of problem is it?
  - TCRP D-12 (rail transit study):
    - Limited complaints, mostly near particular transit systems
    - Train-induced ground-borne noise loudest in 31.5-100 Hz range (peaked in the 40 to 80 Hz range)
    - Airborne noise may reduce likelihood that it will be noticed, but airborne noise *mitigation* could lead to increased sensitivity to it

- How do you calculate it?
  - Sound pressure level (Lp), vibration velocity level (Lv)

    Lp = Lv - 5 dB (TCRP D-12)
  - Lv calculation in FTA guidance

FTA guidance to determine impacts

Land Use Category*	Ground-Borne Noise Impact Levels** (dBA)		
	Frequent Events	Occasional Events	Infrequent Events
Cat 1: vib would interfere with operations	n/a	n/a	n/a
Cat 2: residential or buildings where people sleep	35	38	43
Cat 3: institutional land uses – primarily daytime use	40	43	48

*special buildings have other limits
**max level

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Typical FTA applications

- For special buildings (e.g., recording studios, theaters) ➔ GBN is evaluated

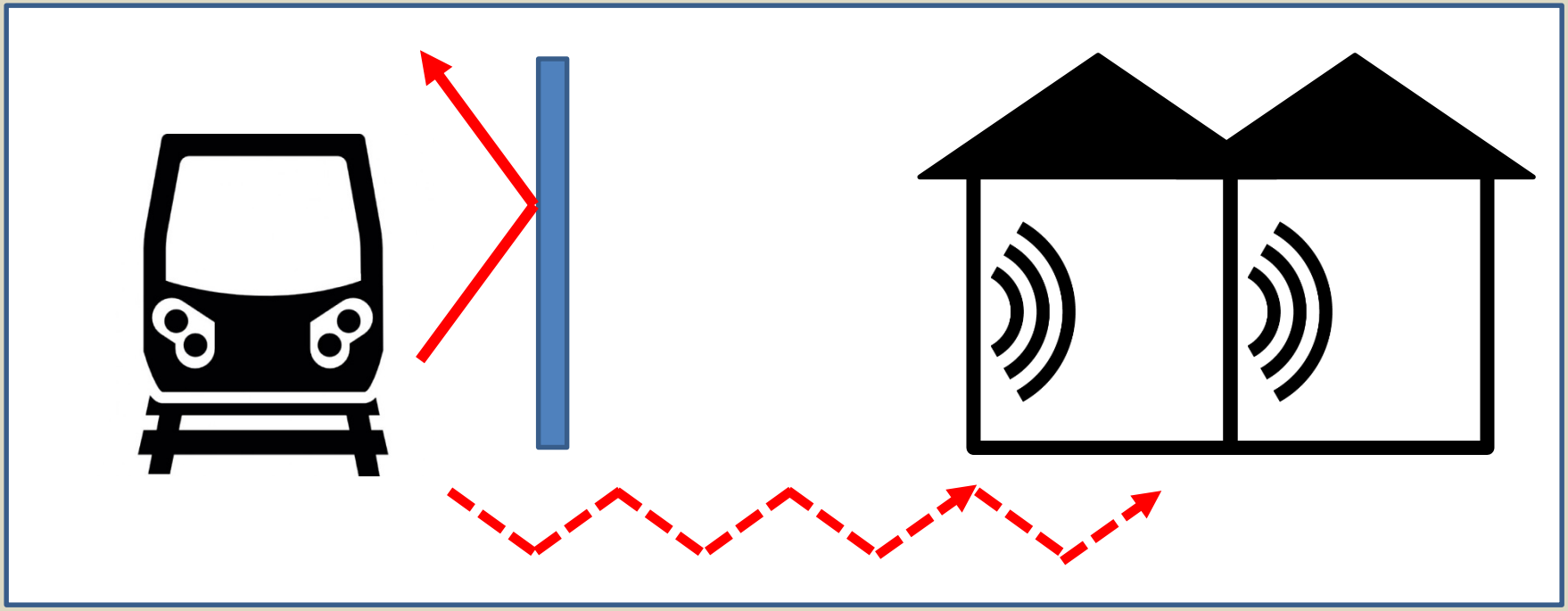
- Rail alignment underground or in trench ➔ GBN is evaluated

- For surface rail systems, evaluating GBN is debatable
  - Airborne rail noise will be louder than GBN ➔ no need to evaluate

  OR …

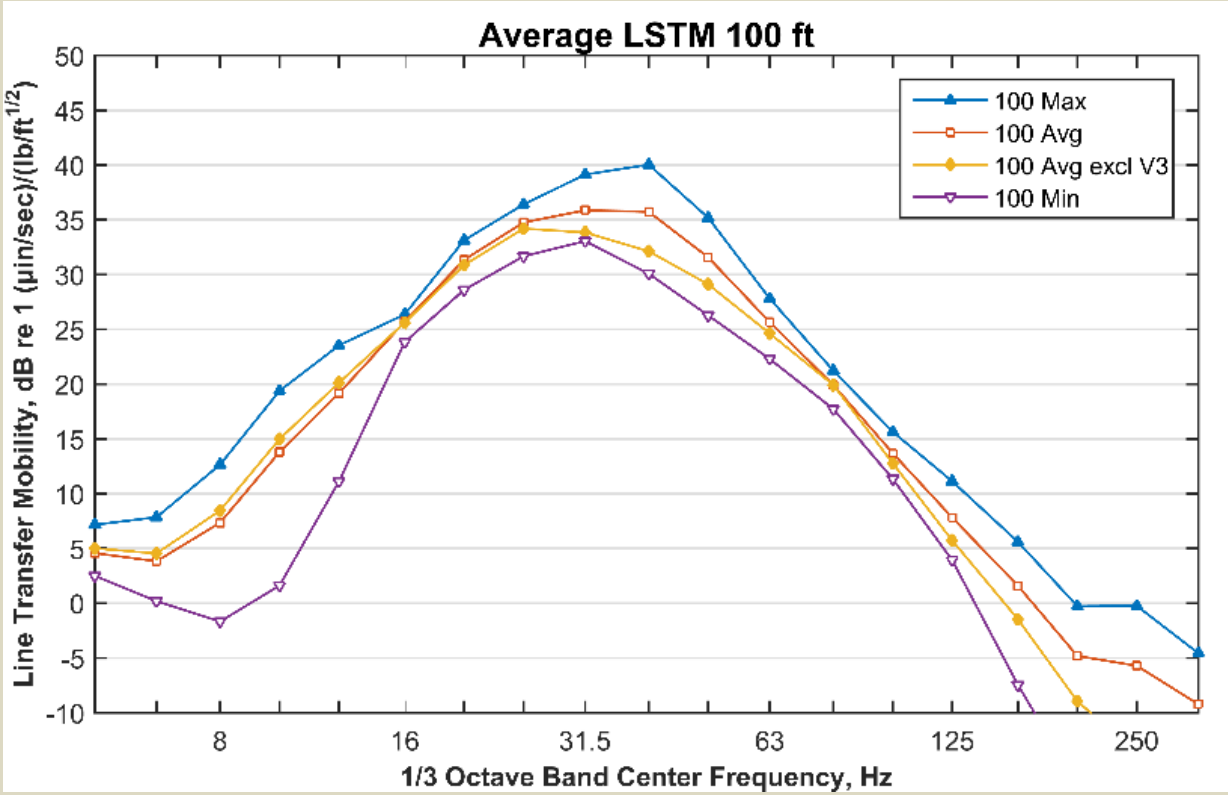
Reasons for evaluating GBN for surface rail

- Airborne noise from trains may be shielded by …
  - Other buildings or portions of buildings
  - Mitigation that is designed to block noise
  - Terrain that may block propagation path



Reasons for evaluating GBN for surface rail

- Vibration propagation may be very efficient
  - Example of efficient propagation (measured by ATS)



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Evaluating GBN impacts

- Direct comparison of predicted GBN to FTA limits
  - What does it mean to base GBN impacts on *maximum* levels?
    - Level limits are fairly low (35 dBA residential) – exceeded easily?
    - Airborne noise applies Ldn (residential) and Leq (institutional) for limits, why not GBN?
  - What does it mean to have a limit *not* based on existing noise?
    - Particularly in urban areas, this may result in an overly conservative number of impacts
    - Airborne noise limits are based on existing noise, why not GBN?

Evaluating GBN impacts

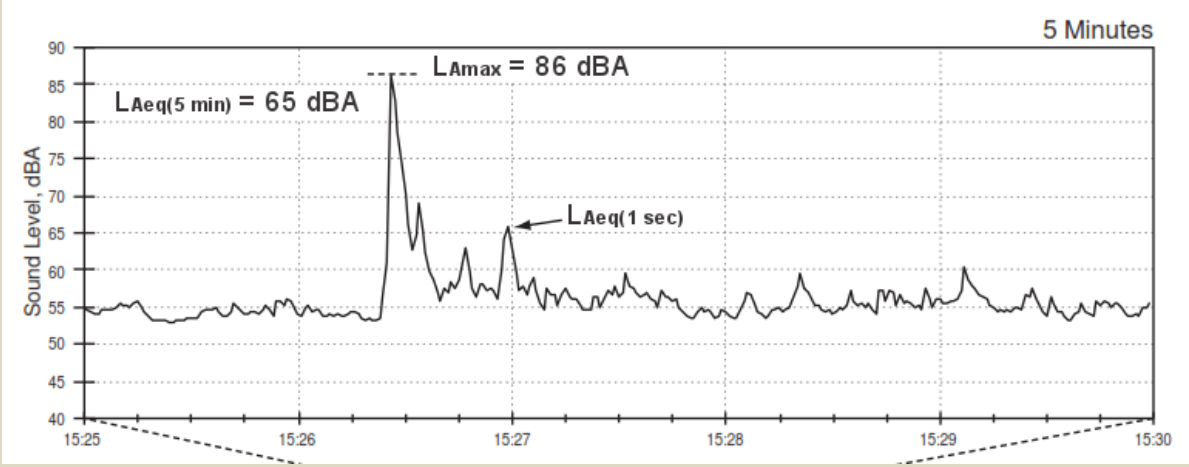
- Other options for limits
  - What if operational airborne train noise masks GBN (and you know airborne noise will not be mitigated)?
    - Could compare predicted max GBN to max train noise (interior level)
    - Could convert max GBN to Ldn or Leq based on operations and compare to predicted train noise (interior level)
  - What if existing noise masks GBN?
    - Could convert max GBN to Ldn or Leq based on operations and compare to existing noise (interior level)

Example scenario: GBN masked by train noise

- Residential
- GBN = 50 dBA interior max
- Unmitigated train noise = 86 dBA exterior max – 25 = 61 dBA interior max

- Apply FTA limit: 50 dBA > 35 dBA ➔ impact
- Apply comparison to max train noise: 50 dBA < 61 dBA, also < 61 – 5 = 56 dBA

  (5 dB less would mathematically contribute no more than 1 dB) ➔ no impact



Source: FTA Guidance

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Example scenario: GBN *not* masked by mitigated train noise

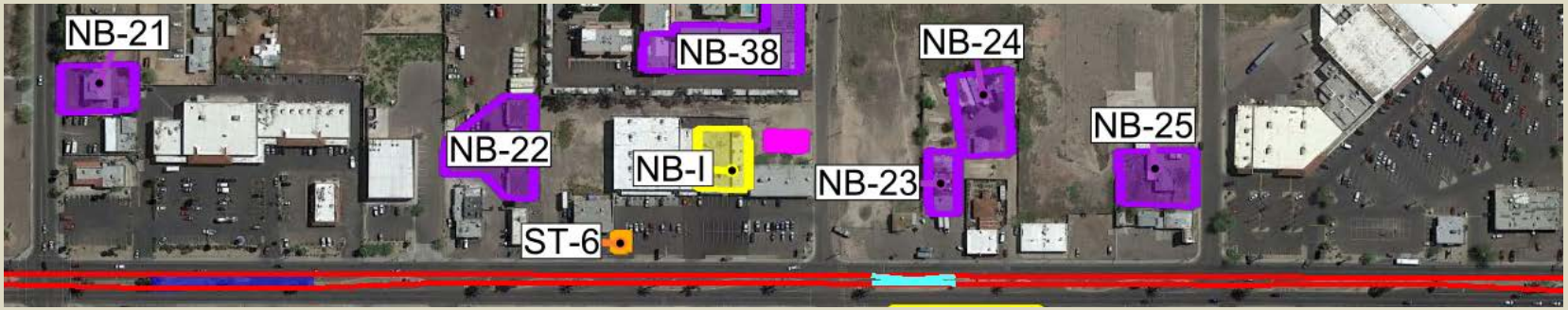
- Same receiver, GBN = 50 dBA interior max
- Mitigated train noise = 86 – 10 = 76 dBA exterior max – 25 = 51 dBA interior max

- Apply FTA limit: 50 dBA > 35 dBA ➔ impact
- Apply comparison to train noise: 50 dBA < 51 dBA, BUT > 51 – 5 = 46 dBA

  (within 5 dB would mathematically contribute more than 1 dB) ➔ impact

Real case 1

- At-grade alignment in area of moderate existing noise
- Calculated max GBN
- Set limit to predicted operational train max level
- Impacts found
  - GBN and vibration impacts found at several receivers
  - At some locations, GBN impact and no vibration impact – due to efficient vibration propagation at mid-range frequencies
- Impacts avoided
  - Some properties would have had predicted impacts if comparing to FTA limits, which were too low in these cases



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Real case 2

- At-grade alignment adjacent to highway – high existing noise
- Calculated max GBN and converted to Ldn for residences
- Set limit at 5 dB below interior existing noise (exterior minus 25 dB)
- Impacts found
  - GBN impacts found at some of the vibration-impacted receivers
- Impacts avoided
  - Some properties would have had predicted impacts if comparing to FTA limits, which were too low in these cases

Conclusions

- Analyzing GBN for at-grade alignments can find potential impacts
- Applying FTA criteria may over-estimate number or severity of impacts
- Case-dependent limits should be considered, perhaps based on …
  - Predicted operational train noise, when that source will be dominant
  - Existing noise when nearby sources will be dominant