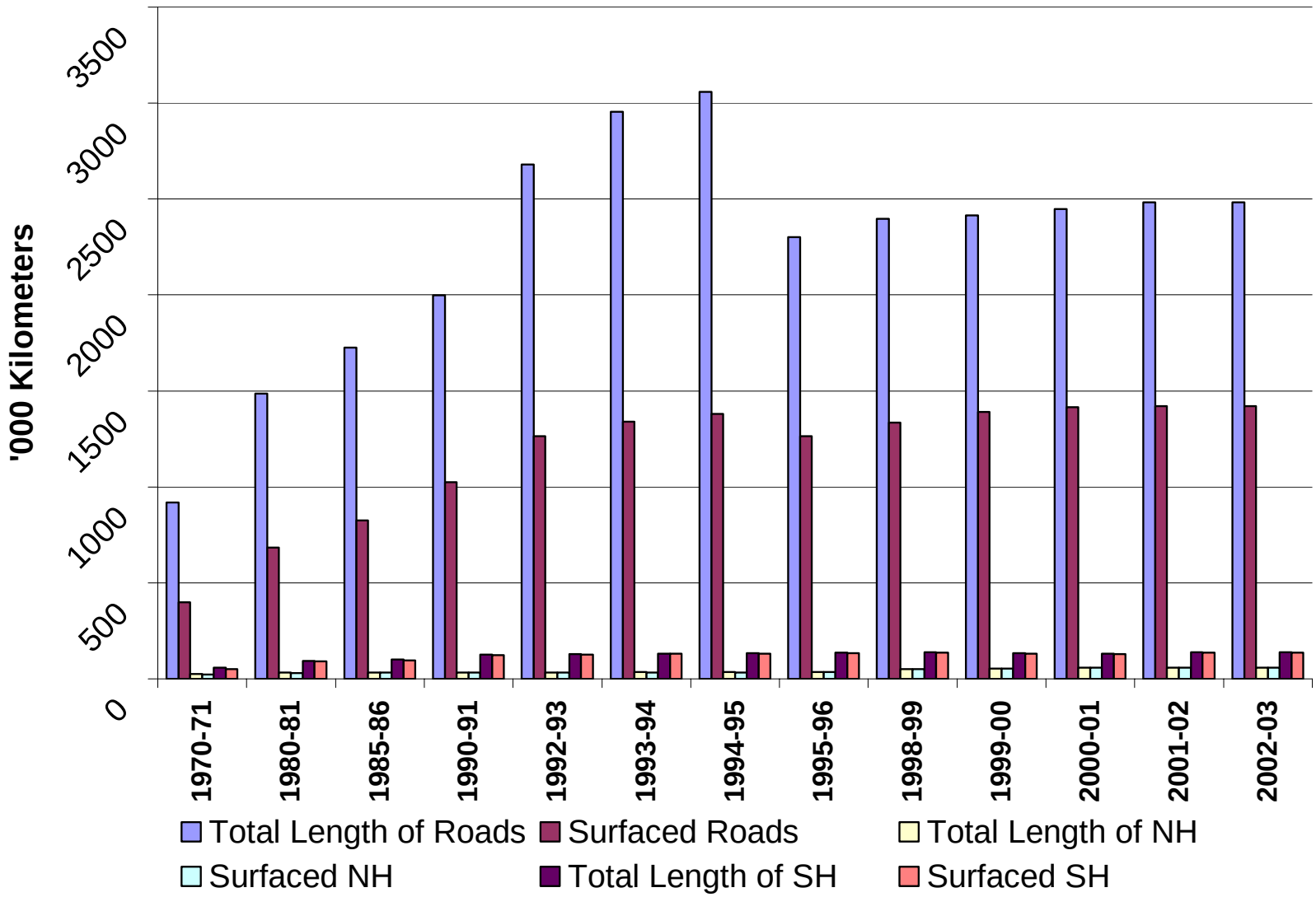
Transportation Vibration Measurement

Transportation Vibration Measurement

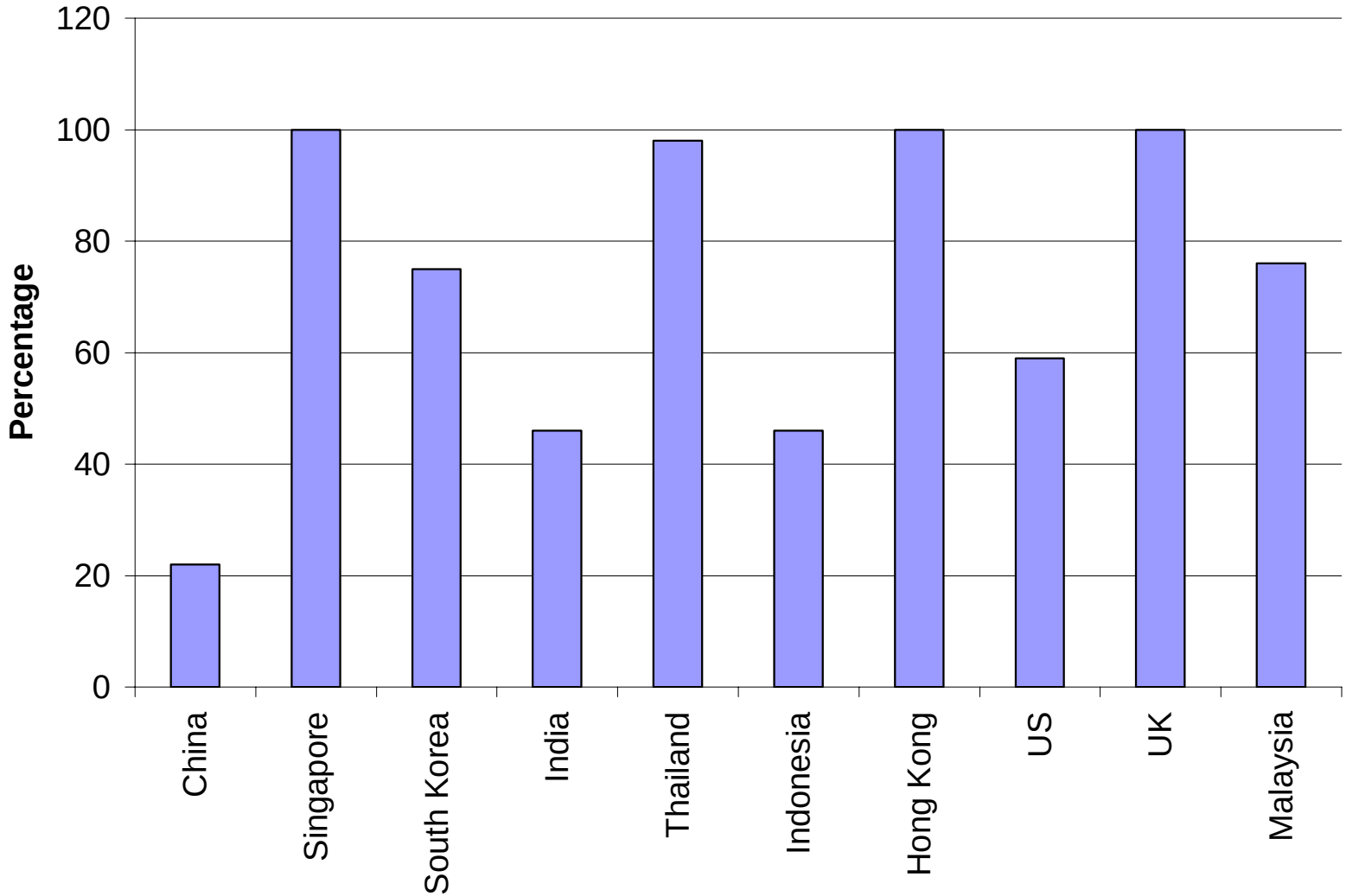
- Free trade agreements have been on the rise in all regions of the world in the past decade.
- This has allowed for global distribution and marketing of products in an international market.
- Countries such as Mexico, China, India, Malaysia, even Vietnam are now regularly mentioned when many of us discuss the logistics involved in our respective distribution systems.

Measurement and Analysis of Truck and Rail Shipping Environment in India

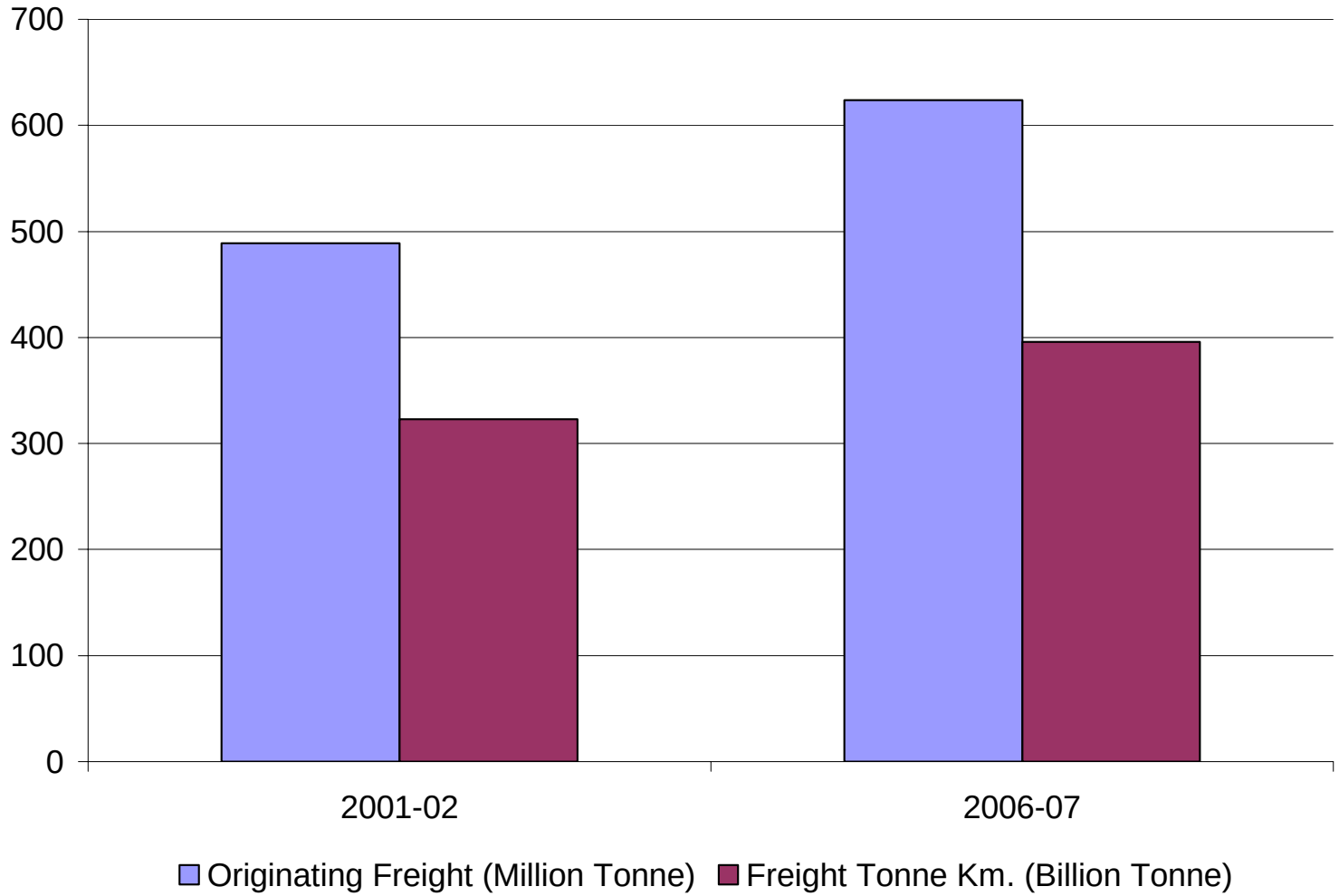
Truck and Rail Transportation Routes Investigated in India



Total and Surfaced National and State Highways in India



Roads Paved: Percentage of Total Roads



Projection for Railway Freight Traffic in India

Instrumentation

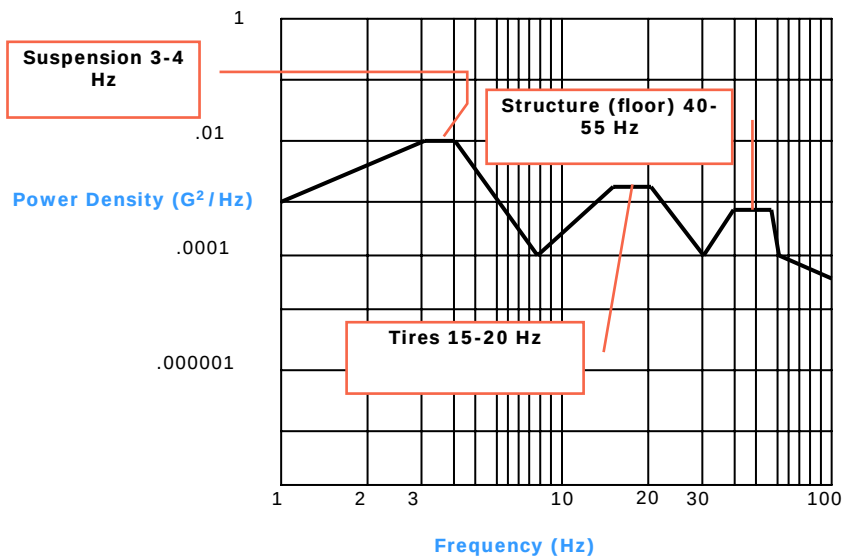
- Minimum Time Triggered Sampling: 10 min
- Trigger Threshold Level: 2.4G
- Minimum Sampling Rate: 651 samples per second
- Minimum Recording Window: 1.57 seconds
- Sample Size: 1024
- Temperature/Humidity Intervals: Same as Vibration Sampling

Recorder Mounting

- The recorders were mounted directly on to the vehicle (truck and rail) platform base.
- The recorders had a mounting platform that was bolted to the base of the trailer or rail car floor.
- The recorders were always mounted at the rear location of the truck bed and were positioned on the curbside corner.
- This allowed measurements of the highest levels of vibration conditions.

Power Spectral Density Spectrums

- A typical power spectral density (PSD) function shows the strength of the variations (energy) as a function of frequency.
- It shows at which frequencies variations are strong and at which frequencies variations are weak.
- The unit of PSD is energy (Power Density in G^2/Hz) versus frequency (Hz).

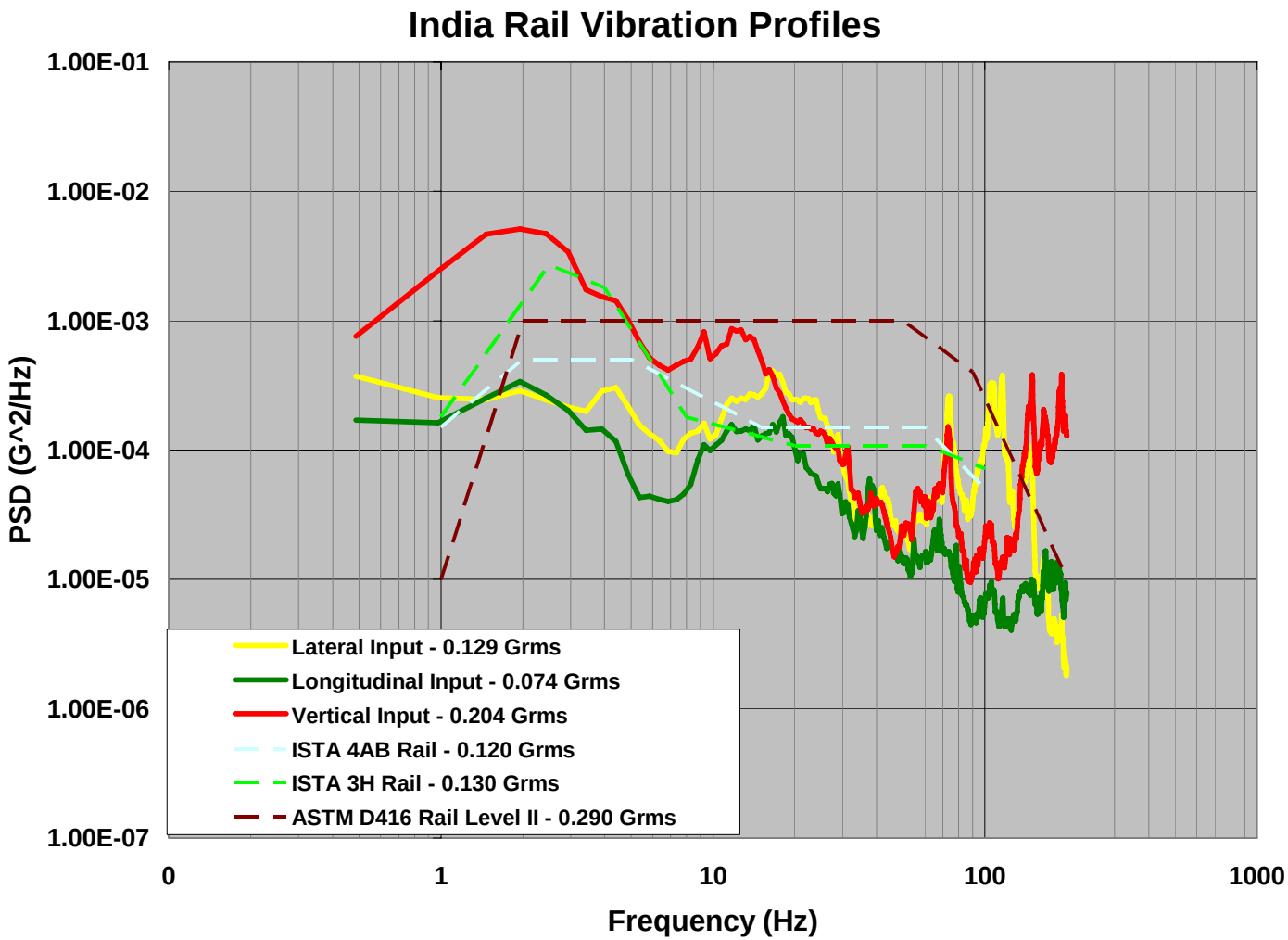


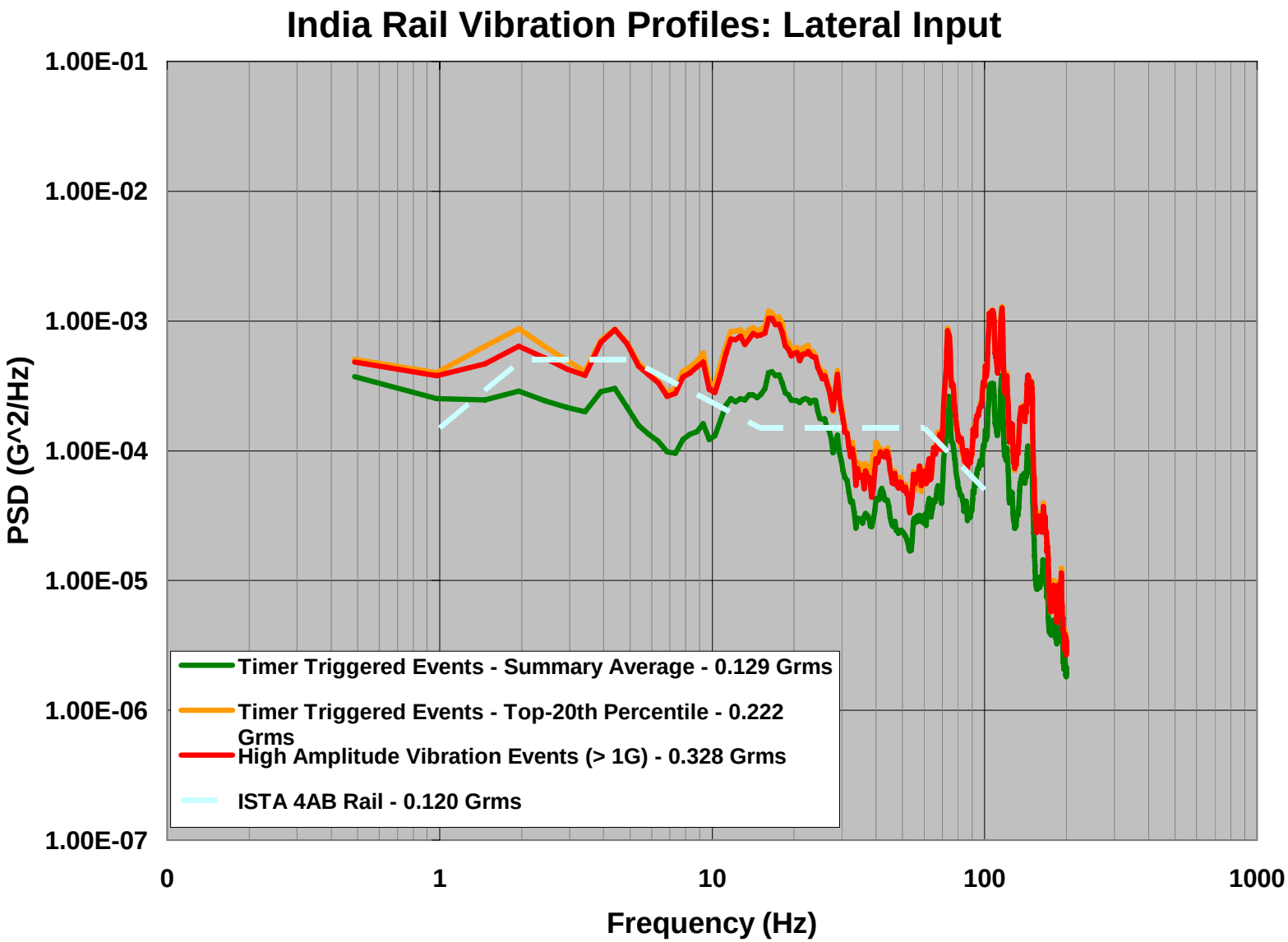
A Typical PSD Plot for Truck Transportation (US)

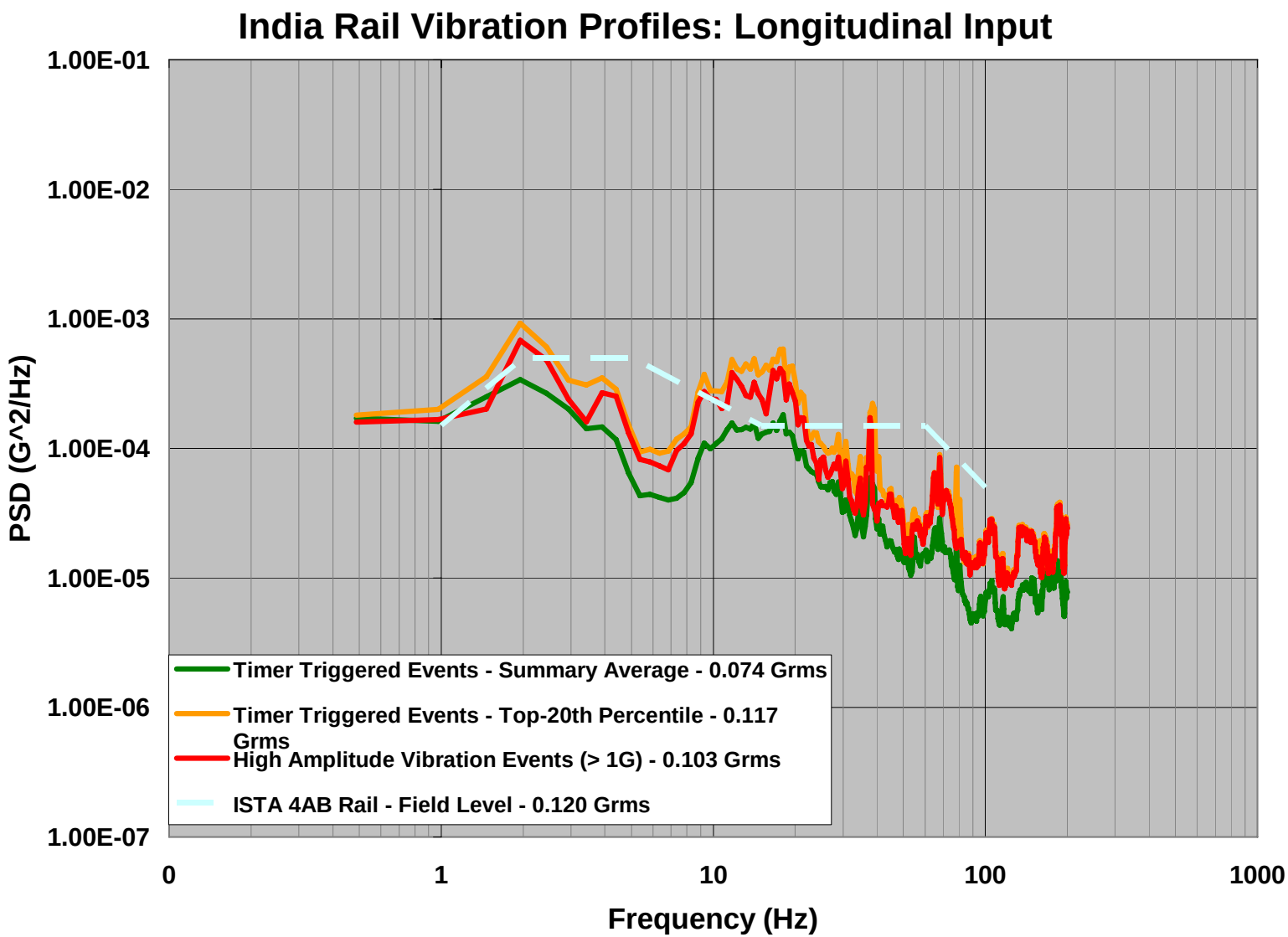
Objectives

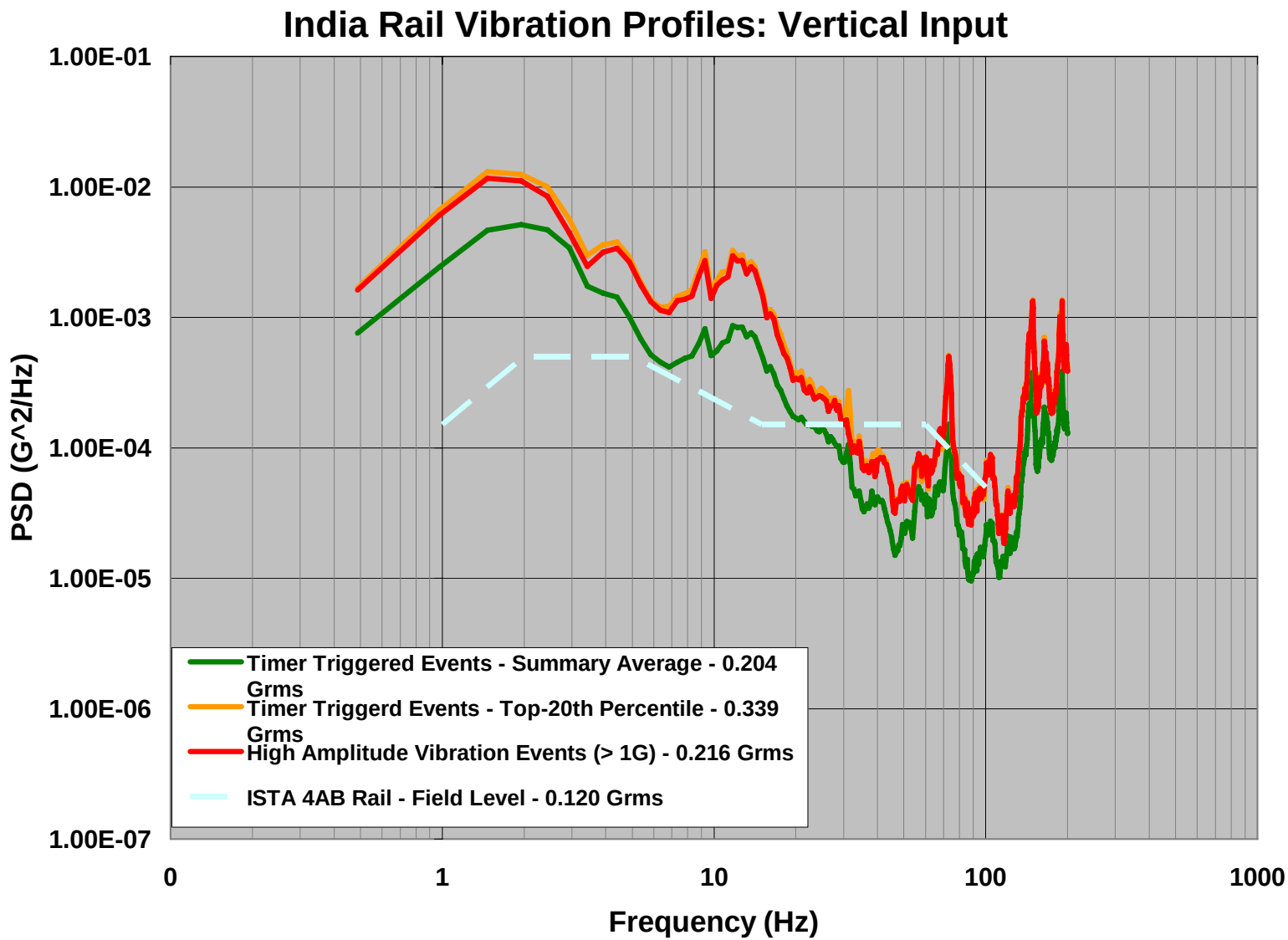
- Measure vibration levels in truck and rail shipments of freight to various major domestic and international regions
- Compare the vibration levels in trucks versus railcars.
- Develop lab simulated vibration test methods to simulate truck and rail shipments.

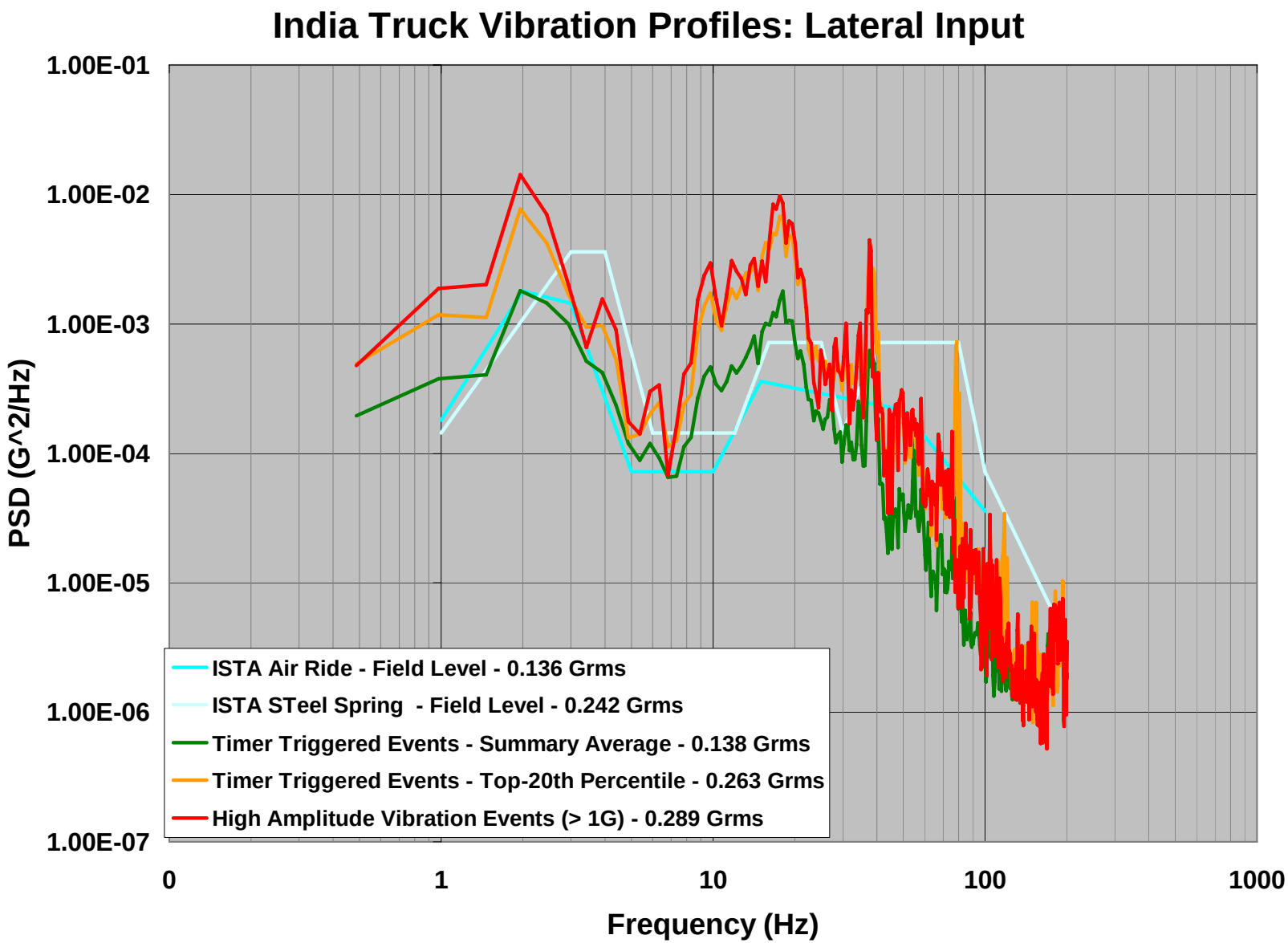
Results

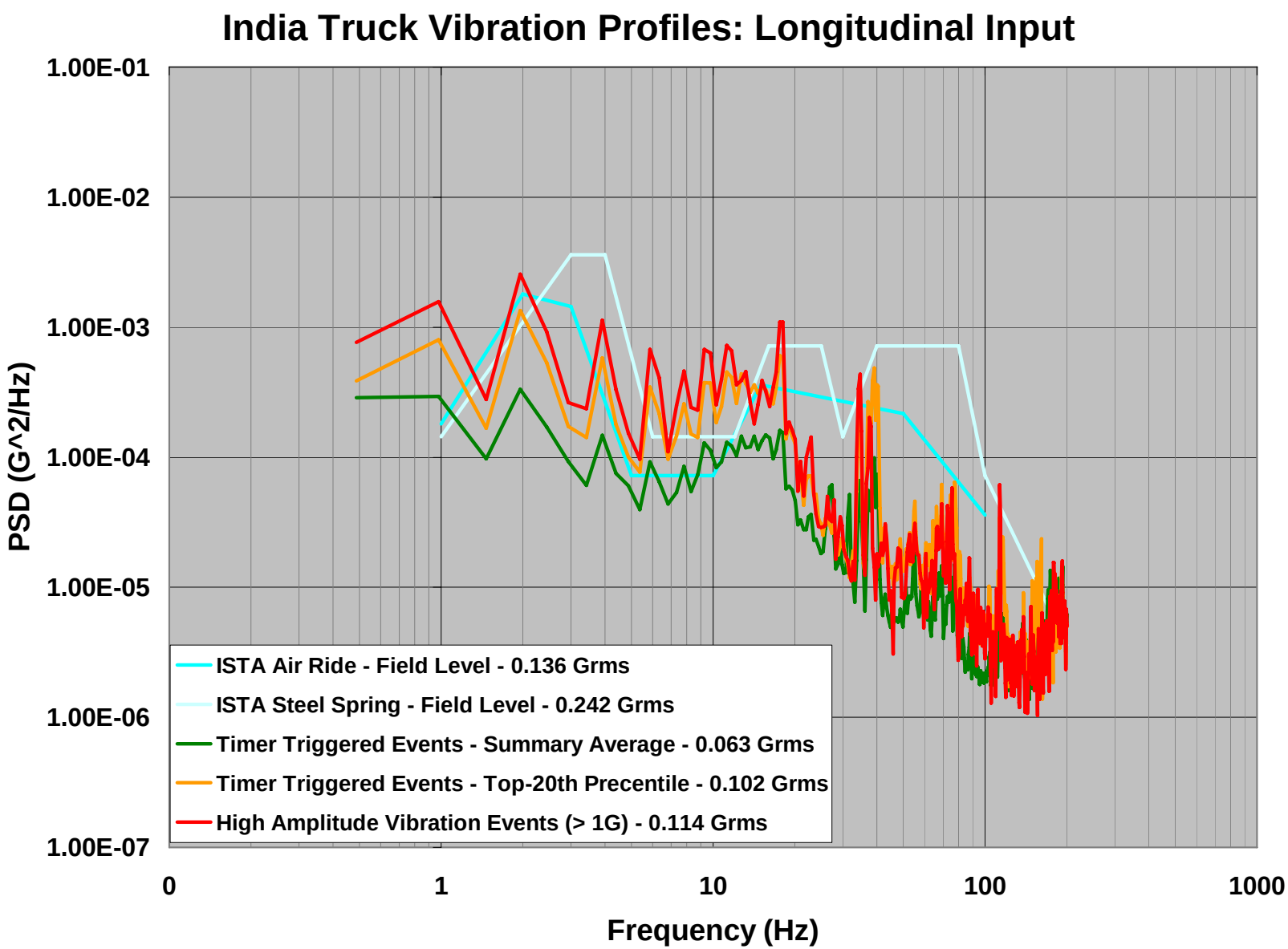

India Rail Vibration Profiles
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1.00E-06
1.00E-07
PSD (G^2/Hz)
0
1
10
100
1000
Frequency (Hz)
Lateral Input - 0.129 Grms
Longitudinal Input - 0.074 Grms
Vertical Input - 0.204 Grms
ISTA 4AB Rail - 0.120 Grms
ISTA 3H Rail - 0.130 Grms
ASTM D416 Rail Level II - 0.290 Grms

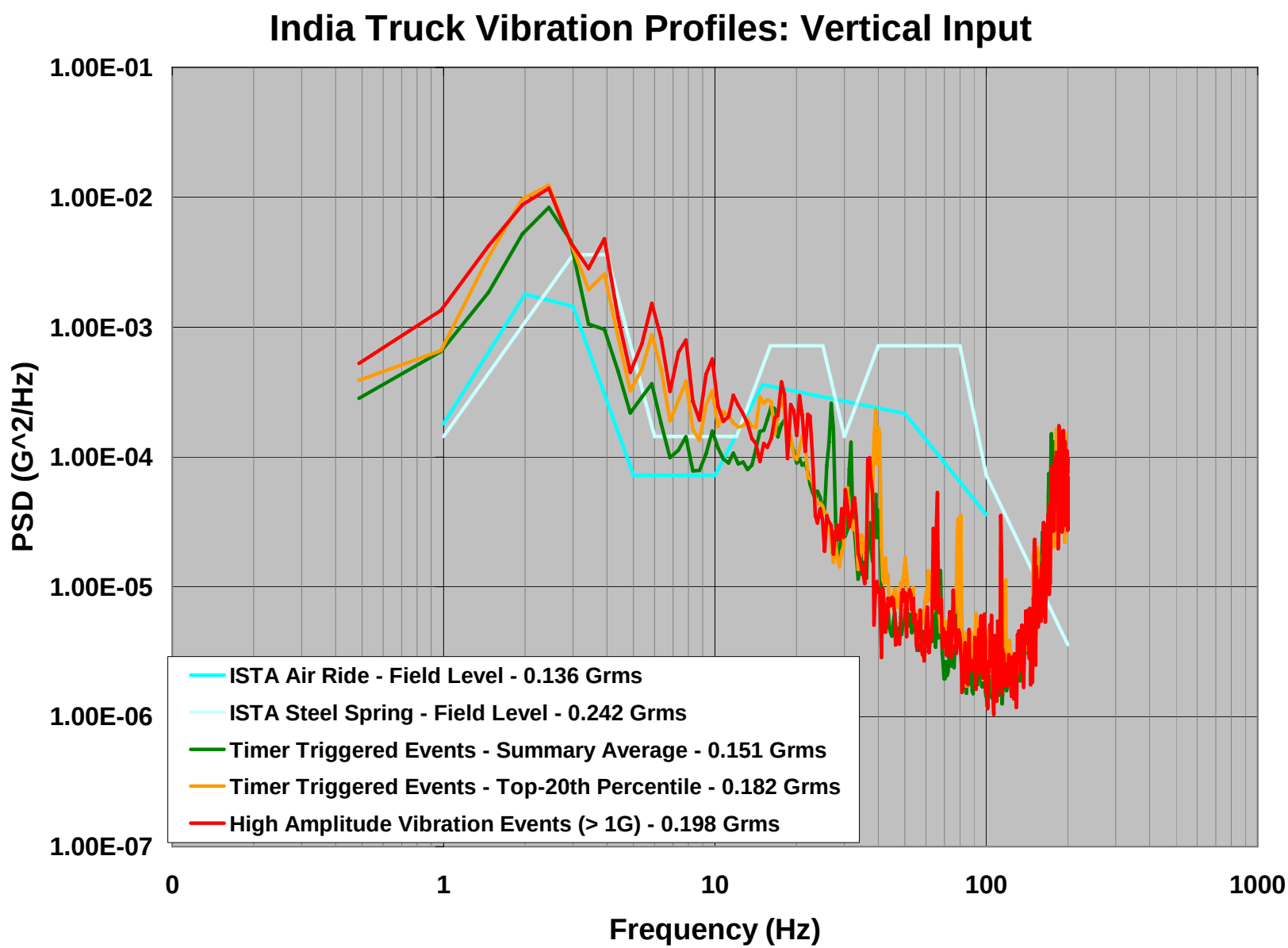

India Rail Vibration Profiles: Lateral Input
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1.00E-06
1.00E-07
PSD (G^2/Hz)
0
1
10
100
1000
Frequency (Hz)
Timer Triggered Events - Summary Average - 0.129 Grms
Timer Triggered Events - Top-20th Percentile - 0.222 Grms
High Amplitude Vibration Events (> 1G) - 0.328 Grms
ISTA 4AB Rail - 0.120 Grms


India Rail Vibration Profiles: Longitudinal Input
PSD (G^2/Hz)
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1.00E-06
1.00E-07
0
1
10
100
1000
Frequency (Hz)
Timer Triggered Events - Summary Average - 0.074 Grms
Timer Triggered Events - Top-20th Percentile - 0.117 Grms
High Amplitude Vibration Events (> 1G) - 0.103 Grms
ISTA 4AB Rail - Field Level - 0.120 Grms


India Rail Vibration Profiles: Vertical Input
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1.00E-06
1.00E-07
PSD (G^2/Hz)
0
1
10
100
1000
Frequency (Hz)
Timer Triggered Events - Summary Average - 0.204 Grms
Timer Triggerd Events - Top-20th Percentile - 0.339 Grms
High Amplitude Vibration Events (> 1G) - 0.216 Grms
ISTA 4AB Rail - Field Level - 0.120 Grms


India Truck Vibration Profiles: Lateral Input
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1.00E-06
1.00E-07
PSD (G^2/Hz)
0
1
10
100
1000
Frequency (Hz)
ISTA Air Ride - Field Level - 0.136 Grms
ISTA STeel Spring - Field Level - 0.242 Grms
Timer Triggered Events - Summary Average - 0.138 Grms
Timer Triggered Events - Top-20th Percentile - 0.263 Grms
High Amplitude Vibration Events (> 1G) - 0.289 Grms


India Truck Vibration Profiles: Longitudinal Input
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1.00E-06
1.00E-07
PSD (G^2/Hz)
0
1
10
100
1000
Frequency (Hz)
ISTA Air Ride - Field Level - 0.136 Grms
ISTA Steel Spring - Field Level - 0.242 Grms
Timer Triggered Events - Summary Average - 0.063 Grms
Timer Triggered Events - Top-20th Precentile - 0.102 Grms
High Amplitude Vibration Events (> 1G) - 0.114 Grms


India Truck Vibration Profiles: Vertical Input
PSD (G^2/Hz)
1.00E-01
1.00E-02
1.00E-03
1.00E-04
1.00E-05
1.00E-06
1.00E-07
0
1
10
100
1000
Frequency (Hz)
ISTA Air Ride - Field Level - 0.136 Grms
ISTA Steel Spring - Field Level - 0.242 Grms
Timer Triggered Events - Summary Average - 0.151 Grms
Timer Triggered Events - Top-20th Percentile - 0.182 Grms
High Amplitude Vibration Events (> 1G) - 0.198 Grms

Results

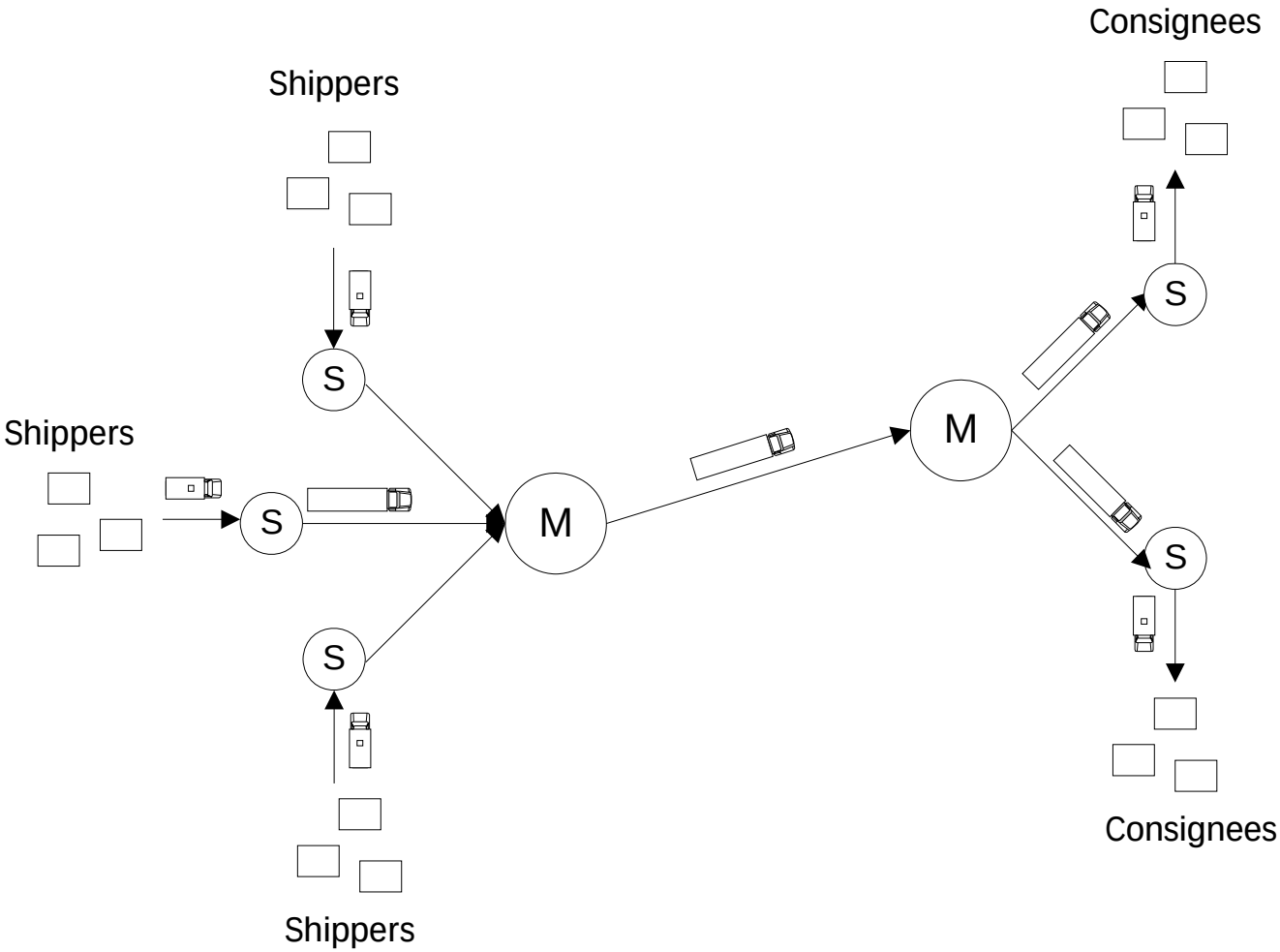
Spectrum	Type	Transportation Method	Orientation	Level (Grms)
1	*Measured*	Rail	Vertical	0.204
2	*Measured*	Rail	Lateral	0.129
3	*Measured*	Rail	Longitudinal	0.074
4	*Test Method ISTA 4AB*	Rail	Vertical	0.12
5	*Test Method ISTA 3H*	Rail	Vertical	0.13
6	*Test Method ASTM D 4169 Lev II*	Rail	Vertical	0.29
7	*Measured*	Truck	Vertical	0.161
8	*Measured*	Truck	Lateral	0.138
9	*Measured*	Truck	Longitudinal	0.063
10	*Test Method ISTA 4AB*	Truck – Leaf Spring	Vertical	0.242
11	*Test Method ISTA 4AB*	Truck – Air Ride	Vertical	0.136
12	*Test Method ASTM D4169 Lev II*	Truck	Vertical	0.519

Composite Spectrum for Truck Vertical Vibration in India

S. No.	Frequency (Hz)	Power Density (G^2/Hz)
1	1	0.006
2	2	0.01
3	3	0.01
4	4	0.001
5	7	0.0002
6	20	0.0002
7	100	0.00002

Composite Spectrum for Rail Vertical Vibration

S. No.	Frequency (Hz)	Power Density (G^2/Hz)
1	1	0.0003
2	1.5	0.0005
3	3	0.0005
4	7	0.00006
5	9	0.00008
6	12	0.00008
7	50	0.00001
8	100	0.00001



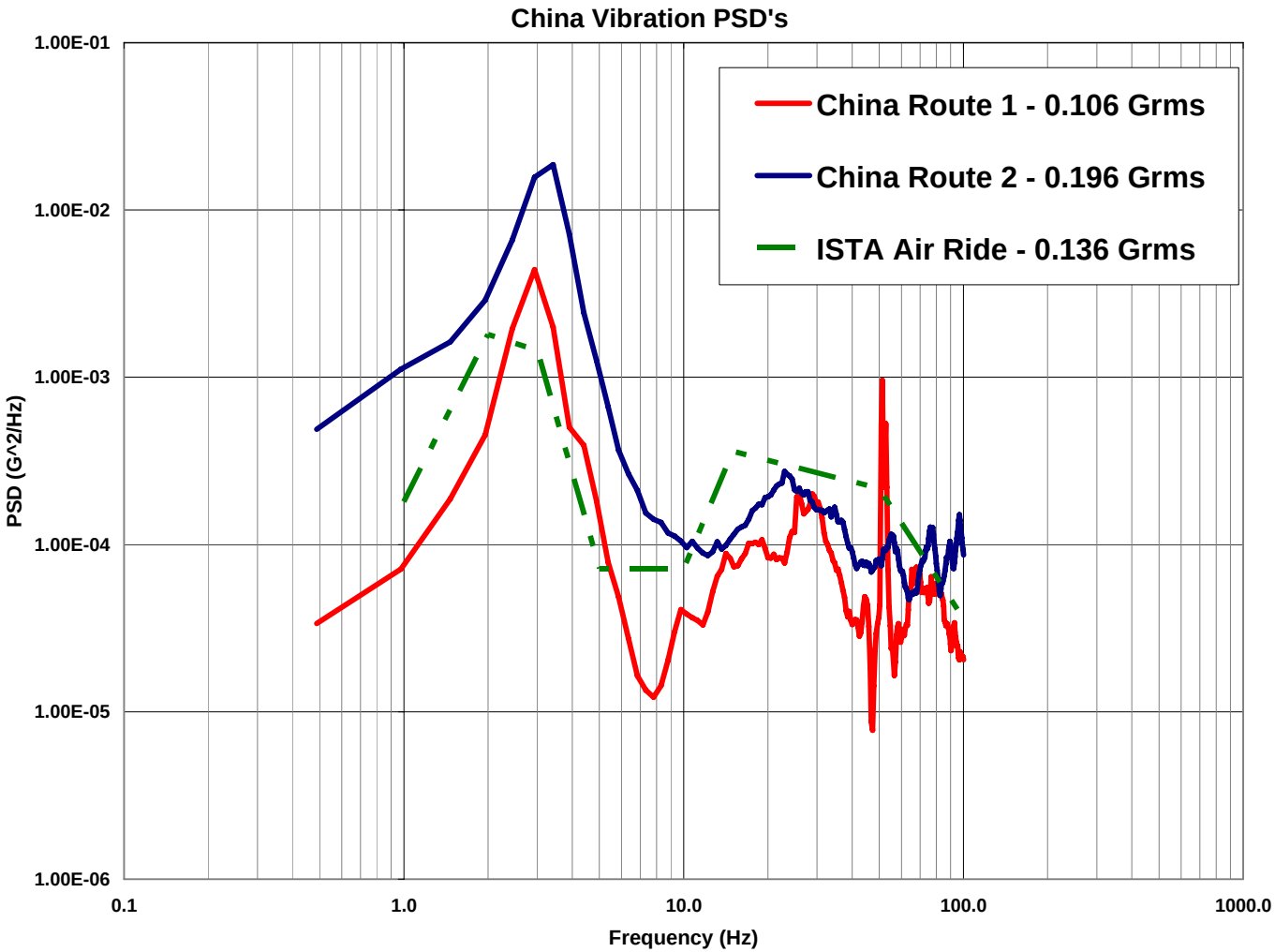
S: Satellite Terminal

M: Main Terminal

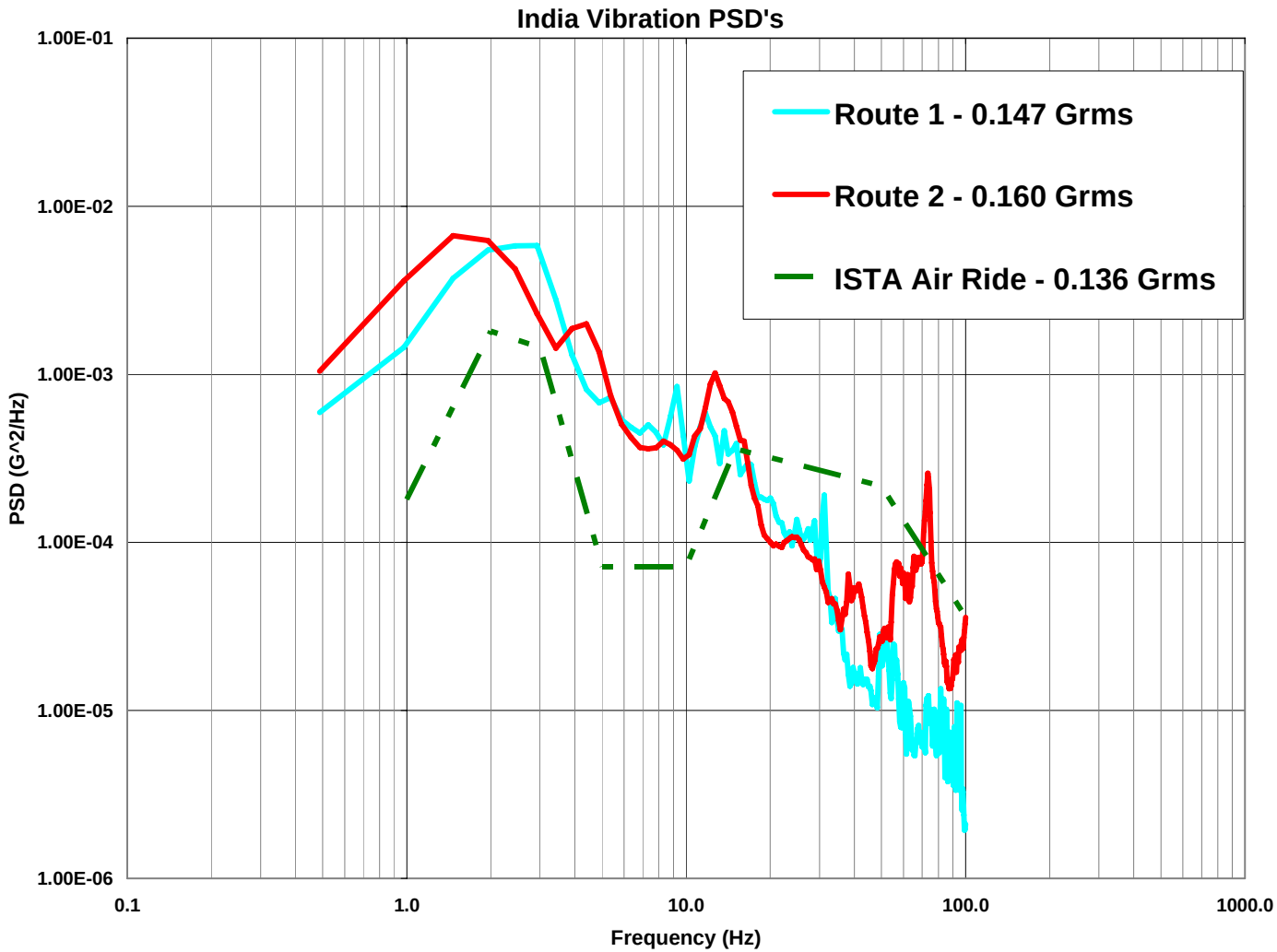
Less-than-Truckload (LTL) operations

DATA SPECTRUMS

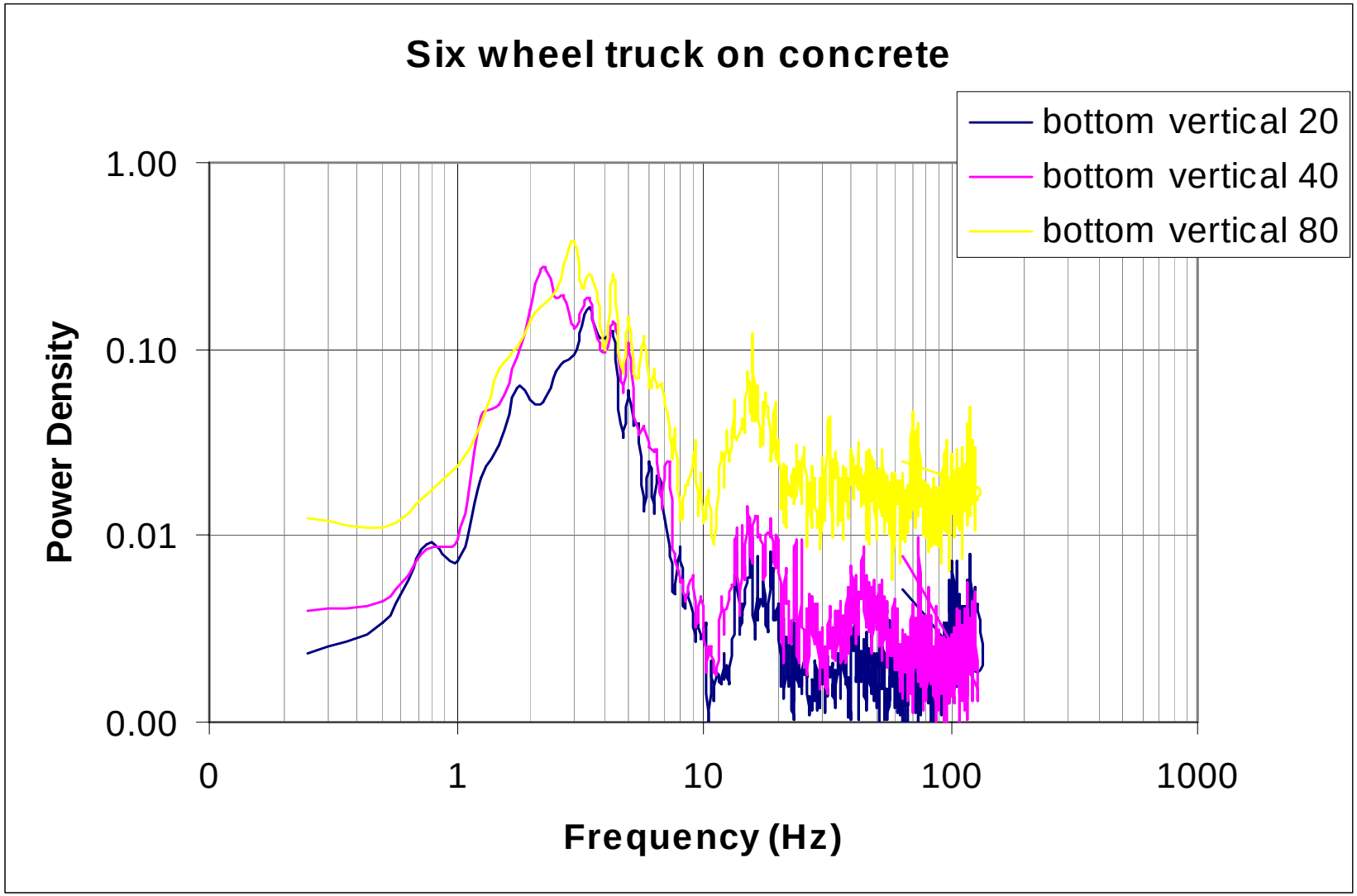
- Some sample power density spectrums from various segments of transportation measurements conducted in the past year globally are shown on the next slides.
- This data is not be used for any simulation purposes since they reflect partial segments of the measured environment.
- The intent is to show how the data varies in different regions when compared to levels recommended in existing other ISTA and ASTM test methods.



Vertical (bottom of trailer) Power Spectral Density (PSD) Spectrums from Eastern China, expressway, half-loaded, open trailer



Vertical (bottom of trailer) Power Spectral Density (PSD) Spectrums from India



Vertical (bottom of trailer) *PD* Spectrums for Six Ton Truck on Concrete at Three Traveling Speeds of 20, 40 and 80 km/h in Thailand

Brazil Study

- Recently completed and published he truck distribution environment in Brazil

Measurement	Day	City
1	**1**	**RJO – Rio de Janeiro (RJ)**
2	**2**	**CPN – Campinas (SP)**
3	**3**	**SPO – São Paulo (SP)**
4	**4**	**CWB – Curitiba (PR)**
5	**5**	**VDA – Videira (SC)**
6	**8**	**IAI/ FLN – Itajaí (SC)**
7	**9**	**POA – Porto Alegre (RS)**
8	**10**	**MRU – Marau (RS)**
9	**13**	**RVE – Rio Verde (GO)**
10	**16**	**REC – Recife (PE)**


VENEZUELA
COLOMBIA
GUYANA
SURI-NAM
FR. GUAYANA
Belém
Manaus
Amazonas
Fortaleza
Porto Velho
Recife
10
Salvador
PERU
Brasilia
BOLIVIA
Belo Horizonte
Vitória
9
1
2
3
4
PARAGUAY
CHILE
Curitiba
Rio de Janeiro
San Pablo
5
6
7
8
ARGENTINA
Porto Alegre
URUGUAY

Conclusions

- Comparison of the India Project data for both truck and rail vibration as compared to the ASTM and ISTA shows that the measured vertical vibration levels are more severe than levels used for existing test methods.
- The measured levels in lateral should be used in conjunction with vertical levels for packages and products that may not be perfectly cubed in the trailer and result in void spaces. The truck and rail vibration data shows excessive lateral and longitudinal movement in Asia and S. America.

Conclusions

- Recognition and appreciation for the higher intensity vibration as compared to levels from North America and Europe.
- There is a difference between vibration levels in “truck” versus “rail” shipments and are at different frequencies than those observed in North America and Europe.

Reference MSU CDP studies

1. Garcia-Romeu-Martinez, M., Singh, P., Cloquell-Ballester, V. “Measurement and Analysis Levels for Truck Transport in Spain as a Function of Payload, Suspension and Speed,” In Print. Published online in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/pts.798
2. Rissi, G. O., Singh S. P., Burgess, G., Singh, J. “Measurement and Analysis of Truck Transport Environment in Brazil,” Packaging Technology and Science, Published online in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/pts.797
3. Singh, S. P., Singh, J., Gaur, P., Saha, K. “Measurement and Analysis of Vibration Levels on Warehouse and Retail Store Material Handling Equipment,” Journal of Applied Packaging Research, Vol. 2, No. 2, December 2007
4. Singh, S. P,, E. Joneson, J. Singh and G. Grewal, “Dynamic Analysis of Less than Truck Load Shipments and Test Method to Simulate this Environment”, Packaging Technology and Science, 2007.
5. Singh, S. P., A. P. S. Sandhu, E. Joneson and J. Singh, "Measurement and Analysis of Truck and Rail Shipping Environment in India”, *Accepted for publication,* Journal of Packaging Technology and Science, John Wiley and Sons, 2007.
6. Singh, J., S. P. Singh, and E. Joneson. “Measurement and Analysis of U.S. Truck Vibration for Leaf Spring and Air Ride Suspensions and Development of Tests to Simulate these Conditions”. Packaging Technology and Science, Volume 19, Issue 6, Pages 309 – 323, 2006.
7. Jarimopas B, S. P. Singh, and W. Saengnil, Measurement and Analysis of Truck Transport Vibration Levels in Thailand and Damage to Packaged Tangerines During Transit. Packaging Technology and Science, 18: 179-188, 2005.