ISO/SAE Status Report: Quiet Car

December 5, 2012

QRTV IG #2

Berlin, Germany

Overview

- Provide QRTV IG with in-progress findings of SAE/ISO workgroup.
  - Testing and measurement issues to provide accurate, repeatable, and reproducible measurement results at the test conditions identified in the NHTSA/Volpe research report on proposed sound specifications.
- Issues identified
- Ideas for improvement and optimization
- Next Steps

Comparison of SAE/ISO and VOLPE/NHTSA

Technical Point	Current ISO(16254) and SAE (J2889-1)	Volpe/NHTSA proposal
Vehicle test conditions	0 km/h (stationary) and 10 km/h cruise. Implied ability to test 0 km/h with microphones in front or rear of vehicle	0 km/h (stationary) with microphones in front and rear. 10, 20, 30 km/h cruise.
Measurement metric(s)	Overall sound pressure level (SPL, db(A)), pitch shift (% per km/h)	1/3 octave frequency at eight (8) bands in range [315 -5000] Hz
Information metric	1/3 octave frequency spectrum at value corresponding to reported SPL	Not specific, although modulation is discussed.
Indoor test	Permitted if facility requirements met	No mention. Assumed all measurements outdoors.
Component test	Permitted if facility requirements met. Practical experience shows necessary for pitch shift.	No mention.
Pitch Shift	Based on narrowband analysis and assumed foreknowledge of signal. Component test permitted.	Not specific, Tone-to-Noise ratio discussed. Assumed full vehicle test.

Data Collection Plan

- ISO/SAE developed data collection plan to address published VOLPE/NHTSA research report.
  - Work Package 1: Measurement of vehicles at the conditions outlined by NHTSA/Volpe in the published research report. Measurements include both Indoor and Outdoor evaluations.
    - Data collected to date: Background noise evaluations, vehicle measurements
  - Work package 2: Measurement of interior sound (recordings and analysis), Evaluation of transmission loss.
    - Data collected to date: Recordings available, Transmission Loss evaluated.
  - Work Package 3: Correlation of detection and recognition to proposed levels.
    - Data collected to date: Jury evaluations of detection and recognition
  - Work Package 4: Measurement of Frequency shift at conditions outlined in NHTSA/Volpe research report
    - Data collected to date: Indoor and outdoor evaluations

Presentation of data collected to date

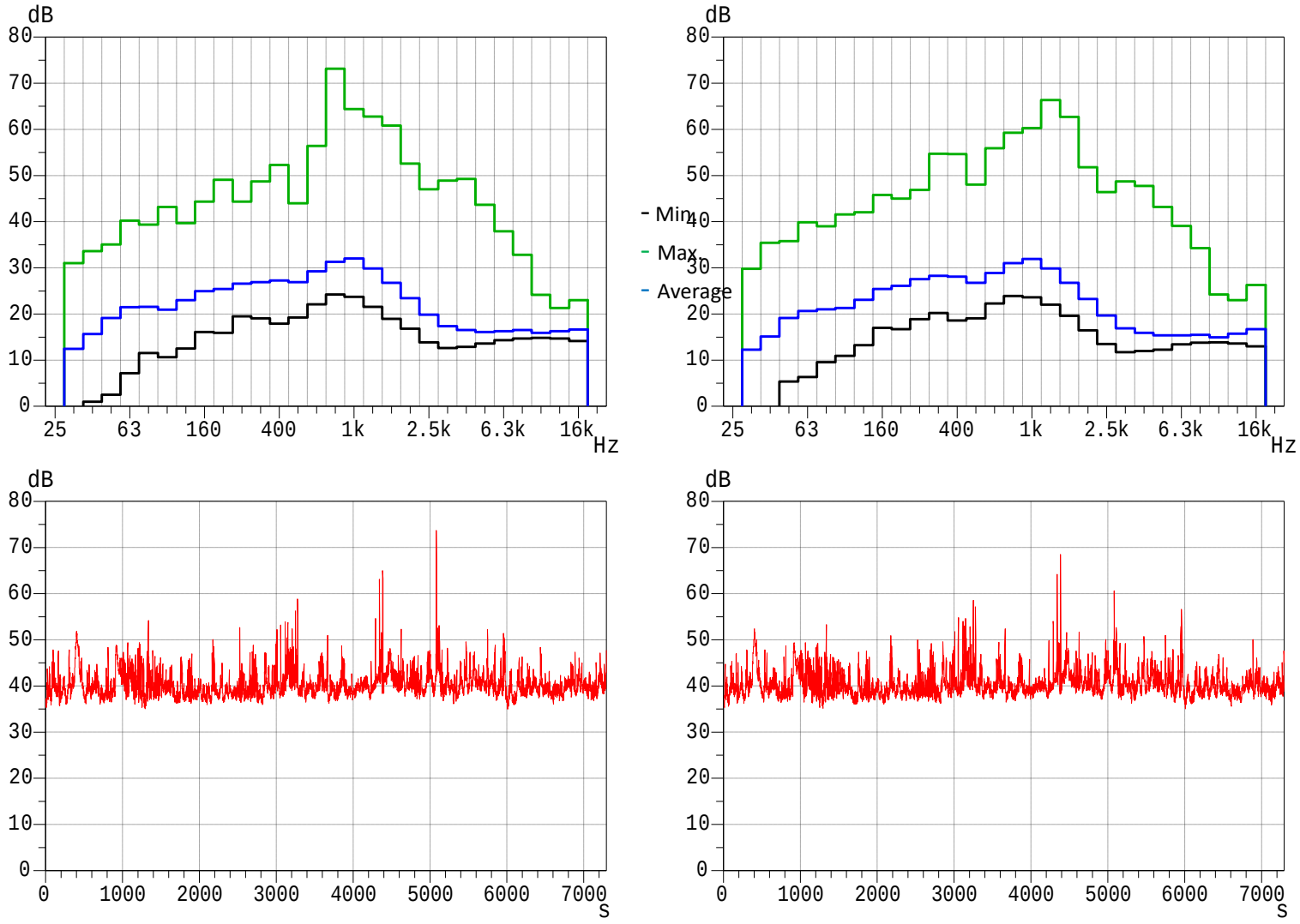
- Ambient noise levels – spectral variability.
- Vehicle measurement results
  - 1/3 octave variability
  - ICE vehicle results (To be presented by OICA)
  - Indoor/Outdoor comparison
  - Measurement of Pitch Shift

- Vehicle detection and recognition studies

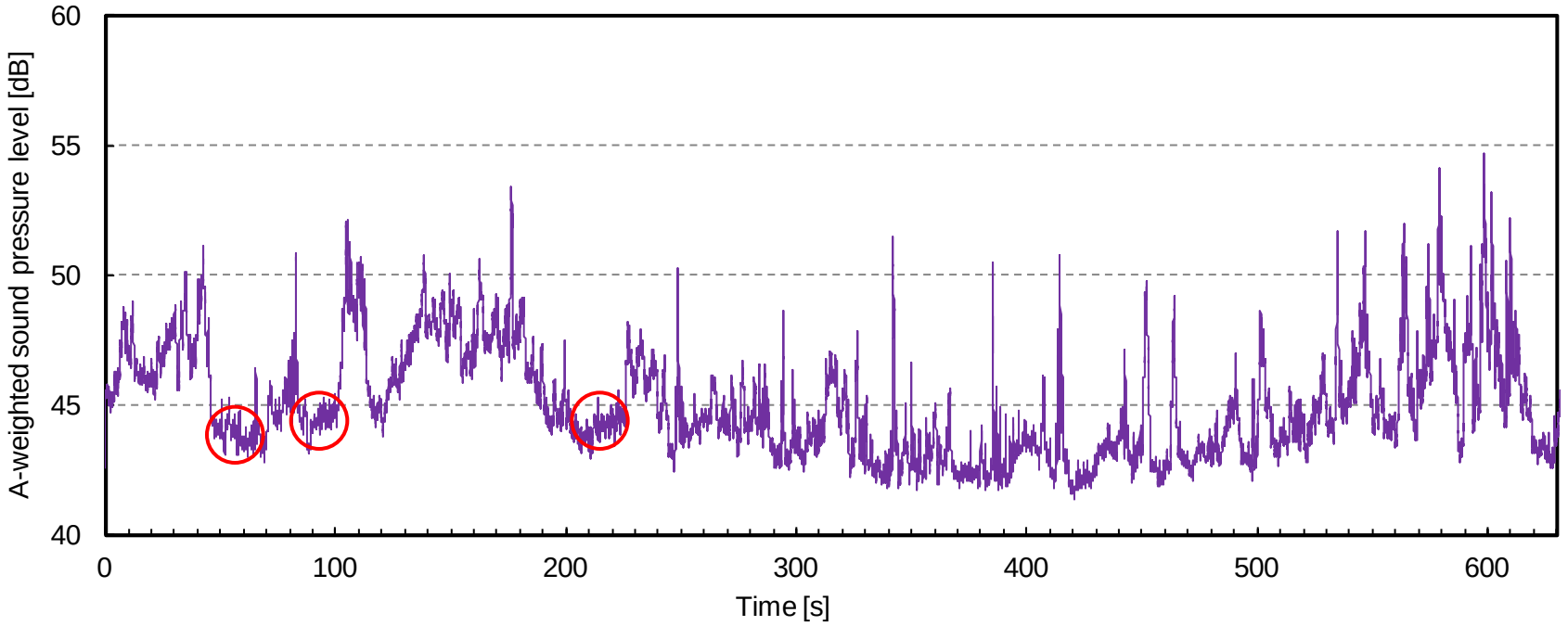
Work Package 1 Data

- Ambient noise measurements
  - Results from multiple locations at multiple times
- Vehicle noise measurements (OICA)
  - Internal combustion vehicles
  - Vehicles where countermeasures are foreseen

Background Noise Test Track ~ 2h

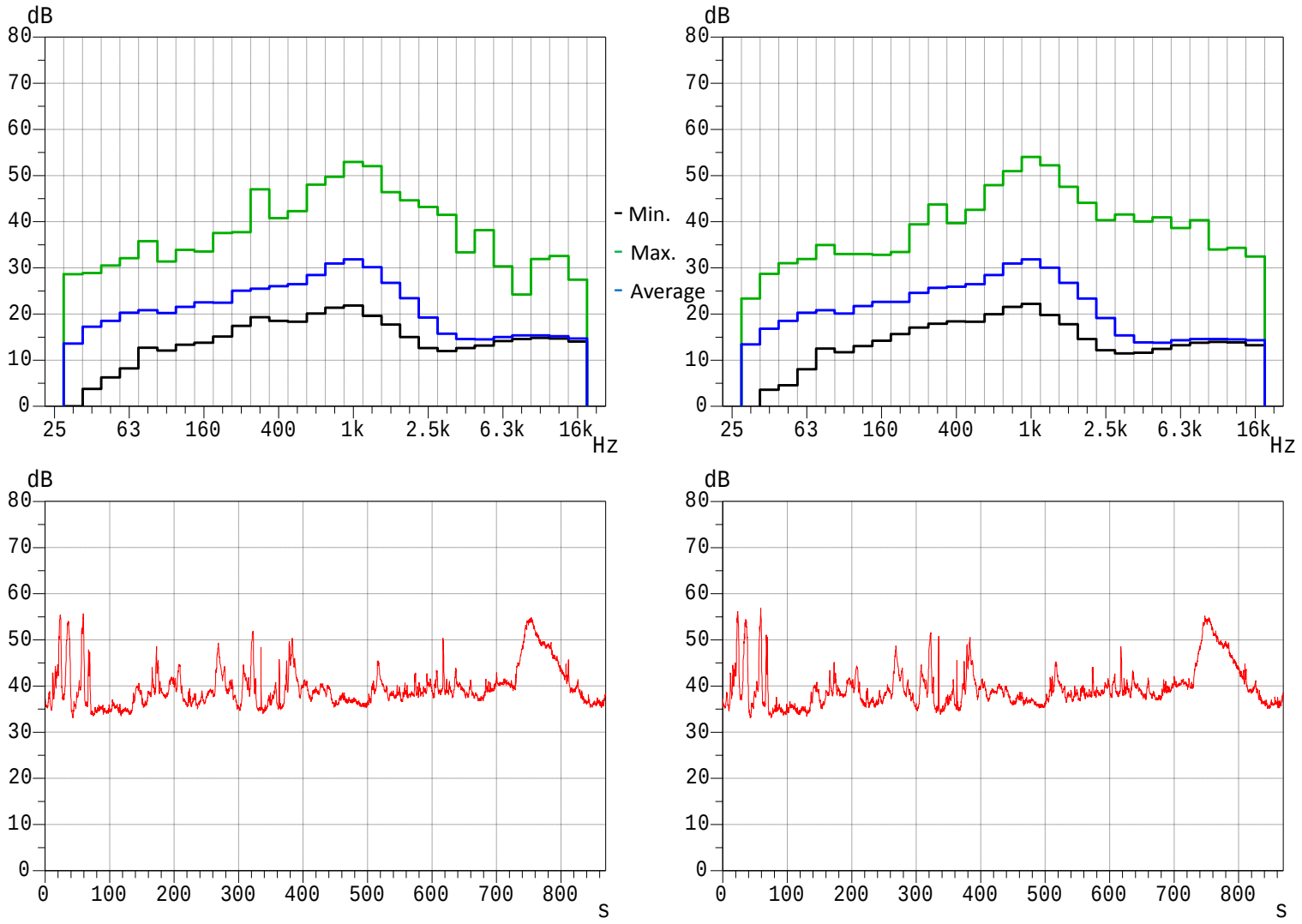


Fluctuation of ambient noise in outdoor

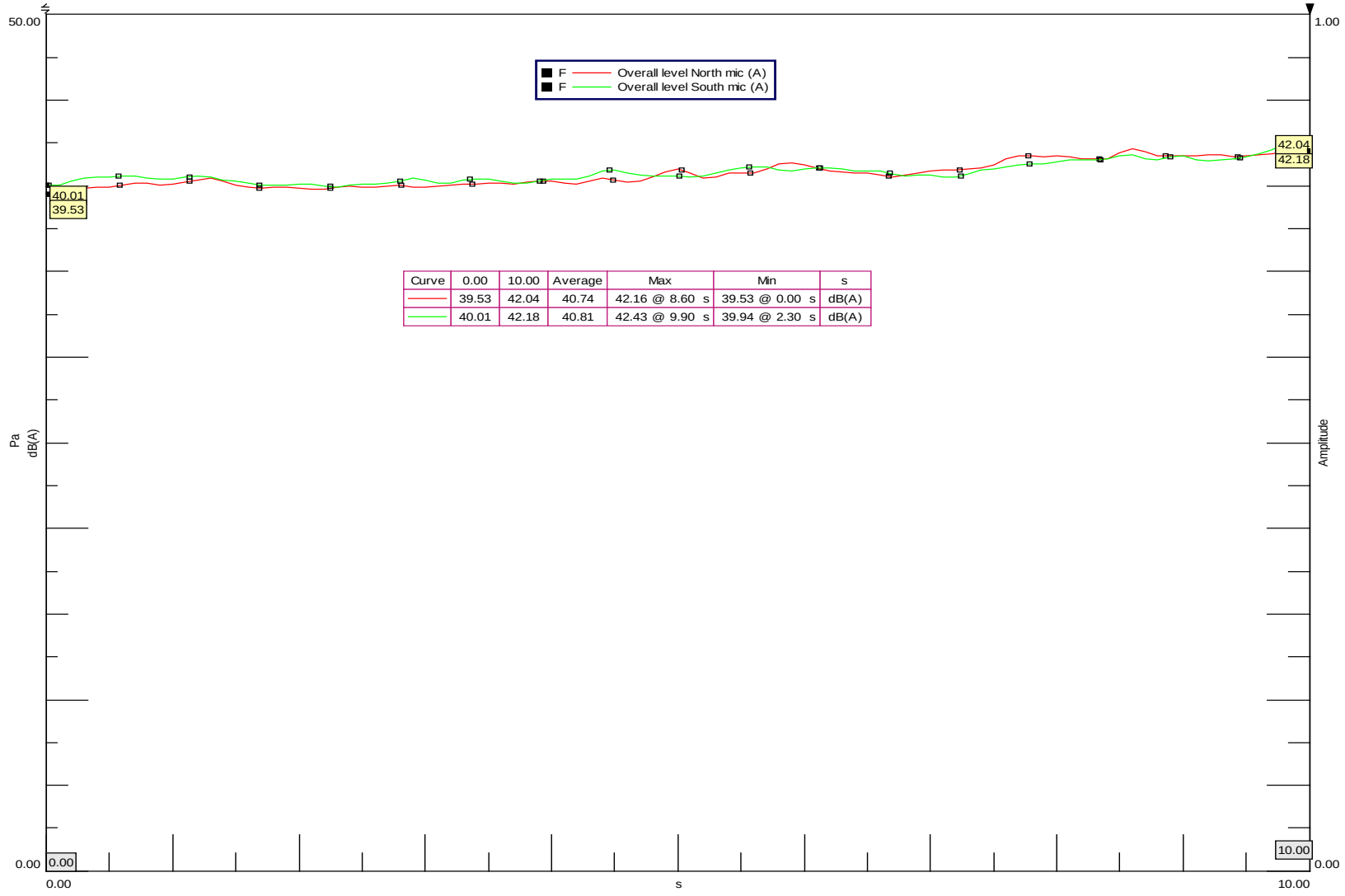


Need engineering judgment.
We can do for OA but cannot do for 1/3 octave

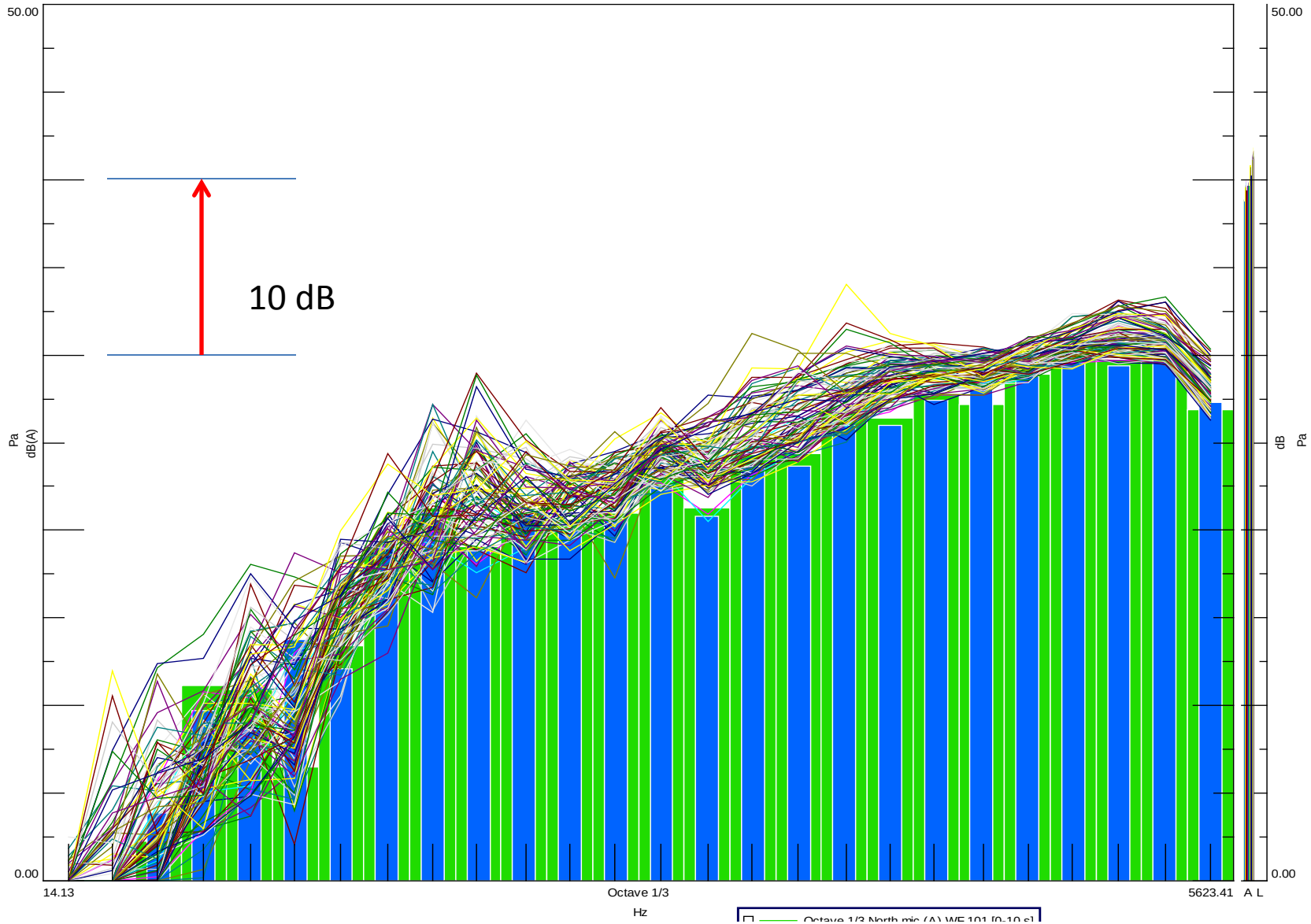
Background Noise Test Track ~ 15min



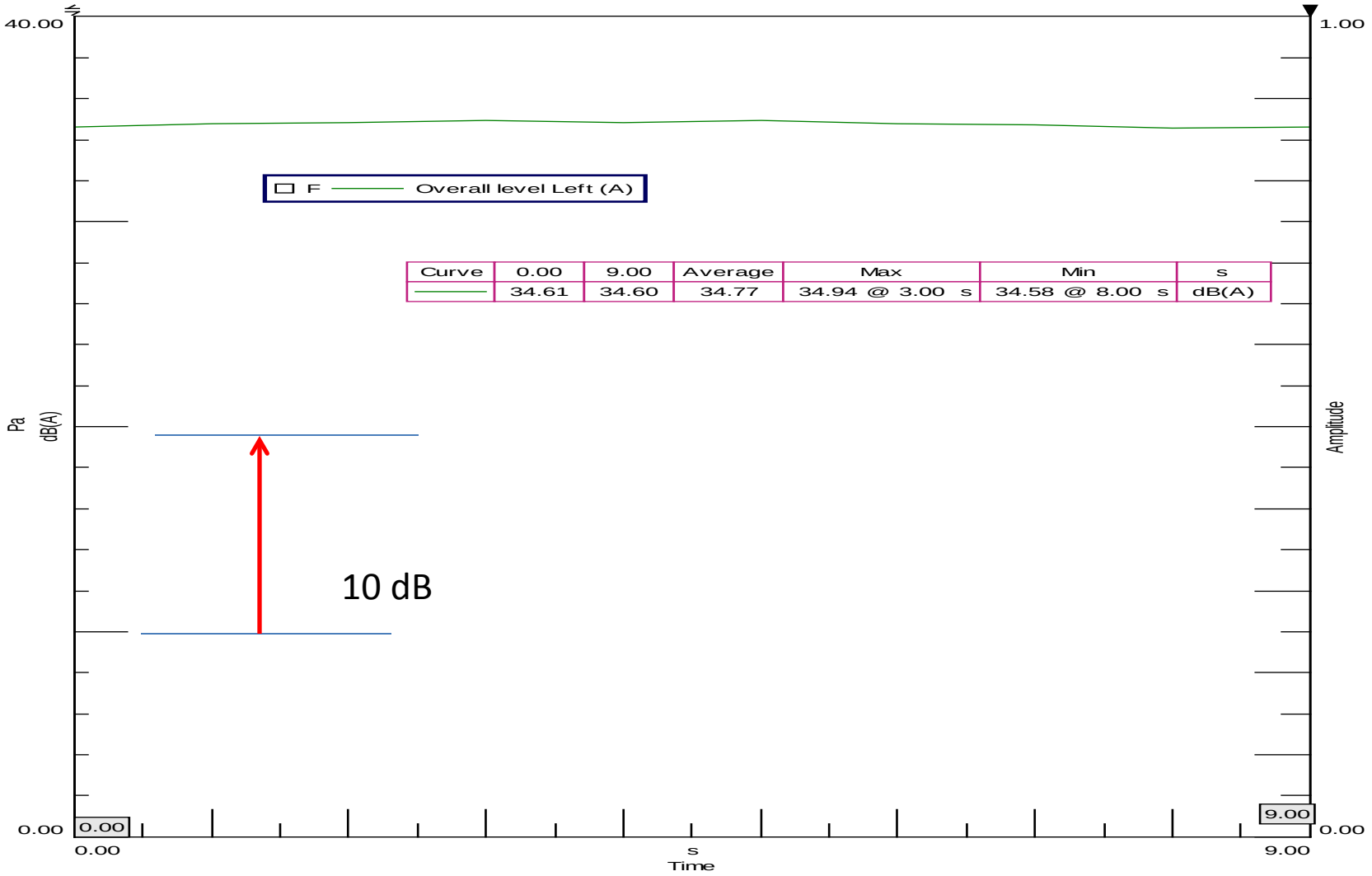
Outdoor Ambient Noise Variability – 10 seconds



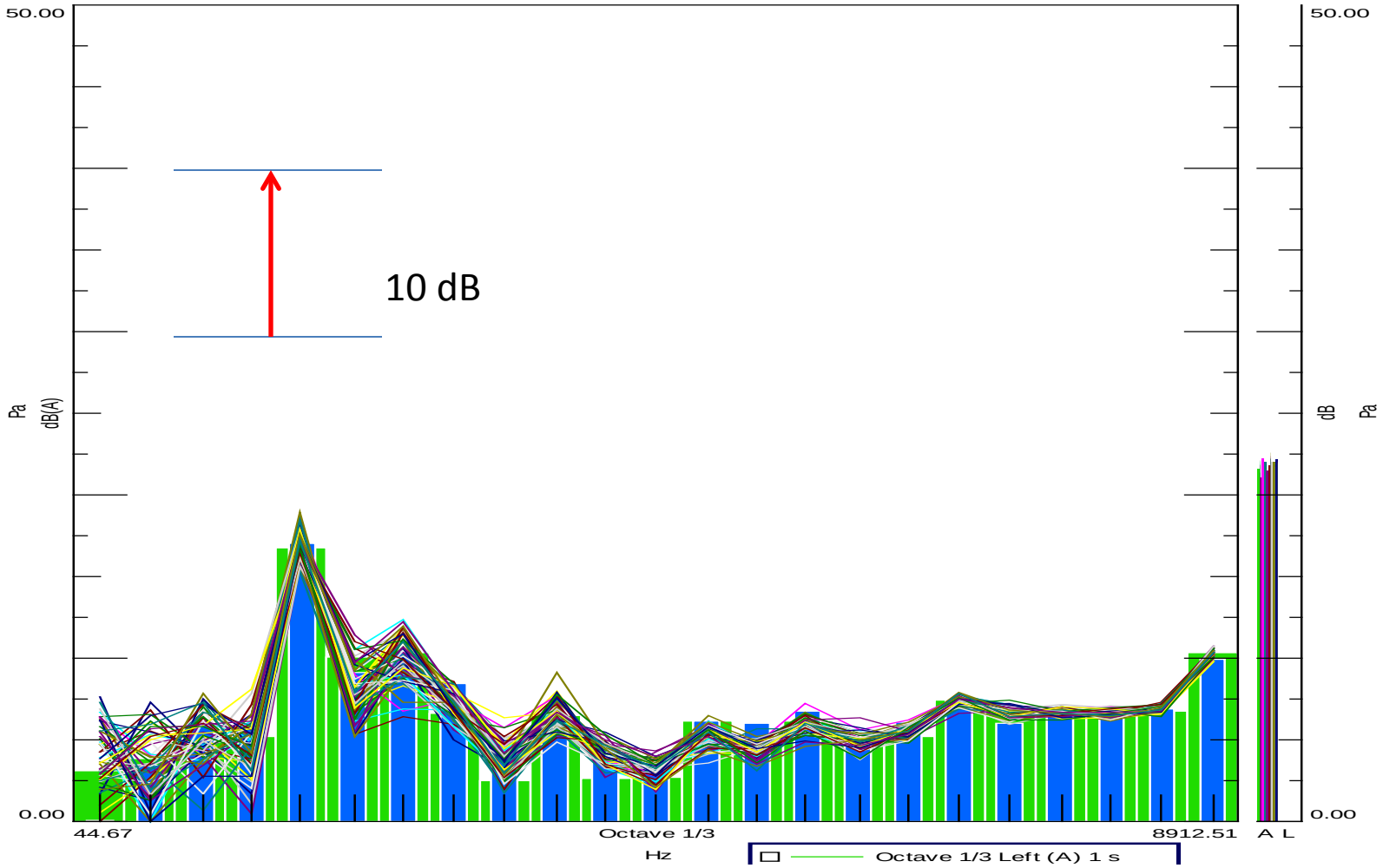
Outdoor Ambient Noise Variability 1/3 octaves over 10 sec



Indoor Ambient Noise Variability -10 seconds

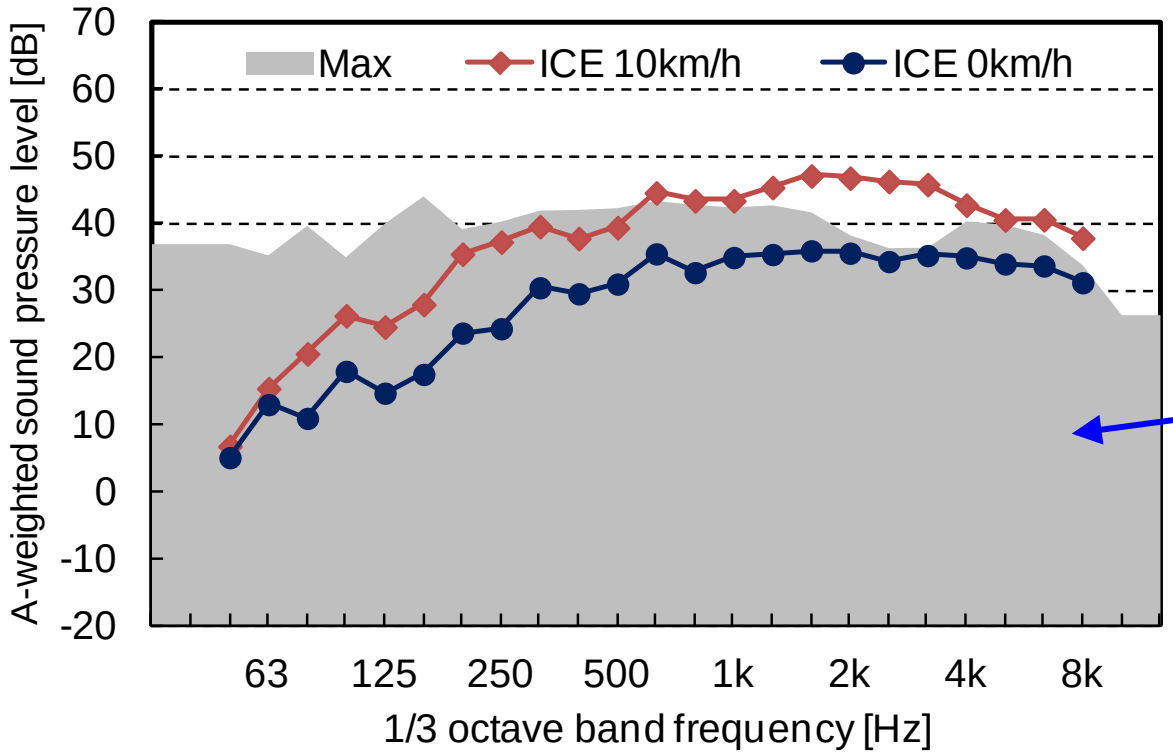


Indoor Ambient Noise Variability -10 seconds



Ambient noise in outdoor compared with sound level of ICE

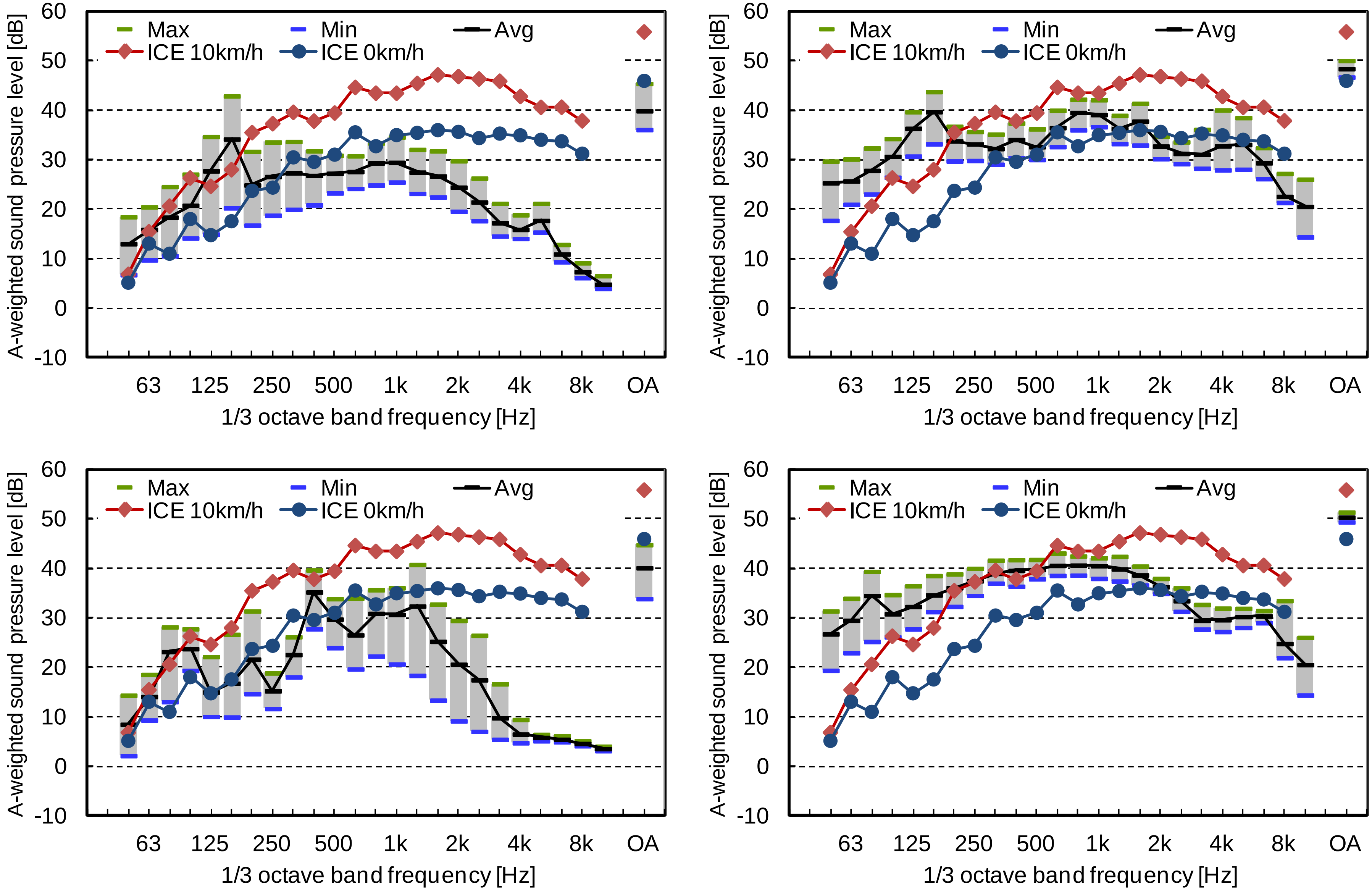
1/3 octave analyses are significantly influenced at a proving ground where the background noise is less than 10dB difference between test object and ambient noise at each 1/3 octave band of interest.



Envelope of ambient noise at multiple proving grounds

Ambient noise variation in several proving grounds

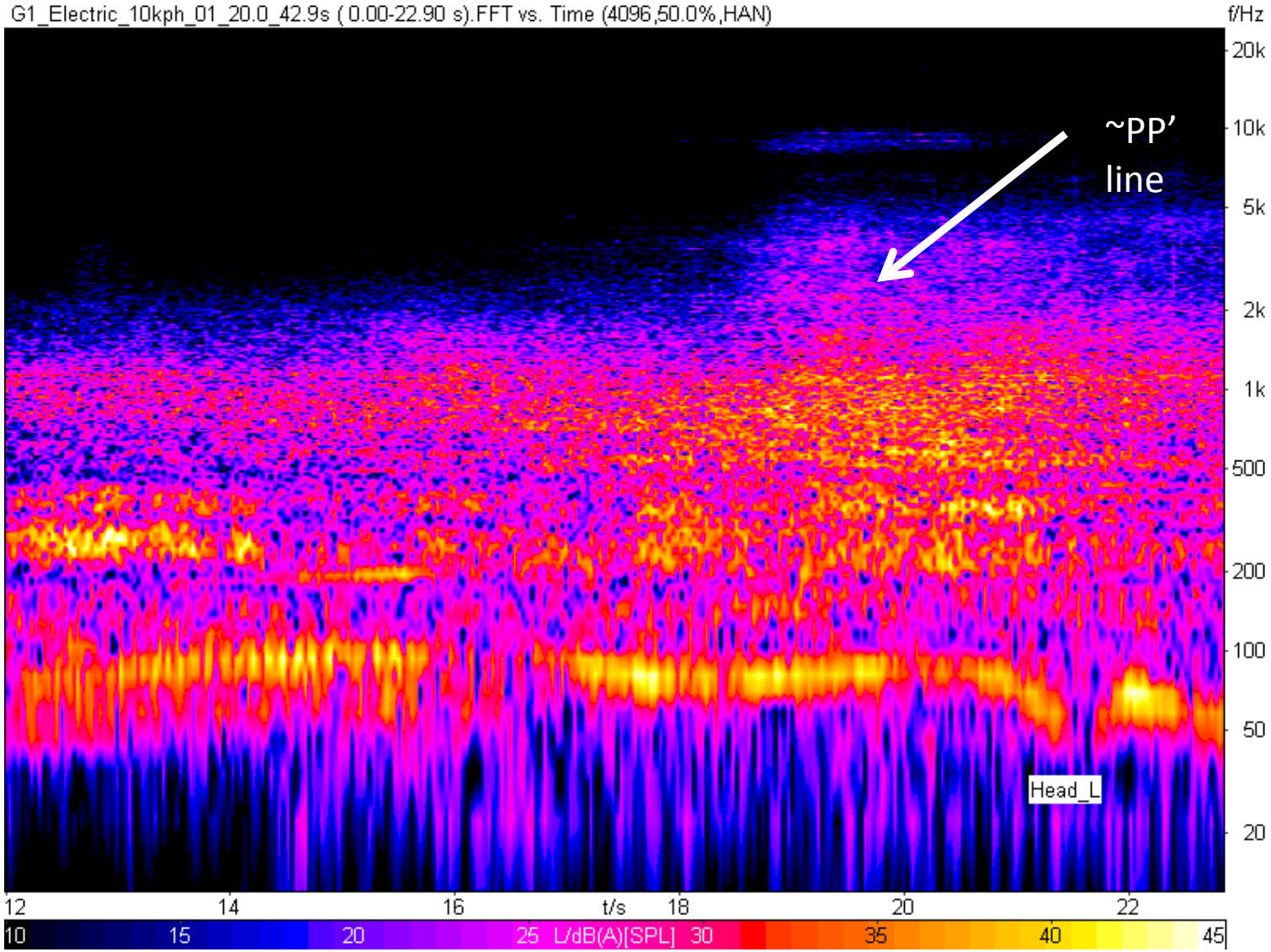
1/3Oct. ICE（0km/h, 10km/h）S/N>10dB



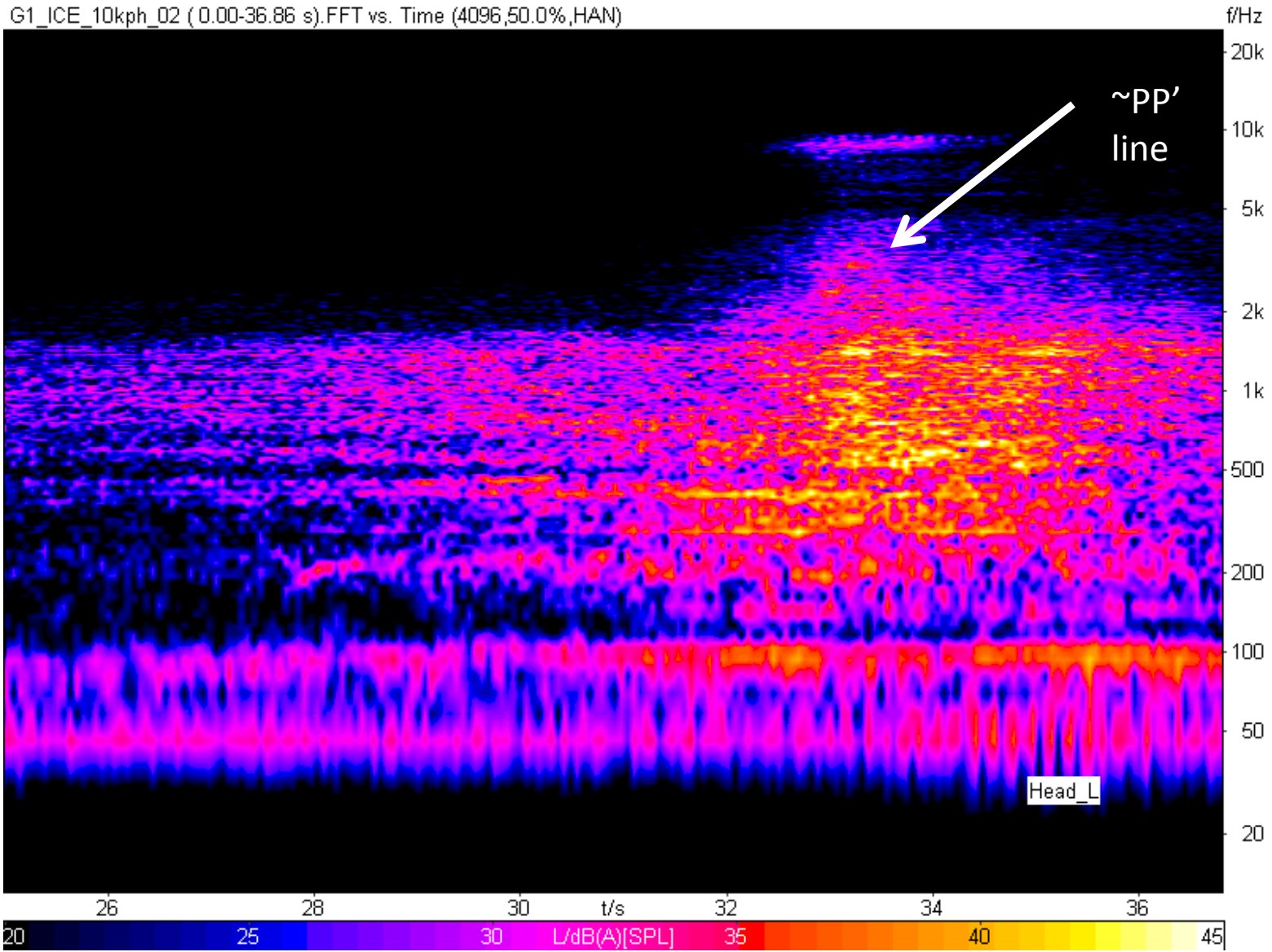
Vehicle Test Data

- Run to Run variation

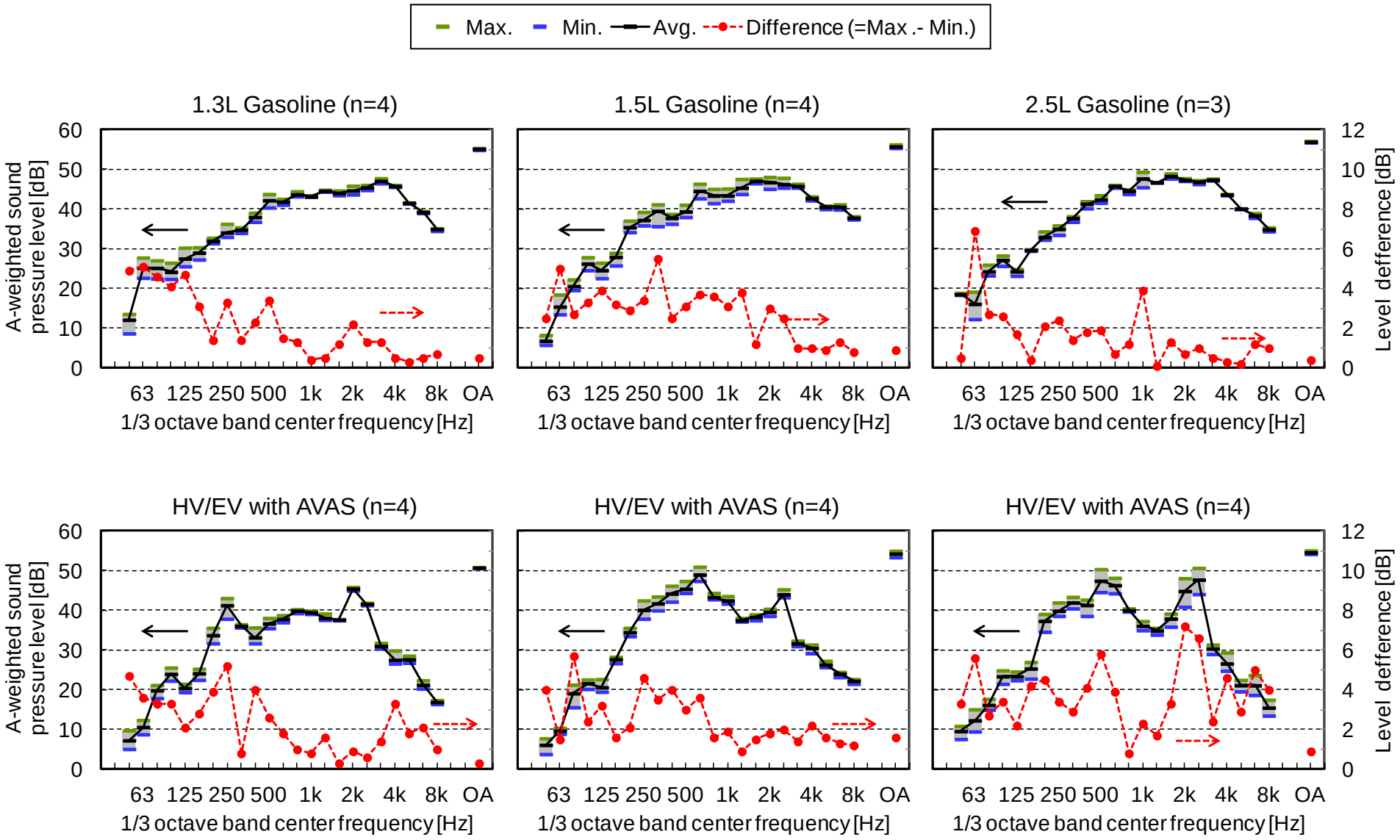
Vehicle Measurements - Electric



Vehicle Measurements -ICE



Example of dispersion in each measurement : 10 km/h cruise @ISO test track



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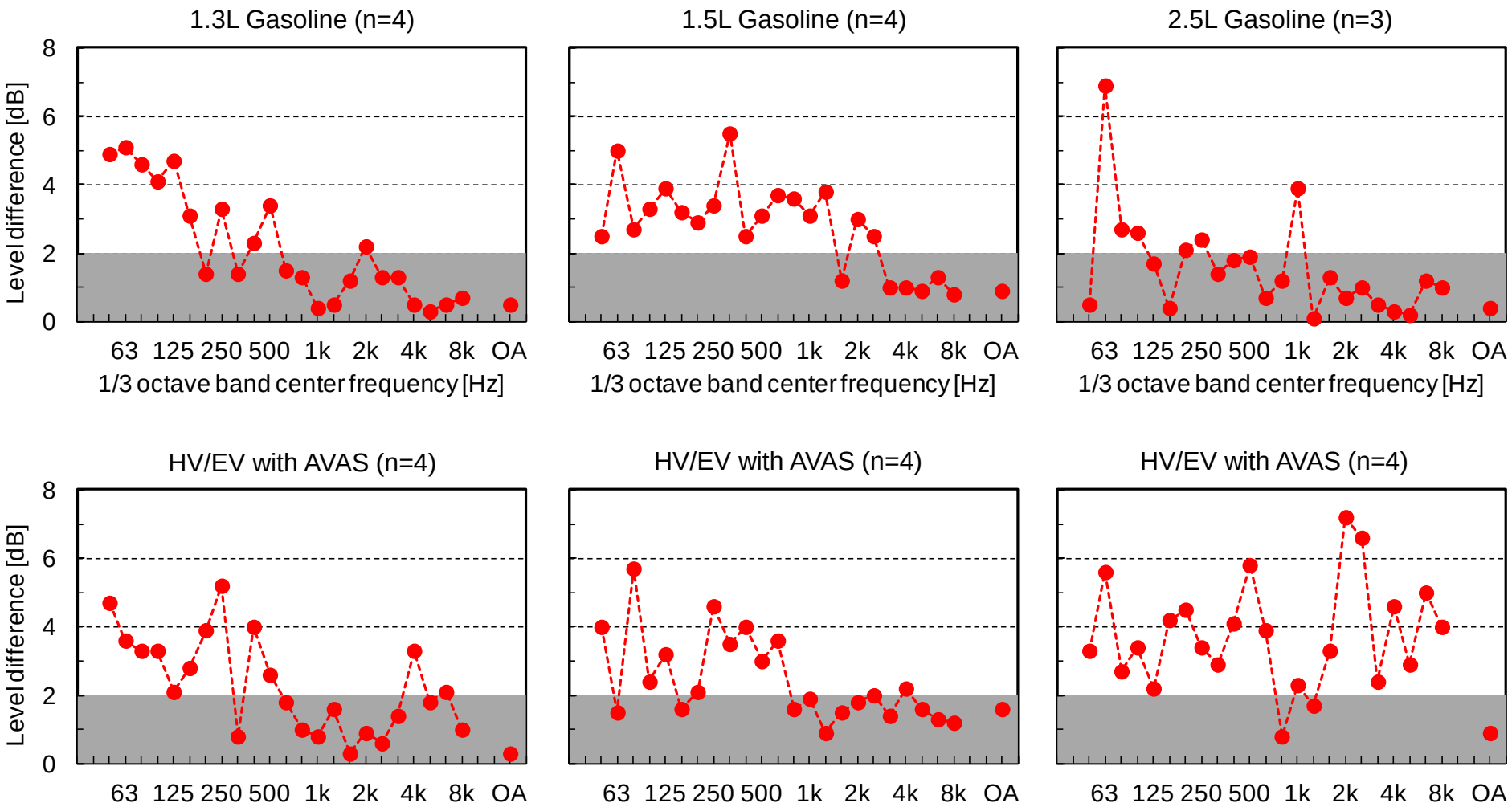
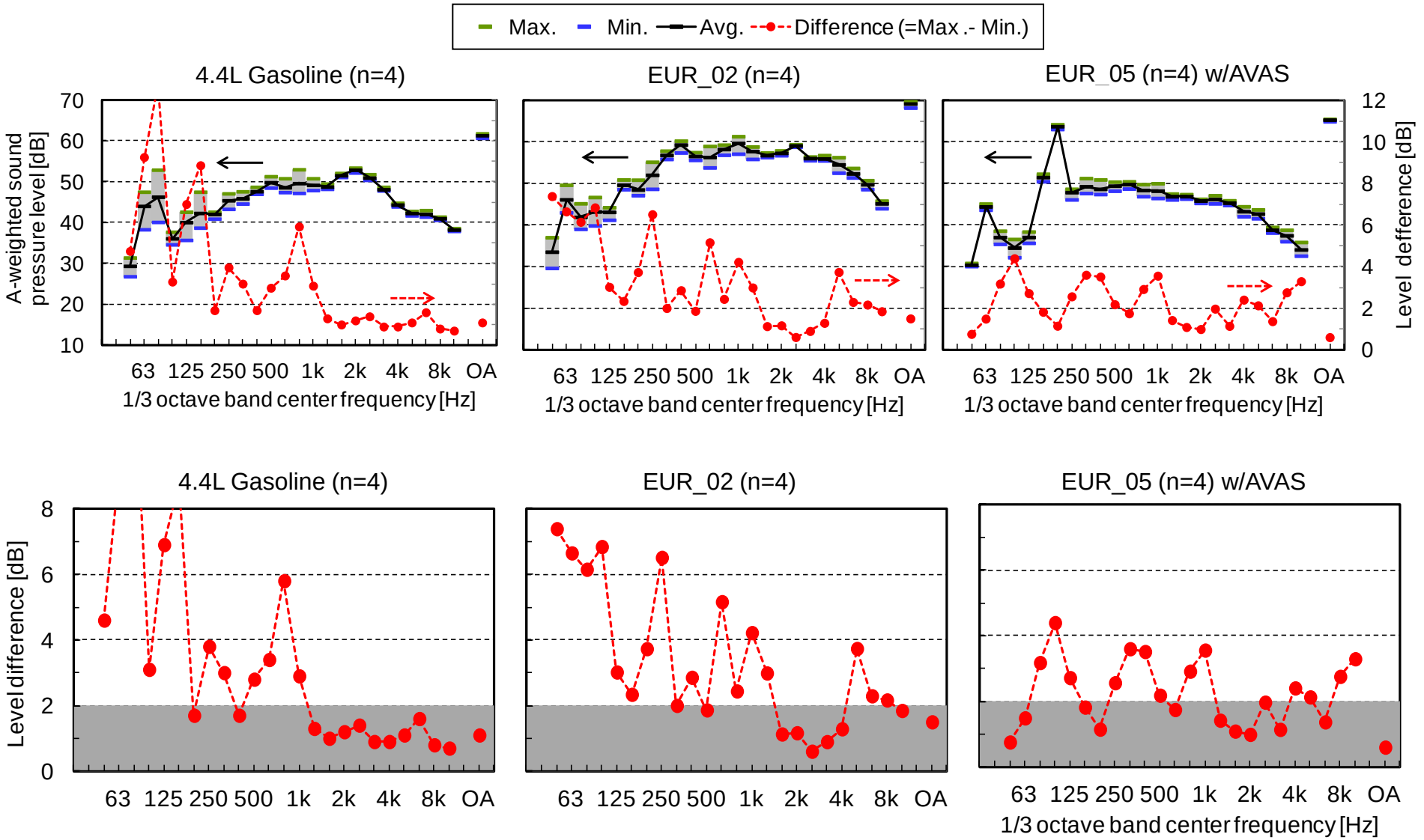


The variation of OA level is within 2dB. Normally the data within 2dB are valid,
But the variations of 1/3 octave level are much more than 2dB.

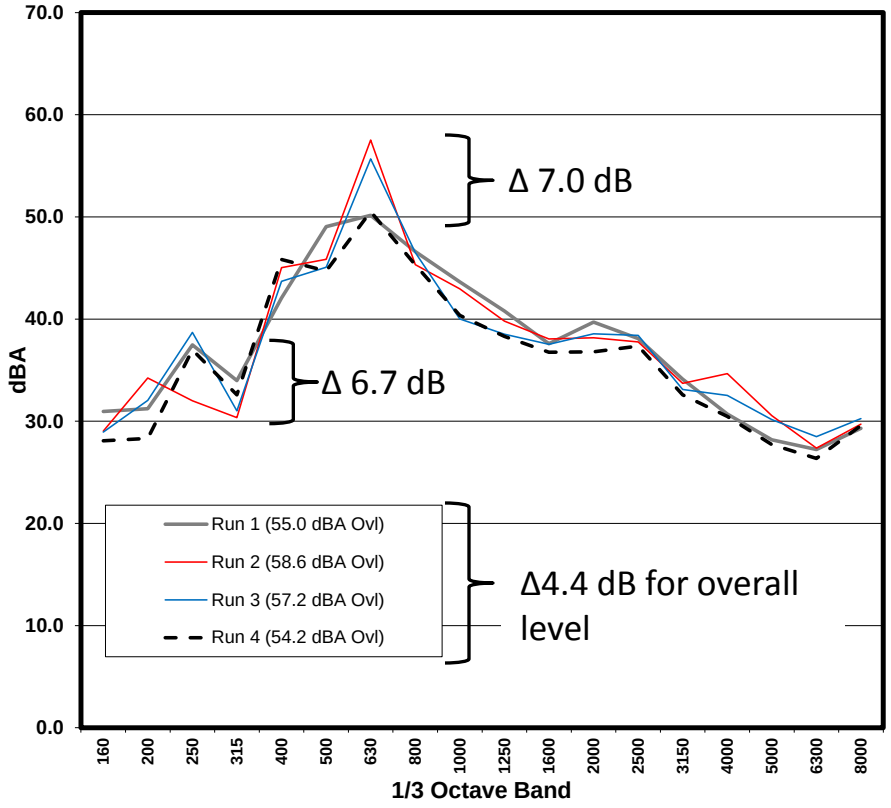
Example of dispersion in each measurement : 10 km/h cruise @ISO test track



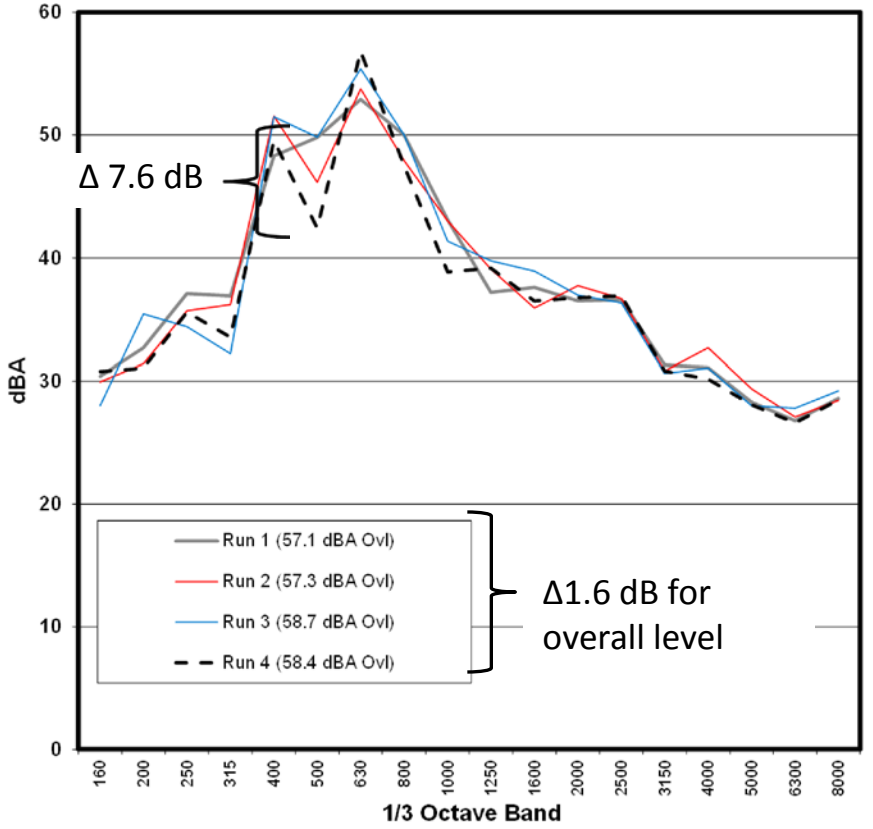
1/3-octave Requirements: Run-to-Run Variability

- ***Are the 1/3 octave levels more variable than the overall levels?***

BEV with alert "A":
10 kph, driver side

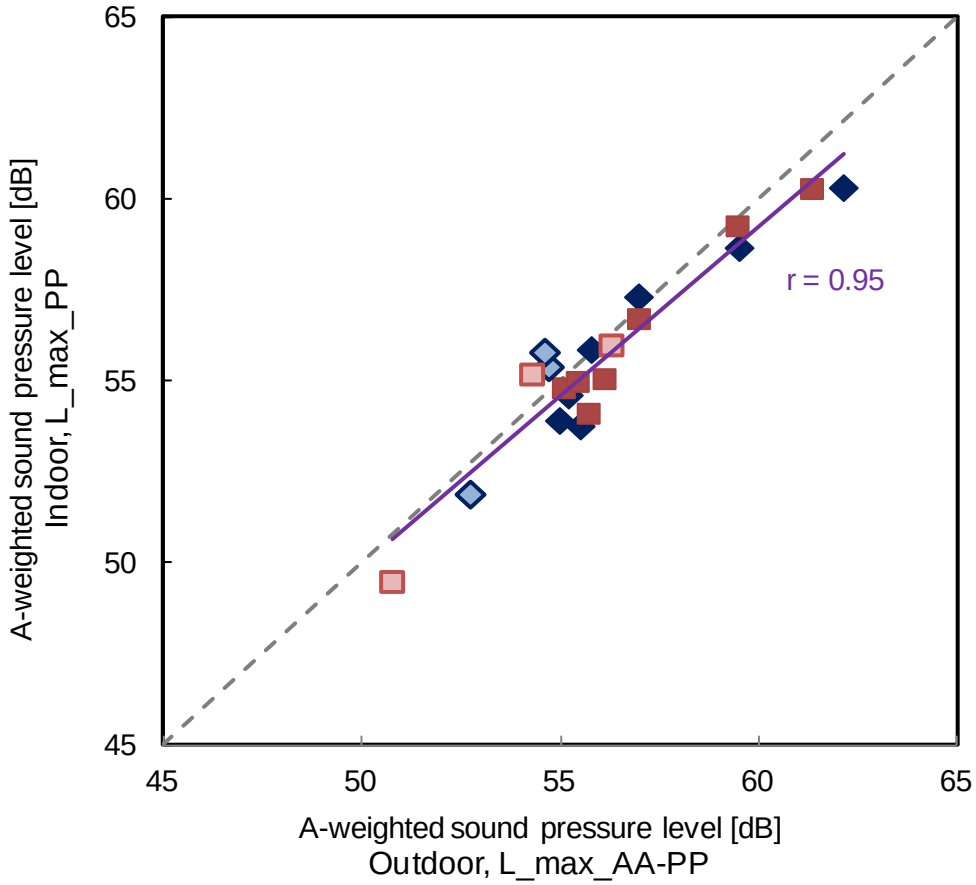


BEV with alert "B"
10 kph, driver side



Indoor/Outdoor Comparison

"Outoor" vs "Indoor"



10 km/h

- ICE vehicle (Left)
- ICE vehicle (Right)
- HV/EV with AVAS (Left)
- HV/EV with AVAS (Right)

In constant speed test, sound level at PP for indoor test is same sound level for outdoor test.

Conformity between outdoor and indoor test results is well.

Work Package 3

- Evaluation of detection and recognition models

1/3-octave Requirements & Detection/Recognition

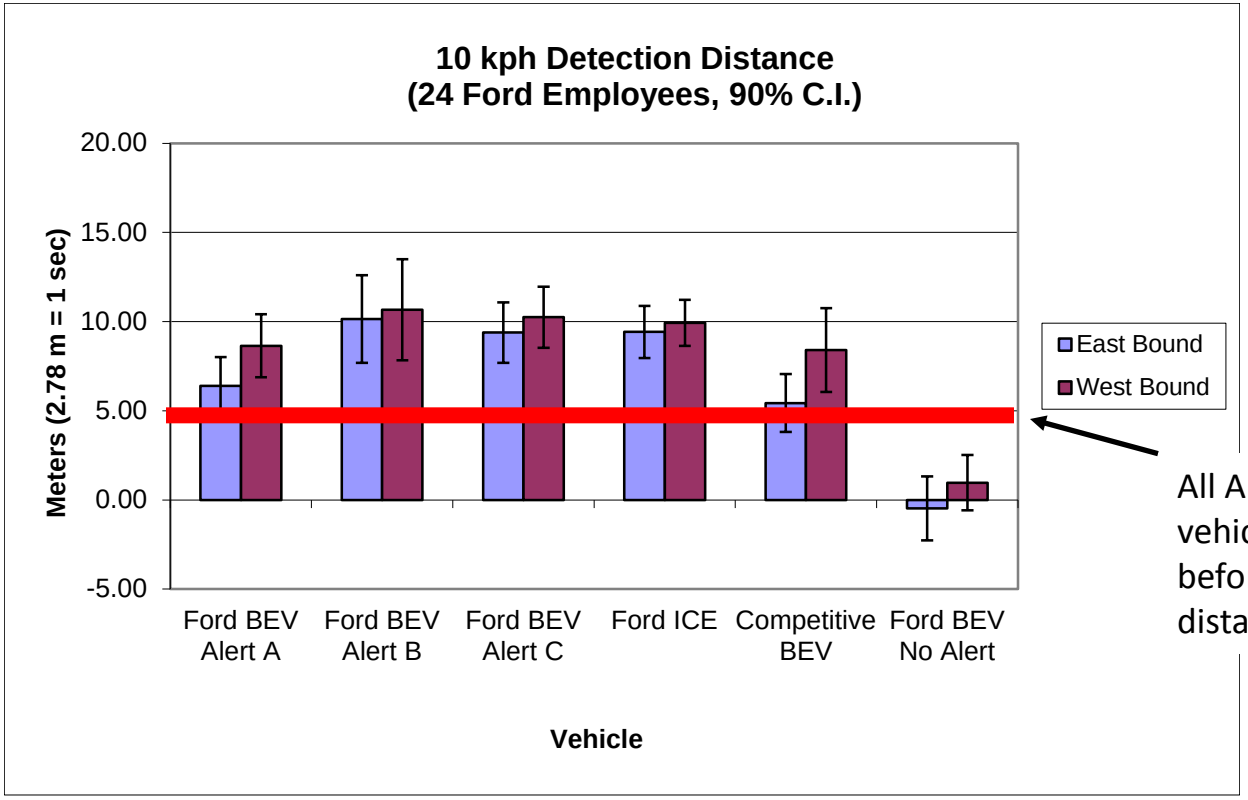
- ***Detection/Recognition Study Background***
  - Binaural recordings made of 5 vehicles:
    - C-segment ICE
    - C-segment BEV w/three different alert sounds
    - C-segment BEV competitor with alert
  - Detection
    - Recordings were mixed with 55dBA Pedersen noise and presented over headphone to 28 subjects
      - 24 normal vision, 4 visually impaired
    - 10 kph passbys were used to evaluate detection distances
      - Subjects clicked a mouse when the first heard the vehicle
      - Detection distances were calculated

1/3-octave Requirements & Detection/Recognition

- ***Detection/Recognition Study Background***
  - Recognition
    - Recordings were mixed with 55dBA Pedersen noise and presented over headphone to 28 subjects
      - 24 normal vision, 4 visually impaired
    - Evaluation conditions
      - 10 kph pass-bys
      - Other conditions in progress
    - 1-5 recognition scale used

1/3-octave Requirements & Detection/Recognition

- ***Detection Results***

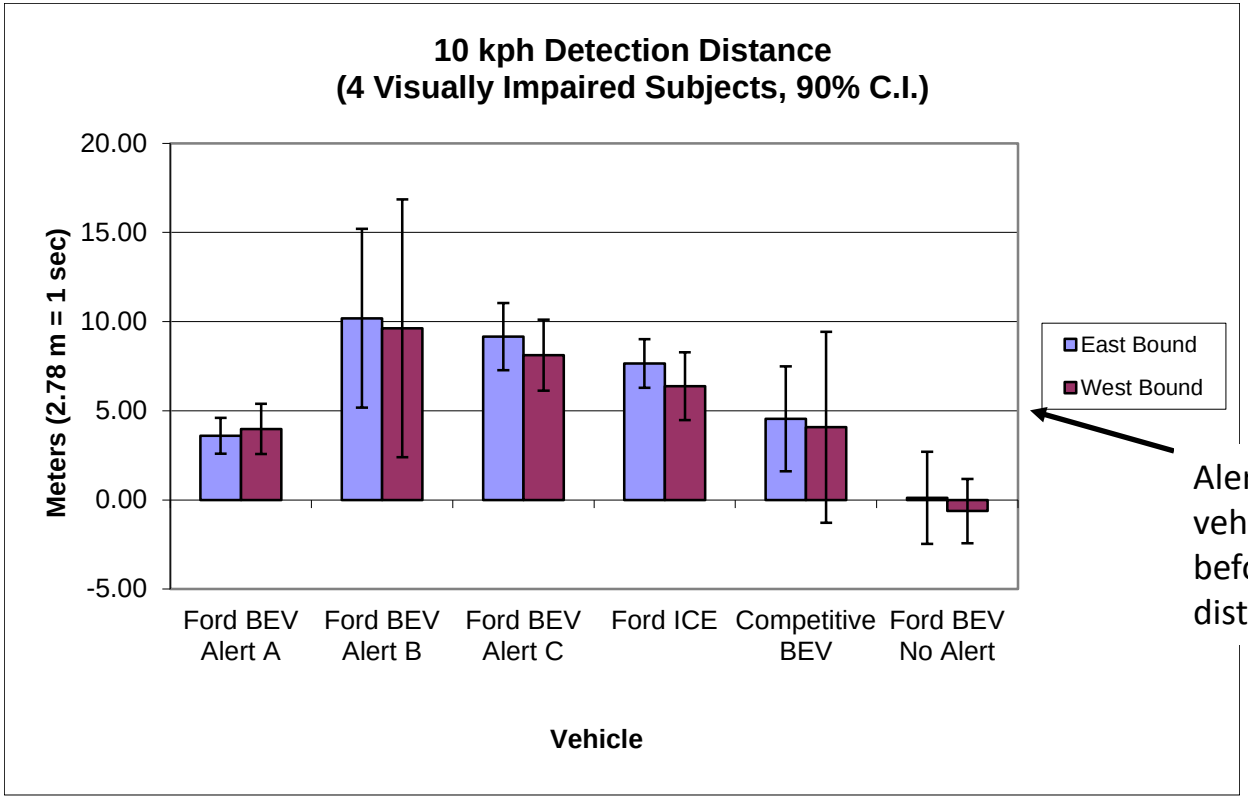


All Alert and ICE vehicles detected before 5 meter critical distance

NHTSA 1/3-octave Requirements & Detection/Recognition

- ***Detection Results***

Note: Two subjects indicated known hearing loss

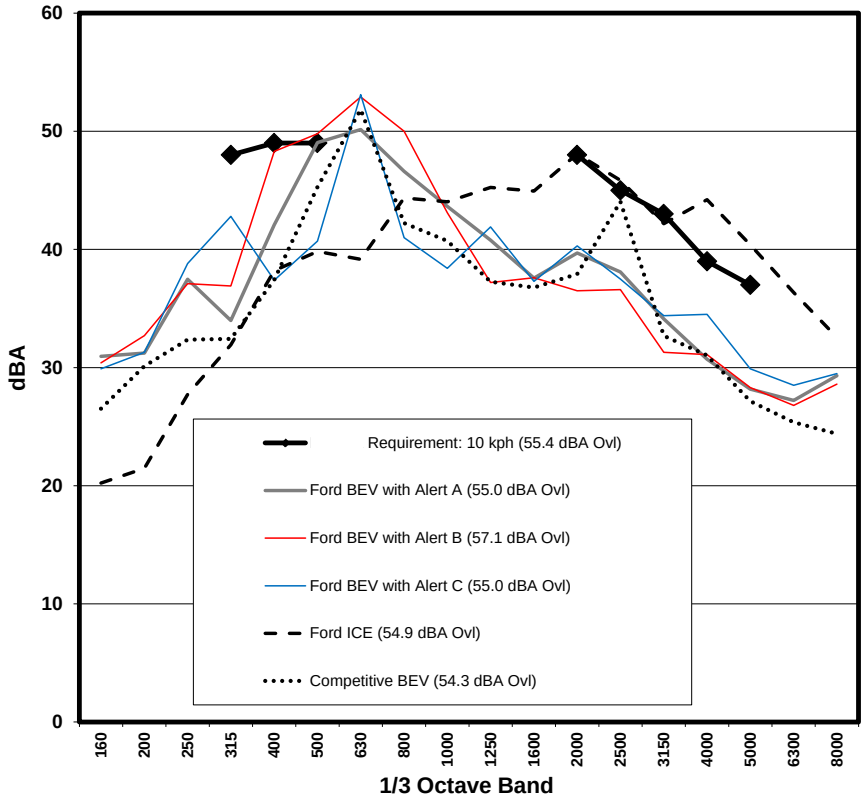


Alert B, C and ICE vehicles detected before 5 meter critical distance

1/3-octave Requirements & Detection/Recognition

- ***1/3-octave Requirements Compared to Vehicles used in the Study– 10 kph***

Minimum Required Frequency Content compared with Study Vehicles
Condition: 10kph Pass-by @ PP' Line, Location: Driver Side Mic.



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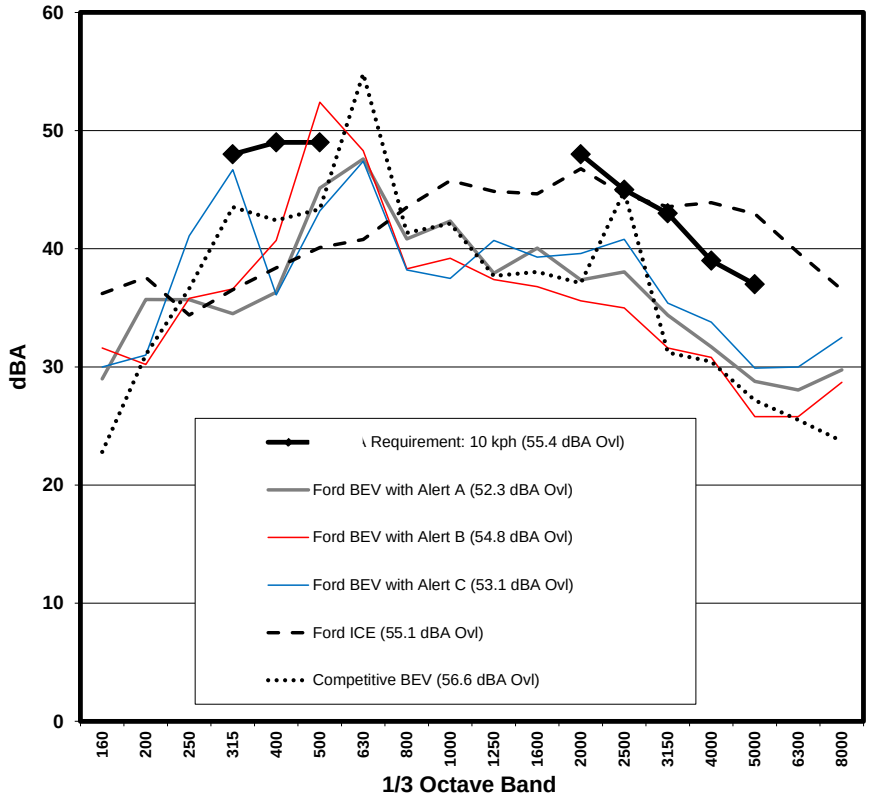
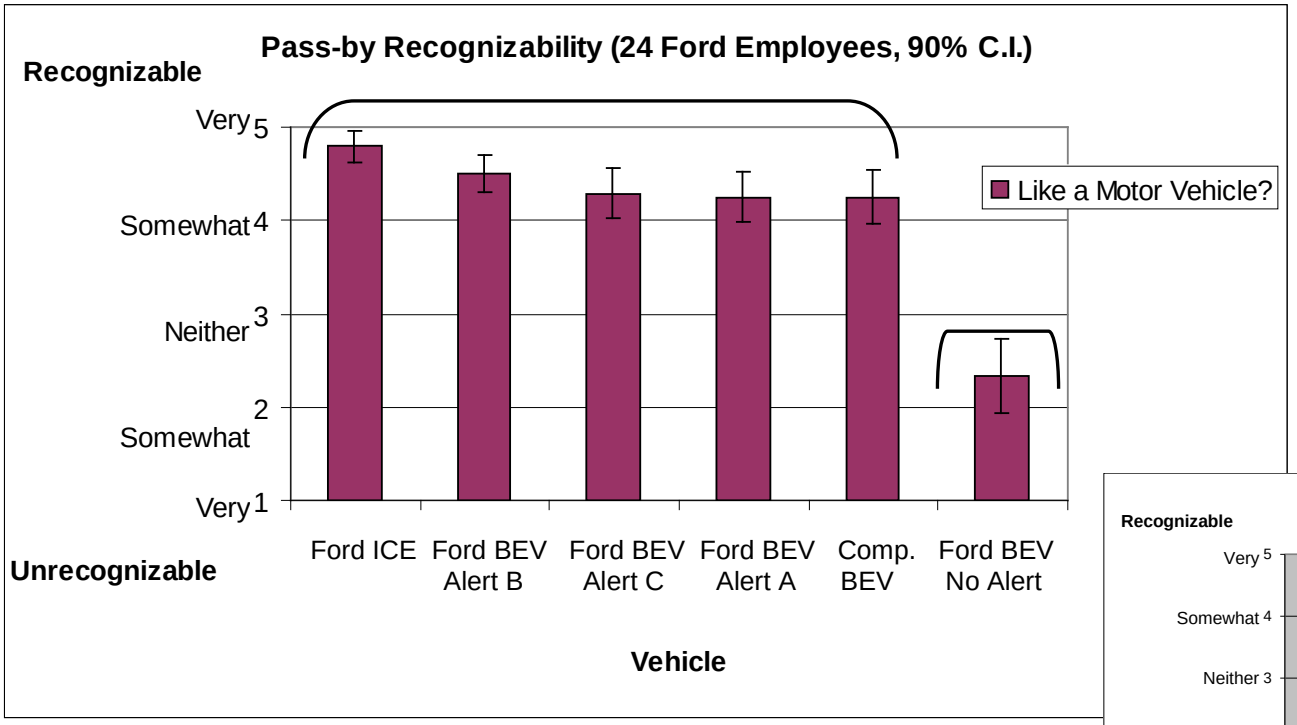
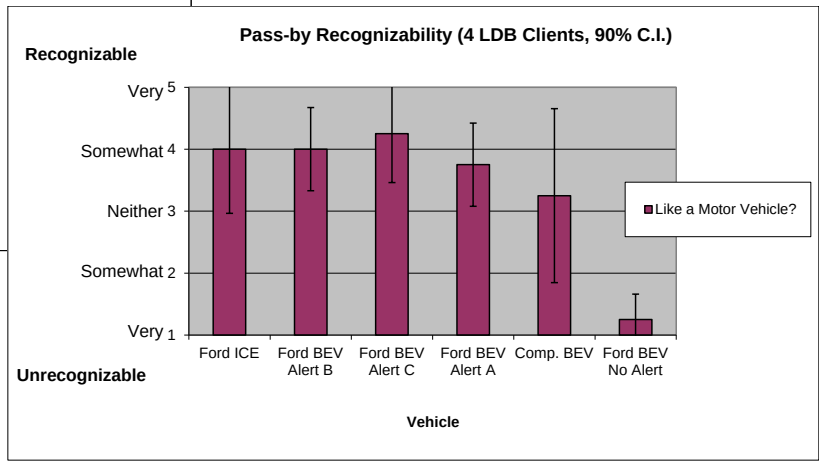


1/3-octave Requirements & Detection/Recognition

- ***Recognition Results w/significance groupings***
  - ***10 kph Pass-by***

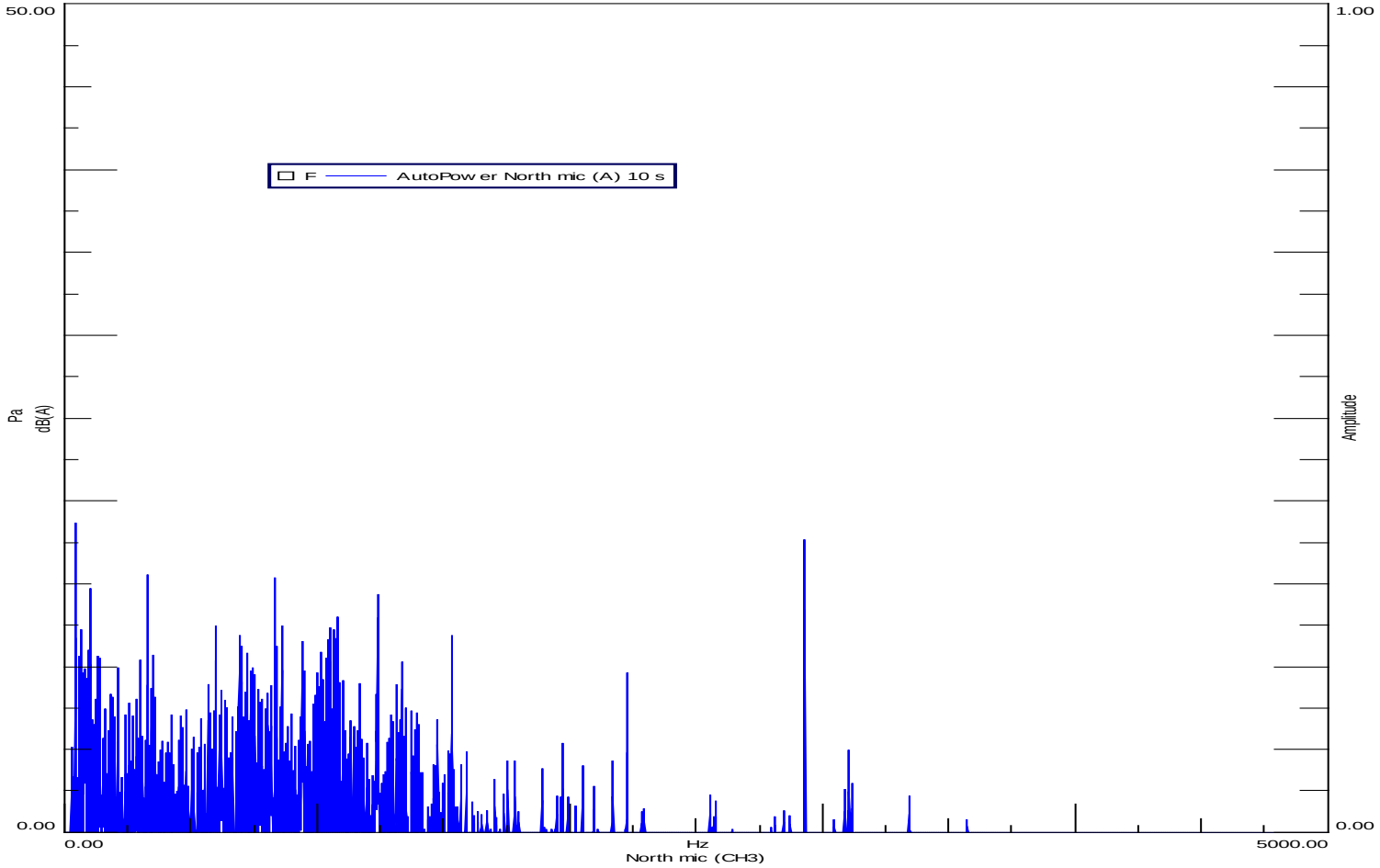




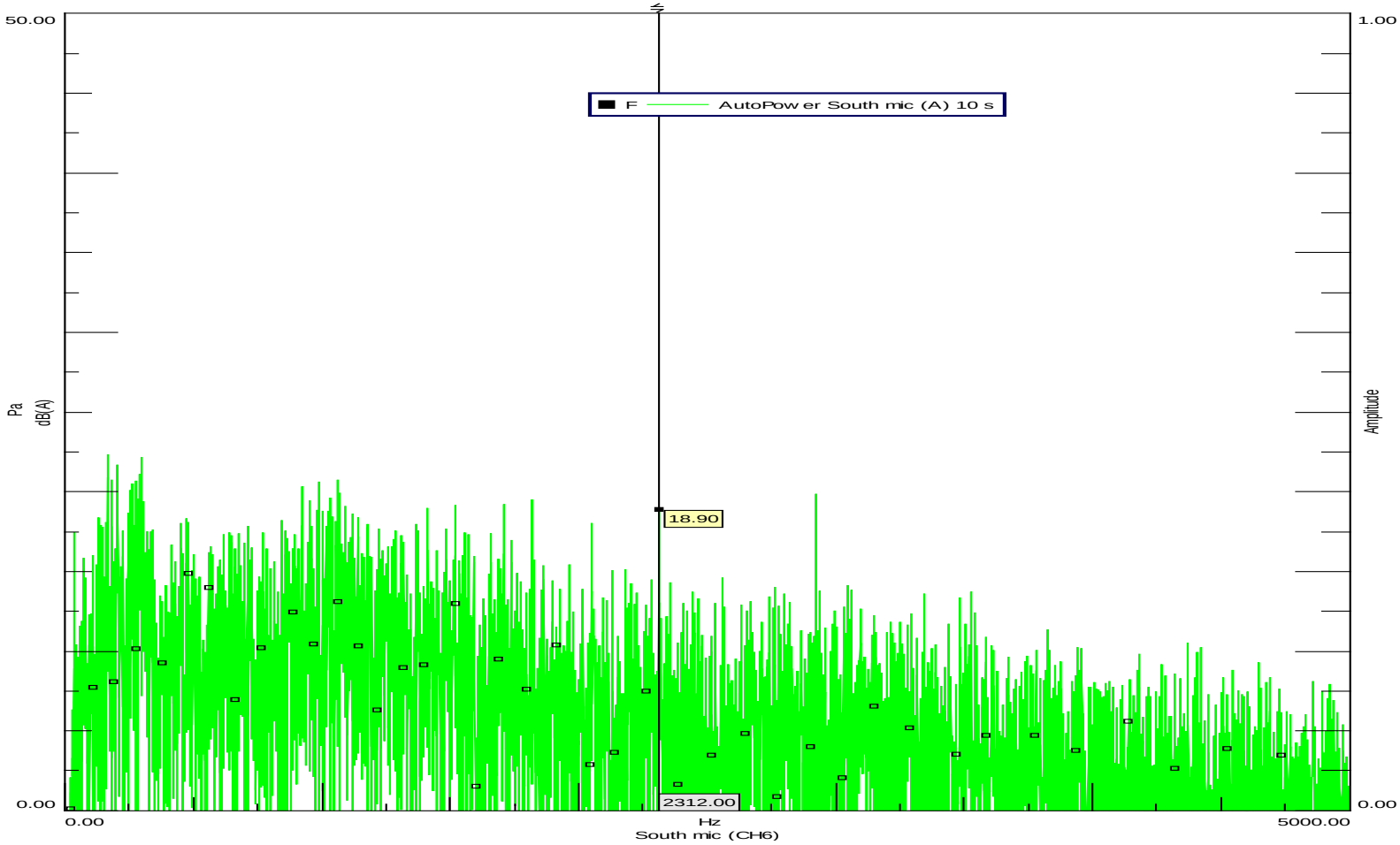
Work Package 4

- Pitch Shift Measurement and Analysis

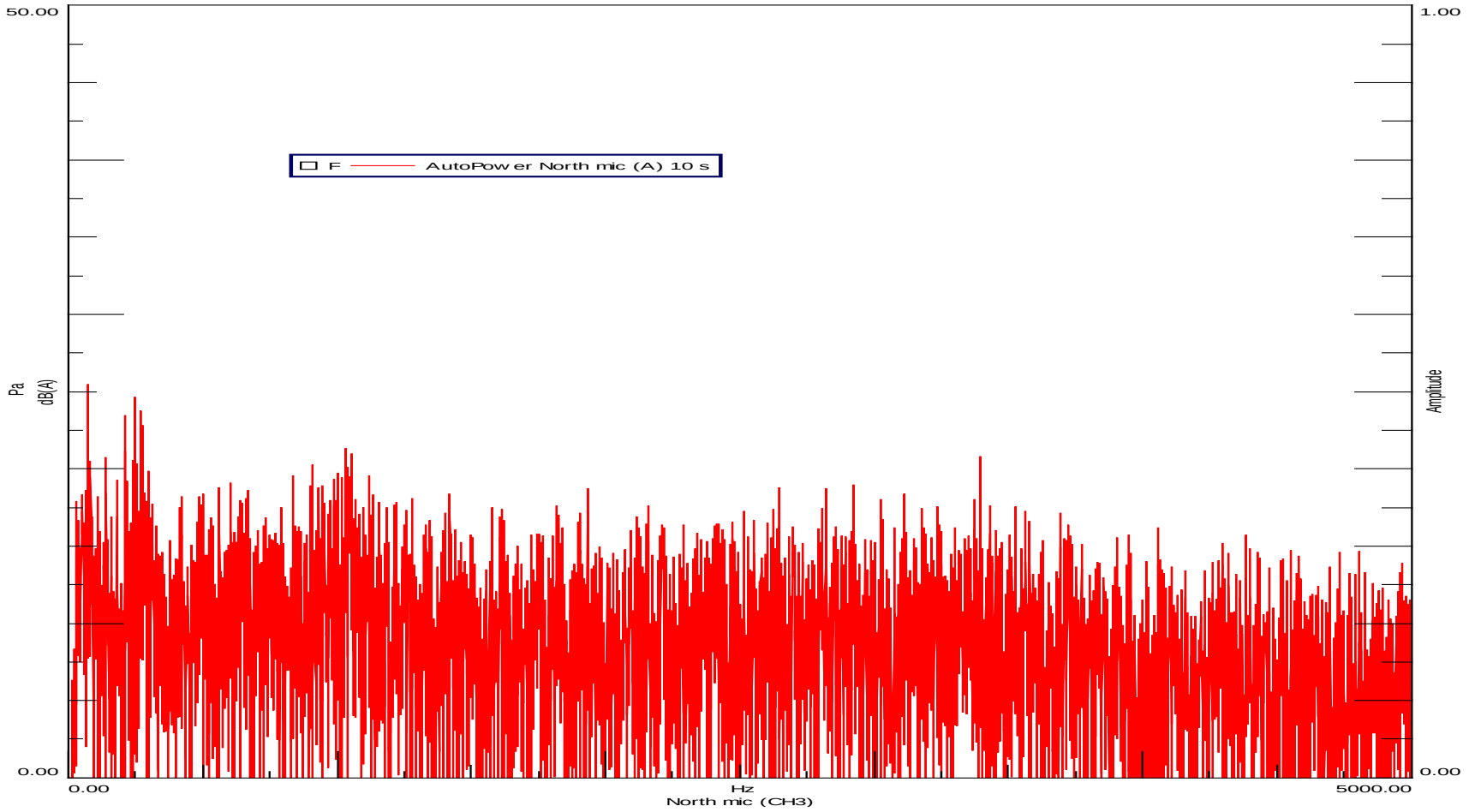
Pitch Shift – Outdoor 10 kph



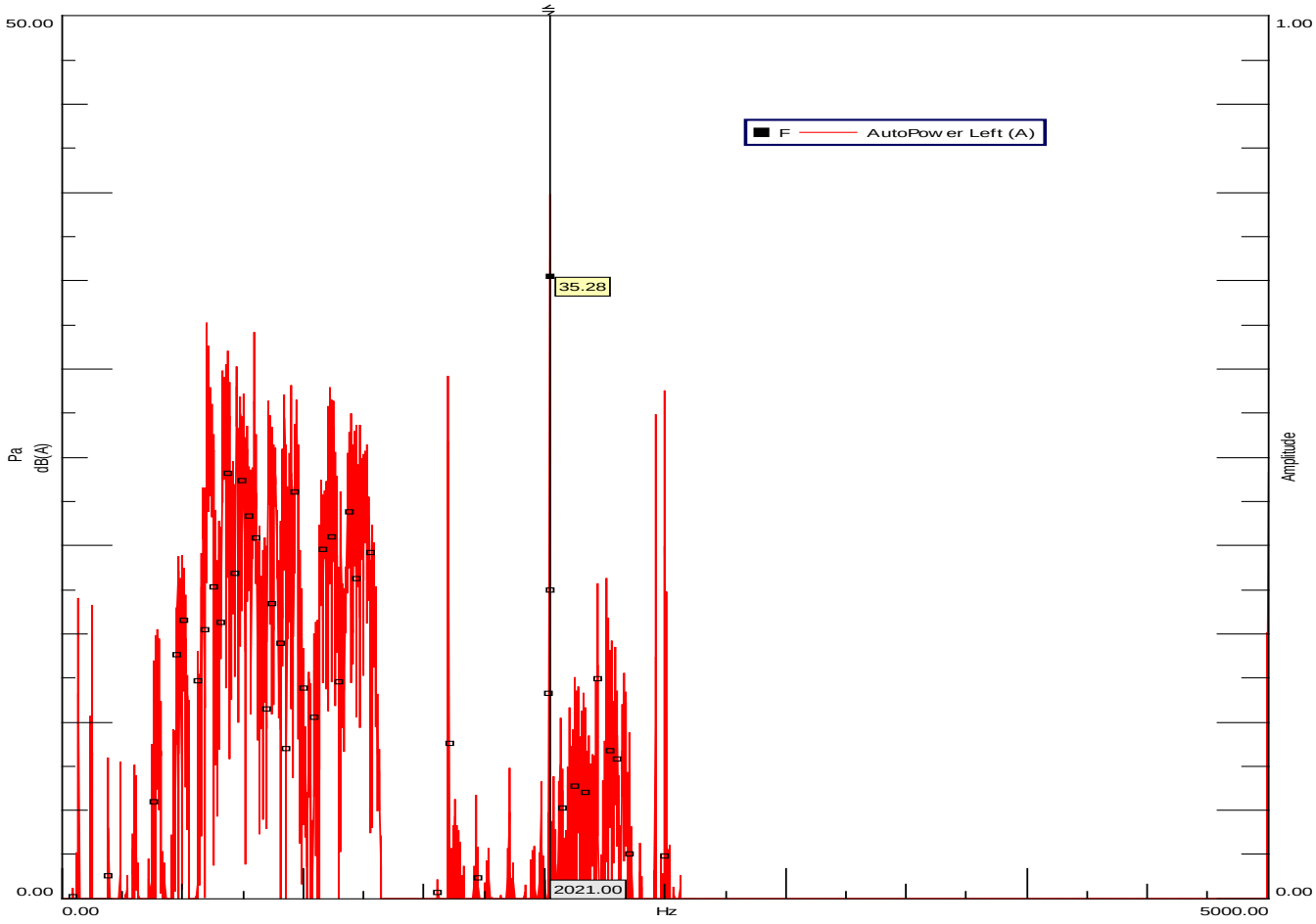
Pitch Shift – Outdoor 20 kph



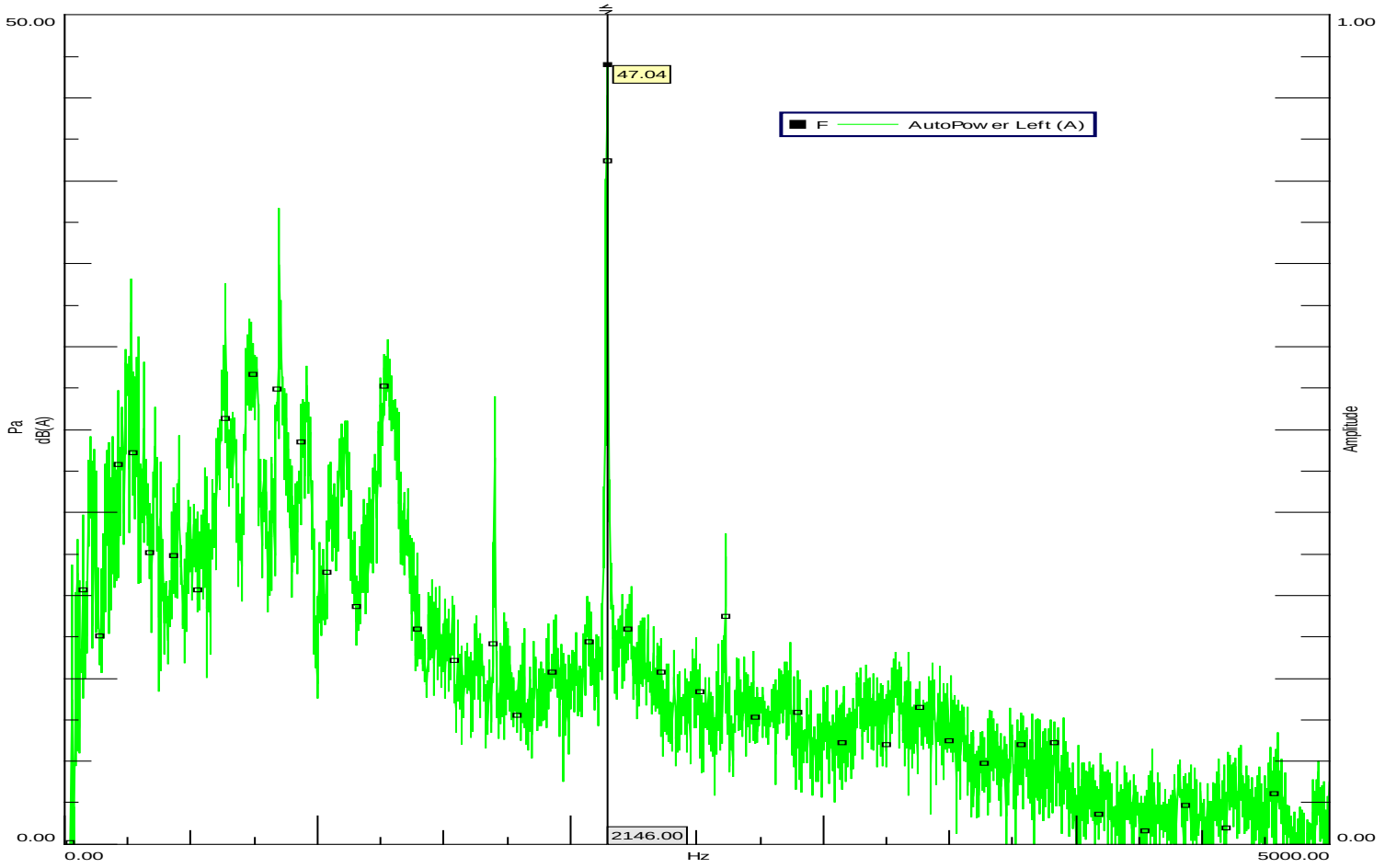
Pitch Shift – Outdoor 30 kph



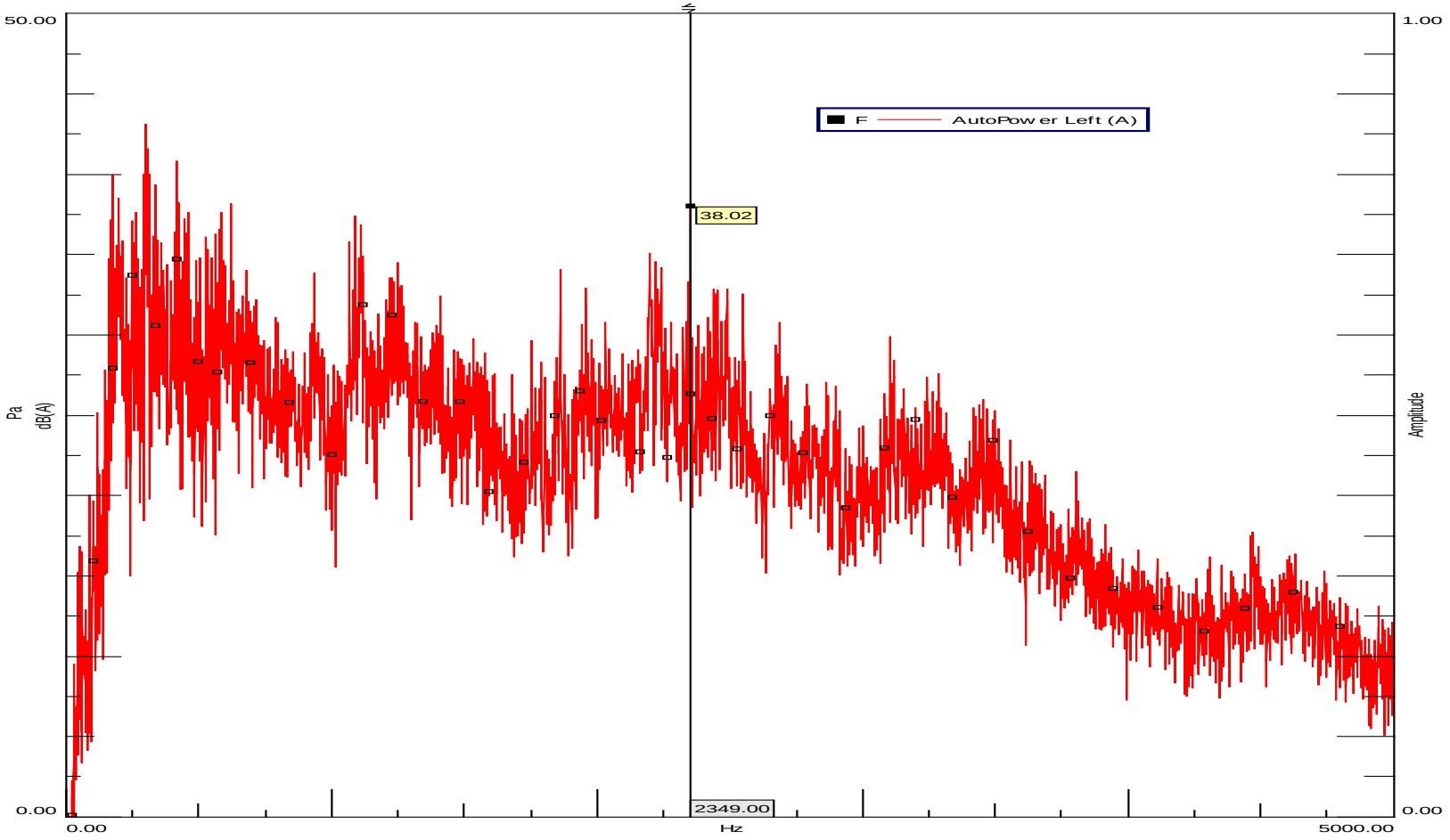
Pitch Shift – Indoor Stationary



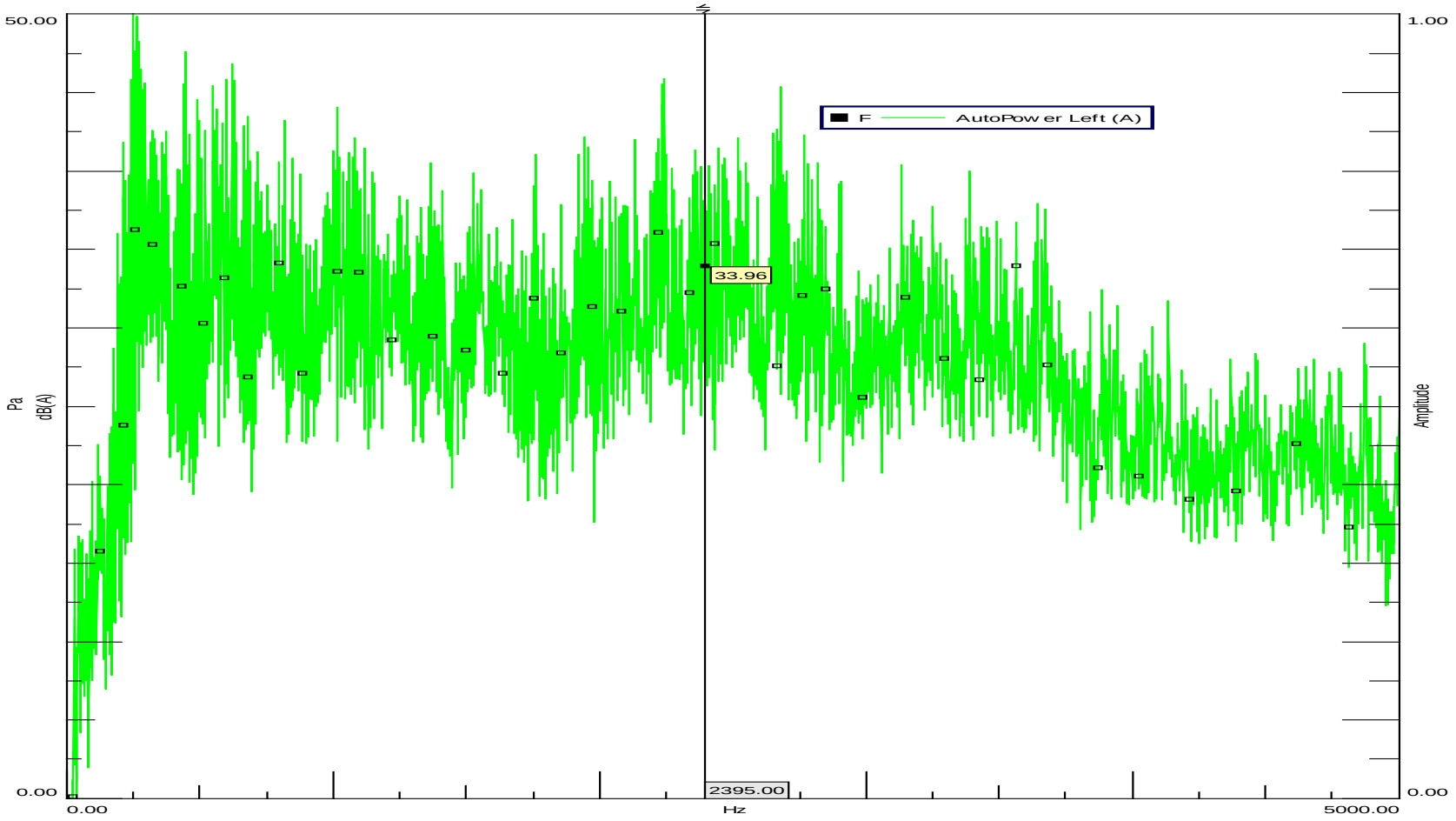
Pitch Shift 10kph Indoor



Pitch Shift 20 kph Indoor



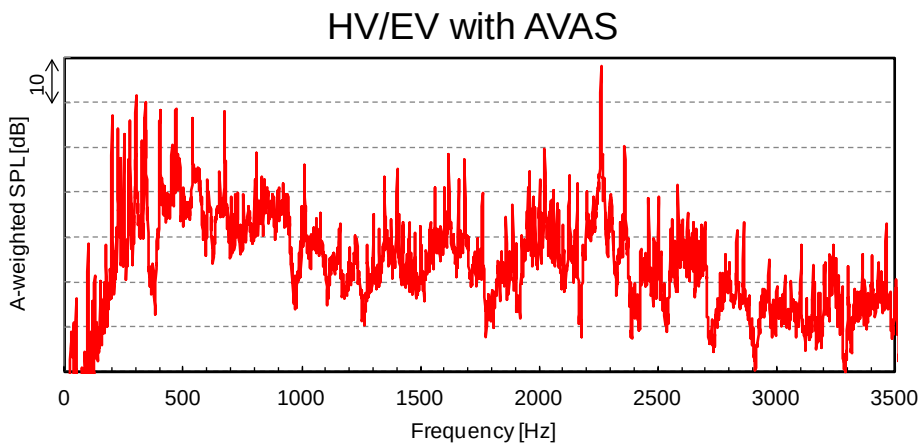
Pitch Shift 30 kph Indoor



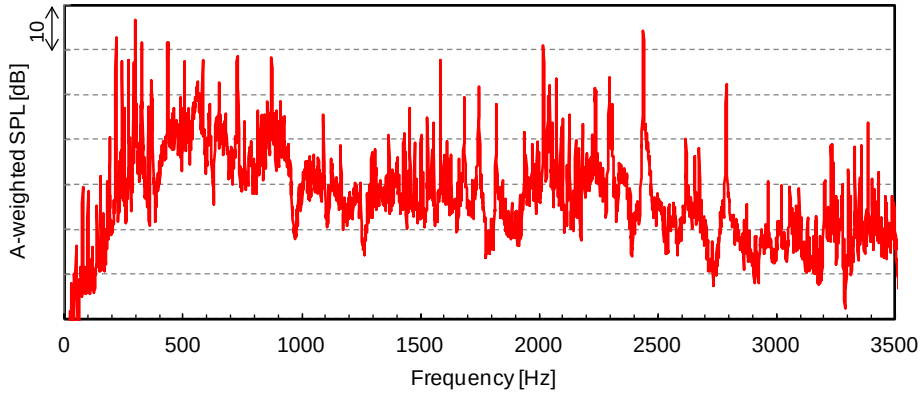
Examples of measurement results @ Semi-anechoic room (using external speed signal)

EV+AVAS

10 km/h

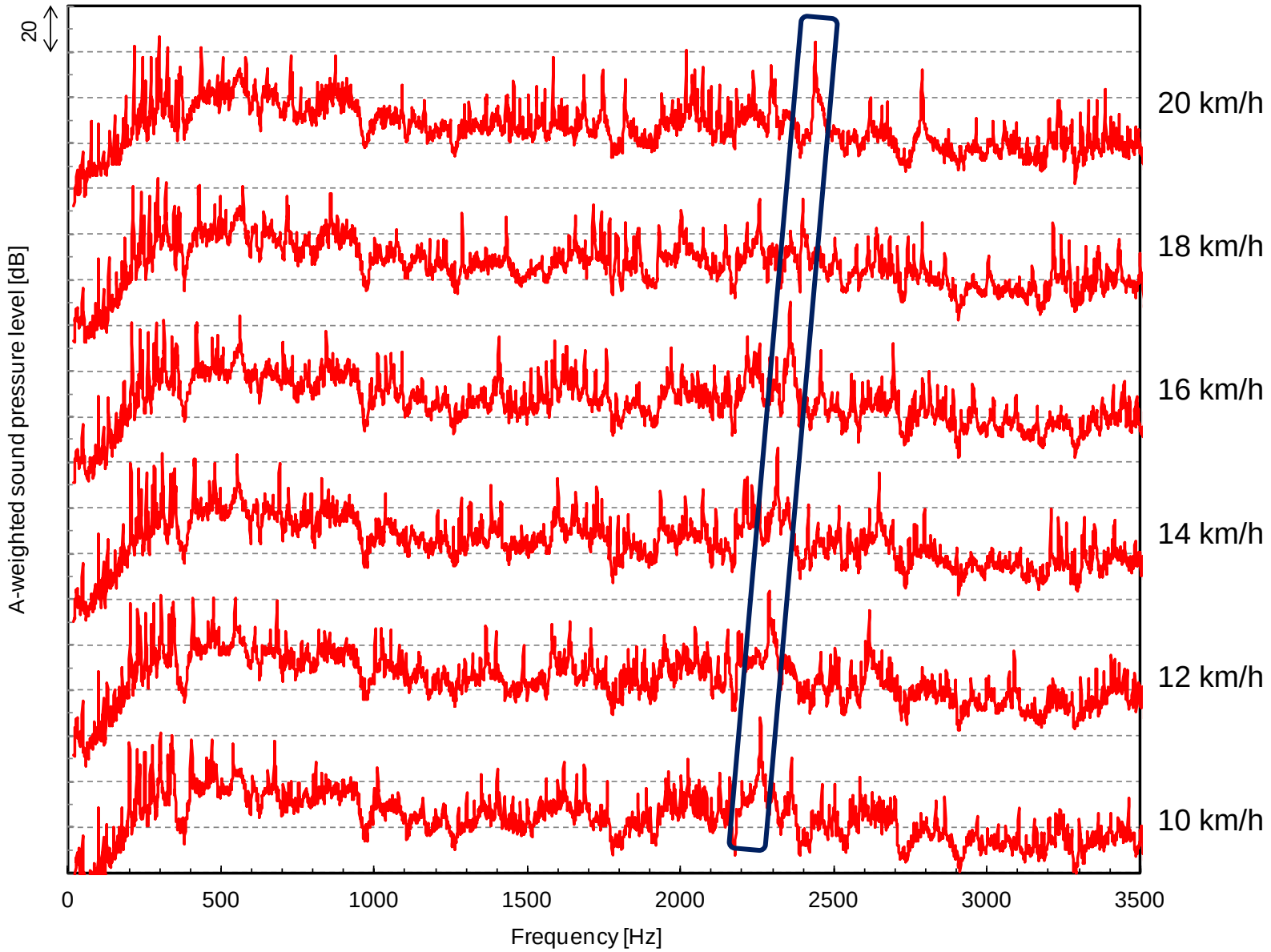


20 km/h



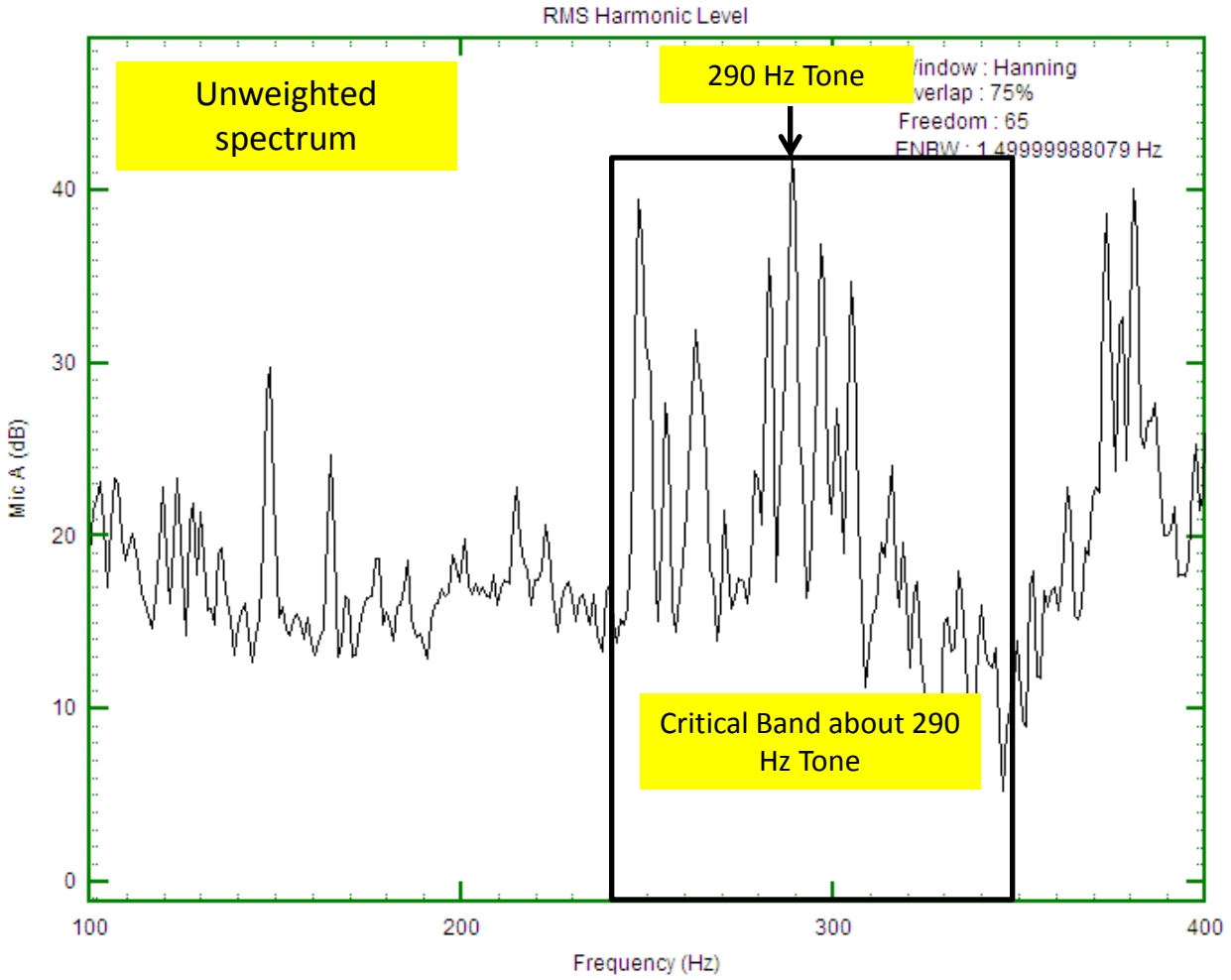
Examples of detailed measurement results @ Semi-anechoic room

➢From 10 to 20 km/h every 2 km/h → Find shifted frequency



Tonal Identification

- ***Identification of tone below 400 Hz:***



Spectra of BEV Alert B

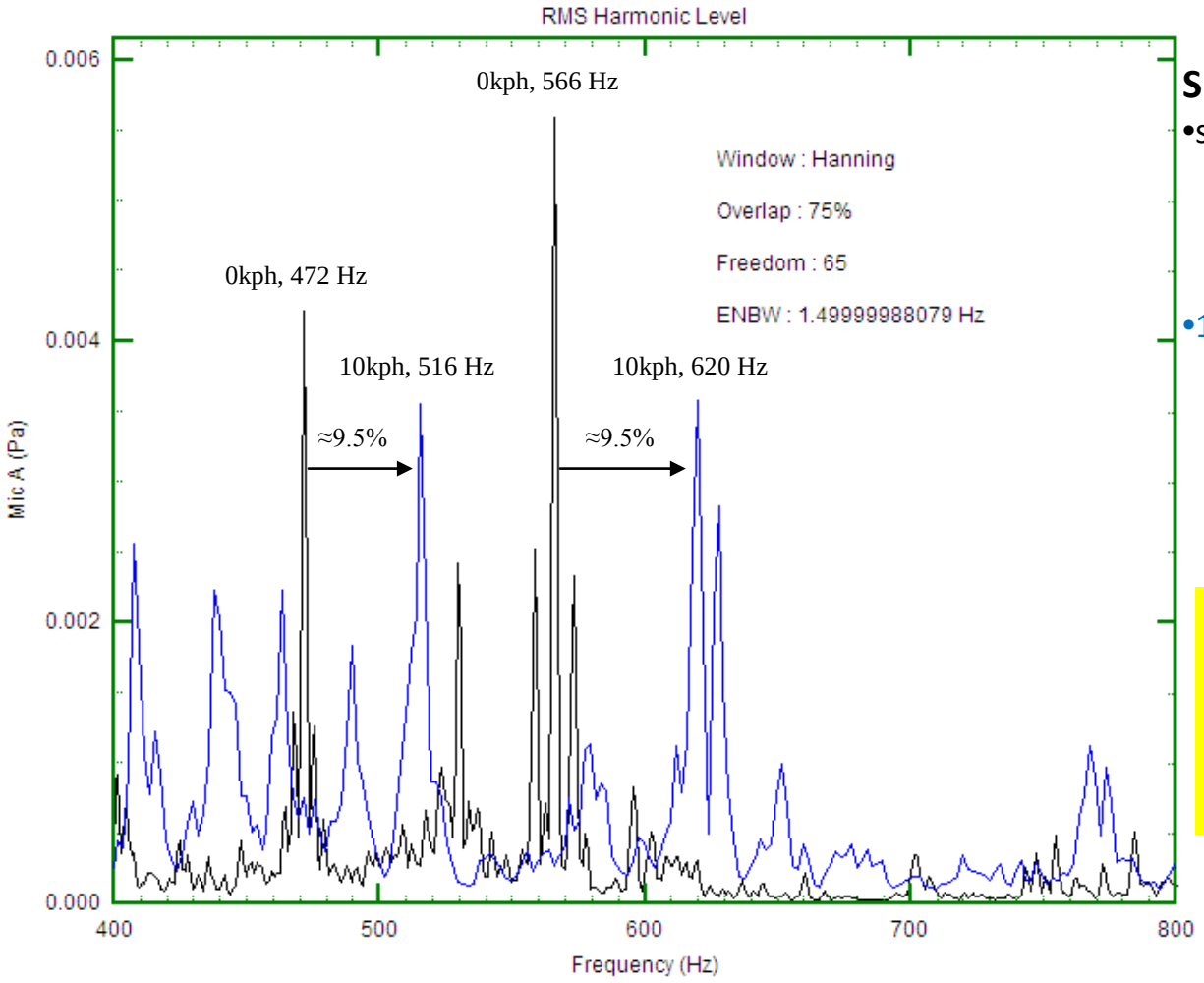
- stationary condition
- Frequency resolution =1 Hz
- window= Hanning
- overlap=75%
- averages = 65

Tone-to-Noise Ratio (TNR) > 6dB

- TNR compares tone power to noise power in a Critical Band
- **Issue: How to deal with other tones in the same Critical Band?**

Frequency Shifting

- ***Frequency Shifting of 1% per kph:***



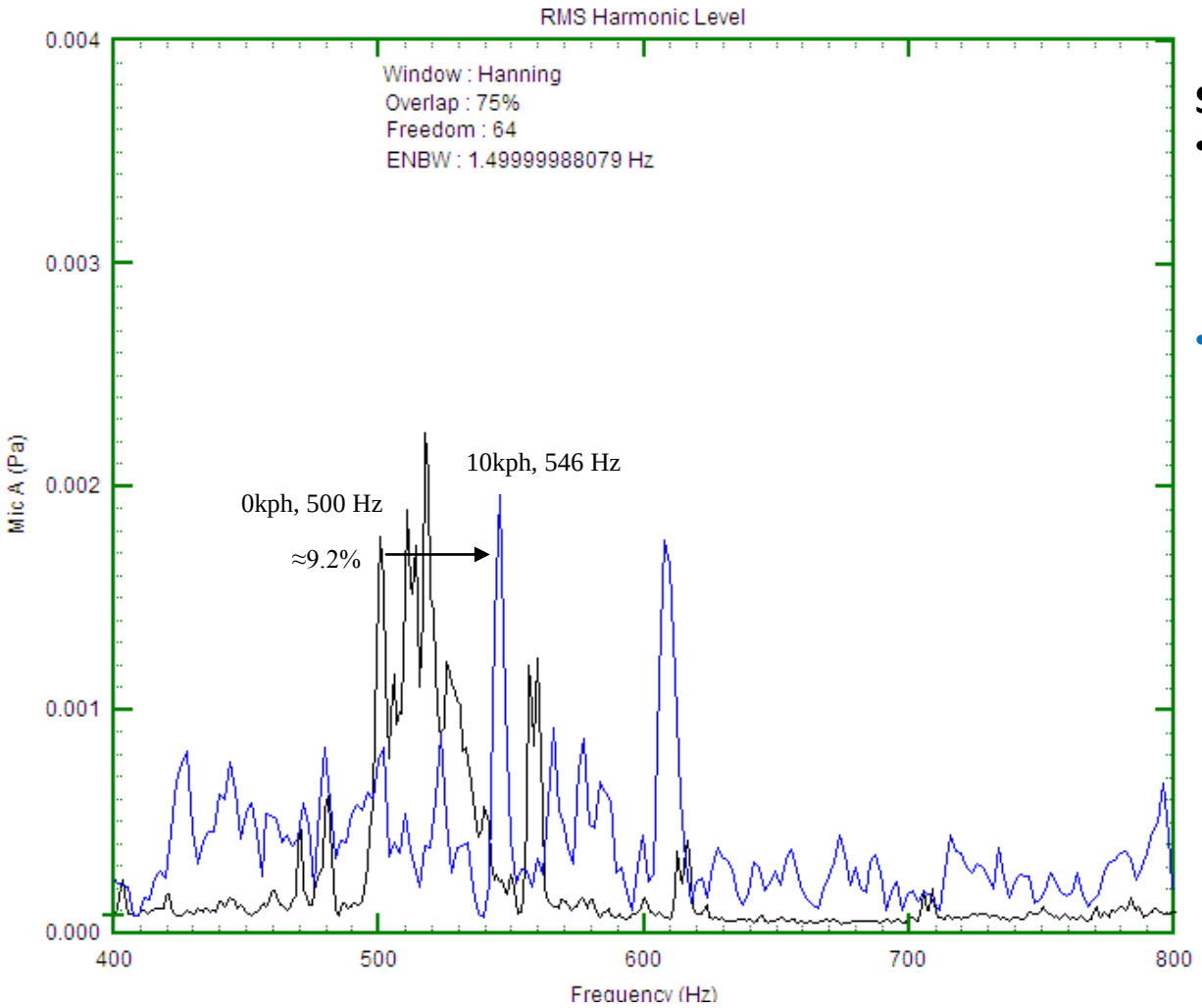
Spectra of BEV Alert B

- stationary condition
  - Frequency resolution =1 Hz
  - window= Hanning
  - overlap=75%
  - averages = 65
- 10 kph
  - Frequency resolution =1 Hz
  - window= Hanning
  - overlap=75%
  - Last 1 sec before PP'

Fairly easy to manually track tone(s) when they are not clustered together

Frequency Shifting

- ***Frequency Shifting of 1 % / kph:***



Spectra of BEV Alert C

- stationary condition
  - Frequency resolution =1 Hz
  - window= Hanning
  - overlap=75%
  - averages = 65
- 10 kph
  - Frequency resolution =1 Hz
  - window= Hanning
  - overlap=75%
  - Last 1 sec before PP'

Challenging to manually track tone(s) when they are clustered together.

Issues Identified

- Measurement and correction for 1/3 octave data.
  - Min, max, L vs. R, Ave., Time slice, windows, filters, averaging.
- Measurement uncertainty – all sources
  - Run to run
  - Day to day
  - Site to site
  - ISO has standard procedures and processes (“GUM”) for evaluation of uncertainty that are required for every published International Standard.
- Use of minimum sound levels in 1/3 octaves for detection and recognition
  - Confirmation with existing IC vehicles
  - Confirmation with Jury evaluations
- Pitch Shift measurement and analysis
  - Ability to measure full vehicle at higher speeds (20, 30 kph)
  - Specification of measurement and analysis methods.
  - Prior knowledge of signals

Ideas for Improvement and Optimization

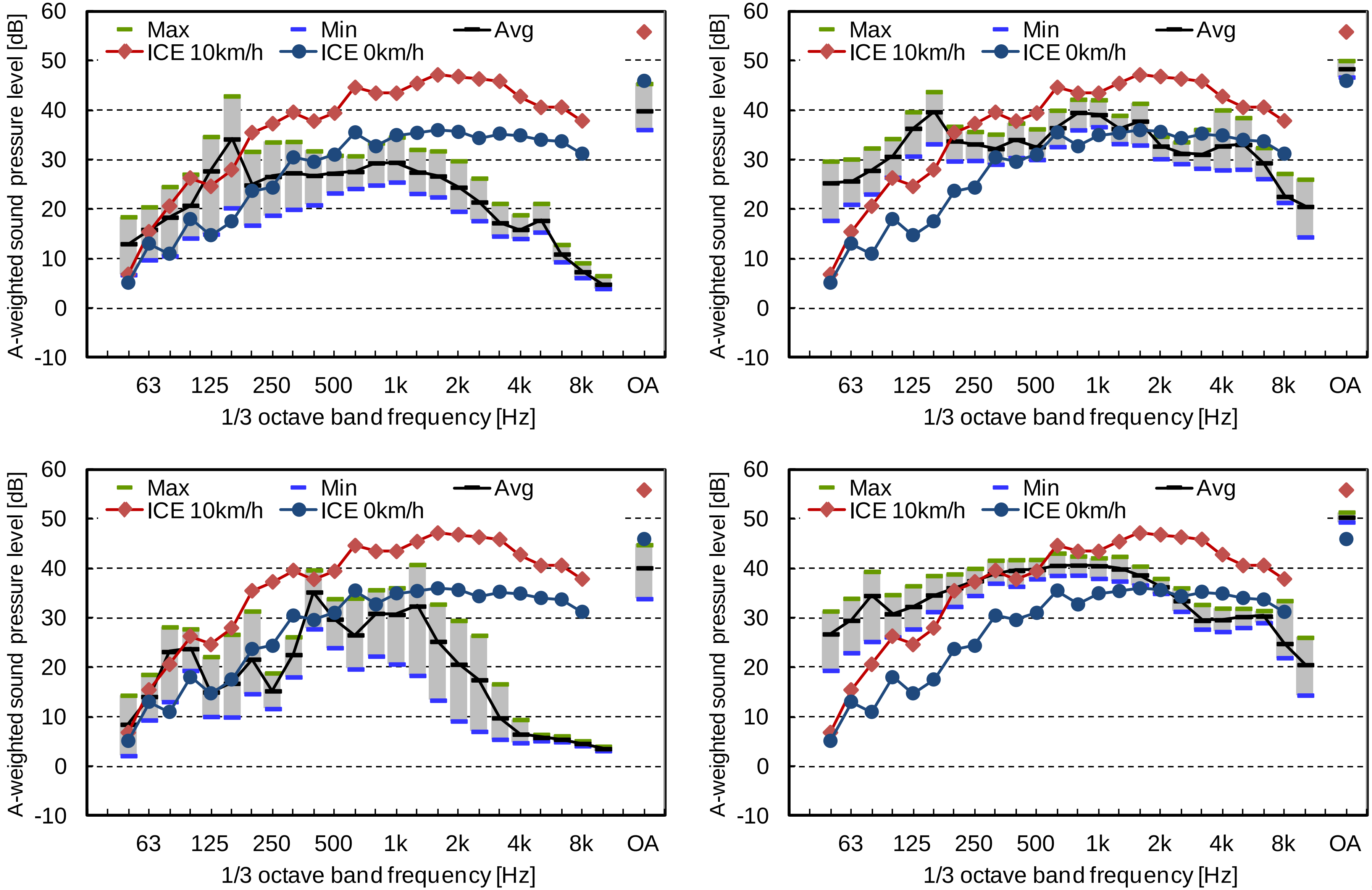
- Use of indoor facilities and their widespread availability
  - Solves background noise issues
  - Potential reduction in run to run variability
  - 7.5m passby facility not necessary –> 2m facilities with cutoff frequencies below 200Hz are widely available.
- Revised 1/3 octaves
  - Consistent with data presented.
  - Further data to be considered
- Revised Pitch shift measurement and analysis
  - Measurement at component level
  - Full vehicle acceleration measurement

Next Steps

- Incorporation of comments from industry, government, and SAE/ISO on measurement program.
  - Recent ISO WG42 full committee meeting in Brazil to discuss comments on ISO/CD 16254
- Conclusion of measurements by Dec 2012.
  - Joint ISO WG42 / SAE TF3 meeting Dec. 11th (Detroit) to consider final results, comments, and to determine necessary revisions to the test procedures.
  - Expect updates to draft ISO/SAE test procedures to handle editorial, clarification, and technical issues relating to pitch shift measurement in near term (3-4 months)
  - Development of test procedure for 1/3 octave measurement and measurement of “commencing motion” will require additional time

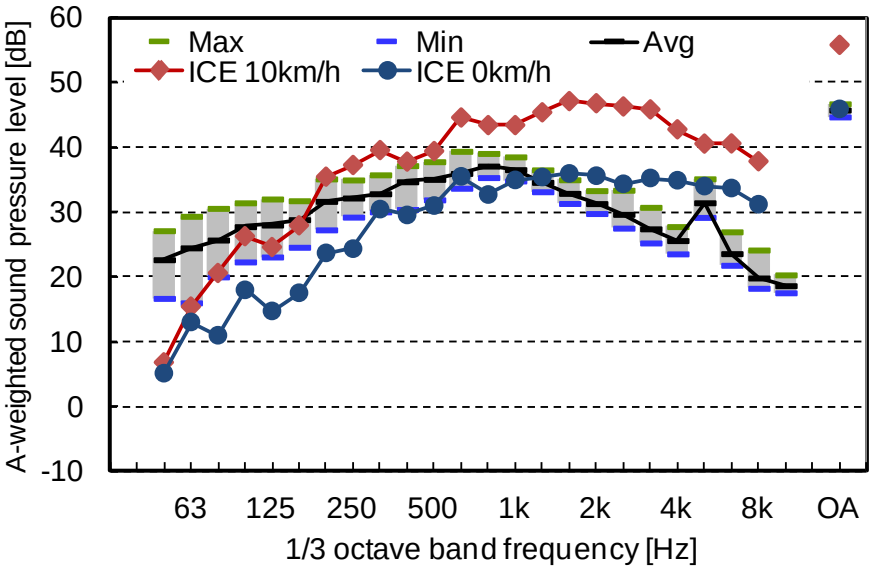
Ambient noise variation in several prouving grounds

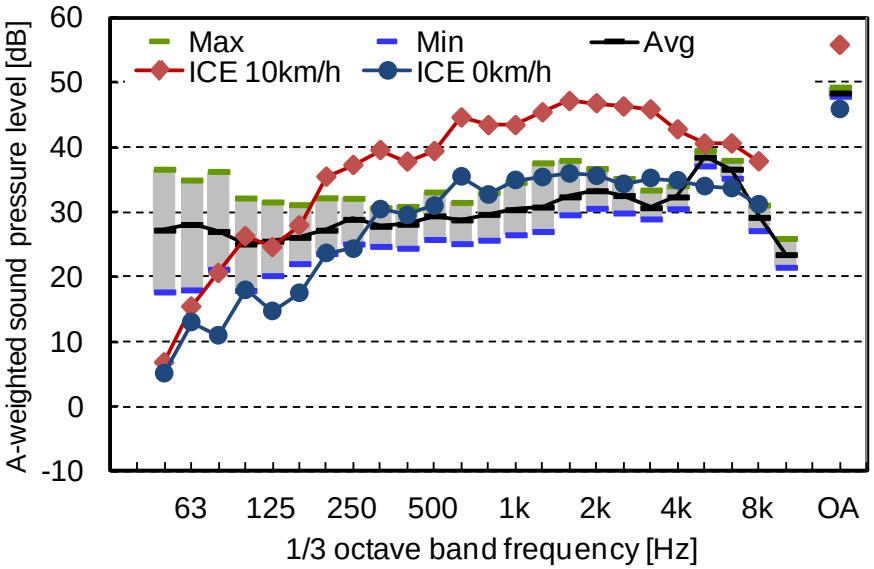
1/3Oct.（0km/h, 10km/h）S/N>10dB

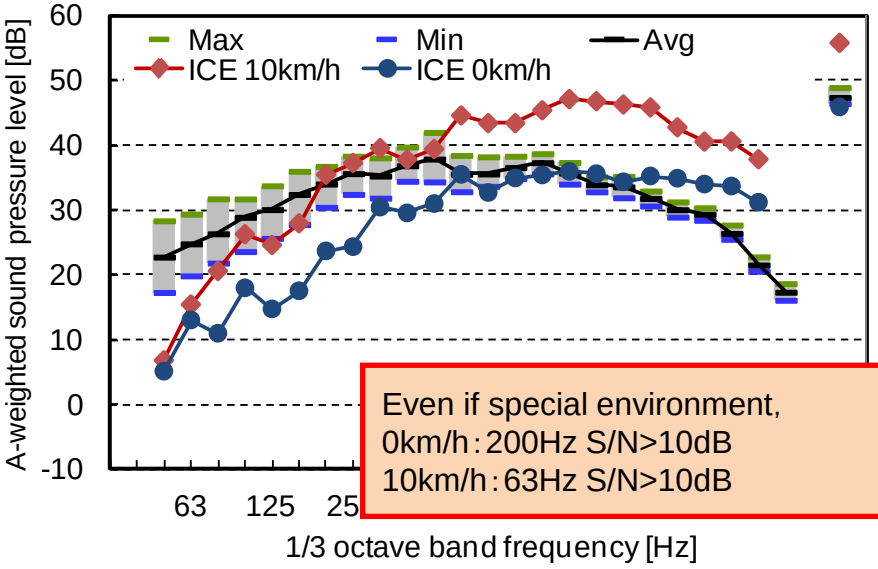


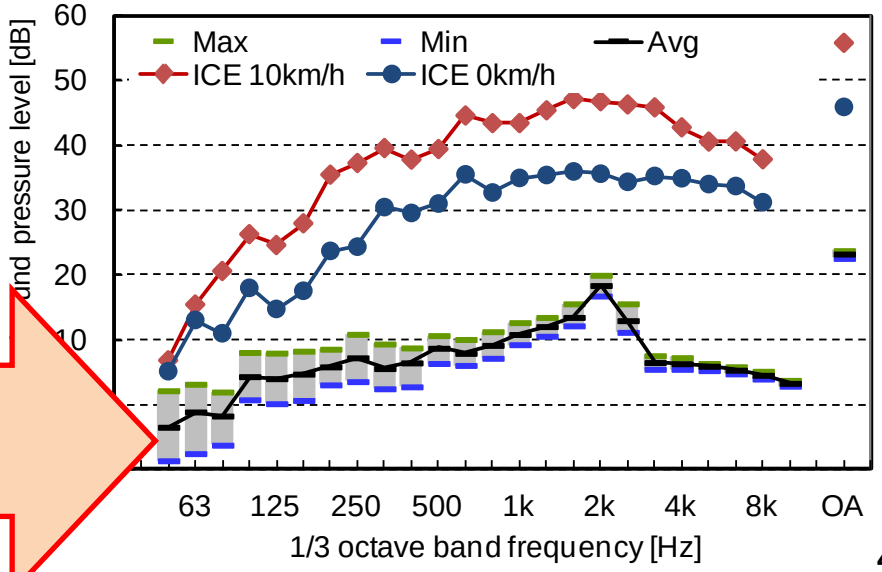
Ambient noise variation in several prouving grounds

1/3Oct. ICE（0km/h, 10km/h）S/N>10dB



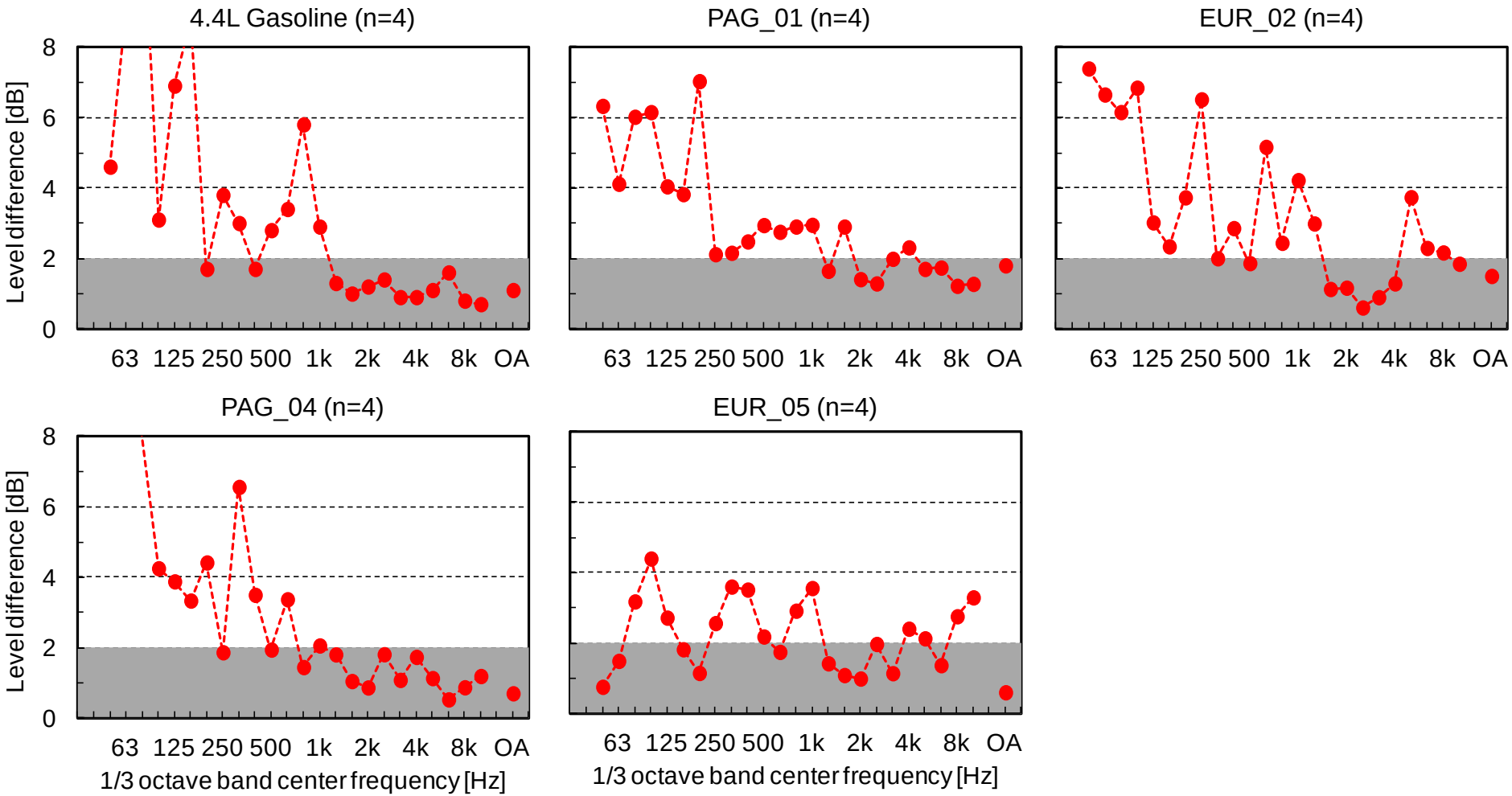






Even if special environment,
0km/h：200Hz S/N>10dB
10km/h：63Hz S/N>10dB

Example of dispersion in each measurement : 10 km/h cruise @ISO test track



The variation of OA level is within 2dB. Normally the data within 2dB are valid,
But the variations of 1/3 octave level are much more than 2dB.