Sonic Boom Variation of a Wing-Body-Tail-Nacelle Configuration

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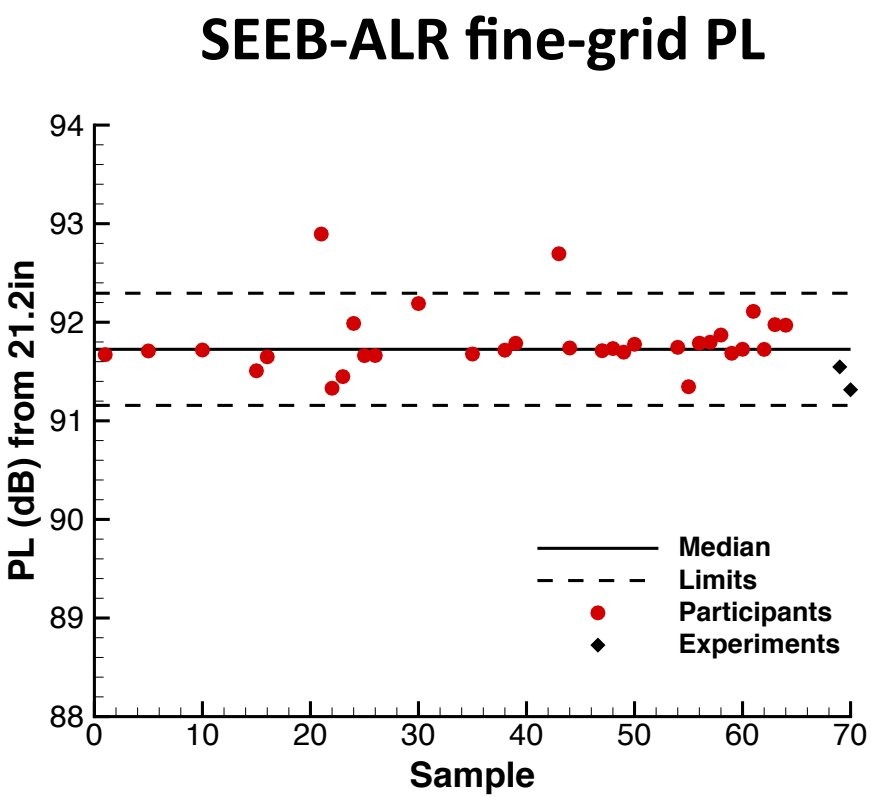
Background and Motivation

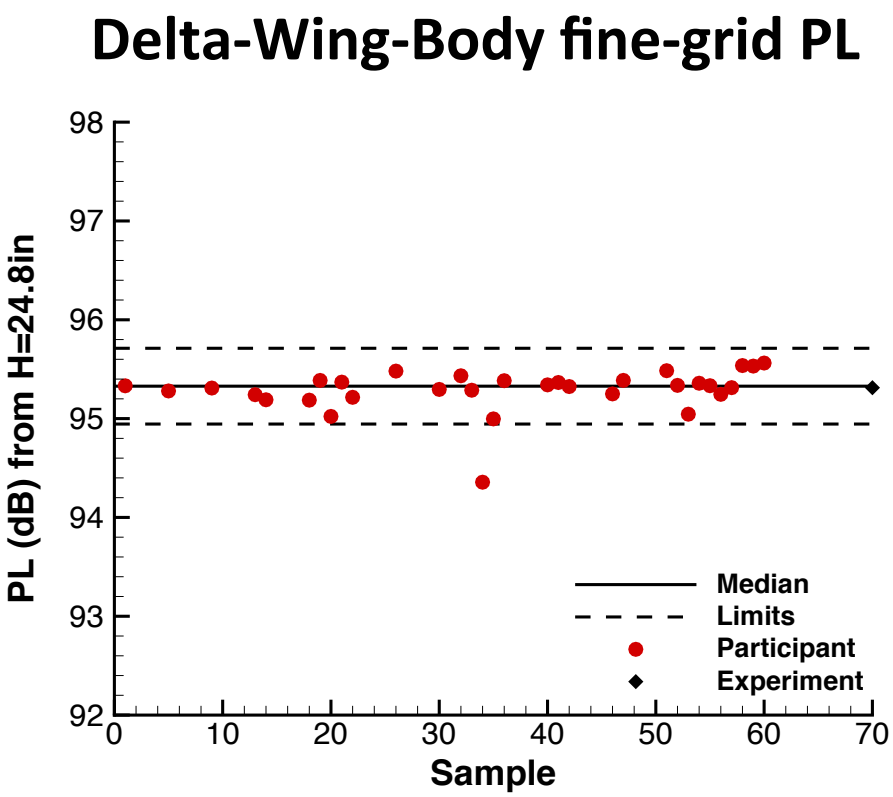
- At the First AIAA Sonic Boom Workshop (SBPW-1) at SciTech 2014
  - Perceived Level (PL) noise measure variation for the two simple required cases was about 1 dB
  - PL variation for the optional wing-body-tail-nacelle configuration was about 10 dB
  - Humans can discern about a 2 dB difference
- Why was the variation larger for optional case?
- How should we approach the next workshop (SBPW-2) at SciTech 2017?

SBPW-1 Models

[image: Aftosmis, Nemec AIAA-2014-558]

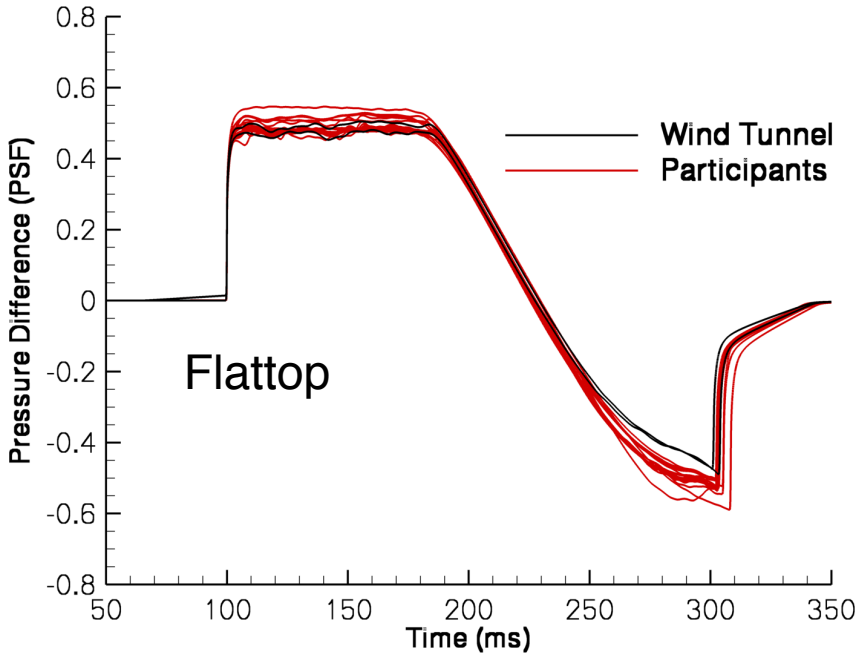
Background and Motivation



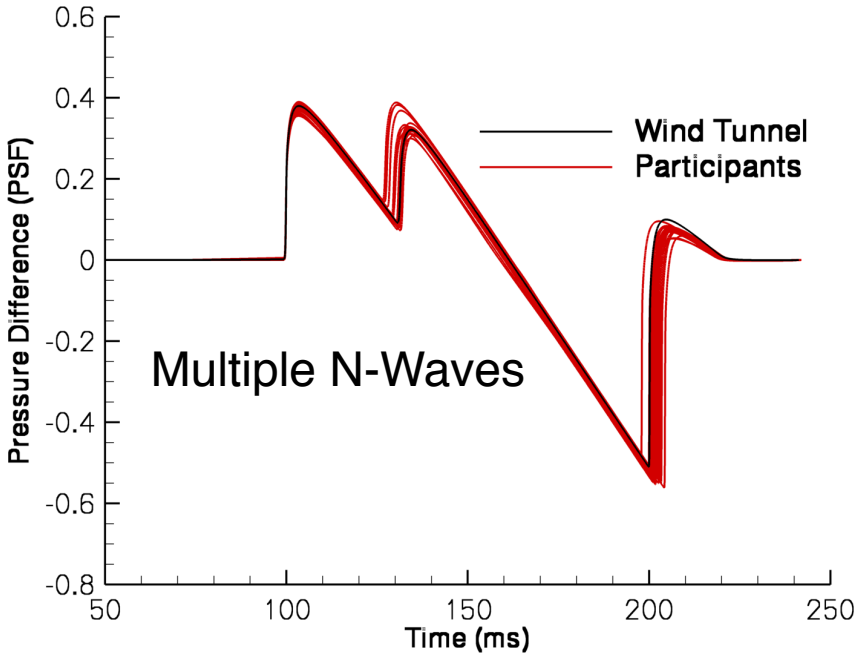


Background and Motivation

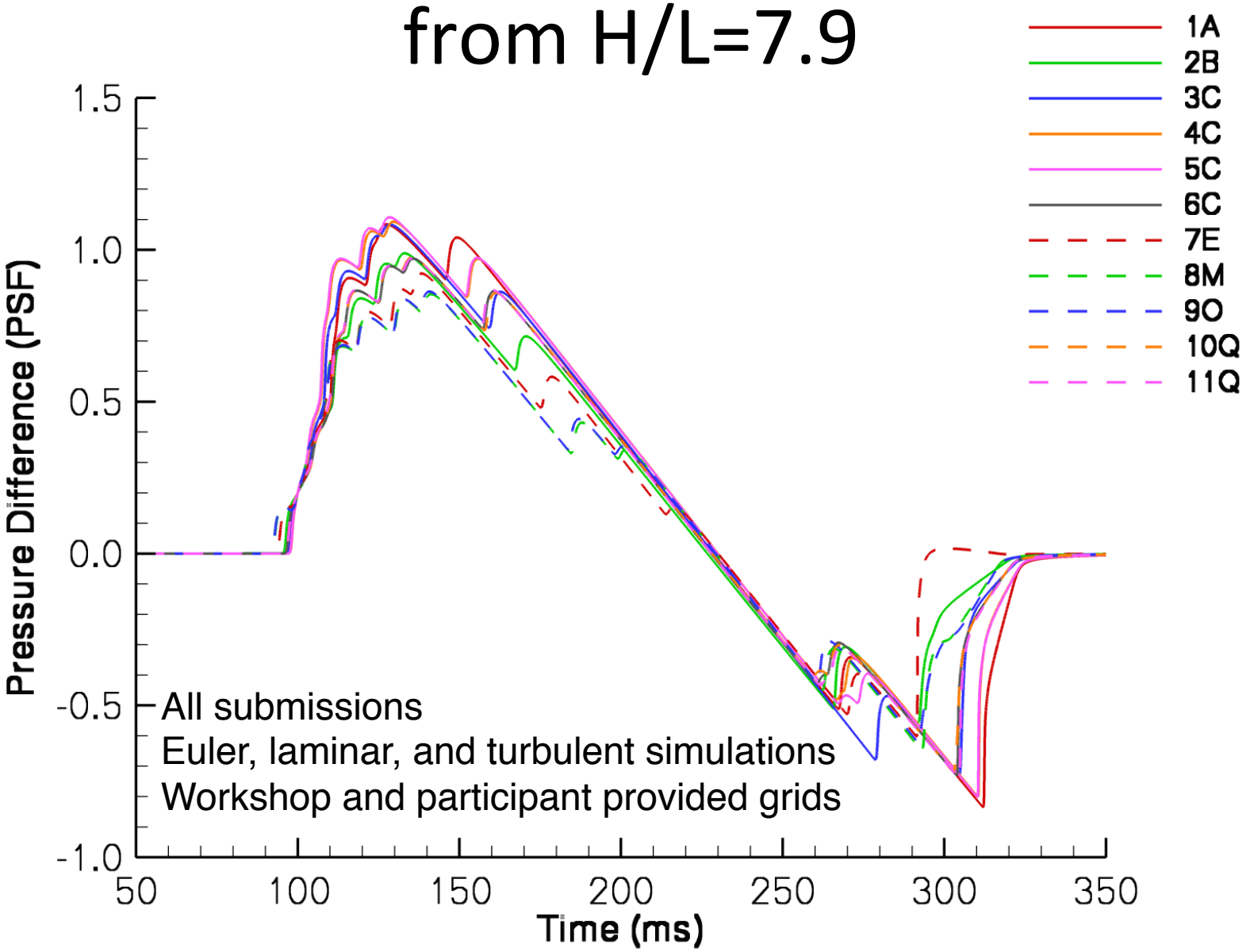
SEEB-ALR fine-grid ground



Delta-Wing-Body fine-grid ground



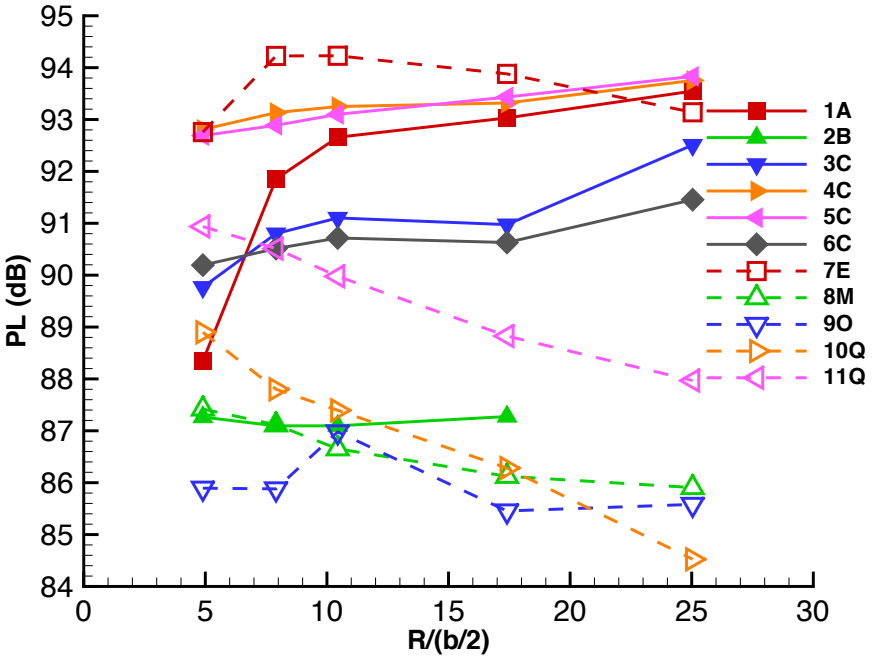
LM1021 Centerline Ground Signatures from H/L=7.9



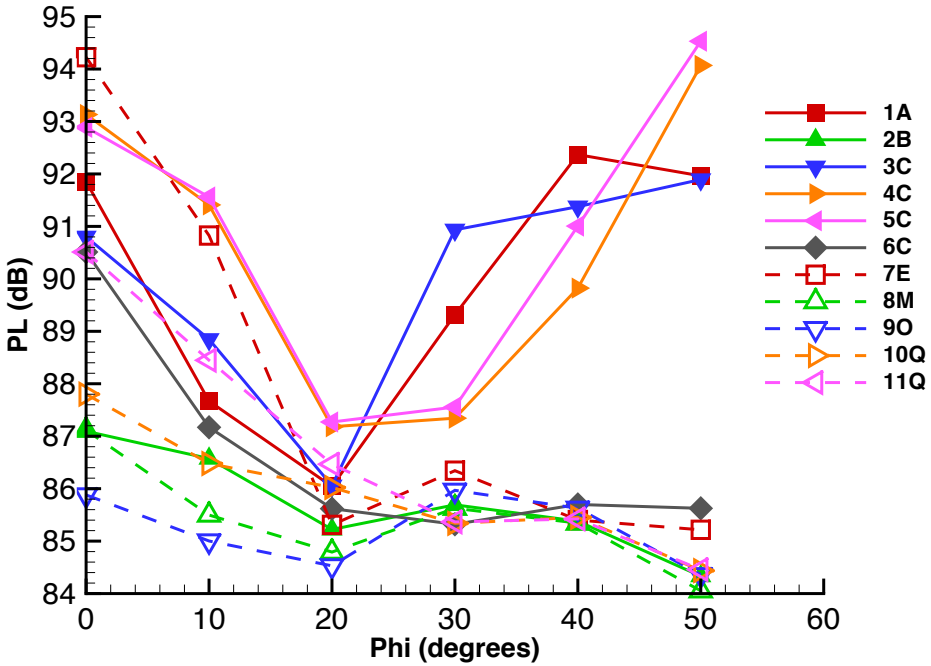
LM 1021 Background and Motivation

PL extracted at different H/L

PL extracted at different phi



At centerline

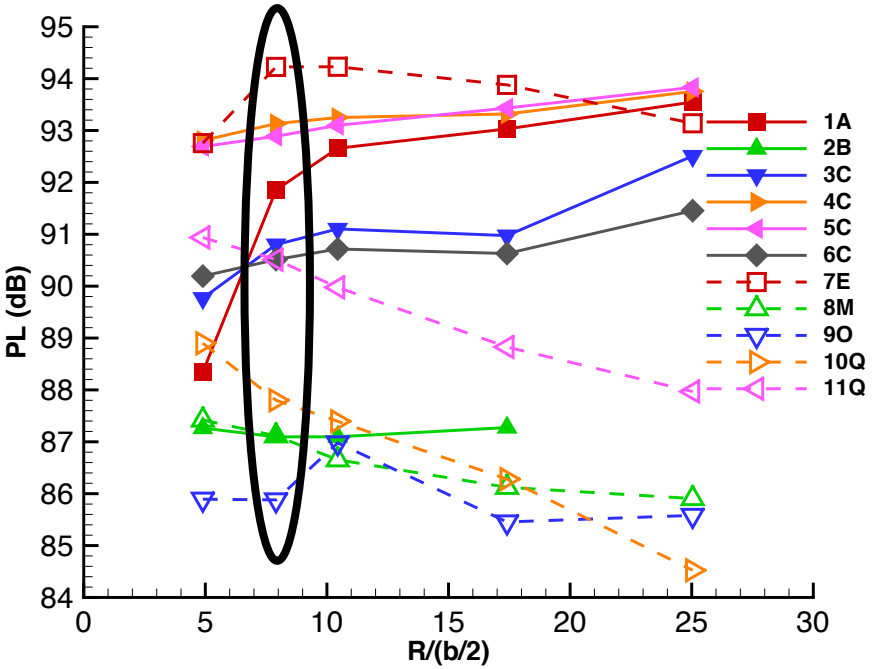


From R/(b/2)=7.9

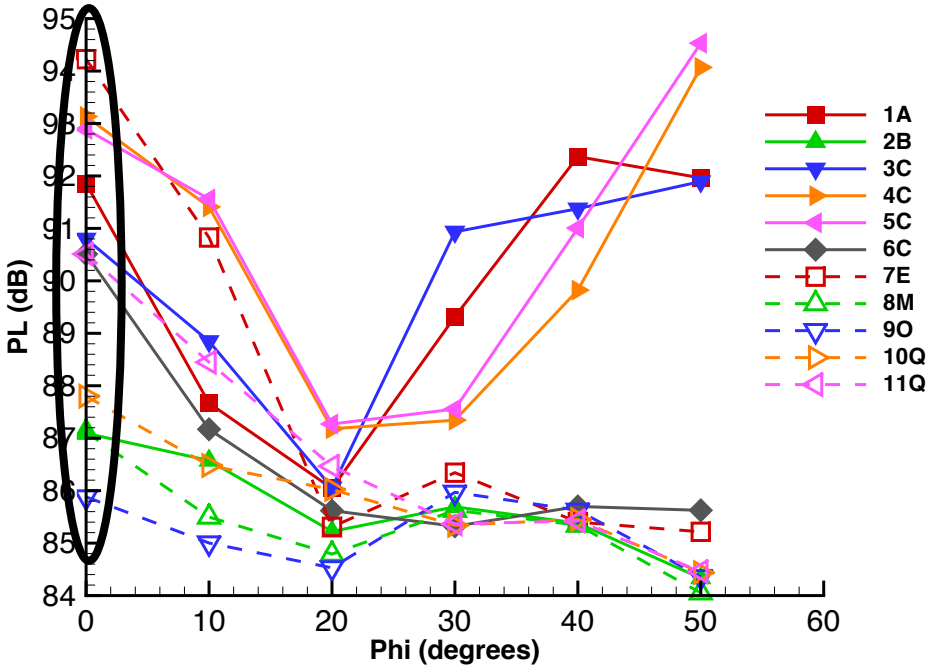
LM 1021 Background and Motivation

PL extracted at different H/L

PL extracted at different phi



At centerline



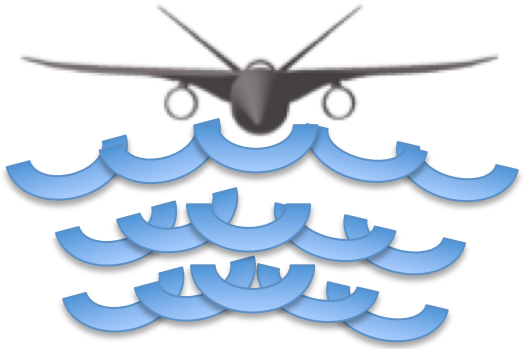
From R/(b/2)=7.9

Examine Size of Variation Sources

- Far-field multipole correction
- Signature close-out reconstruction
- Contribution of each shock (i.e., nose and tail shocks)
- Extraction distance
- Off-track

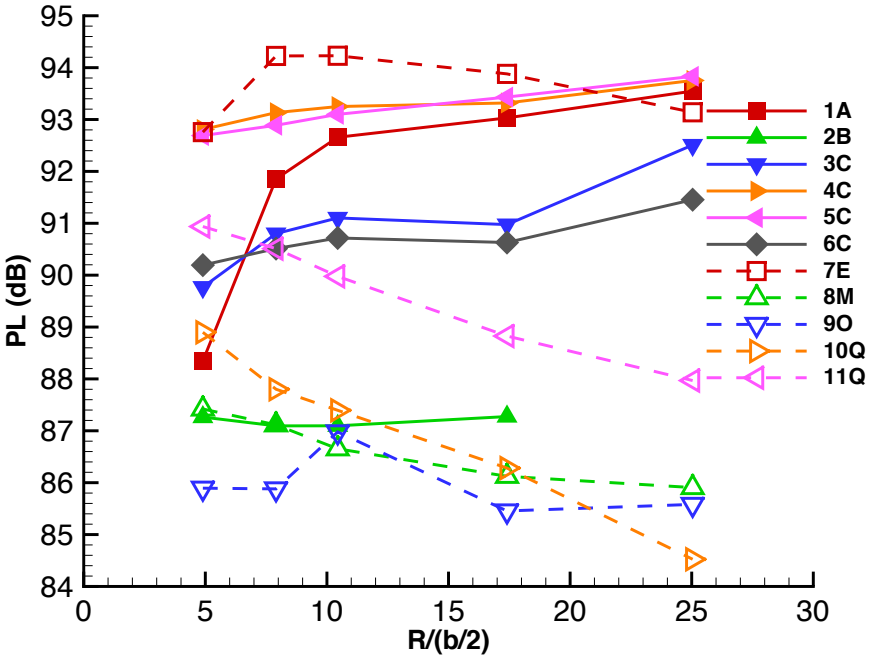
Multipole Far-Field Correction

- Page and Plotkin AIAA-91-3275
- Corrects for diffraction of acoustic sources in span wise direction
  - Mitigate sampling near-field pressure too close to the configuration
  - Correction is configuration dependent and decreases to zero with distance



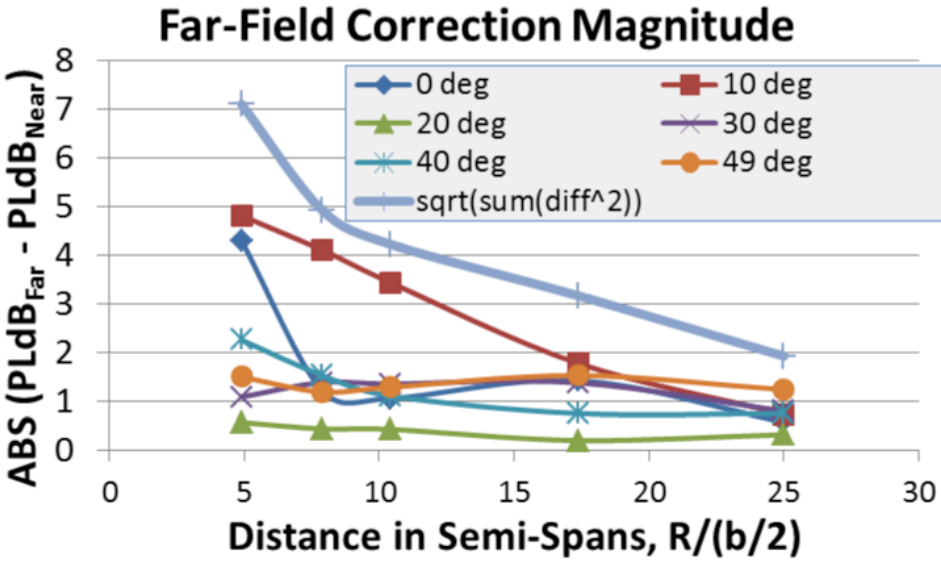
LM 1021 Far-Field (Multi-Pole) correction

PL extracted at different H/L



At centerline

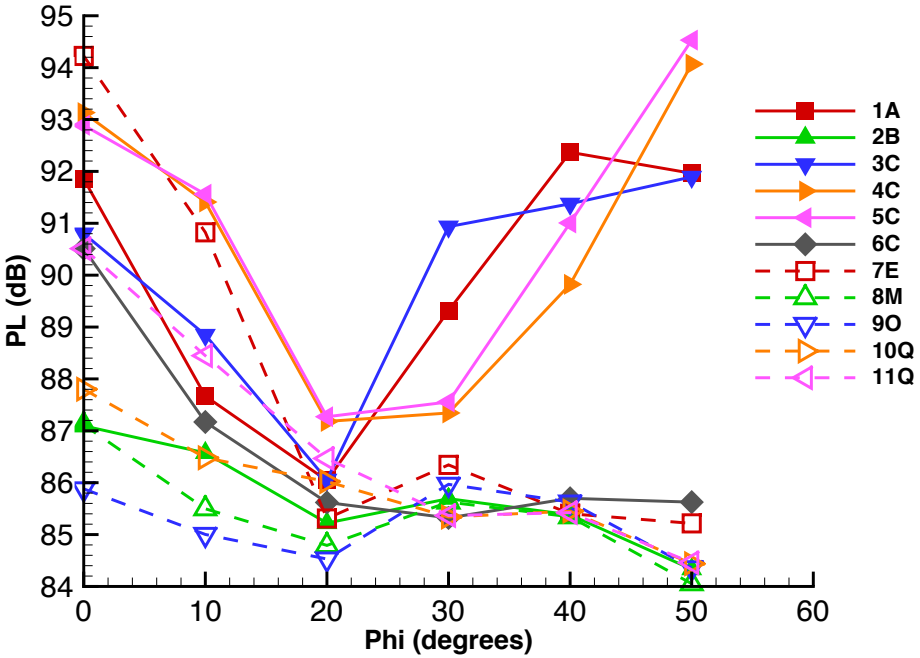
Multi-pole correction



[AIAA-2014-2006]

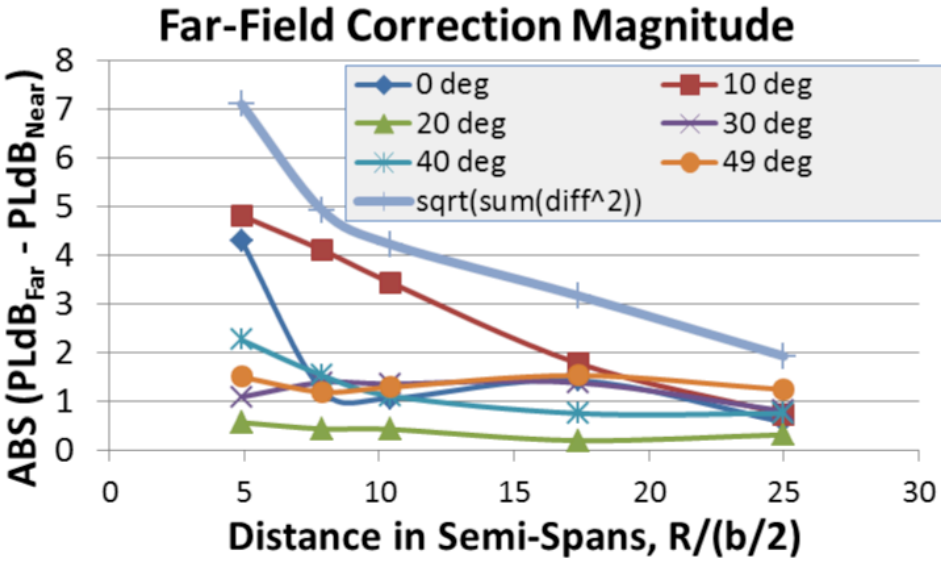
LM 1021 Far-Field (Multi-Pole) correction

PL extracted at different phi



From R/(b/2)=7.9

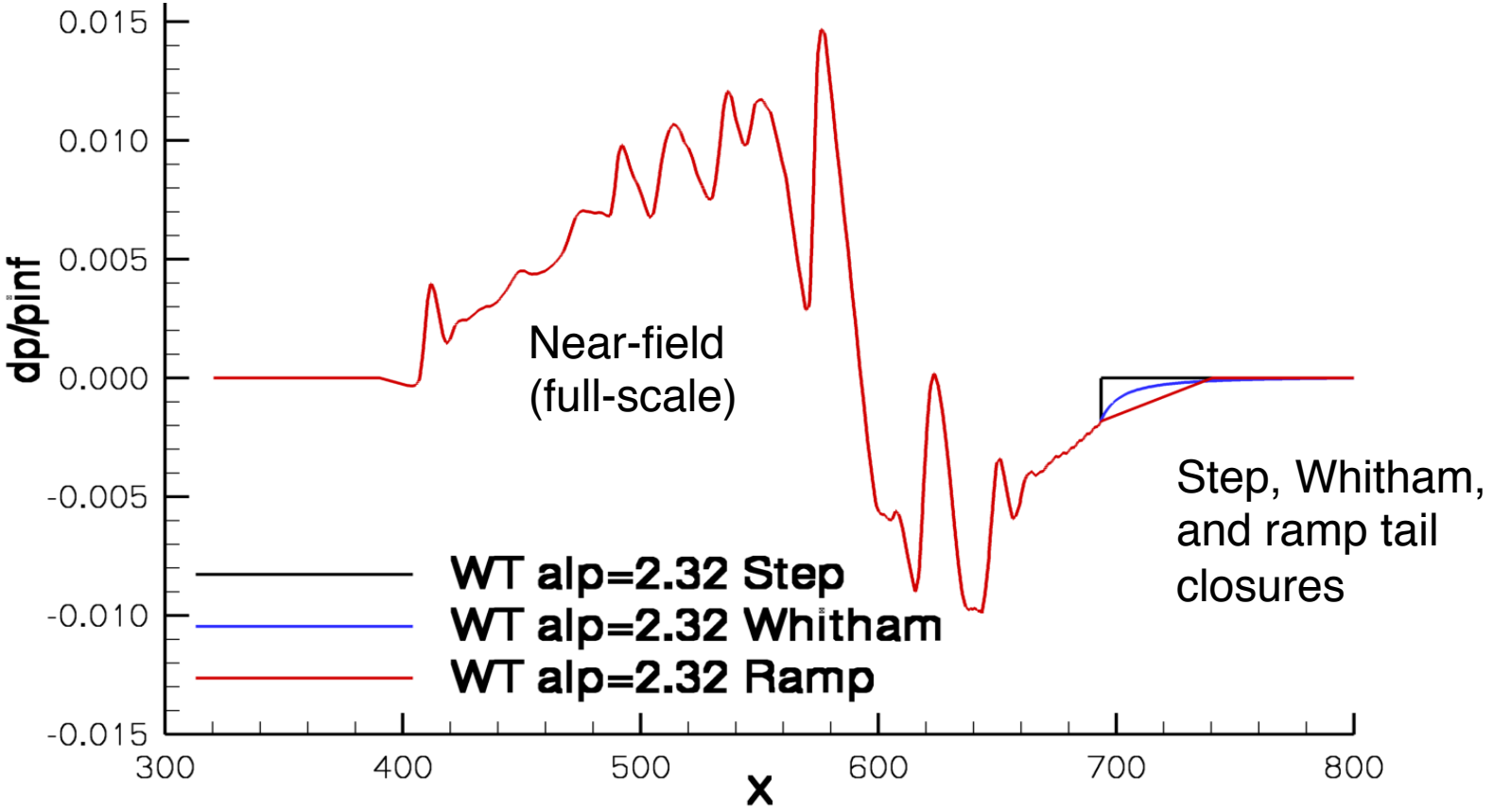
Multi-pole correction



[AIAA-2014-2006]

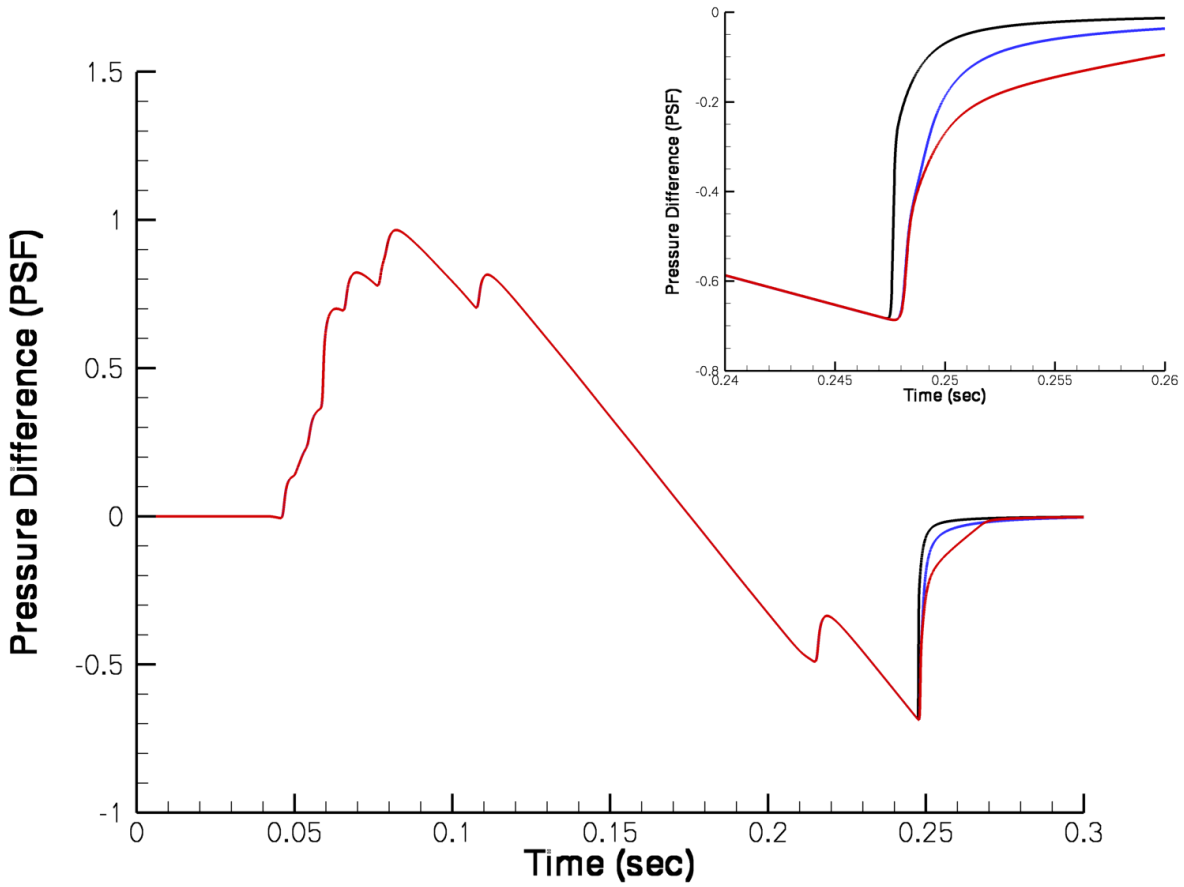
Tail closure

- LM1021 wind tunnel model aft signature must be recreated to remove the mounting sting from the measurements and simulation



Tail closure

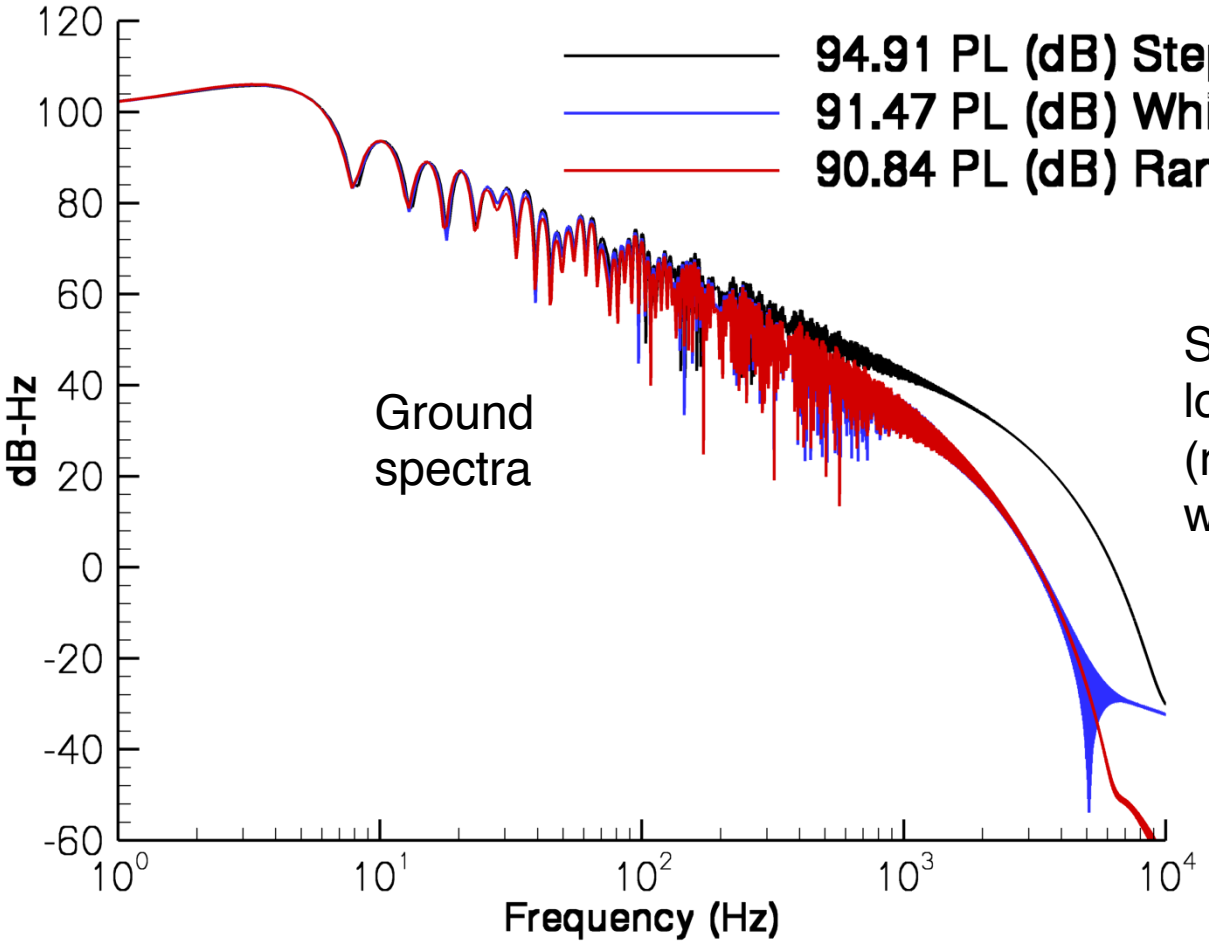
- The steepness of the aft shock of this model is sensitive to the aft signature reconstruction method



Step, Whitham, and ramp tail closures

Tail closure

- Higher frequencies are impacted by tail shock steepness

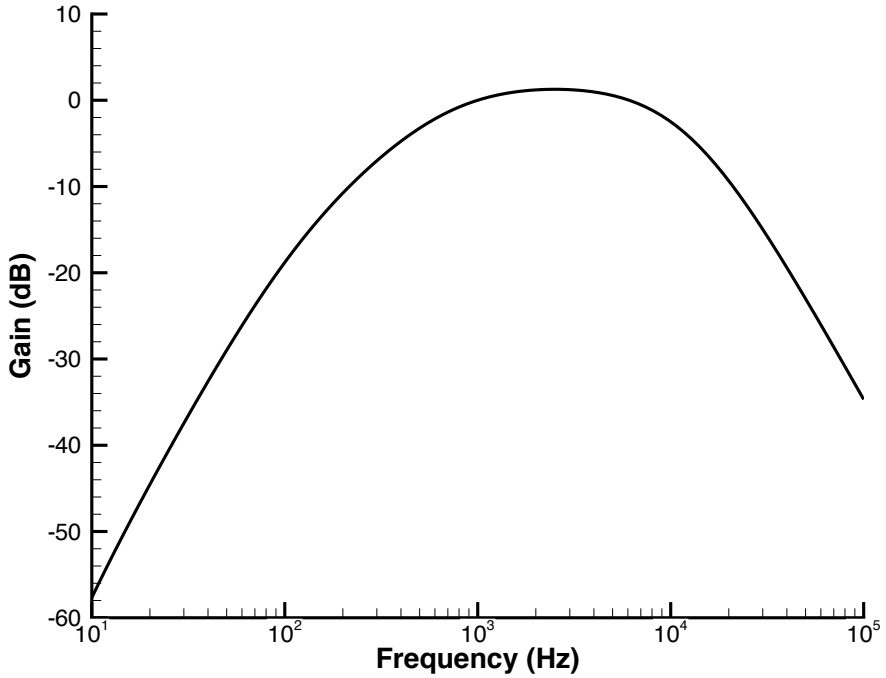


Step closure 4 PL (dB) louder than ramp (ramp was used at workshop)

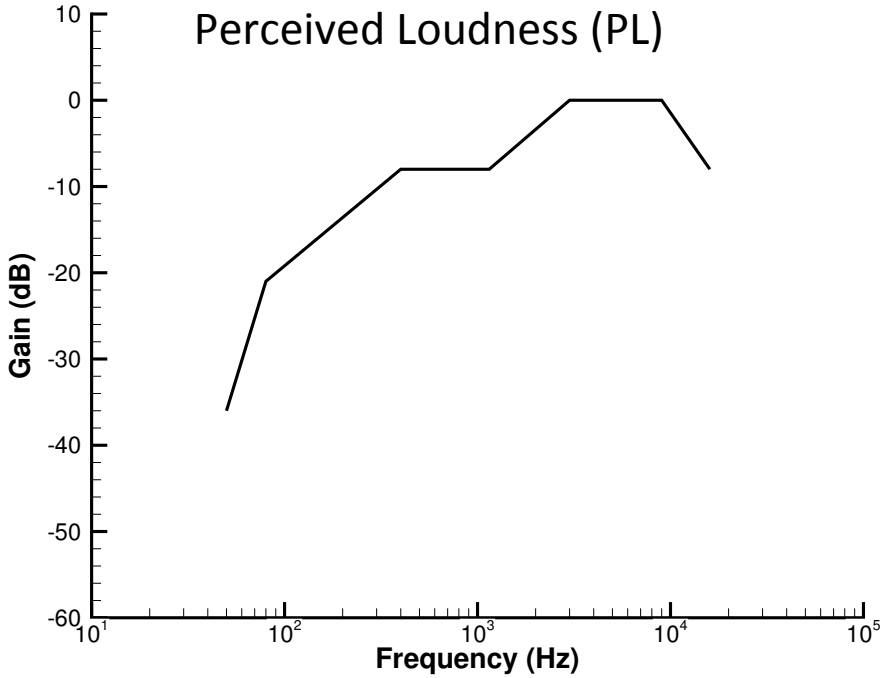
PL and A-Weighted Sound Exposure Level (ASEL)

- Humans perceive noises to be louder if they are 600 Hz to 10,000 Hz
- Measures have been evaluated in experiments (PL best loudness correlation)
- ASEL is a good surrogate for PL and is a continuous weighting

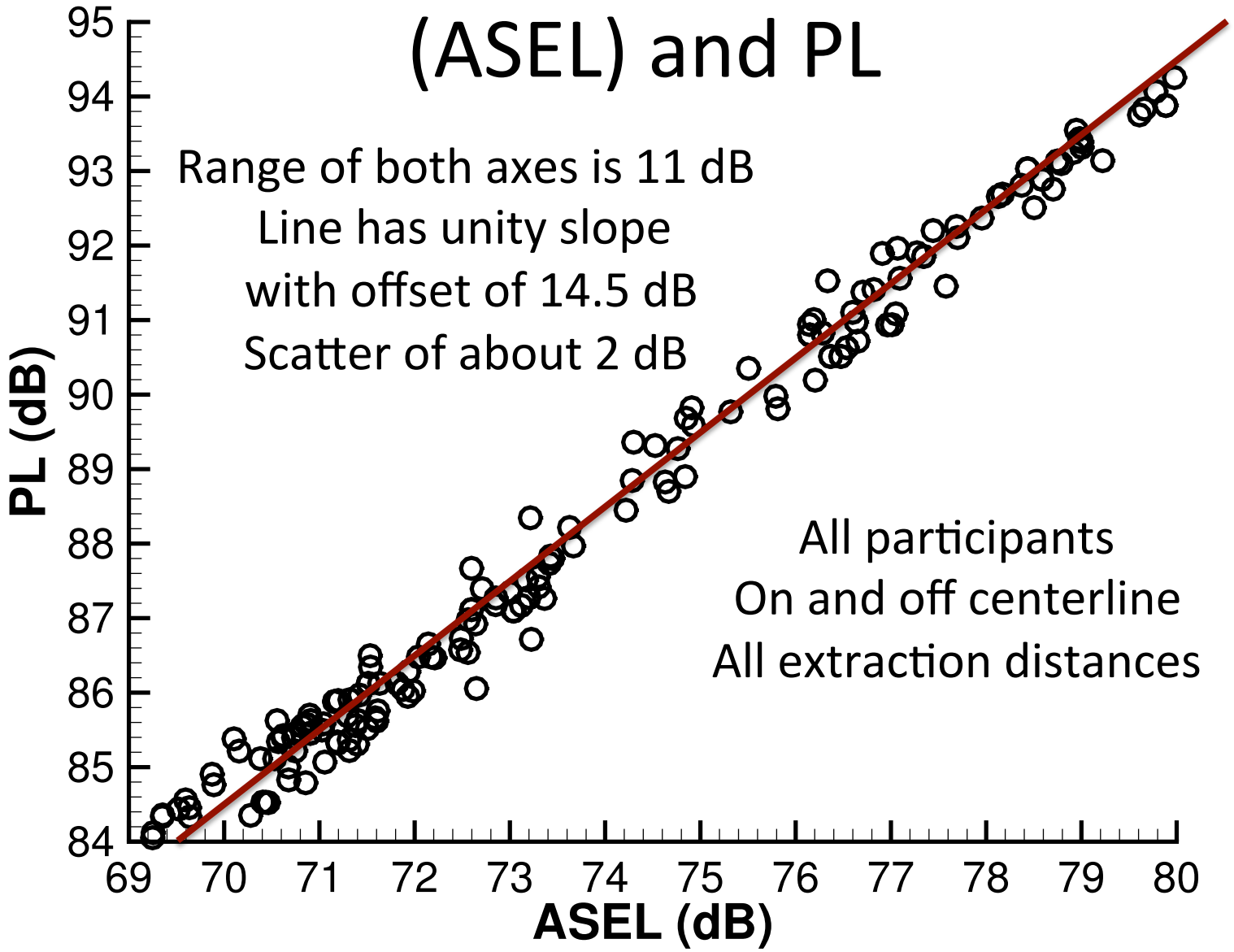
A-Weighted Sound Exposure Level



Stevens JASA (1971)
Perceived Loudness (PL)



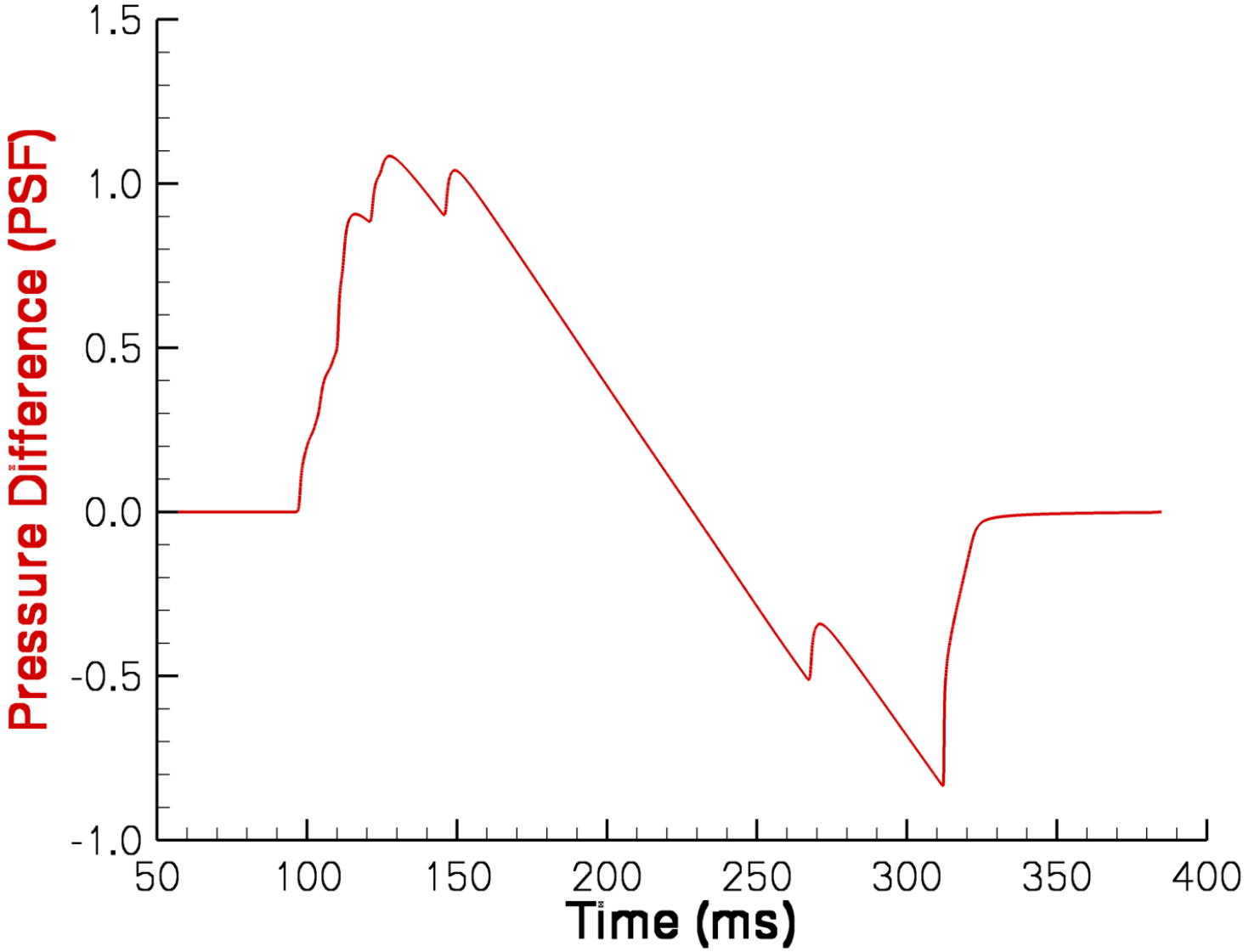
A-Weighted Sound Exposure Level (ASEL) and PL



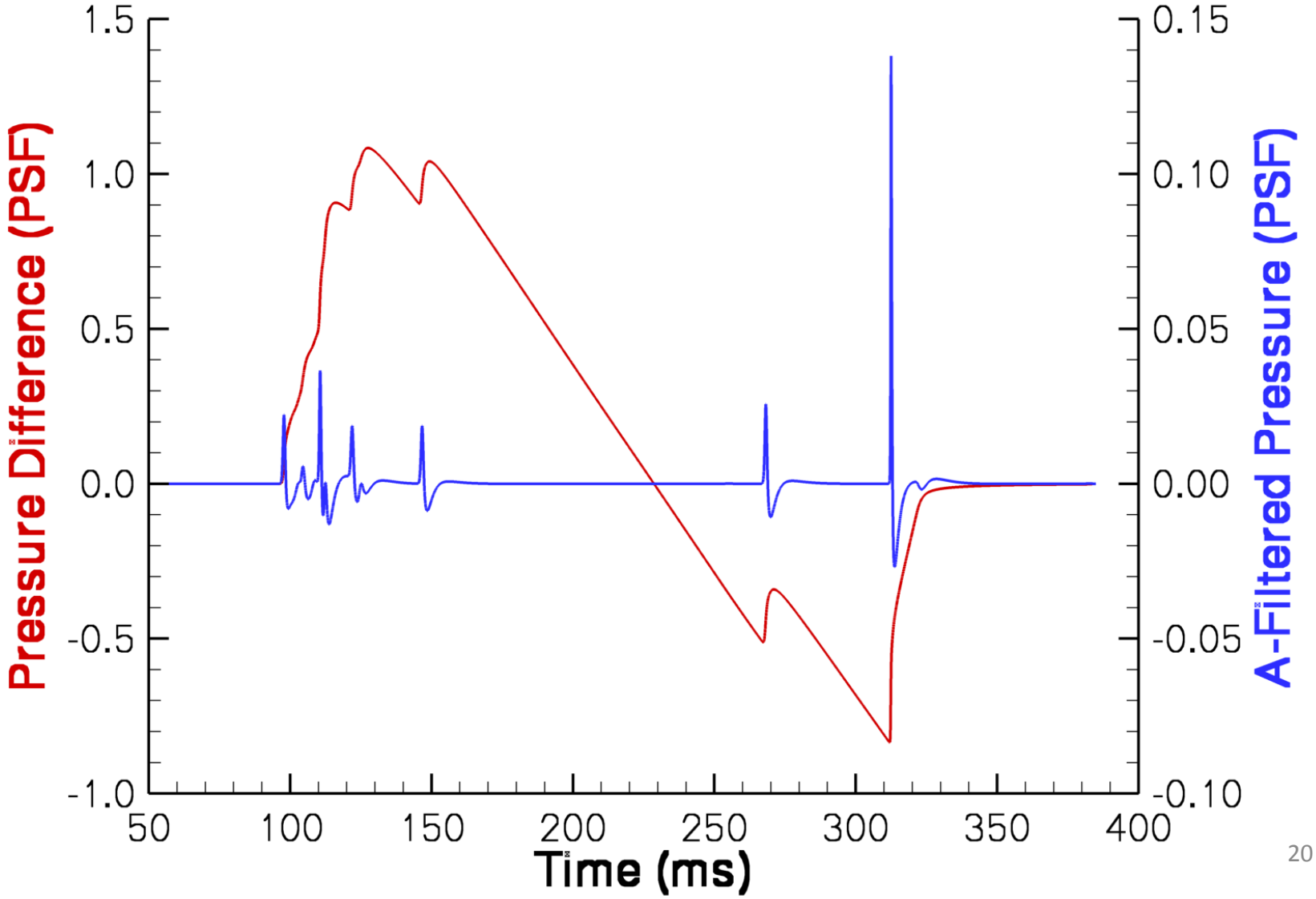
Time Domain A-Weighted Filter

- Continuous weighting of ASEL enables time domain filtering
- Integrated to yield ASEL as a function of position
  - See the contribution of each ground signature feature to the total

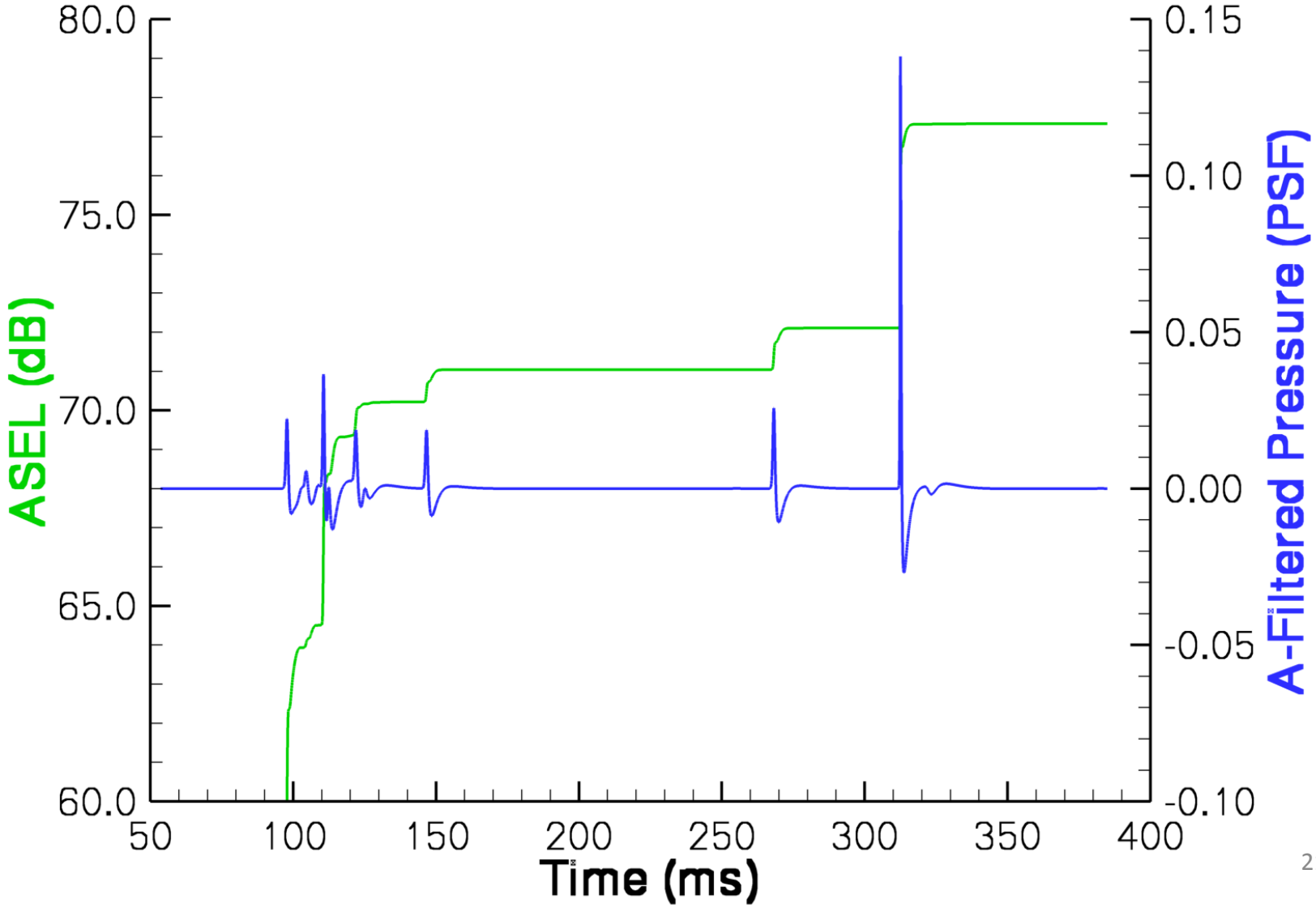
LM1021 Ground Signature



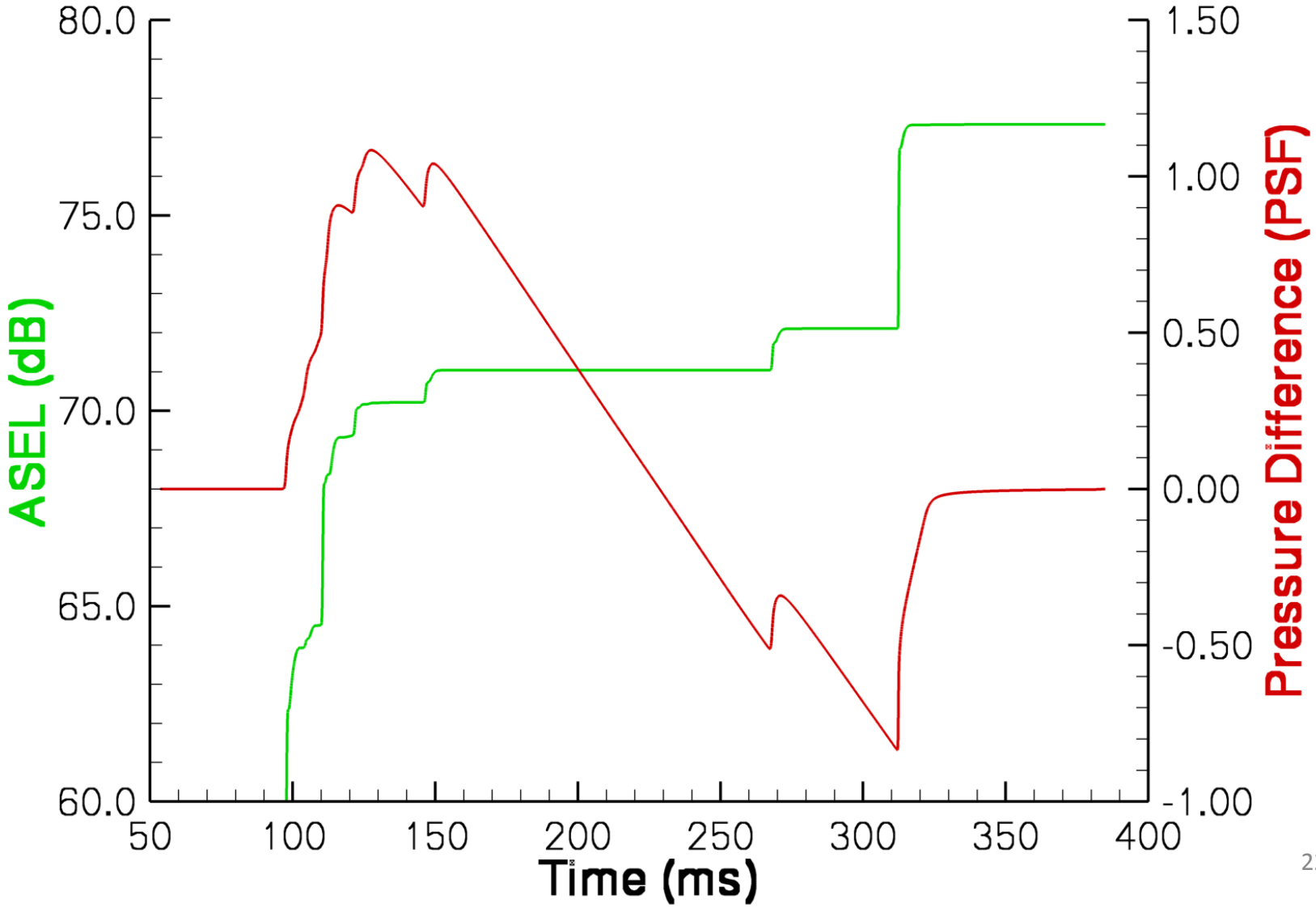
LM1021 A-Filtered Pressure and Ground Signature



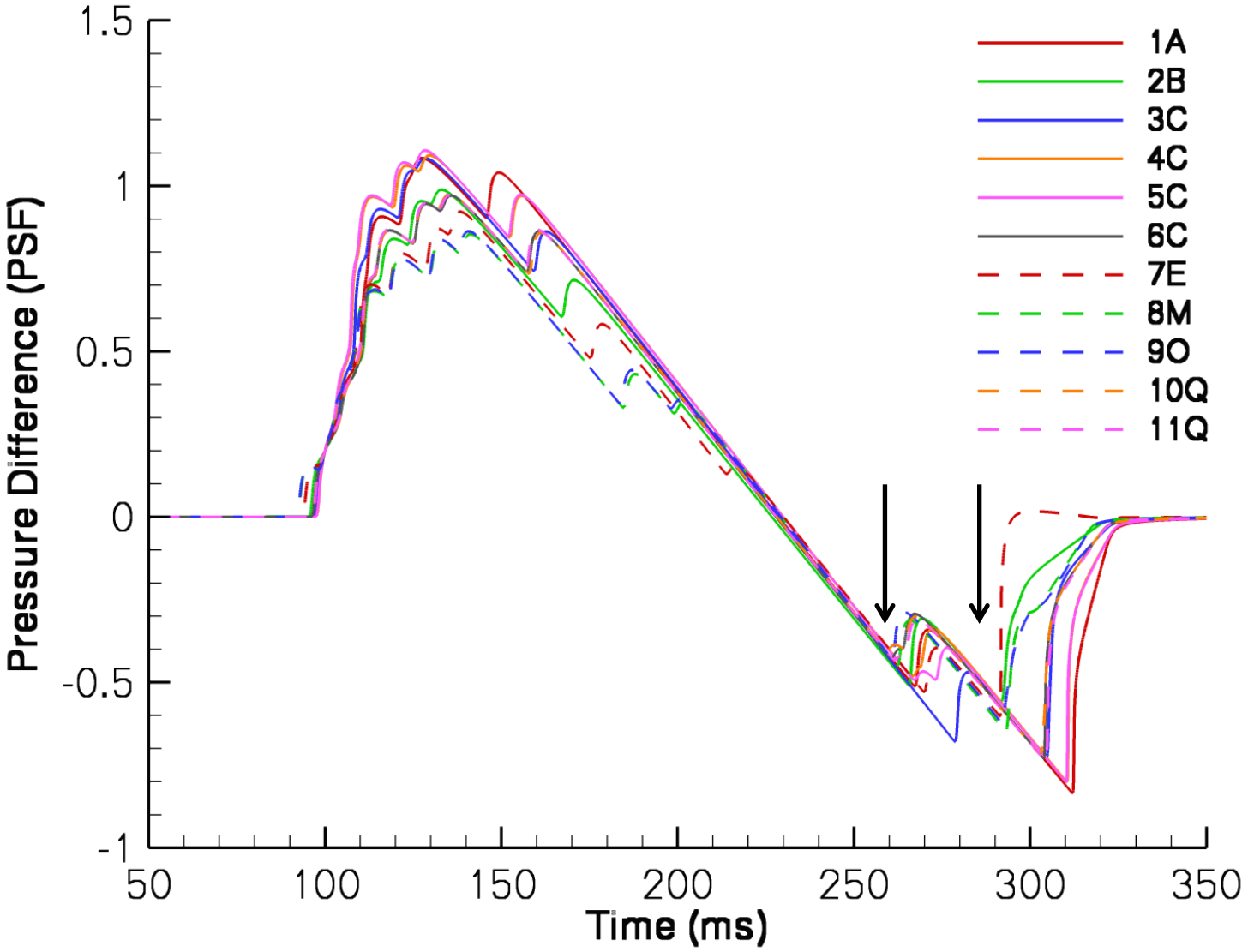
LM1021 ASEL and A-Filtered Pressure



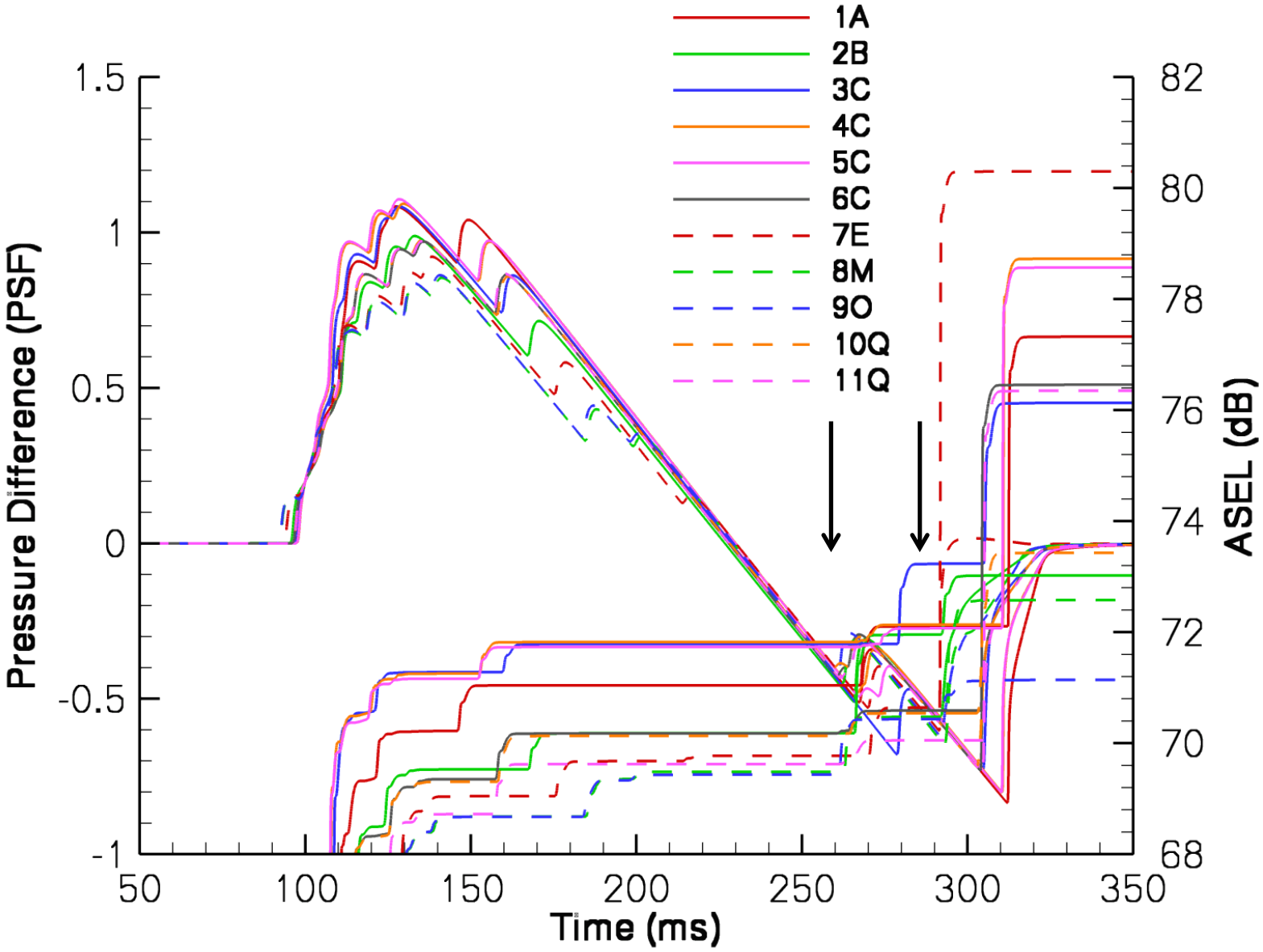
LM1021 Ground and ASEL



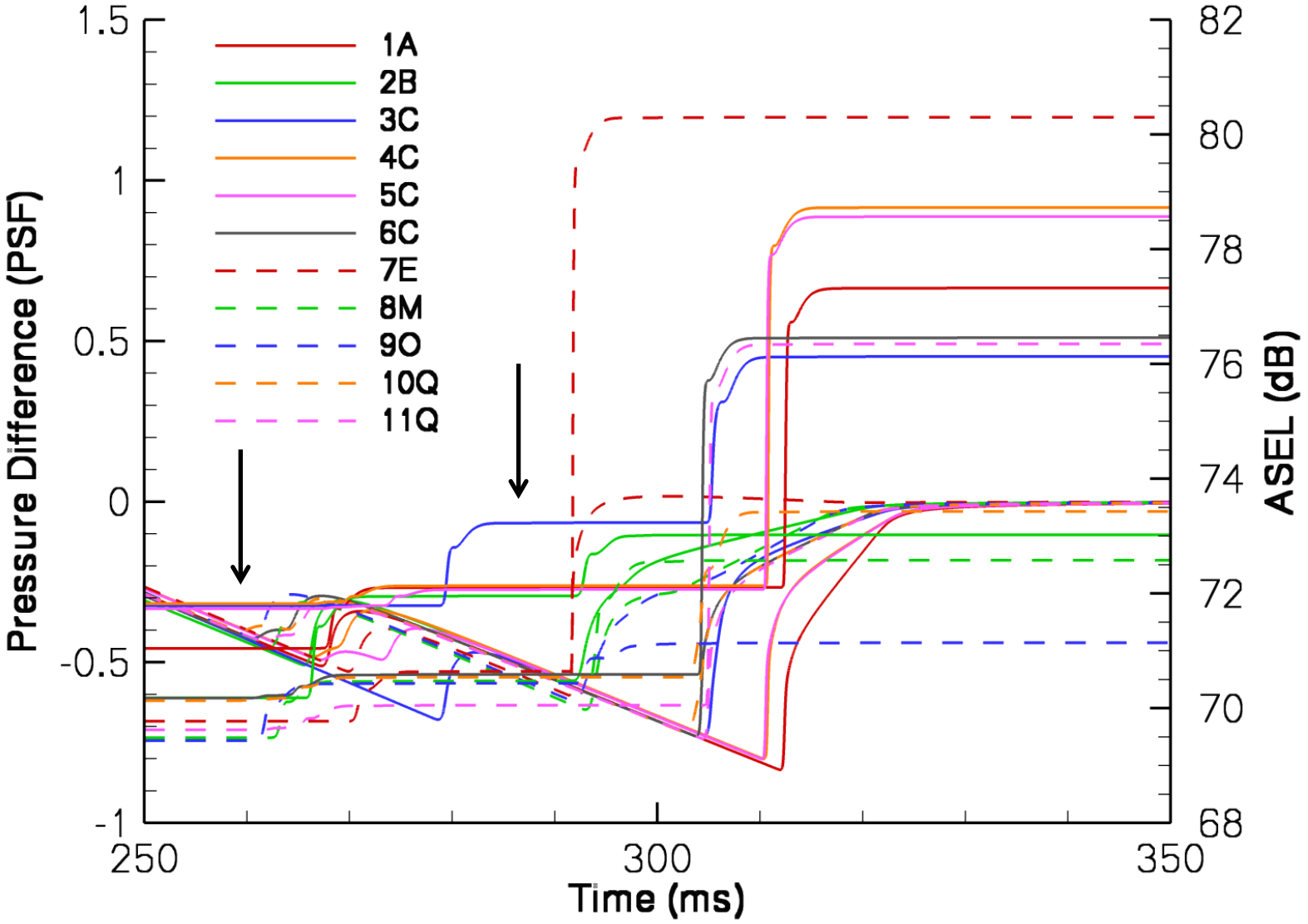
LM1021 Ground Signature



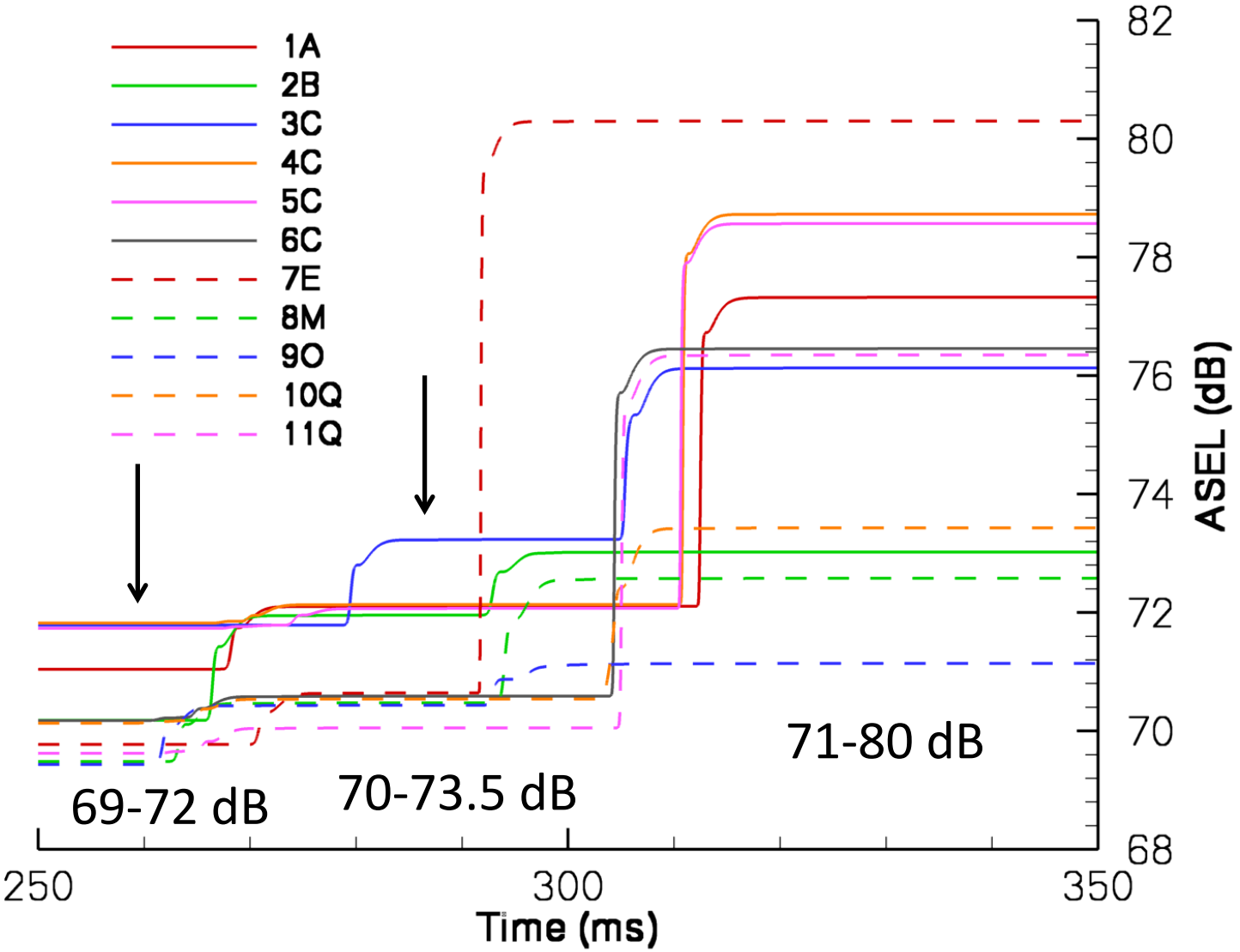
LM1021 Ground Signature and ASEL



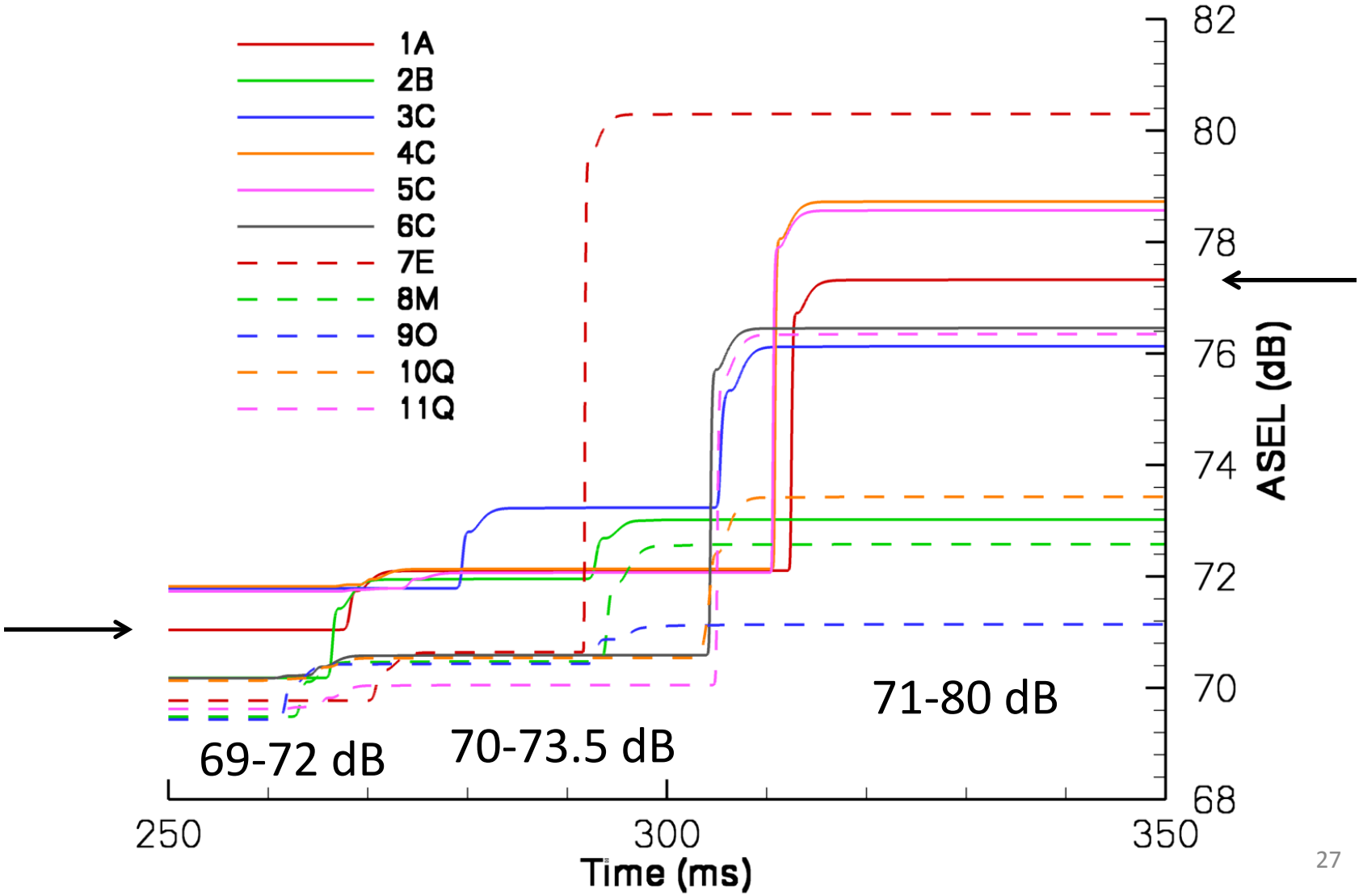
LM1021 Ground Signature and ASEL



LM1021 Ground Signature and ASEL

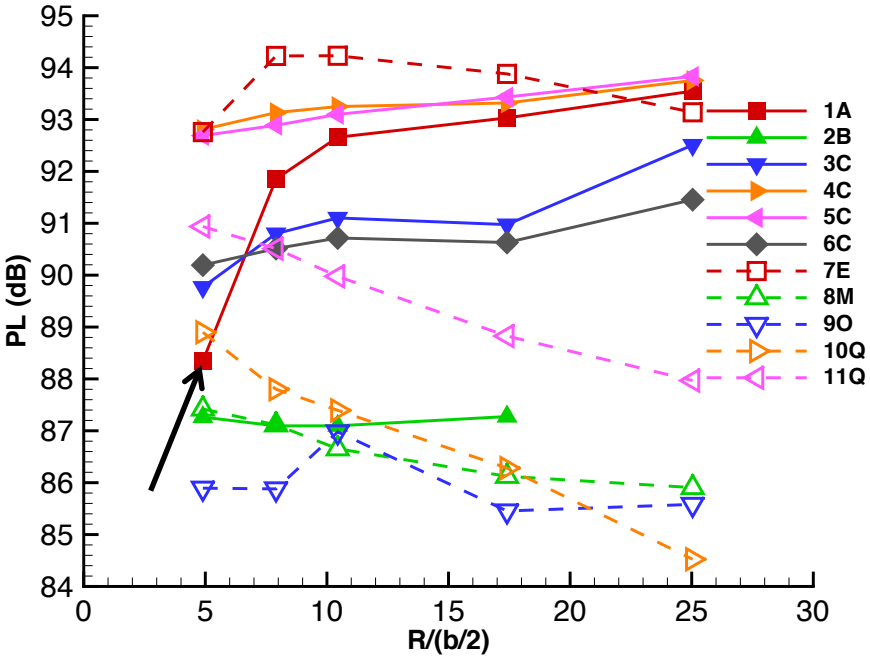


LM1021 Ground Signature and ASEL



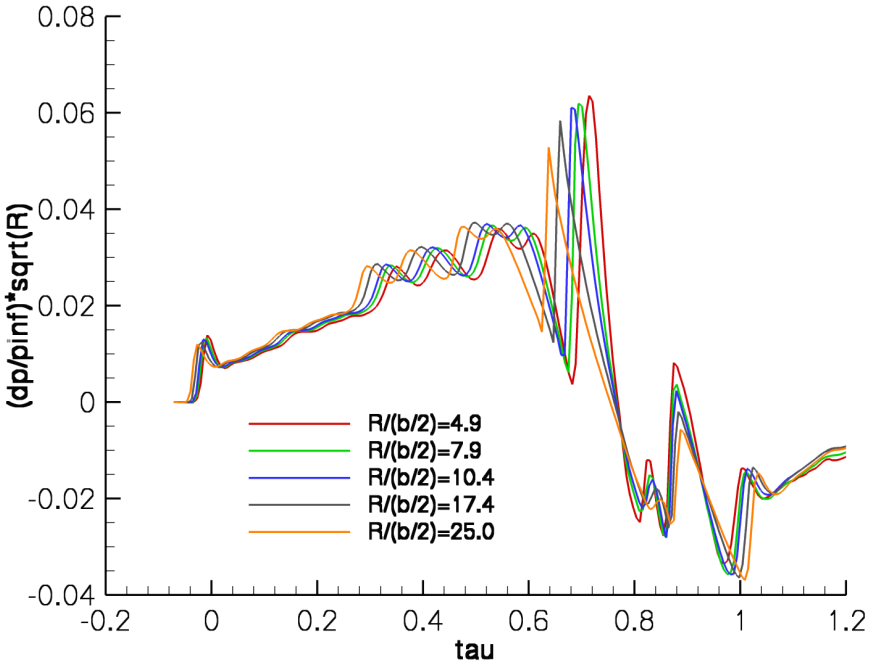
LM 1021 Background and Motivation

PL extracted at different H/L



At centerline

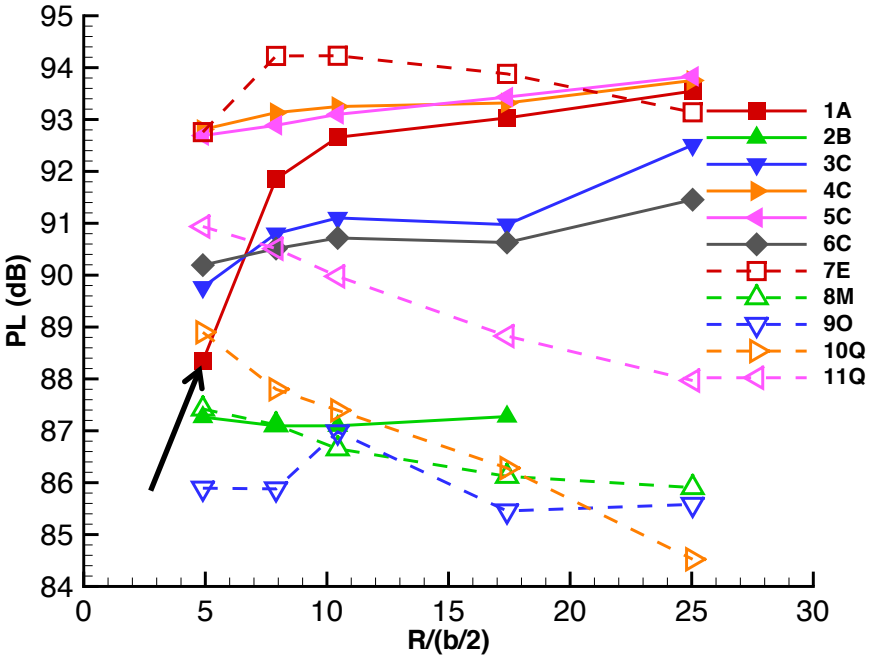
Near-field extracted at diff. H/L



At centerline

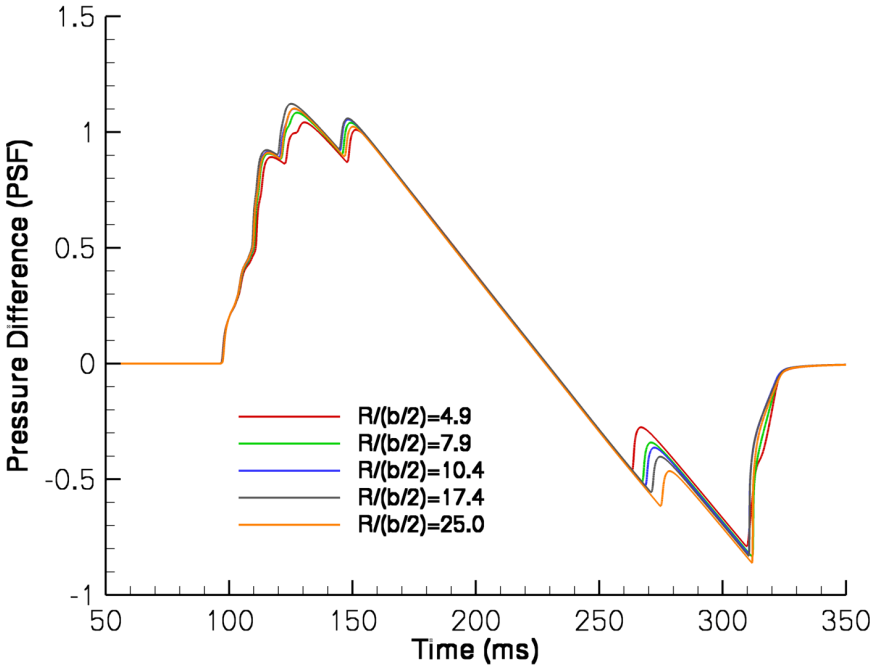
LM 1021 Background and Motivation

PL extracted at different H/L



At centerline

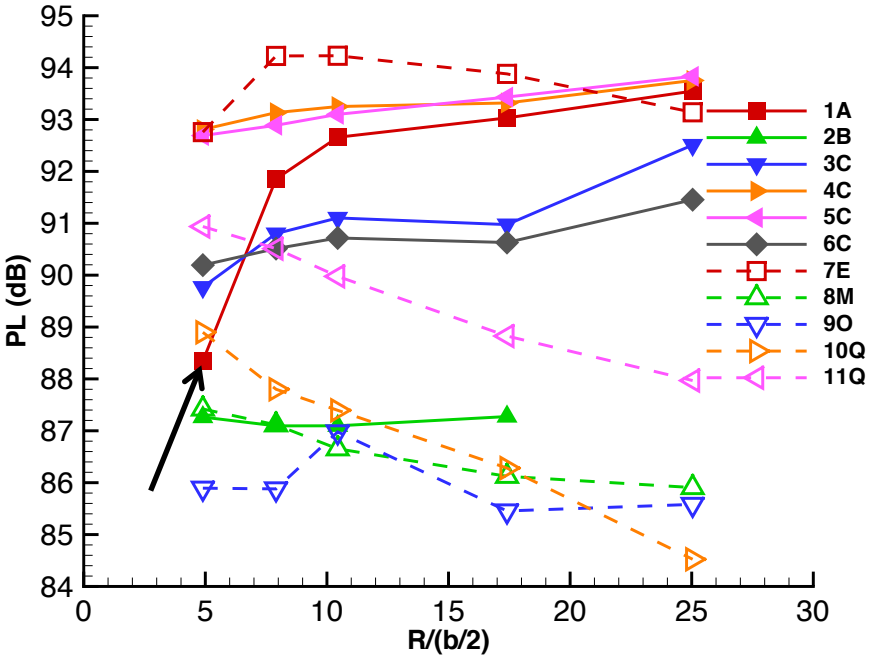
Ground extracted at different H/L



At centerline

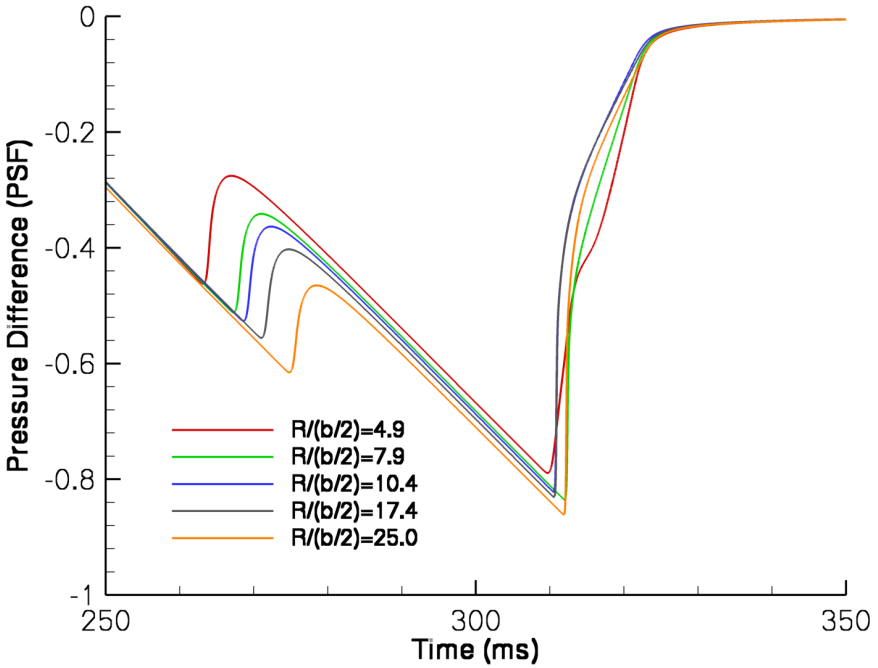
LM 1021 Background and Motivation

PL extracted at different H/L



At centerline

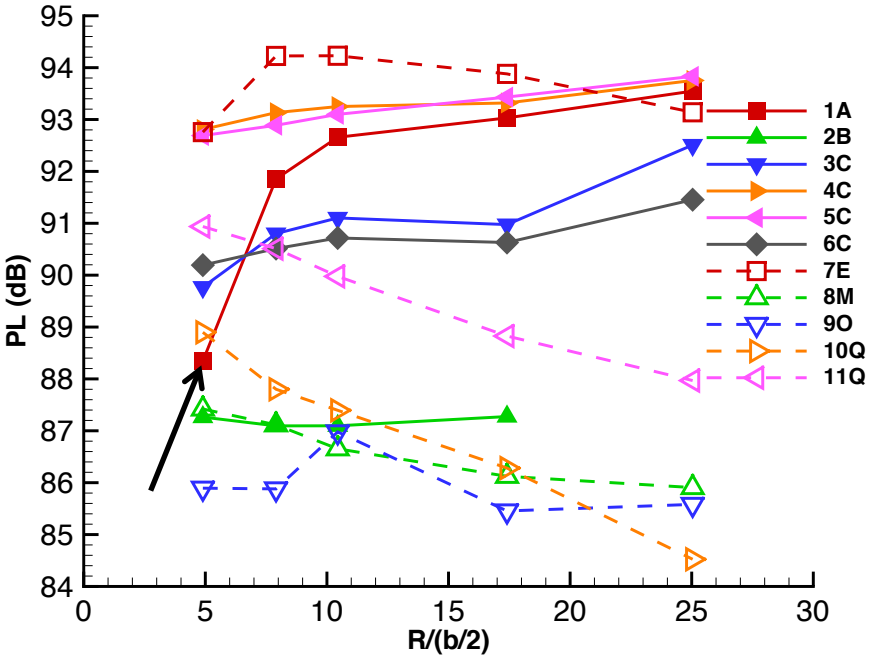
Press. extracted at different H/L



At centerline

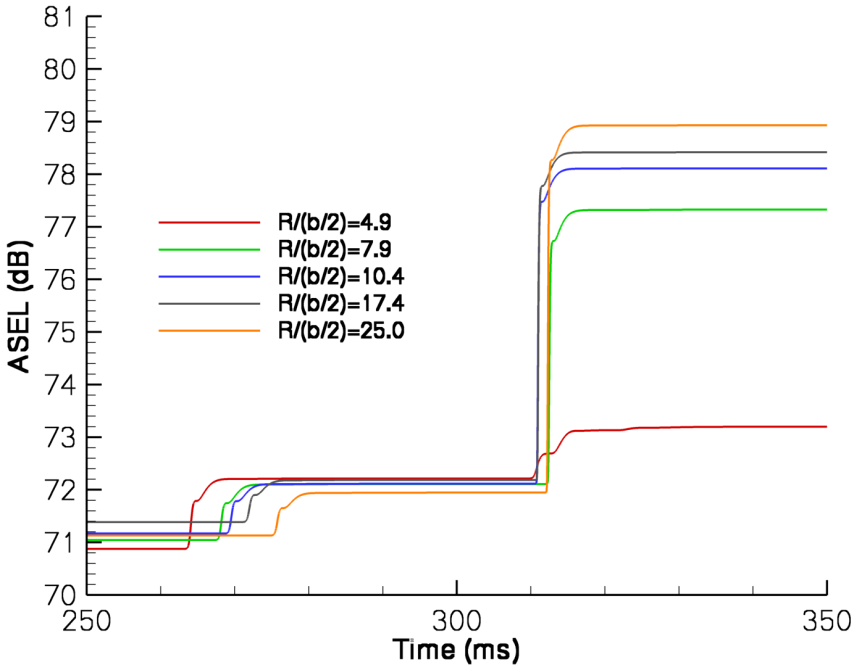
LM 1021 Background and Motivation

PL extracted at different H/L



At centerline

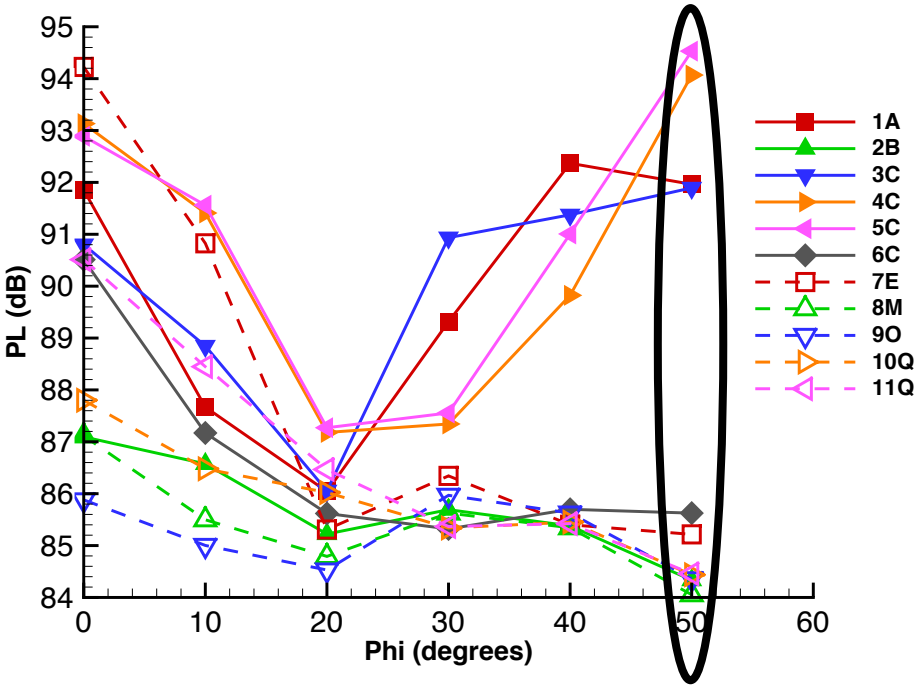
ASEL extracted at different H/L



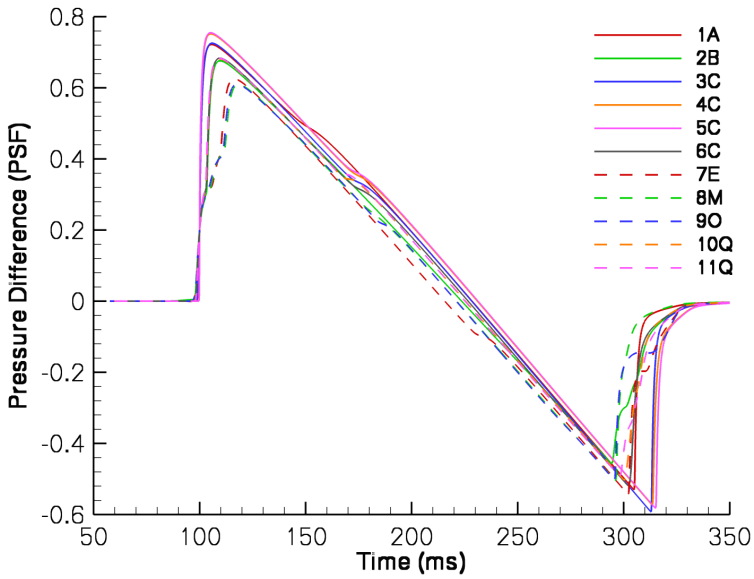
At centerline

LM 1021 Phi = 50 Degrees

PL extracted at different phi

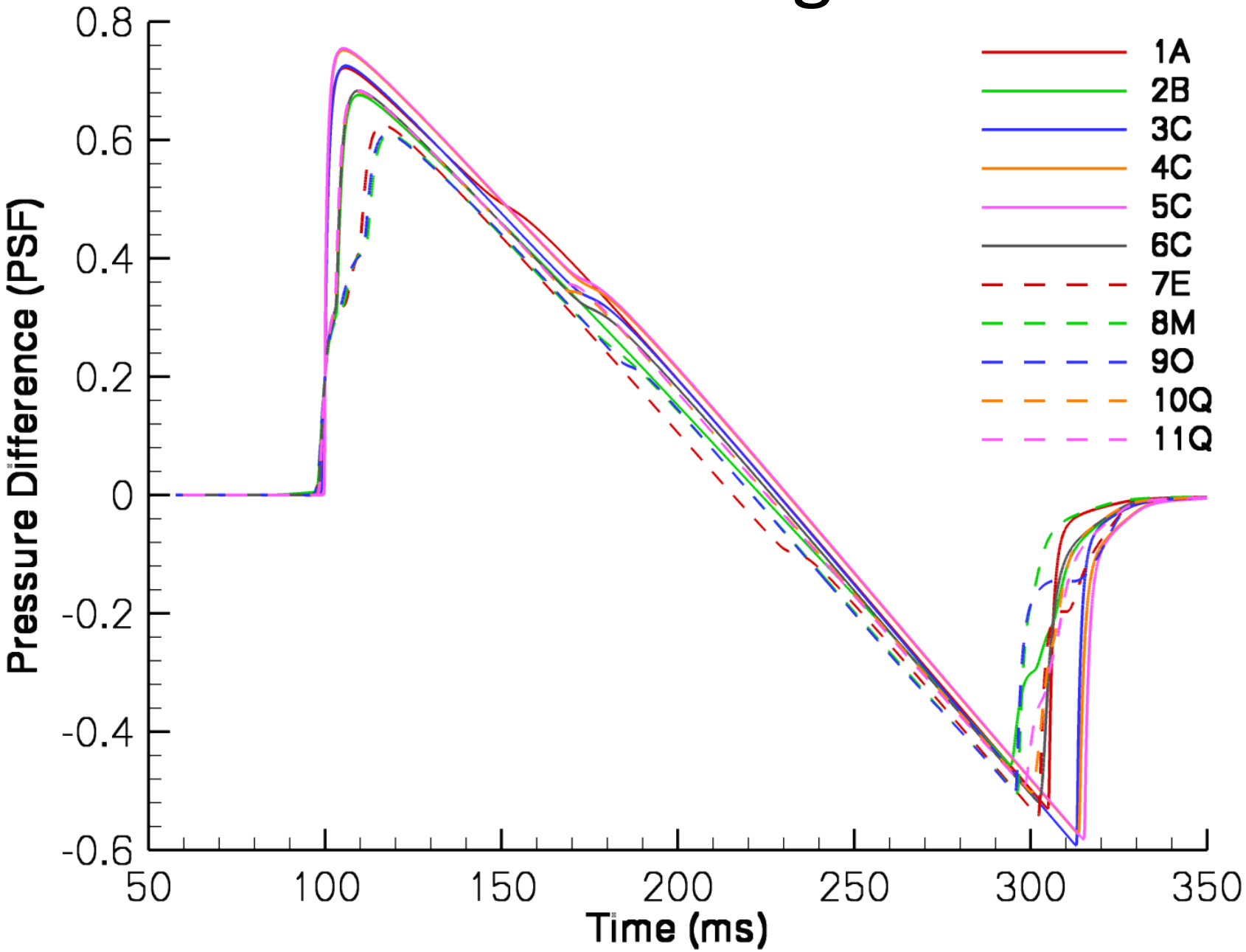


Ground Pressure



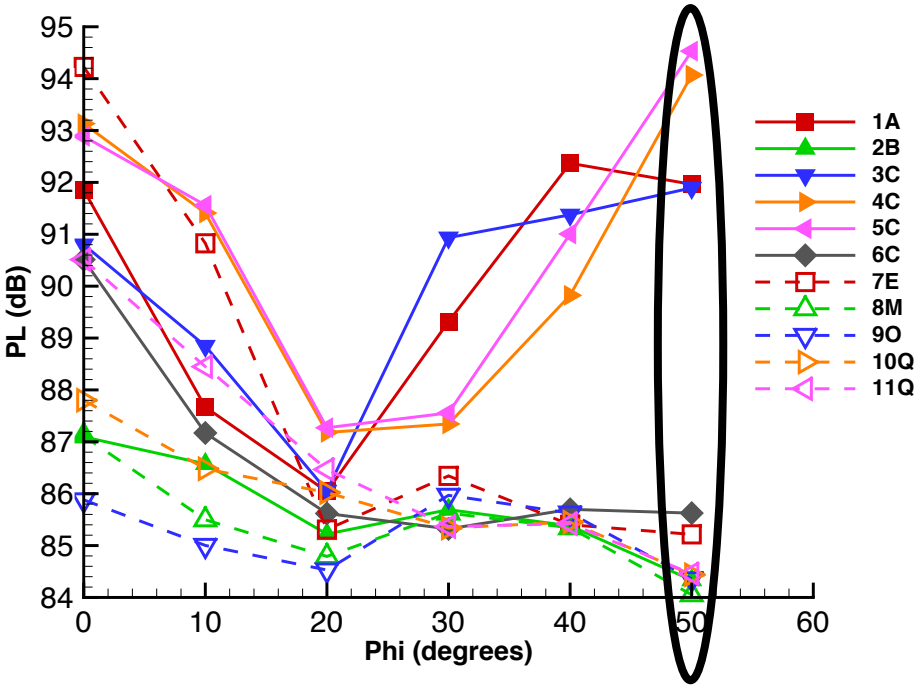
H/L=25, phi=50 degrees

LM 1021 Phi = 50 Degrees Ground

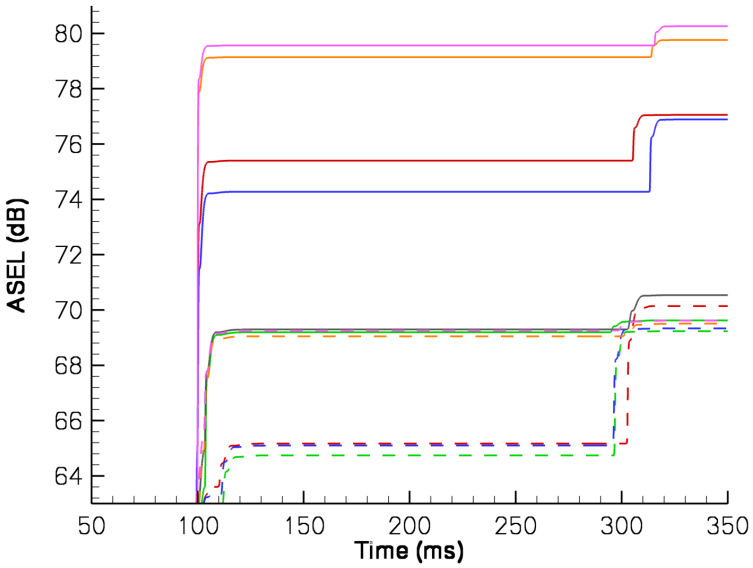


LM 1021 Phi = 50 Degrees

PL extracted at different phi

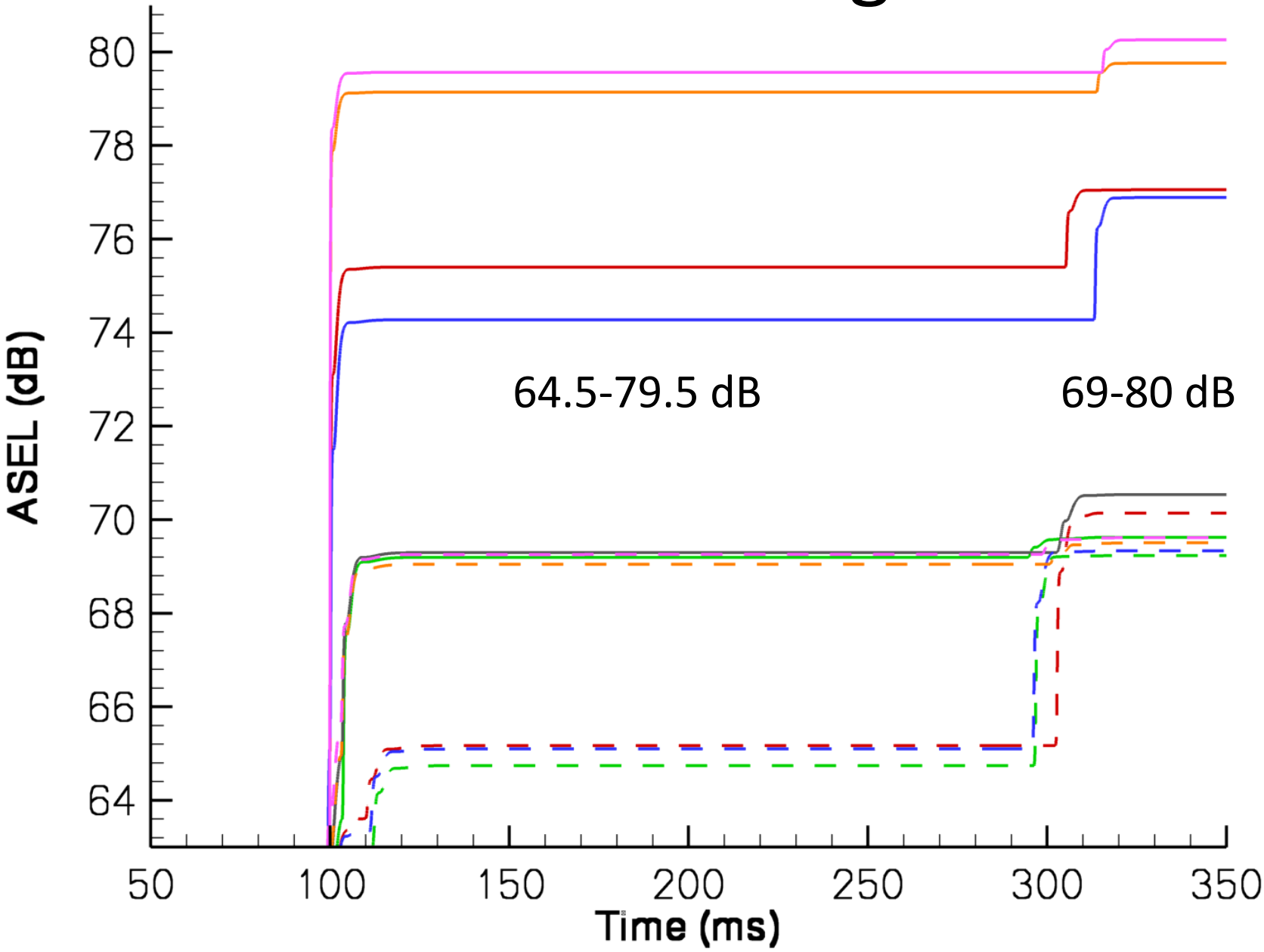


ASEL



H/L=25, phi=50 degrees

LM 1021 Phi = 50 Degrees ASEL



Conclusions

- Multiple sources of variation for LM1021 PL and ASEL
  - Centerline ground noise measures are dominated by the tail shock
  - Both bow and tail shocks contribute to the 50 degree off-track ground noise measures
- A-weighted Sound Exposure Level (ASEL) is a useful surrogate for Perceived Level (PL)
- ASEL is continuous and can be applied in both the frequency and time domains

Recommendations

- Design for reduced PL and ASEL sensitivity to small localized signature changes
- Identify the sensitive portions of the signal (and model) to target for adequate grid refinement
- Minimize the variation introduced during reconstruction of aft pressure signature for models with sting or extend aft boundary for free-flight models
- Apply far-field (multipole) correction into participant evaluations in a more consistent manner
- Use A-weighted filter and ASEL with PL for compiling statistics

Acknowledgment

- Sriram Rallabhandi, National Institute of Aerospace, and Joe Salamone, formerly Gulfstream Aerospace, provided the suggestion of A-weighted filter for time domain analysis

Participate

- Visit Sonic Boom Workshop Website http://lbpw.larc.nasa.gov
  - Presentations and references
  - Geometry, grids, submitted data, and derived data are available: **independent analysis encouraged!**
  - Sign up for the low-traffic announcement e-mail list
- See you for the next workshop
  - AIAA SciTech 2017, 7-8 January 2017, Grapevine, Texas, USA
  - Lower PL configurations from 90s to 70s
  - Expand participation to include propagation and noise metric experts
  - Include propulsion effects for optional case
  - Provide uniformly refined grids for all cases