Detecting Compressed Gas Leaks in a Noisy Environment

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Agenda

1. Introduction
2. Scope
3. Challenge
4. Solution
5. Summary
6. Closing

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Intro to Matt Hoffmeyer and Southwest Research Institute

- Matt has been supporting engine noise and vibration work at SwRI since 2018. He graduated with his BSME in Mechanical Engineering from the University of Texas in 2012
- SwRI is an independent, non-profit R&D organization that works for both governments and industry on a wide range of topics from deep sea to deep space
- The Powertrain Design & Development Department works to reduce engine emissions and improve powertrain efficiency

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Challenge/project scope

- Freight trains used compressed air systems to actuate brakes on each car in the train, as well as for various other purposes on the locomotives such as horns, bells, shutters, windshield wipers, valve actuation, and more.

- A train has thousands of possible air leak locations and miles of air lines

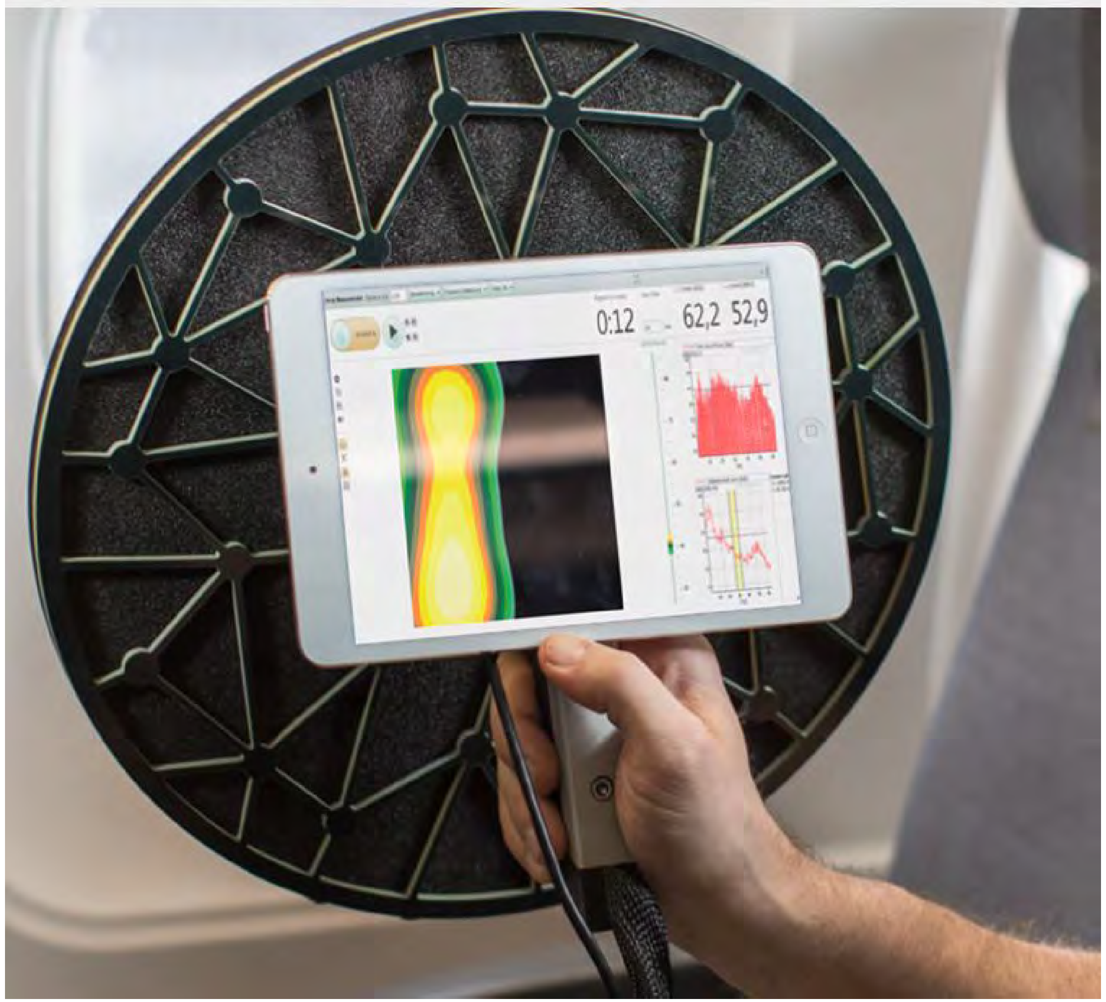
- ‘Allowable’ leaks account for large energy losses
  - Air leaks require the compressor to work harder to maintain line pressure
  - SwRI estimates that this leads to 37 to 111 million gallons of excess annual fuel consumption on North American Class I railroads

- Currently, leak detection is done by manual inspection. Only the largest leaks are detected with this approach

- Is it possible to detect these leaks with a microphone?

Brüel & Kjær Equipment That Can Be Applied To This Problem

- We used half inch microphones, which provide Type 1 accuracy up to 20 kHz
- We soon realized that ultrasonic measurements were very useful
  - Fortunately, half inch microphones provide a useful signal to at least 50 kHz
  - For improved accuracy at high frequency, ¼- or 1/8-inch microphones should be used
- Brüel & Kjær offers an acoustic camera, Type 9712-W-FEN, that can be used for this type of work



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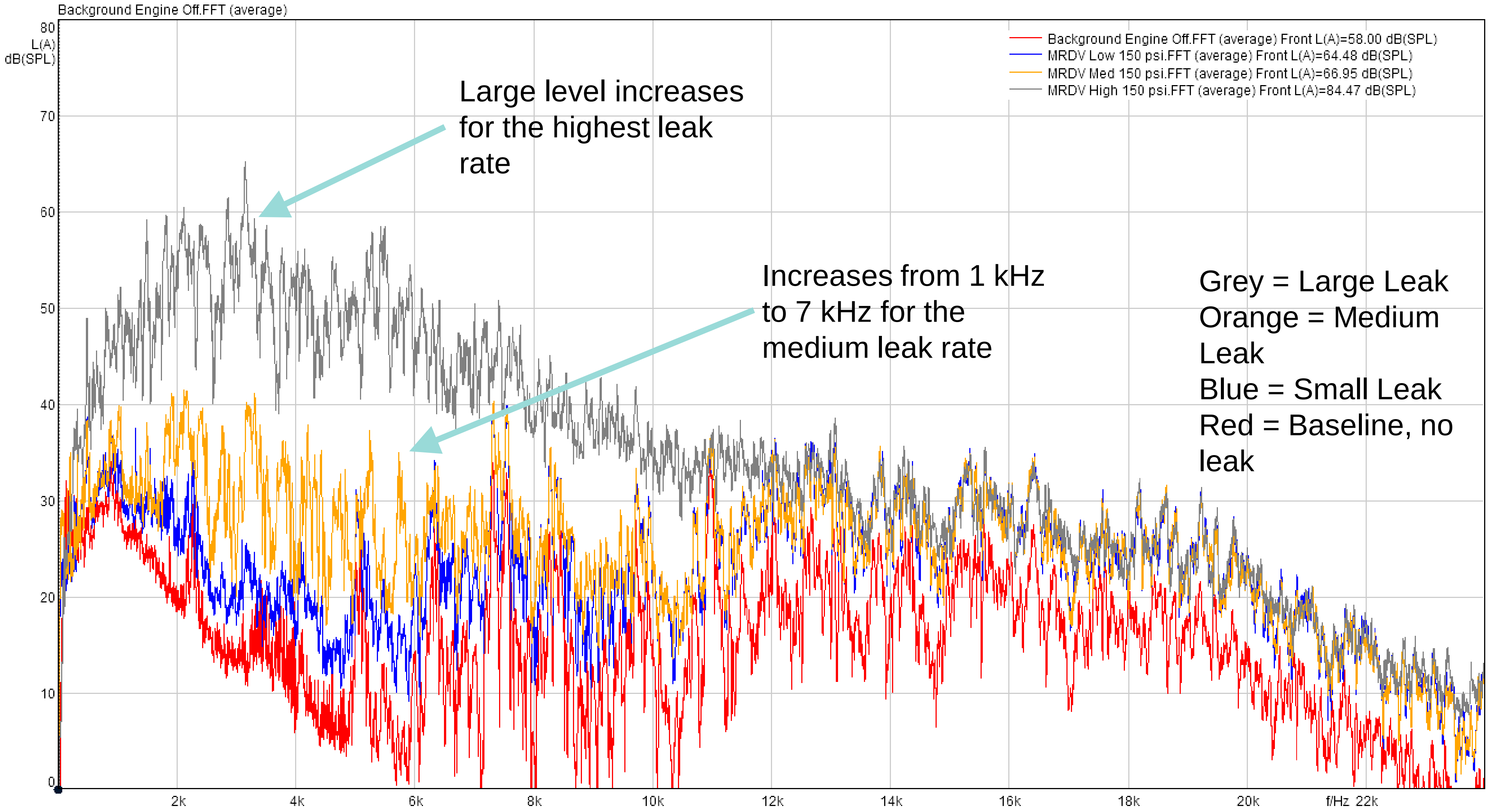
Initial Stationary Locomotive Leak Measurements

- Measured induced air leaks under 3 conditions:
  - Engine off, system pressure 100 psi
  - Engine off, system pressure 150 psi
  - Engine on at Notch 3, system pressure 150 psi
- Air leaks were induced at four locations at low, medium, and high leak rates
- Two microphones were positioned next to the locomotive, one near the front and one near the rear
- There was a steady leak throughout all testing coming from the air brake compartment near the front of the locomotive

Engine Off – 150 psi, Front Mic, Main Reservoir Drain Valve Leak

- With the engine off, leaks of all sizes detectable compared to baseline noise level



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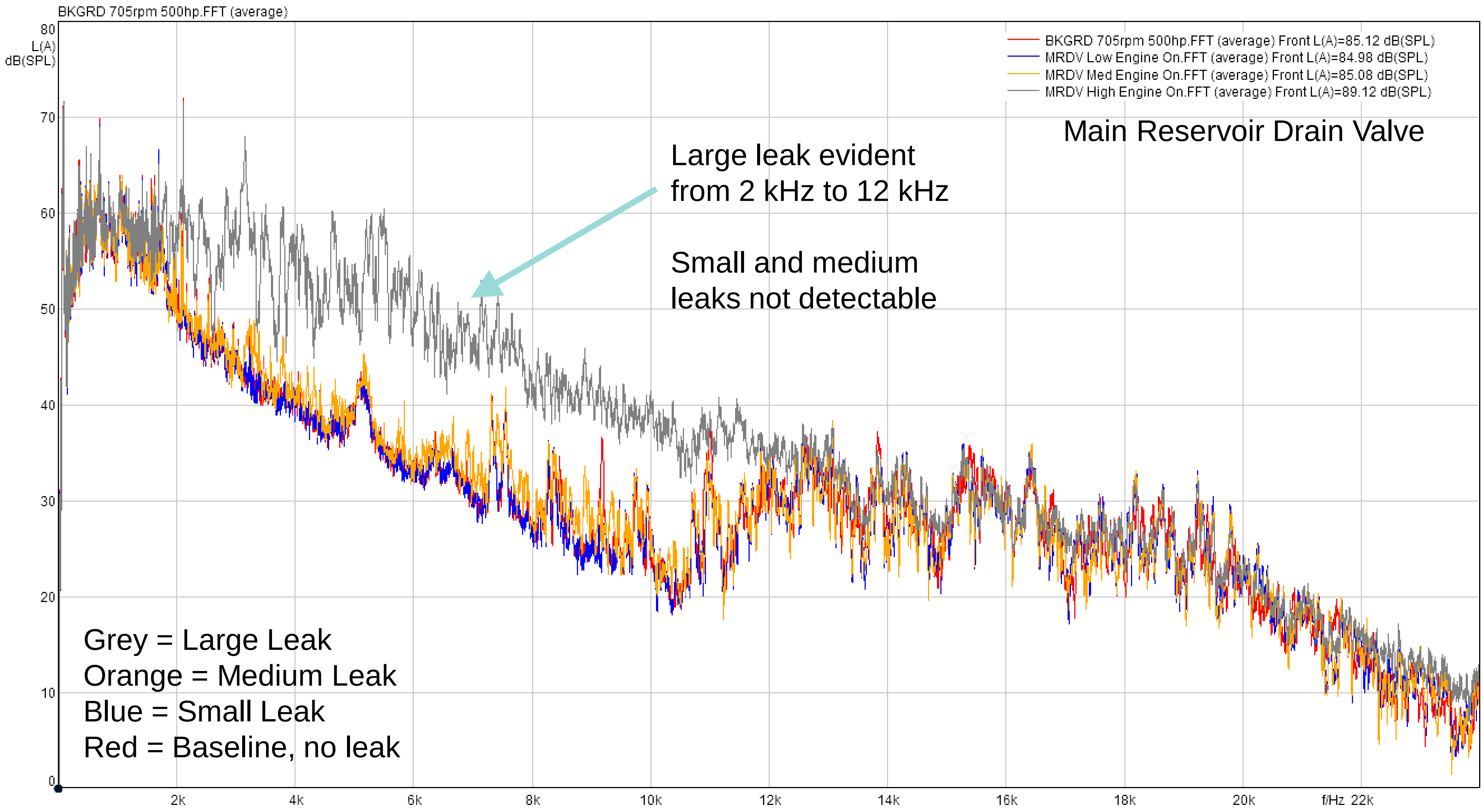
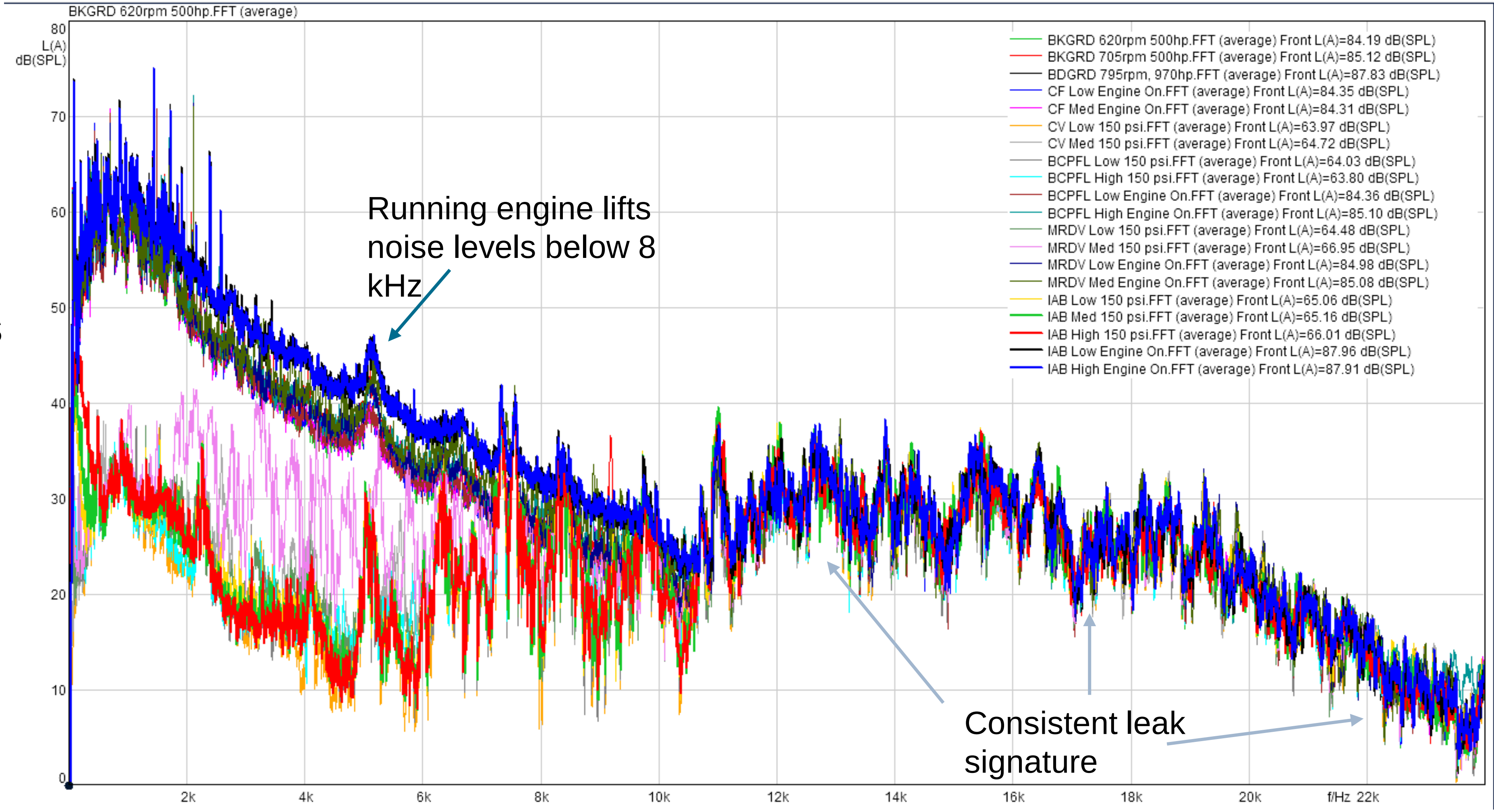
Engine On, Front Mic, 150 PSI, Main Reservoir Drain Valve Leak

- With the engine on, only the largest leak is distinguishable
- The reason for this is the acoustic content above 12 kHz was due to a separate leak we weren't initially aware of



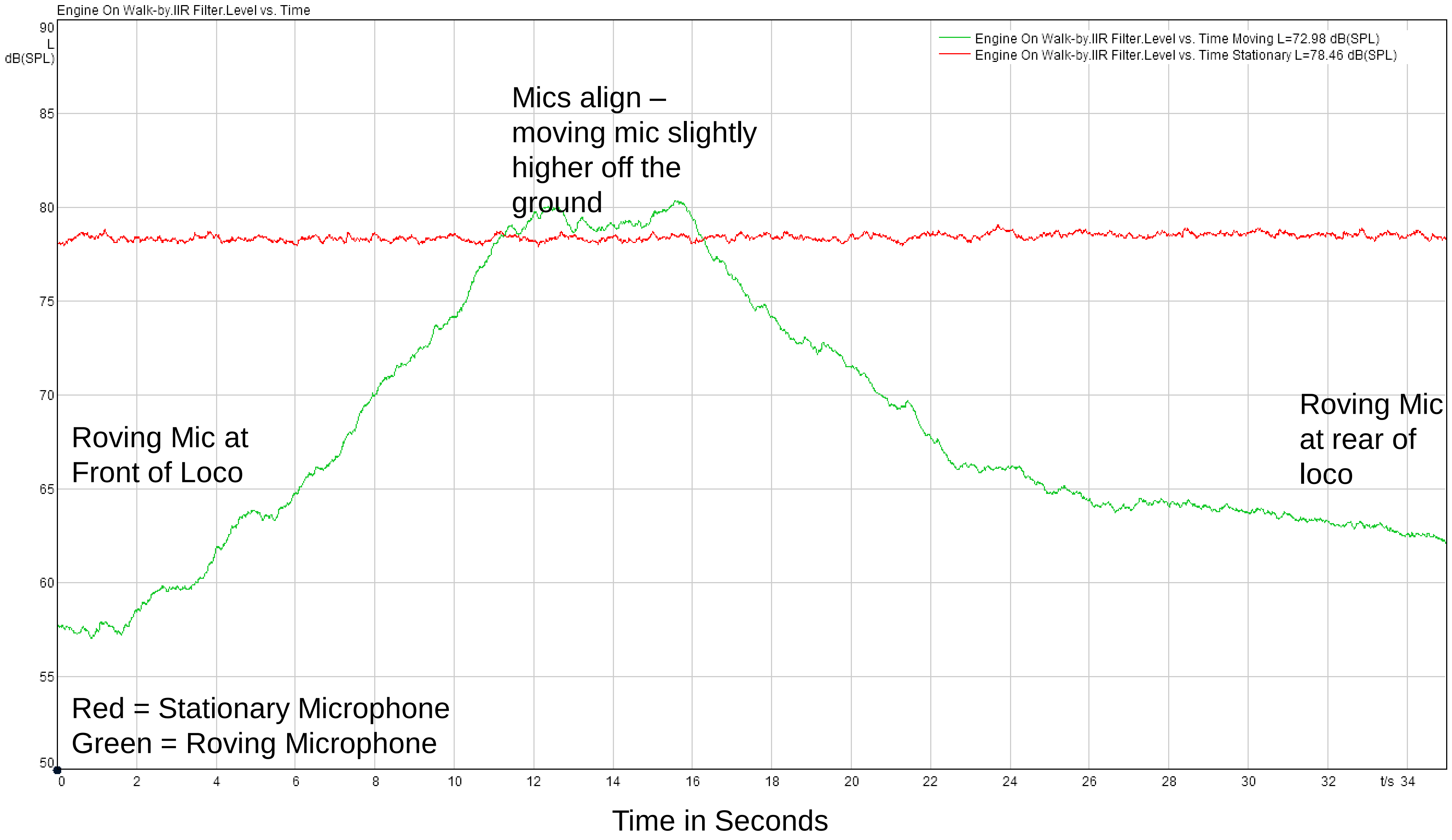
Leak Signature

- Throughout all testing, there was a leak in the air brake compartment
- This leak had a consistent acoustic signature that was observed across multiple measurements both with the engine on and off
- This finding suggests that characteristic signatures of different types of leaks could be determined and used in a leak detection solution



Both Mics, Level vs Time, 12 kHz High-pass Filter, Engine Running

- Overall level vs time, with one mic walked from front to back of loco
- When mic passes by the leak source, high-frequency noise noticeably increases



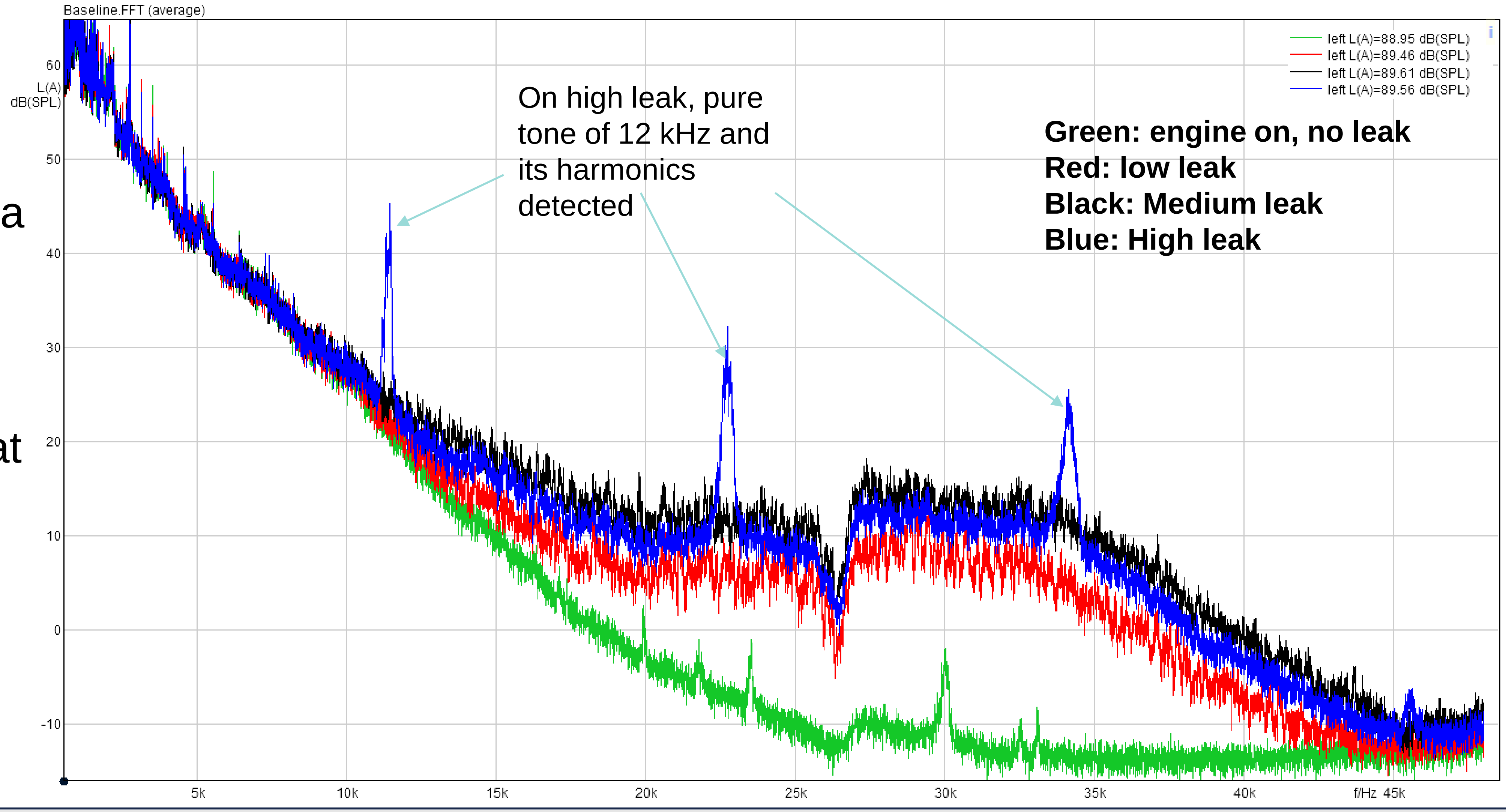
Second Set of Stationary Locomotive Leak Measurements

- Two microphones located near front of loco

- Sampling rate set to 96 kHz to calculate spectrum up to 48 kHz
  - Objective was to evaluate the acoustic signature beyond the audible range

Sample Spectra – Engine On

- There is clear broadband noise above 15 kHz for a leak of any magnitude.
- The dips in level at 26 kHz is due to the properties of the microphone used

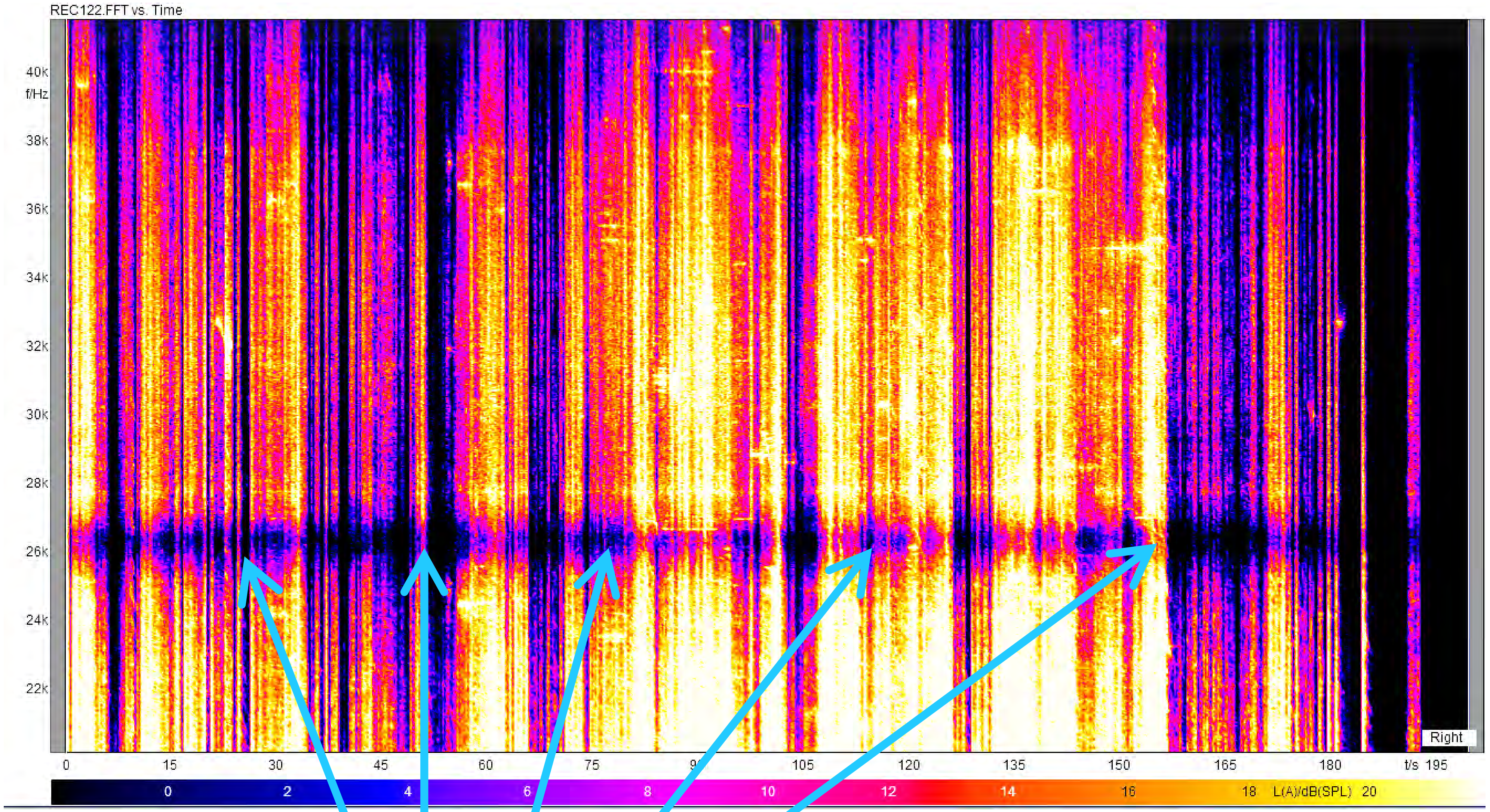


Measurements on passing train

- Set up two microphones next to rail tracks running behind the SwRI Locomotive Research Center
- The ‘left’ microphone was located near the end of a curved section of track
- The ‘right’ microphone was next to a straight section of track, about 50 feet away from the ‘left’ microphone
- Due to the proximity to the curve, wheel squeal was frequently observed in data

Sample FFT vs Time

- Data shown here was sampled at 96 kHz
- Most of the peaks are caused by wheel squeal, which generates broadband high-frequency noise
- Any presence of wheel squeal eliminates the ability to detect a leak since the magnitude is higher than what an air leak would generate



Microphone Diaphragm Resonance at 26 kHz

Beamforming Leak Detection with Acoustic Camera

- Acoustic camera tested on moving locomotive
- High-frequency noise isolated for hot-spot detection
- Leak sources successfully identified and tracked with motion
- We found that data at 30 – 45 kHz or 35 – 50 kHz was the least sensitive to background noise from the operating locomotive

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Potential Applications

- Option 1: Wayside detection

- Option 2: Portable equipment for car inspectors

Summary

Challenge

There are many potential leak sources of compressed gas along the length of a train. Current manual inspection methods pose potential dangers to inspectors and only detect the largest leaks. Leaks cause additional fuel consumption and represent potential safety risks.

Solution

Leaks of any magnitude generate an ultrasonic noise source that is distinguishable from mechanical noise sources. Acoustic cameras can be used to detect these noise sources at wayside monitoring locations or as a hand-held solution for inspectors.

Benefit

Leak information, detected at wayside monitoring points, can be sent to railroad operators and those leaks can be corrected when the train reaches a service yard. The capability to detect leaks earlier and more often can lead to significant fuel savings for railroad operators and improved safety. This advanced detection method also reduces the risk of injury to inspectors and repair personnel.

Thank You

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