Rail Vehicle Moving Source Beamforming

WEBINAR 2021

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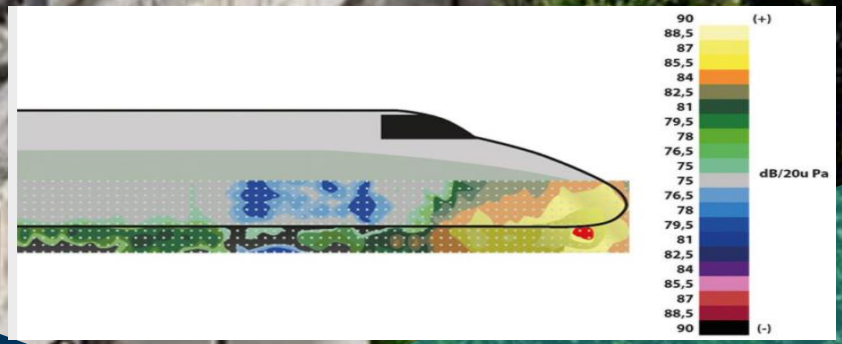
Mike Turner
Frank Rasmussen



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Mike Turner

Product Manager Array acoustics

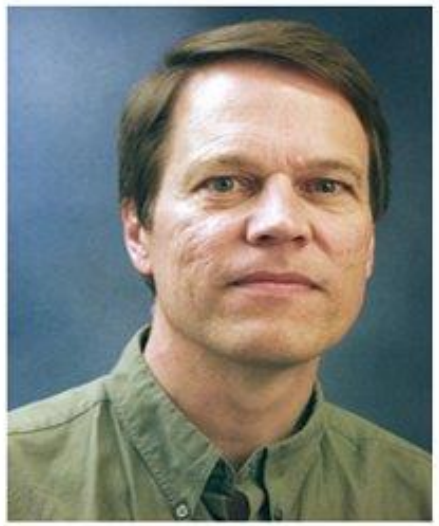
Bachelor degree in Mechanical Engineering, Denmarks Technical University, 1997, thesis in Acoustics.

Brüel & Kjær since 2002,

- Sales Engineer,
- Market Manager Environmental measurements,
- Product Manager Array Acoustics, LAN-XI and conditioning products

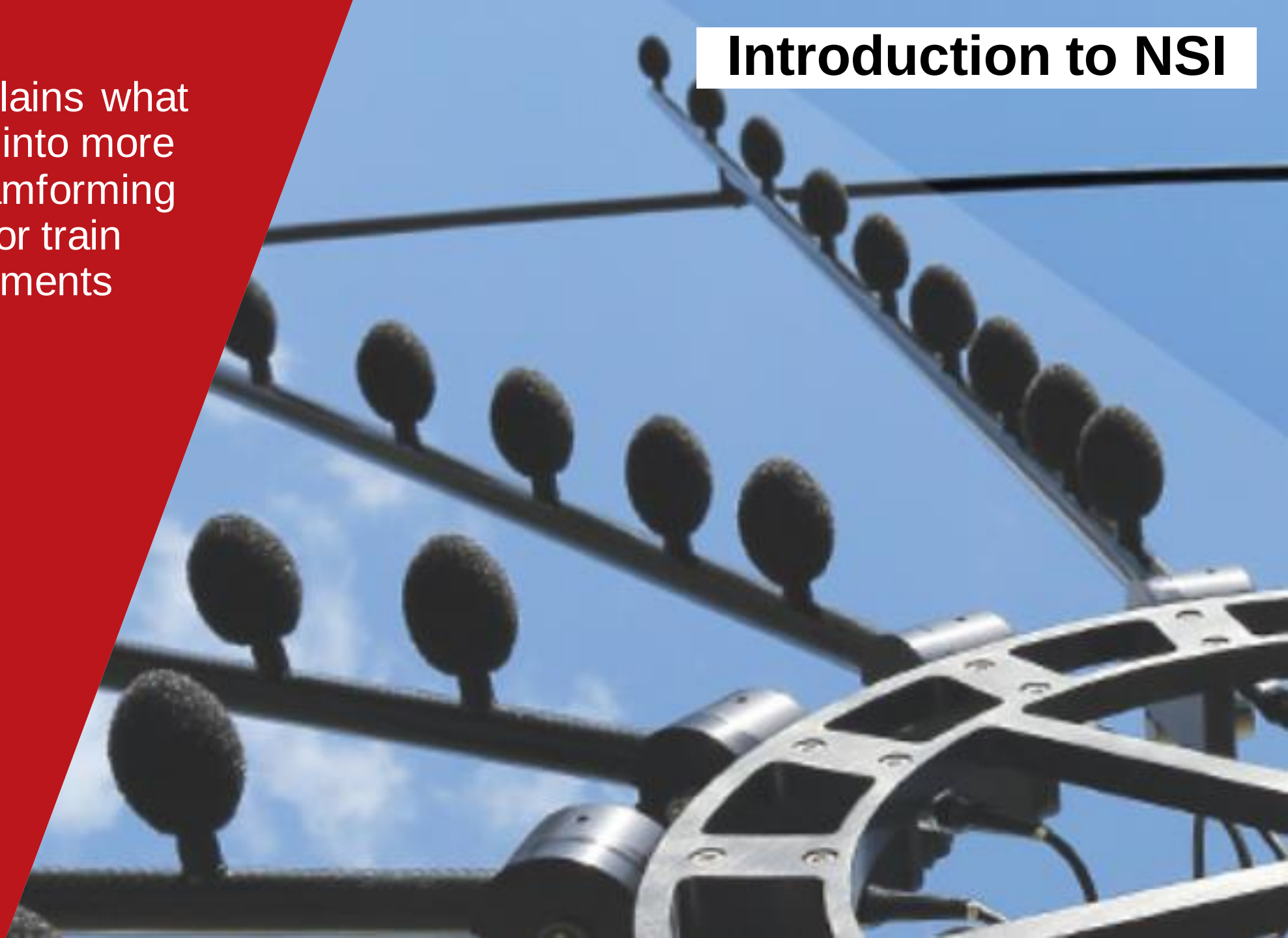
Frank Rasmussen

- Ms.C. from EMI, DTU, 1984. (Fault Detection in Fibre Optics Cables)
- Brüel & Kjær since 1984.
- SW-Developer for customer specified solution 1984-1995
  - PULSE LabShop
- Application Engineer in Germany 1995-1997
- Project Manager for customer specified solution 1997-2003
- Application Engineer for Scandinavia and German speaking countries 2003 – 202X
  - With focus on LabShop and BK Connect
- Enjoy biking and chess



Introduction to NSI

This chapter explains what NSI is and goes into more detail on the beamforming algorithm used for train passby measurements



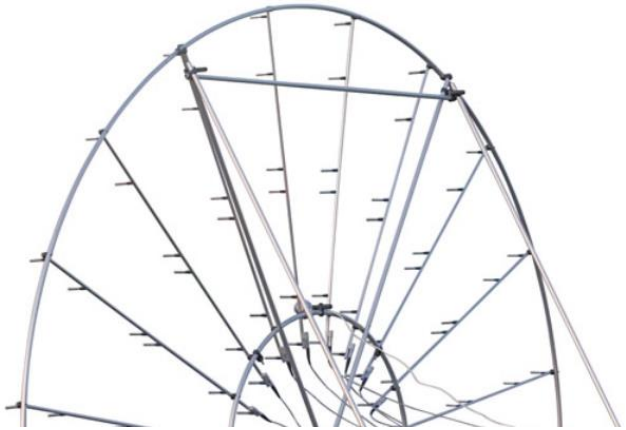
What is Noise Source Identification (NSI)?

One microphone

- Total noise: absolute sound pressure level
- Frequency content
- Cannot separate sound sources
- Senstive to background noise

Array of microphones

- Relative levels, sound power, sound intensity
- Position: From where is noise radiated?
- Frequency content: What are the characteristics of the noise?
- Quantify contributions: How important is it?
- Not senstive to background noise (wind noise)



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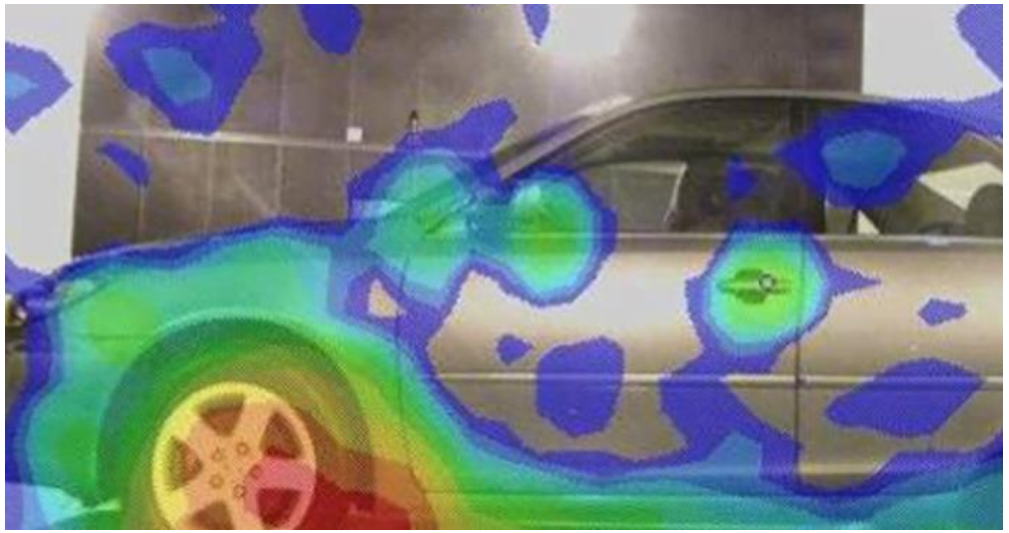
NSI algorithms

NSI algorithm selection based on:

- Frequency range
- Measurement distance to source
- Required resolution
- Area covered by measurement
- Background noise

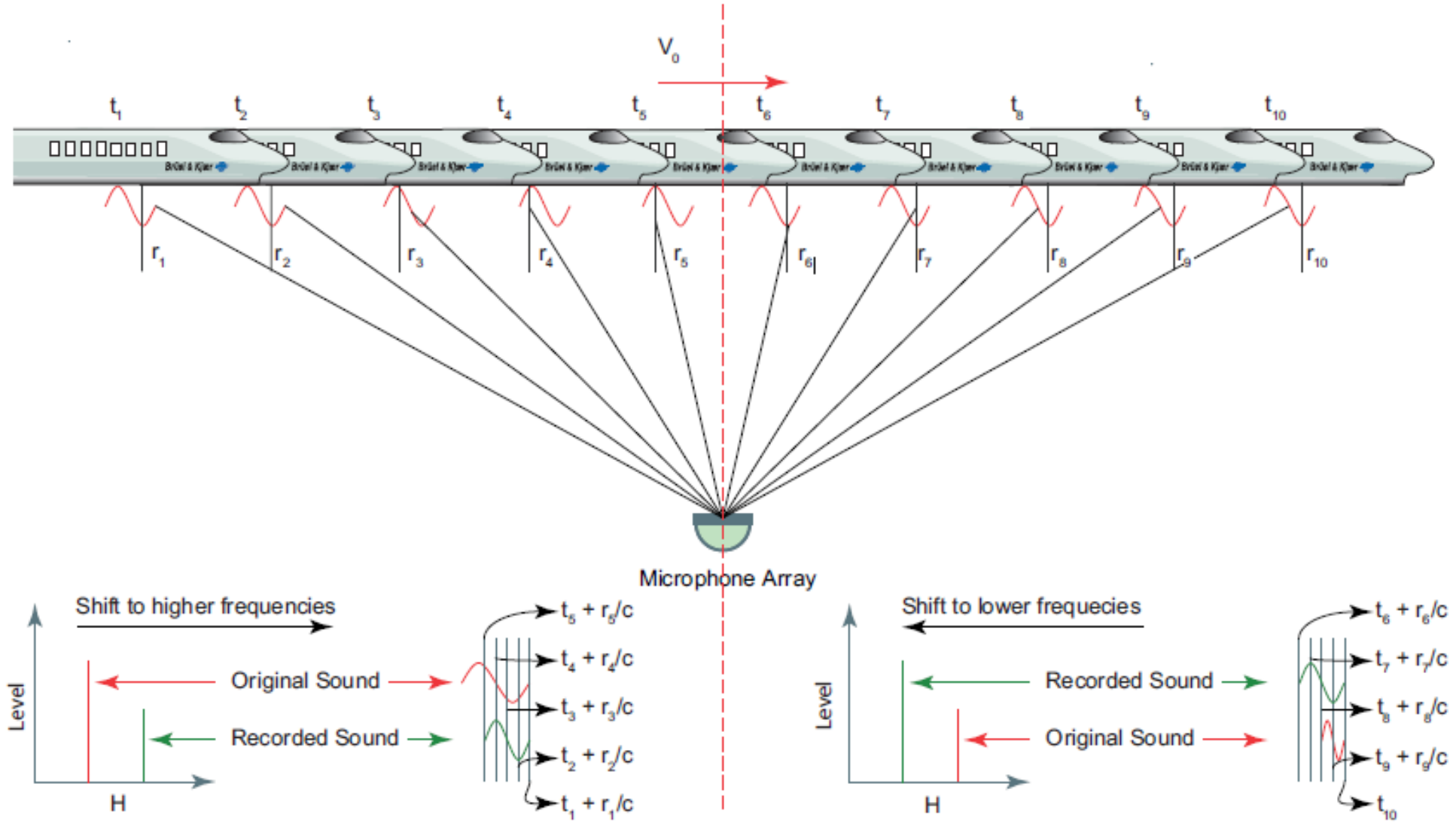


Beamforming

Suitable technique for Railways:

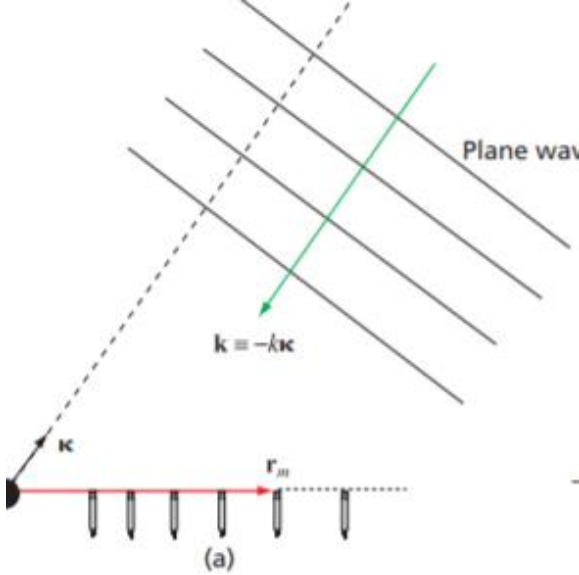
- Frequency range: 500 Hz to 20 kHz
- Distance: several metres
- Resolution: fine enough to differentiate the different sources
- On large objects (full vehicle) – array can be smaller than object.
- Background noise: negligible

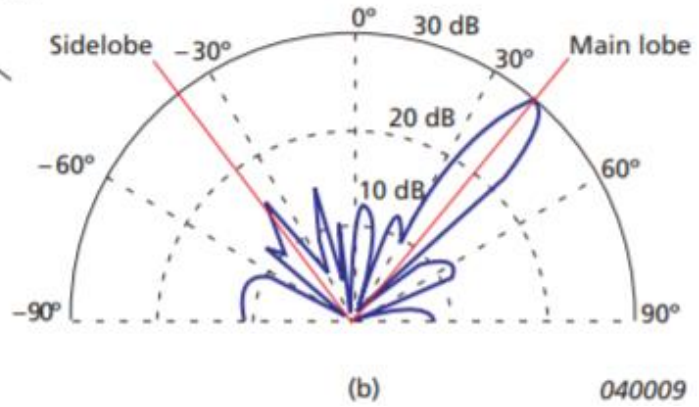
Moving Source Beamforming: Doppler effect correction

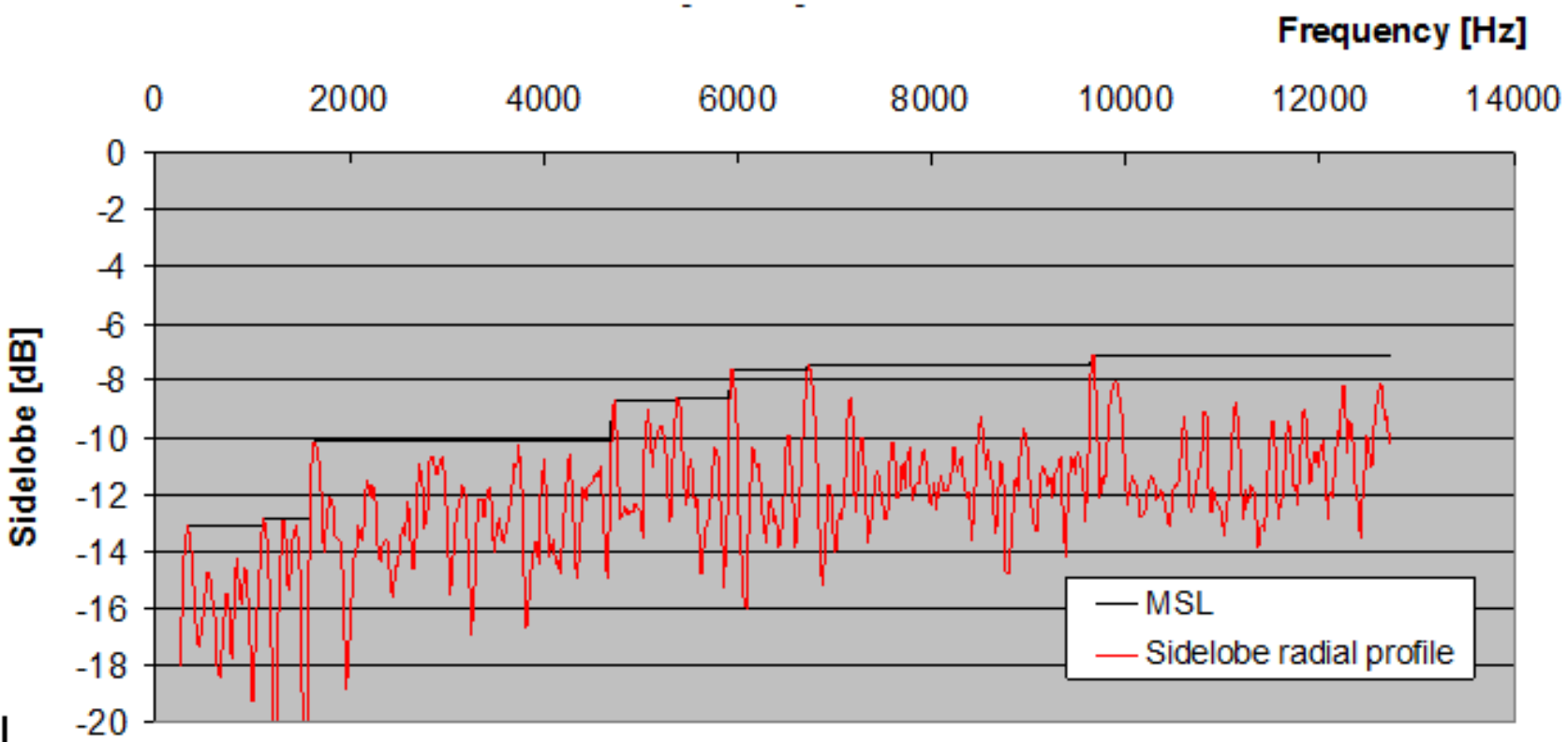


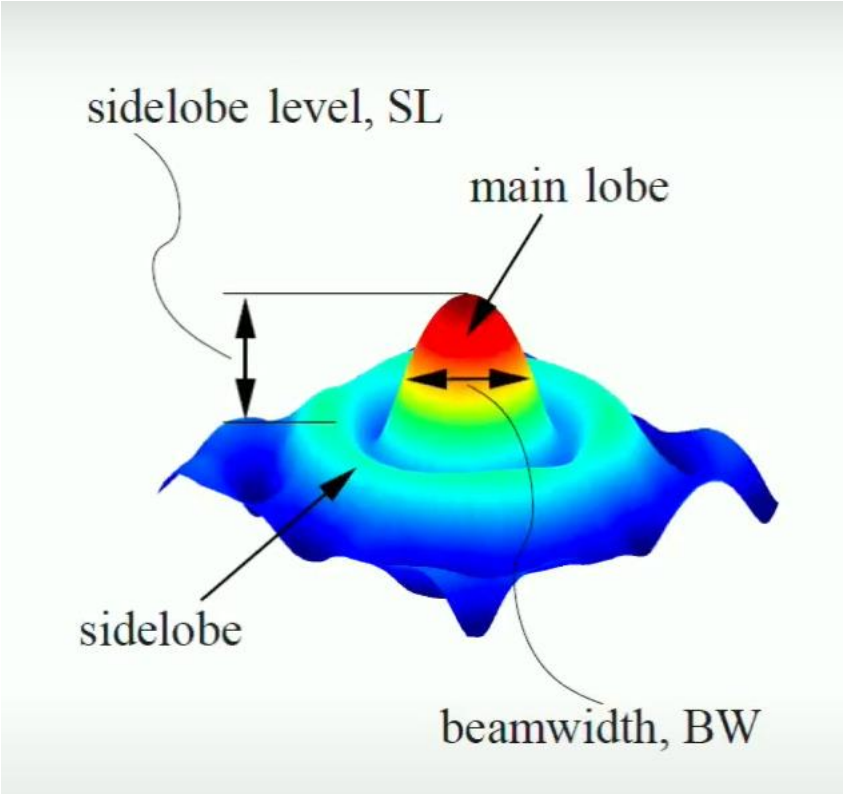
Beamforming limitations

- Lower sidelobe levels mean less visible ghost images
- Sidelobes suppressed using deconvolution techniques.



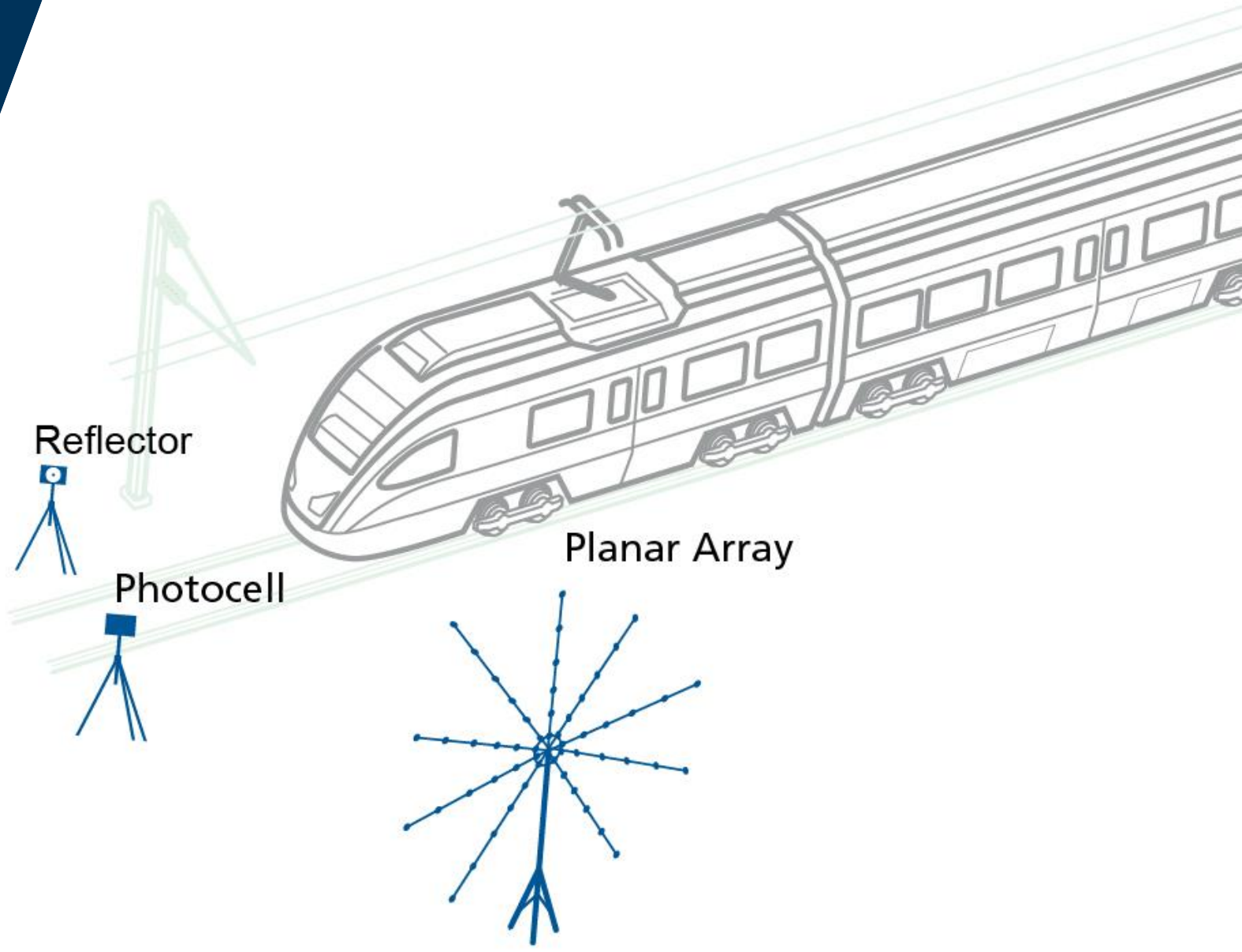






Measurement setup

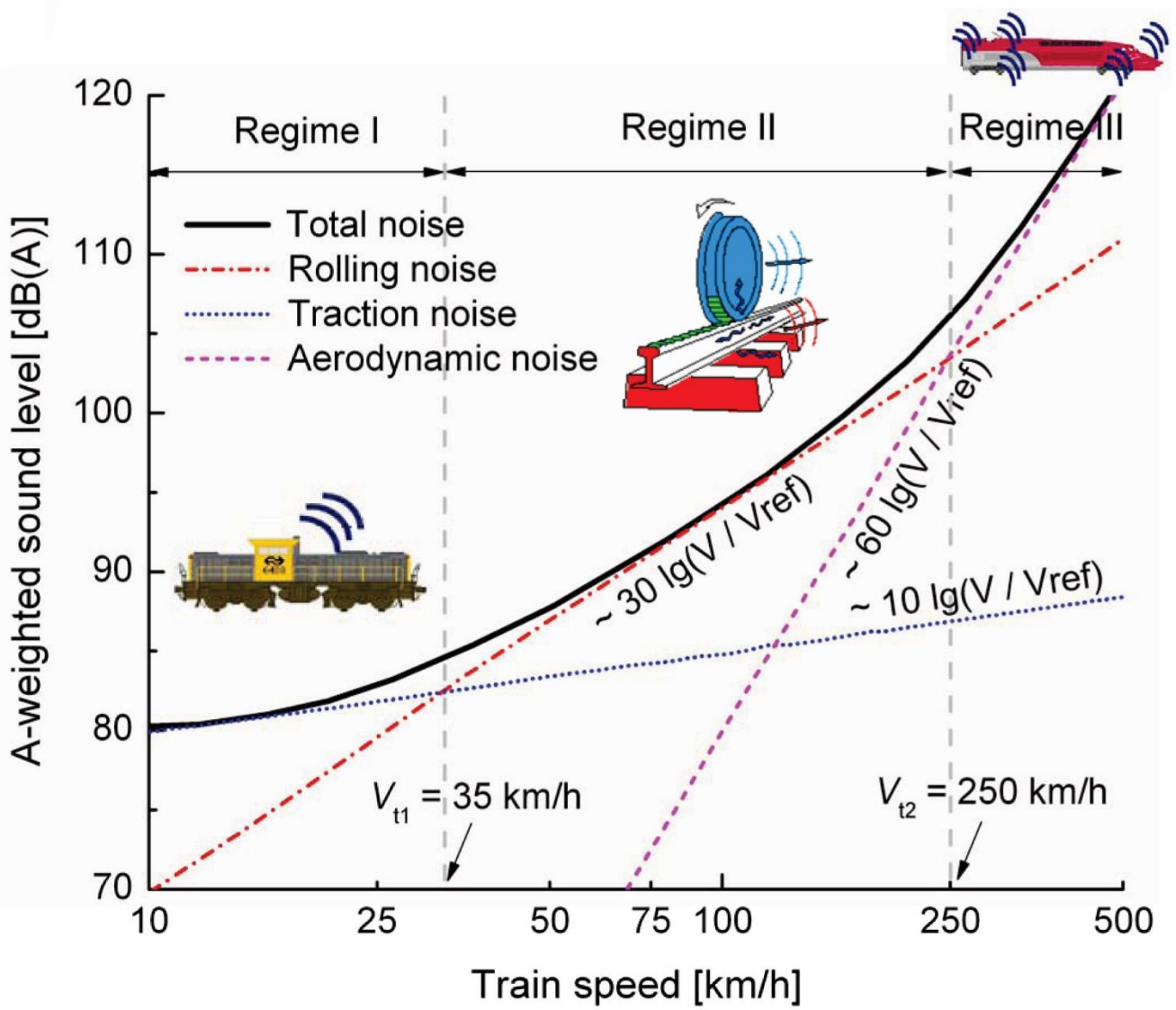
This chapter looks at what noise sources one can expect from a train and the practical measurement setup needed to perform MSBF on trains



Railway exterior noise as a function of train speed

Total noise is the sum of 3 main components:

- Traction noise, predominant at low speed, < 35 km/hr
- Rolling noise, normal speed
- Aerodynamic noise, predominant at high speed, > 250 km/hr

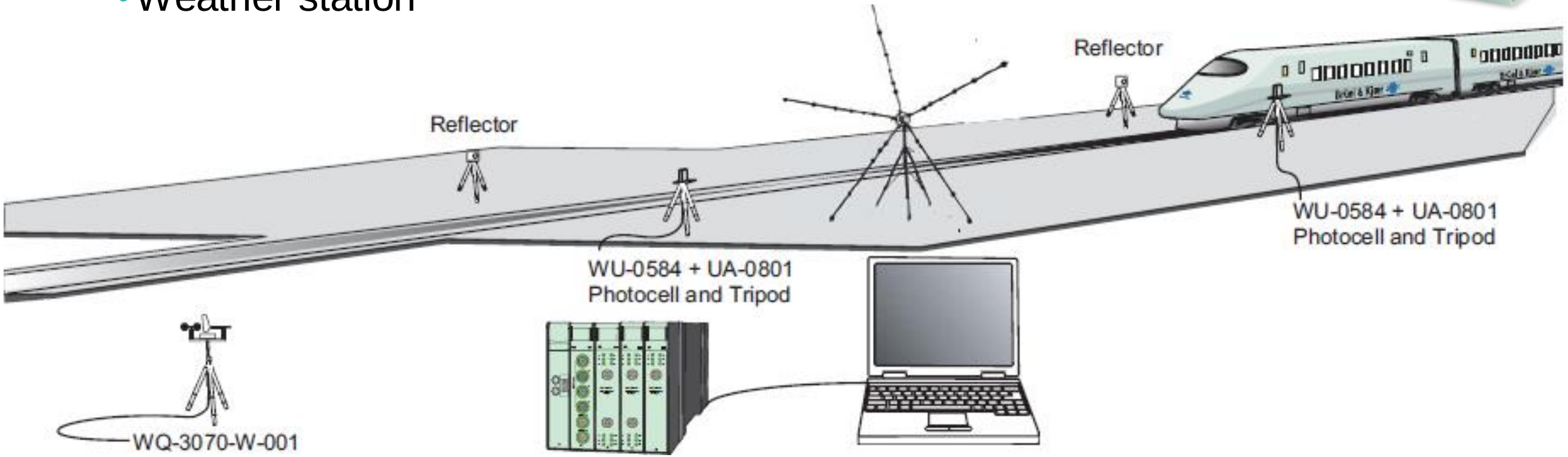


Environmental noise limits for rail noise

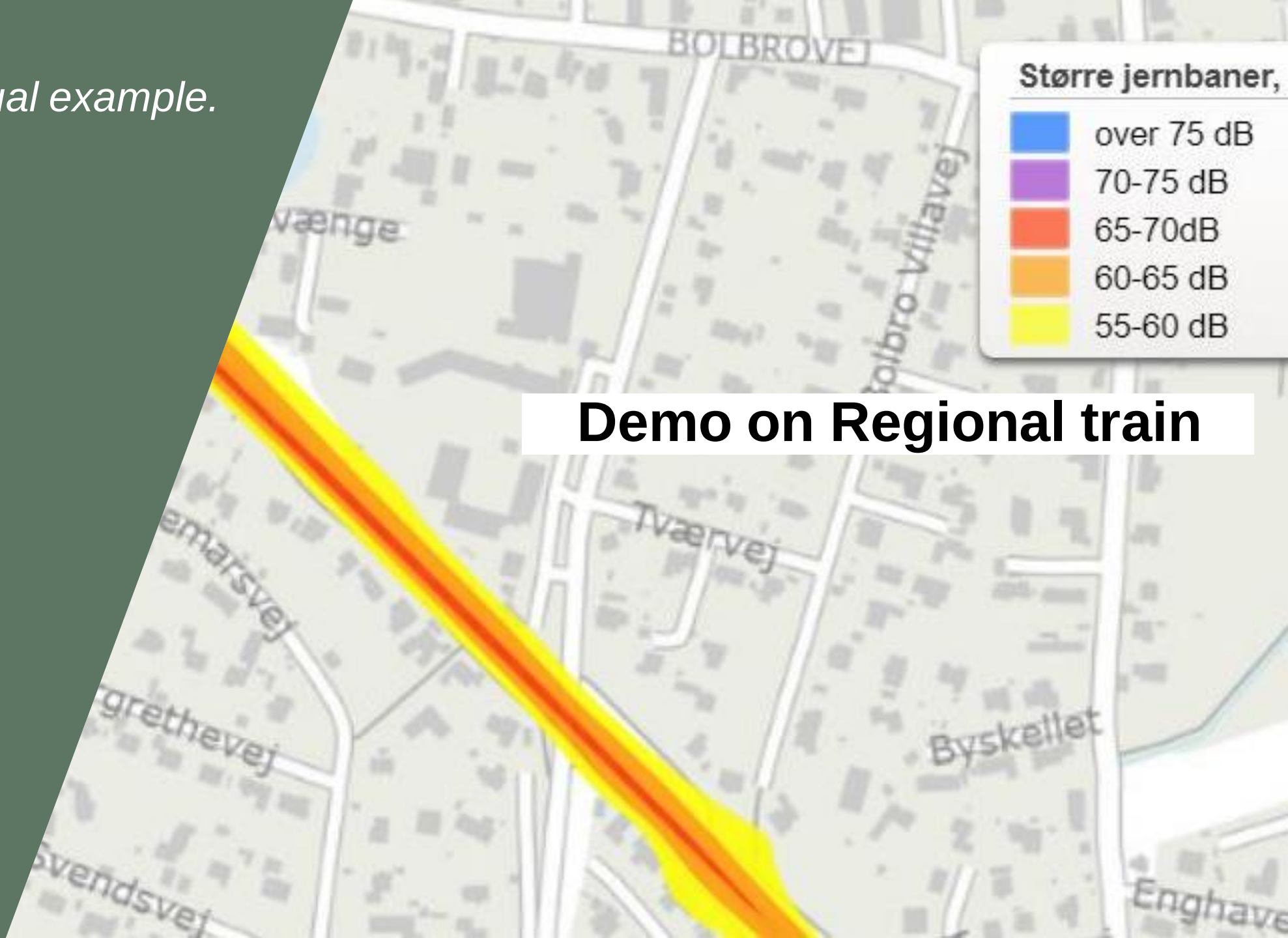
- National guidelines
- Max level during passby (85 dBA)
- Annual daily average (64 dBA)

Standard hardware setup for MSBF

- Planar Array
- Data acquisition units
- PC
- Photocells
- Weather station

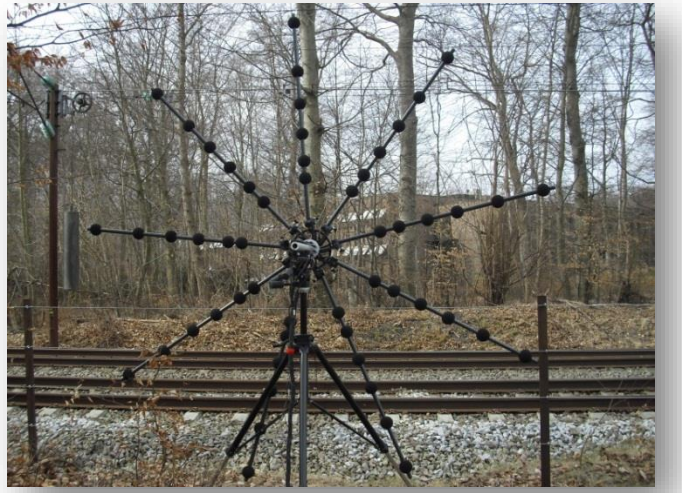


A look at an actual example.



HARDWARE: Track side measurement setup

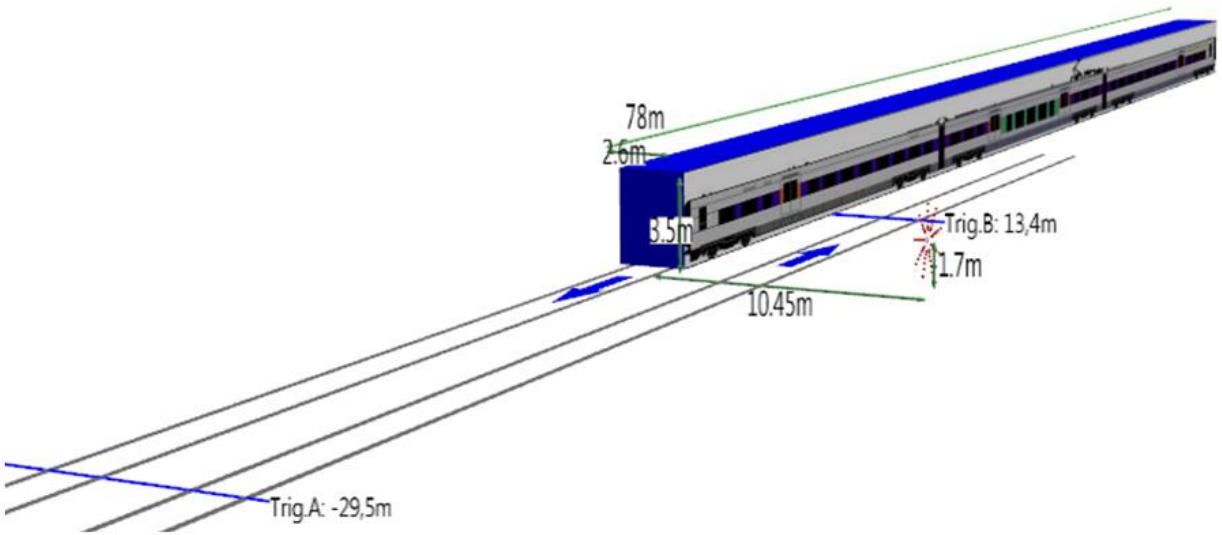
- Array: WA-1676-W-003- 9 arm, 54 channel, foldable, planar array, Ø 2,5m (system 9712-W-D22)
- Microphones: Type 4959 with windscreens
- DAQ: 6 x 12 ch Type 3053 modules
- Triggers: Two photocells as triggers, 43m apart



SOFTWARE: set up

Configure

- Position of array relative to the track.
- Trigger setup (incl. position)
- Meteorology
- Direction of travel
- Mirror ground



Site Setup

Application
Road | Rail | Fly-Over | Not Used

Meteorological
Temperature (°C): 12
Humidity (%): 50
Barometric Pressure (hPa): 1013,25
Precipitation: 0
Wind Speed (m/s): 2
Wind Direction (°): 225

Direction
To the left | To the right

Site
Array Distance (Right) (m): 3
Array Distance (Left) (m): 6
Track Elevation (m): -0,55
Mirror Ground: Off
Configuration: Dual Trigger
Trigger 1: -29,4
Signal (Trigger 1): Ref/Aux 1 (Atc
Trigger 2: 13,4
Signal (Trigger: Ref/Aux 1 (Atc

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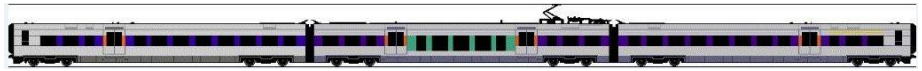
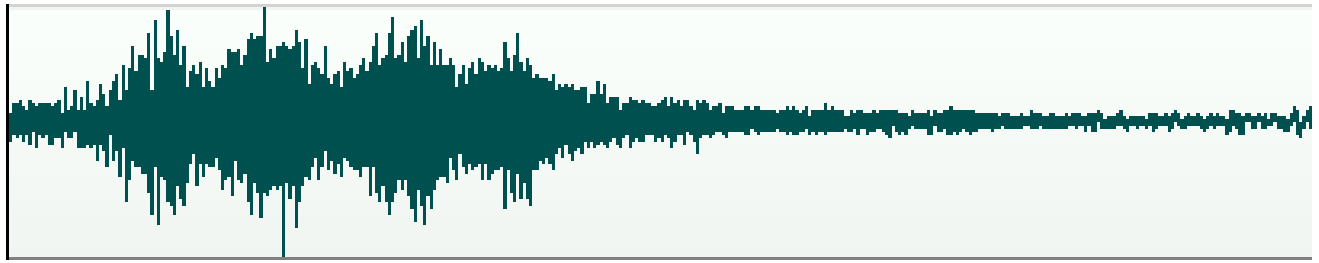
Passby signals: 3 carriages & 6 carriages

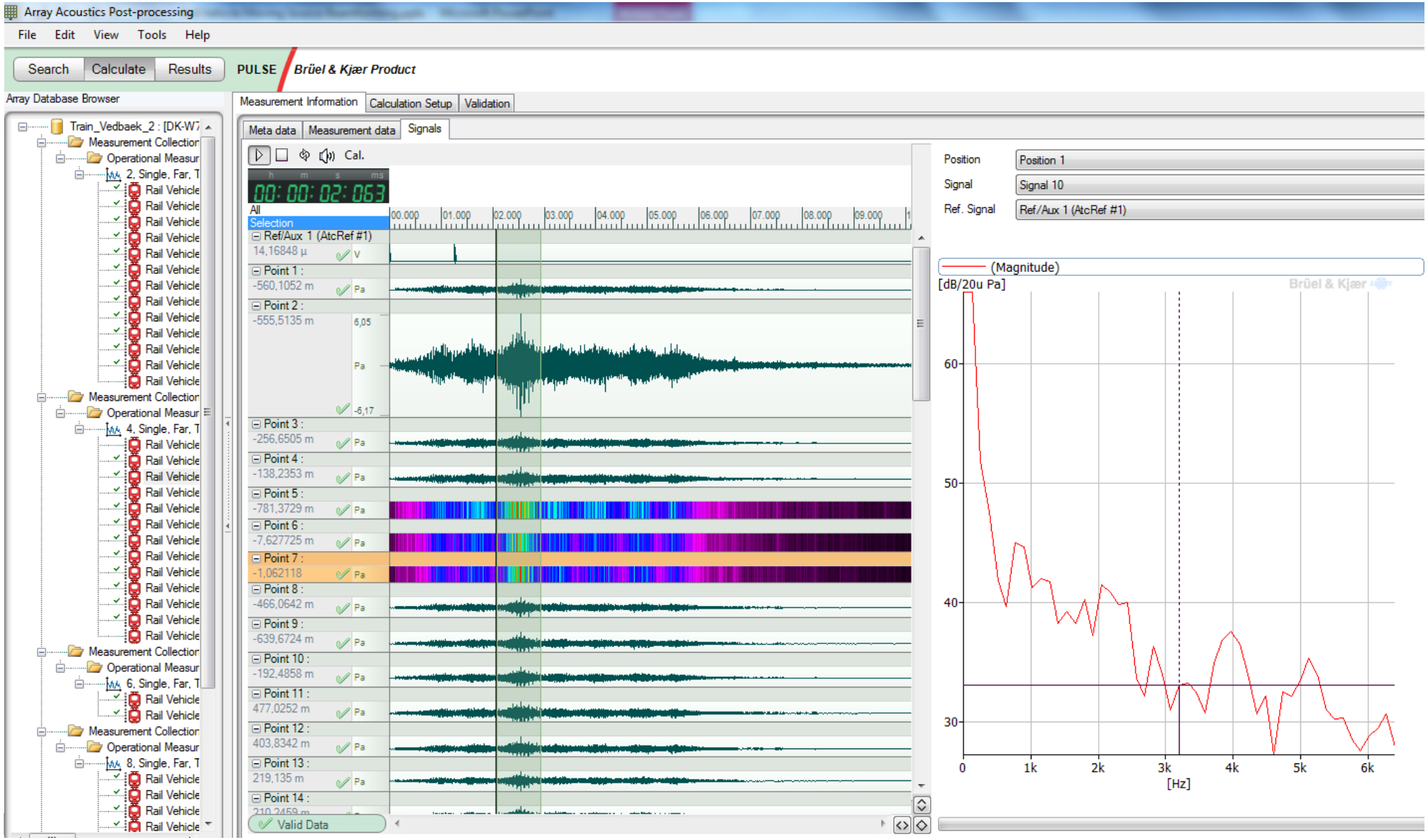
3 carriages left to right



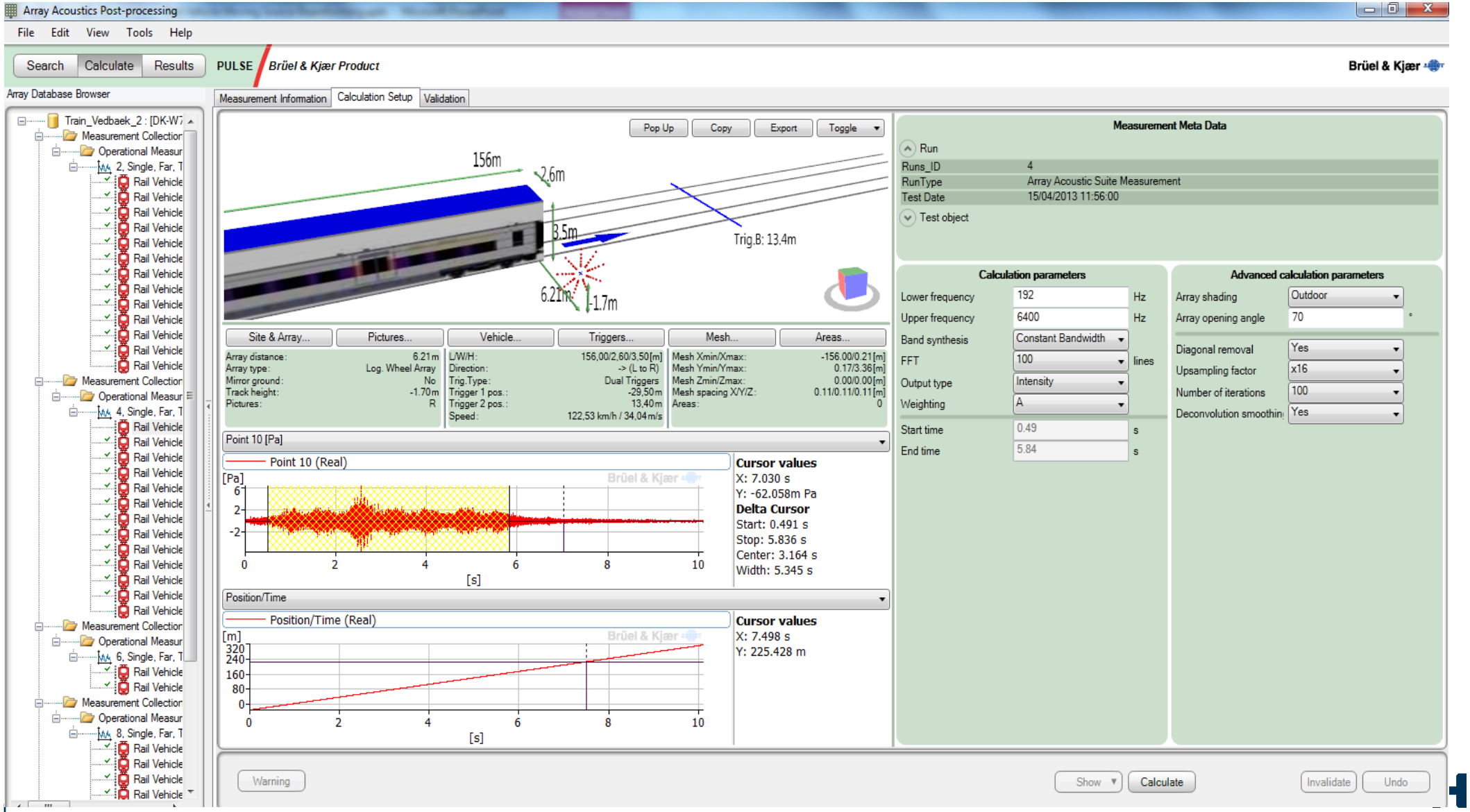


6 carriages left to right

Calculate: Measurement information



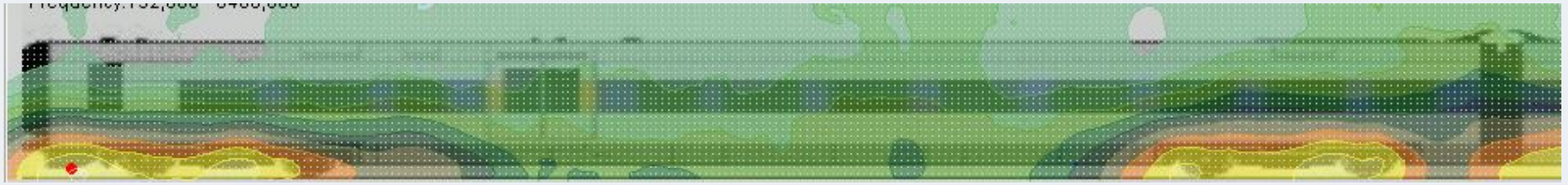
Calculate: calculation setup



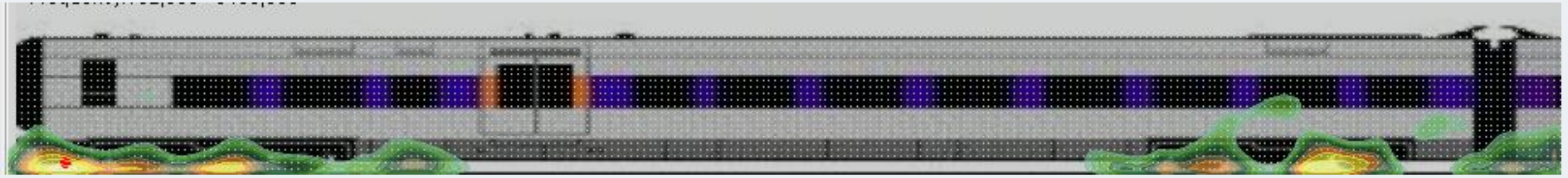
RESULTS: Refined beamforming noise maps improvements

- Train moving at 112 km/hr
- Sound intensity contour maps. Frequency range 192Hz to 6400Hz

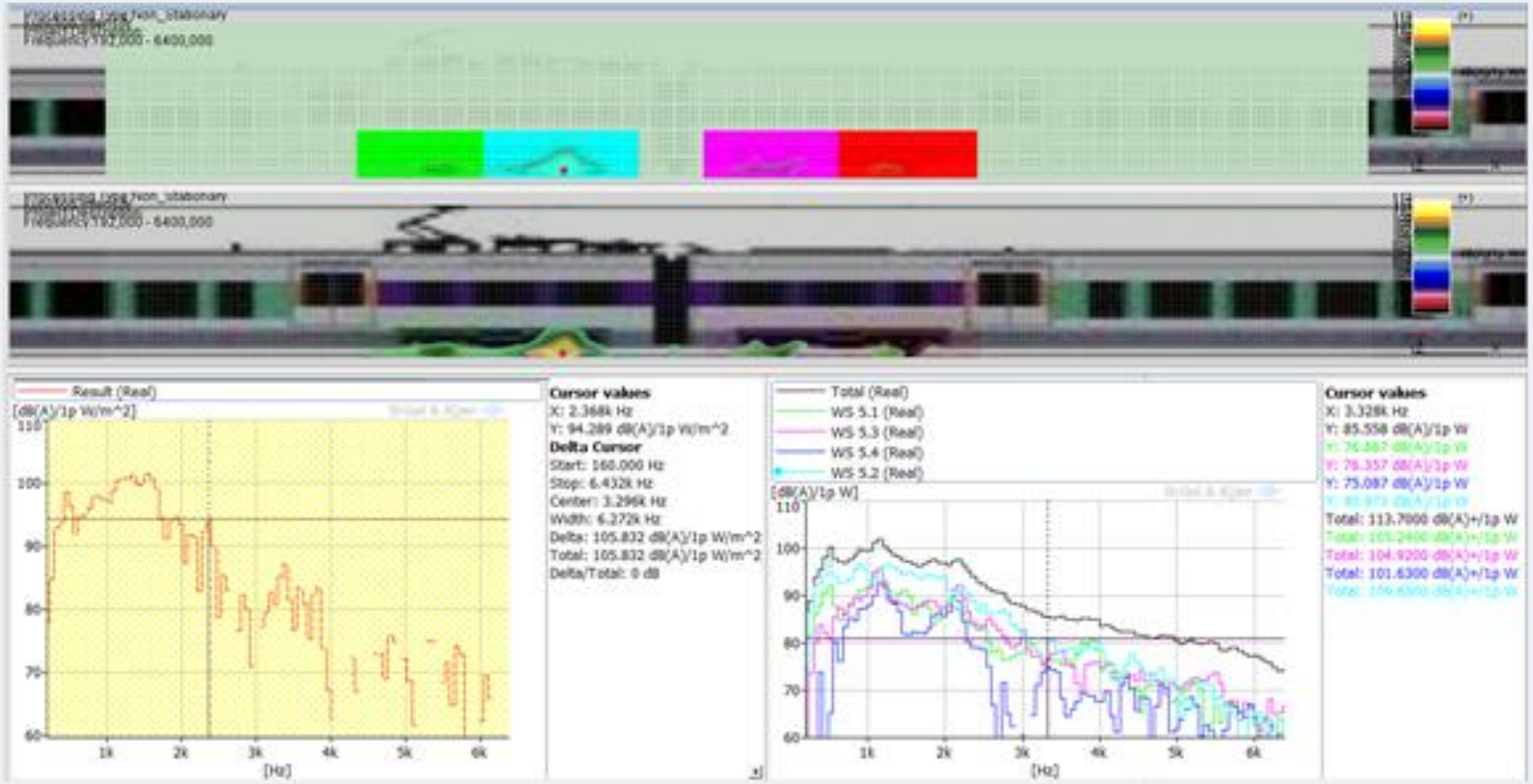
Array Shading: None; no diagonal removal; no deconvolution (DAS)



Array Shading: Outdoor; diagonal removal; NNLS deconvolution

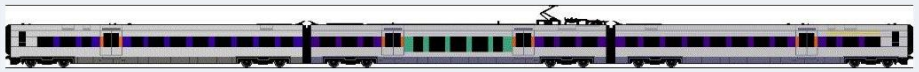


RESULTS: detailed Sound power levels for bogies



Time	Nr. of carrriages	Direction of travel	Speed km/hr	Bogie 8 WS 1	Bogie 8 WS 2	Bogie 9 WS 1	Bogie 9 WS 2	Total
11:56	6	Right	124,4	105,2	109,7	104,9	101,6	113,7

RESULTS Sound power levels for train passbys



				Sound power of bogies dB(A)							
Time	Nr. of carrriages	Direction of travel	Speed km/hr	Bogie 1	Bogie 2 & 3	Bogie 4 & 5	Bogie 6				Whole train
11:50	3	Left	122,6	107,9	111,1	111,4	107,3				116,7
12:03	3	Right	121,6	97,6	102,9	102,2	97,3				110,5
12:10	3	Left	114,4	107,4	110,0	111,0	105,9				115,8
				Bogie 1	Bogie 2 & 3	Bogie 4 & 5	Bogie 6 & 7	Bogie 8 & 9	Bogie 10 & 11	Bogie 12	
11:56	6	Right	124,4	104,6	109,9	110,0	110,4	112,7	110,0	106,3	118,8
12:01	6	Left	123,5	106,6	109,8	109,2	111,3	109,5	108,8	107,0	119,6
12:11	6	Right	124,9	104,3	109,2	109,7	109,2	109,1	108,7	106,4	117,4

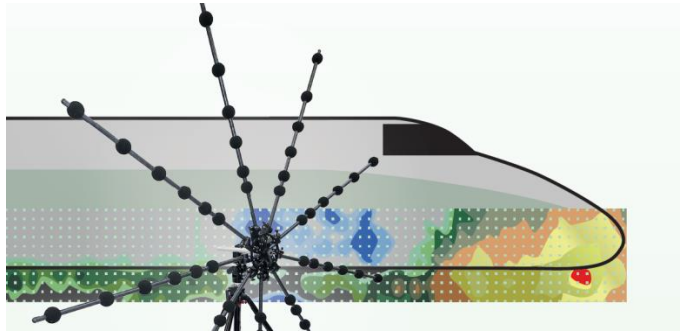
CONCLUSION

Moving source beamforming:

- Doppler effect of moving train
- Sidelobes suppressed for better resolution

Analyses

- Troubleshoot train pass-bys with user-configurable noise maps
- Locate and rank noise sources on individual trains
- Calculate sound power levels for user selected areas of the train



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