

VOLVO

**3D acoustic camera for sound quality
analysis at Volvo Trucks**

Volvo Group Trucks Technology (GTT)

Sound quality



Why sound quality?

Important to have
a relaxing & positive
driving experience



Constantly improving the sound quality



Siemens

3D Acoustic camera

Measurements

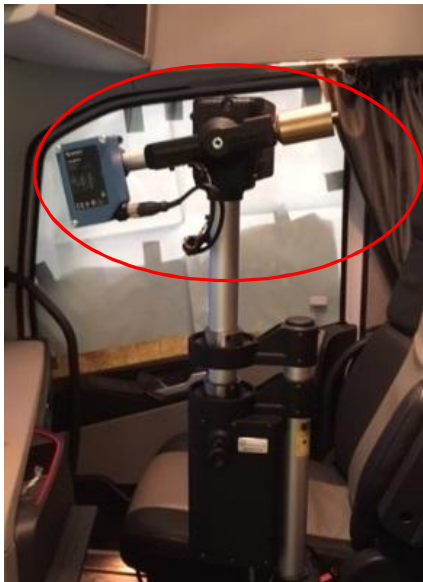
- in vehicle
- test cell
- component testing

ü find areas for improvement

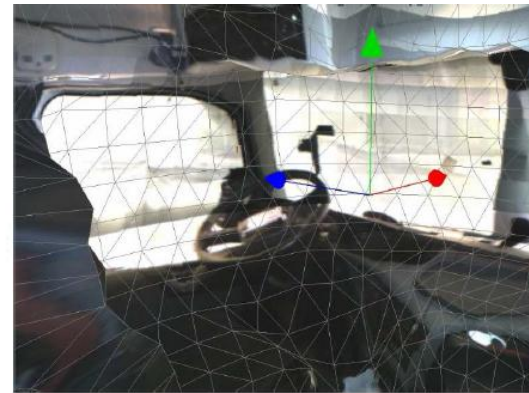
ü compare concepts

Measurement set up

1. scanning of the test object



Laser scanner



3D meshing of the cabin



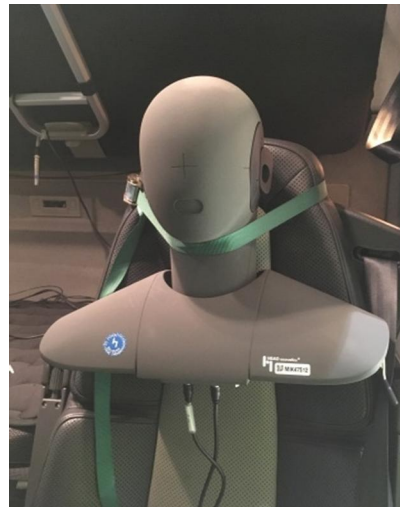
Mesh of the cab

Measurement set up

2. Collecting data:



Microphone sphere



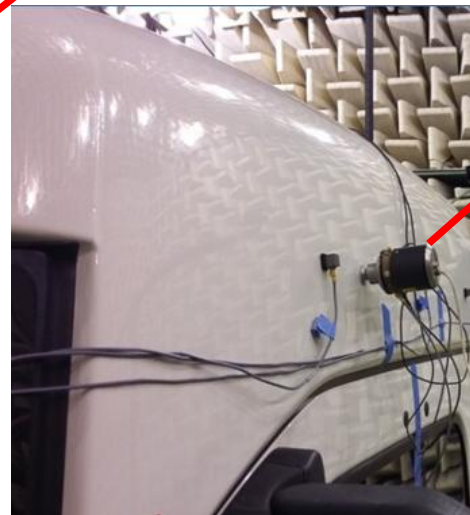
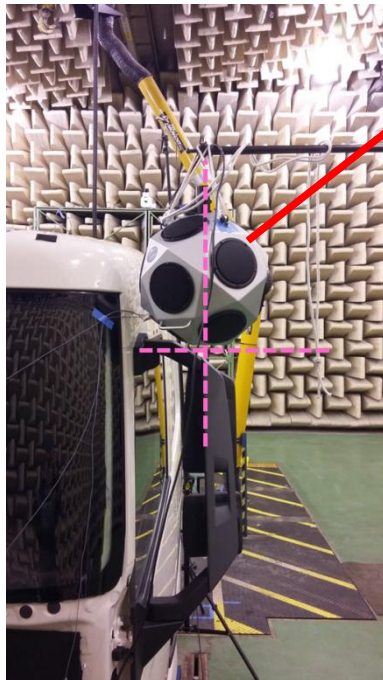
*Driver
artificial head*



LMS frontend

Measurement setup

System & component testing



a practical illustration.....

Measurement procedure

Hällered Proving ground

Different test tracks



Measurement procedure



Measurement campaign in wind tunnel

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Measurement in vehicle

Collecting data:

Sensor for wind speed & direction



Analysis procedure

Important to compare same running conditions!

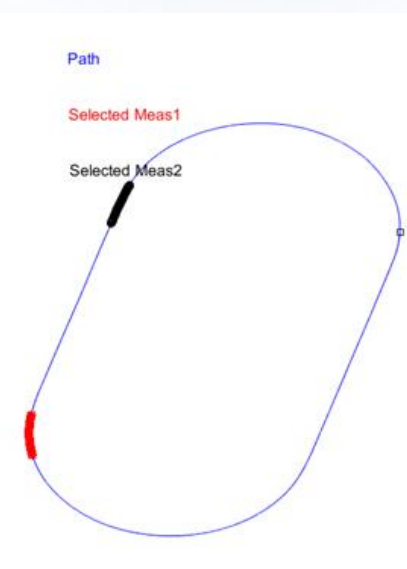
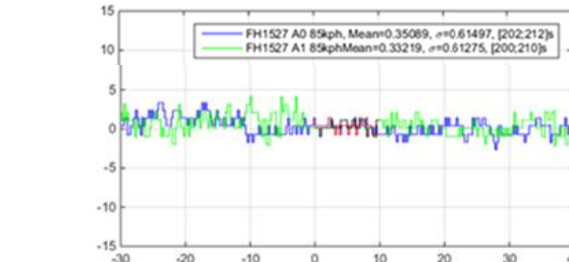
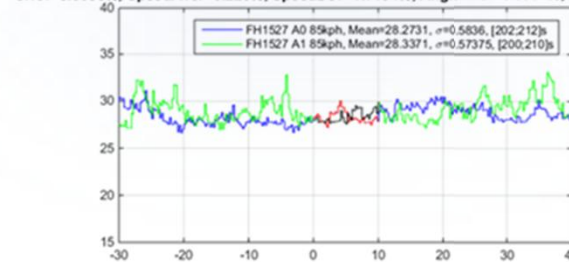
Matlab script

Optimum conditions

Position at test track

```
subplot('time [s]');plot('wind speed [m/s]')
subplot('time [s]');plot('wind angle [degrees]')
%Running some stuff
%Figsave(1)
save('data', 'Normalised', 'GlobalPosition', [0 0.2 0.8 0.8]) % Added by Robert Larsson 161026, adjusts the plot
independent of screen resolution and also allows
% save as zip file if 'saveaszip' is set to true
saveaszip('data','saveaszip')
subplot(2,2,1)
plot('time_start_1(INN(1,2)),speed','b')hold on
plot('time_start_2(INN(1,2)),speed','r')hold on
plot('time_start_3(INN(1,2)),speed','g')hold on
plot('time_start_4(INN(1,2)),speed','b')hold on
plot('time_start_5(INN(1,2)),speed','r')hold on
plot('time_start_6(INN(1,2)),speed','g')hold on
plot('time_start_7(INN(1,2)),speed','b')hold on
plot('time_start_8(INN(1,2)),speed','r')hold on
plot('time_start_9(INN(1,2)),speed','g')hold on
plot('time_start_10(INN(1,2)),speed','b')hold on
plot('time_start_11(INN(1,2)),speed','r')hold on
plot('time_start_12(INN(1,2)),speed','g')hold on
plot('time_start_13(INN(1,2)),speed','b')hold on
plot('time_start_14(INN(1,2)),speed','r')hold on
plot('time_start_15(INN(1,2)),speed','g')hold on
plot('time_start_16(INN(1,2)),speed','b')hold on
plot('time_start_17(INN(1,2)),speed','r')hold on
plot('time_start_18(INN(1,2)),speed','g')hold on
plot('time_start_19(INN(1,2)),speed','b')hold on
plot('time_start_20(INN(1,2)),speed','r')hold on
plot('time_start_21(INN(1,2)),speed','g')hold on
plot('time_start_22(INN(1,2)),speed','b')hold on
plot('time_start_23(INN(1,2)),speed','r')hold on
plot('time_start_24(INN(1,2)),speed','g')hold on
plot('time_start_25(INN(1,2)),speed','b')hold on
plot('time_start_26(INN(1,2)),speed','r')hold on
plot('time_start_27(INN(1,2)),speed','g')hold on
plot('time_start_28(INN(1,2)),speed','b')hold on
plot('time_start_29(INN(1,2)),speed','r')hold on
plot('time_start_30(INN(1,2)),speed','g')hold on
plot('time_start_31(INN(1,2)),speed','b')hold on
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plot('time_start_35(INN(1,2)),speed','r')hold on
plot('time_start_36(INN(1,2)),speed','g')hold on
plot('time_start_37(INN(1,2)),speed','b')hold on
plot('time_start_38(INN(1,2)),speed','r')hold on
plot('time_start_39(INN(1,2)),speed','g')hold on
plot('time_start_40(INN(1,2)),speed','b')hold on
plot('time_start_41(INN(1,2)),speed','r')hold on
plot('time_start_42(INN(1,2)),speed','g')hold on
plot('time_start_43(INN(1,2)),speed','b')hold on
plot('time_start_44(INN(1,2)),speed','r')hold on
plot('time_start_45(INN(1,2)),speed','g')hold on
plot('time_start_46(INN(1,2)),speed','b')hold on
plot('time_start_47(INN(1,2)),speed','r')hold on
plot('time_start_48(INN(1,2)),speed','g')hold on
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plot('time_start_50(INN(1,2)),speed','r')hold on
plot('time_start_51(INN(1,2)),speed','g')hold on
plot('time_start_52(INN(1,2)),speed','b')hold on
plot('time_start_53(INN(1,2)),speed','r')hold on
plot('time_start_54(INN(1,2)),speed','g')hold on
plot('time_start_55(INN(1,2)),speed','b')hold on
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plot('time_start_57(INN(1,2)),speed','g')hold on
plot('time_start_58(INN(1,2)),speed','b')hold on
plot('time_start_59(INN(1,2)),speed','r')hold on
plot('time_start_60(INN(1,2)),speed','g')hold on
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plot('time_start_62(INN(1,2)),speed','r')hold on
plot('time_start_63(INN(1,2)),speed','g')hold on
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plot('time_start_78(INN(1,2)),speed','g')hold on
plot('time_start_79(INN(1,2)),speed','b')hold on
plot('time_start_80(INN(1,2)),speed','r')hold on
plot('time_start_81(INN(1,2)),speed','g')hold on
plot('time_start_82(INN(1,2)),speed','b')hold on
plot('time_start_83(INN(1,2)),speed','r')hold on
plot('time_start_84(INN(1,2)),speed','g')hold on
plot('time_start_85(INN(1,2)),speed','b')hold on
plot('time_start_86(INN(1,2)),speed','r')hold on
plot('time_start_87(INN(1,2)),speed','g')hold on
plot('time_start_88(INN(1,2)),speed','b')hold on
plot('time_start_89(INN(1,2)),speed','r')hold on
plot('time_start_90(INN(1,2)),speed','g')hold on
plot('time_start_91(INN(1,2)),speed','b')hold on
plot('time_start_92(INN(1,2)),speed','r')hold on
plot('time_start_93(INN(1,2)),speed','g')hold on
plot('time_start_94(INN(1,2)),speed','b')hold on
plot('time_start_95(INN(1,2)),speed','r')hold on
plot('time_start_96(INN(1,2)),speed','g')hold on
plot('time_start_97(INN(1,2)),speed','b')hold on
plot('time_start_98(INN(1,2)),speed','r')hold on
plot('time_start_99(INN(1,2)),speed','g')hold on
plot('time_start_100(INN(1,2)),speed','b')hold on
%save the data to a file
save('data','Normalised','GlobalPosition', [0 0.2 0.8 0.8])
%save as zip file if 'saveaszip' is set to true
saveaszip('data','saveaszip')
```

error=5.9085%, SpeedAver=0.226%, SpeedDev=1.7154%, AngleAver=5.6304%, AngleDev=0.36253%



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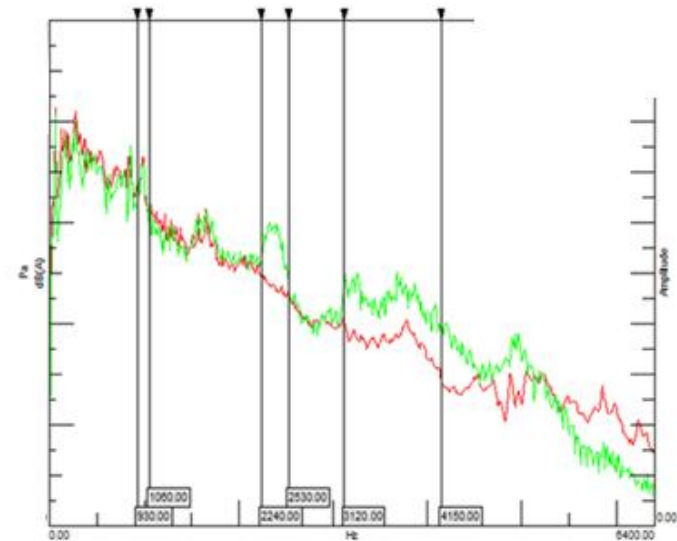
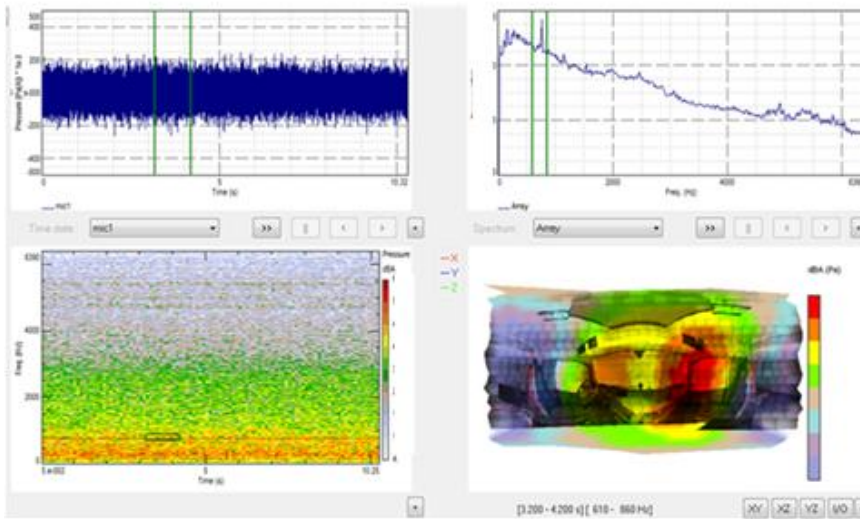
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Analysis procedure

1. check data

2. Zoom in

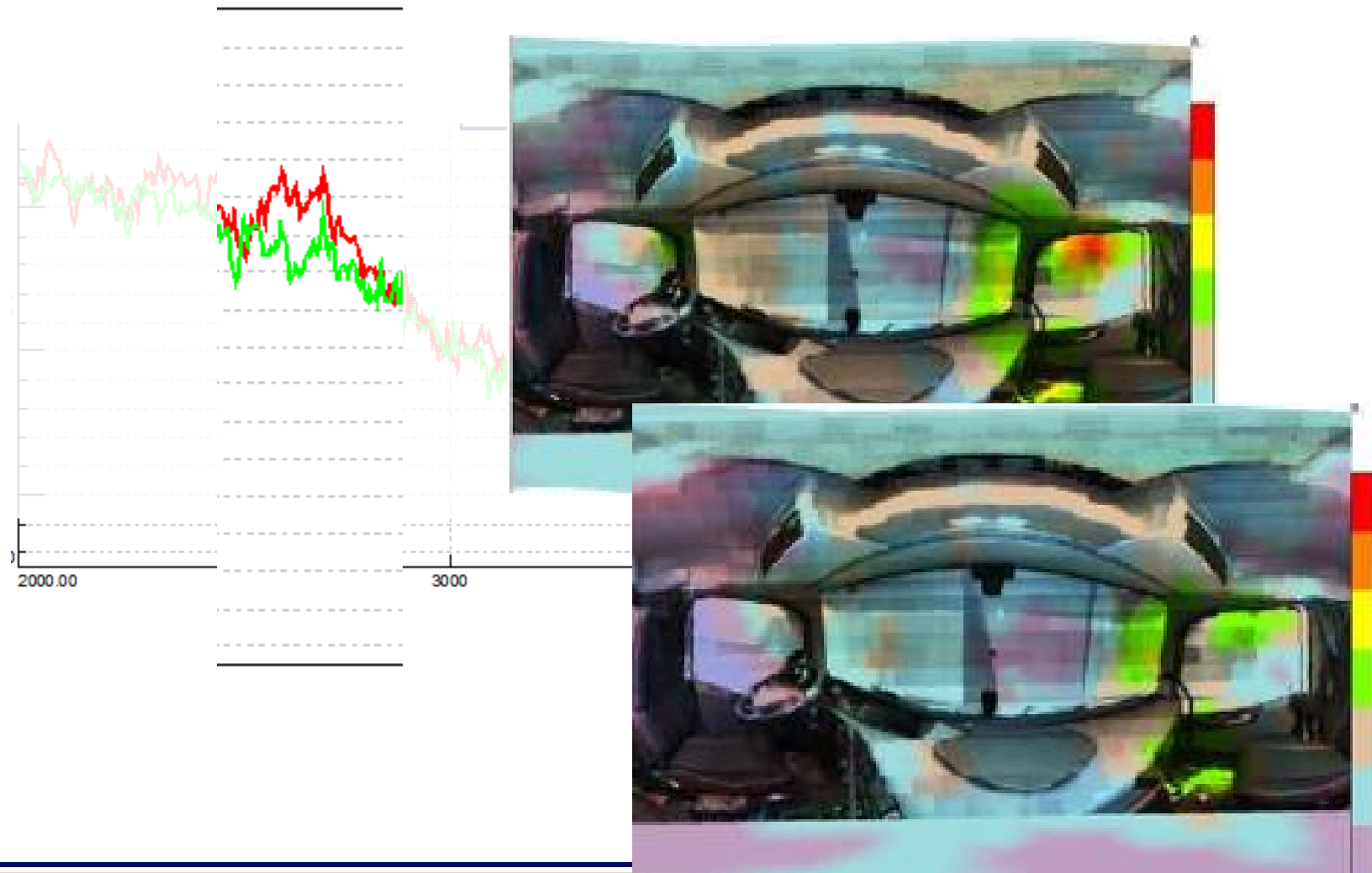
Analysis of measured data with 3D acoustic Camera



Initial analysis:

- time signal
- frequency spectrum
- contour plot (freq. vs dB level vs time)
- 3D Camera dB picture

find sound source...



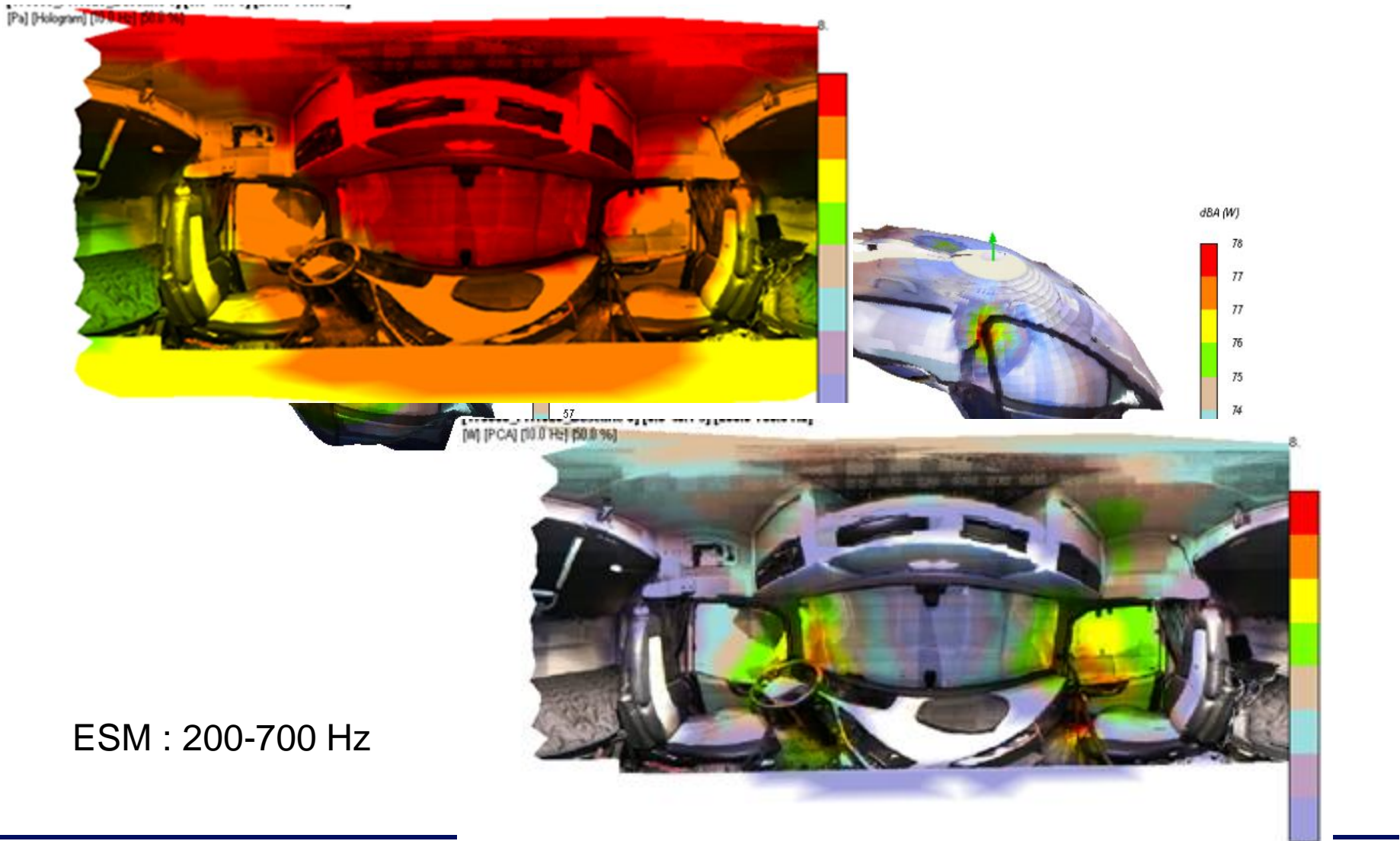
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Low frequency: ESM



ESM : 200-700 Hz

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Multibatch processing tool



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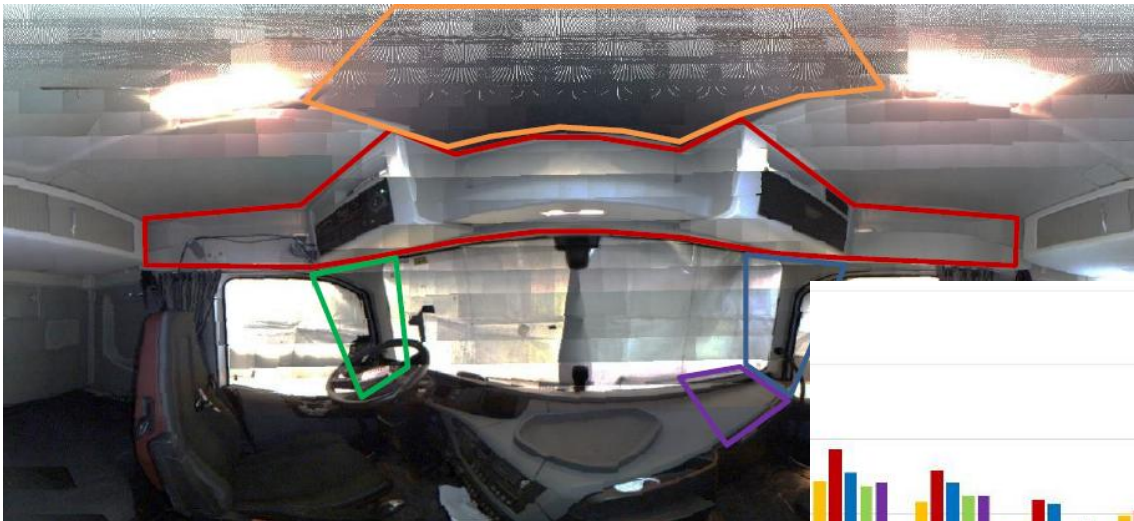
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Listen to point sources

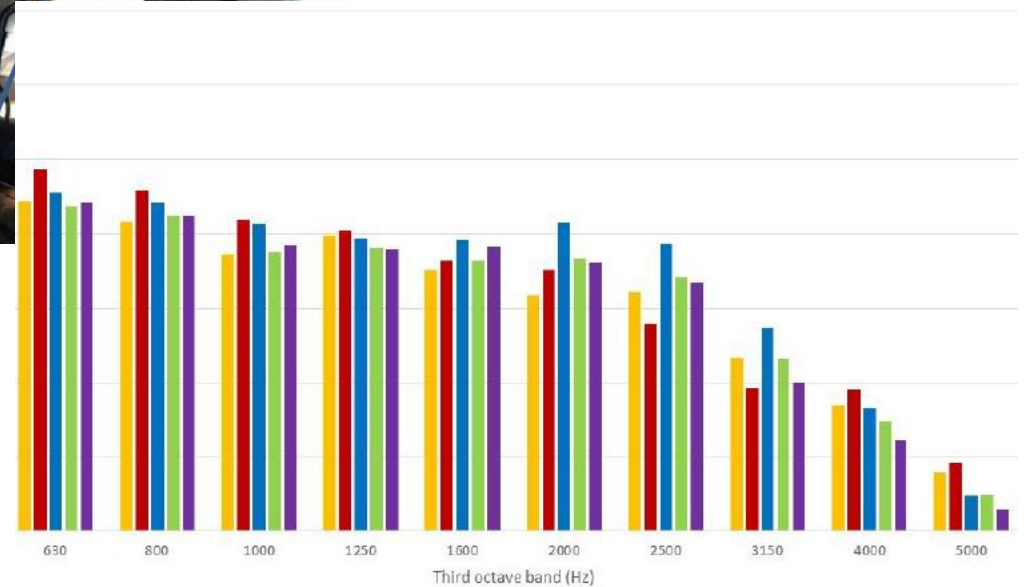


Sound contribution analysis

combine larger areas



contribution ranking



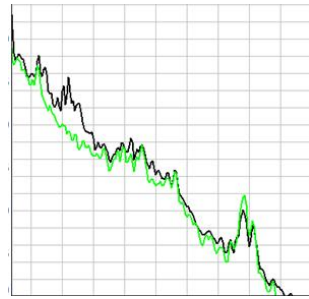
Analysis procedure

1. check data

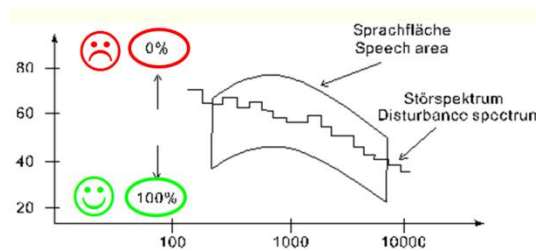
2. Zoom in

3. Make modifications

User friendly tool to present for designers, management (not always acousticians!...) vs traditional metrics:



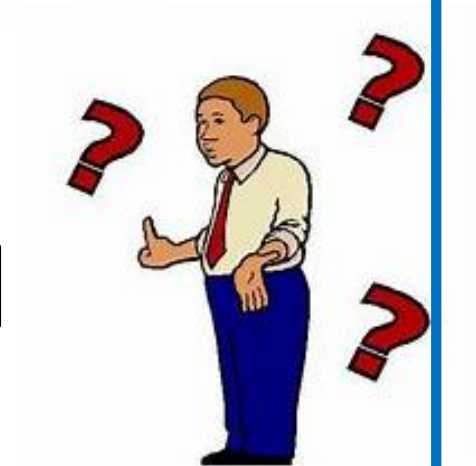
FFT spectrum



AI [%]

48.5 dB(A)

SPL,SWL...



Analysis procedure

1. check data

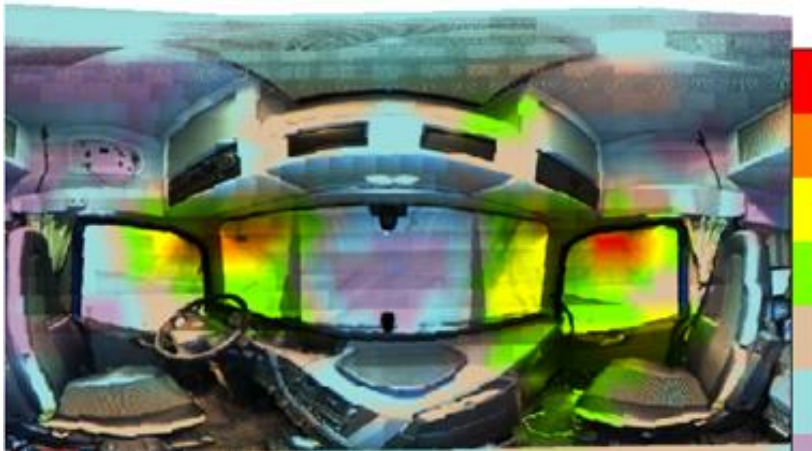
2. Zoom in

3. Make modifications

One picture



clear message



Summary

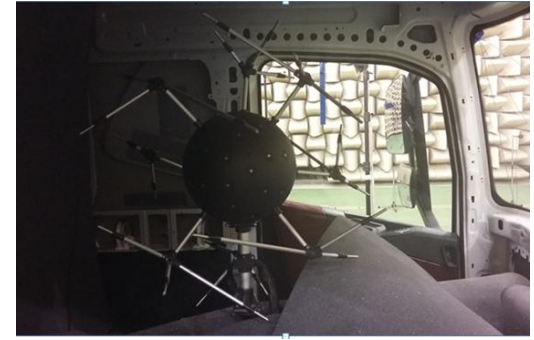
q Sound quality



On road

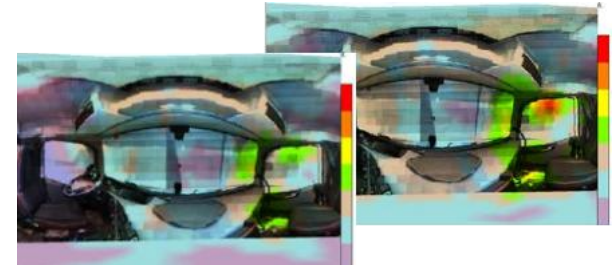
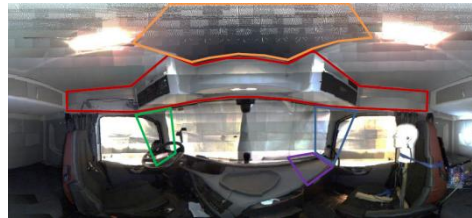


Wind tunnel



Test cell

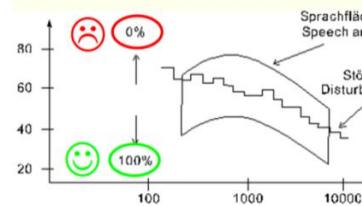
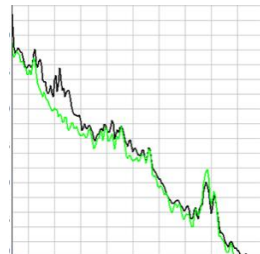
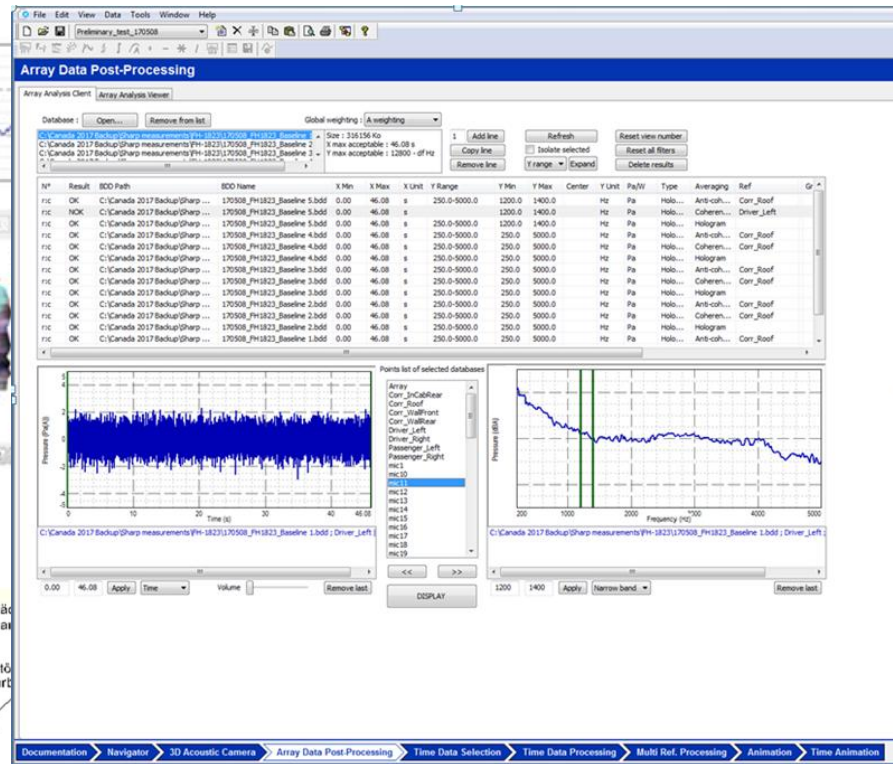
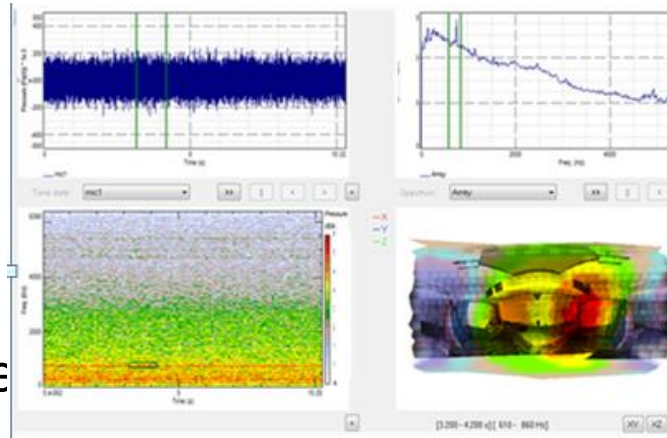
q Collect data à analyze (source, ranking, compare..) à next step...



Summary

Several analysis methods for the engineer

q"ε



SPL, SWL, AI, Loudness.....

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Thank you!

Questions?..