Uncertainty Effects ISO/DIS 16254 5-microphone results

GRBP - QRTV

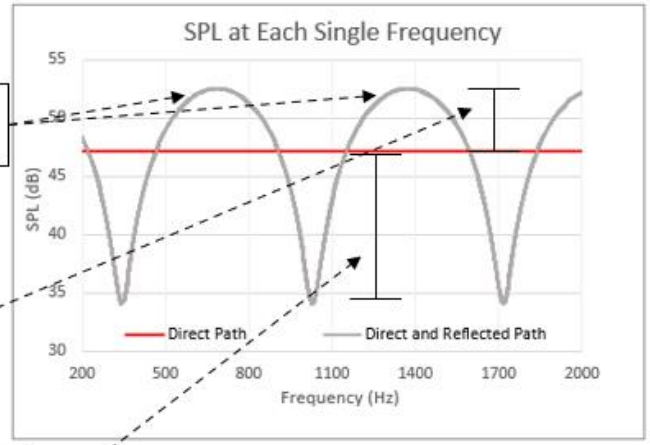
November 8, 2022

The Physics – and Psychoacoustics - of the issue

Portion of signal human ear detects

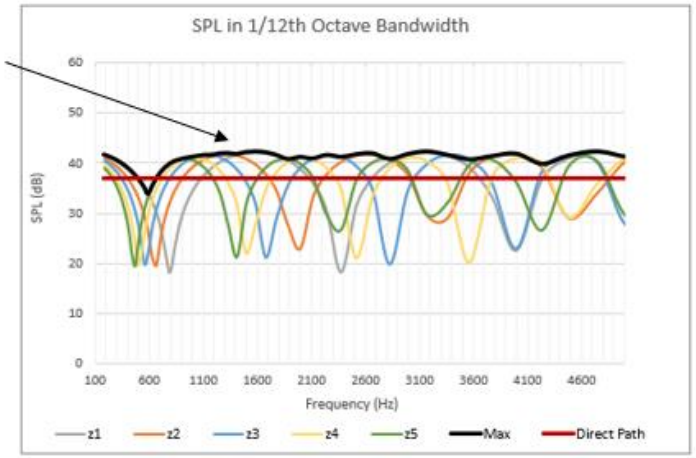
Amplification due to correlated direct and reflected path signals

Partial cancelation due to direct and reflected path interference



The 5-microphone array reduces the effects from destructive interference.

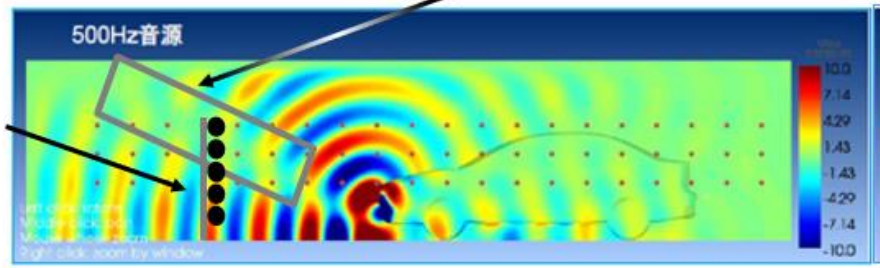
Example of Proposed 5-Microphone Array Amplitude

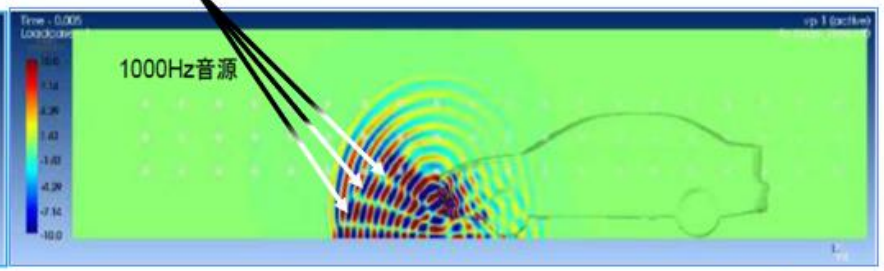


AVAS Dead Zone at 500 Hz

AVAS Dead Zones at 1000 Hz

5-Microphone Array

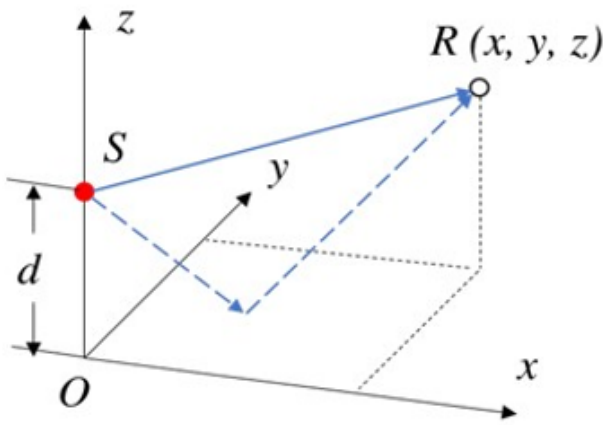




Summary statement:
Single microphone measurements are subject to wave cancellation effects, which are not how humans perceive sound. Human hearing has two "microphones" and a human is always in motion, resulting in detection of sound over a spatial area.

Overview of Analytic Simulation model

- An evaluation method was developed to investigate the environmental uncertainty in sound propagation for the sound profile and pass-by noise of AVAS/PFAF systems.
- The variation between an input sound power of a 60 dB point source is evaluated at field point, $\boldsymbol{R}$.
- The main impact quantities considered:
  - Temperature, T $(°C)$
  - Pressure, P (Pa)
  - Relative humidity, RH (%)
  - Wind speed, W_s $\left(\frac{\mathrm{m}}{\mathrm{s}}\right)$
  - Wind gradient index, $W_g(n)$
  - Temperature gradient, $T_g(T,z)$ $\left(\frac{°\mathrm{C}}{\mathrm{m}}\right)$
  - Surface absorption, α (%)
  - Source height above ground, $\boldsymbol{d}$
  - Sensor/detector position, $\boldsymbol{R}(\boldsymbol{x},\boldsymbol{y},\boldsymbol{z})$



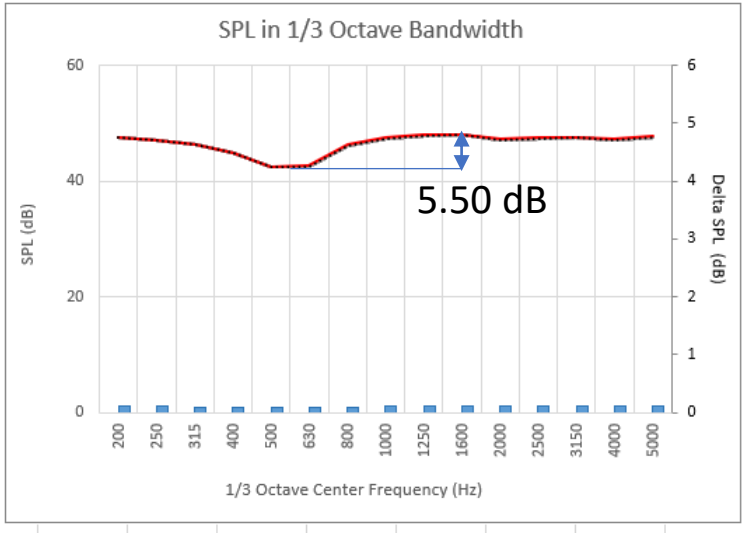
Summary statement:
Baseline case used a single microphone to determine the main impact quantities from those being investigated.

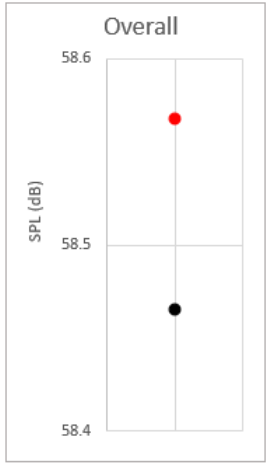
Situation	Input Quantity	estimated deviations of the meas. result (peak-peak @ 95% CI)		Probability Distribution	Variance OA	Variance 1/3 Octave	Standard deviation OA	Standard deviation 1/3	Share [%] OA	Share [%] 1/3	Combined standard uncertainty OA	Combined standard uncertainty 1/3 Octave
		L_OA	L_1/3									
Inherent spatial frequency bias	Bias from human psychoacoustic response	NA	1.5	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable	Not applicable
Inherent spatial frequency variation	Variation from human psychoacoustic response	0.1	5.50	rectangular	0.001	2.521	0.025	1.588	0.1%	26.6%	0.03	1.59
single Run to single Run	Wind speed (+/- 5 m/s)	0.02	0.20	gaussian	0.000	0.003	0.005	0.050	0.0%	0.0%	0.89	2.47
	Wind Gradient	0.01	0.00	gaussian	0.000	0.000	0.003	0.000	0.0%	0.0%		
	Temperature (0-40 deg C)	0.04	1.40	gaussian	0.000	0.123	0.010	0.350	0.0%	1.3%		
	Temperature gradient	0.05	0.20	gaussian	0.000	0.003	0.013	0.050	0.0%	0.0%		
	Relative Humidity	0.00	0.10	gaussian	0.000	0.001	0.000	0.025	0.0%	0.0%		
	Speed variations of +/- 1km/h	1.20	1.20	gaussian	0.090	0.090	0.300	0.300	5.7%	0.9%		
	Varying background noise	1.00	1.00	gaussian	0.063	0.063	0.250	0.250	4.0%	0.7%		
	Deviation from centered driving +/- 50 cm)	3.20	7.27	gaussian	0.640	3.303	0.800	1.818	40.7%	34.8%		
Day to Day	Pressure	0.00	0.00	gaussian	0.000	0.000	0.000	0.000	0.0%	0.0%	0.90	2.52
	Microphone X location tolerance	0.00	0.02	gaussian	0.000	0.000	0.000	0.005	0.0%	0.0%		
	Microphone Y location tolerance	0.32	0.90	gaussian	0.006	0.051	0.080	0.225	0.4%	0.5%		
	Microphone Z location tolerance	0.27	1.66	gaussian	0.005	0.172	0.068	0.415	0.3%	1.8%		
Site to Site	Barometric Pressure / Altitude	0.00	0.02	gaussian	0.000	0.000	0.000	0.005	0.0%	0.0%	0.94	2.60
	Test Track Surface Absorption	0.12	0.13	gaussian	0.001	0.001	0.030	0.033	0.1%	0.0%		
	Microphone Class 1 IEC 61672	1.00	1.00	gaussian	0.063	0.063	0.250	0.250	4.0%	0.7%		
	Sound calibrator IEC 60942	0.50	0.50	gaussian	0.016	0.016	0.125	0.125	1.0%	0.2%		
	IEC 61260-1 one-third octave filter tolerance	NA	2.00	rectangular		0.333		0.577		3.5%		
	Speed measuring equipment continuous at PP	0.12	0.12	gaussian	0.001	0.001	0.030	0.030	0.1%	0.0%		
Vehicle to Vehicle	Production Variation Speaker Output	3.00	6.00	gaussian	0.563	2.250	0.750	1.500	35.8%	23.7%	1.25	3.08
	Production variation path transfer function	1.00	2.00	gaussian	0.063	0.250	0.250	0.500	4.0%	2.6%		
	Production variation amplifier output voltage	1.00	2.00	gaussian	0.063	0.250	0.250	0.500	4.0%	2.6%		
	Sound Character											
					1.572	9.491		2.640		73.4%		
								Overall Combined Uncertainty +/-		Expanded uncertainty (95%) +/-		
				Coverage Factor								
				k=2 (95%)			1/3 Octave Test Only	2.60		5.19		
							1/3 Octave 3rd party and/or COP	3.08		6.16		
							Overall SPL Test Only	0.94		1.88		
							Overall SPL 3rd party and/or COP	1.25		2.50		

Inherent Spatial Frequency Variation

Wave amplification/cancellation is the largest uncertainty factor. Uncertainty arises from the acoustic field variation over short spatial distances within the ranges of the source and receiver locations as a function of frequency. These values are calculated with nominal distances and environmental conditions. These results are further used to define "Laboratory Nominal" from which variation of all other terms is assessed.

Inherent Bias: Difference between the maximum and mean sound pressure over the entire frequency range.
Inherent Variation: Variation of sound pressure levels from the mean level as a function of frequency
Overall Sound Pressure Level (OA SPL): Not frequency dependent. Any real sound may have variation depending on Frequency content.
One-Third Octave Sound Pressure Level: Frequency dependent. Results reported do not assume any particular sound source



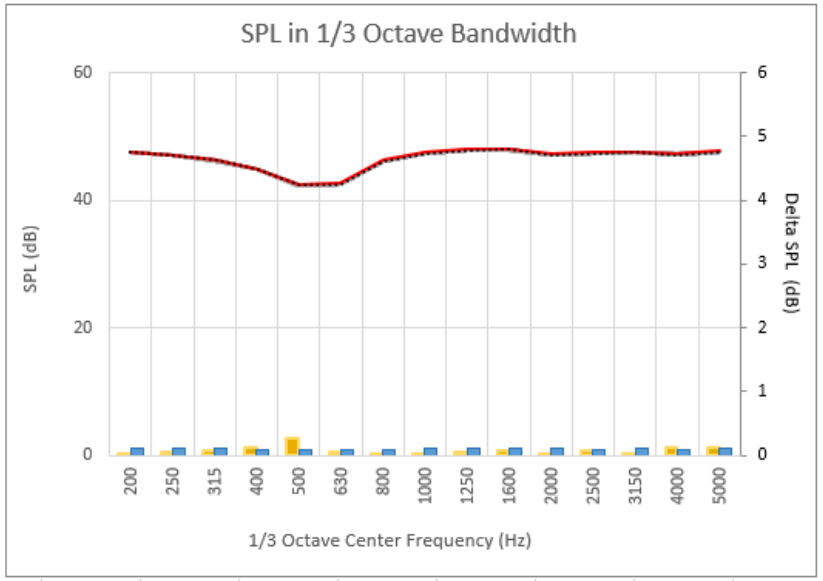


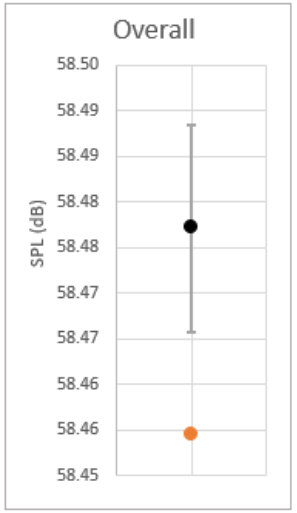
Results	OA	1/3 octave
Bias	NA	1.5
Variation	0.1	5.50

Wind Speed

Wind speed effects direct and reflected path sound propagation. ISO 16254 sets maximum wind speed as 5.0 m/s2. This values was used to assess the variation form the "Laboratory Nominal" response solely due to wind speed

Indoor Lab Nominal Values	Nominal Environmental Factors	Relevant Atmospheric Range
$W_s = 0 \frac{m}{s}$	$W_s = 0 \frac{m}{s}$	$W_s = 0 \pm 5 \frac{m}{s}$





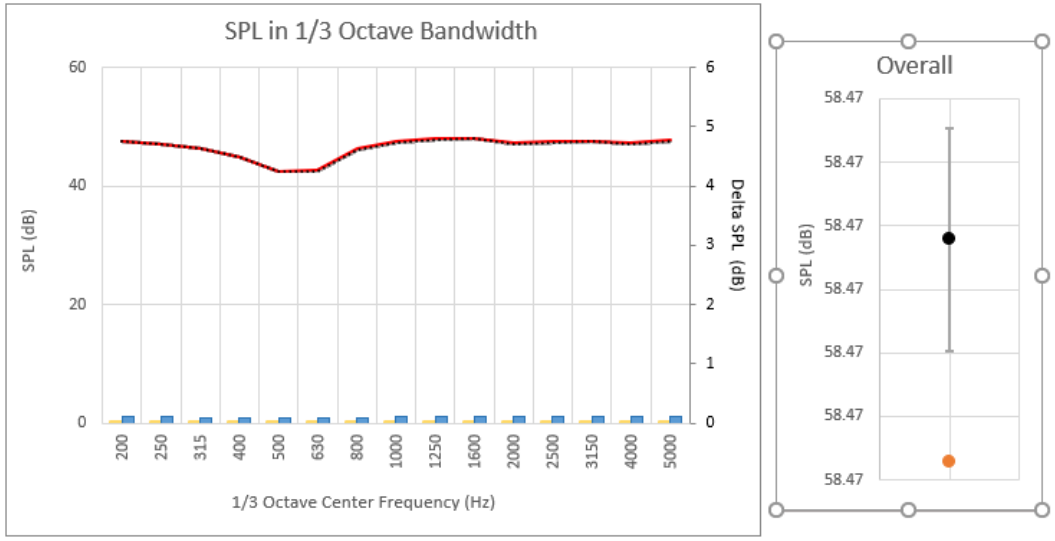
Results	OA	1/3 octave
	0.02	0.20

Wind Gradient

Wind gradient effects direct and reflected path sound propagation. Wind gradient range chosen based on 5m/sec wind speed at receiver height.

This values was used to assess the variation form the "Laboratory Nominal" response solely due to wind gradient effect.

Indoor Lab Nominal Values	Nominal Environmental Factors	Relevant Atmospheric Range
$W_g = 0\ s^{-1}$	$W_g = 0\ s^{-1}$	$W_g = 0 - 1.06\ s^{-1}$

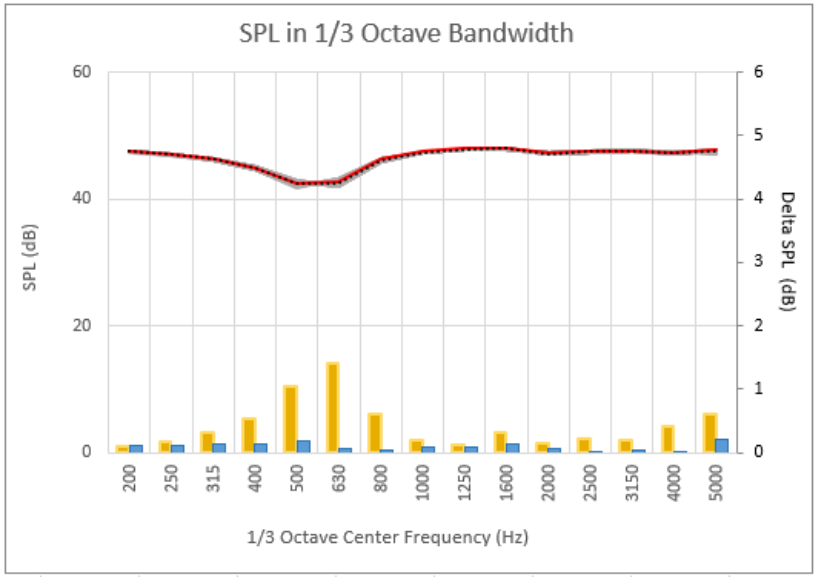


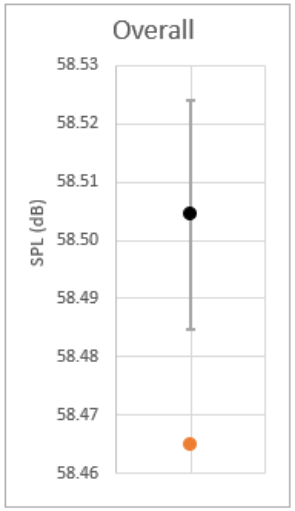
Results	OA	1/3 octave
	0.01	0.01

Temperature

Temperature effects direct and reflected path sound propagation.
Temperature range chosen based ISO 16254 range.
These values were used to assess the variation form the "Laboratory Nominal" response solely due to temperature effect.

Indoor Lab Nominal Values	Nominal Environmental Factors	Relevant Atmospheric Range
$T = 20\ °C$	$T = 20\ °C$	$T = 20 \pm 20\ °C$



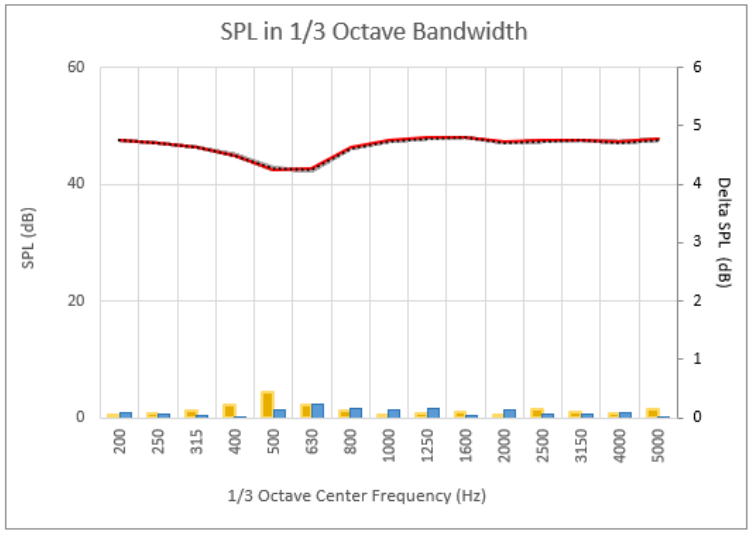


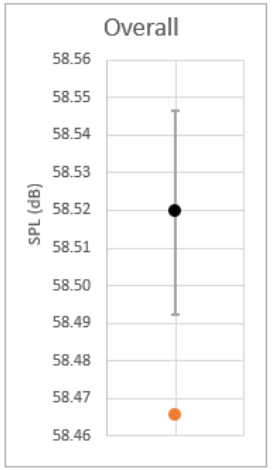
Results	OA	1/3 octave
	0.04	1.40

Temperature Gradient

Temperature gradient effects direct and reflected path sound propagation.
Temperature gradient range chosen based temperature gradient effect from research [1].
These values were used to assess the variation form the "Laboratory Nominal" response solely due to temperature gradient effect.

Indoor Lab Nominal Values	Nominal Environmental Factors	Relevant Atmospheric Range
$T_g = 0 \frac{°C}{m}$	$T_g = 9.8 \times 10^{-3} \frac{°C}{m}$ (dry adiabatic)	$T_g \approx 4.37 \pm 4.37 \frac{°C}{m}$



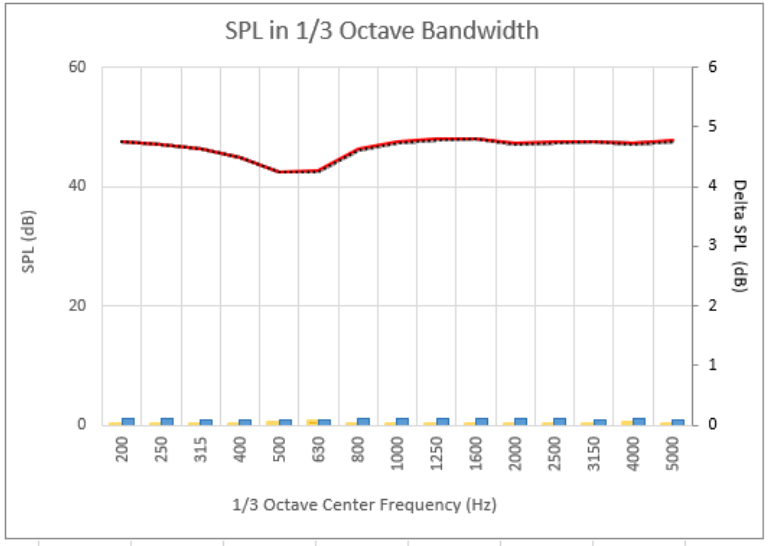


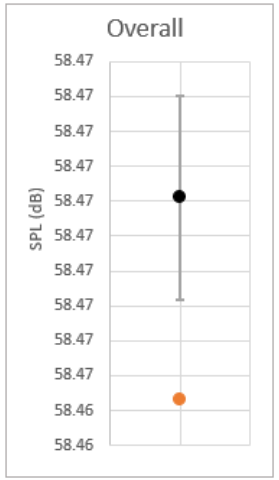
Results	OA	1/3 octave
	0.05	0.20

Relative Humidity

Relative humidity effects direct and reflected path sound propagation.
Relative Humidity range chosen to cover 10% to 90% relative humidity
These values were used to assess the variation form the "Laboratory Nominal" response solely due to relative humidity effect.

Indoor Lab Nominal Values	Nominal Environmental Factors	Relevant Atmospheric Range
$RH = 40\ \%$	$RH = 50\ \%$	$RH = 50 \pm 40\ \%$



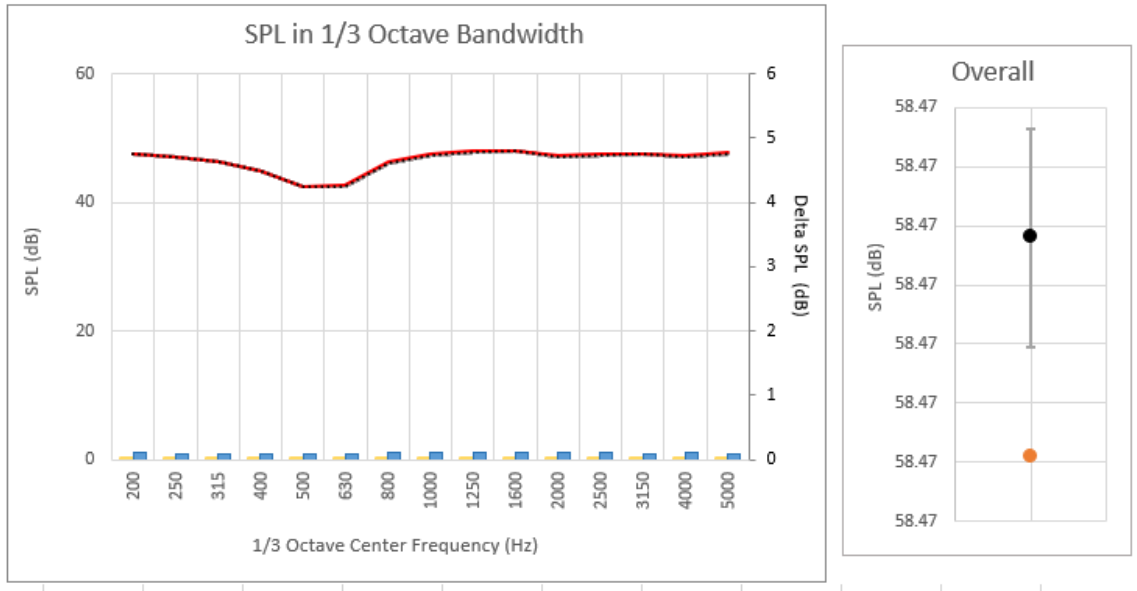


Results	OA	1/3 octave
	0.00	0.10

Pressure – variations over a day

Pressure effects direct and reflected path sound propagation.
Day to day pressure range chosen to cover +/- 8% from Mean Sea Level Pressure.
These values were used to assess the variation form the "Laboratory Nominal" response solely due to pressure effect.

Indoor Lab Nominal Values	Nominal Environmental Factors	Relevant Atmospheric Range
$P = 101.325$ kPa (mean sea level)	$P = 101.325$ kPa (mean sea level)	$P = 101.325$ kPa $\pm$ 8%



Results	OA	1/3 octave
	0.00	0.00

Speed Variation – Test Tolerance

Speed variation effect is taken as the same as determined for ISO 362-1 for both overall sound pressure level and one-third Octaves.

This effect was not modeled analytically.

Regulations (UN R138 and FMVSS 141) have 6dB expected SPL change between 0/10/20/30 km/h.

This gives a maximum possible change of 1.67 dB over the 2 km/h tolerance window. Therefore, using the ISO 362-1 uncertainty estimation was judged a good starting point.

Results	OA	1/3 octave
	1.20	1.20

Background Noise

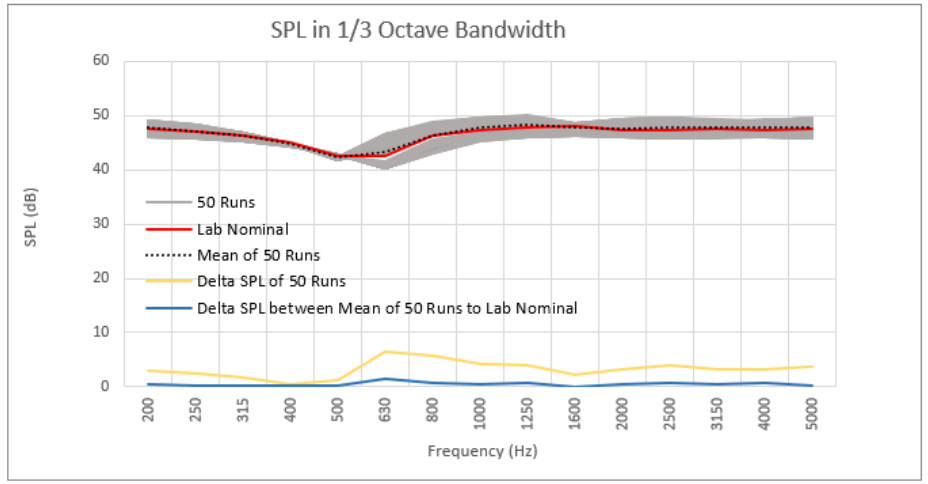
Background noise effect is theoretically determined from the minimum possible signal to noise ratio of 6 dB
As defined in ISO/DIS 16254.
It is assumed to apply equally to overall sound pressure level and to one-third octave sound pressure levels.

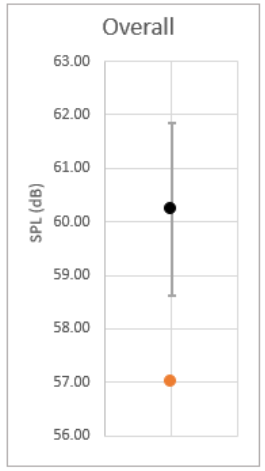
Results	OA	1/3 octave
	1.00	1.00

Deviation from Centered Driving

Deviation from centered driving effect changes the relative location of the source and receiver, resulting in different propagation paths. Results presented cover both microphone sides. The amount of deviation chosen reflect maximums observed in real testing.

Nominal Value	Factor range
0.0m	+/- 0.5m



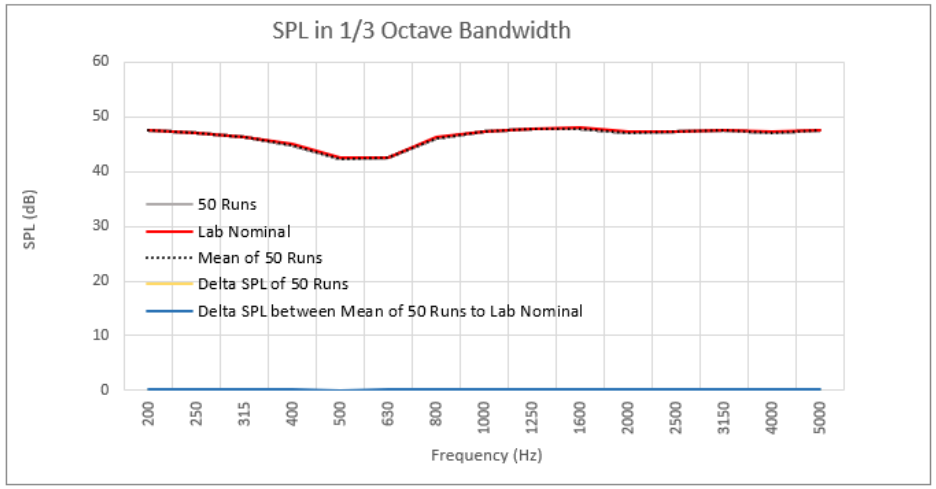


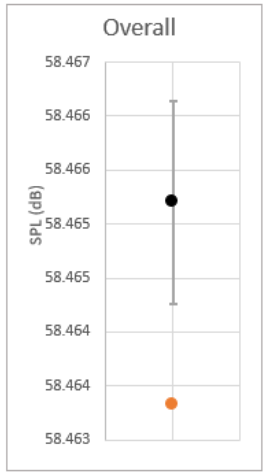
Results	OA	1/3 octave
	3.23	7.27

Microphone Location – X direction test tolerance

Microphone location – X direction effect changes the relative location of the source and receiver, resulting in different propagation paths. Results presented cover both microphone sides. The amount of deviation chosen reflect tolerances specified in ISO/DIS 16254.

Nominal Position	Range Tolerance
0 m	$x = 0 \pm 0.05$ m



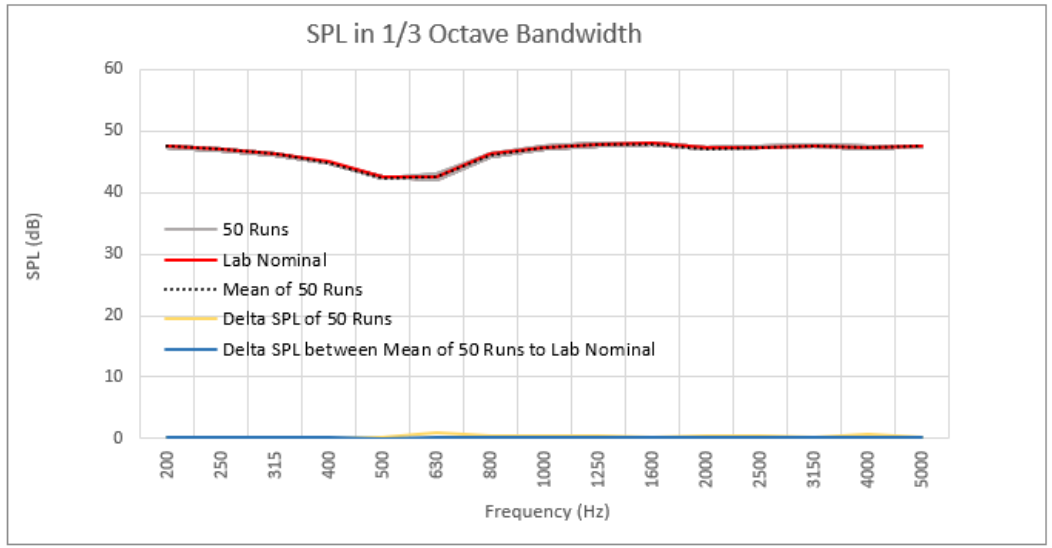


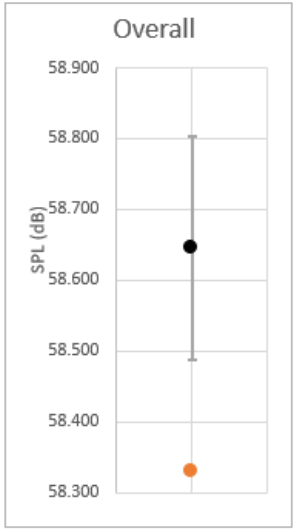
Results	OA	1/3 octave
	0.00	0.02

Microphone Location – Y direction test tolerance

Microphone location – Y direction effect changes the relative location of the source and receiver, resulting in different propagation paths. Results presented cover both microphone sides. The amount of deviation chosen reflect tolerances specified in ISO/DIS 16254.

Nominal Position	Range Tolerance
2 m	$y = 2 \pm 0.05$ m



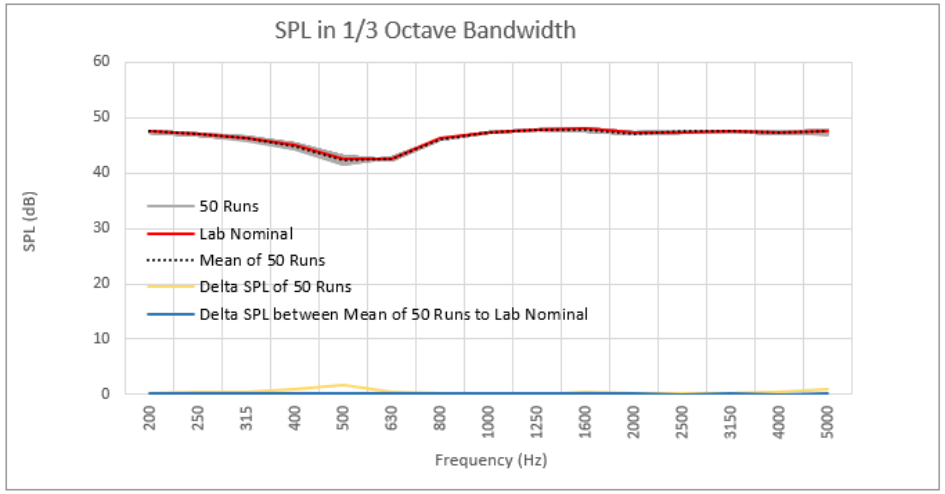


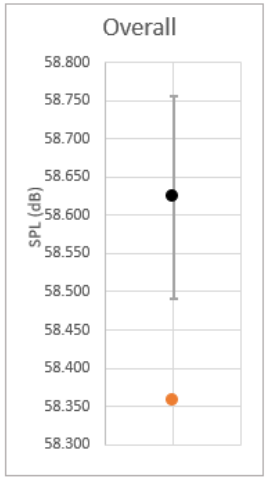
Results	OA	1/3 octave
	0.316	0.90

Microphone Location – Z direction test tolerance

Microphone location – Z direction effect changes the relative location of the source and receiver, resulting in different propagation paths. Results presented cover both microphone sides. The amount of deviation chosen reflect tolerances specified in ISO/DIS 16254.

Center Microphone	Range Tolerance
1.2 m	$z = 1.2 \pm 0.05$ m



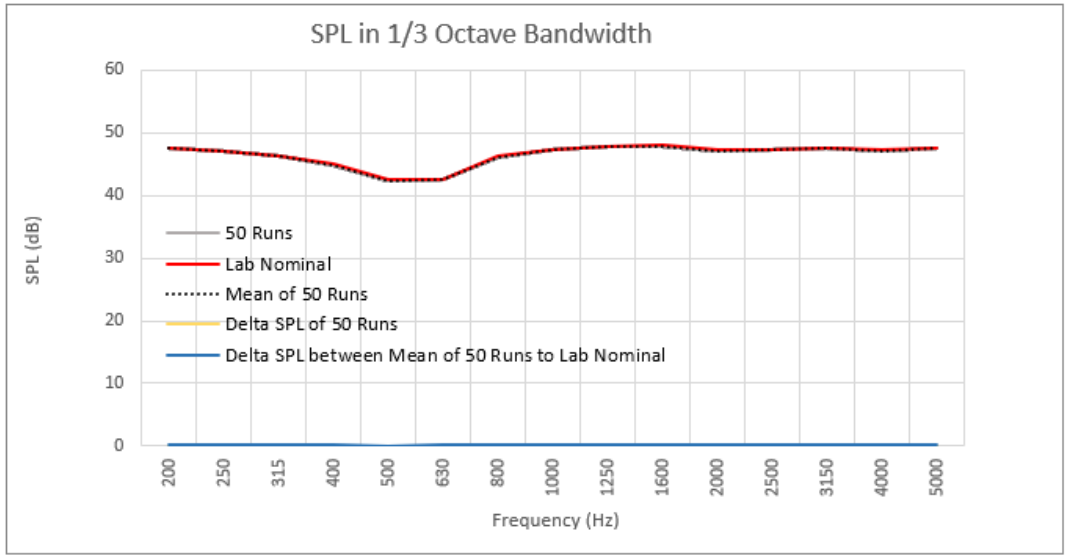


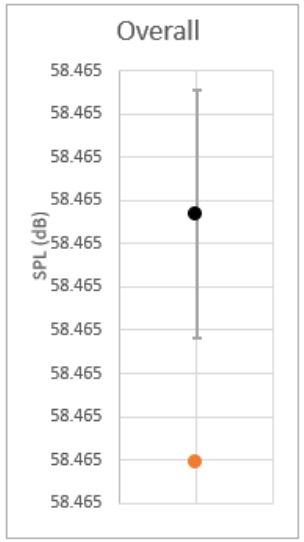
Results	OA	1/3 octave
	0.27	1.66

Pressure – test site difference due to altitude

Pressure effects direct and reflected path sound propagation.
Site to Site pressure range chosen to cover altitude change of 0-2500m (0-8202ft).
These values were used to assess the variation form the "Laboratory Nominal" response solely due to pressure effect.

FMVSS 141	Factor Range
101.325 kPa	101.3kPa – 73.4kPa



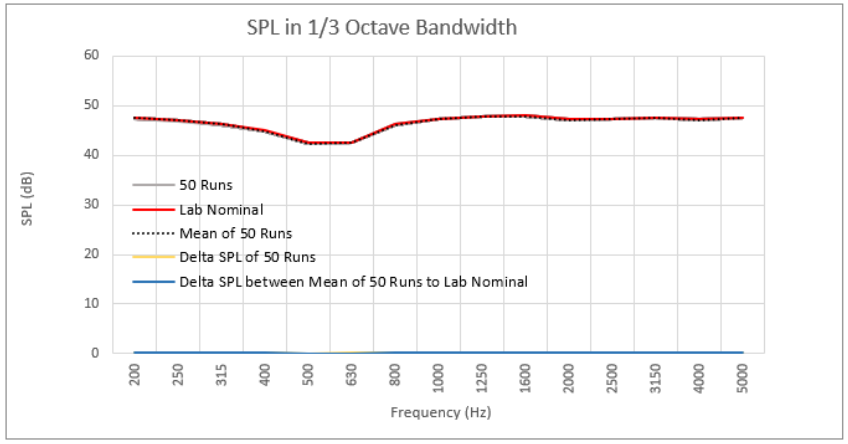


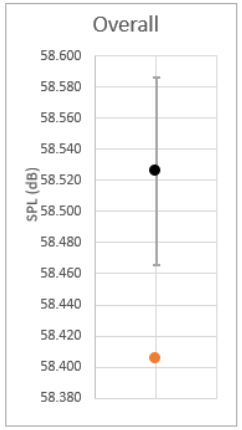
Results	OA	1/3 octave
	0.00	0.02

Test track surface absorption

Surface absorption effects reflected path sound propagation.
Absorption rates reflect values permitted by ISO 10844:2021 with a practical lower limit of 2%
These values were used to assess the variation form the "Laboratory Nominal" response solely due to absorption effect.

Nominal Value	Factor range
α = 0.05	0.02 – 0.08





Results	OA	1/3 octave
	0.12	0.13

Microphone – Class 1 IEC tolerance

- Use same background as for ISO 362-1.
  - Assume uncertainty applied to overall sound pressure level (OA SPL) is also applied to one-third octave bands

Microphone calibrator tolerance – IEC 61260-1

- Use same background as for ISO 362-1.
  - Assume uncertainty applied to overall sound pressure level (OA SPL) is also applied to one-third octave bands

Speed measuring equipment tolerance

- *Speed variation effect is taken as the same as determined for ISO 362-1 for both overall sound pressure level and one-third Octaves.*

This effect was not modeled analytically.

Regulations (UN R138 and FMVSS 141) have 6dB expected SPL change between 0/10/20/30 km/h. This gives a maximum possible change of 0.83 dB over the 1 km/h (+/- 0.5) tolerance window.

Discussion if the ISO 362-1 P-P of 0.12 is adequate

Production variation speaker output

- Need estimates of speaker variation. Initial input based from audio speakers is +/- 3 dB
  - Expect to be similar amount for one-third octaves

Production variation – vehicle path transfer function

- No estimates at present

Production variation – Amplifier output voltage

- No estimates at present