ISO 16254
Status of Development

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Overview

- ISO 16254 is the technical basis for the current ECE R138.
- ISO WG42 has launched a full review of ISO 16254 to improve the measurement method
  - Reduce uncertainties experienced in regulatory compliance testing of ECE R138, FMVSS 141, and Korea and China national regulations derived from ECE R138.
  - Provide additional option for the determination of frequency shift that can be used without knowledge of the signal and provide assurance the signal is audible to pedestrians.

WG42 and supporting work to date

- SAE Cooperative Research Project (CRP) carried out between January 2020 and November 2021.
- ISO 16254 Committee Draft (CD) approved March 2022
- DIS draft in progress, target of January 2024

Technical Highlights

Changes to reduce measurement variation and to produce results better aligned with human perception

- Change of single microphone to a five-microphone array.
- Change of signal processing to “max-hold” in each one-third octave bands.
- Simplification of background noise acceptance criteria and elimination of background noise correction.

Technical Highlights

Changes to improve selection of frequencies to be used for calculation of frequency shift. Enhancing the safety effectiveness of the reported results.

- Introduction of “Tonal Loudness” as a method to identify frequencies appropriate for calculation of frequency shift.
- Introduction of criteria to insure frequencies used in calculating frequency shift are audible to pedestrians.

Measurement Uncertainty

WG42 has undertaken a systematic analysis of measurement uncertainty of ISO 16254 according to the principles of the GRBP TF-MU.

Effects Studied

- Inherent spatial variation – How the measurement system itself influences the result.
- Environmental conditions
- Driver deviations
- Equipment and filter tolerances
- Background noise
- Microphone tolerances
- Speaker location variation.

Example for 1-microphone

1/3 octave
10.1 dB
Uncertainty
At 95% CI

Situation	Input Quantity	estimated deviations of the meas. result (peak-peak @ 95% CI) L_OA	estimated deviations of the meas. result (peak-peak @ 95% CI) L_1/3	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
Inherent spatial frequency bias	Bias from human psychoacoustic response	2.3	6.2	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	4.1	17.11	skewed	1.051	18.300	1.025	4.278	51.1%	65.2%	1.03	4.28
single Run to single Run	Wind speed	0.00	0.31	gaussian	0.000	0.006	0.000	0.077	0.0%	0.0%	1.13	4.98
	Wind Gradient	0.00	0.25	gaussian	0.000	0.004	0.000	0.063	0.0%	0.0%		
	Temperature	0.04	2.38	gaussian	0.000	0.354	0.010	0.595	0.0%	1.3%		
	Temperature gradient	0.00	1.45	gaussian	0.000	0.132	0.000	0.363	0.0%	0.5%		
	Relative Humidity	0.00	0.31	gaussian	0.000	0.006	0.000	0.077	0.0%	0.0%		
	Pressure	0.00	0.28	gaussian	0.000	0.005	0.000	0.071	0.0%	0.0%		
	Speed variations of +/- 1km/h	1.20	1.20	gaussian	0.090	0.100	0.300	0.316	4.4%	0.4%		
	Varying background noise	1.00	1.00	skewed	0.000	0.062	0.000	0.249	0.0%	0.2%		
	Deviation from centered driving (+/- 50cm)	1.50	9.69	gaussian	0.141	5.866	0.375	2.422	6.8%	20.9%		
Day to Day				gaussian				0.000			1.13	5.01
	Microphone X location tolerance	0.00	0.28	gaussian	0.000	0.005	0.000	0.071	0.0%	0.0%		
	Microphone Y location tolerance	0.24	1.04	gaussian	0.004	0.068	0.060	0.261	0.2%	0.2%		
	Microphone Z location tolerance	0.19	1.61	gaussian	0.002	0.163	0.048	0.404	0.1%	0.6%		
Site to Site	Barometric Pressure / Altitude	0.00	0.70	gaussian	0.000	0.031	0.000	0.175	0.0%	0.1%	1.17	5.05
	Test Track Surface Absorption	0.11	0.31	gaussian	0.001	0.006	0.028	0.077	0.0%	0.0%		
	Microphone Class 1 IEC 61672	1.00	1.00	gaussian	0.063	0.063	0.250	0.250	3.0%	0.2%		
	Sound calibrator IEC 60942	0.50	0.50	gaussian	0.016	0.016	0.125	0.125	0.8%	0.1%		
	IEC XXXXX one-third octave filter tolerance	NA	2.00	rectangular	NA	0.333	NA	0.577		1.2%		
	Speed measuring equipment continuous at PP	0.12	0.12	gaussian	0.001	0.001	0.030	0.030	0.0%	0.0%		
Vehicle to Vehicle	Production Variation Speaker Output	3.00	6.00	gaussian	0.563	2.250	0.750	1.500	27.4%	8.0%	1.43	5.30
	Production variation path transfer function	1.00	2.00	gaussian	0.063	0.250	0.250	0.500	3.0%	0.9%		
	Production variation amplifier output voltage	1.00	1.00	gaussian	0.063	0.063	0.250	0.250	3.0%	0.2%		
	Sound Character											
					2.054	28.082				34.8%		

Coverage Factor
k=2 (95%)

	Overall Combined Uncertainty +/-		Expanded uncertainty (95%) +/-
1/3 Octave Test Only	5.05		10.10
1/3 Octave 3rd party and/or COP	5.30		10.60
Overall SPL Test Only	1.17		2.34
Overall SPL 3rd party and/or COP	1.43		2.86

Example for 5-microphone array

1/3 octave
4.5 dB
Uncertainty
At 95% CI

Situation	Input Quantity	estimated deviations of the meas. result (peak-peak @ 95% CI) L_OA	L_1/3	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
Inherent spatial frequency bias	Bias from human psychoacoustic response	1.7	4.7	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	skewed	0.001	3.230	0.025	1.797	0.0%	41.3%	0.03	1.80
single Run to single Run	Wind speed (+/- 5 m/s)	0.02	0.13	gaussian	0.000	0.001	**0.005**	**0.032**	0.0%	0.0%	0.89	2.14
	Wind Gradient	0.01	0.13	gaussian	0.000	0.001	**0.003**	**0.032**	0.0%	0.0%		
	Temperature (0-40 deg C)	0.04	0.77	gaussian	0.000	0.037	**0.010**	**0.192**	0.0%	0.5%		
	Temperature gradient	0.05	0.13	gaussian	0.000	0.001	**0.013**	**0.032**	0.0%	0.0%		
	Relative Humidity	0.00	0.00	gaussian	0.000	0.000	**0.000**	**0.000**	0.0%	0.0%		
	Pressure	0.00	0.00	gaussian	0.000	0.000	**0.000**	**0.000**	0.0%	0.0%		
	Speed variations of +/- 1km/h	1.20	1.20	gaussian	0.090	0.100	**0.300**	**0.316**	5.7%	1.3%		
	Varying background noise	1.00	1.26	gaussian	0.063	0.100	**0.250**	**0.316**	4.0%	1.3%		
	Deviation from centered driving +/- 50 cm)	3.20	4.21	gaussian	0.640	1.109	**0.800**	**1.053**	40.9%	14.2%		
				gaussian				**0.000**				
Day to Day	Microphone X location tolerance	0.00	0.00	gaussian	0.000	0.000	**0.000**	**0.000**	0.0%	0.0%	0.89	2.15
	Microphone Y location tolerance	0.30	0.51	gaussian	0.006	0.016	**0.075**	**0.126**	0.4%	0.2%		
	Microphone Z location tolerance	0.03	0.73	gaussian	0.000	0.033	**0.008**	**0.182**	0.0%	0.4%		
Site to Site	Barometric Pressure / Altitude	0.00	0.70	gaussian	0.000	0.031	**0.000**	**0.175**	0.0%	0.4%	0.94	2.25
	Test Track Surface Absorption	0.12	0.31	gaussian	0.001	0.006	**0.030**	**0.077**	0.1%	0.1%		
	Microphone Class 1 IEC 61672	1.00	1.00	gaussian	0.063	0.063	**0.250**	**0.250**	4.0%	0.8%		
	Sound calibrator IEC 60942	0.50	0.50	gaussian	0.016	0.016	**0.125**	**0.125**	1.0%	0.2%		
	IEC XXXXX one-third octave filter tolerance	NA	2.00	rectangular		0.333		**0.577**		4.3%		
	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**	35.9%	28.7%	1.25	2.80
	Production variation path transfer function	1.00	2.00	gaussian	0.063	0.250	**0.250**	**0.500**	4.0%	3.2%		
	Production variation amplifier output voltage	1.00	2.00	gaussian	0.063	0.250	**0.250**	**0.500**	4.0%	3.2%		
	Sound Character											
					1.567	7.827				58.7%		

Coverage Factor
k=2 (95%)

	Overall Combined Uncertainty +/-	Expanded uncertainty (95%) +/-
1/3 Octave Test Only	2.25	4.51
1/3 Octave 3rd party and/or COP	2.80	5.60
Overall SPL Test Only	0.94	1.88
Overall SPL 3rd party and/or COP	1.25	2.50

Thoughts from looking at measurement uncertainty results

- Uncertainty estimates are conservative - but the 10dB 1/3 octave range is close to what has been observed.
- No two vehicles have the same frequency response function.
- Real uncertainty on a given product will depend on the relation of the specific vehicle's frequency response function at the microphone and the sound chosen.
- Driver left/right deviation has a surprisingly large influence. Suggests requirements for lateral position accuracy may be needed.
- The 5-microphone array reduces uncertainty estimates over 50% by itself.

Thoughts from looking at measurement uncertainty results – regulatory options.

- The 5-microphone array reduces uncertainty estimates over 50% by itself.
- The reduction of the inherent bias in the 5-microphone array will lead to higher reported sound levels – better aligned to human perception.
    - Will have positive effect on real world noise emission, even though vehicle level reported numbers may not change.
    - Manufacturers won't have to "Turn up the gain" just to overcome the influence of the test apparatus.
- Uncertainty gives minimum bound for connecting R138 to R51.
    - Design space will be in addition to this.
- The practical uncertainty will be less than stated, but manufacturers must still account for worst case uncertainty for COP and market surveillance.
- Real uncertainty on a given product will depend on the relation of the specific vehicle's frequency response function at the microphone and the sound chosen.
- Driver left/right deviation has a surprisingly large influence. Suggests requirements for lateral position accuracy may be needed.
- If larger uncertainty reductions are deemed necessary, will need to consider a different spatial location for the 5-microphone array OR eliminate 1/3 octaves altogether and strengthen the overall SPL requirements.

Further work

- Feedback by TF-QRTV on work to date and needs for R138.
- Continue uncertainty evaluations and preparation of explanation slides for all uncertainty effects.
- Continue exchange of information on Tonal Loudness and publication of specifications so all instrument manufactures can verify implementation of algorithms.
  - Request organizations submit real world sound examples for evaluation by WG42
- Evaluation of human detection studies carried out in USA (Virginia Technological University) in relation to proposed ISO/DIS 16254.
- Evaluation of proposed procedures by other organizations.

Thank you !

- Questions ?