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2nd Meeting of GRBP Task Force on Measurement Uncertainties

Tyre noise uncertainties in UN Regulation No. 117

THE EUROPEAN TYRE AND RIM TECHNICAL ORGANISATION

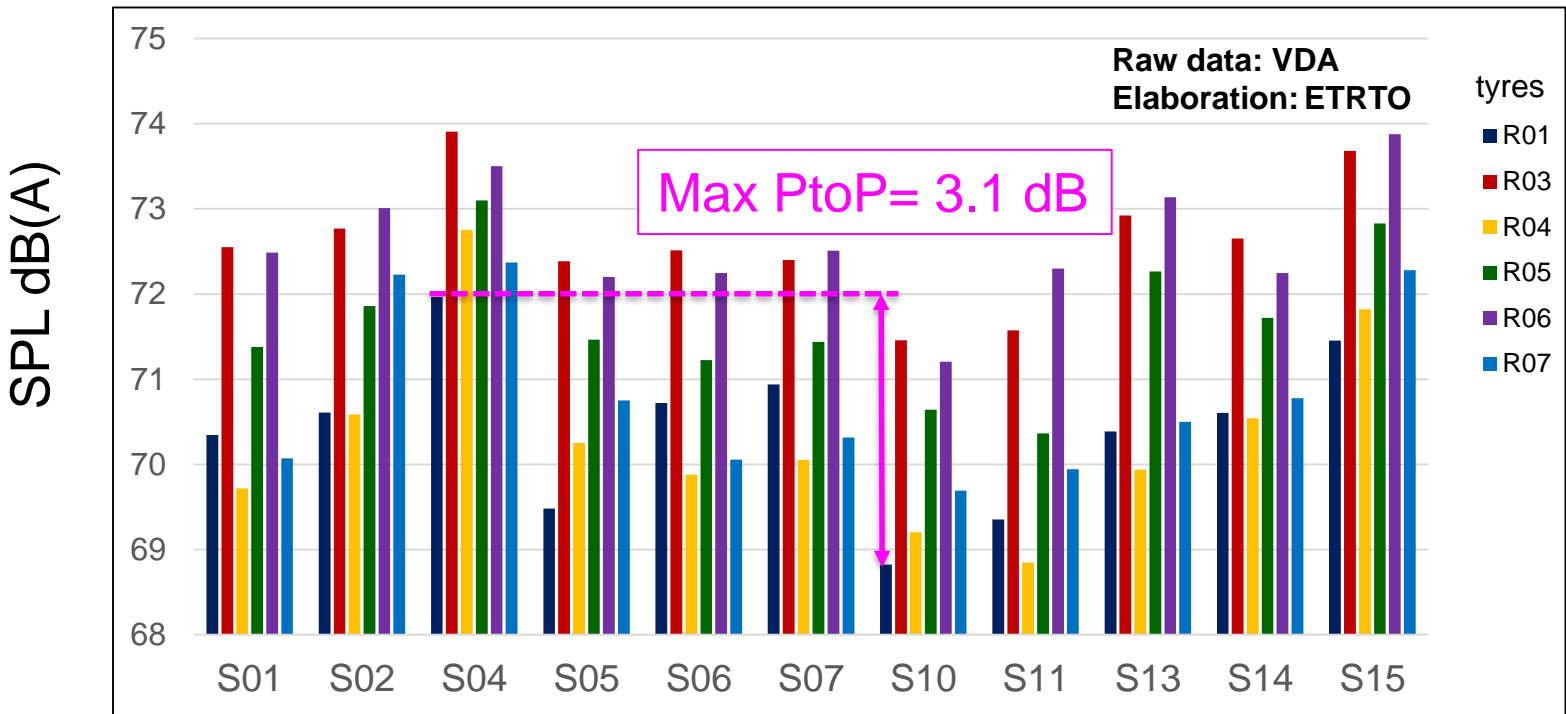


List of topics

- Track to track noise variability: ISO WG11 vs VDA study results
- Tyre noise uncertainty table (Reg.117)
- Proposals for VDA formula validation

Track to Track noise variability: VDA Round robin test

Test performed at 80 km/h (no regression), Track S09 and S012 removed since not compliant with ISO10844 requirements, Slick tyre (R02) not taken into consideration.



$$U = 2 * \sqrt{\frac{1}{T} \sum_{t=1}^T \sigma_t^2}$$

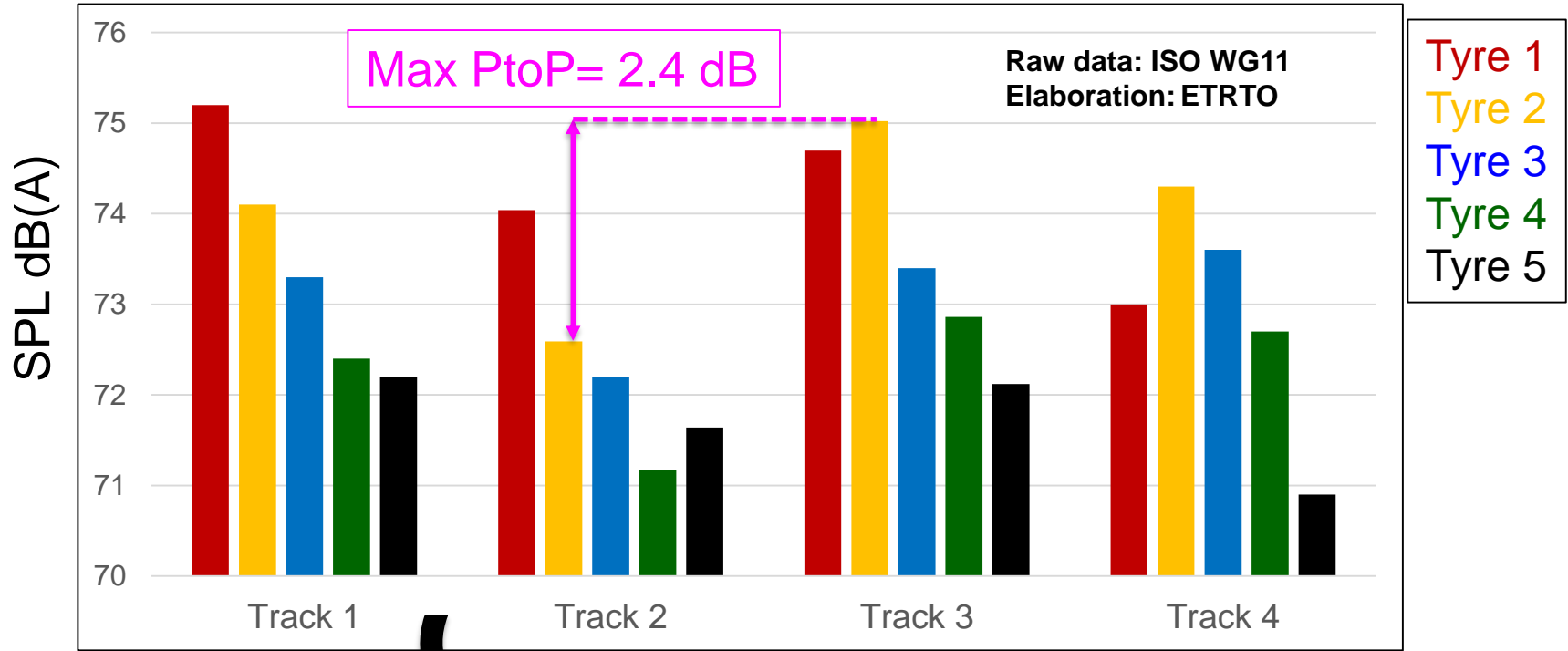
σ = standard deviation
 t = tyre number

Uncertainty = ± 1.8 dB
(95% confidence interval)



Track to Track noise variability: ISO WG11 Round robin test

Five different tyres tested in four different Tracks (Compliant with ISO 10844)
 Both summer and winter tyres are included in the analysis (16" and 18")



$$U = 2 * \sqrt{\frac{1}{T} \sum_{t=1}^T \sigma_t^2}$$

σ = standard deviation
 t = tyre number

Uncertainty = ± 1.6 dB
 (95% confidence interval)

Includes measurement system uncertainty

ISO WG11 results are in line with VDA results



Tyre noise uncertainty table

Uncertainty assessment process:

- Uncertainty sources identification for R117 test
- Estimation of uncertainty values:
 - by literature review
 - through sharing experience among tyre manufacturers
- Conclusions:
 - Estimation of total uncertainty in Reg.117
 - Identification of main contributors to total uncertainty
 - Impact of measurement uncertainty on declared results (Reg.117)

Tyre noise uncertainty table Reg.117

Summary of tyre manufacturers experience

	Uncertainty categories	Systematic or Random	Standard Uncertainty [dB] 95% confidence interval	Description
1	Test Repeatability (day by day)	Random	± 0.6 ^(b)	Result variability once tyres, track, acquisition system, vehicle and modus operandi are the same (Day and driver might be different)
1.1	Test Repeatability (run to run)	Random	± 0.3 ^(b)	Result variability for consecutive test once tyres, track, acquisition system, vehicle and modus operandi are the same
1.2	Track Humidity	Random	Unknown	Definition of "dry" is quite vague Humidity may affect more R51 Drive-by than R117
1.3	Speed effect	Random	± 0.13	Minimum requirement for sensor accuracy in R117 is +/- 1km/h- tyre noise vs speed sensitivity= 0.2 dB/km/h PtoP =0.2 dB* 2km/h=0.4 dB (± 0.13)
1.4	Temperature influence (after temperature correction)	Random	± 0.3 ^(b)	Despite temperature correction a residual error remains (Formula not fully correct). Only applicable for C1/C2 tyres
2	Temperature influence (without temperature correction)	Systematic	± 0.6	The systematic error is removed in Reg.117 (except for C3) but not in Reg.51 Reg. 117 allows following temperature ranges: air >5, <40 surface temperature >5,<50 Estimated peak to peak by Reg.117 formula =1.8 dB (± 0.6 dB)
3	Track to Track	Systematic	± 1.8 ^(a)	Estimated by VDA round robin test results
4	Tyre to tyre	Random	± 0.5 ^(b)	Uncertainty due to production variability (Different plants, different period.....) Excluding ageing effect
5	Sound meter-to sound meter	Random	± 0.4 ^(a)	Measurement system shall meet class 1 requirements
6	Vehicle influence	Systematic / Random	± 1.0 ^(b)	Possibility to use different vehicles. Uncertainty takes into consideration differences on: Wheel adjustment, Suspension, Tyre load and inflation, Body-road clearance, shadowing and reflecting properties, Rim, Transmission noise, Bearings, Brake noise (brakes not completely released), Body shape - aerodynamic noise around the vehicle body and extra equipment
	Total Uncertainty C1/C2 tyres		± 2.2 dB	Combined standard uncertainty $U = \sqrt{(u_1^2 + u_3^2 + u_4^2 + u_5^2 + u_6^2)}$
	Total Uncertainty C3 tyres		± 2.3 dB	Combined standard uncertainty $U = \sqrt{(u_1^2 + u_2^2 + u_3^2 + u_4^2 + u_5^2 + u_6^2)}$

^(a) Values retrieved in literature

^(b) Estimation based on experience of some ETRTO members



Tyre noise uncertainty table Reg.117: main contributors

Estimated Uncertainty (95% confidence interval)

C1/C2	± 2.2 dB	Total
	± 1.3 dB	excluding track influence
	± 0.9 dB	excluding track and vehicle influence
C3	± 2.3 dB	Total
	± 1.5 dB	excluding track influence
	± 1.1 dB	excluding track and vehicle influence

Track is the highest contributor to total uncertainty followed by **vehicle** influence

C1/C2 uncertainty lower than C3 because of temperature correction

Impact of measurement uncertainty on declared results (Reg.117)

Example:

Measured Noise Level = **75.2 dB**

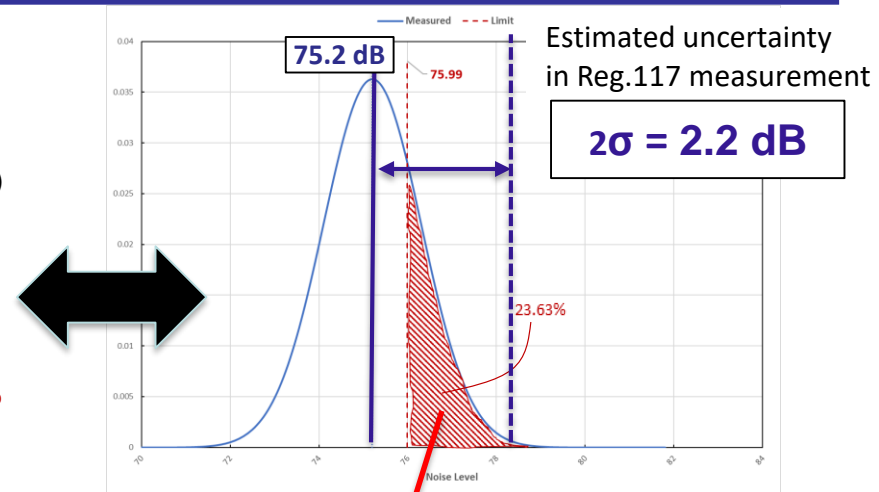
Declared Noise Level = **74 dB** (Allowance = - 1 dB (COP) + Rounding down)

Combined Uncertainty for C1/C2 = $2\sigma = \pm 2.2$ dB

Limit for risk calculation = 75.99 dB

Assuming a normal distribution around the measured value,

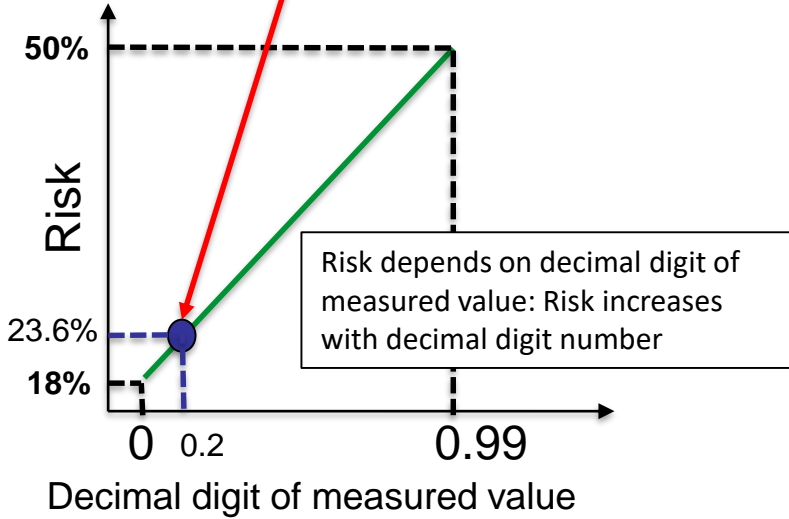
The Risk/Prob. that new test will exceed the declared value is $\approx 23.63\%$



In general the Risk/Prob. that a new test will exceed declared value is within 18% - 50%



Risk is relatively high and it should be reduced and ETRTO is mainly focused on reducing measurement uncertainty



Proposals for VDA formula validation

- Track alignment based on surface characteristics (VDA formula) seems a promising approach but formula must be validated on a new pool of data different from that one used for formula fitting.
- Furthermore, formula validity must be extended to different tyre categories and speeds.

$$L_{p,cruise50} = 60,3 + 27,7 \cdot MPD^{1,5} - 126 \cdot (g \cdot MPD)^{4,3} - 36 \cdot \alpha^{0,9} \text{ dB(A)}$$

Main concerns

One single formula might be not enough because it depends on:

- Test speed
- Tyre categories and tyre size (XL, 3PMSF, Special, C2, C3, Traction, FRT)

Proposal from ETRTO

Using existing VDA data

- Check how the formula works for each tyre tested in VDA study, not only in average;
- Check if formula at 50 km/h works for 80 km/h data: if not, establish a formula for 80 km/h (to be done by BBM Müller)
- Repeat formula fitting by using a reduced set of tracks data therefore validate it on the remain part

Appendix



References

Track to track uncertainty

Round-Robin Test pass-by noise tracks- Europe- Final report 21th March 2017 (VDA)

Sound level meter uncertainty

Experimental approach for reducing uncertainties associated with road vehicle noise according to ISO362: L.F.Pardo, T.Ageron,S,Ficheux,C.Berthou,Euronoise 2008 conference, pp. 4955-4958, Paris, 2008

Vehicle Uncertainty

EU project-SILENCE "Possibilities to Replace Outdoor Coast-by Tyre/Road Noise Measurements with Laboratory Drum Measurements" pag.22