SINTEF REPORT

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TITLE

Tyre/road noise modelling – noise measurements of 12 passenger car tyres

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ABSTRACT

Noise measurements of 12 passenger car tyres have been made on 7 dense asphalt concrete surfaces in Norway. The tyres are typical for replacement tyres (after-market) in Norway and the road surfaces also represent pavements types widely used in Norway.
Partly, the measurements have been performed to investigate the noise ranking of these tyres and partly as a basis for a modelling project, using the SPERoN hybrid model for tyre/road noise.
The noise measurements have been done, using the CPX-trailer of the Norwegian Public Road Administration, according to the method described in ISO/CD 11819-2, where the noise is measured with microphones close to the tyres.

The results show a noise difference of 2-3 dB(A) between the tyres at a speed range of 50-80 km/h.

KEYWORDS	ENGLISH	NORWEGIAN
GROUP 1	Acoustics	Akustikk
GROUP 2	Noise	Støy
SELECTED BY AUTHOR	Tyre/road noise	Dekk/vegbanestøy
	Passenger car tyres	Personbildekk

Preface

This project was jointly financed by the State Pollution Agency, the Norwegian Public Roads Administration and the Norwegian Research Council through the program “Environmental Noise - Phase III”.

Research Scientist Truls Berge has been the project manager. The measurements have been performed with the assistance of senior engineer Asbjørn Ustad and engineer Frode Haukland at SINTEF ICT.

MüllerBBM, Germany, by Dr.Thomas Beckenbauer and Chalmers University, Sweden, by Prof. Wolfgang Kropp are responsible for the modelling part of the project, as sub-contractors.

TABLE OF CONTENTS

1 Introduction

Normally tyre/road noise is a dominating source of traffic noise for constant speed driving from 30 km/h and upwards (light vehicles). The use of more silent tyres on light vehicles/passenger cars can therefore be an effective tool to reduce the overall traffic noise. Presently, noise from tyres is regulated in the EU-directive 2001/43/EC[1] and measurements are performed on a smooth road surface (ISO 10844[2] - a type of a dense asphalt concrete (DAC) with maximum chipping size of 8 mm). Such a surface is normally not used on roads in Norway, except for certain test sections. Typical road surfaces in Norway are DAC of 16 mm or Stone Mastic Asphalt (SMA) of 11 to 16 mm.

The important issue raised in this project is to investigate the distribution of noise levels from tyres on typical road surfaces used in Norway. By a combination of measurement results and modelling results, the ranking of noise levels on normal used road surfaces and ISO-surface is investigated. The main question is whether a reduction of noise limits according to the EU-directive will give an equivalent reduction in rolling noise levels on typical surfaces in Norway, which has a rougher texture due to studded tyres and winter conditions.

In the modelling part of the project, the noise ranking on ISO-surface will be compared to both modelling and measurement results of the tyres included in this report. The modelling will be presented in a separate report.

2 Tyres

In addition to the tyre used in the pre-project[3] 10 additional passenger car summer tyres were chosen for measurements. The tyres were chosen to fulfil the following requirements:

- be representative for the after market tyres in Norway
- cover a range from low performance/cheap tyres to high performance/expensive tyres
- cover the most used tyre sizes in Norway

After market tyres in this context is defined as replacement tyres, when the original equipment tyres on the new car has been worn out.

The tyres were bought in the early part of autumn 2007, and there was some limitation in the accessibility of summer tyres in the dimensions wanted for the project. In addition, dimensions had to be chosen so that pairs of different tyres could be measured with the trailer at the same time.

The chosen tyres were approved by the organisation of tyre importers in Norway as representative for the after market in this country.

Since the measurements were performed with a CPX-trailer with the possibility to measure with two tyres at the same time (one in each wheel track), it was decided to include another tyre that had been measured in a previous project[4]. This tyre (Tyre 12) was put on the market some years ago, as a special low noise car tyre. The tyre is no longer available on the commercial market.

Tyre 12 is not part of the modelling project.

In agreement with the organisation of the tyre importers in Norway, the 12 tyres have been categorised into 3 categories:

1. Low performance (LP)
2. Medium performance (MP)
3. High performance (HP)

Table 1 show the technical details of the 12 tyres and the category.

In Annex 1, pictures of the tread patterns of the tyres are shown.

Table 1, Technical specifications of the tyres

Tyre No	Category	Dimensions	Load/speed index	Production week/year
1	MP	175/70 R14	84T	1207
2	LP	175/70 R14	84T	0307
3	MP	185/65 R15	88T	1607
4	MP	185/65 R15	88T	4705
5	HP	195/65 R15	91H	0206
6	HP	195/65 R15	91V	0307
7	HP	205/55 R16	91W	1407
8	HP	205/55 R16	94H	3407
9	HP	215/55 R16	93H	0206
10	HP	215/55 R16	97H	1007
11	MP	195/65 R15	91T	0706
12	MP	185/65 R15	92H	1604

3 Measurement locations

The measurements have been performed at 7 different road surfaces in the Trondheim area. The Road locations and surface types are shown in table 2.

Table 2, Road locations and surface types

Surface no.	Road/location	Surface type	Production year
1	E6 Omkj.vn	SMA11	2005
2	E6 Omkj.vn	SMA11	2006
2B	E6 Omkj.vn	SMA11	2007
3	E6 Omkj.vn	SMA16	1999
4	E6 Melhus	SMA11 1%[1)]	2005
5	E6 Melhus	SMA11 3%[1)]	2005
6	Rv707 Flakk	DAC16	1992

1) Thin layers with 1% and 3% rubber added to the bitume

Surfaces 1-6 are identical to the surfaces measured with 3D laser profile texture measurement equipment and previously reported in the pre-project[3].
Surface 2B is new surface, not exposed to winter conditions/studded tyres, and is more or less identical to surface 2, at the time of measurement in 2006 (the pre-project).
In 2007, 2D texture measurements have been performed on all 7 surfaces[5], and these results show that the texture of Surface 2 had changed during the first winter season, and that the texture of Surface 2B is very similar to Surface 2 at the time of measurements in 2006.

When comparing the modelling and measurements results, road surface 2B will then replace surface 2, as a SMA11 road surface, not exposed to winter conditions.

4 Measurement procedures

The noise levels of tyres are type approved according to the EU-directive (2001/43/EC). The measuring method is a coast-by method (engine switched off), performed at a closed test-track (ISO-surface) without the influence of any other traffic. On normal trafficked roads, however, it is a rather difficult, costly and time consuming method, as one has to do pass-bys in-between other vehicles. In addition, one would need 4 samples of each tyre to be mounted on the vehicle.
To compare tyres, it was decided to use the CPX-method (see 4.1) as the basic method for all tyres, but include measurements for one set of a tyre after the method described in the EU-directive.

The SPERoN-model[6] is used to calculate the noise of the tyres, with a reference distance of 7.5 m. To compare modelling and measurement results, the CPX-data (at 0.2 m) are recalculated to 7.5 m. This recalculation can be done in several ways[6], and to check the recalculation procedures, it was decided to measure one set of tyres also according to the coast-by method.

4.1 CPX-measurements

The CPX-method (ISO/CD 11819-2[7]), is a method where the tyres are mounted on a trailer, towed by a vehicle. On the trailer, 2 microphones on each side of the trailer are in mounted in an angle of 45° to the perpendicular axes of the centre of the tyre and at a distance of 0.2 m from the tyre sidewall. The height is 0.1 m above the ground.
Normally, this method is used for measurements of the road surface influence to the road traffic noise, using standardised tyres. However, it is also useful for comparing rolling noise levels of tyres under equal conditions.

The measurements were performed as paired measurements using the CPX-trailer of the Norwegian Public Roads Administration, see figure 1.

Figure 1, CPX-trailer

Paired measurements mean that tyres 1 and 2, 3 and 4, 5 and 6, etc, were measured at the same time with one tyre at each side of the trailer.

Before the measurement, all tyres were run-in at a minimum distance of 100 km. The inflation pressure was adjusted to 170 kPa before mounting on the trailer.

With the CPX-trailer, a minimum of 2 runs at each road surface were performed at the two speeds of 50 and 80 km/h. An exception of this was at Surface 6, where measurements were done only at 50 km/h, due to a posted speed limit of 60 km/h.

The 3D texture profiles were measured over a distance of approx. 25 m. However, the noise measurements were done over a distance of approx. 300 m, covering the area of the texture measurements.

The measurement results are given as an average (energy based) A-weighted level, L_{AF}, for the 2 microphones and over the measured distance. This L_{AF} –level is a summation of average levels over 20 m segments.

All measurement results are temperature corrected to + 20 °C, using a correction factor of -0.05 dB/°C.

4.2 Coast-by measurement

For one of the tyres, Tyre 8 (205/55 R16), additional 4 tyres were made available and measured according to the procedure given in the EU-directive. The microphone is located at the road side 7.5 m from the centre line of the road lane in use and at a height of 1.2 m.

The vehicle runs at a minimum of 4 different speeds below 80 km/h and 4 different speeds above 80 km/h. During the pass-by, the engine is switched off and the maximum A-weighted level, L_{AmaxF}, is measured, along with the vehicle speed. Based on the regression curve for sound level vs. vehicle speed, the sound level at 80 km/h is calculated as the reference level.

5 Measurement results

5.1 CPX-results

For each road surface, the average (over approx. 300 m) A-weighted sound level, L_{AF}, is presented, together with the standard deviation and 95% confidence intervals (given as ± values in the tables).

In addition, the average level of the 12 tyres and the difference between the highest and lowest level is presented.

Table 3, Surface 1, SMA11 2005

Tyre no.	50 km/h L_{AF} dB(A)	St.dev	95% Conf.	80 km/h L_{AF} dB(A)	St.dev	95% Conf.
1	**92.6**	0.31	0.15	**99.6**	0.35	0.17
2	**94.0**	0.24	0.12	**101.2**	0.19	0.09
3	**93.1**	0.26	0.13	**100.2**	0.46	0.22
4	**93.6**	0.19	0.09	**100.1**	0.19	0.09
5	**95.7**	0.24	0.12	**102.0**	0.22	0.11
6	**95.7**	0.26	0.13	**101.9**	0.20	0.10
7	**94.8**	0.31	0.15	**101.6**	0.26	0.13
8	**93.1**	0.32	0.16	**100.4**	0.16	0.08
9	**94.5**	0.29	0.14	**101.0**	0.13	0.06
10	**94.8**	0.18	0.09	**101.1**	0.23	0.11
11	**95.3**	0.25	0.12	**101.7**	0.28	0.14
12	**94.1**	0.16	0.08	**99.7**	0.15	0.07
Average	**94.2**			**100.9**		
Max diff.	**3.1**			**2.4**		

Table 4, Surface 2, SMA11 2006

Tyre no.	50 km/h L_{AF} dB(A)	St.dev	95% Conf.	80 km/h L_{AF} dB(A)	St.dev	95% Conf.
1	**91.7**	0.25	0.12	**99.0**	0.23	0.11
2	**93.6**	0.25	0.12	**100.9**	0.26	0.13
3	**92.2**	0.18	0.09	**99.7**	0.16	0.08
4	**92.8**	0.17	0.09	**99.9**	0.22	0.11
5	**94.6**	0.10	0.05	**101.4**	0.16	0.08
6	**94.3**	0.21	0.10	**101.5**	0.20	0.10
7	**94.3**	0.19	0.10	**101.1**	0.22	0.11
8	**92.9**	0.38	0.19	**99.7**	0.20	0.10
9	**93.4**	0.19	0.09	**100.6**	0.20	0.10
10	**93.5**	0.32	0.16	**100.3**	0.25	0.12
11	**93.9**	0.19	0.09	**101.0**	0.24	0.12
12	**92.9**	0.32	0.16	**99.0**	0.21	0.10
Average	**93.4**			**100.5**		
Max diff.	**2.9**			**2.4**		

Table 5, Surface 2B, SMA11 2007

Tyre no.	50 km/h L_{AF} dB(A)	St.dev	95% Conf.	80 km/h L_{AF} dB(A)	St.dev	95% Conf.
1	**89.4**	0.26	0.13	**97.0**	0.37	0.18
2	**91.8**	0.27	0.13	**98.7**	0.47	0.23
3	**90.4**	0.34	0.17	**97.7**	0.41	0.20
4	**90.8**	0.27	0.13	**97.7**	0.33	0.16
5	**91.9**	0.38	0.19	**98.7**	0.42	0.21
6	**91.8**	0.38	0.19	**98.6**	0.42	0.21
7	**91.4**	0.44	0.21	**98.2**	0.41	0.20
8	**90.4**	0.30	0.15	**97.6**	0.37	0.18
9	**90.4**	0.36	0.17	**97.7**	0.53	0.26
10	**90.7**	0.40	0.20	**97.9**	0.38	0.19
11	**91.2**	0.21	0.10	**98.1**	0.37	0.18
12	**90.1**	0.27	0.13	**96.6**	0.41	0.20
Average	**91.1**			**98.1**		
Max diff.	**2.5**			**2.1**		

Table 6, Surface 3, SMA16 1999

Tyre no.	50 km/h L_{AF} dB(A)	St.dev	95% Conf.	80 km/h L_{AF} dB(A)	St.dev	95% Conf.
1	**92.4**	0.16	0.08	**100.2**	0.22	0.11
2	**94.2**	0.20	0.10	**101.8**	0.19	0.09
3	**92.9**	0.20	0.10	**100.5**	0.31	0.15
4	**93.7**	0.37	0.18	**100.9**	0.17	0.08
5	**94.9**	0.17	0.08	**102.0**	0.14	0.07
6	**95.4**	0.13	0.06	**102.6**	0.22	0.11
7	**94.8**	0.21	0.10	**101.8**	0.17	0.08
8	**93.4**	0.37	0.18	**100.7**	0.21	0.10
9	**93.7**	0.20	0.10	**101.2**	0.17	0.08
10	**94.1**	0.24	0.12	**101.3**	0.22	0.11
11	**94.4**	0.15	0.08	**101.9**	0.21	0.10
12	**93.7**	0.28	0.14	**100.1**	0.23	0.11
Average	**94.1**			**101.4**		
Max diff.	**3**			**2.5**		

Table 7, Surface 4, SMA11 1% 2005

Tyre no.	50 km/h L_{AF} dB(A)	St.dev	95% Conf.	80 km/h L_{AF} dB(A)	St.dev	95% Conf.
1	**92.7**	0.29	0.14	**100.0**	0.27	0.13
2	**94.4**	0.17	0.09	**101.9**	0.34	0.17
3	**93.7**	0.20	0.10	**101.0**	0.20	0.10
4	**94.4**	0.15	0.08	**101.2**	0.30	0.15
5	**94.9**	0.17	0.08	**102.0**	0.30	0.15
6	**95.0**	0.21	0.10	**102.1**	0.39	0.19
7	**95.3**	0.25	0.12	**102.1**	0.25	0.12
8	**93.6**	0.16	0.08	**100.8**	0.22	0.11
9	**93.6**	0.14	0.07	**101.0**	0.19	0.09
10	**93.7**	0.21	0.10	**100.9**	0.20	0.10
11	**94.4**	0.43	0.21	**101.8**	0.21	0.10
12	**93.4**	0.31	0.15	**99.9**	0.39	0.19
Average	**94.4**			**101.5**		
Max diff.	**2.6**			**2.2**		

Table 8, Surface 5, SMA11 3% 2005

	50 km/h			80 km/h		
Tyre no.	**L_{AF} dB(A)**	**St.dev**	**95% Conf.**	**L_{AF} dB(A)**	**St.dev**	**95% Conf.**
1	**91.7**	0.35	0.17	**99.0**	0.42	0.23
2	**92.8**	0.40	0.19	**100.2**	0.49	0.27
3	**92.8**	0.40	0.21	**99.9**	0.24	0.13
4	**92.9**	0.50	0.26	**99.7**	0.39	0.20
5	**93.9**	0.35	0.17	**100.6**	0.52	0.27
6	**93.2**	0.77	0.38	**100.6**	0.51	0.26
7	**94.4**	0.35	0.17	**100.9**	0.36	0.18
8	**92.0**	0.45	0.22	**99.2**	0.43	0.22
9	**92.7**	0.43	0.21	**99.9**	0.45	0.23
10	**91.7**	0.72	0.35	**99.2**	0.34	0.17
11	**93.6**	0.32	0.16	**100.7**	0.33	0.16
12	**91.7**	0.56	0.28	**98.2**	0.46	0.23
Average	**93.1**			**100.1**		
Max diff.	**2.7**			**2.7**		

Table 9, Surface 6, DAC16 1992

	50 km/h		
Tyre no.	**L_{AF} dB(A)**	**St.dev**	**95% Conf.**
1	**92.2**	0.57	0.28
2	**94.5**	0.34	0.17
3	**93.1**	0.34	0.17
4	**94.2**	0.40	0.19
5	**94.5**	0.37	0.18
6	**95.3**	0.64	0.31
7	**94.4**	0.31	0.15
8	**93.0**	0.52	0.26
9	**93.7**	0.40	0.20
10	**94.2**	0.63	0.31
11	**94.3**	0.43	0.21
12	**94.2**	0.47	0.23
Average	**94.0**		
Max diff.	**2.1**		

In figures 2 and 3, the results in the tables are presented graphically.

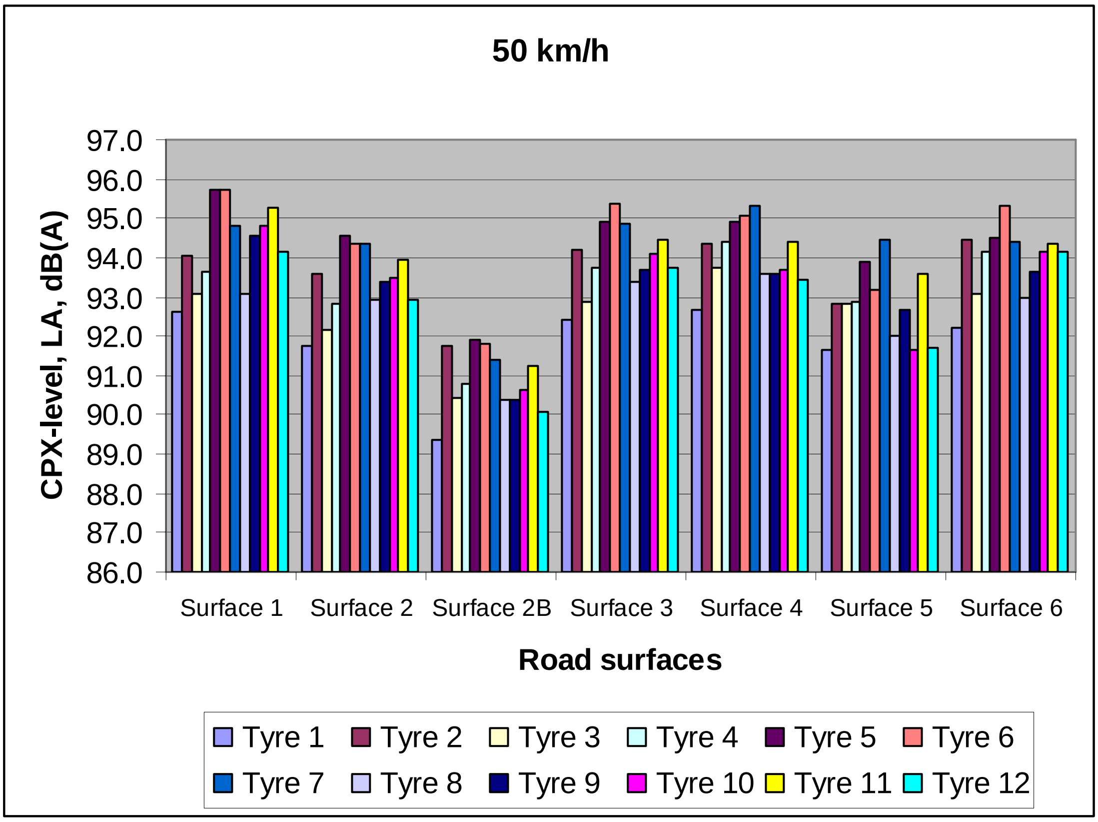


Figure 2, CPX-measurements at 50 km/h

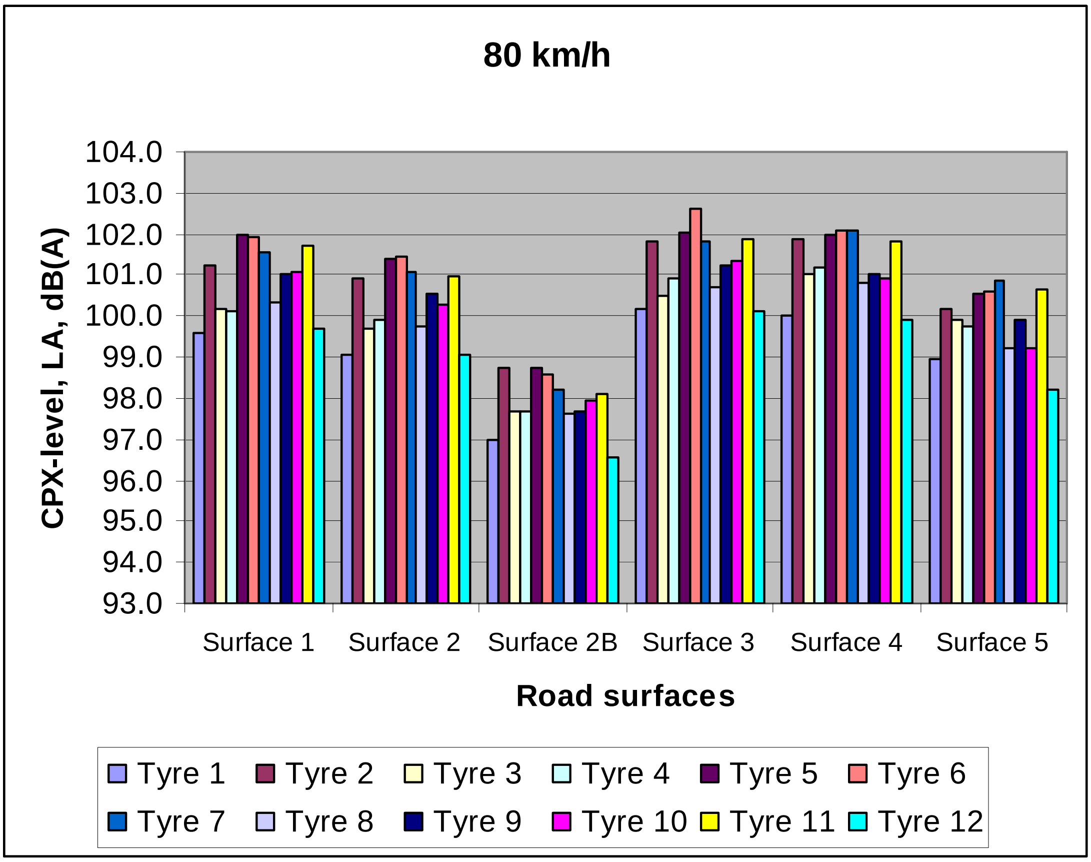


Figure 3, CPX-measurements at 80 km/h

In figures 4 to 15, the results are shown individually for each road surface, including the 95% confidence intervals. These figures, together with tables 3-9, are used as a basis for the noise ranking of the tyres on the different road surfaces.

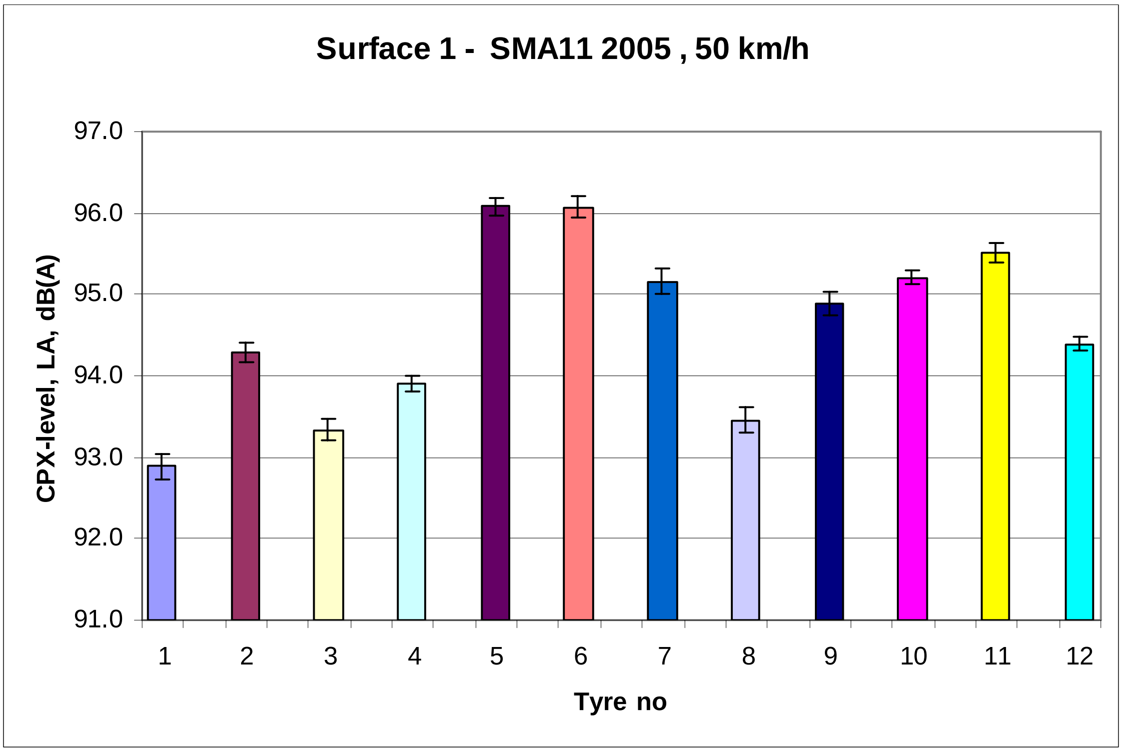


Figure 4

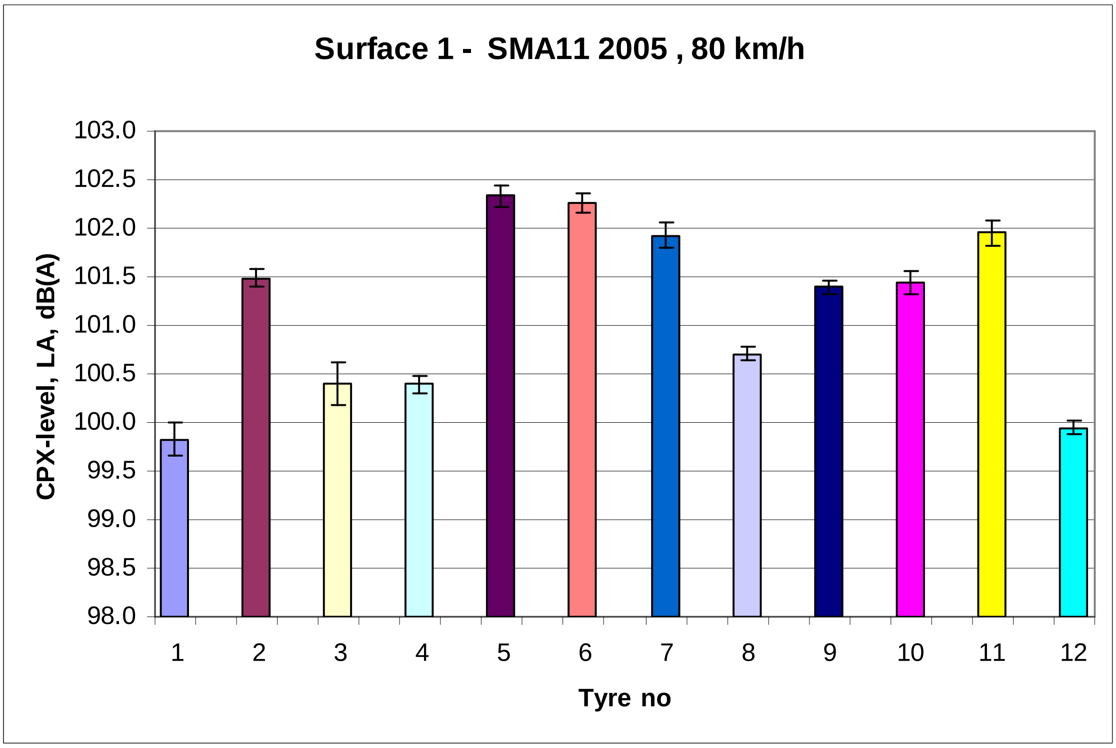
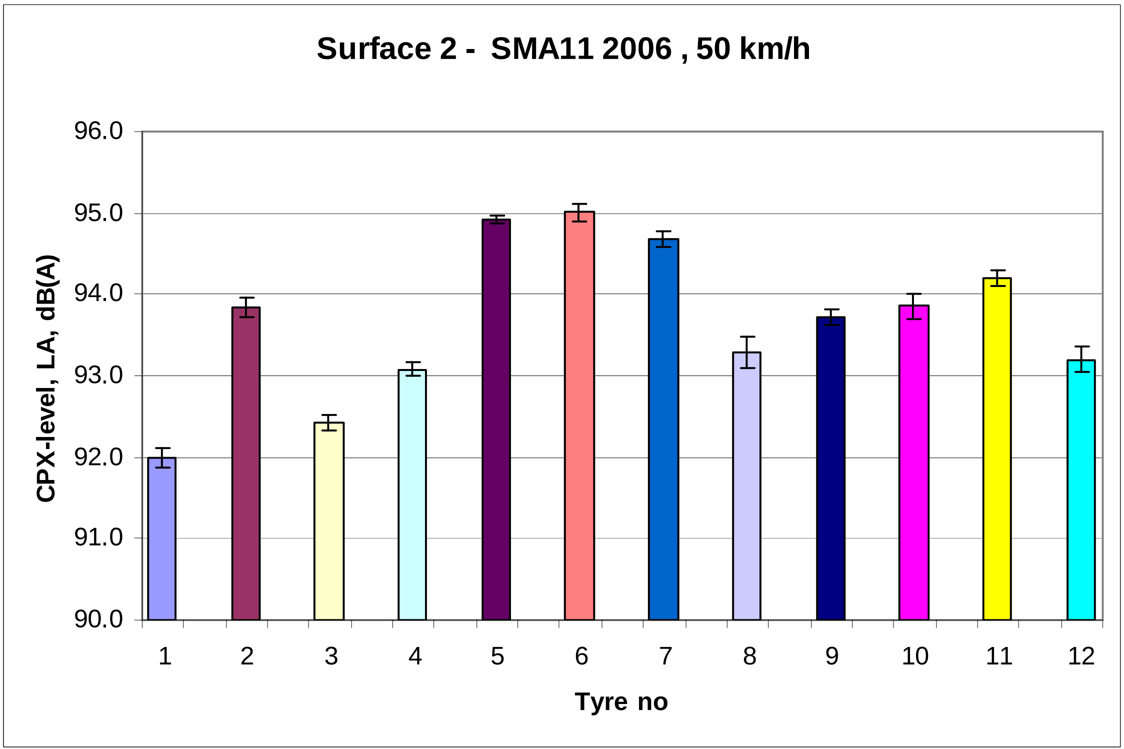


Figure 5



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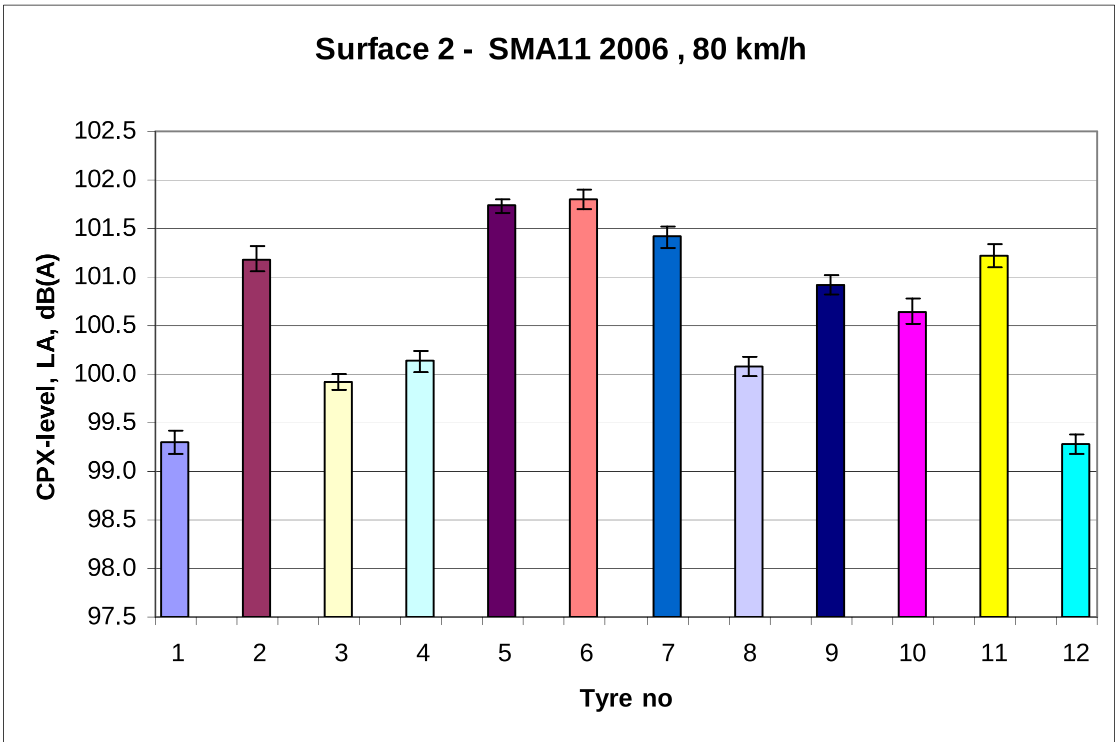

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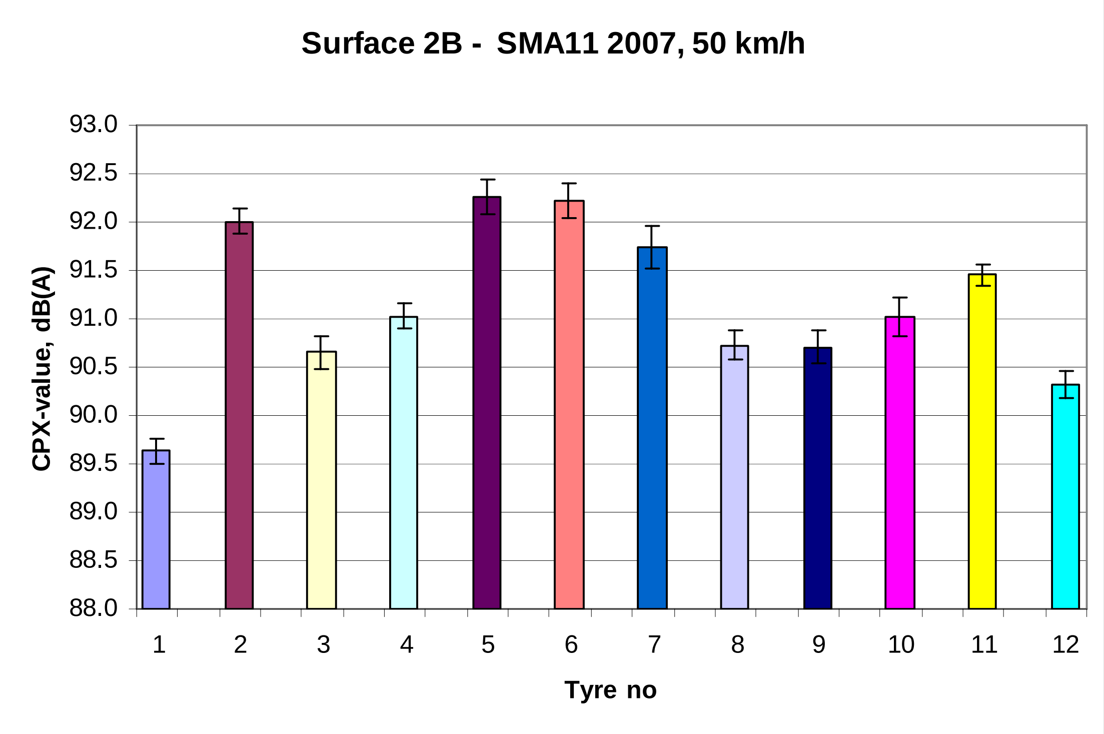

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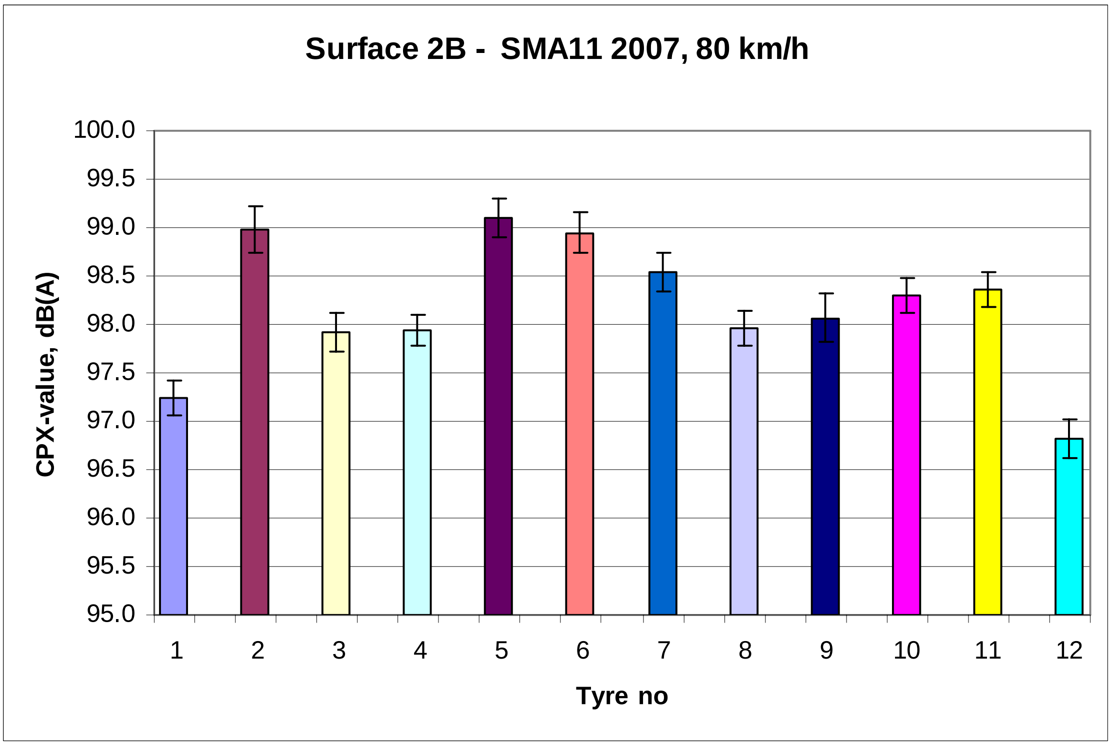

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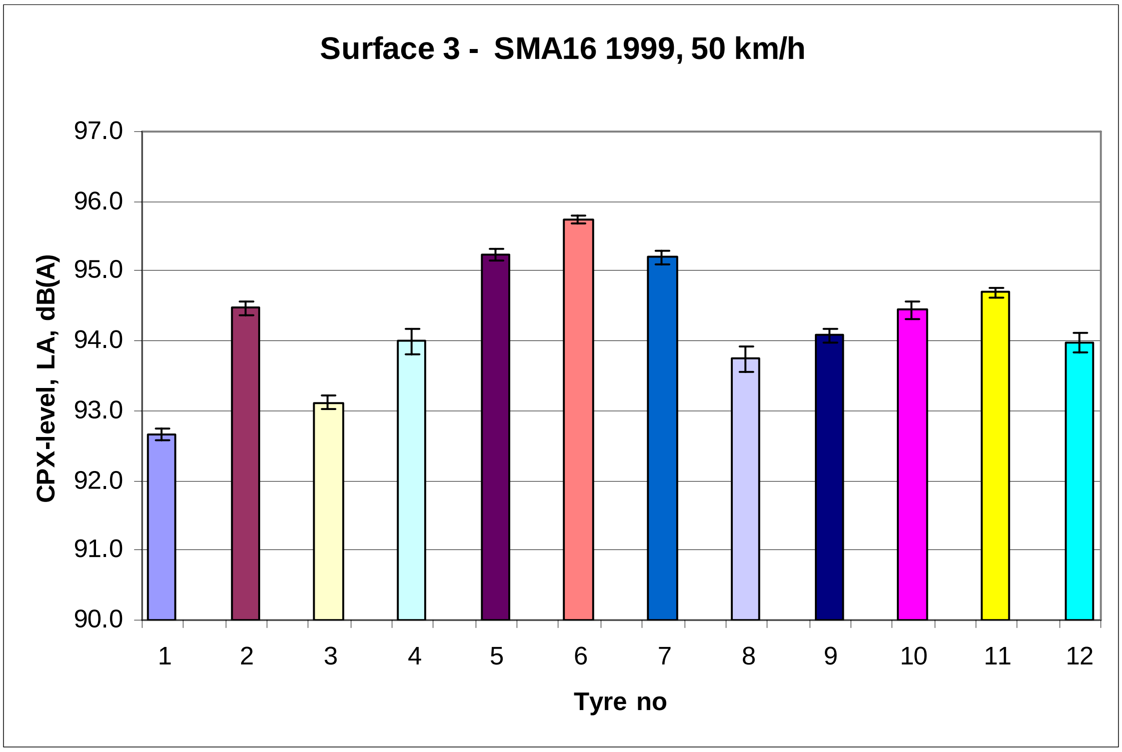


Figure 10

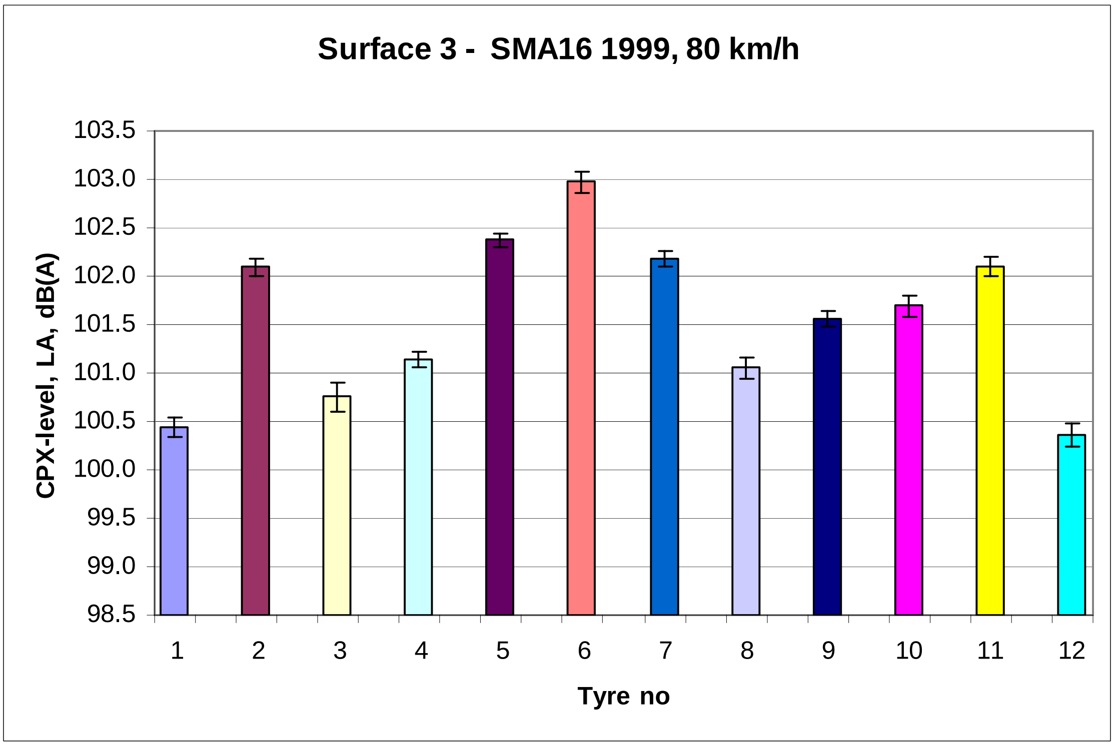
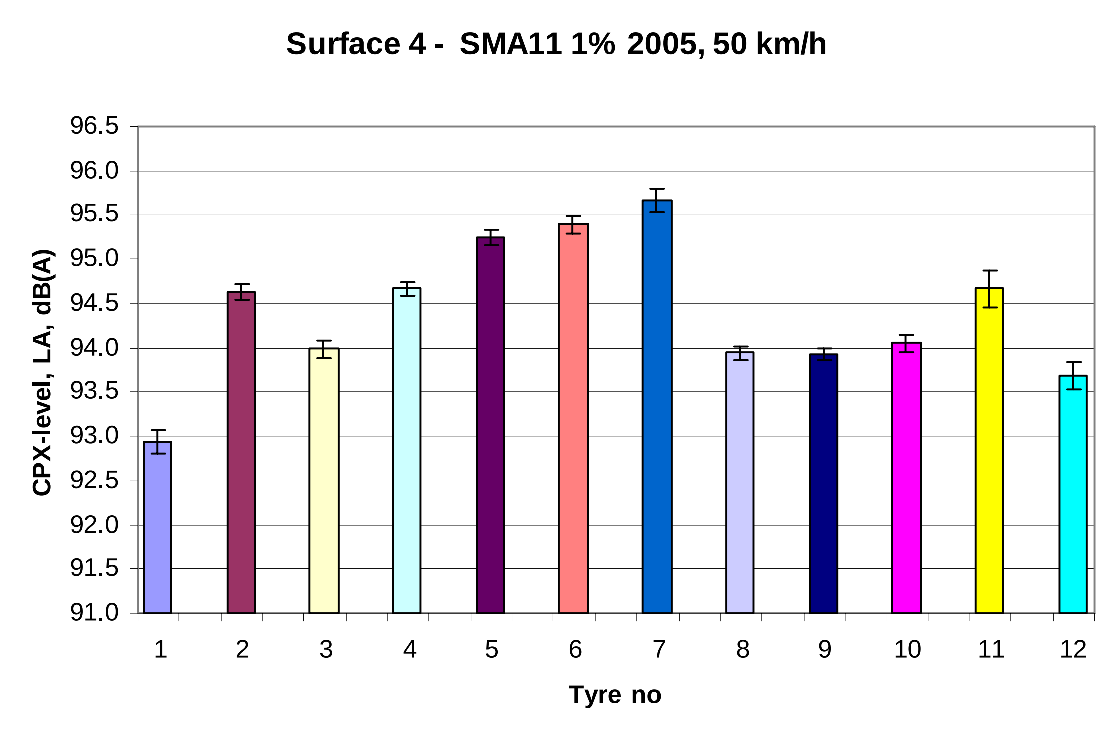


Figure 11



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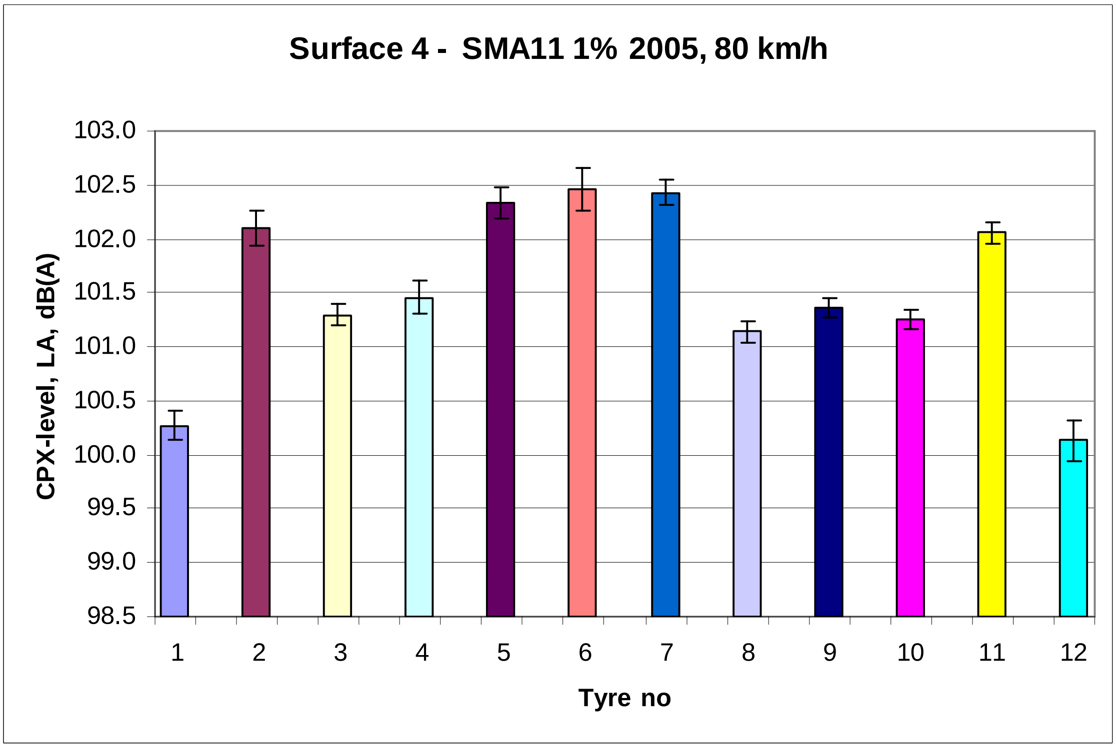

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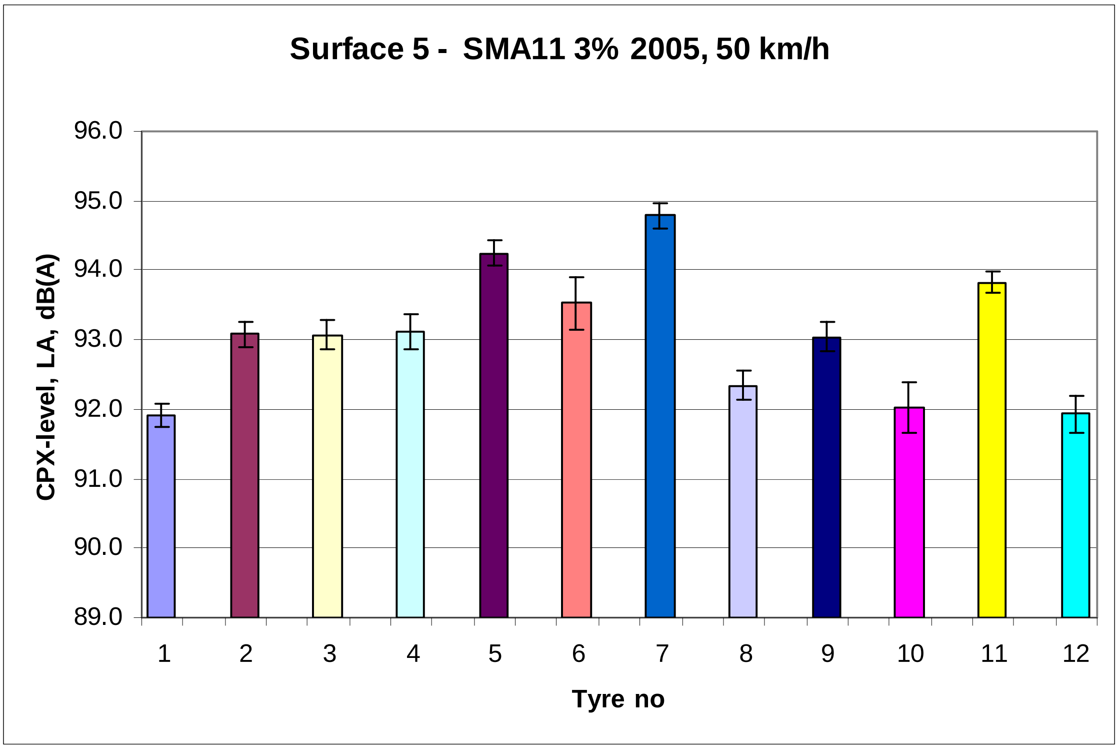

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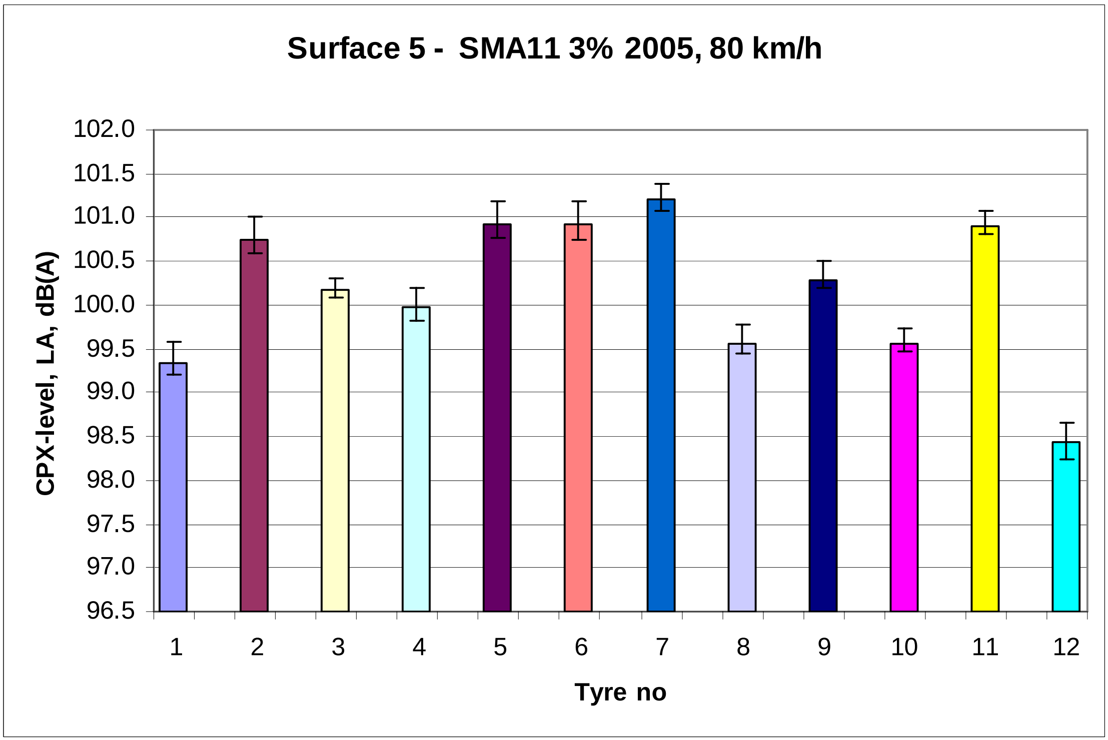


Figure 15

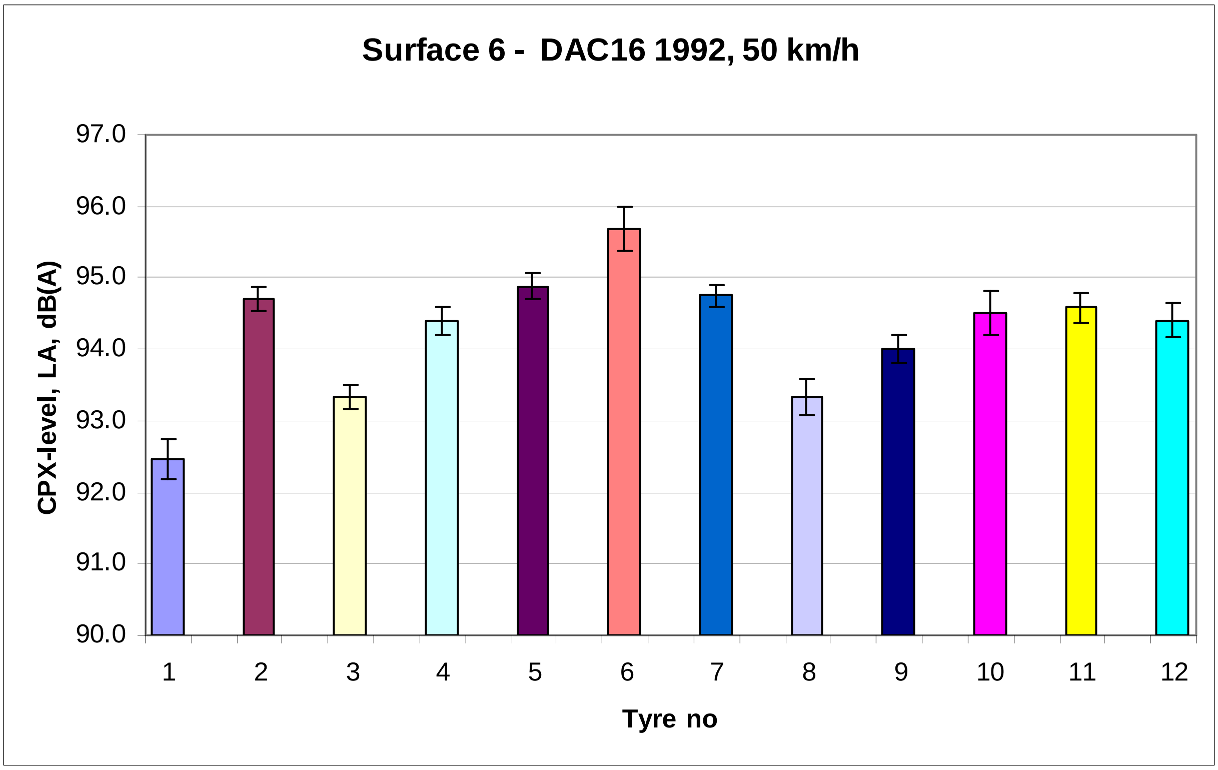


Figure 16

The frequency spectra for all these measurements are shown in appendix 2.

The different surfaces have some differences in age, and in figure 17 and 18, the results are presented in a way that the oldest surface is to the left in the figures and the newest to the right.

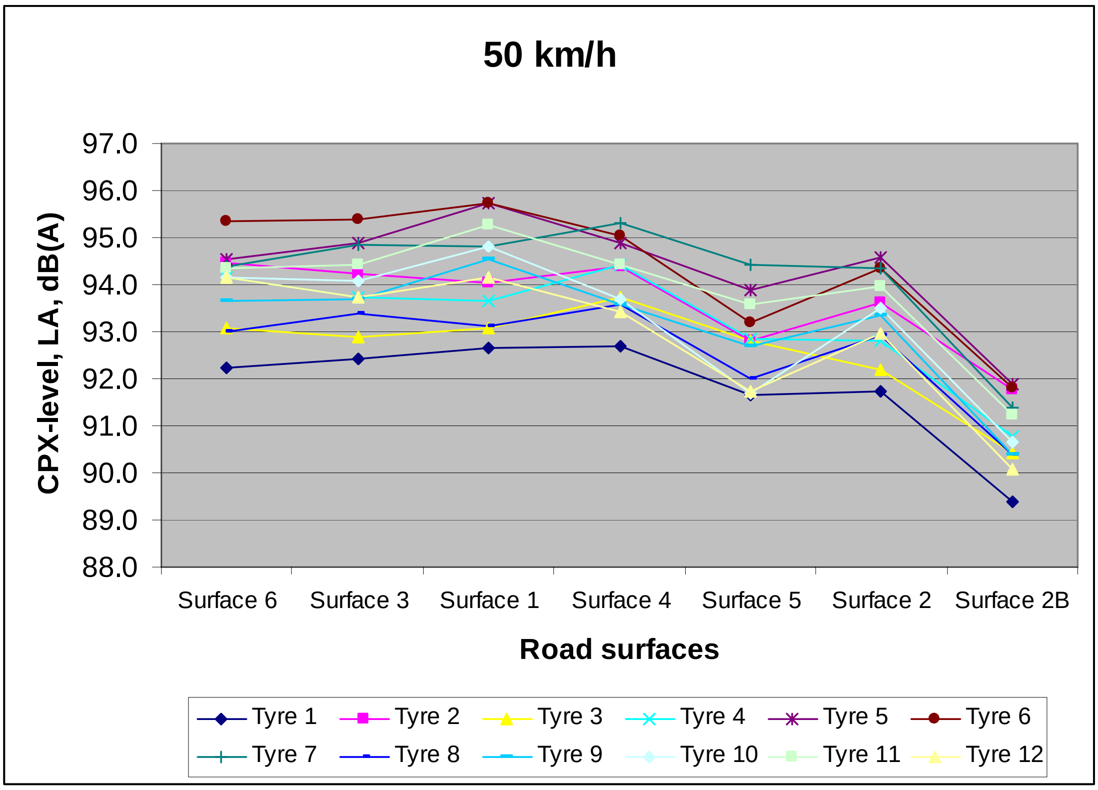


Figure 17, CPX-measurements at 50 km/h

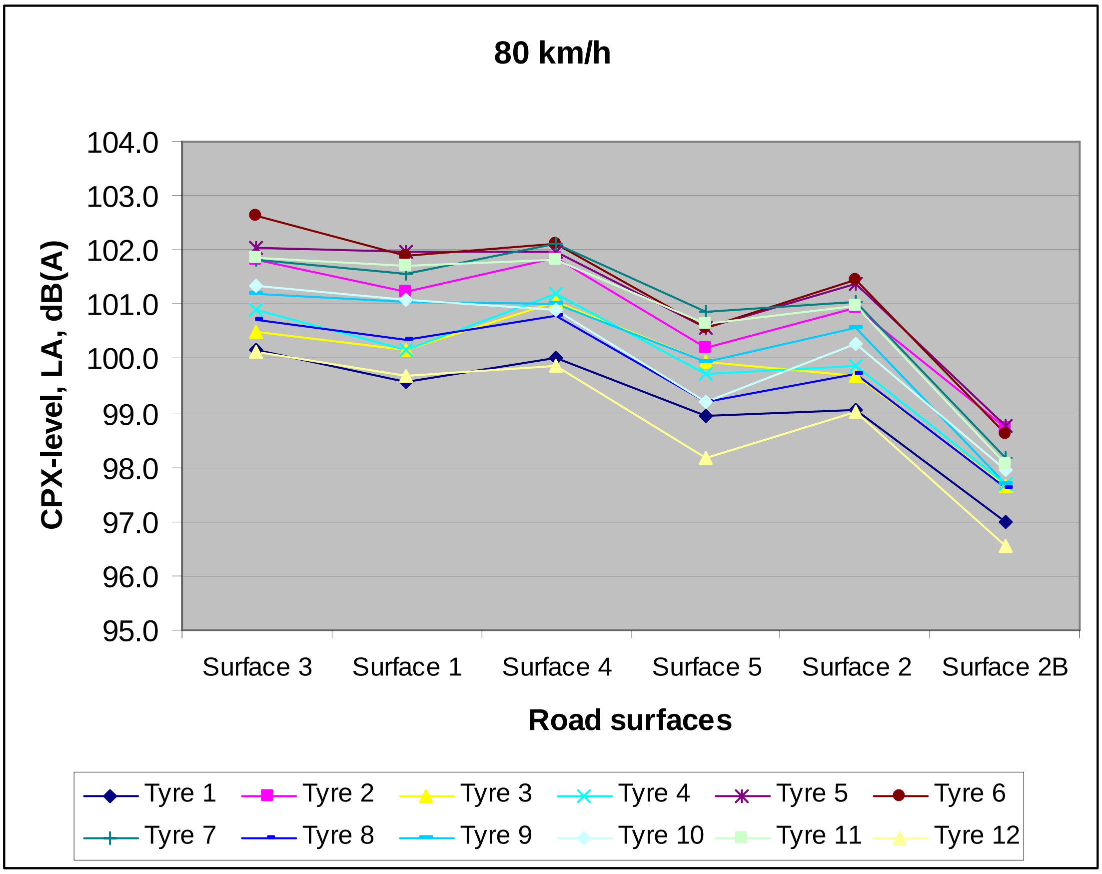


Figure 18, CPX-measurements at 80 km/h

The reason that the levels on Surface 5 (SMA11 3% 2005) is lower than on Surface 2 (SMA11 2006) is probably caused by the fact that Surface 5 is the left lane of a 4 lane motorway, where 90 % of the traffic is in the right lane (on Surface 4), while Surface 2 is the right lane of a 4 lane motorway, with about 15-20 times more traffic volume (ADT) than on Surface 5.

5.2 Coast-by measurements (CPB).

4 tyres of Tyre 8 (205/55 R16) were mounted on a VW Passat Sedan (2007 model).

A total of 14 coast-by measurements (engine switched off) at speeds from 53 to 96 km/h were made on Surface 5 (SMA11 3% 2005).

In figure 19 the noise level vs. speed is shown, along with the regression line. Based on the regression equation the noise level at 80 km/h is calculated. Table 10 show the calculated levels as a function of speed, based on the regression equation.

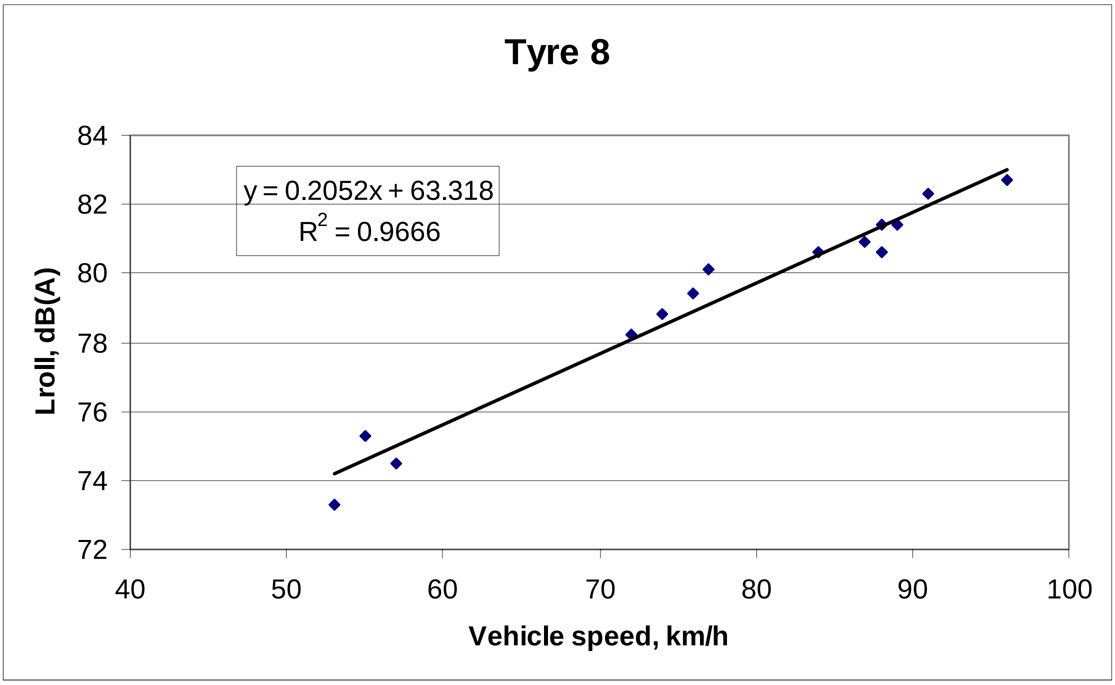


Figure 19, Regression analysis

Table 10, Noise level vs. speed

Vehicle speed, km/h	L_roll, dB(A)
40	71.5
50	73.6
60	75.6
70	77.7
80	79.7
90	81.8
100	83.8
110	85.9
120	87.9

According to the EU-directive, the noise limit for this type of tyre and tyre width (Class 1) is 75 dB(A), measured on an ISO-surface, at 80 km/h.
To compare the results with the limit in the directive, the level is “reduced” to 79 dB(A) (levels are only given without decimals) and then subtracted 1 dB(A) (uncertainty). The comparable level is then 78 dB(A). The road surface influence is then the reason that the level of this tyre is 3 dB(A) ***above*** the limit.

5.3 Coast-by vs. CPX

From the SILVIA-project[8] a relationship between statistical pass-by levels of light vehicles and CPX-measurements has been established on the form:
$L_{veh,cars}$ = a CPXL + b

When measuring with only one single tyre (of “Tyre A”- type), the CPXL is defined as L_A + 1.0 dB(A). For dense road surfaces and at a speed of 80 km/h, the slope a was found to be in the area of 0.8…1.2 and the offset b: -21.2 ± 0.8 dB(A).

According to our CPX-measurements of Tyre 8 on Surface 5 (see table 8), L_A = 99.2 dB(A). Using a slope, a, of 1.0, we then calculate the coast-by level CBL:

CBL = 1.0*100.2-21.2 = 79.0 dB(A)

According to table 10, the calculated level, based on measurements and the regression curve, is 79.7 dB(A).
By choosing a slope of 1.0, we have a good agreement between the measured coast-by level at 7.5 m and the CPX-level, with inner microphones at 0.2 m.

Both during the CPX and the CPB-measurements, the 1/3rd octave band frequency spectra were measured in the bands 315 to 5000 Hz. For CPX, the measurements are normalised to the reference speeds of 50 and 80 km/h, while during CPB, the spectra at the speeds close to the reference speeds have been chosen. All results are temperature corrected to + 20 ºC.

For the CPX-measurements, the frequency spectra is the average of the front and rear microphone. In figures 20 and 21 m the spectra from CPX –measurements are compared with the two CPB-measurements closest to 50 and 80 km/h.

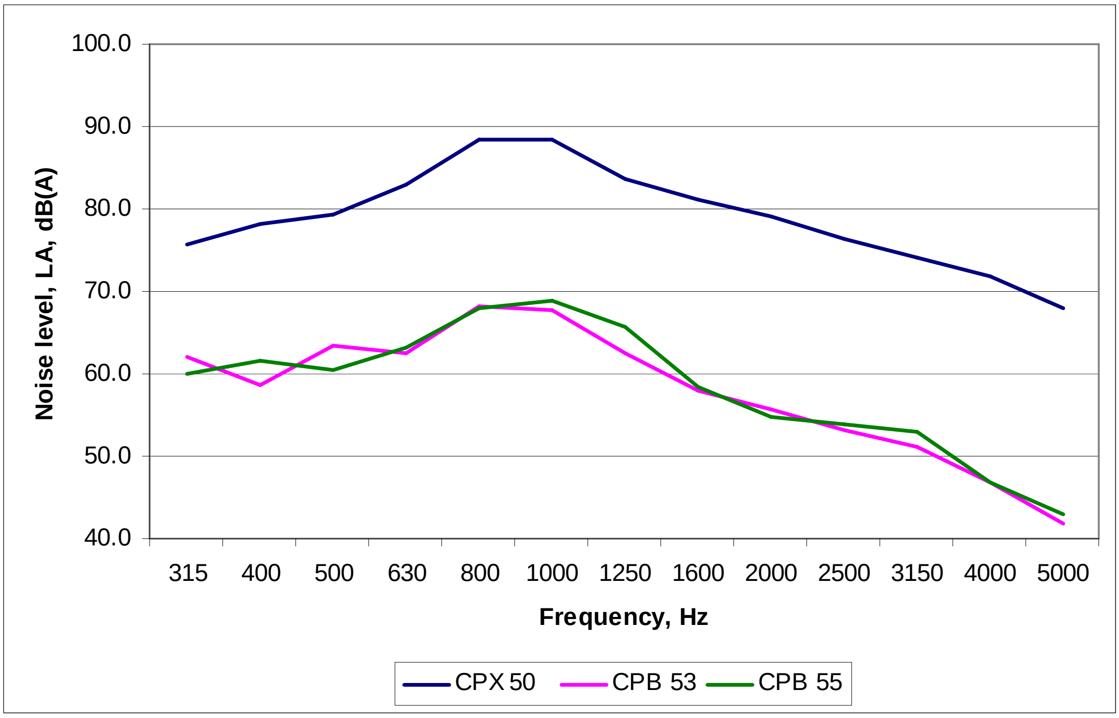


Figure 20, Tyre 8, frequency spectra, CPX at 50 vs CPB at 53 and 55 km/h.

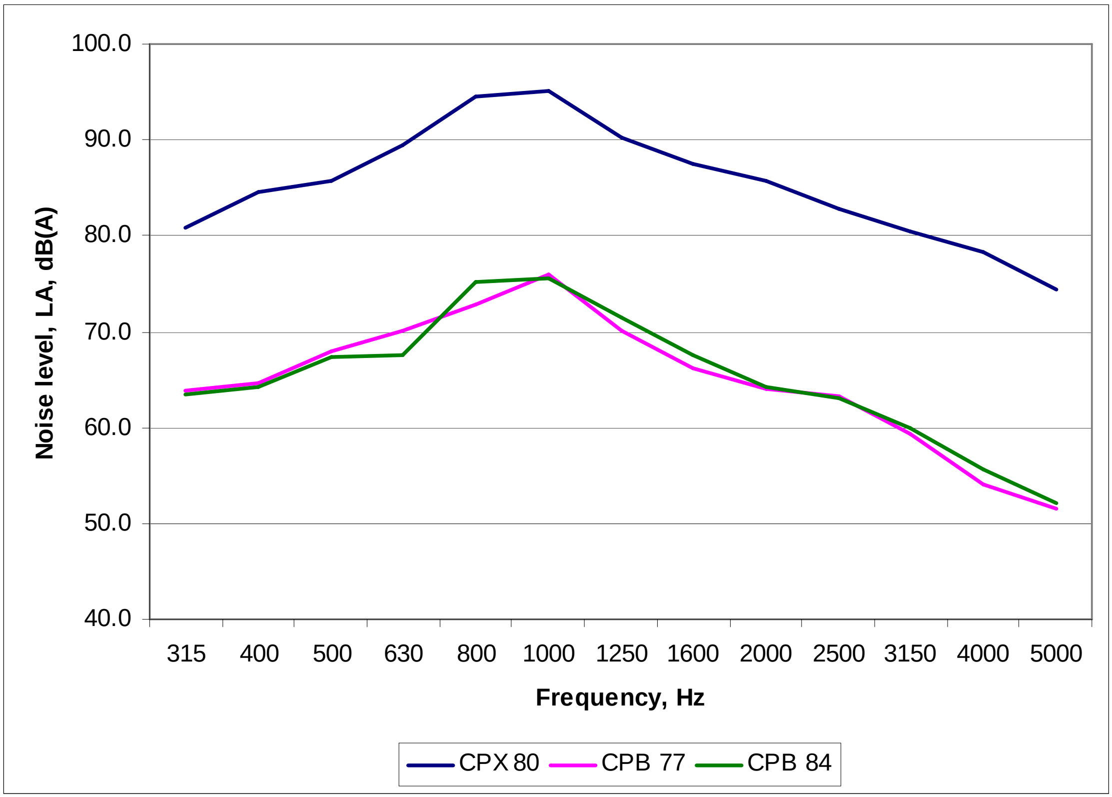


Figure 21, Tyre 8, frequency spectra, CPX at 80 vs CPB at 77 and 84 km/h.

The frequency spectra show in general a good agreement between CPX and CPB-measurements.

5.4 Noise vs. tyre width

In the EU-directive on tyre noise, the limits are related to tyre width. Previous studies[9] have shown a clear relationship between rolling noise and tyre width, especially in the range 135-195 mm. However, more recent studies[10] indicates that this relationship is not very strong, in the order of 1 dB(A) pr 100 mm. Figure 22 show the relationship between tyre width and type approval levels according to the directive, measured on ISO-surface (smooth surface).

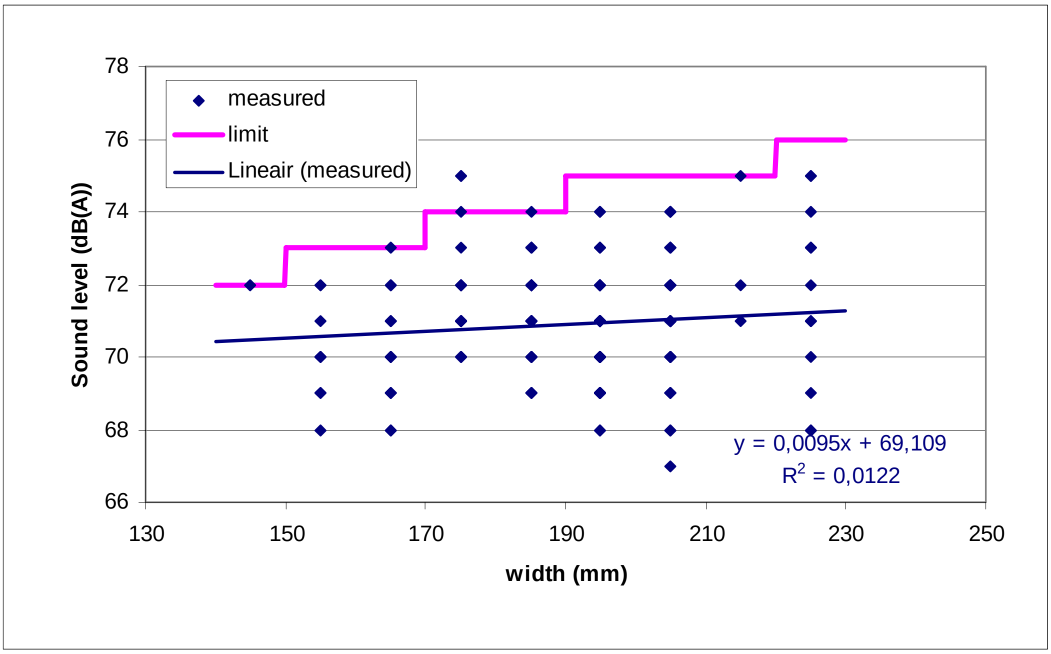


Figure 22, Noise level for passenger car tyres vs. tyre width[8]

The measured tyres in this project varies from 175 to 215 mm and figures 23 and 24 show the relationship between noise level (CPX-levels) and tyre width on Surface 3 (rough surface) and Surface 2B (smooth surface).

Comparing the results for Surface 2B with the ISO-results in figure 22, we find about the same relationship, which is however not statistically significant.

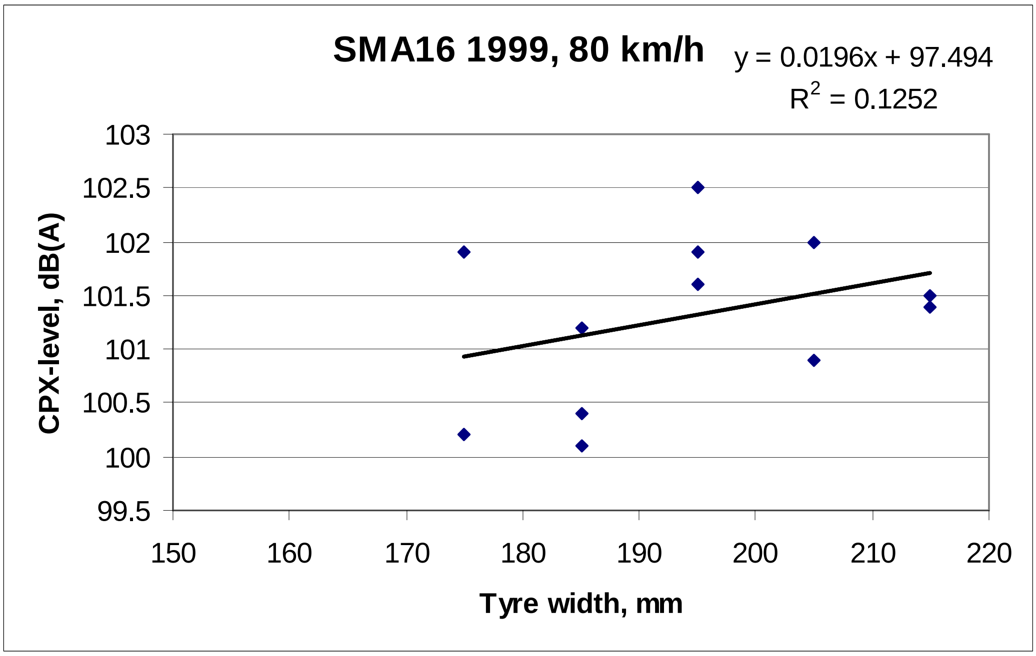


Figure 23, Surface 3, noise level vs. tyre width

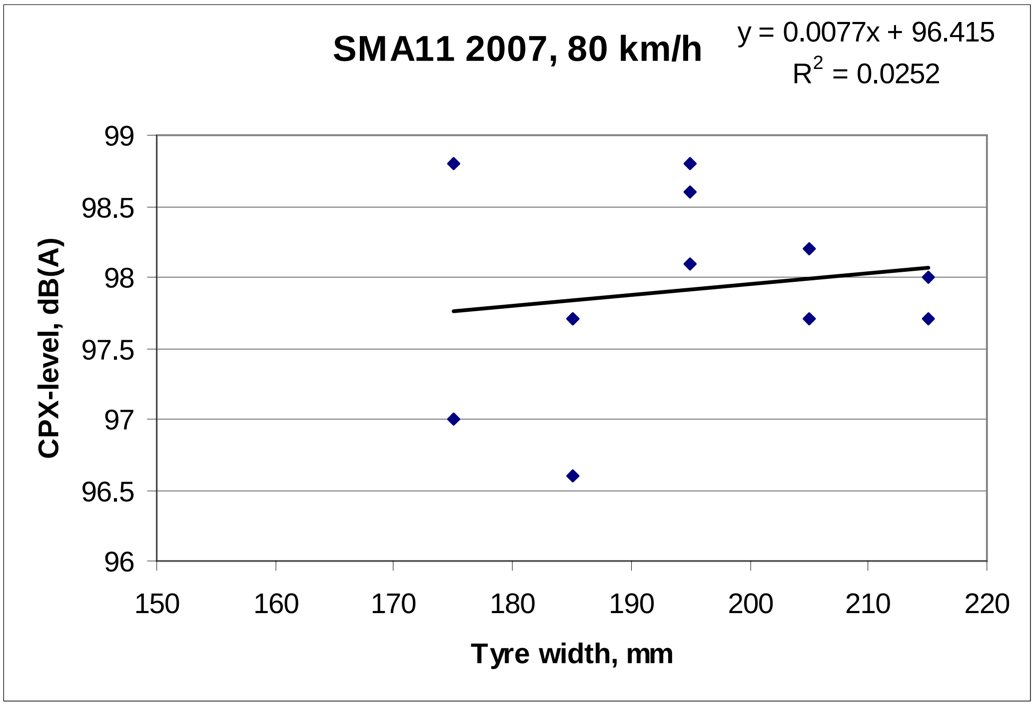


Figure 24, Surface 2B, noise level vs. tyre width

5.5 Noise ranking of tyres

In general, the results - see for example figures 2 and 3 – show that the noise ranking of tyres are quite similar, independent of type of road surface. The tyres with the lowest noise levels on more rough surfaces (like Surface 3 and Surface 6) have also the lowest levels on the smoother road surfaces, like Surface 2B and Surface 5.

In table 11, we have ranked the tyres depending on the average levels and the 95% confidence intervals, as shown in tables 3 to 9 and figures 4 to 16.
If two or more tyres cannot be separated acoustically (the levels are within the same confidence intervals), they are ranked at the same level. Ranking 1 has the lowest sound level, while ranking 8 has the highest sound level.

Table 11, Noise ranking on each surface

	SURFACE 1		SURFACE 2		SURFACE 2B		
Speed, km/h	**50**	**80**	**50**	**80**	**50**	**80**	
Ranking:	**Tyre no**	**Tyre no**	**Tyre no**	**Tyre no**	**Tyre no**	**Tyre no**	
1	1	1,12	1	1,12	1	12	
2	3,8	3,4	3	3	12	1	
3	4	8	4,8,12	4,8	3,8,9	3,4,8,9	
4	2,12	2,9,10	2,9,10	10	4,10	10,11	
5	9	7,11	11	9	11	7	
6	7,10	5,6	7	2,11	2,7	2,5,6	
7	11		5,6	7	5,6		
8	5,6			5,6			
	SURFACE 3		**SURFACE 4**		**SURFACE 5**		**SURFACE 6**
Speed, km/h	**50**	**80**	**50**	**80**	**50**	**80**	**50**
Ranking:	**Tyre no**	**Tyre no**	**Tyre no**	**Tyre no**	**Tyre no**	**Tyre no**	**Tyre no**
1	1	1,12	1	1,12	1,12	12	1
2	3	3	12	8	8,10	1,8,10	3,8
3	8	4,8	3,8,9,10	3,4,9,10	2,3,4,6,9	3,4,9	9
4	4,9,12	9,10	2,4,11	2,11	11	2,5,6,7,11	2,4,5,7,10,11,12
5	2,10	2,7,11	5,6	5,6.7	5		6
6	11	5	7		7		
7	5,7	6					
8	6						

Based on the ranking number of each tyre in table 11, the average ranking on all surfaces and at both speeds is calculated and shown in table 12.

Table 12, Average ranking of tyres

Tyre	Average ranking	Category	Dimensions
1	1.2	MP	175/70 R14
12	2.0	MP	185/65 R15
3	2.5	MP	185/65 R15
8	2.6	HP	205/55 R16
4	3.2	MP	185/65 R15
9	3.6	HP	215/55 R16
10	3.8	HP	215/55 R16
2	4.5	LP	175/70 R14
11	4.8	MP	195/65 R15
7	5.5	HP	205/55 R16
5	6.0	HP	195/65 R15
6	6.1	HP	195/65 R15

As table 12 show, there is no clear relationship between tyre category or dimensions and the noise levels.

From table 11, there are no clear indications that rougher surfaces distinguish more between the tyres, than the more smooth surfaces.

6 Conclusions

- The noise measurements show that there is a difference in noise level between the tyres in the range of ***2-3 dB(A)*** between the most silent tyres and the most noisy tyres (tables 3-9).
- The difference is not speed dependent in the area 50 to 80 km/h.
- The noise ranking of tyres is quite similar on all road surfaces
- Combining the most silent tyre with the most silent road surface in this investigation gives a potential noise reduction of approximately ***6 dB(A)*** of the rolling noise levels, at both 50 and 80 km/h (figures 17 and 18), when comparing with the “worst” combination of tyre and road surface type.

References

[1] 2001/43/EC amending Council Directive 92/93/EEC relating to tyres for motor vehicles and their trailers to their fitting. June 27th 2001.

[2] ISO 10844:1994 "Acoustics - Specification of test track for the purpose of measuring noise emitted by road vehicles."

[3] T.Berge: Tyre/road noise modelling – results from noise and texture measurements in Norway. SINTEF Report A935, January 2007.

[4] T.Berge: Measurements of tyre/road noise from passenger car tyres according to the EU-directive 2001/43/EC, on a number of different road surfaces. SINTEF Report STF90A05135, November 2005.

[5] Svein Å.Storeheier: Texture measurements on test road surfaces for tyre/road noise modelling. SINTEF Memo 90E239, 2007-11-24.

[6] T.Beckenbauer, W.Kropp: Prediction of tyre/road noise. Application of the SPERoN model. Müller BBM Report No. M68 231/1, 2007-11-30.

[7] ISO/CD 11819-2: "Acoustics – Measurements of the influence of road surfaces on traffic noise – Part2: The close-proximity method", 2000-12-31.

[8] SILVIA- Sustainable road surfaces for traffic noise control: Guidance manual for the implementation of low-noise road surfaces, chapter A2.2, FEHRL report 2006/02, Brussels 2006.

[9] S.Å.Storeheier, U.Sandberg: "Vehicle Related Parameters Affecting Tyre/Road Noise". Proceedings if the International Tire/Road Noise Conference 8-10 August 1990. Gothenburg.

[10] European Federation for Transport and Environment (T&E): Quieter tyres: a cost effective way to protect public health. Part 1 of 2, Brussels, October 2007.

Appendix 1 – Tyres and tread pattern

Tyre 1 – 175/70 R14

Tyre 4 – 185/65 R15

Tyre 2 – 175/70 R14

Tyre 5 – 195/65 R15

Tyre 3 – 185/65 R15

Tyre 6 – 195/65 R15

Tyre 7 – 205/55 R16

yre 8 – 205/55 R16

Tyre 9 – 215/55 R16

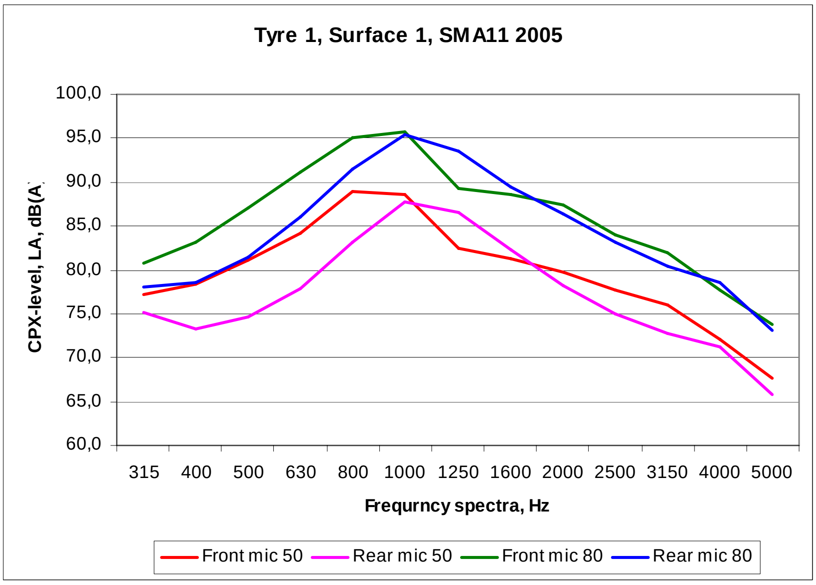
Tyre 10 – 215/55 R16

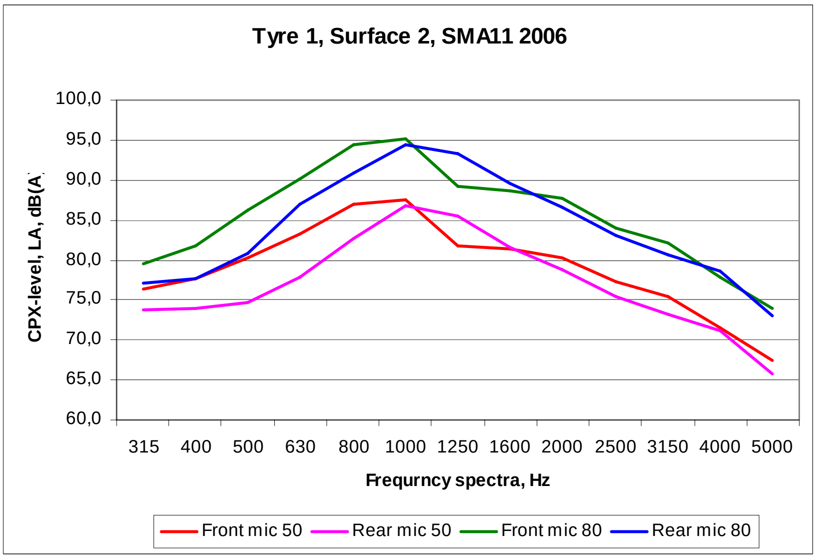
Tyre 11 – 195/65 R15

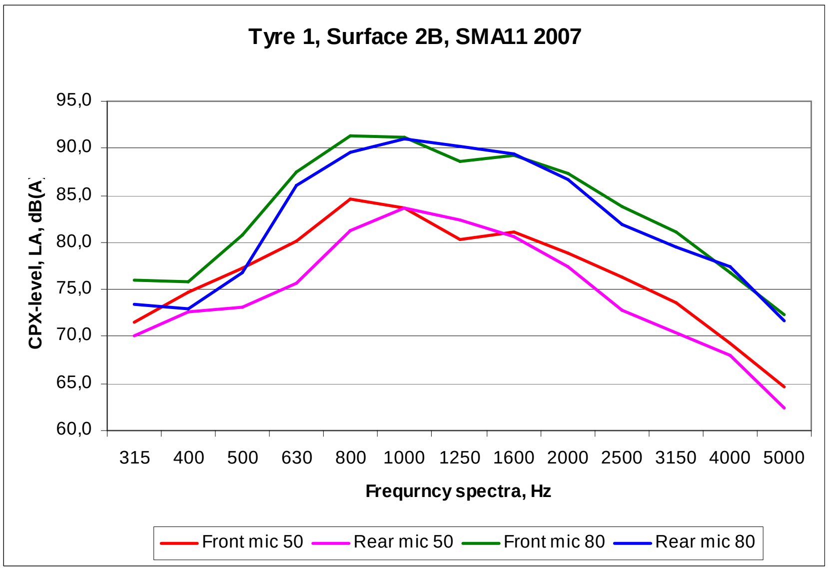
Tyre 12 – 185/65 R15

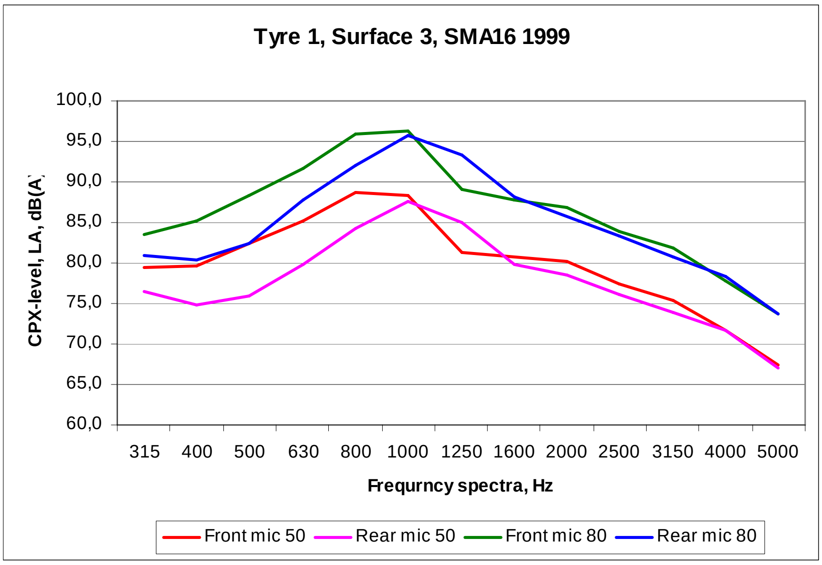
APPENDIX 2 – Frequency spectra, CPX- measurements.

Tyre 1 – 175/70 R14

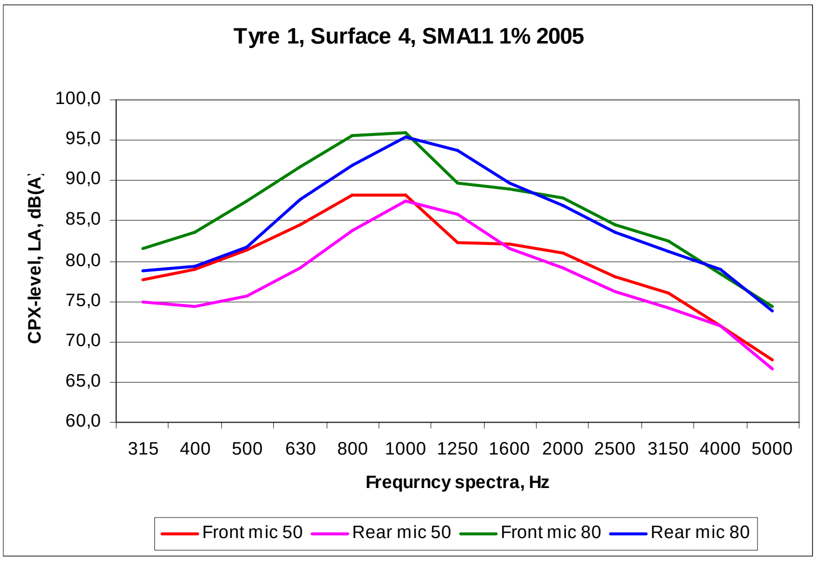




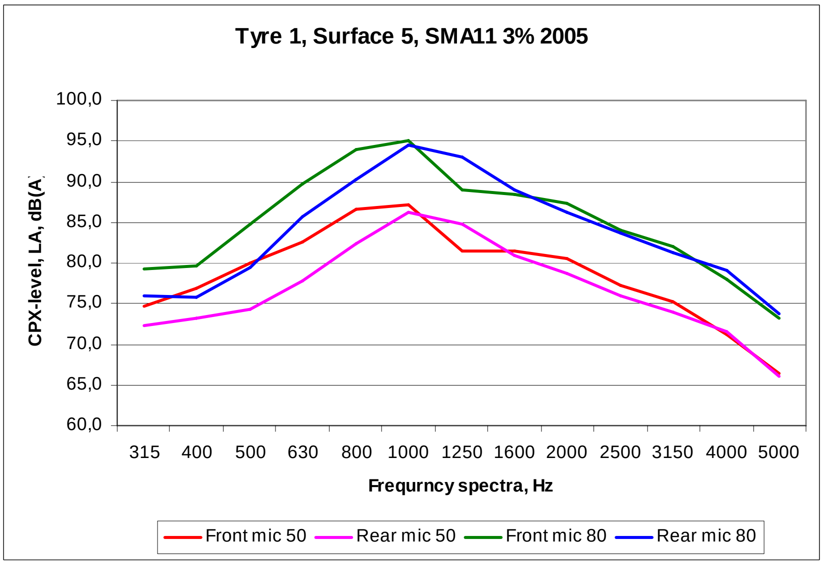




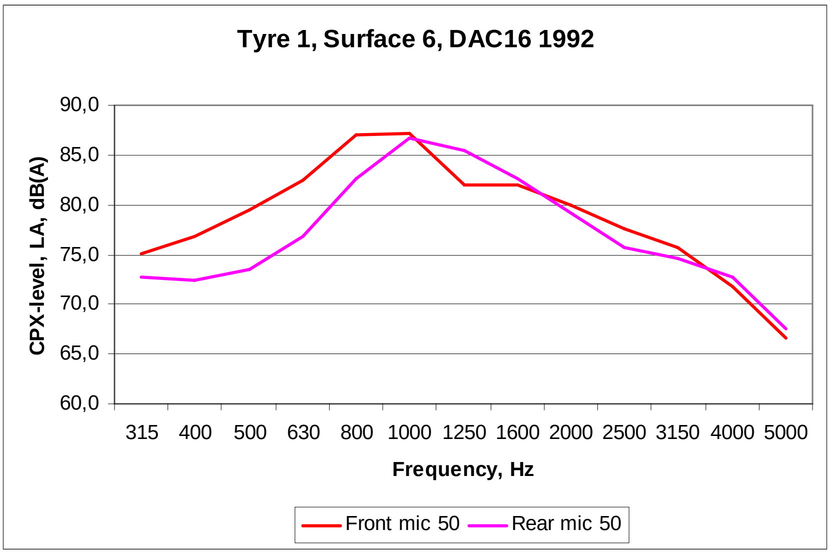
Tyre 1, Surface 3, SMA16 1999
CPX-level, LA, dB(A)
100,0
95,0
90,0
85,0
80,0
75,0
70,0
65,0
60,0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequrncy spectra, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80



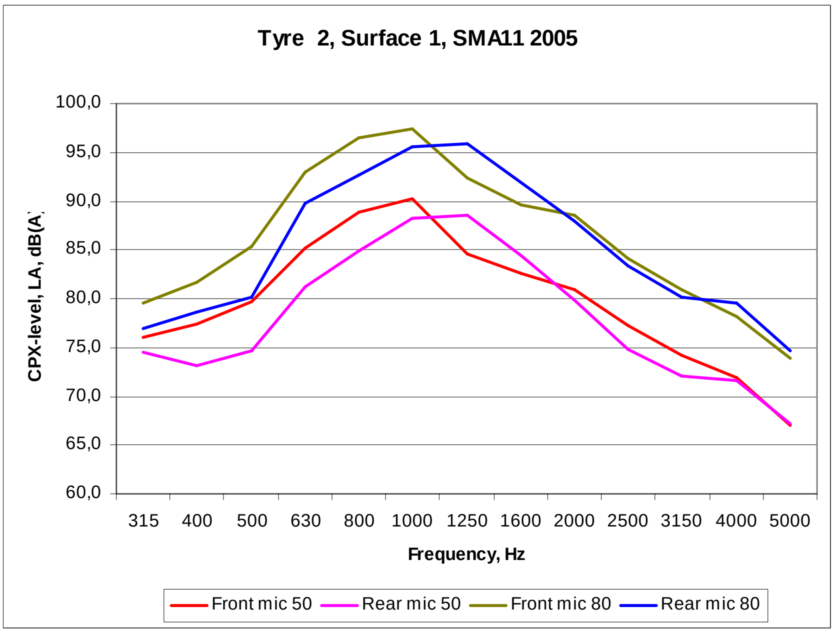
Tyre 1, Surface 4, SMA11 1% 2005
CPX-level, LA, dB(A)
100,0
95,0
90,0
85,0
80,0
75,0
70,0
65,0
60,0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequrncy spectra, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

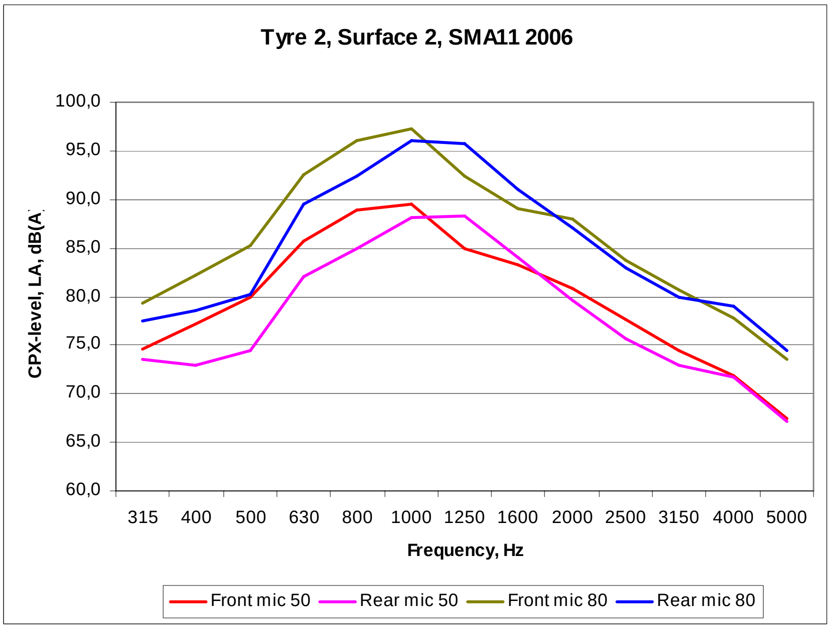


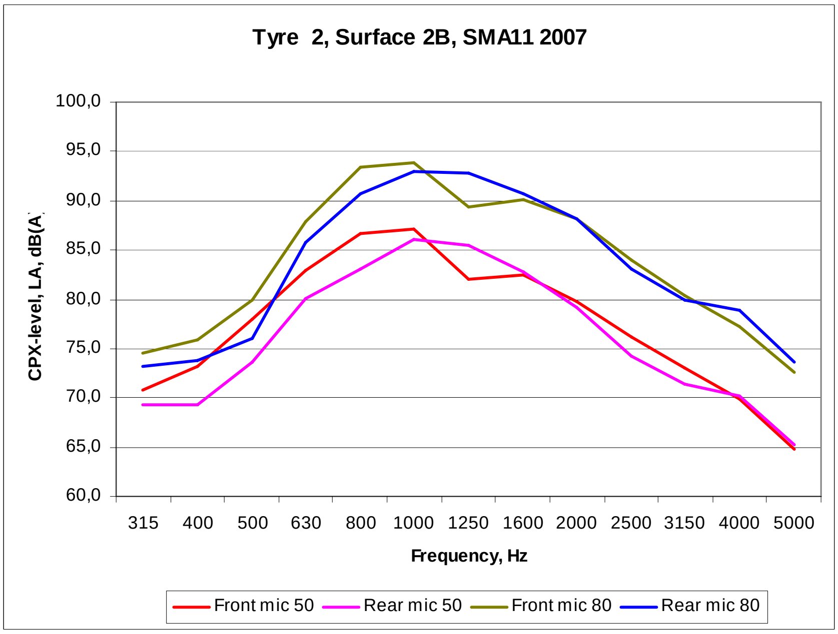
Tyre 1, Surface 5, SMA11 3% 2005
CPX-level, LA, dB(A)
100,0
95,0
90,0
85,0
80,0
75,0
70,0
65,0
60,0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequrncy spectra, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

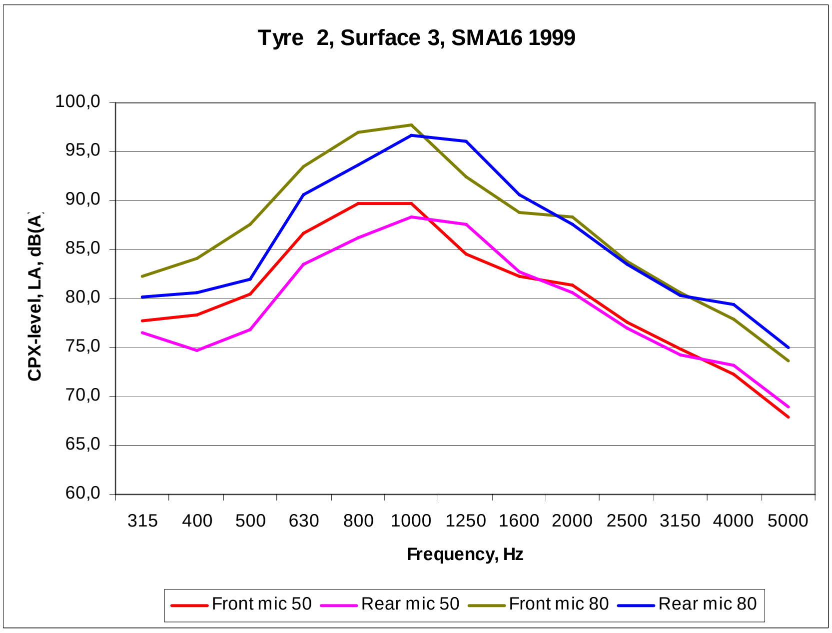


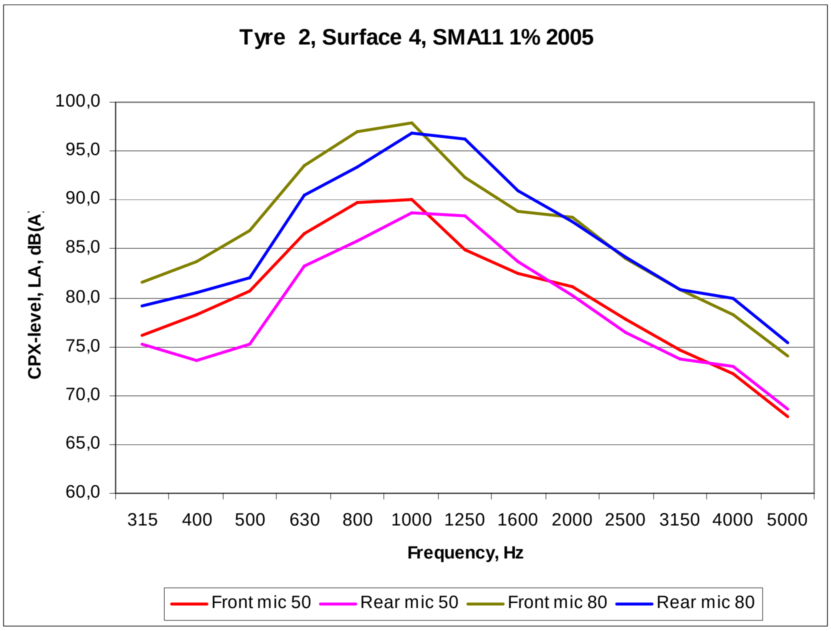
Tyre 2 – 175/70 R14

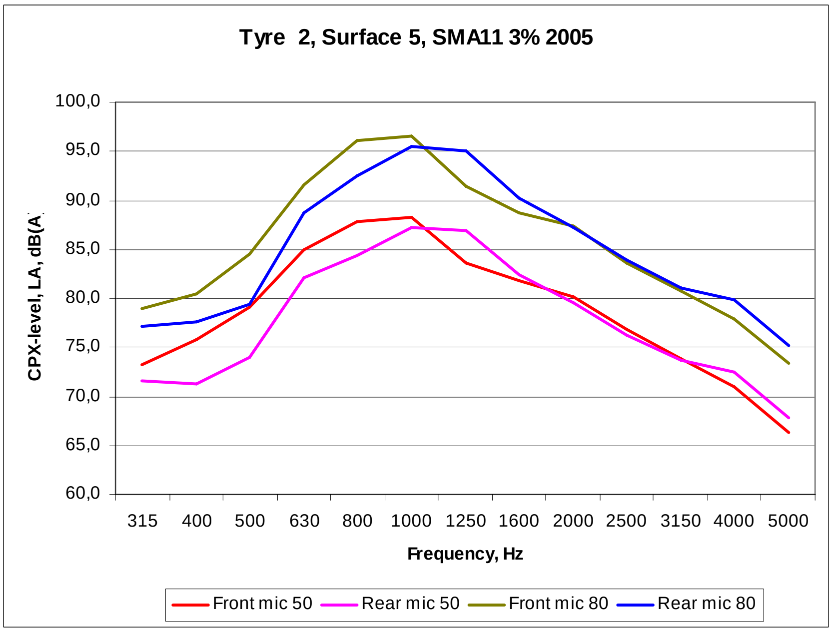


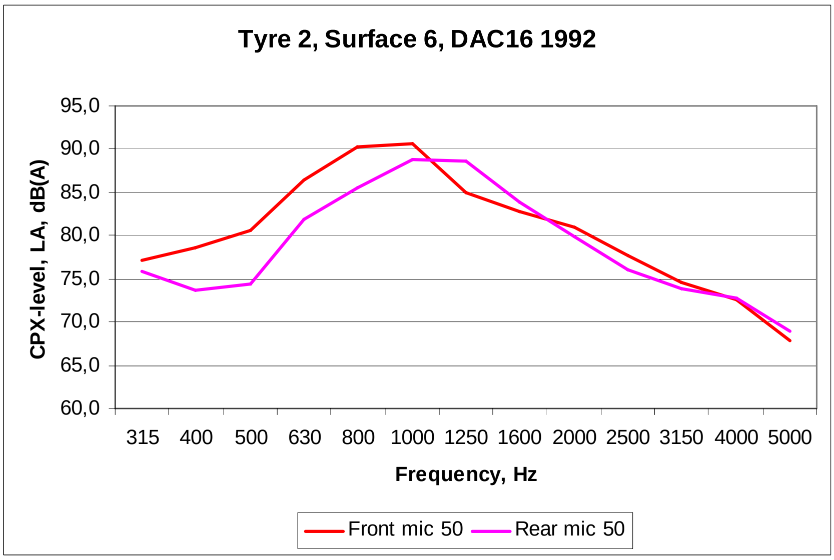

Tyre 2, Surface 2, SMA11 2006
100,0
95,0
90,0
85,0
80,0
75,0
70,0
65,0
60,0
CPX-level, LA, dB(A)
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80


Tyre 2, Surface 2B, SMA11 2007
100,0
95,0
90,0
85,0
80,0
75,0
70,0
65,0
60,0
CPX-level, LA, dB(A)
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

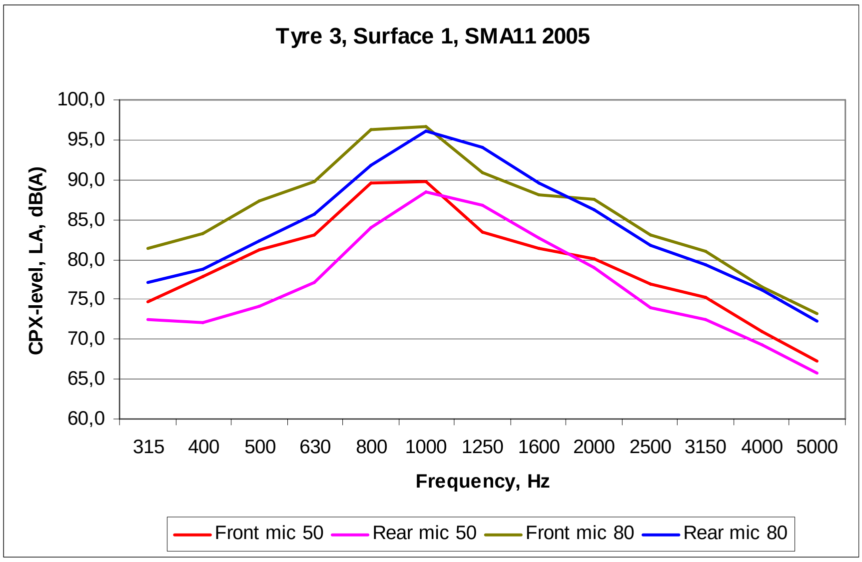

Tyre 2, Surface 3, SMA16 1999
100,0
95,0
90,0
85,0
80,0
75,0
70,0
65,0
60,0
CPX-level, LA, dB(A)
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

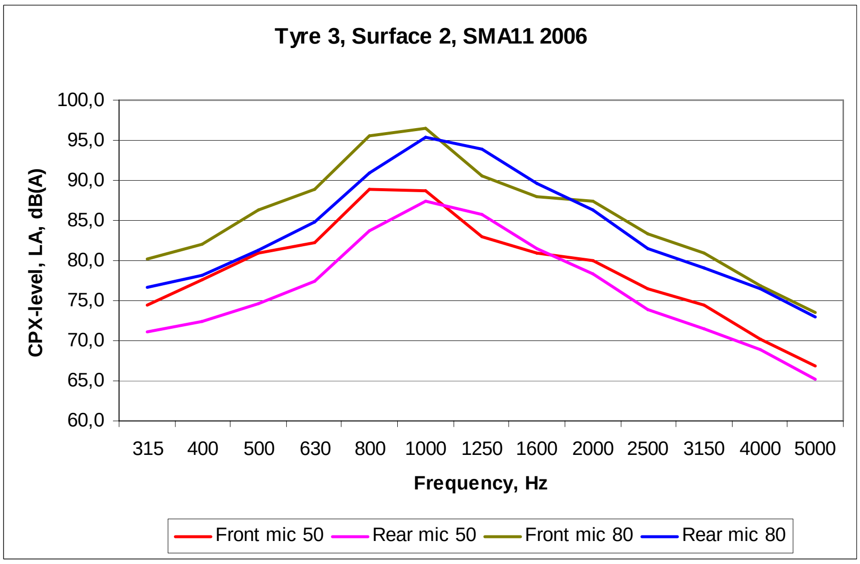

Tyre 2, Surface 4, SMA11 1% 2005
CPX-level, LA, dB(A)
100,0
95,0
90,0
85,0
80,0
75,0
70,0
65,0
60,0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

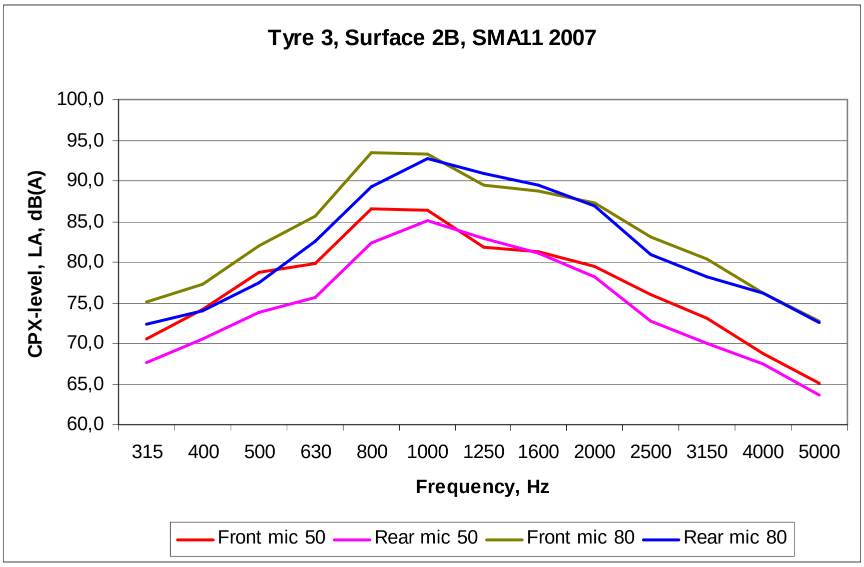

Tyre 2, Surface 5, SMA11 3% 2005
CPX-level, LA, dB(A)
100,0
95,0
90,0
85,0
80,0
75,0
70,0
65,0
60,0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

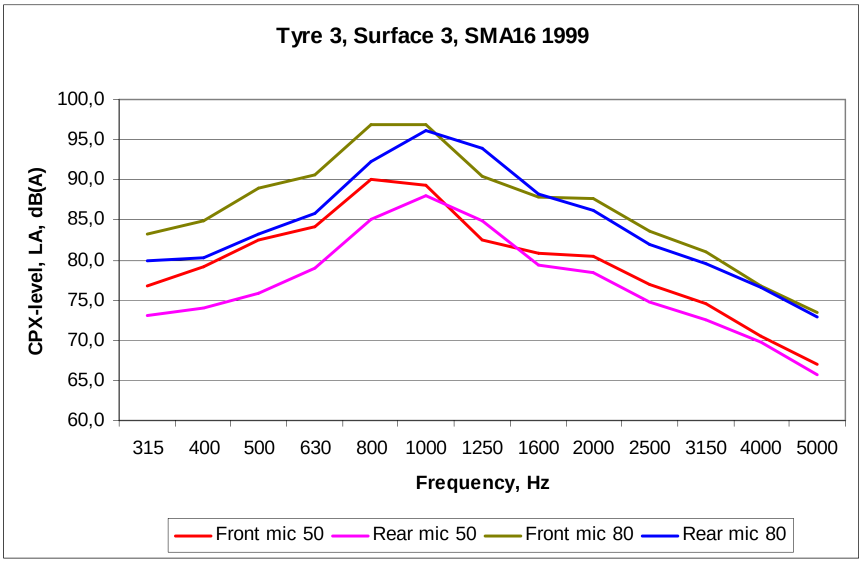

Tyre 2, Surface 6, DAC16 1992
CPX-level, LA, dB(A)
95,0
90,0
85,0
80,0
75,0
70,0
65,0
60,0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50

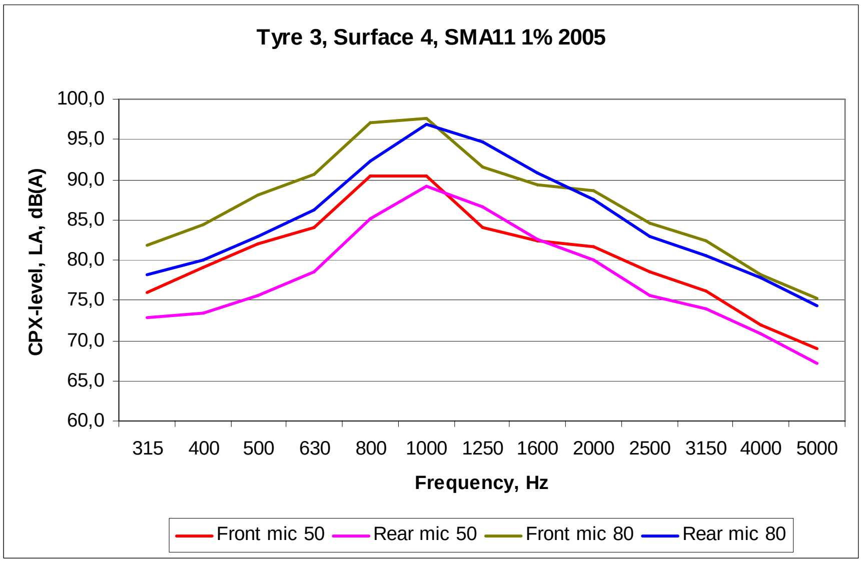
Tyre 3 – 185/65 R15

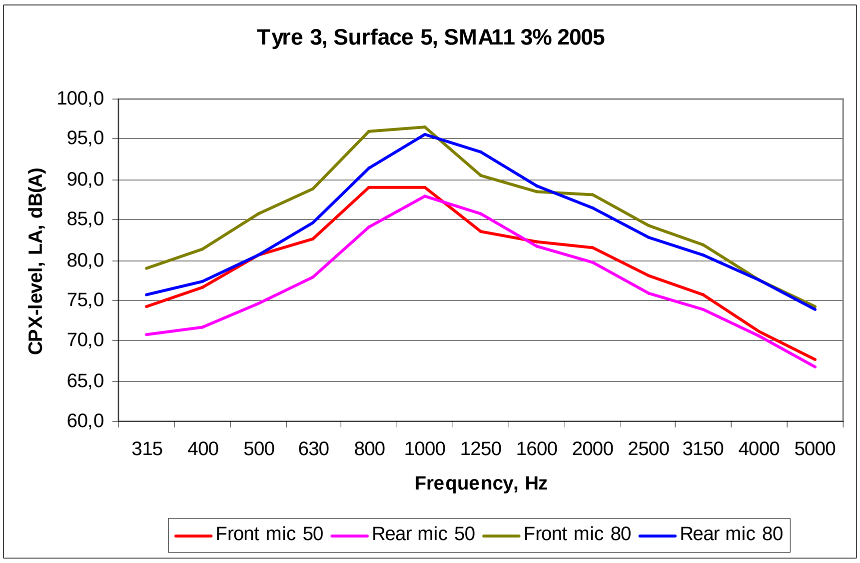


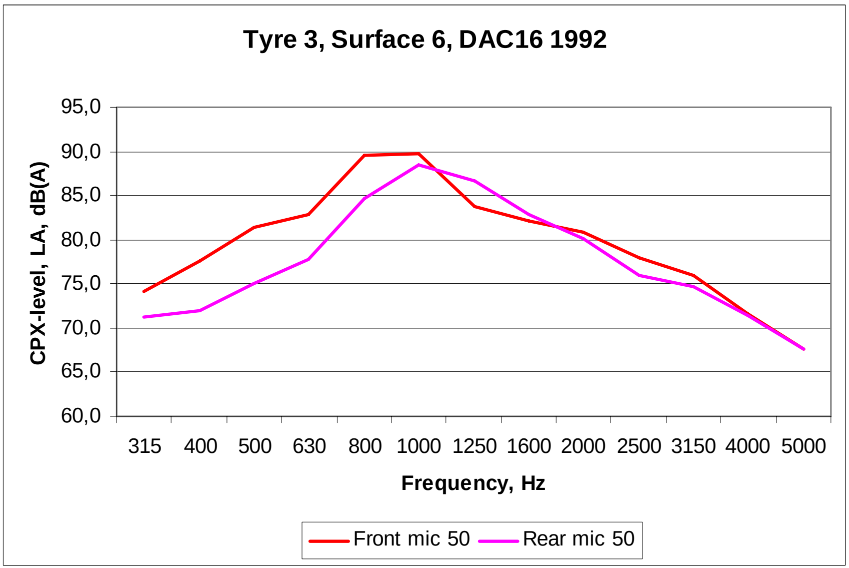




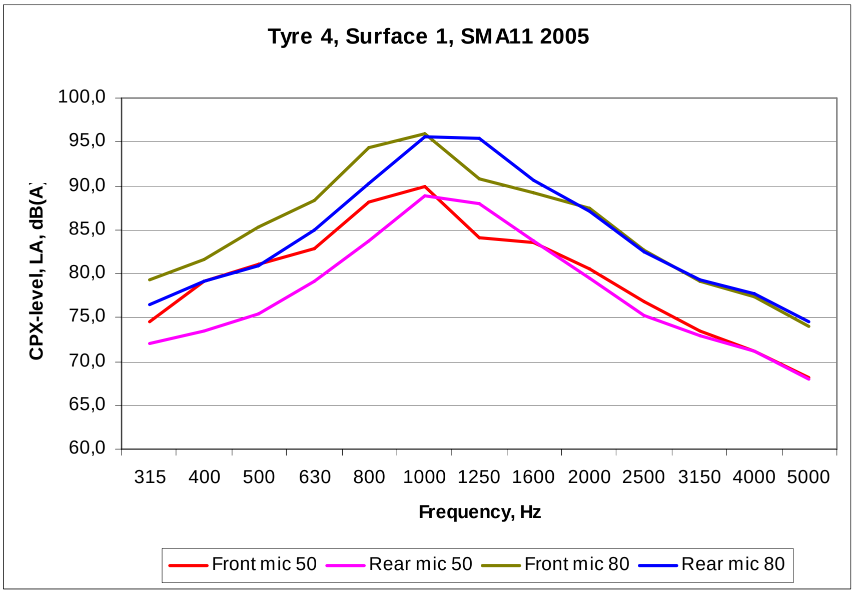

Tyre 3, Surface 3, SMA16 1999
100,0
95,0
90,0
85,0
80,0
75,0
70,0
65,0
60,0
CPX-level, LA, dB(A)
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

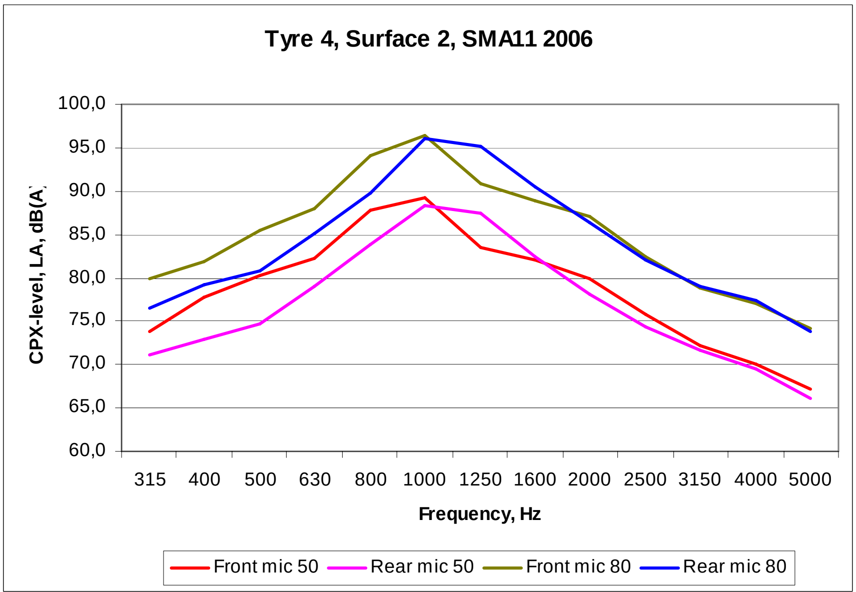

Tyre 3, Surface 4, SMA11 1% 2005
100,0
95,0
90,0
85,0
80,0
75,0
70,0
65,0
60,0
CPX-level, LA, dB(A)
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

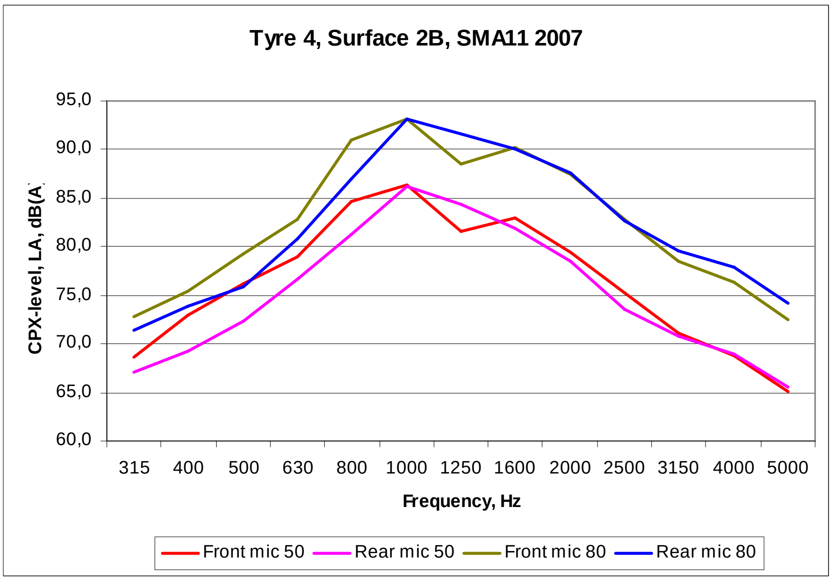

Tyre 3, Surface 5, SMA11 3% 2005
100,0
95,0
90,0
85,0
80,0
75,0
70,0
65,0
60,0
CPX-level, LA, dB(A)
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

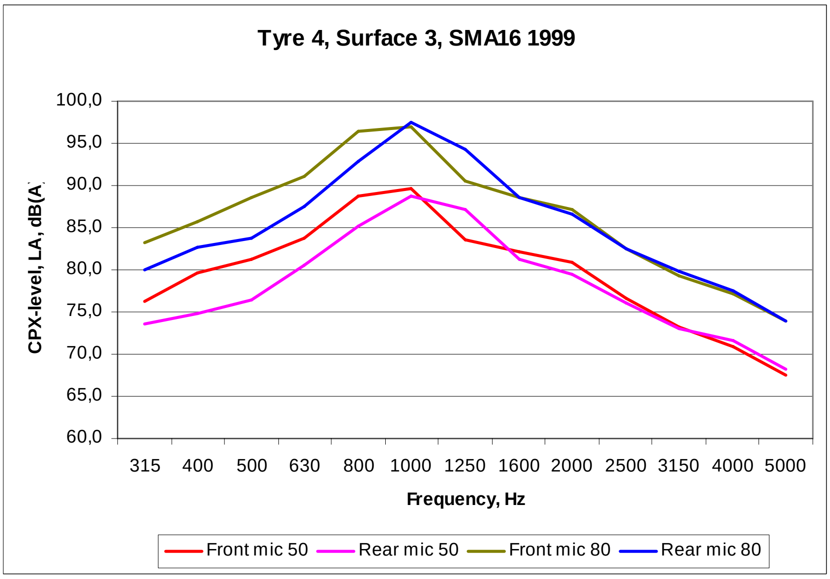


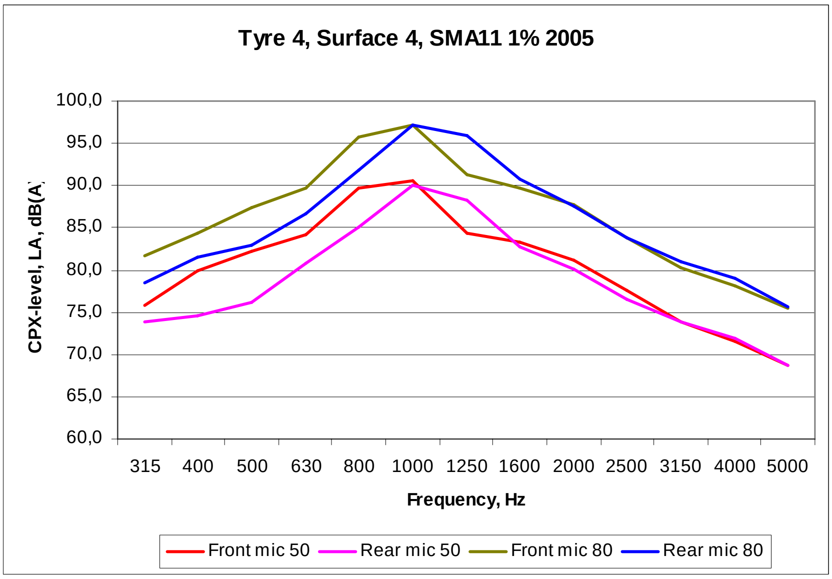
Tyre 4 – 185/65 R15

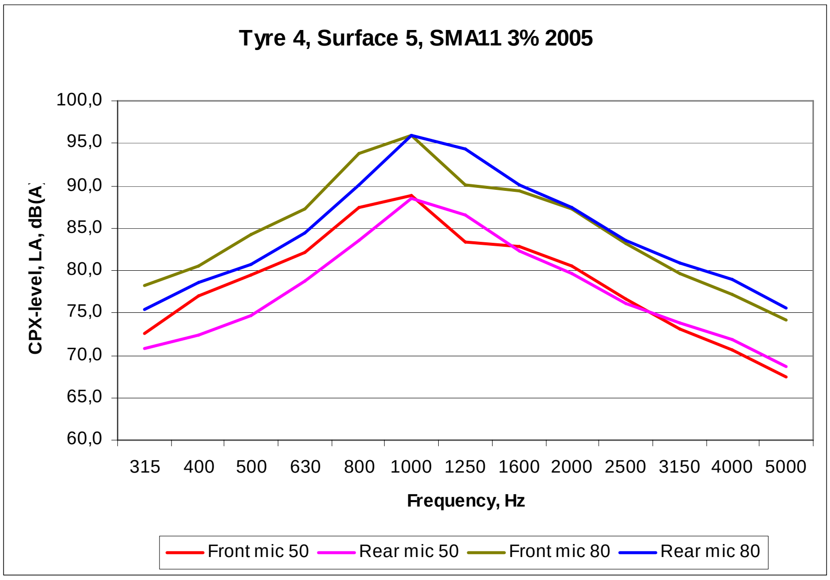


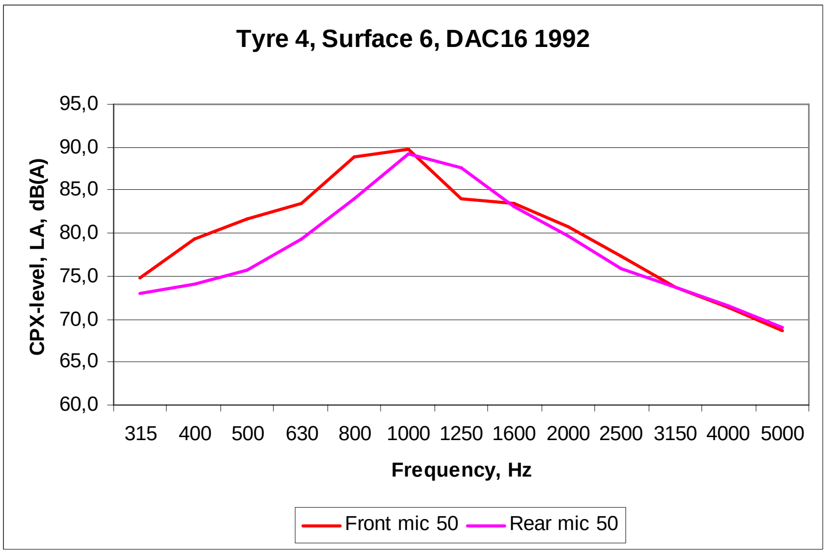



Tyre 4, Surface 2B, SMA11 2007
95,0
90,0
85,0
80,0
75,0
70,0
65,0
60,0
CPX-level, LA, dB(A)
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

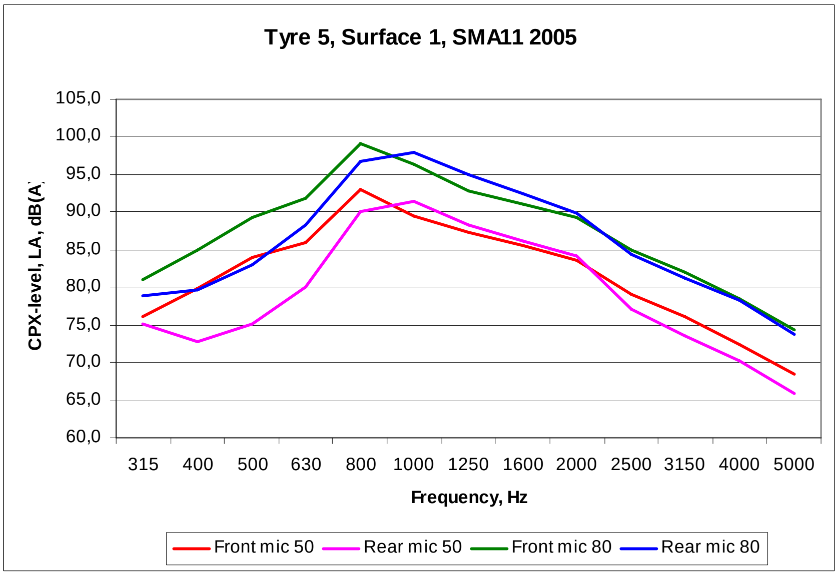

Tyre 4, Surface 3, SMA16 1999
100,0
95,0
90,0
85,0
80,0
75,0
70,0
65,0
60,0
CPX-level, LA, dB(A)
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

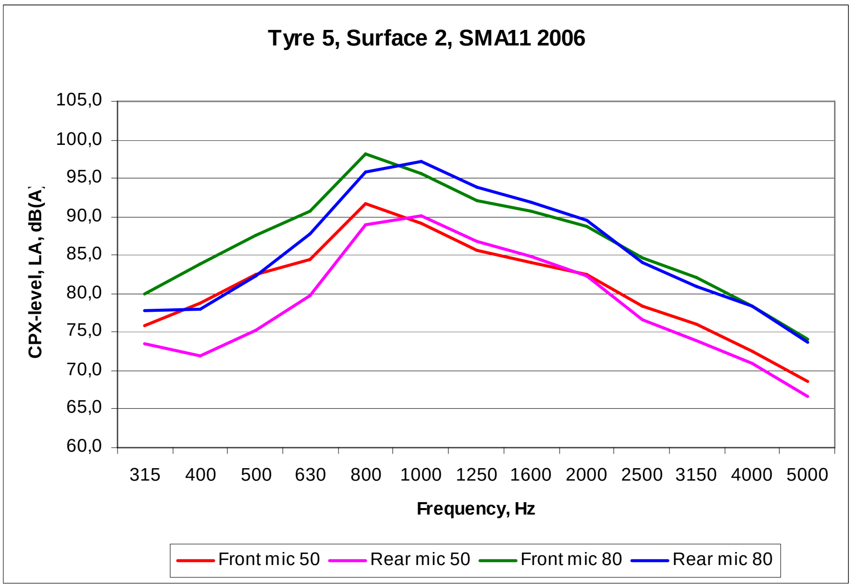

Tyre 4, Surface 4, SMA11 1% 2005
100,0
95,0
90,0
85,0
80,0
75,0
70,0
65,0
60,0
CPX-level, LA, dB(A)
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

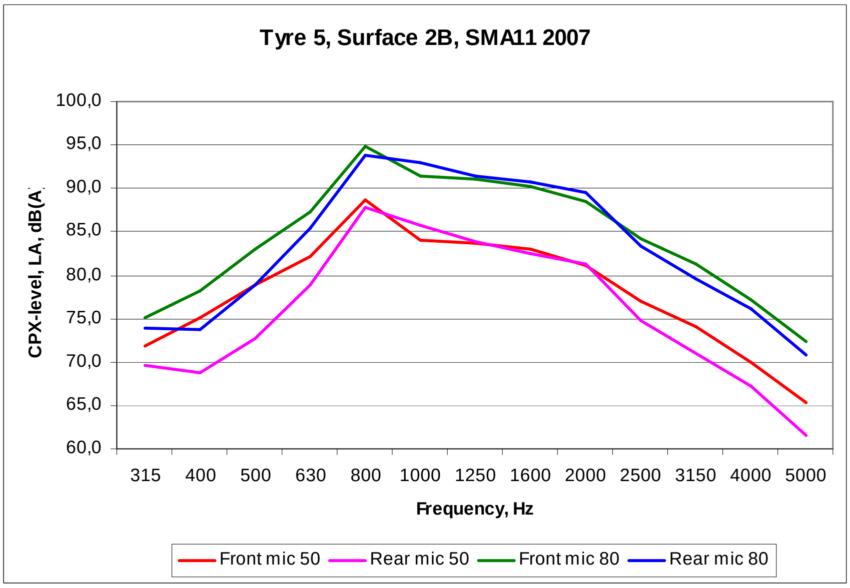


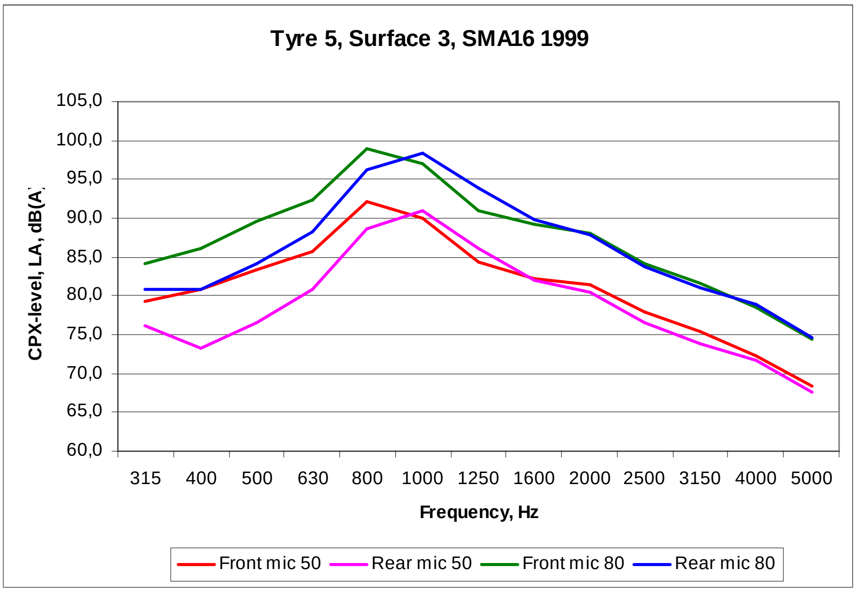


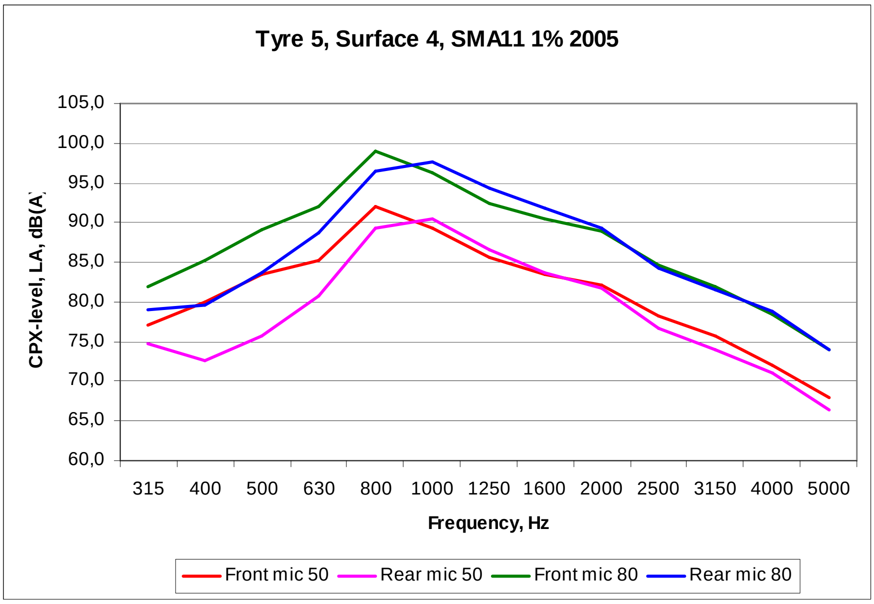
Tyre 5 – 195/65 R15

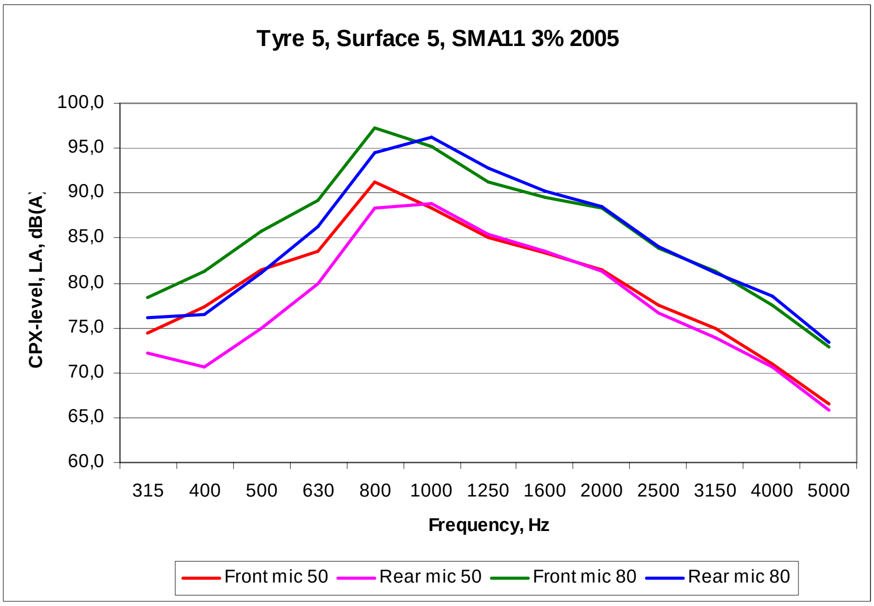


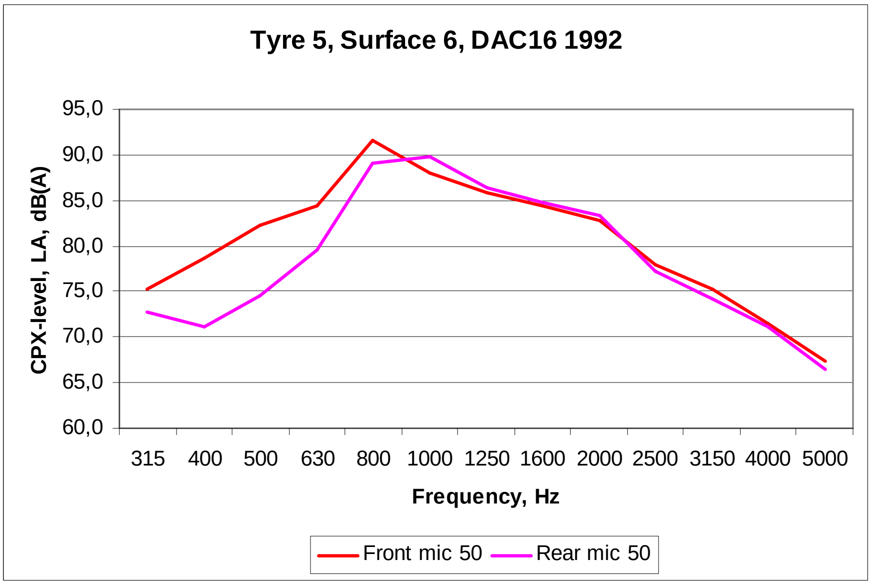

Tyre 5, Surface 2, SMA11 2006
CPX-level, LA, dB(A)
105,0
100,0
95,0
90,0
85,0
80,0
75,0
70,0
65,0
60,0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80


Tyre 5, Surface 2B, SMA11 2007
CPX-level, LA, dB(A)
100,0
95,0
90,0
85,0
80,0
75,0
70,0
65,0
60,0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

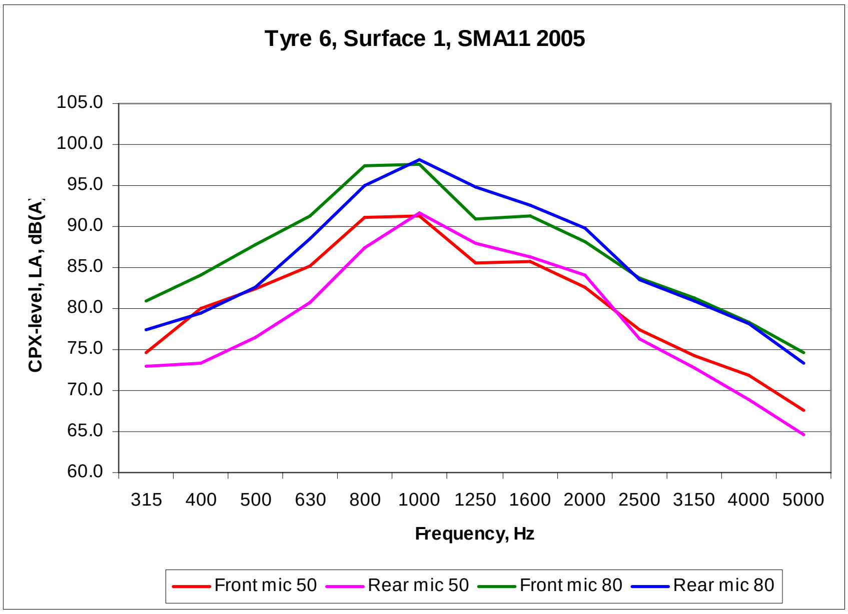

Tyre 5, Surface 3, SMA16 1999
CPX-level, LA, dB(A)
105,0
100,0
95,0
90,0
85,0
80,0
75,0
70,0
65,0
60,0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

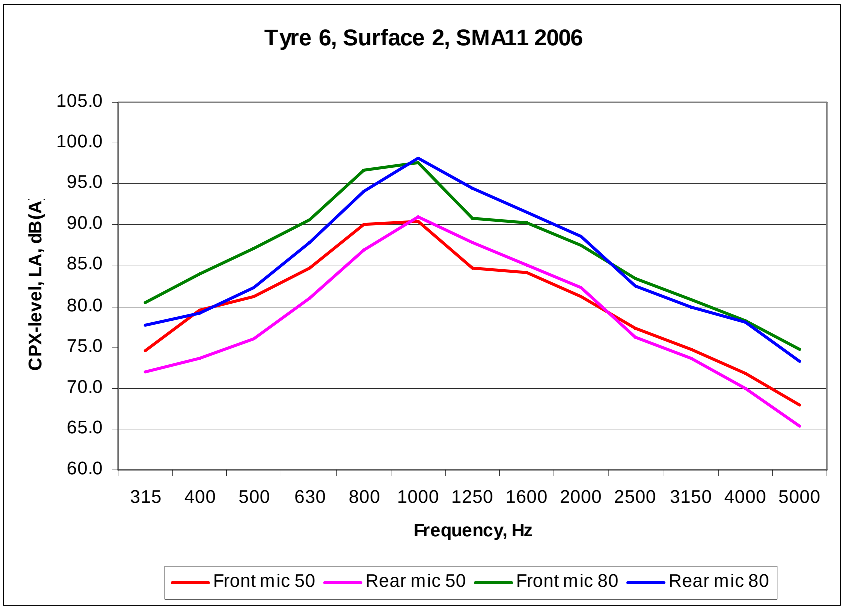

Tyre 5, Surface 4, SMA11 1% 2005
CPX-level, LA, dB(A)
105,0
100,0
95,0
90,0
85,0
80,0
75,0
70,0
65,0
60,0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

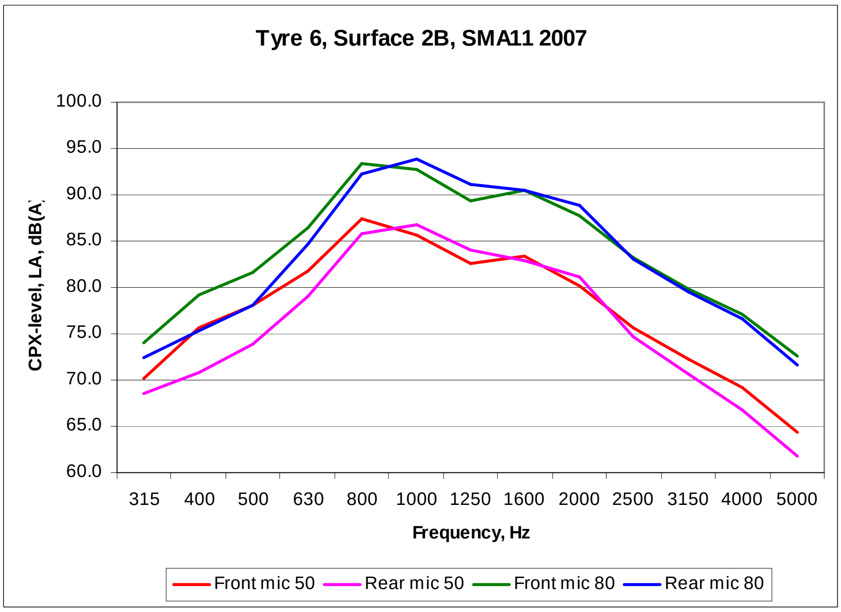

Tyre 5, Surface 5, SMA11 3% 2005
CPX-level, LA, dB(A)
100,0
95,0
90,0
85,0
80,0
75,0
70,0
65,0
60,0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

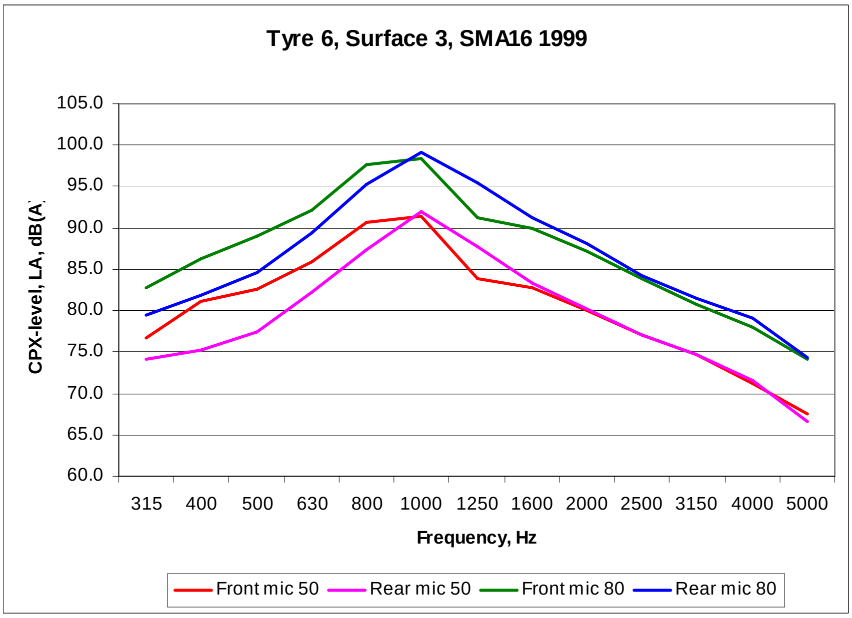

Tyre 5, Surface 6, DAC16 1992
CPX-level, LA, dB(A)
95,0
90,0
85,0
80,0
75,0
70,0
65,0
60,0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50

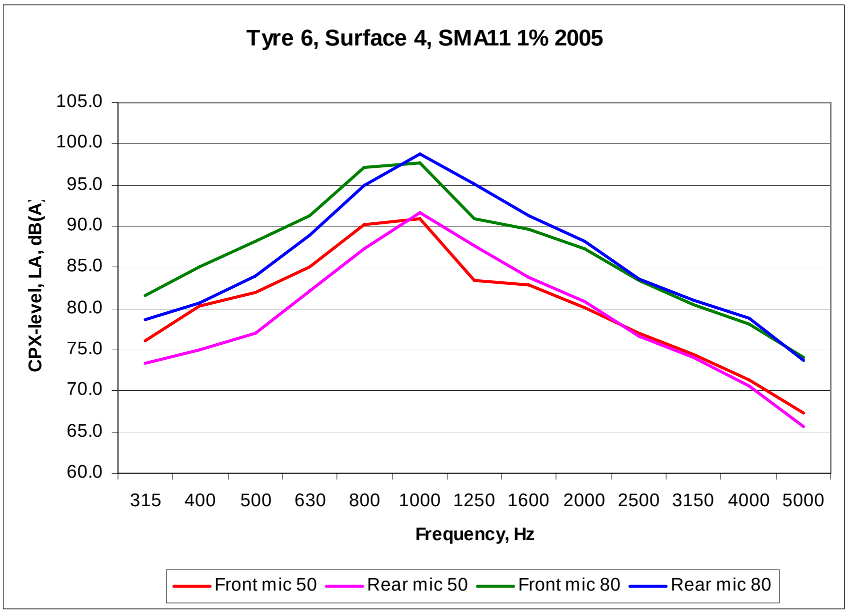
Tyre 6 – 195/65 R15

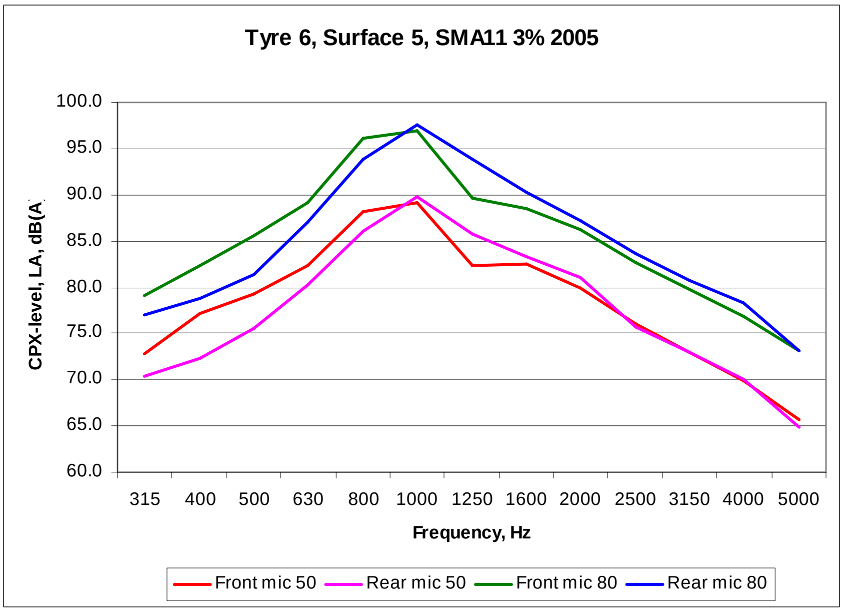


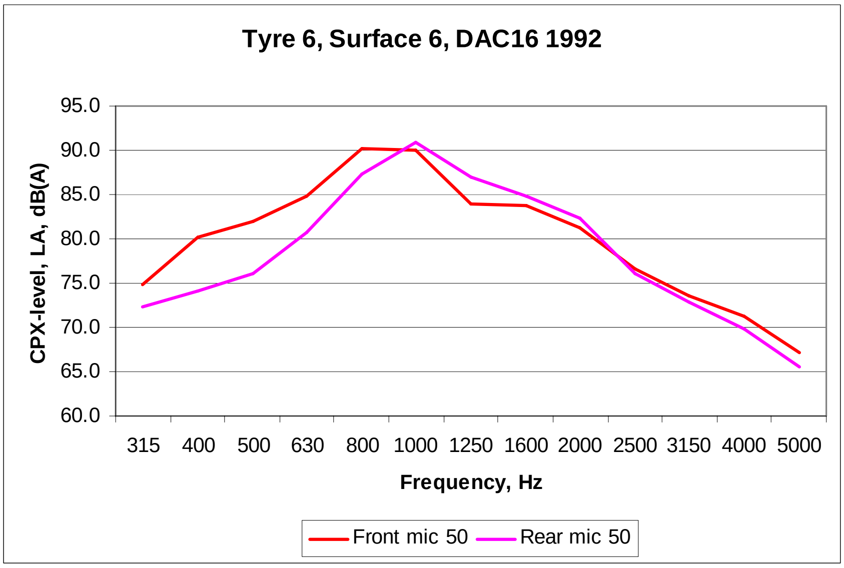




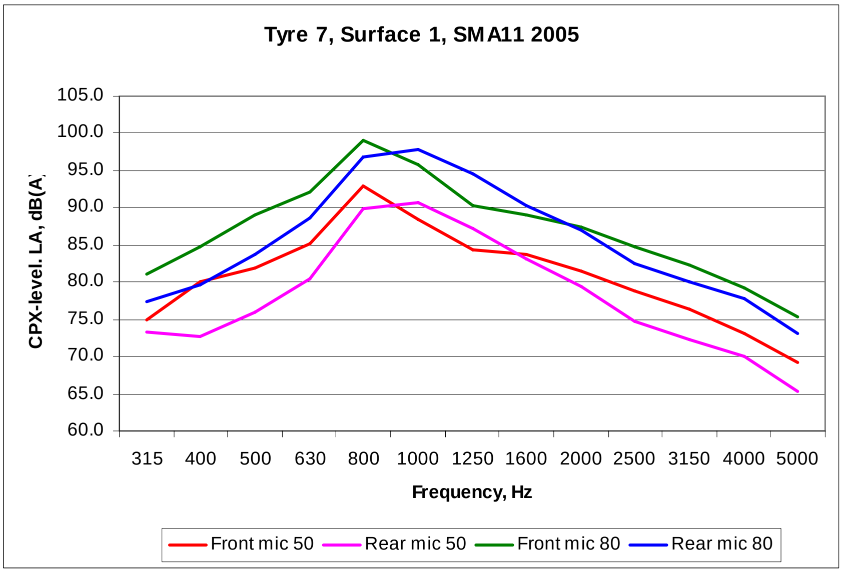

Tyre 6, Surface 3, SMA16 1999
CPX-level, LA, dB(A)
105.0
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

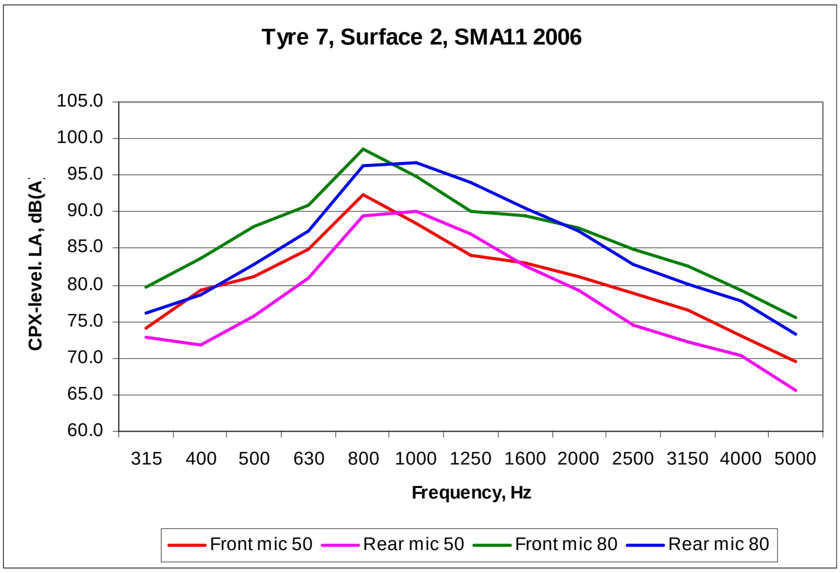

Tyre 6, Surface 4, SMA11 1% 2005
CPX-level, LA, dB(A)
105.0
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

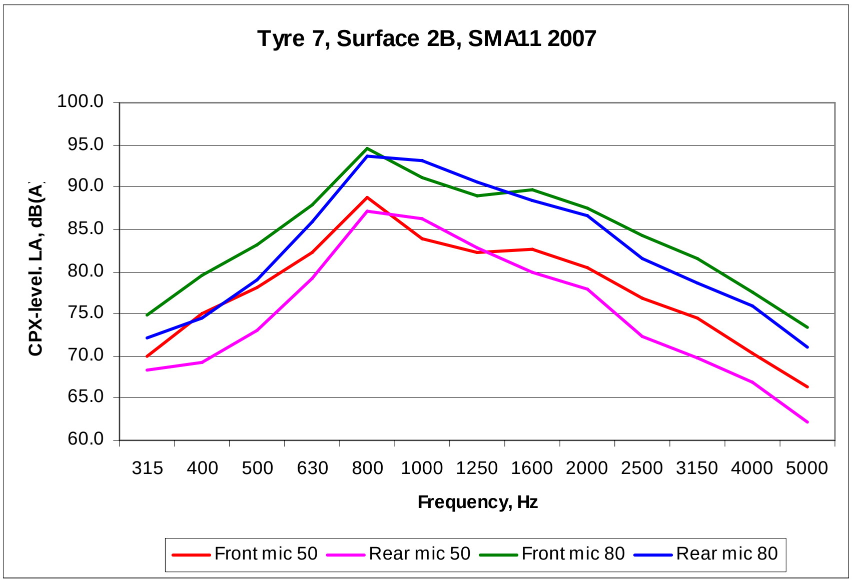

Tyre 6, Surface 5, SMA11 3% 2005
CPX-level, LA, dB(A)
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

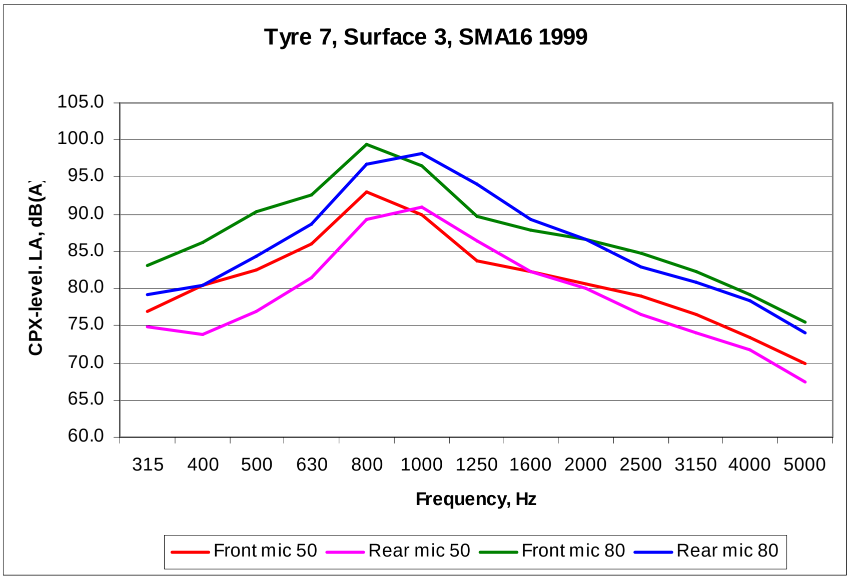


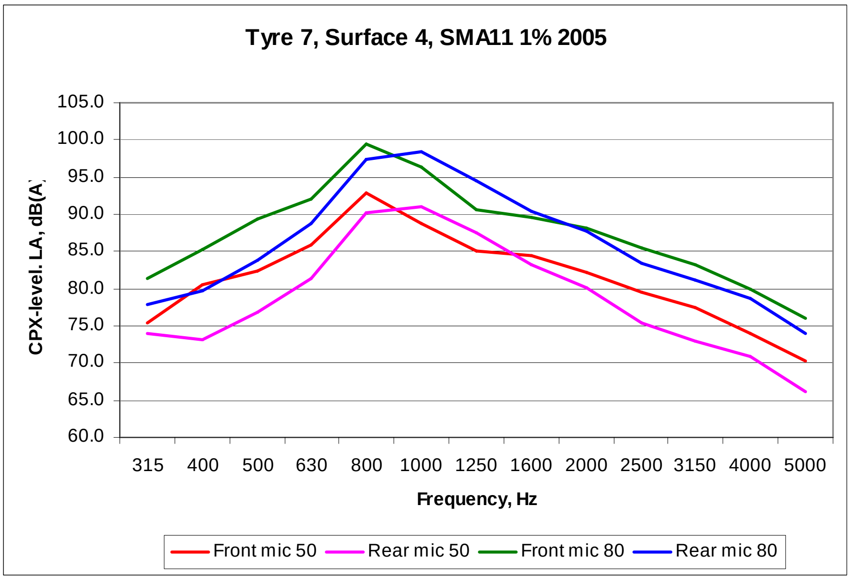
Tyre 7 – 205/55 R16

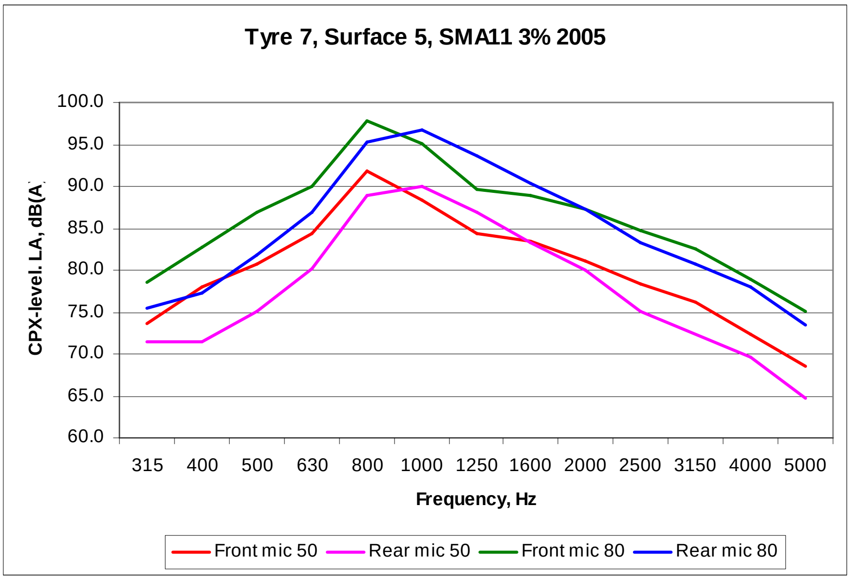


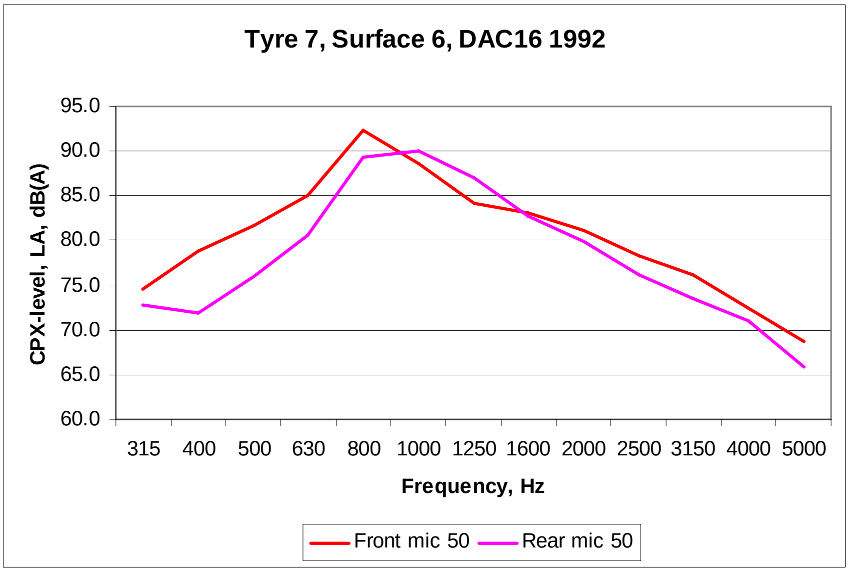



Tyre 7, Surface 2B, SMA11 2007
CPX-level. LA, dB(A)
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

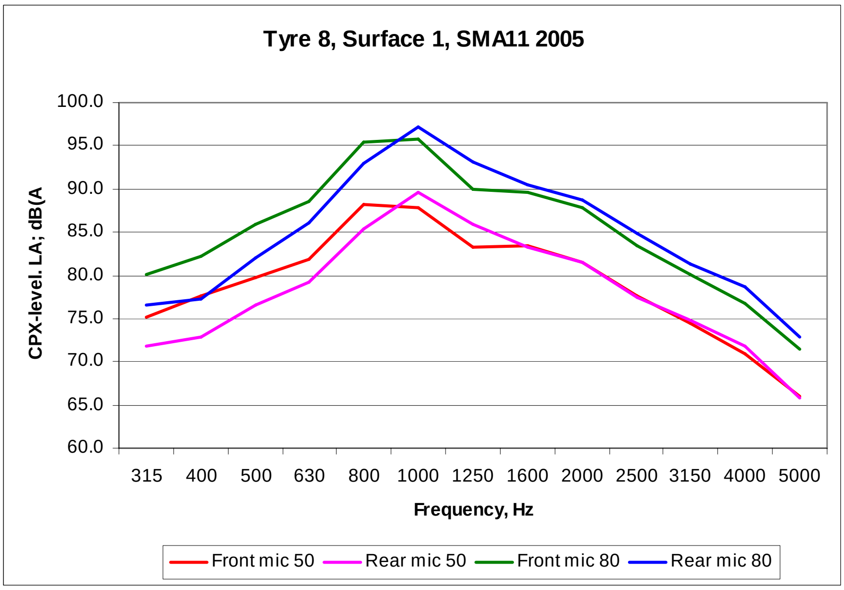

Tyre 7, Surface 3, SMA16 1999
CPX-level. LA, dB(A)
105.0
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

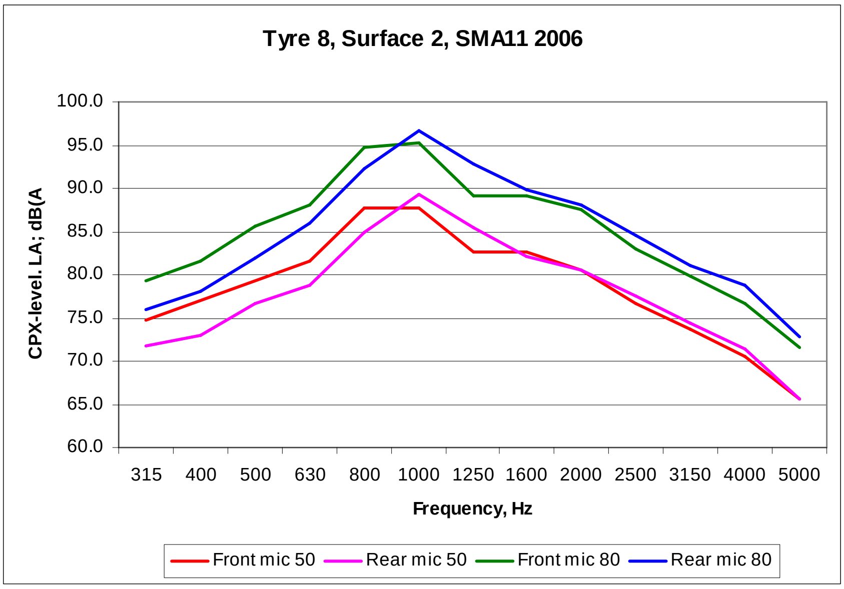

Tyre 7, Surface 4, SMA11 1% 2005
CPX-level. LA, dB(A)
105.0
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

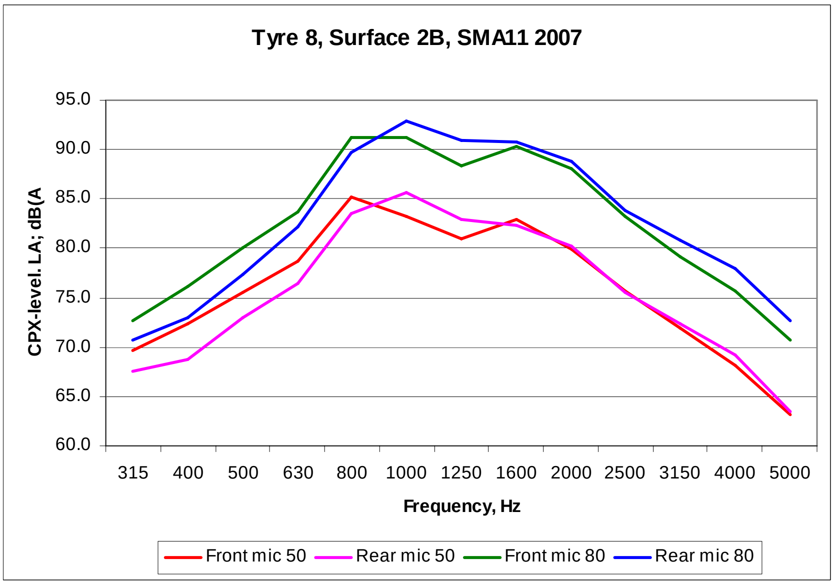


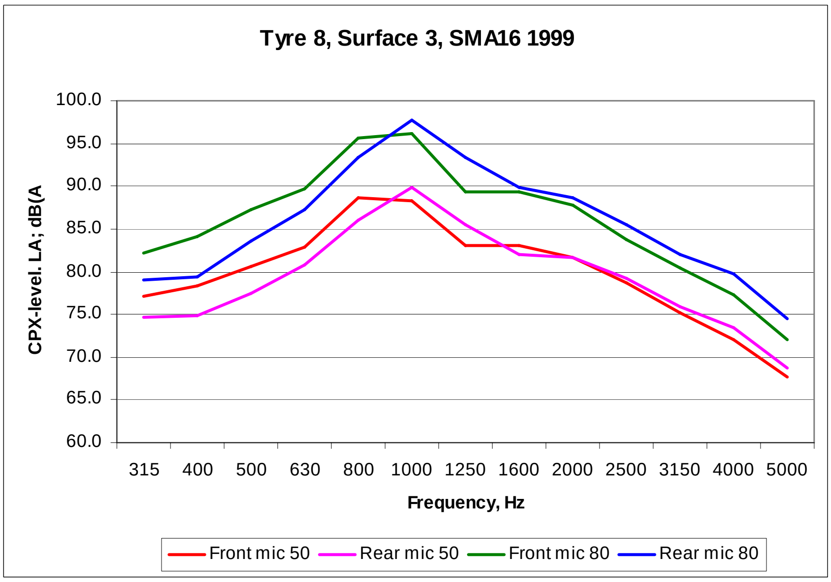


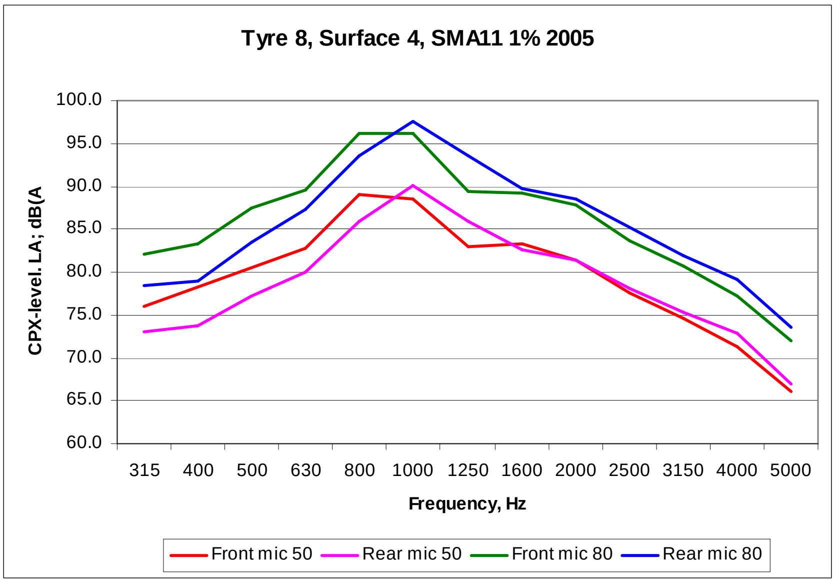
Tyre 8 – 205/55 R16



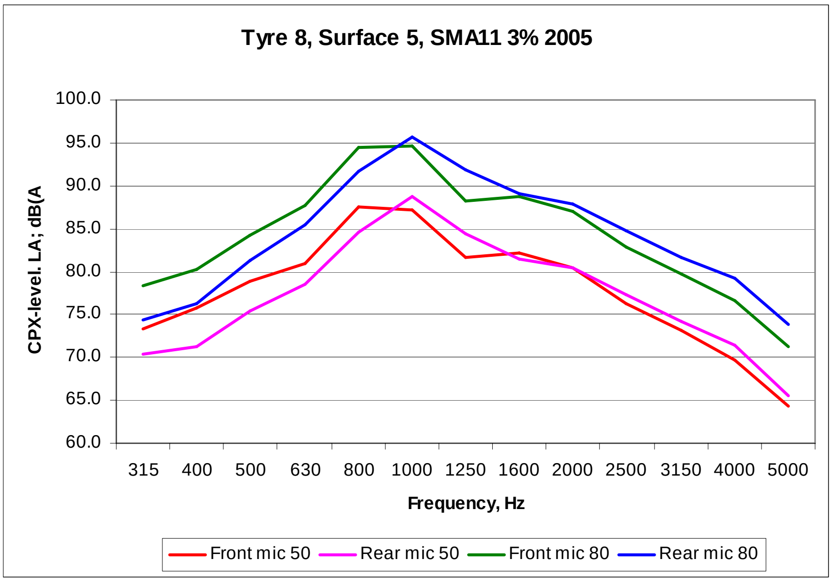

Tyre 8, Surface 2, SMA11 2006
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
CPX-level. LA; dB(A
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80


Tyre 8, Surface 2B, SMA11 2007
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
CPX-level. LA; dB(A
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

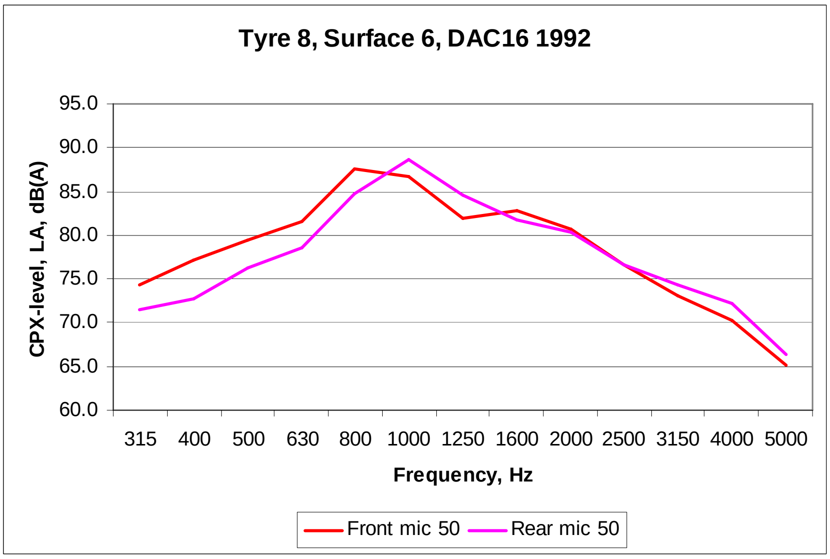

Tyre 8, Surface 3, SMA16 1999
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
CPX-level. LA; dB(A
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80



Tyre 8, Surface 4, SMA11 1% 2005
CPX-level. LA; dB(A
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

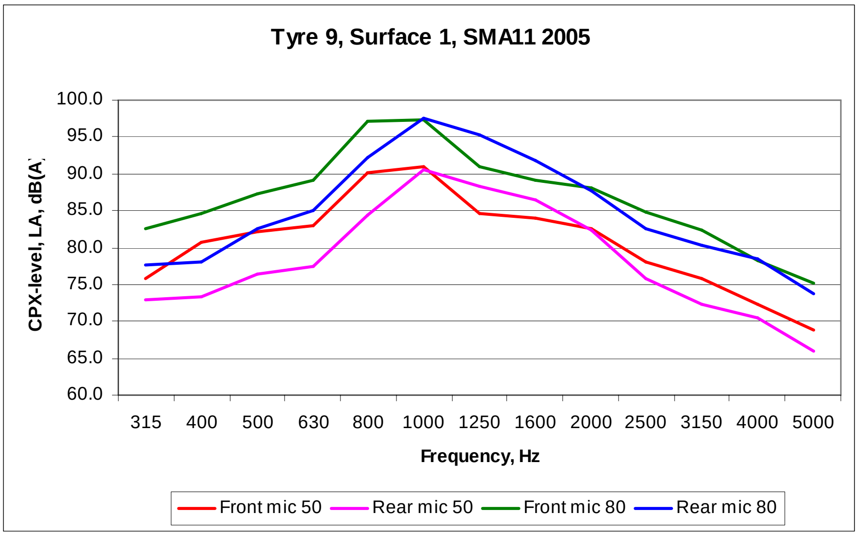


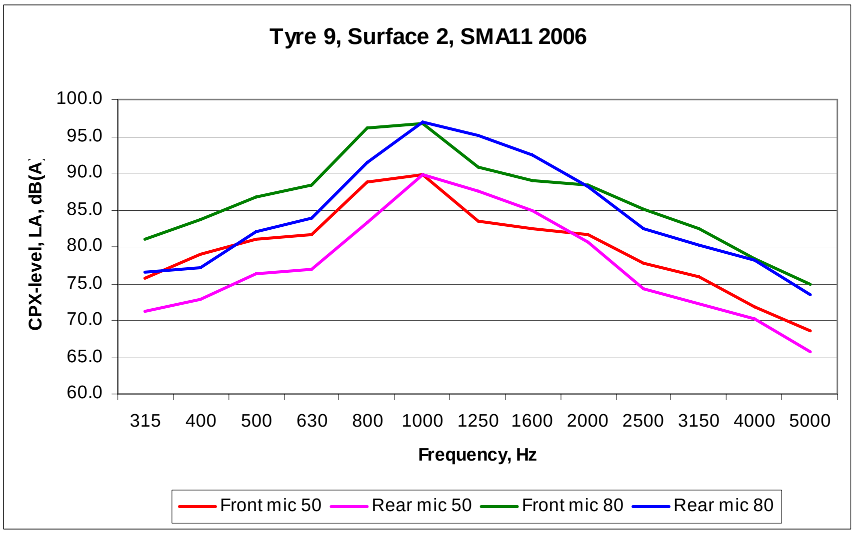
Tyre 8, Surface 5, SMA11 3% 2005
CPX-level. LA; dB(A
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

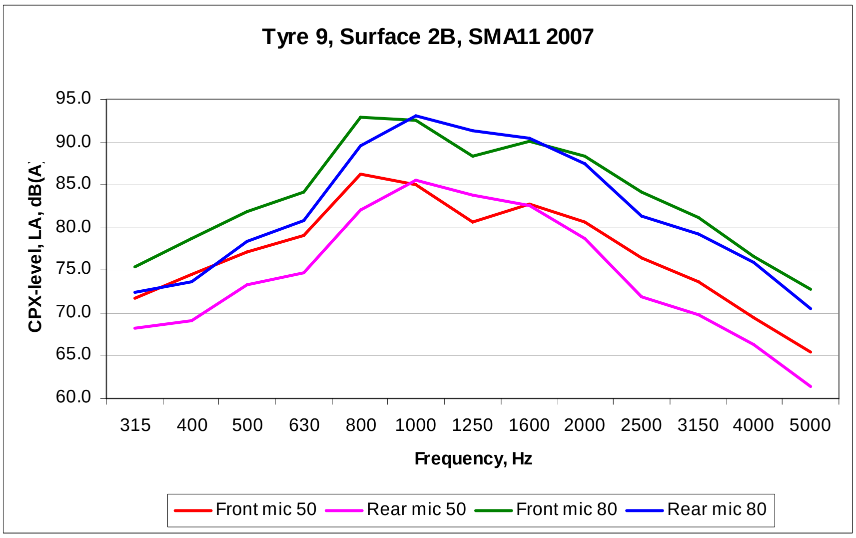


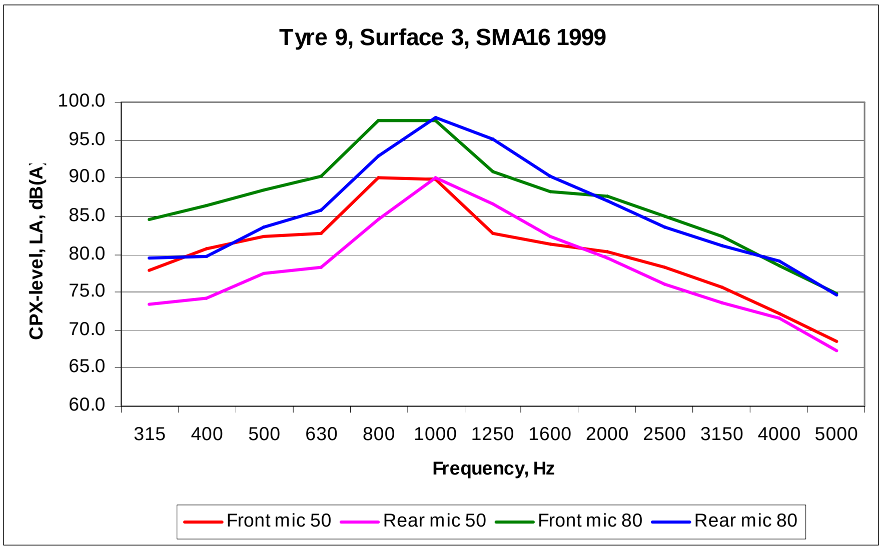
Tyre 8, Surface 6, DAC16 1992
CPX-level, LA, dB(A)
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50

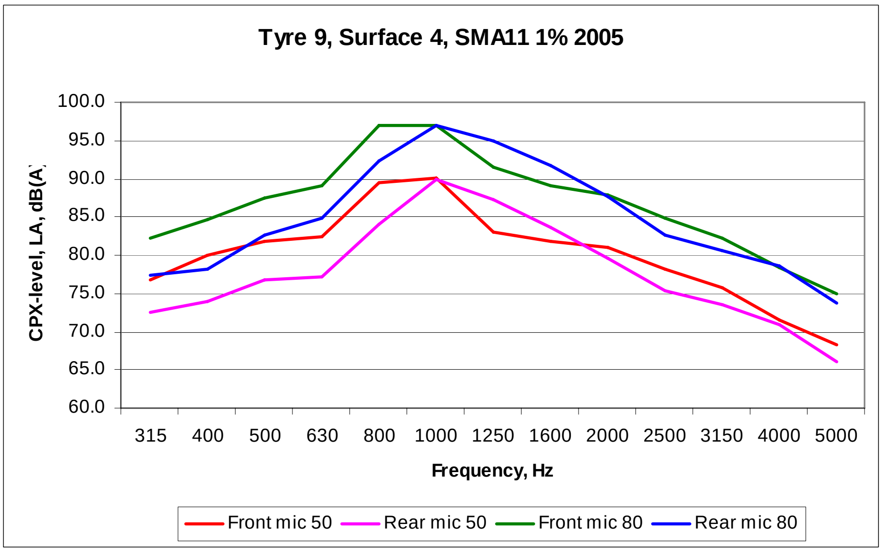
Tyre 9 – 215/55 R16

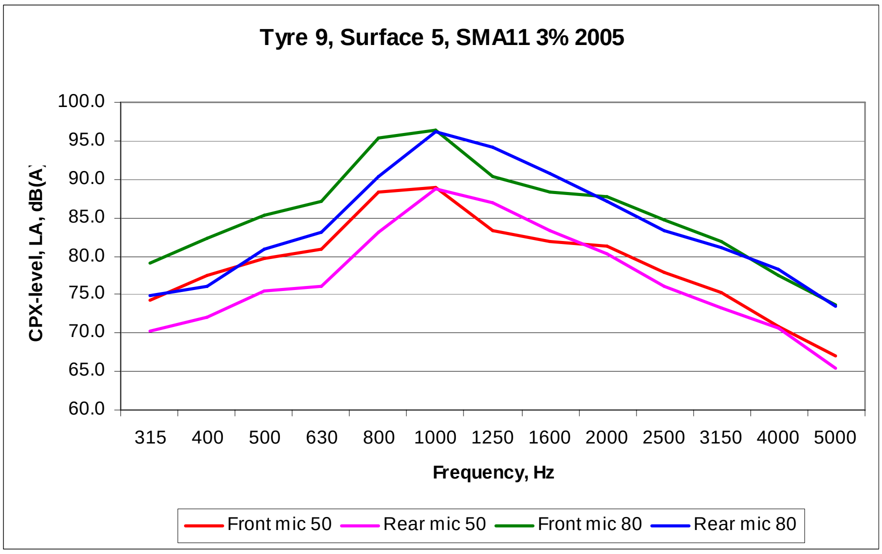


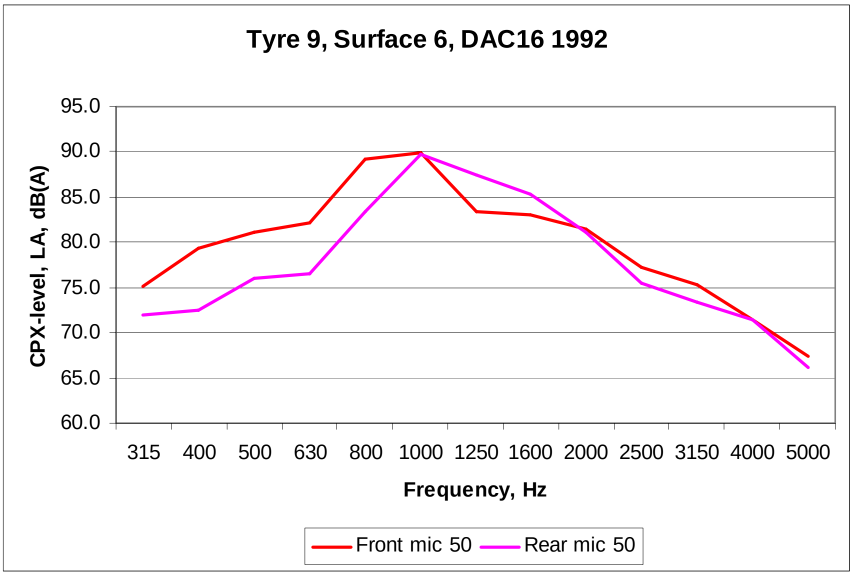




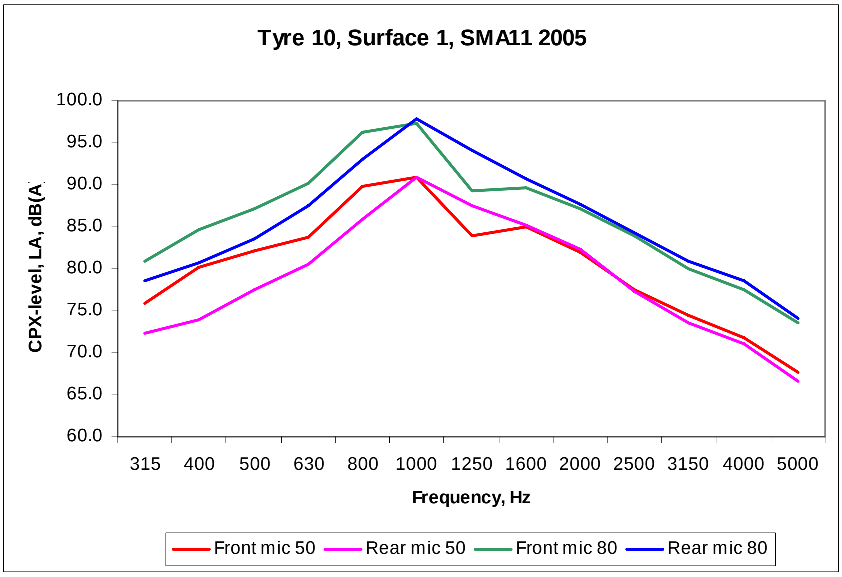

Tyre 9, Surface 3, SMA16 1999
CPX-level, LA, dB(A)
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
315
400
500
630
800
1000
1250
1600
2000
2500
3150
4000
5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

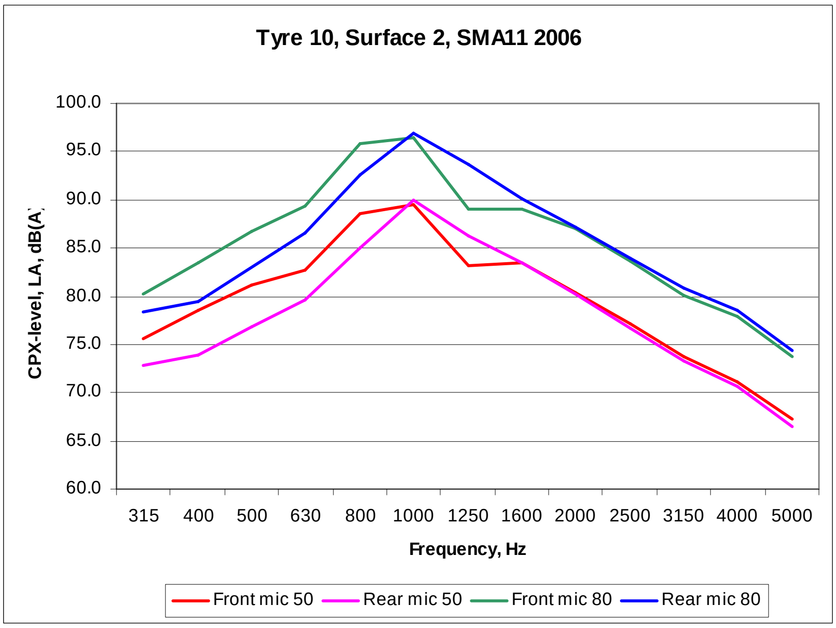

Tyre 9, Surface 4, SMA11 1% 2005
CPX-level, LA, dB(A)
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
315
400
500
630
800
1000
1250
1600
2000
2500
3150
4000
5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

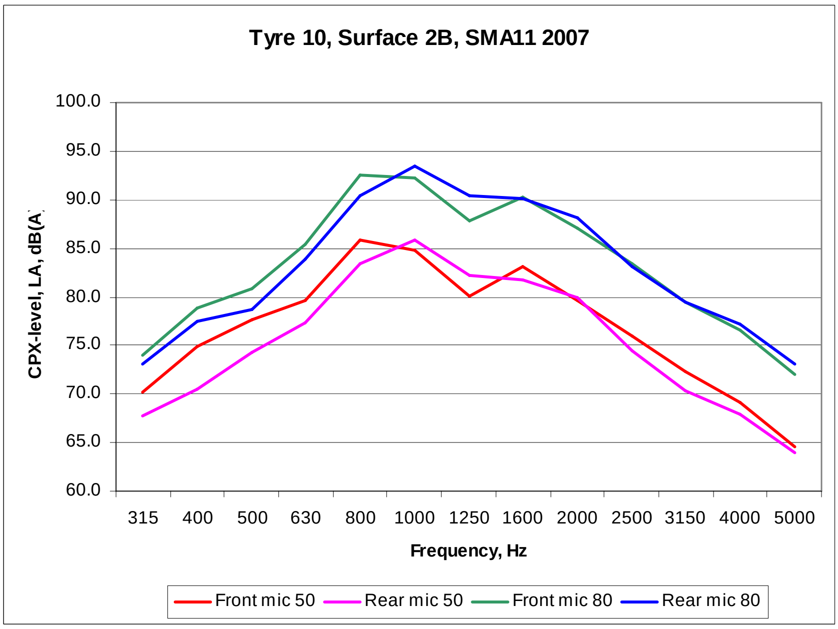

Tyre 9, Surface 5, SMA11 3% 2005
CPX-level, LA, dB(A)
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
315
400
500
630
800
1000
1250
1600
2000
2500
3150
4000
5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

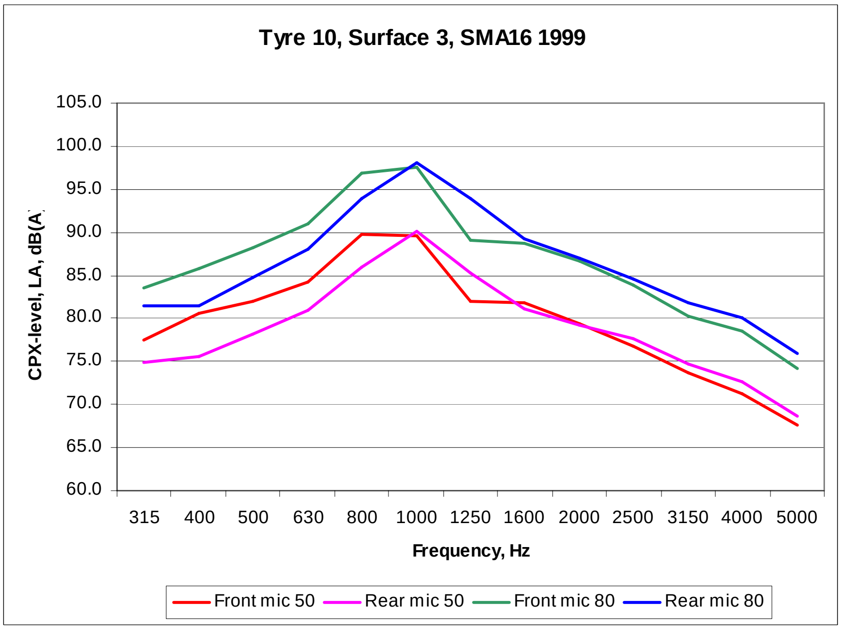


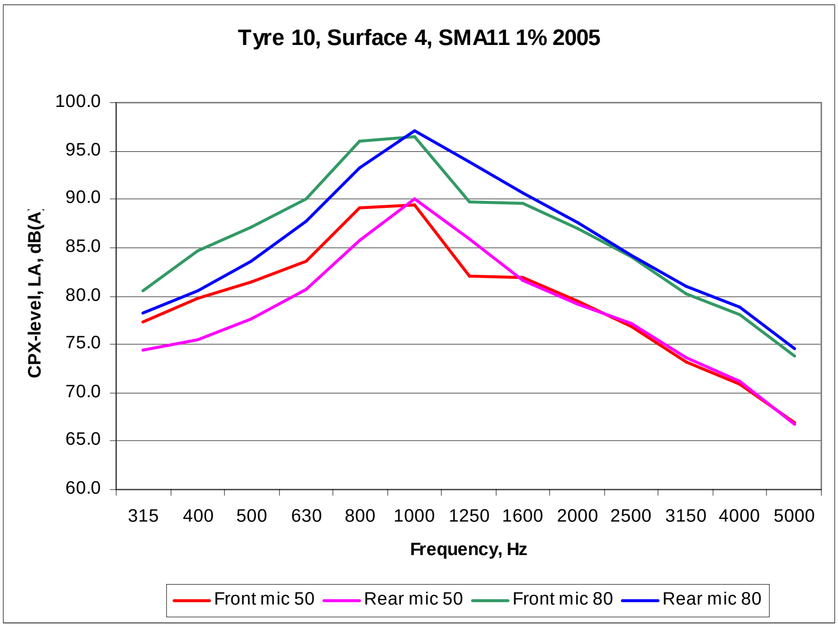
Tyre 10 – 215/55 R16

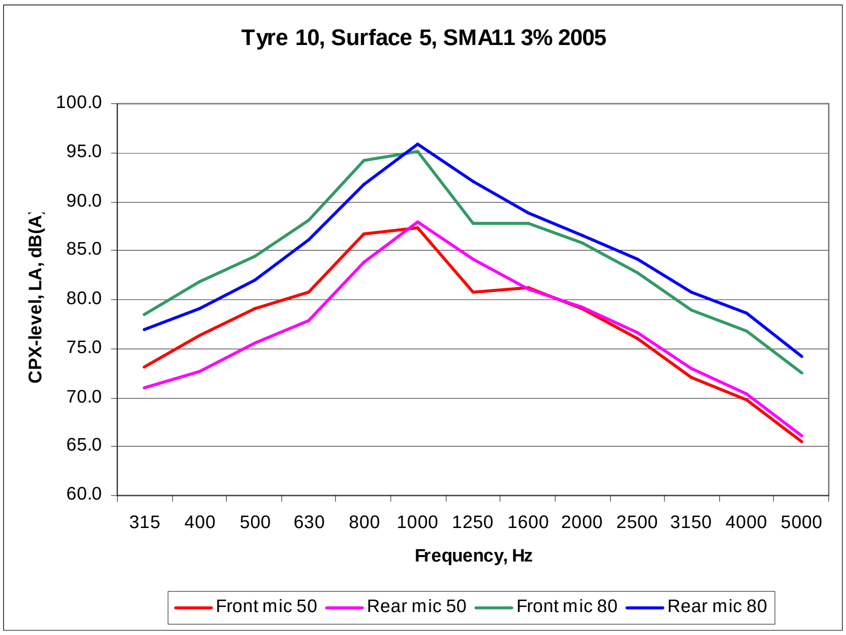


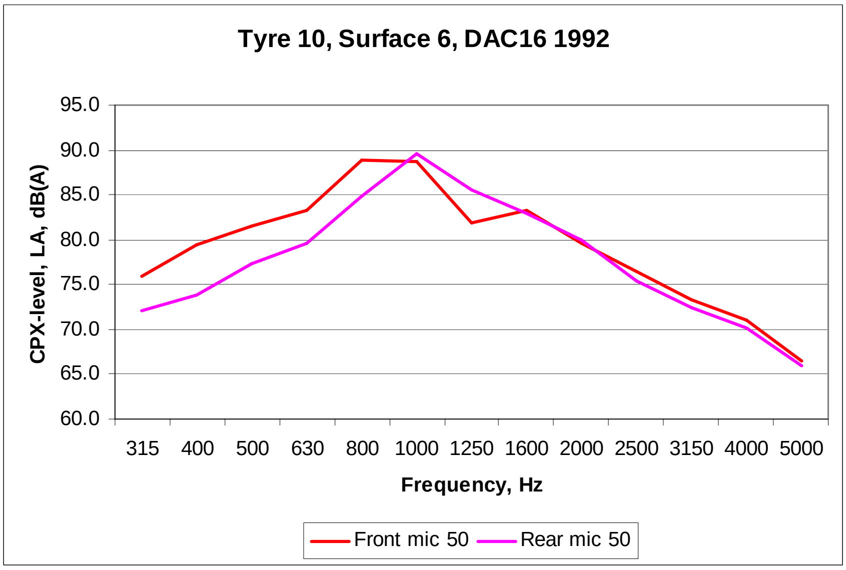

Tyre 10, Surface 2, SMA11 2006
CPX-level, LA, dB(A)
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80


Tyre 10, Surface 2B, SMA11 2007
CPX-level, LA, dB(A)
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

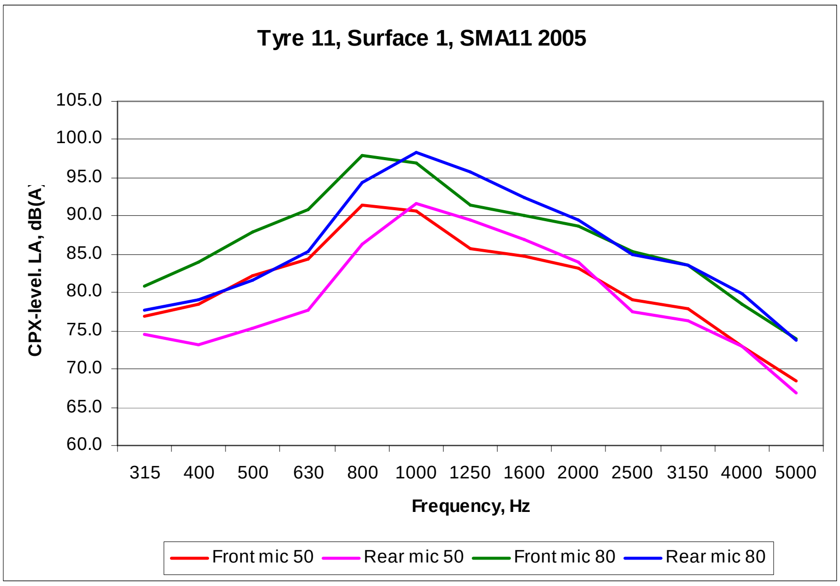

Tyre 10, Surface 3, SMA16 1999
CPX-level, LA, dB(A)
105.0
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

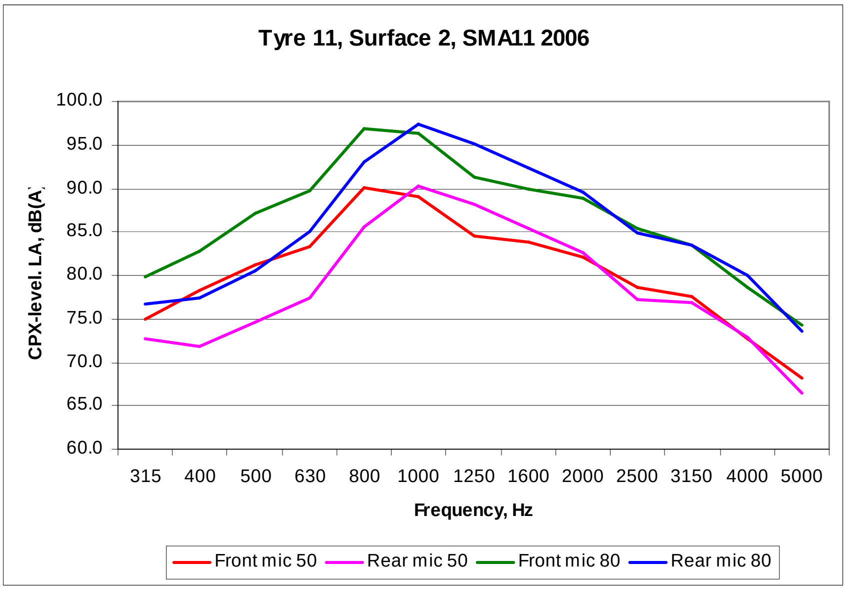

Tyre 10, Surface 4, SMA11 1% 2005
CPX-level, LA, dB(A)
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

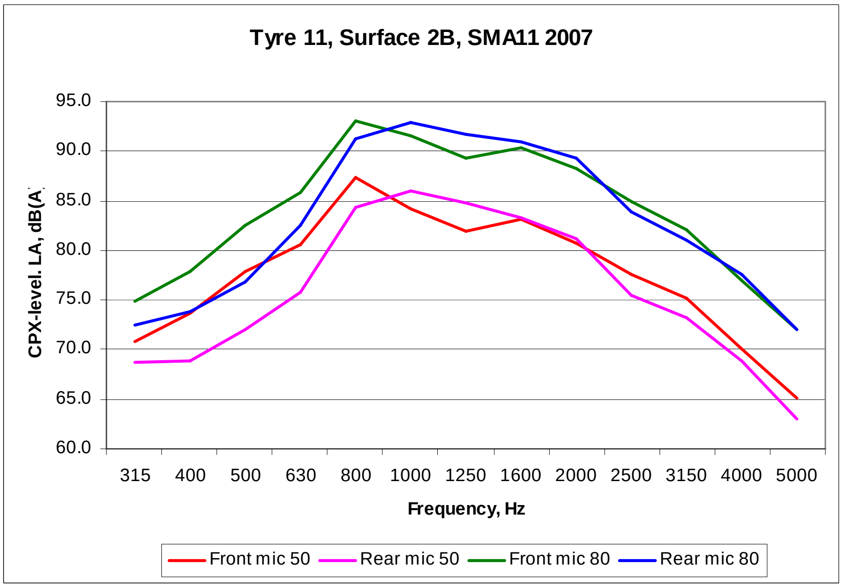

Tyre 10, Surface 5, SMA11 3% 2005
CPX-level, LA, dB(A)
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

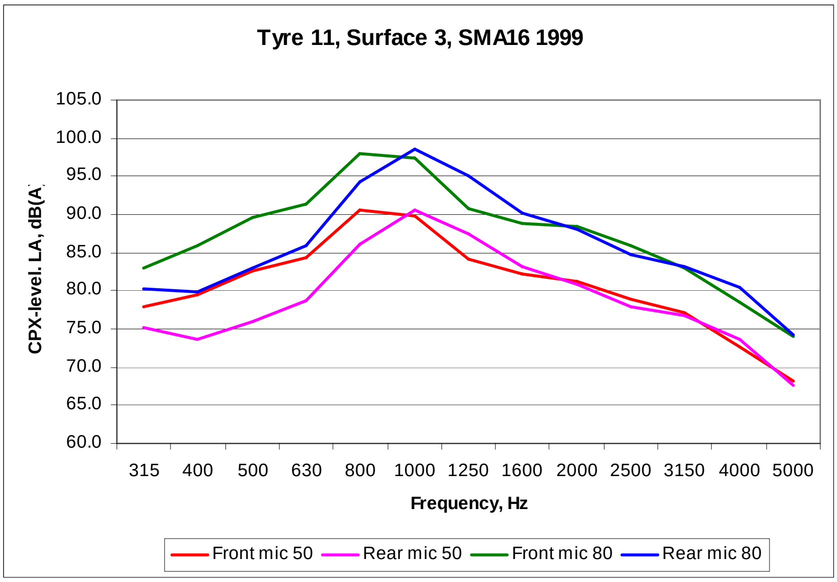

Tyre 10, Surface 6, DAC16 1992
CPX-level, LA, dB(A)
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50

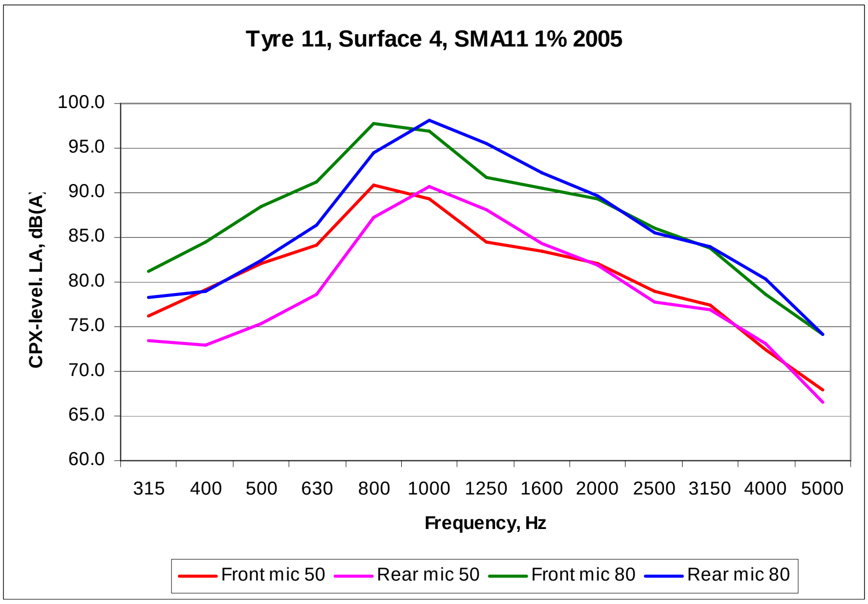
Tyre 11 – 195/65 R15

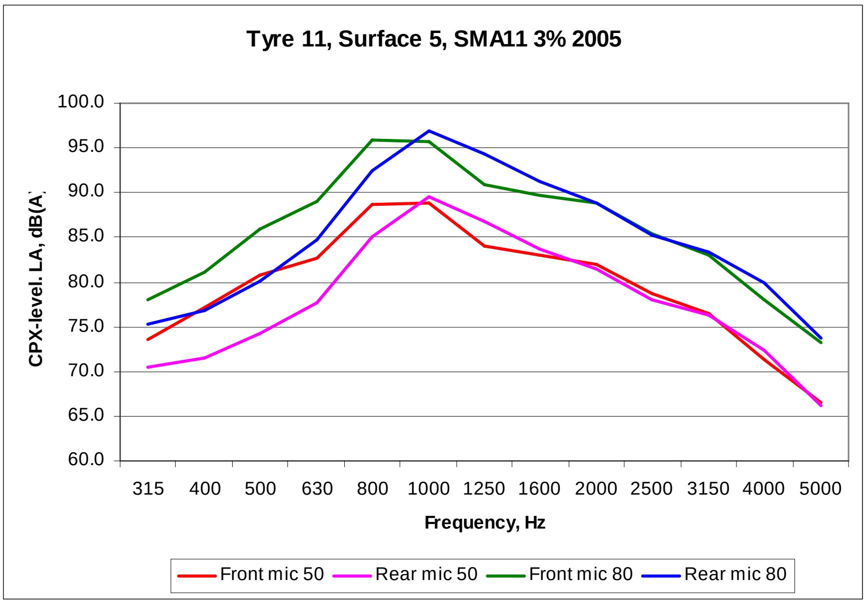


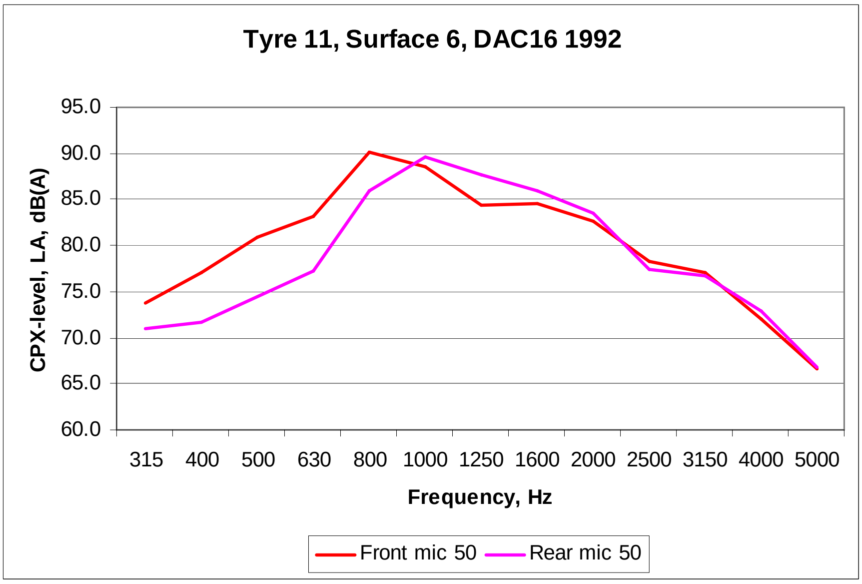




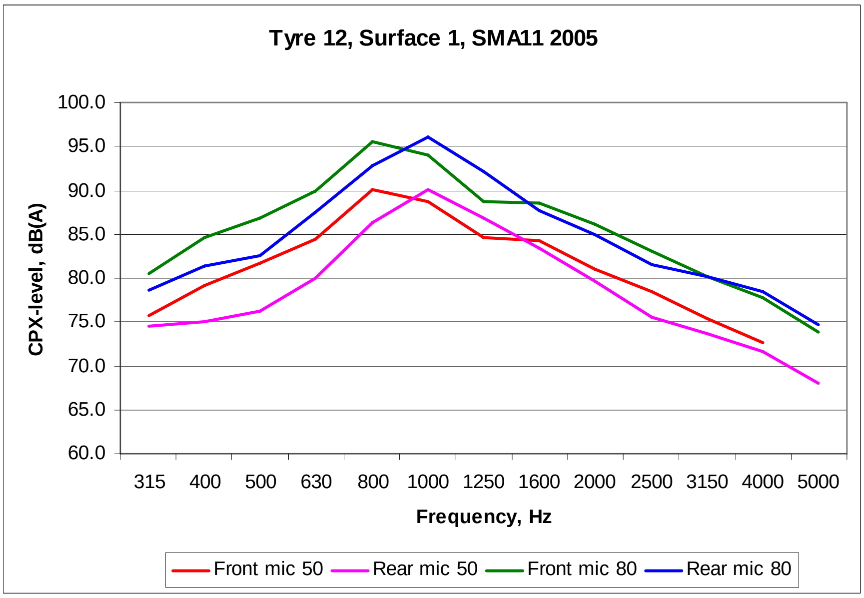

Tyre 11, Surface 3, SMA16 1999
CPX-level. LA, dB(A)
105.0
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

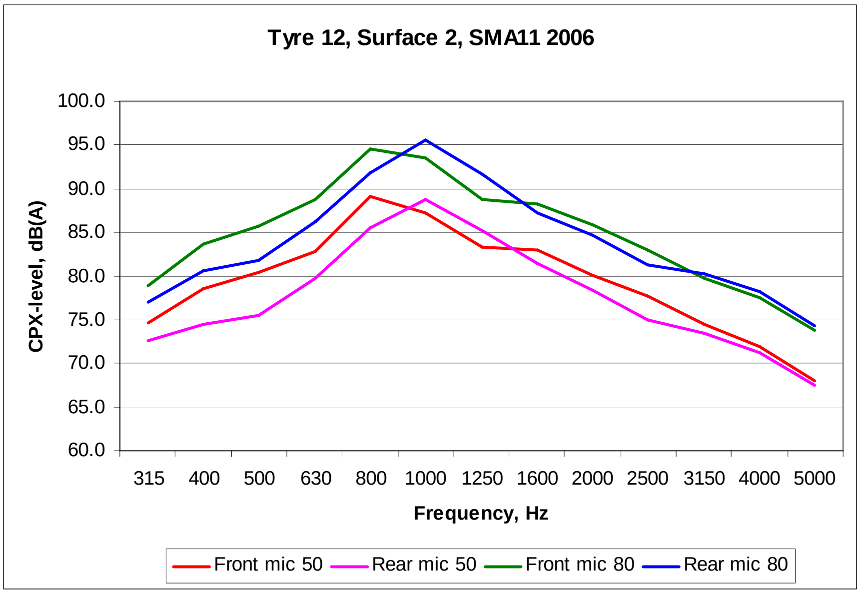

Tyre 11, Surface 4, SMA11 1% 2005
CPX-level. LA, dB(A)
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80

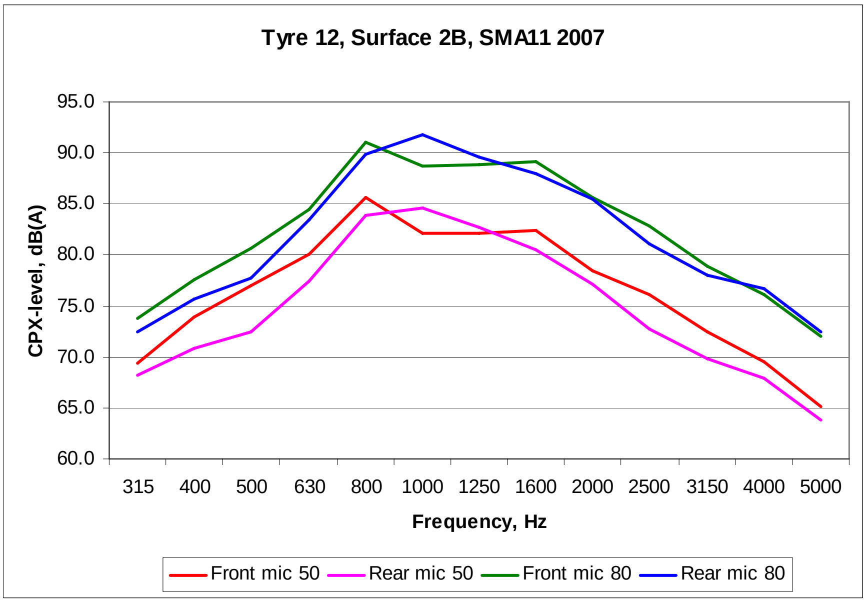


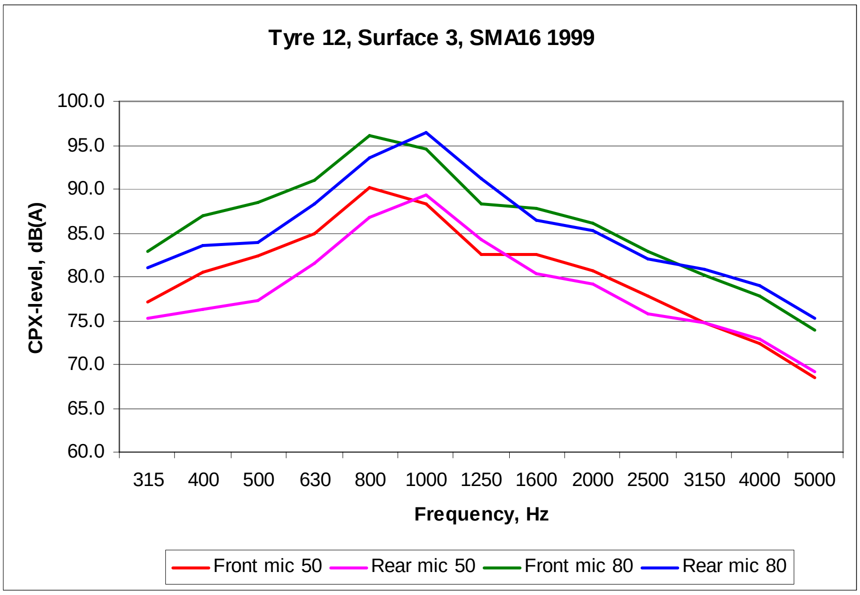


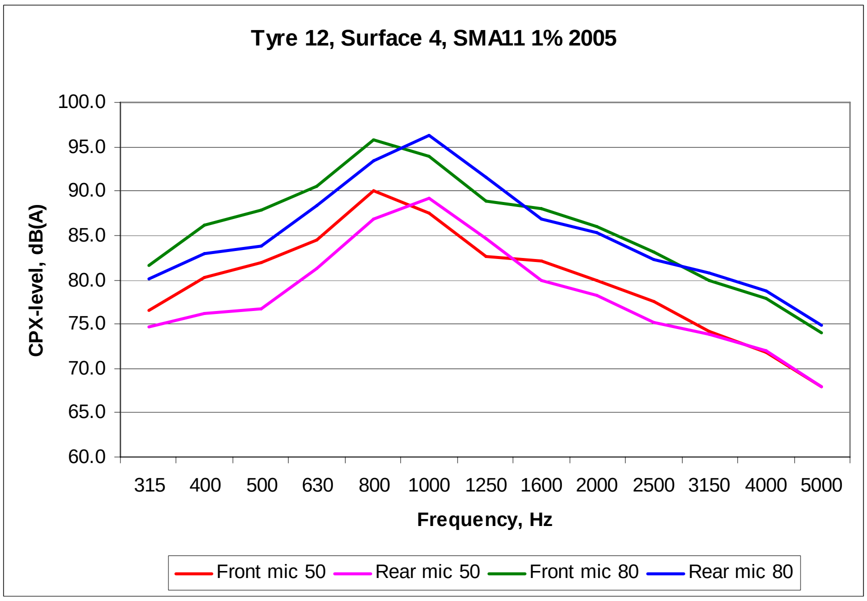
Tyre 12 – 185/65 R15

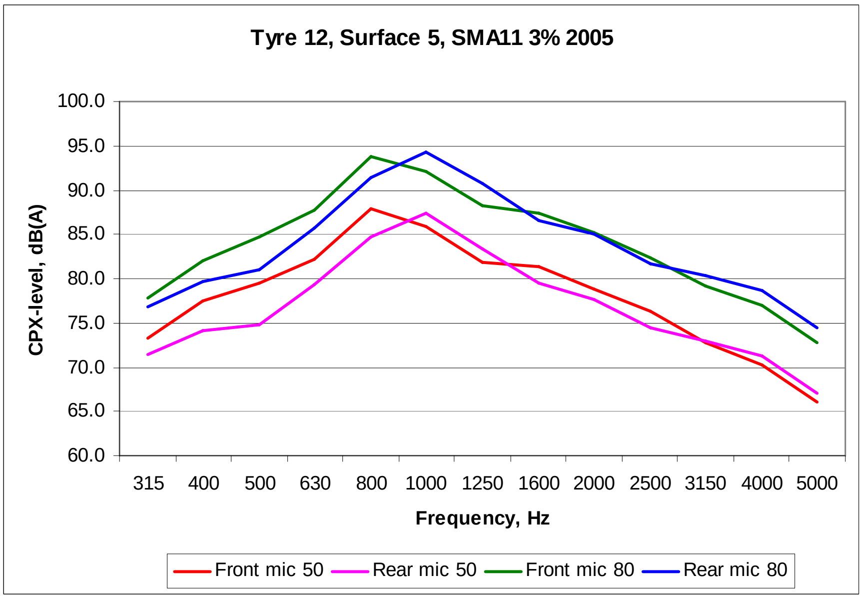


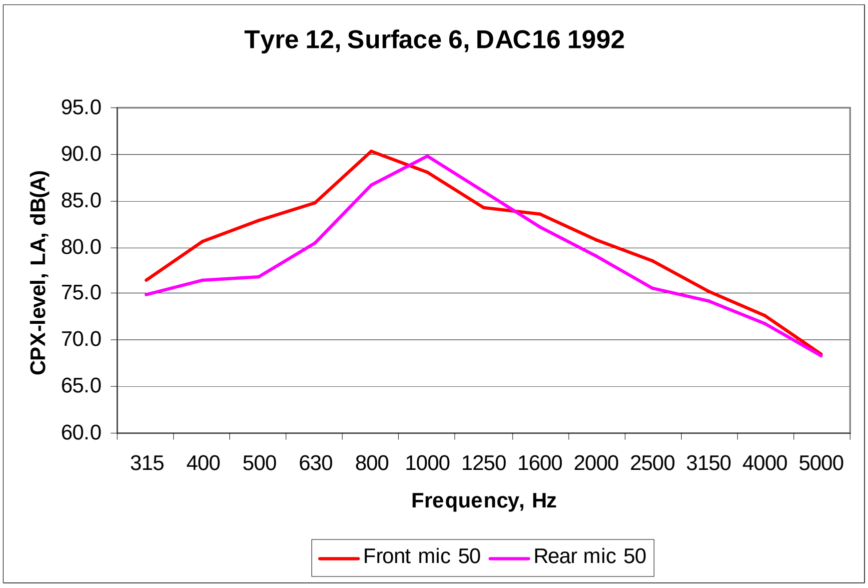

Tyre 12, Surface 2, SMA11 2006
CPX-level, dB(A)
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80


Tyre 12, Surface 2B, SMA11 2007
CPX-level, dB(A)
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80


Tyre 12, Surface 3, SMA16 1999
CPX-level, dB(A)
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80


Tyre 12, Surface 4, SMA11 1% 2005
CPX-level, dB(A)
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80


Tyre 12, Surface 5, SMA11 3% 2005
CPX-level, dB(A)
100.0
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50
Front mic 80
Rear mic 80


Tyre 12, Surface 6, DAC16 1992
CPX-level, LA, dB(A)
95.0
90.0
85.0
80.0
75.0
70.0
65.0
60.0
315 400 500 630 800 1000 1250 1600 2000 2500 3150 4000 5000
Frequency, Hz
Front mic 50
Rear mic 50