INTERCOMPARISON OF TRAFFIC NOISE COMPUTER SIMULATIONS

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INTRODUCTION

The proposal of starting this intercomparison came from the Scientific Committee of the Conference on "Traffic noise in Europe" organized by the Italian Acoustical Association (A.I.A) and the International Association Against Noise (AICB).
A previous intercomparison of computer programmes was organized by A.I.A. in 1989 [1], in which a very simple traffic configuration was investigated and the simulations compared with experimental measurements. In this project the traffic configurations proposed for the simulation are completely theoretical and therefore a true value of the results does not exist.
The aim of the project is to compare the results given by i) different programmes and, ii) by different users of the same programme.

DESCRIPTION OF THE TEST CASES

Two different traffic configurations have been proposed for the test: one very simple (case 1) and one more complex (case 2). The first case (case 1) concerns a motorway in flat country with just one building one hundred meters from the center line of the road; six receiver positions have been chosen, near and far away from the motorway. This case was divided in two parts, one without barriers (case 1A) and one with a barrier at one border of the road (case 1B). The second more complex configuration (case 2) concerns a junction of a motorway situated in country with hills, woods and residential buildings; fifteen receiver positions have been investigated. The receivers were positioned close to the source, in order to compare the source models, and far away, to test the sound attenuation models.
For a complete description of the two test cases, with geometric, acoustic and traffic data and the questionnaire on the programme features, see annexes 1 and 2.

PARTICIPANTS AND PROGRAMMES

Twenty-three participants, from eigtht different countries (A, D, DK, F, I, J, N, NL), have taken part in this intercomparison. The name and the address of the participants are in annex 3. Eleven different computer programmes have been compared. Four were developed by the users as research works, the other seven were commercial programmes: DGMR, LIMA, MITHRA, MICRO BRUIT, NBSTOY, RAYNOISE, SOUNDPLAN. Some participants have used more than one programme and some programmes have been used by more than one participant. Seven programmes give results directly in dB(A), the others also in frequency bands (1/1 octave). Table 1 shows the main features of the programmes.

RESULTS

The paper deals with results given in dB(A): the analysis of the sound pressure level prediction in 1/1 octave bands will be discussed in a further paper.
The results have been analysed using very simple statistical parameters such as the average value, the difference between the maximum and minimum value and the standard deviation.

Case 1

All the participants give predictions for this case. Table 2 summarises the results for the traffic configuration 1/A (without the barrier). Programmes are identified by letters from A to M. For each position and for each programme the table gives the mean value of the sound pressure level (dB(A)) and, when possible, the difference between Lmax and Lmin. The last four columns show the average values of the mean sound pressure levels given by each programme, the maximum and the minimum of such levels and their difference. Table 3 shows the same data for case 1/B (with the barrier). In order to compare the barrier attenuation predicted by the programmes, table 4 shows the differences between cases 1/A and 1/B. The same results are described in graphic form in figures 1 to 3.
Figures 17 to 22 show, for each position, the values of the sound pressure level predicted by the different users. The repetition of the same number means that the simulations have been carried out by different users of the same participant, or by the same participant with different programmes, or introducing different programme parameters. In the latter case only the simulation with the programme parameters close to that proposed by the organizers of the intercomparison, has been considered in the calculation of the mean values for each programme. The same figures also report the average values of all the sound pressure levels predicted, the difference between the maximum and the minimum values and the standard deviation.
Figures 23 to 28 shows the barrier attenuation in each position.

In order to point out the differences in the sound propagation model, in figures 29 and 30, the sound pressure level differences between position 1 (nearest to the source) and both positions 2 and 3, are reported.
Figures 4 to 12 report the sound pressure level values in each receiver position predicted by different users of the same programme. The number of users made this comparison possible only for programmes B, C and D.
Case 2

Not all the participants gave predictions for this more complex case. Table 5 summarises the results for this configuration. In the table, the meaning of the values are as described in case 1. Figure 13 shows the same results in graphic form. Figures 31 to 45 show the sound pressure level in each position, for each participant.
Figures 14 to 16 report the sound pressure level values in each receiver position predicted by different users of the same programme.

CONSIDERATIONS AND CONCLUSIONS

The analysis of the results shows that the differences between the programmes are relevant not only far away from the source, but also near.
In case 1/A, in the nearest position (position 1) the difference (Lmax-Lmin) is 8 dB(A) and the standard deviation is 2.7. This means that the source models introduce significant differences in the prediction.
The data of figures 29 and 30 show that the standard deviation of the differences from point 1 to point 2 and also from point 1 to point 3 are not so large as near the source (posisition 1). Therefore the propagation models seem to introduce smaller differences in the prediction results with respect to the source models.
Significant differences between the different programmes have beeen found in the barrier attenuation (table 4 and figure 3).
Considering programmes B, C and D, the differences between the results given by different users of the same programme are quite small.
From figures 5 to 16, it is possible to see that all the results are very close to the average values with the exception of a few predictions.
The evaluation of results in case 2 is more complex but it seems possible to arrive at a similar conclusion as in case 1.
It seems that there is a strong need to standardize these models at an international level, as ISO is doing with the DIS 9613/2 " Attenuation of sound during propagation outdoors". Moreover it is considered useful to proceed with the intercomparison with a real traffic situation where it will be possible to take measurements of traffic flow, vehicle velocity, meteorological and acousical parameters.

ACKNOWLEDGMENTS

The Authors are grateful for the cooperation of all the participants. Special thanks to the Environmental Acoustic Group (G.A.A.) of the Italian Acoustical Association (A.I.A.) for the support in the organization of the project.

REFERENCES

[1] *Numerical methods for road traffic noise prediction* (in italian), in proc. of the Italian Acoustics Association (AIA), edit by R. Pompoli, Parma, 1989.
[2] ISO/DIS 9613/2, *Attenuation of sound during propagation outdoors*.

Programmes	Commercial	Output	Mathematical model
ASJ	Not	dB(A)	Empiric formulae
DGMR	Yes	dB(A) + freq.bands	Empiric formulae + image sources
LIMA	Yes	dB(A)	Empiric formulae
MIHTRA	Yes	dB(A) + freq.bands	Ray tracing
MICRO-BRUIT	Yes	dB(A) + freq.bands	Ray tracing + image sources
NBSTOY	Yes	dB(A)	Empiric formulae
RAY NOISE	Yes	dB(A) + freq.bands	Ray +beam tracing
RLSTR81	Not	dB(A)	Empiric formulae
ROAR 1.1	Not	dB(A)	Empiric formulae
RVS 3.114	Not	dB(A)	Empiric formulae
SOUND PLAN	Yes	dB(A)	Ray + beam tracing

Table 1: main features of the programmes

Position in the map	Programme	A	B	C	D	E	F	G	H	I	L	M	Lmed	Lmax	Lmin	Lmax-Lmin	Std. dev.
	Number of users	*1*	*6*	*4*	*4*	*2*	*3*	*1*	*1*	*1*	*1*	*1*					
1	Mean values	***65.7***	***71.5***	***67.5***	***69.2***	***73.0***	***71.6***	***69.7***	***65.0***	***71.3***	***71.5***	***67.5***	**69.4**	*73.0*	*65.0*	*8.0*	*2.7*
	Lmax-Lmin		*3.3*	3.4	2.7	0.0	0.5										
2	Mean values	***63.4***	***66.8***	***62.7***	***64.4***	***70.3***	***66.8***	***66.0***	***61.6***	***67.2***	***68.5***	***63.1***	**65.5**	*70.3*	*61.6*	*8.7*	*2.7*
	Lmax-Lmin		*1.0*	3.3	3.7	0.5	0.5										
3	Mean values	***60.1***	***64.7***	***59.3***	***62.2***	***68.0***	***63.4***	***64.3***	***60.3***	***62.8***	***67.3***	***60.8***	**63.0**	*68.0*	*59.3*	*8.7*	*2.9*
	Lmax-Lmin		*2.7*	3.3	4.3	0.0	2.5										
4	Mean values	***60.4***	***65.2***	***63.5***	***63.9***	***72.0***	***63.8***	***65.1***	***63.1***	***62.8***	***67.9***	***62.1***	**64.5**	*72.0*	*60.4*	*11.6*	*3.1*
	Lmax-Lmin		*2.8*	3.2	3.7	0.0	2.5										
5	Mean values	***60.3***	***65.6***	***65.7***	***64.7***	***72.5***	***64.2***	***66.3***	***64.2***	***62.8***	***67.5***	***63.0***	**65.2**	*72.5*	*60.3*	*12.2*	*3.1*
	Lmax-Lmin		*2.8*	3.1	3.1	1.0	2.5										
6	Mean values	***53.6***	***52.3***	***43.4***	***48.5***	***47.5***	***52.4***	***54.8***	***41.5***	***51.5***	***55.7***	***47.7***	**49.9**	*55.7*	*41.5*	*14.2*	*4.6*
	Lmax-Lmin		*3.2*	4.0	5.6	9.0	1.4										

Table 2: Case 1-A: mean values for each of the 11 simulation programmes

Position in the map	Programme	A	B	C	D	E	F	G	H	I	L	M	Lmed	Lmax	Lmin	Lmax-Lmin	Std. dev.
	Number of users	*1*	*6*	*4*	*4*	*2*	*3*	*1*	*1*	*1*	*1*	*1*					
1	Mean values	***54.7***	***59.2***	***55.6***	***56.9***	***56.0***	***59.9***	***57.8***	***53.6***	***56.0***	***59.0***	***52.1***	**56.4**	*59.9*	*52.1*	*7.8*	*2.4*
	Lmax-Lmin		*4.1*	3.2	3.6	2.0	0.2										
2	Mean values	***50.5***	***56.6***	***52.5***	***53.0***	***55.0***	***57.3***	***55.4***	***50.6***	***52.4***	***56.2***	***48.8***	**53.5**	*57.3*	*48.8*	*8.5*	*2.8*
	Lmax-Lmin		*4.5*	3.5	4.0	2.0	0.3										
3	Mean values	***46.2***	***55.5***	***50.5***	***51.2***	***55.5***	***54.9***	***54.9***	***49.9***	***48.3***	***55.2***	***46.9***	**51.7**	*55.5*	*46.2*	*9.3*	*3.6*
	Lmax-Lmin		*5.1*	3.4	4.4	1.0	3.5										
4	Mean values	***45.2***	***56.0***	***52.0***	***52.6***	***55.5***	***55.4***	***55.4***	***51.2***	***48.8***	***55.8***	***49.1***	**52.5**	*56.0*	*45.2*	*10.8*	*3.6*
	Lmax-Lmin		*4.9*	3.5	4.0	1.0	3.3										
5	Mean values	***45.7***	***56.5***	***53.1***	***53.6***	***55.3***	***55.9***	***55.8***	***51.6***	***49.3***	***55.4***	***50.4***	**53.0**	*56.5*	*45.7*	*10.8*	*3.4*
	Lmax-Lmin		*4.8*	3.8	3.7	1.5	3.2										
6	Mean values	***44.7***	***48.8***	***40.9***	***41.0***	***48.0***	***49.9***	***47.7***	***39.9***	***43.7***	***45.2***	***39.8***	**44.5**	*49.9*	*39.8*	*10.1*	*3.7*
	Lmax-Lmin		*9.4*	4.2	3.3	4.0	2.7										

Table 3: Case 1-B: mean values for each of the 11 simulation programmes

Position in the map	Programme	A	B	C	D	E	F	G	H	I	L	M	med	max	min	Lmax-Lmin	Std. dev.
	Number of users	*1*	*6*	*4*	*4*	*2*	*3*	*1*	*1*	*1*	*1*	*1*					
1	Mean values	***11.0***	***12.4***	***11.9***	***12.3***	***17.0***	***11.7***	***11.9***	***11.4***	***15.3***	***12.5***	***15.4***	**13.0**	*17.0*	*11.0*	*6.0*	*2.0*
	max-min		1.3	0.8	1.0	2.0	0.5										
2	Mean values	***12.9***	***10.2***	***10.2***	***11.3***	***15.3***	***9.5***	***10.6***	***11.0***	***14.8***	***12.3***	***14.3***	**12.0**	*15.3*	*9.5*	*5.7*	*2.0*
	max-min		3.6	1.1	0.4	2.5	0.6										
3	Mean values	***13.9***	***9.2***	***8.8***	***11.0***	***12.5***	***8.5***	***9.4***	***10.4***	***14.5***	***12.1***	***13.9***	**11.3**	*14.5*	*8.5*	*6.0*	*2.2*
	max-min		5.0	0.9	0.2	1.0	1.2										
4	Mean values	***15.2***	***9.2***	***11.5***	***11.4***	***16.5***	***8.4***	***9.7***	***11.9***	***14.0***	***12.1***	***13.0***	**12.1**	*16.5*	*8.4*	*8.1*	*2.5*
	max-min		5.3	0.8	0.5	1.0	1.1										
5	Mean values	***14.6***	***9.1***	***12.6***	***11.0***	***17.3***	***8.3***	***10.5***	***12.6***	***13.5***	***12.1***	***12.6***	**12.2**	*17.3*	*8.3*	*9.0*	*2.5*
	max-min		5.1	0.9	0.6	0.5	1.0										
6	Mean values	***8.9***	***3.5***	***2.5***	***7.5***	***-0.5***	***2.6***	***7.1***	***1.6***	***7.8***	***10.5***	***7.9***	**5.4**	*10.5*	*-0.5*	*11.0*	*3.6*
	max-min		6.3	1.5	2.3	5.0	1.3										

Table 4: barrier attenuation (defferences between case 1-A and case 1-B)

Position in the map	Programme / Number of users	A	B	C	D	E	F	G	H	I	L	M	Lmed	Lmax	Lmin	Lmax-Lmin	Std. dev.
	Number of users	*0*	*6*	*4*	*4*	*0*	*3*	*1*	*1*	*1*	*1*	*1*					
1	Mean values		***71.4***	***66.5***	***69.1***		***69.8***	***67.6***	***65.5***	***69.3***	***72.5***	***69.9***	**69.1**	*72.5*	*65.5*	*7.0*	*2.2*
	Lmax-Lmin		*6.2*	1.0	5.5		2.0										
2	Mean values		***71.4***	***70.3***	***70.5***		***70.0***	***68.5***	***66.8***	***69.0***	***73.2***	***70.6***	**70.0**	*73.2*	*66.8*	*6.4*	*1.8*
	Lmax-Lmin		*5.4*	0.6	5.4		2.5										
3	Mean values		***71.6***	***72.0***	***70.5***		***70.7***	***69.5***	***68.4***	***69.1***	***73.5***	***70.5***	**70.6**	*73.5*	*68.4*	*5.1*	*1.6*
	Lmax-Lmin		*4.7*	0.5	6.0		2.3										
4	Mean values		***66.4***	***58.5***	***62.9***		***60.2***	***60.8***	***57.2***	***58.2***		***63.7***	**61.0**	*66.4*	*57.2*	*9.2*	*3.1*
	Lmax-Lmin		*10.5*	4.0	6.1		4.9										
5	Mean values		***65.2***	***62.8***	***64.0***		***59.1***	***56.6***	***59.1***	***48.8***		***63.8***	**59.9**	*65.2*	*48.8*	*16.4*	*5.4*
	Lmax-Lmin		*6.4*	1.3	5.6		9.8										
6	Mean values		***65.7***	***64.3***	***63.5***		***62.8***	***60.8***	***59.9***	***54.9***		***64.1***	**62.0**	*65.7*	*54.9*	*10.8*	*3.4*
	Lmax-Lmin		*6.2*	1.2	6.5		2.8										
7	Mean values		***65.7***	***61.3***	***64.9***		***66.0***	***63.1***	***60.8***	***62.3***		***65.2***	**63.7**	*66.0*	*60.8*	*5.2*	*2.1*
	Lmax-Lmin		*8.5*	1.5	5.6		1.8										
8	Mean values		***65.9***	***64.8***	***66.4***		***66.1***	***63.5***	***61.4***	***63.0***		***66.5***	**64.7**	*66.5*	*61.4*	*5.1*	*1.9*
	Lmax-Lmin		*8.2*	0.9	5.6		2.2										
9	Mean values		***66.6***	***67.4***	***67.1***		***66.7***	***65.6***	***62.7***	***64.6***		***66.4***	**65.9**	*67.4*	*62.7*	*4.7*	*1.6*
	Lmax-Lmin		*6.8*	0.7	6.4		1.5										
10	Mean values		***61.3***	***53.8***	***54.0***		***59.0***	***59.2***	***54.5***	***56.0***		***59.6***	**57.2**	*61.3*	*53.8*	*7.5*	*2.9*
	Lmax-Lmin		*8.7*	3.4	7.8		3.1										
11	Mean values		***62.3***	***56.4***	***56.3***		***60.1***	***61.2***	***60.2***	***57.8***		***60.7***	**59.4**	*62.3*	*56.3*	*6.0*	*2.3*
	Lmax-Lmin		*7.0*	2.8	7.5		3.4										
12	Mean values		***63.1***	***60.5***	***60.6***		***62.1***	***63.4***	***64.0***	***59.2***		***61.7***	**61.8**	*64.0*	*59.2*	*4.8*	*1.7*
	Lmax-Lmin		*4.7*	3.2	6.3		3.0										
13	Mean values		***78.5***	***77.6***	***78.9***		***78.7***	***77.6***	***73.4***	***78.0***		***77.7***	**77.5**	*78.9*	*73.4*	*5.5*	*1.8*
	Lmax-Lmin		*7.0*	0.3	3.1		0.5										
14	Mean values		***78.9***	***77.6***	***78.9***		***79.3***	***77.6***	***73.8***	***79.0***	***78.5***	***78.2***	**78.0**	*79.3*	*73.8*	*5.5*	*1.7*
	Lmax-Lmin		*7.4*	0.8	3.5		0.7										
15	Mean values		***65.5***	***60.3***	***63.7***		***64.7***	***64.1***	***59.7***	***65.1***	***67.2***	***64.0***	**63.8**	*67.2*	*59.7*	*7.5*	*2.4*
	Lmax-Lmin		*5.5*	1.9	6.2		1.0										

Table 5: Case 2: mean values for each of the 11 simulation programmes

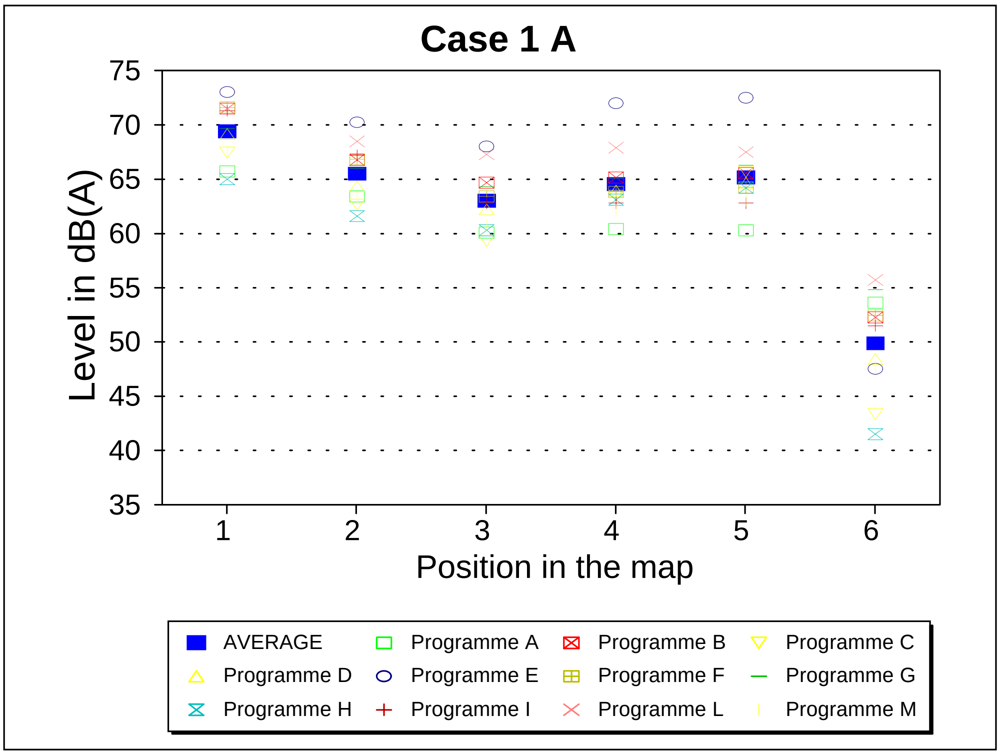

Figure 1: Mean values for each of the 11 simulation programmes and average value of them.

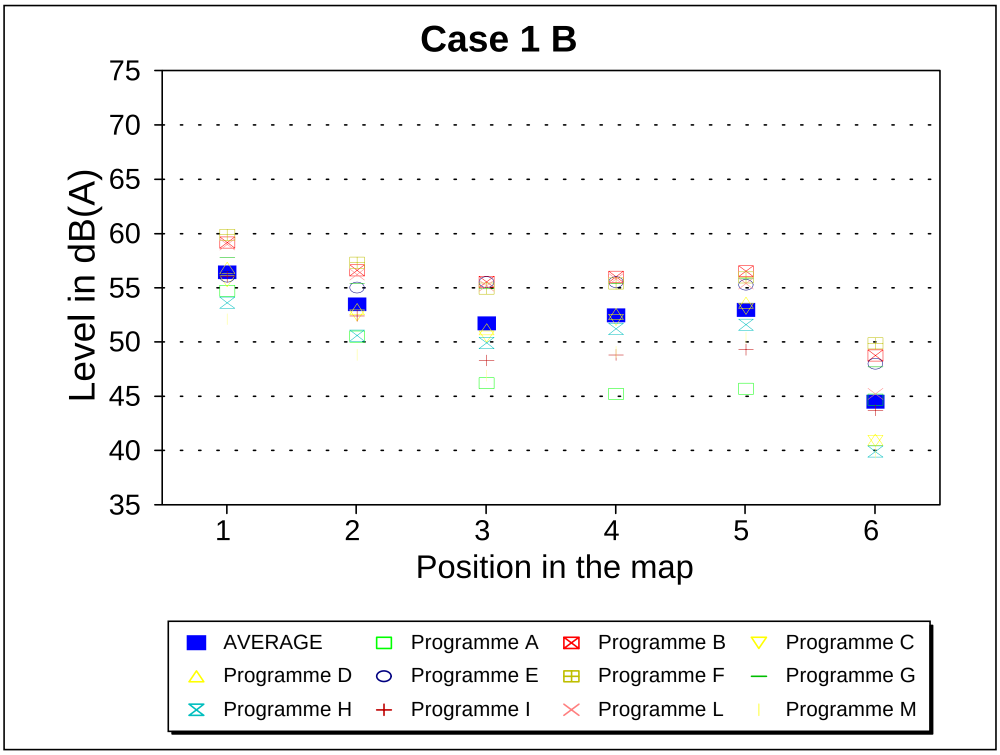

Figure 2: Mean values for each of the 11 simulation programmes and average value of them.

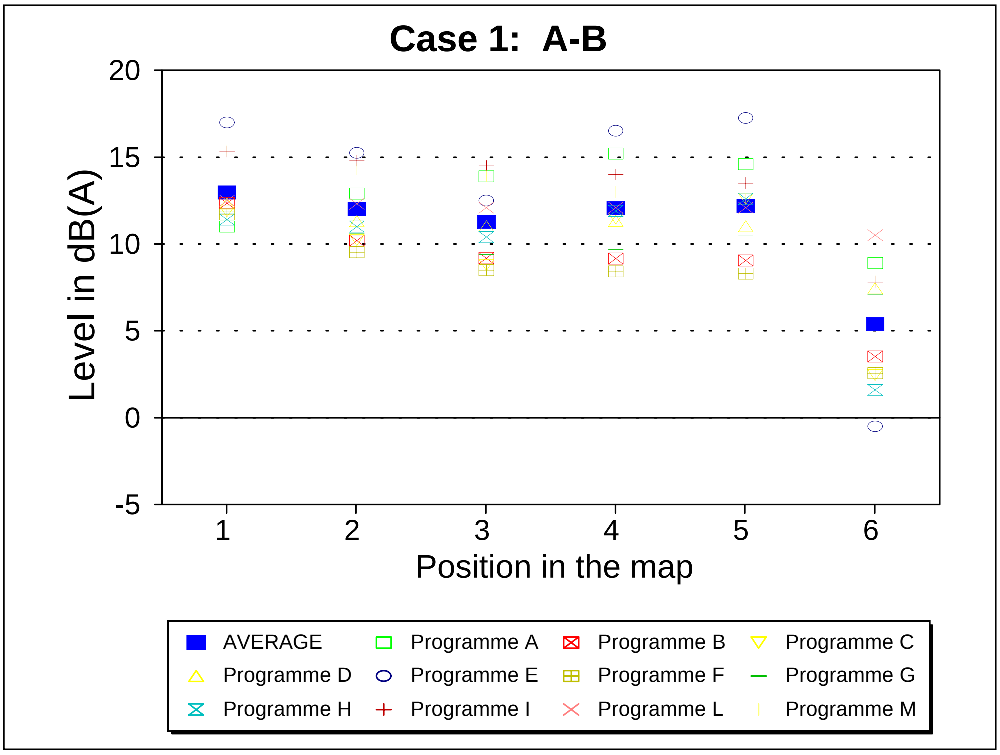

Figure 3: Mean values of the barrier attenuation for each of the 11 simulation programmes and average value of them.

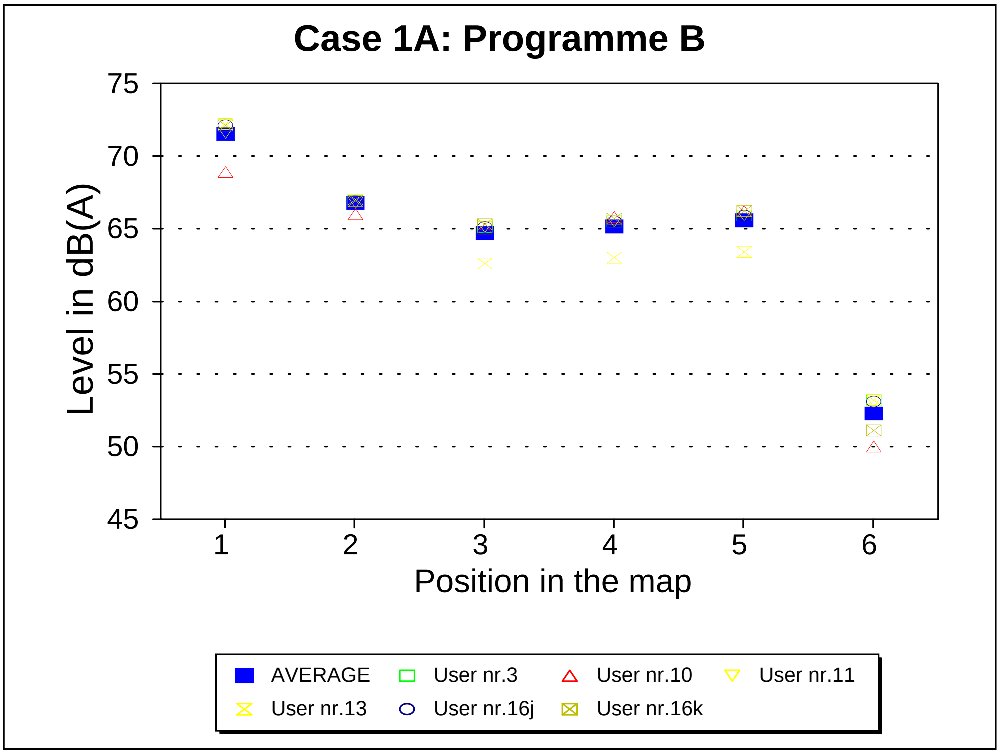

Figure 4: Case 1A: prediction for each user and average value.

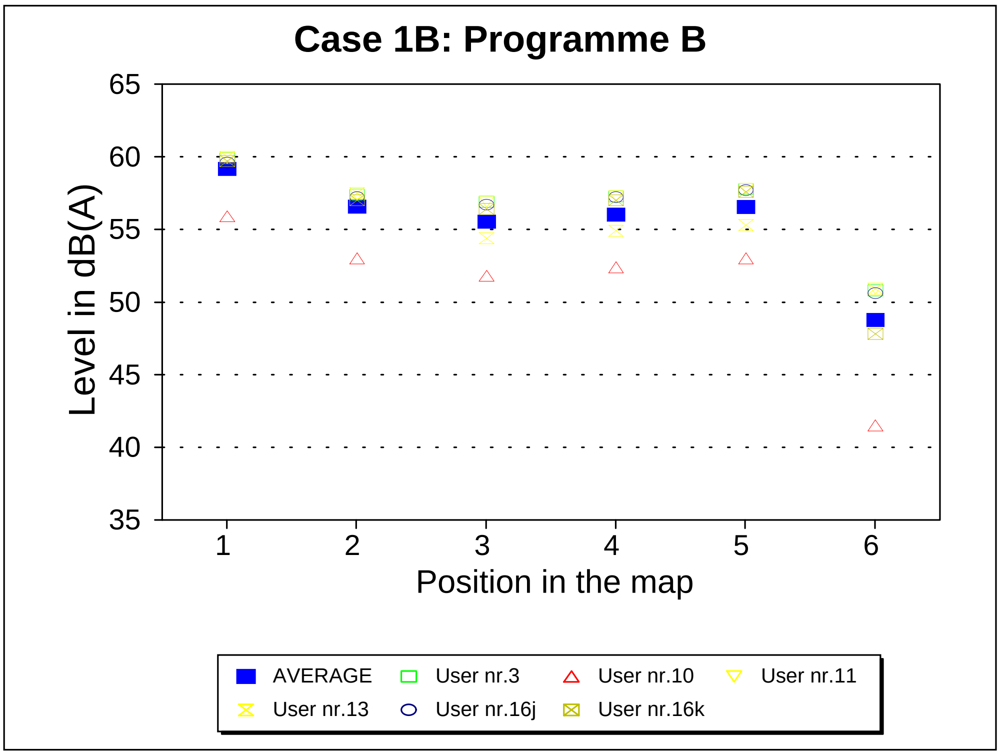

Figure 5: Case 1B: prediction for each user and average value.

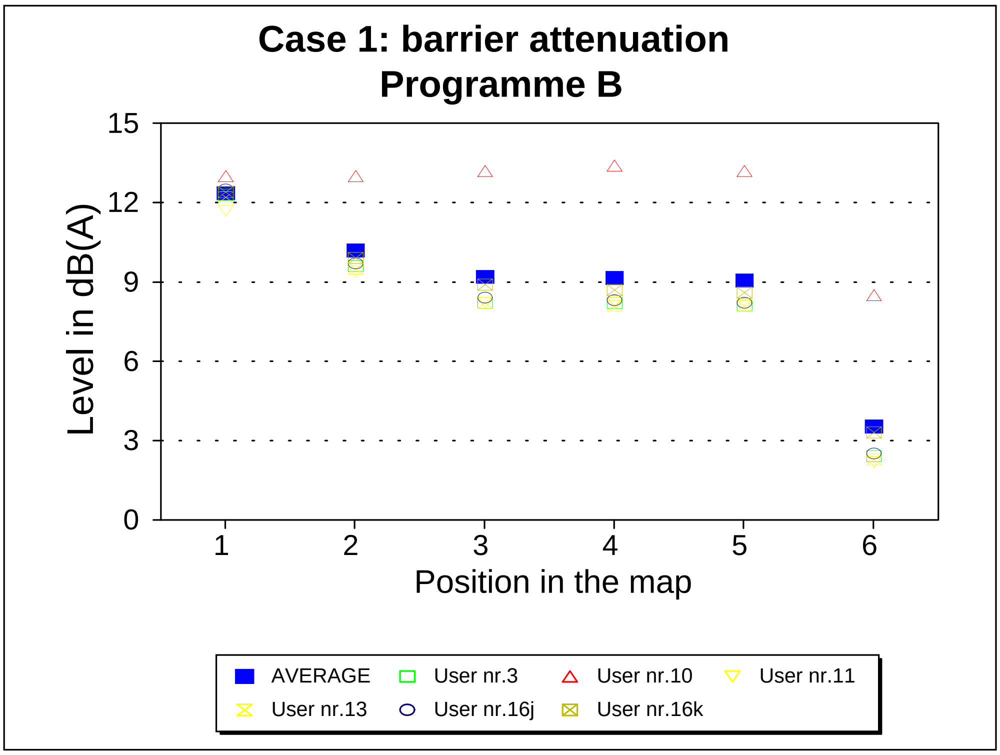

Figure 6: Case 1: barrier attenuation for each user and average value.

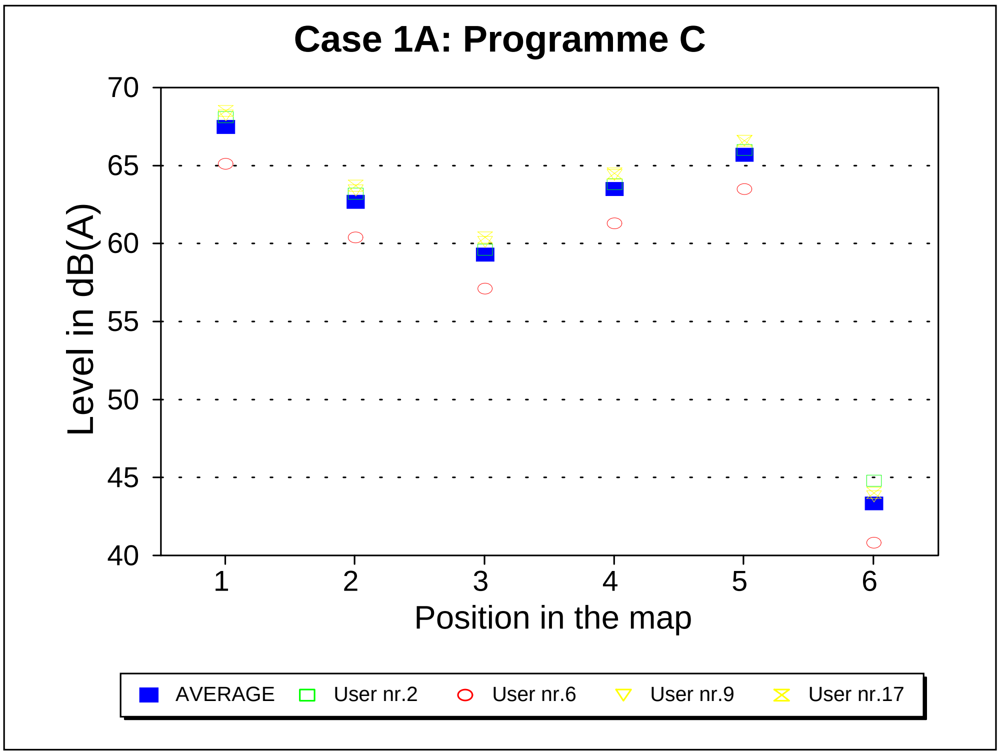

Figure 7: Case 1A: prediction for each user and average value.

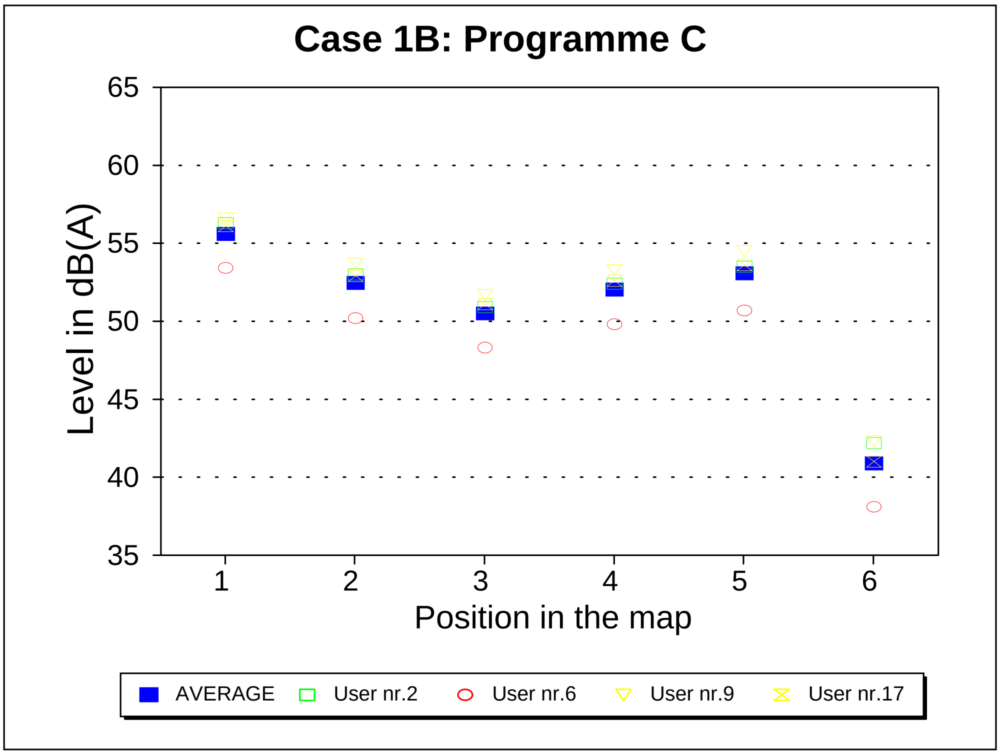

Figure 8: Case 1B: prediction for each user and average value.

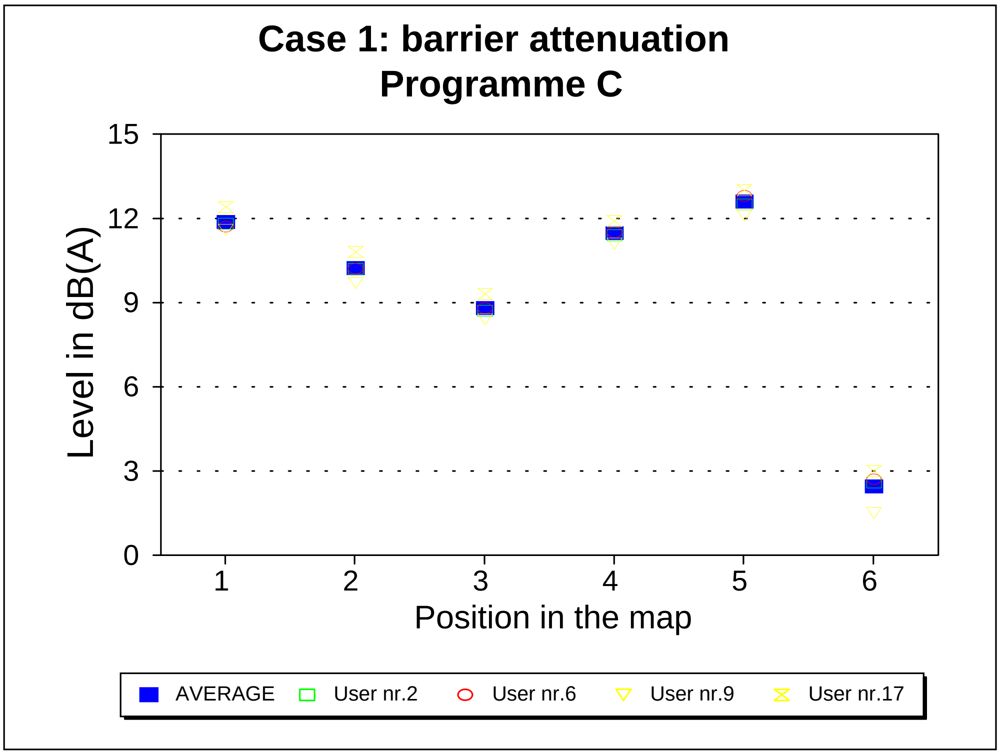

Figure 9: Case 1: barrier attenuation for each user and average value.

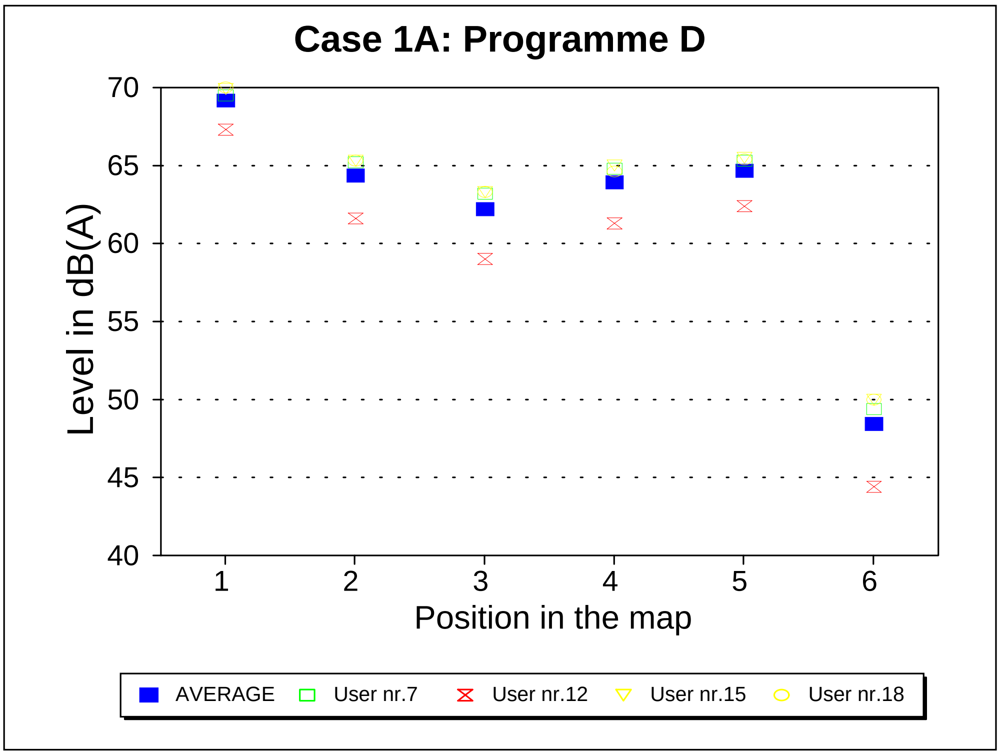

Figure 10: Case 1A: prediction for each user and average value.

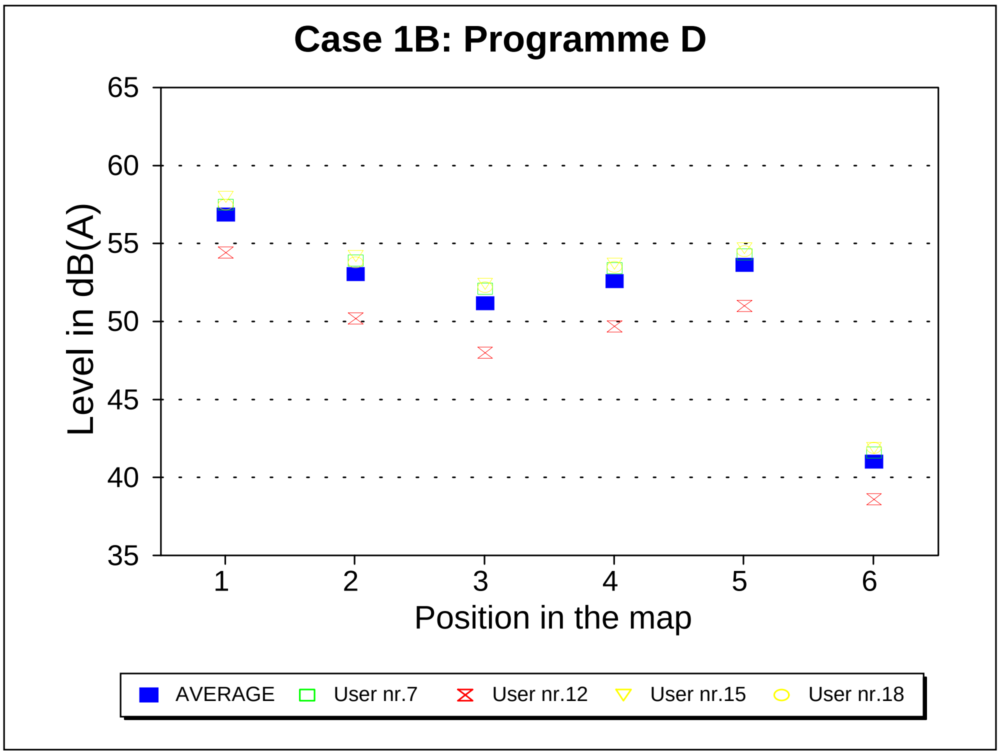

Figure 11: Case 1B: prediction for each user and average value.

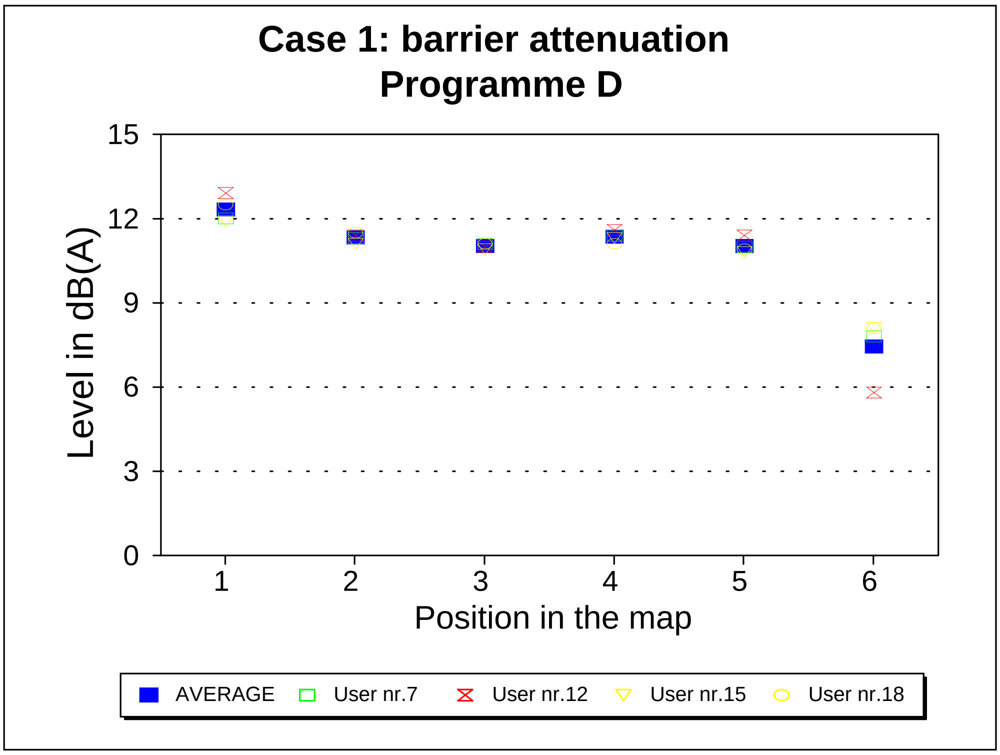

Figure 12: Case 1: barrier attenuation for each user and average value.

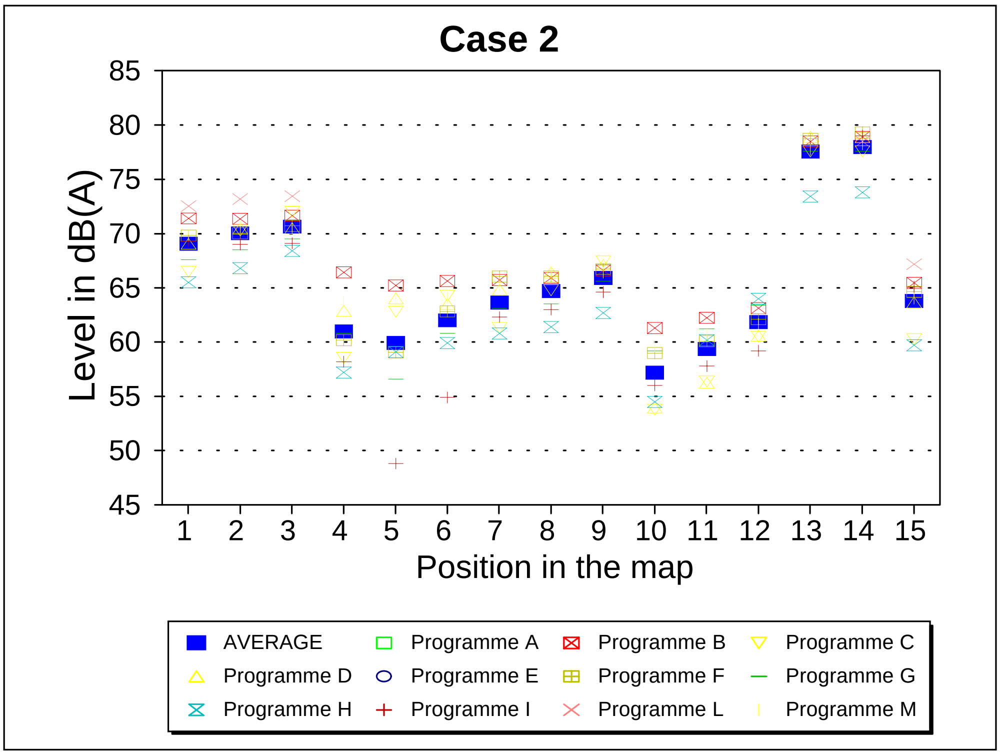

Figure 13: Mean values for each of the 11 simulation programmes and average value of them.

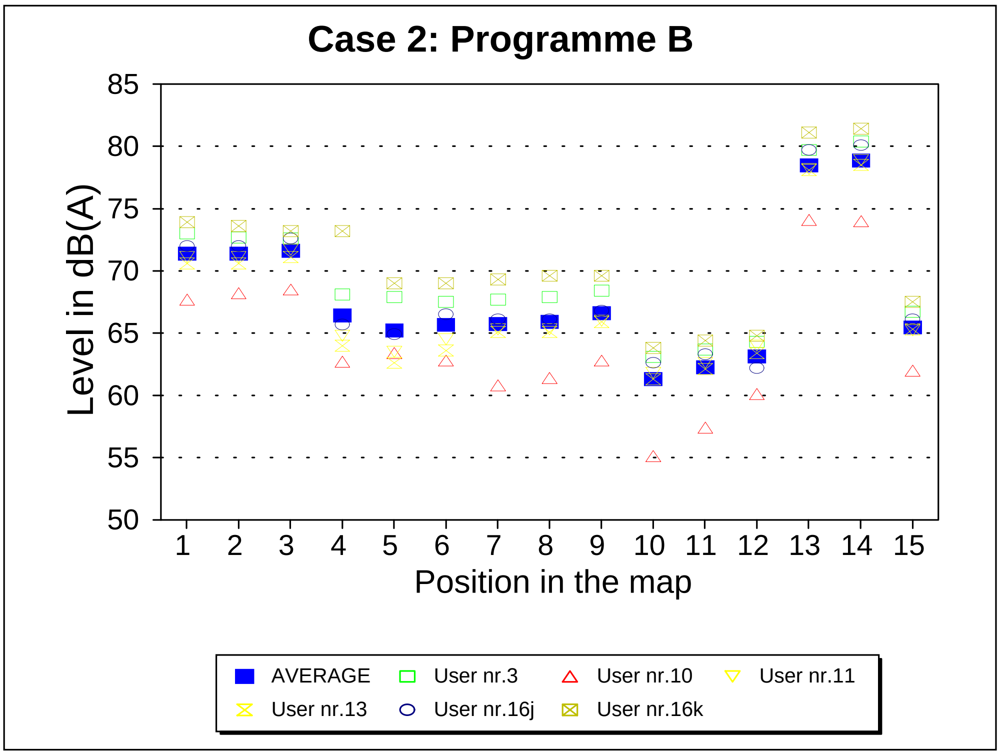

Figure 14: Case 2: prediction for each user and average value.

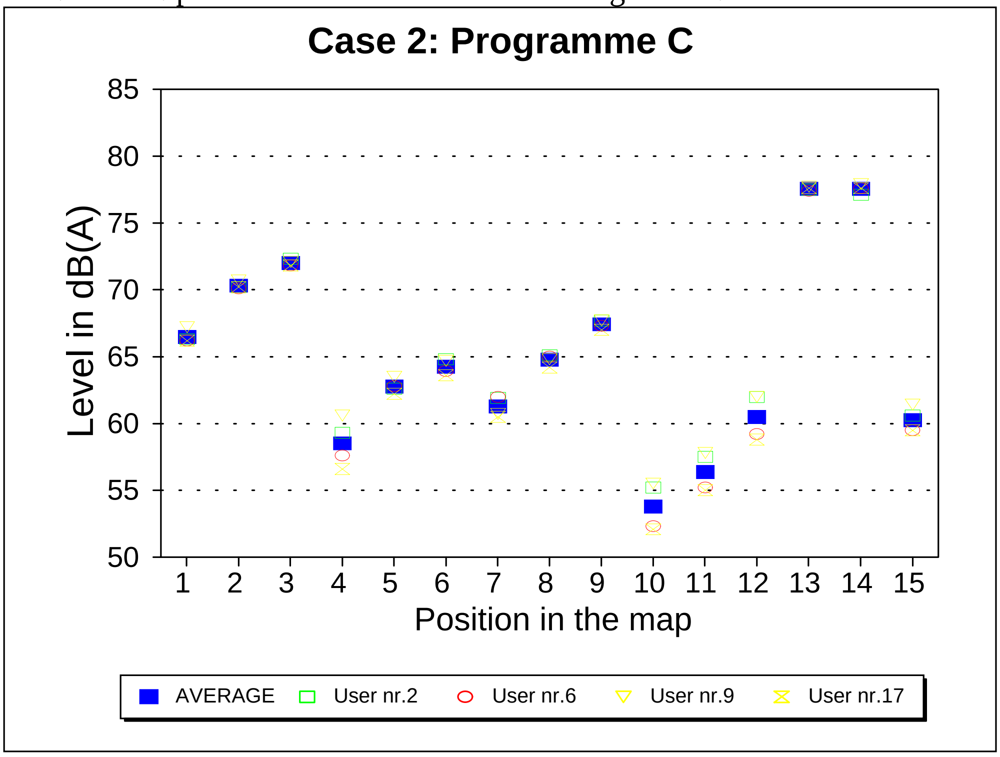

Figure 15: Case 2: prediction for each user and average value.

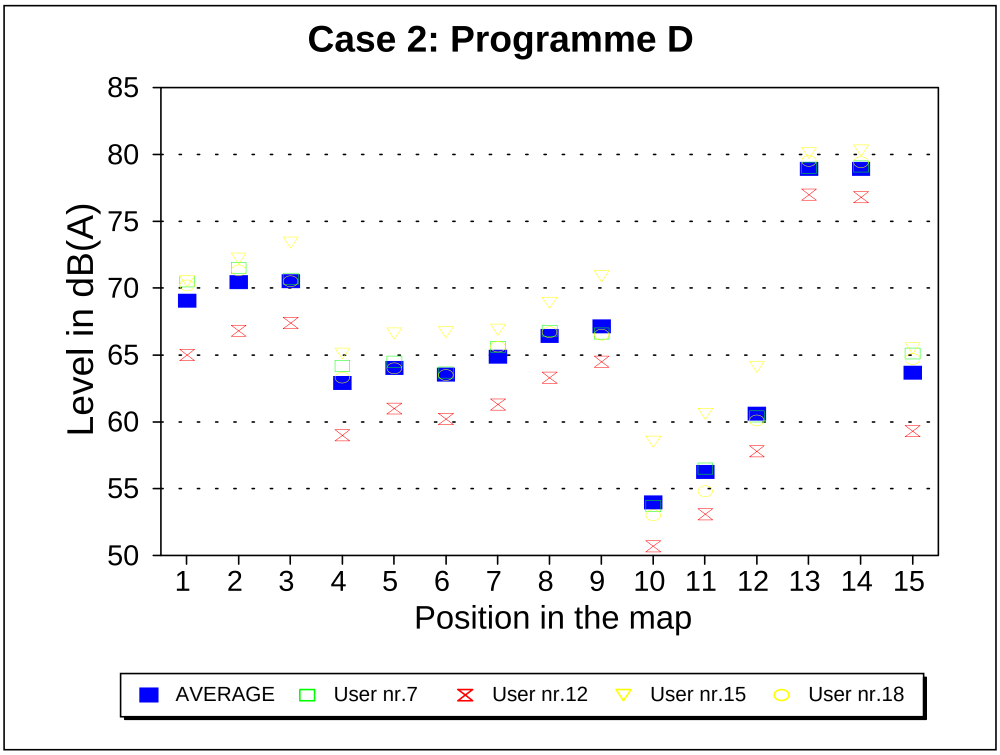

Figure 16: Case 2: prediction for each user and average value.

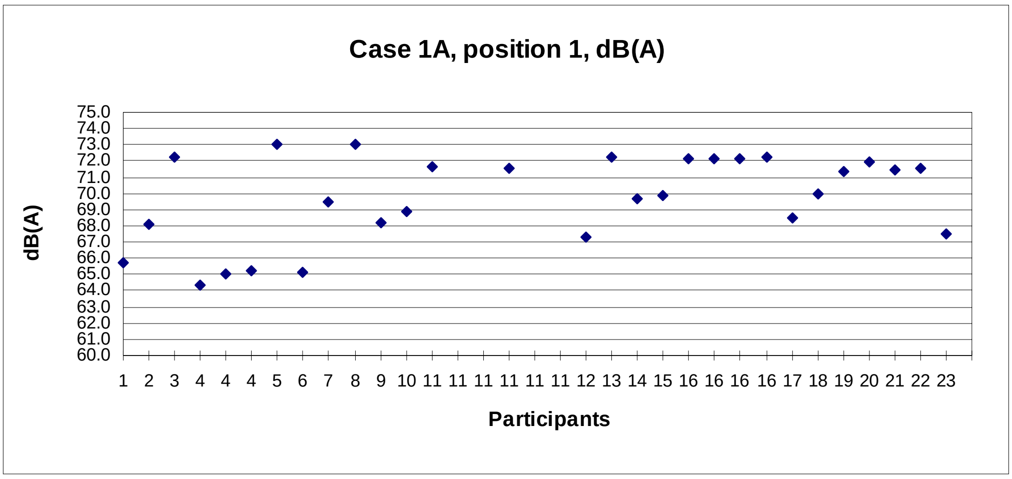

Fig. 17: Lmed = 69.7 dB(A) Lmax - Lmin = 8.7 dB(A) Std.Dev. = 2.66

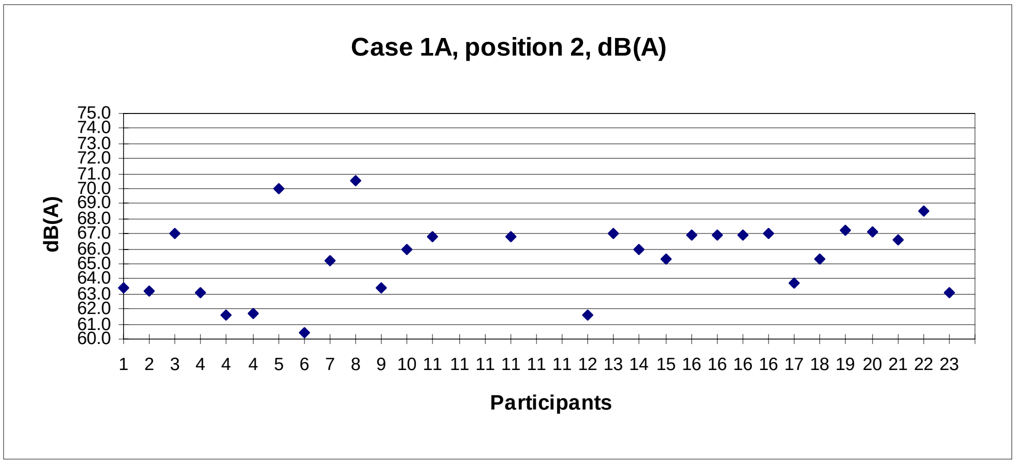

Fig. 18: Lmed = 65.5 dB(A) Lmax - Lmin = 10.1 dB(A) Std.Dev. = 2.47

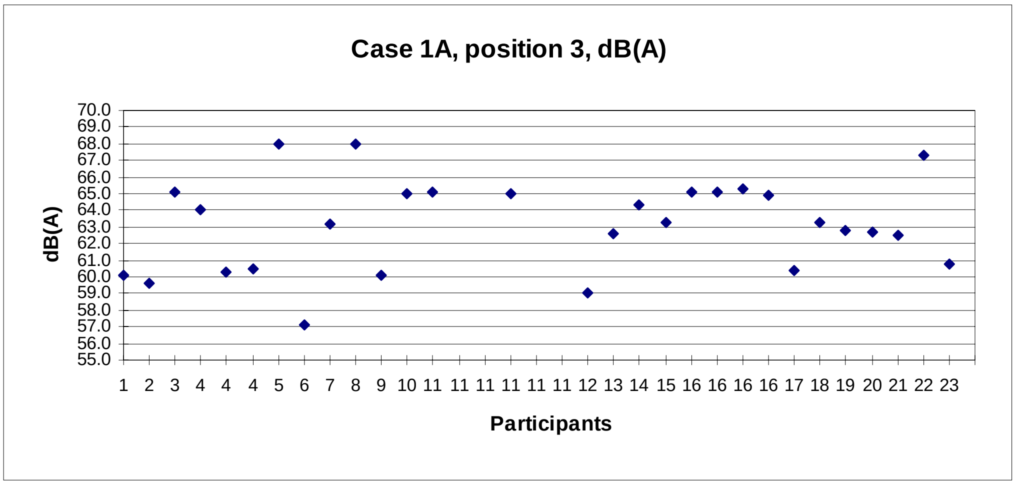

Fig. 19: Lmed = 63.1 dB(A) Lmax - Lmin = 10.9 dB(A) Std.Dev. = 2.69

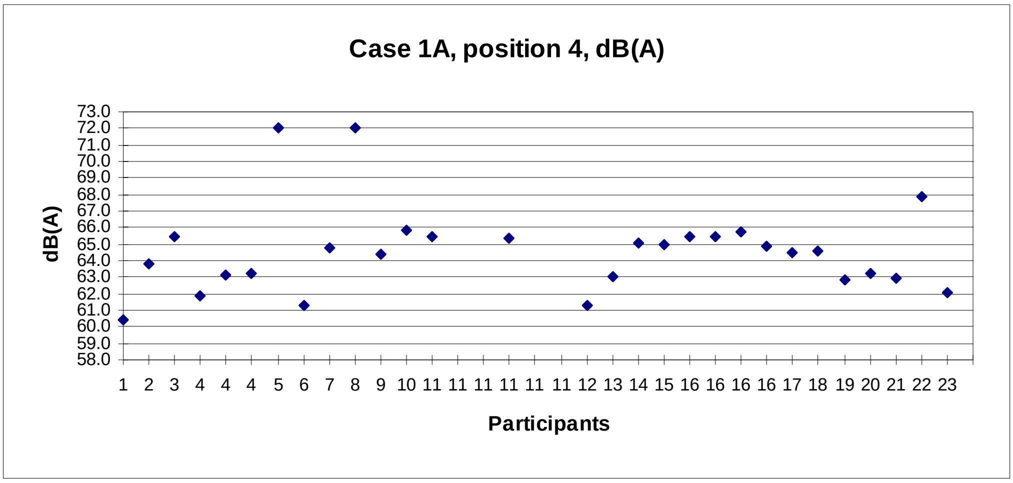

Fig. 20: Lmed = 64.6 dB(A) Lmax - Lmin = 11.6 dB(A) Std.Dev. = 2.60

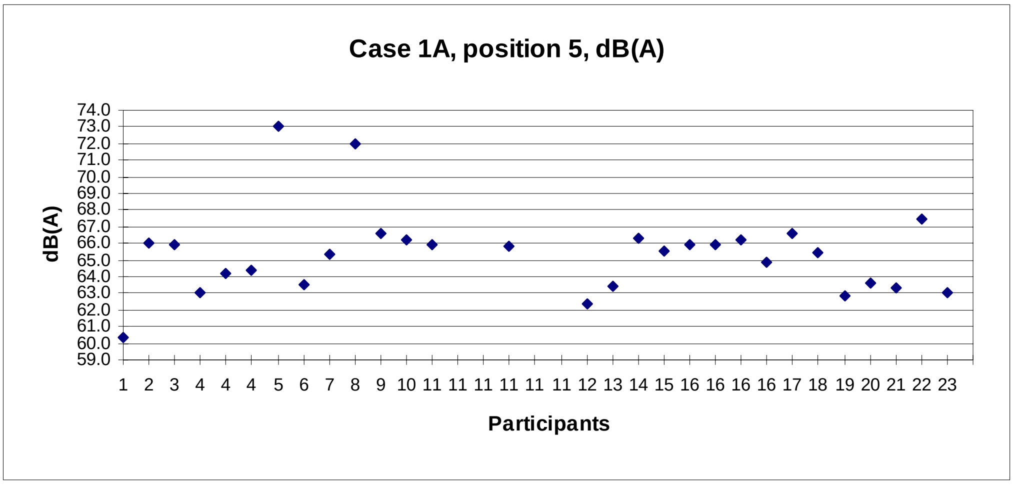

Fig. 21: Lmed = 65.3 dB(A) Lmax - Lmin = 12.7 dB(A) Std.Dev. = 2.51

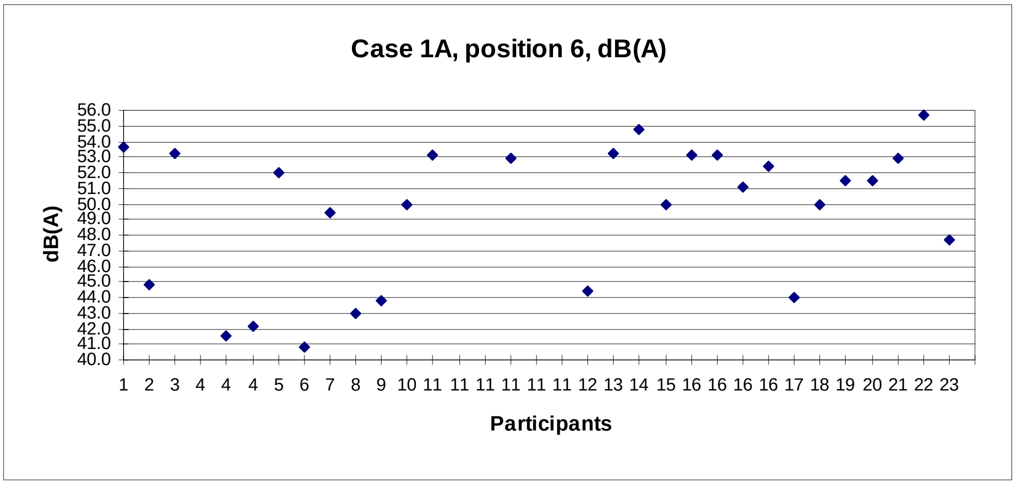

Fig. 22: Lmed = 49.5 dB(A) Lmax - Lmin = 14.9 dB(A) Std.Dev. = 4.42

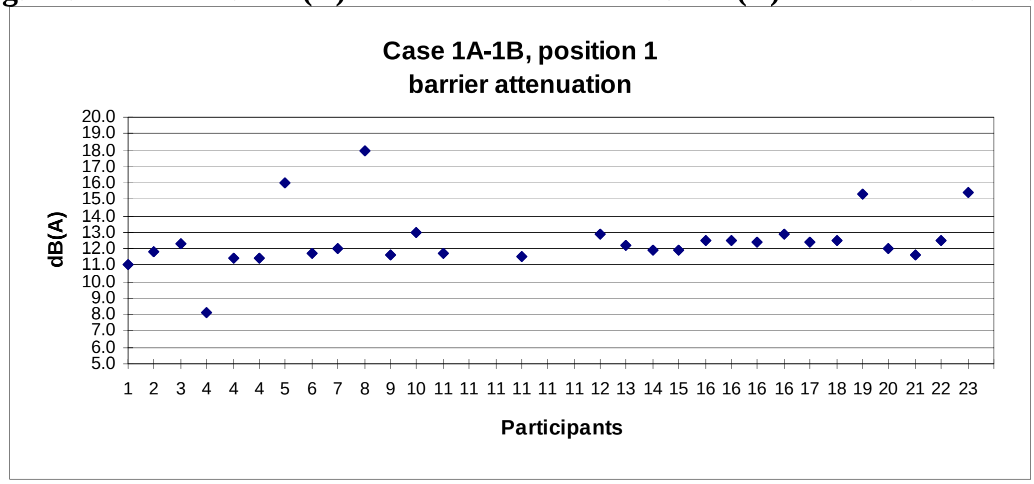

Fig. 23: med = 12.5 dB(A) (max - min) = 9.9 dB(A) Std.Dev. = 1.77

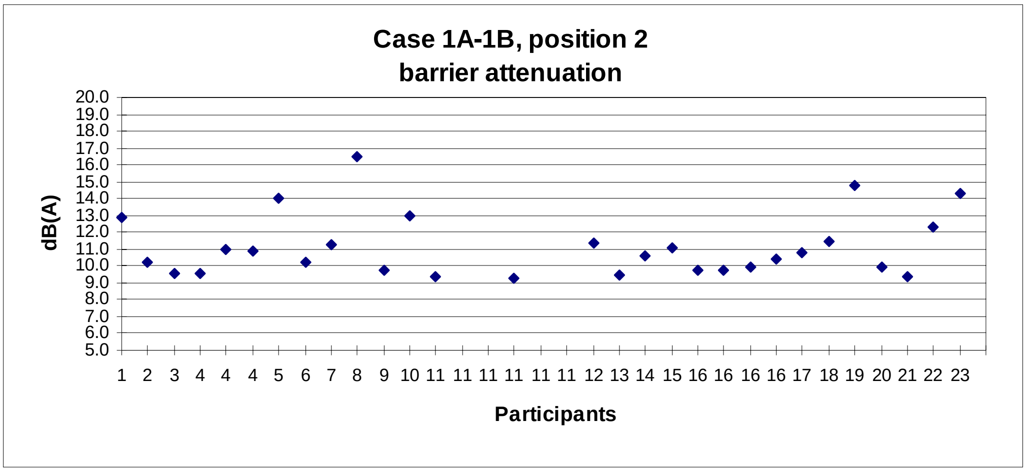

Fig. 24: med = 11.1 dB(A) (max - min) = 7.2 dB(A) Std.Dev. = 1.85

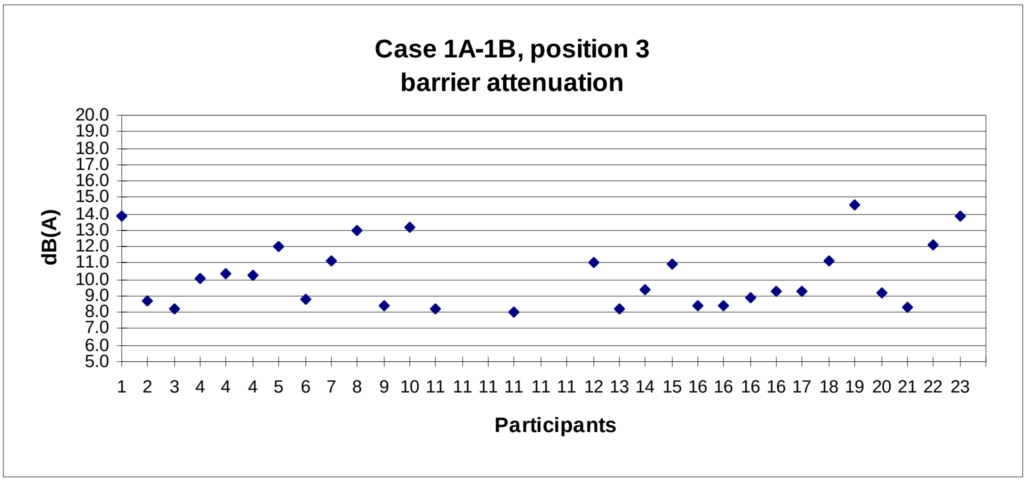

Fig. 25: med = 10.2 dB(A) (max - min) = 6.5 dB(A) Std.Dev. = 1.97

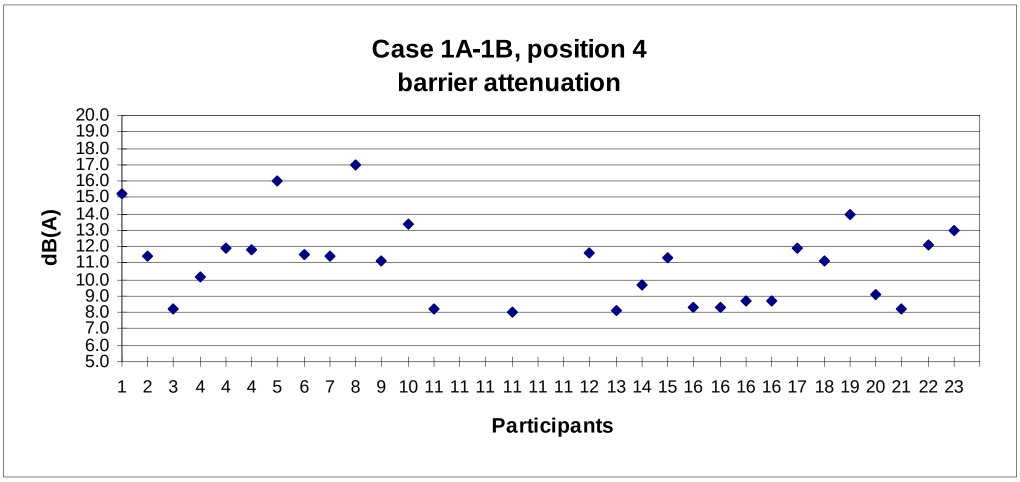

Fig. 26: med = 11.0 dB(A) (max - min) = 9.0 dB(A) Std.Dev. = 2.47

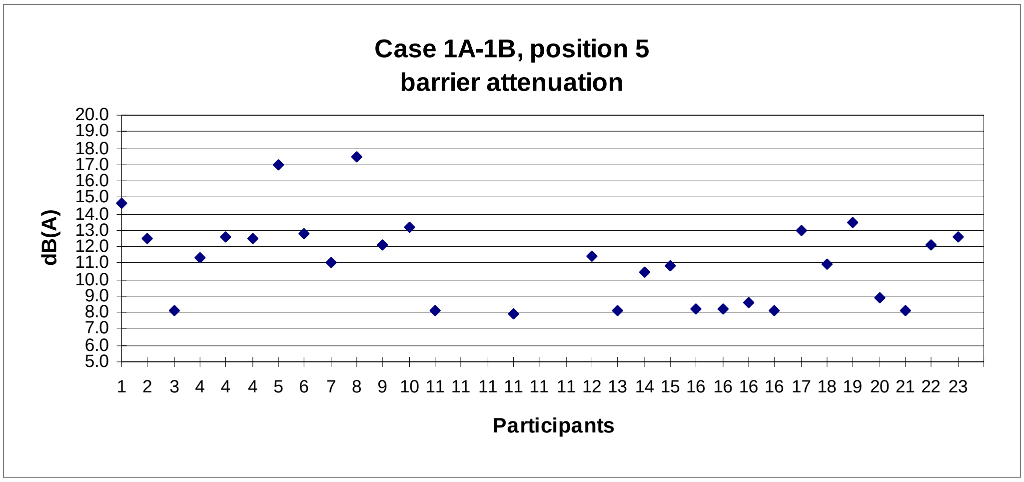

Fig. 27: med = 11.2 dB(A) (max - min) = 9.6 dB(A) Std.Dev. = 2.64

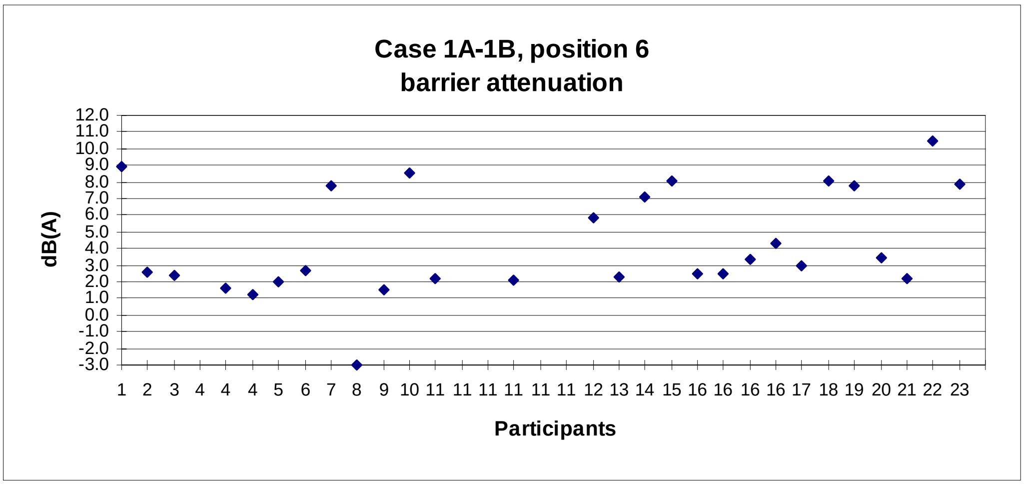

Fig. 28: med = 4.3 dB(A) (max - min) = 13.5 dB(A) Std.Dev. = 3.14

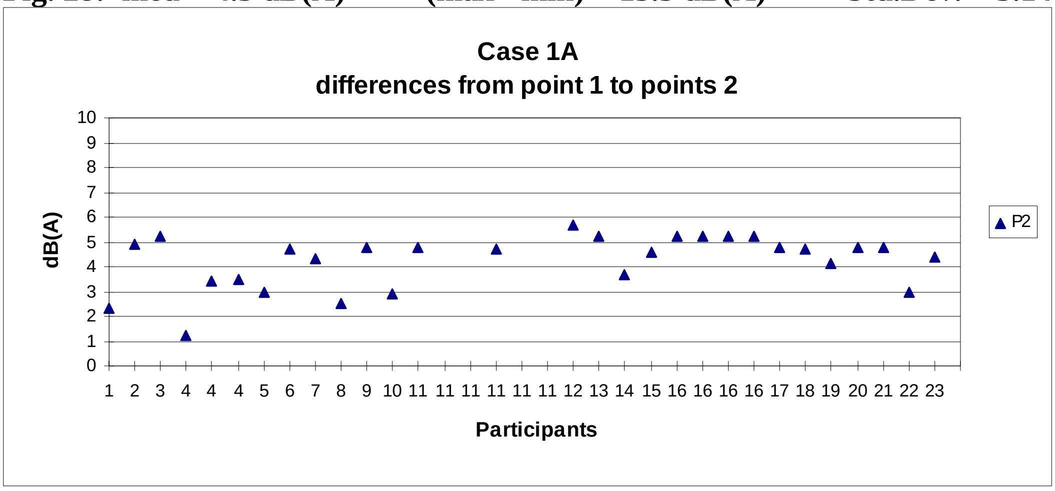

Figure 29: differences from point 1 to point 2:
med = 4.2 dB(A) (max - min) = 4.5 dB(A) Std.Dev. = 1.1

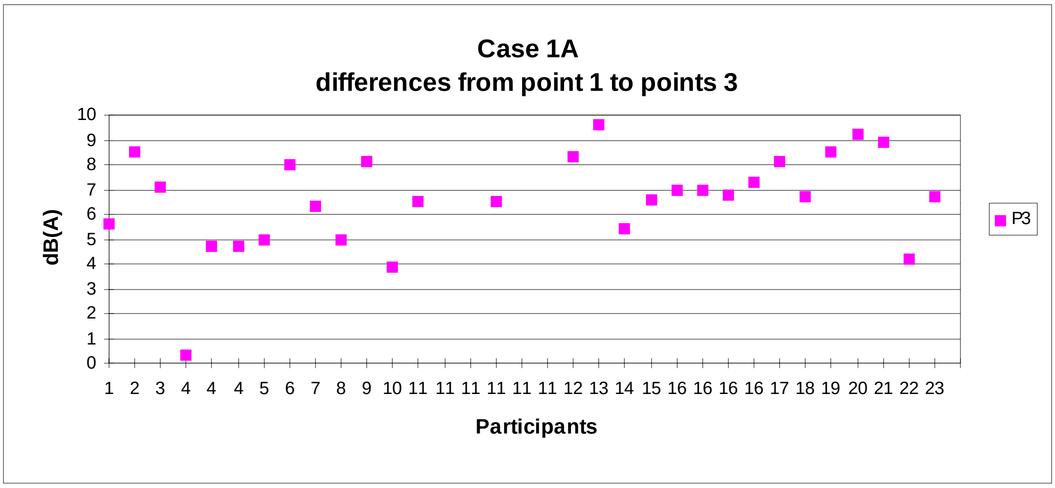

Figure 30: differences from point 1 to point 3:
med = 6.6 dB(A) (max - min) = 9.3 dB(A) Std.Dev. = 1.9

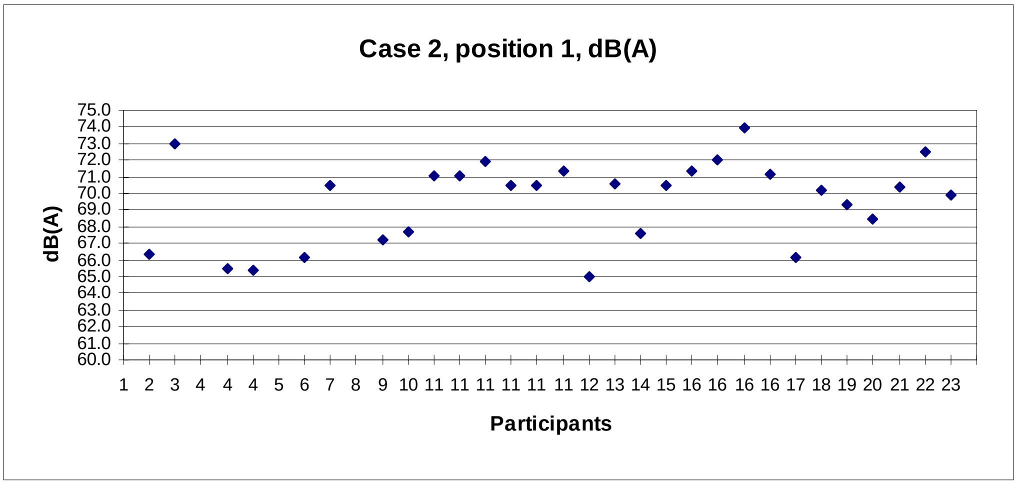

Fig. 31: Lmed = 69.6 dB(A) Lmax - Lmin = 8.9 dB(A) Std.Dev. = 2.44

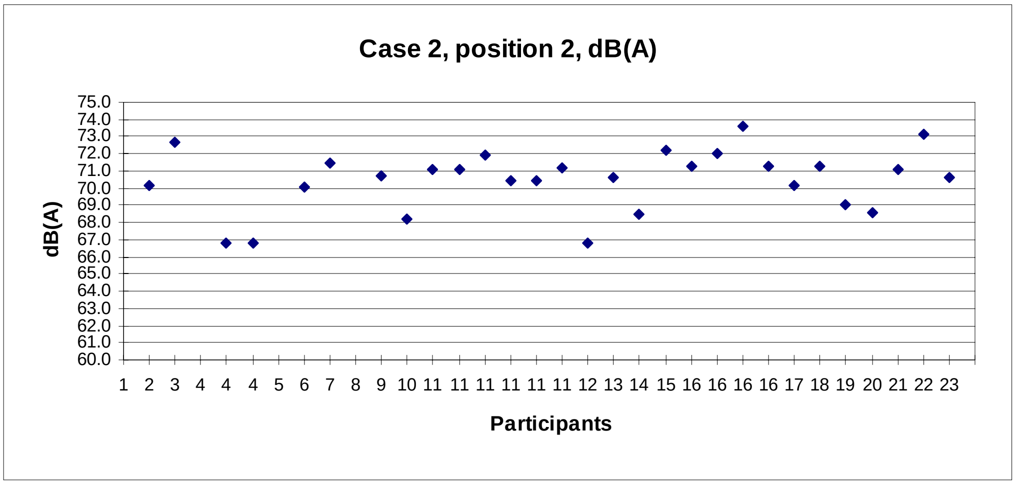

Fig. 32: Lmed = 70.5 dB(A) Lmax - Lmin = 6.8 dB(A) Std.Dev. = 1.76

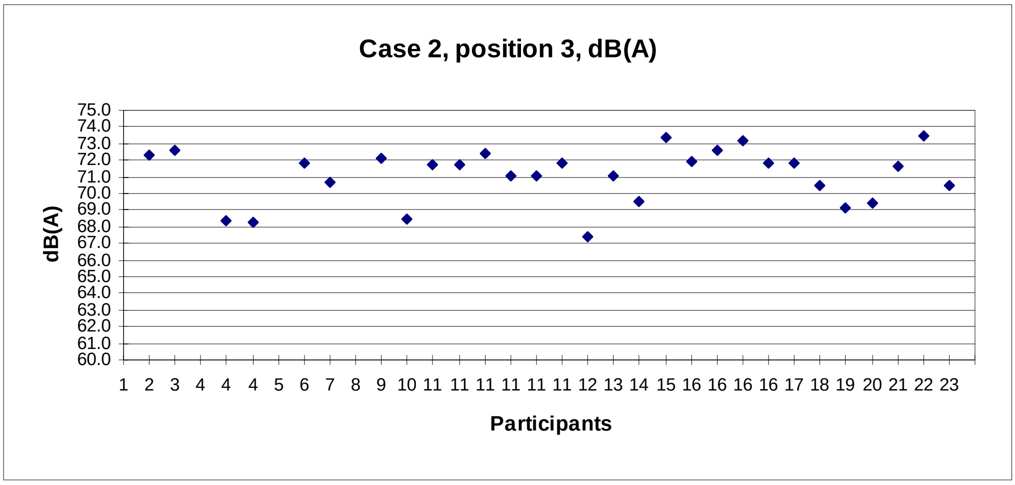

Fig. 33: Lmed = 71.1 dB(A) Lmax - Lmin = 6.1 dB(A) Std.Dev. = 1.59

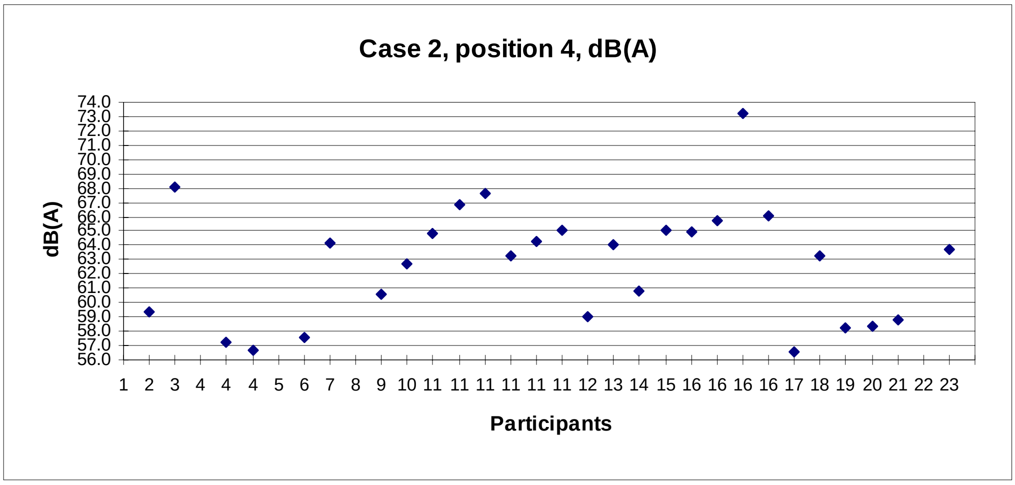

Fig. 34: Lmed = 62.7 dB(A) Lmax - Lmin = 16.6 dB(A) Std.Dev. = 3.99

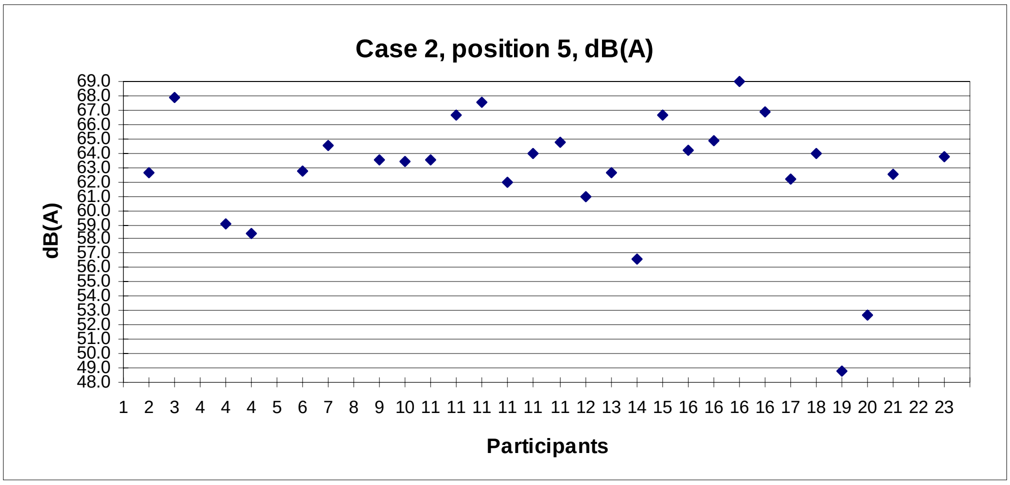

Fig. 35: Lmed = 62.7 dB(A) Lmax - Lmin = 20.2 dB(A) Std.Dev. = 4.33

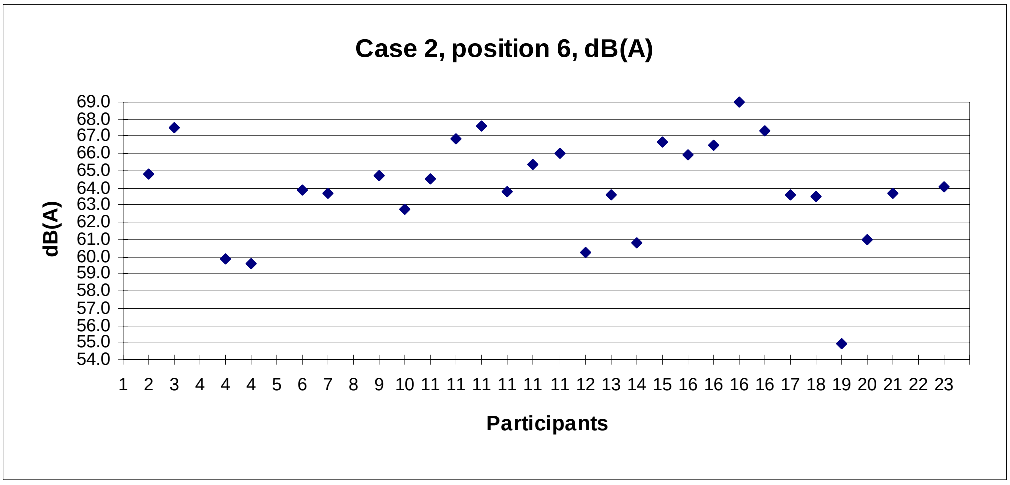

Fig. 36: Lmed = 64.0 dB(A) Lmax - Lmin = 14.1 dB(A) Std.Dev. = 2.98

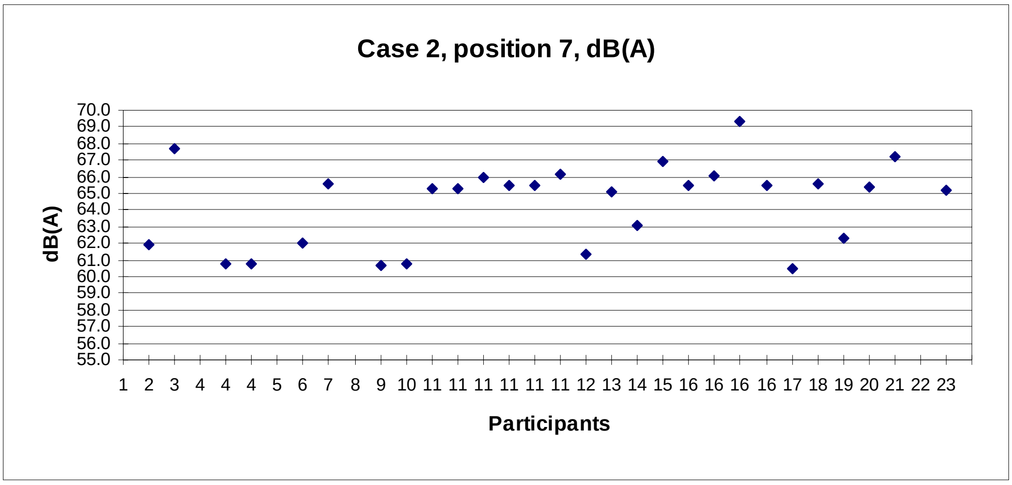

Fig. 37: Lmed = 64.4 dB(A) Lmax - Lmin = 8.8 dB(A) Std.Dev. = 2.42

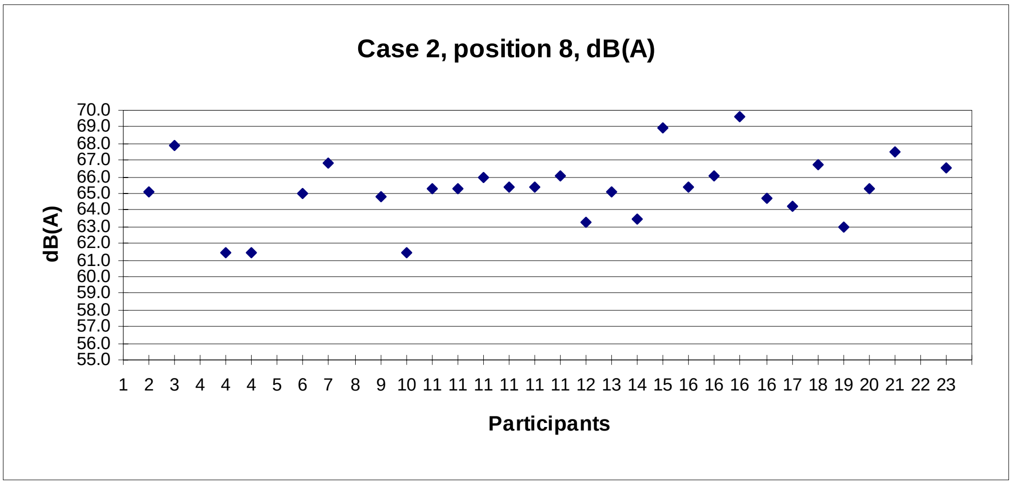

Fig. 38: Lmed = 65.3 dB(A) Lmax - Lmin = 8.2 dB(A) Std.Dev. = 1.99

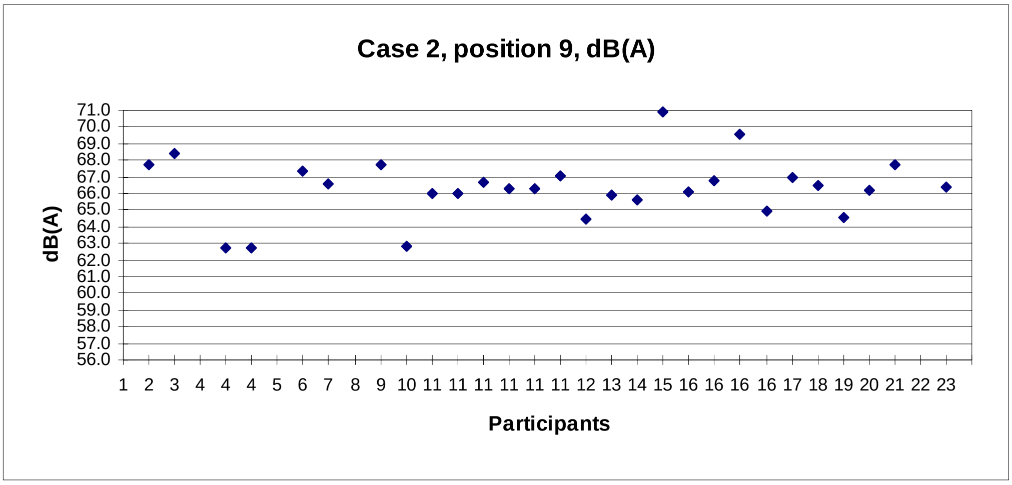

Fig. 39: Lmed = 66.3 dB(A) Lmax - Lmin = 8.2 dB(A) Std.Dev. = 1.81

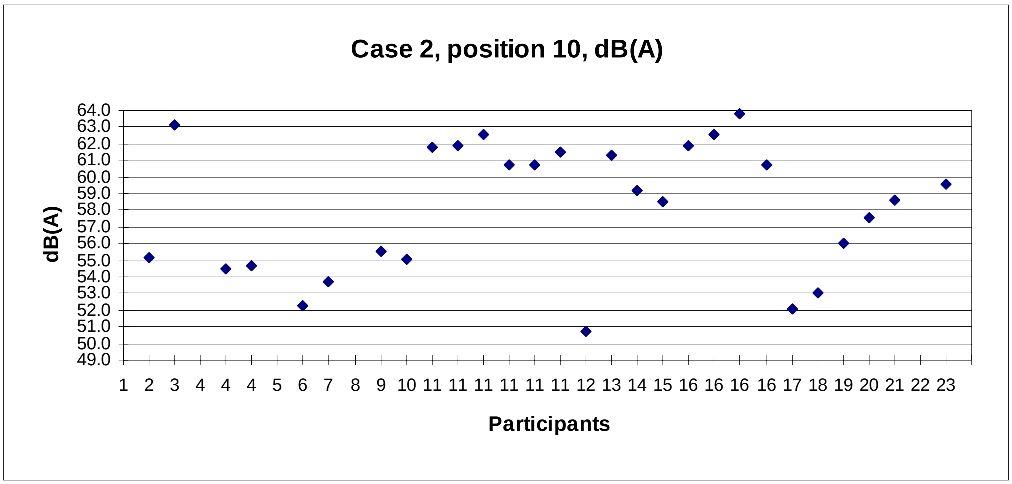

Fig. 40: Lmed = 58.2 dB(A) Lmax - Lmin = 13.1 dB(A) Std.Dev. = 3.82

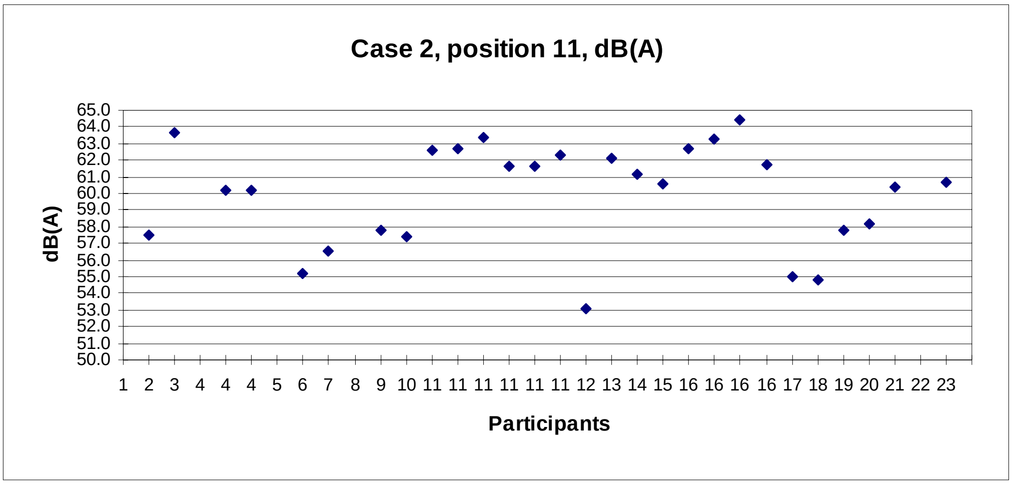

Fig. 41: Lmed = 60.0 dB(A) Lmax - Lmin = 11.3 dB(A) Std.Dev. = 3.03

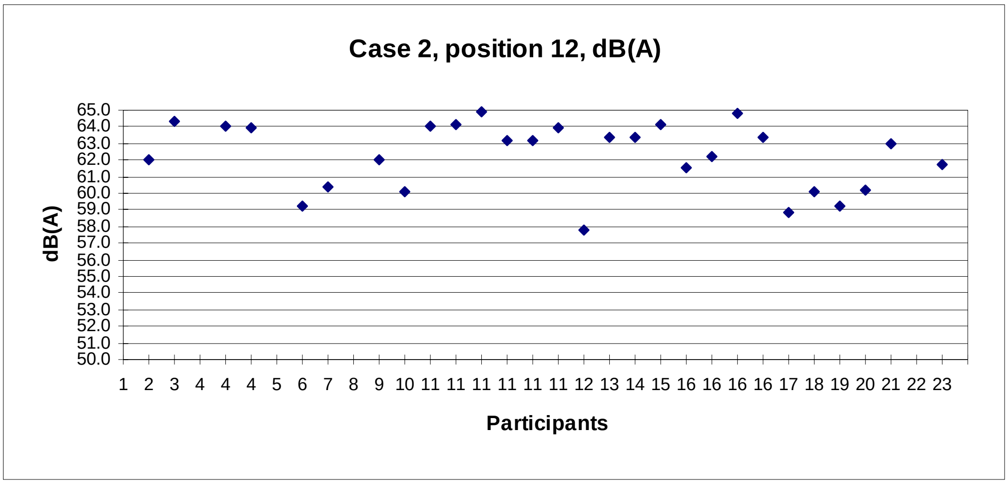

Fig: 42: Lmed = 62.2 dB(A) Lmax - Lmin = 7.1 dB(A) Std.Dev. = 1.99

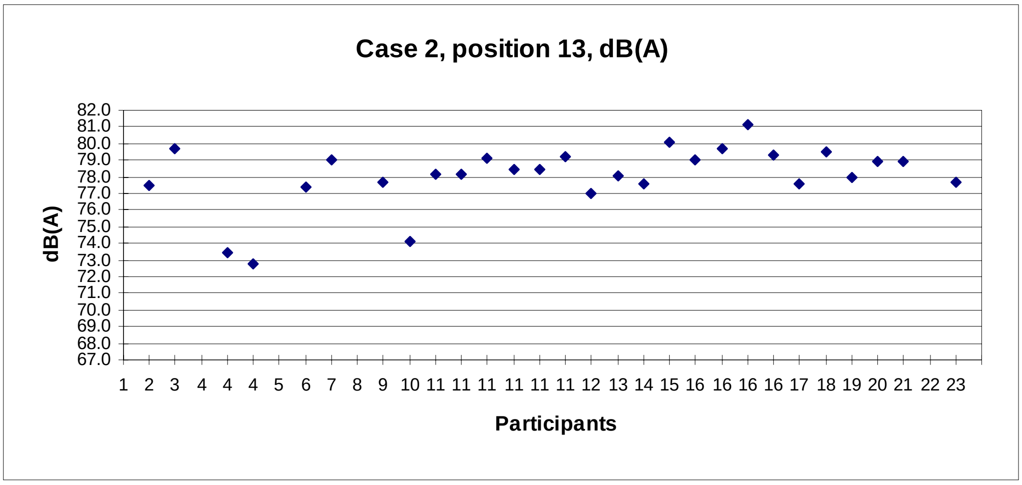

Fig. 43: Lmed = 78.1 dB(A) Lmax - Lmin = 8.3 dB(A) Std.Dev. = 1.85

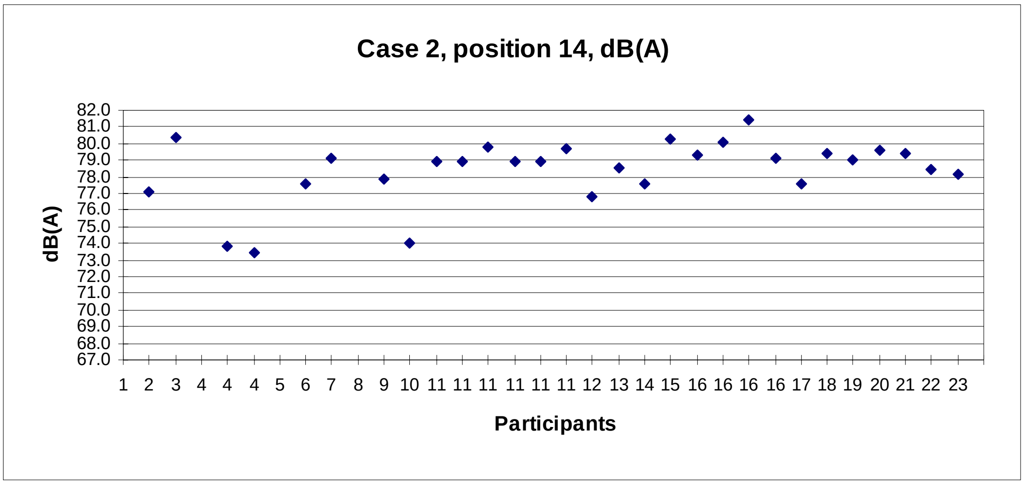

Fig. 44: Lmed = 78.4 dB(A) Lmax - Lmin = 8.0 dB(A) Std.Dev. =1.87

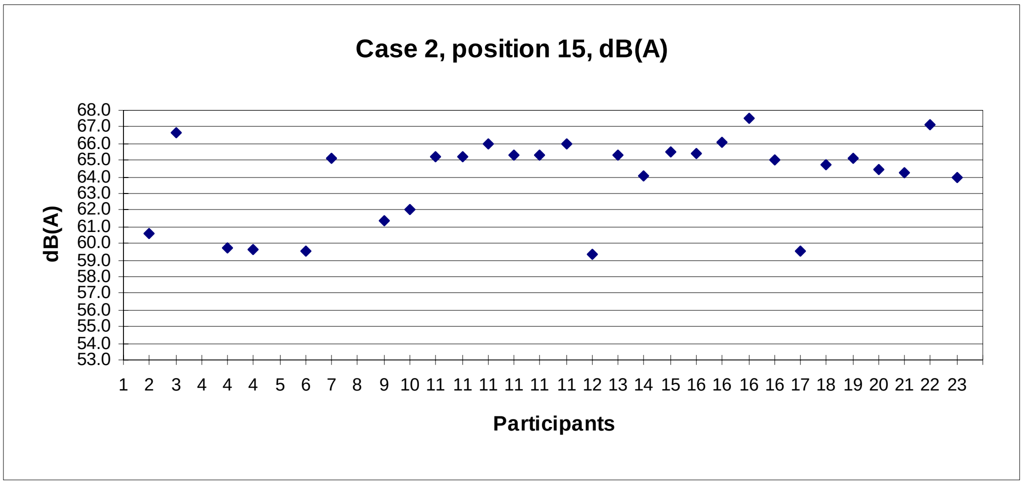

Fig. 45: Lmed = 64.0 dB(A) Lmax - Lmin = 8.2 dB(A) Std.Dev. = 2.50