Loudspeaker Frequency Response Targets at high Frequencies

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1. Introduction

For tuning a loudspeaker box system targets of frequency response curves are very important. Should the speaker system have a neutral tuning with linear frequency response over complete frequency range or an increase of high frequency level to equalize the lower sensitivity of ear? Is then a lower loudspeaker level round 3.5 kHz necessary to consider the higher hearing sensitivity caused by ear tube resonance? In order to receive a quantitative answer different listening tests were been executed, which should give target directions in tweeter and midrange tuning.

2. Listening Test "Tweeter"

Some music tracks were tested regarding their high frequency content and at last a 30 seconds sequence of Johnny Cash's "Roads less travelled" was selected. The sequence was changed by a parametric equalizer according the test specification and stored as different tracks on CD. With a Q-factor of 0.7 the sound pressure level was increased by 3 dB, 6 dB, or 9 dB in each case at frequencies of 8, 12, or 16 kHz. Together with the original signal the test persons had to estimate 10 tracks in statistical sequence presented in mono by 2-way-stereo-loudspeaker system with very flat frequency response sitting in the sweat spot at a distance of 2 m to the connecting line of the 2 m distant boxes. A pink noise on the CD with equal loudness as the music sequence was tuned to 80 dB(A) at every session. The exclusive spectral chance of music signal has the advantage, that temporal effects as long membrane moving caused by high frequent membrane resonances are minimized. The listening tests were executed in a room with a reverberation time of 0.4 s. From the trained test persons aged between 35 and 52 years additionally the threshold in quiet was measured by earphone to see influences of possible high frequency hearing loss. To check influences of test procedure three experiments were done:

In a first session the test persons should estimate the different tracks relatively to the original music section in a paired comparison by distributing numbers in percent, so that they should listen at first to the original sound at track 1 as an anchor and subsequently to the estimating track. As a value of "subjective" impression of the reproduction of high frequencies the brilliance of the ten different tracks should be judged in comparison to the original music, which represents 100 %. In same way the sharpness of sounds has to be estimated as an "objective" value. A criterion of spectral changing should give at last the judgement of quality of reproduction of high frequencies. From the values of the ten test persons for every of the three criteria and the ten tracks the medians and interquartile ranges were calculated, which are drawn in figure 2 as coloured beams or lines, respectively.

In a second session the same criteria were judged in a magnitude estimation without anchor. The test person could fix every corresponding position on line length divided equidistant from 0 to 10. According figure 1 the semantic differential was used by describing the extreme positions by adjectives. The best value for brilliance and sharpness is number 5, for quality of high frequency reproduction is number 10.

In a third session every person gives the number of the preferred track with the best sound.

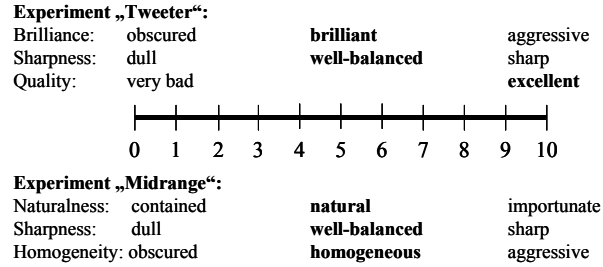


Figure 1: Line length for magnitude estimation with adjectives. Best values are in bold letters.

3. Results of Test "Tweeter"

The results of paired comparison are shown in figure 2. The small interquartile ranges of original sound at track 7, which was additionally presented with anchor track 1 show the good reliability of the judgement. An increasing sound pressure level at 8 kHz leads to an increase of brilliance, but in direction to "aggressive", so that also parallel the sharpness has higher values. The large interquartile ranges suggest high interindividual differences. The quality of high frequency reproduction however takes an opposite course and is with lower interquartile ranges more clearly. Higher level of 9 dB reduces the quality of high frequency reproduction to 65 % in comparison to the original sound. At 12 kHz the same tendency is visible, only the difference to original is smaller. In best case the quality of high frequency reproduction is identically to the reference. At a 3 dB level increase round 16 kHz however the quality of sound reproduction is 7.5 % over the original sound. Brilliance and sharpness are more close to reference in comparison to results at 12 kHz. Also the interquartile ranges get smaller with higher frequencies.

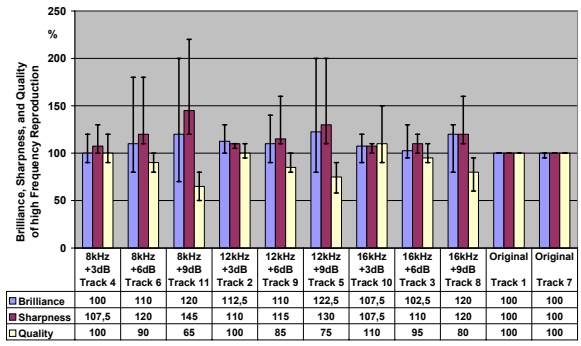
Generally you can find, that the judgement of sharpness is similar, but a little higher as brilliance and with increasing sharpness the quality of high frequency reproduction decreases. The original sound with linear frequency response has a well-balanced listening impression, which could be improved a little bit by 3 dB level increase at 16 kHz.

At the judgement without anchor the results in figure 3 are similar as above. While a 3 dB increase at 8 kHz sounds according value 5 brilliant (brilliance) and well-balanced (sharpness) results a 9 dB higher level an aggressive and sharp impression, which has the worst quality of sound reproduction with value 2. At 12 kHz similar results are visible, the subjective estimated brilliance is up to two steps lower. Brilliance and sharpness have at a 3 dB level increase round 16 kHz the best value with number 5 and get worse with higher level. Also the quality of high frequency repro-

duction has the best value 5.5 and best interquartile range up to value 8 with 3 dB level increase at 16 kHz. In comparison to this the original sound was estimated worse.

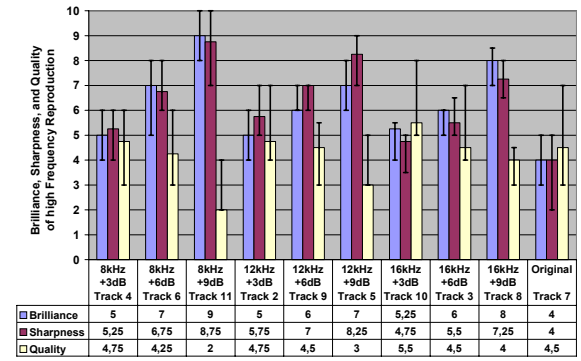
The third session confirms the results of the other investigations and the preferred track is that with a 3 dB level increase at 16 kHz. The two test persons, who have selected the track 9, give also the best values to track 9 in the other sessions. This underlines, that the tracks were good distinguishable and the test person results were very consistent.

Additionally the threshold in quiet was measured from all ten test persons. Although some persons had hearing losses at high frequencies no systematic deviation to the results of normal hearing persons could be ascertained.



	8kHz +3dB Track 4	8kHz +6dB Track 6	8kHz +9dB Track 11	12kHz +3dB Track 2	12kHz +6dB Track 9	12kHz +9dB Track 5	16kHz +3dB Track 10	16kHz +6dB Track 3	16kHz +9dB Track 8	Original Track 1	Original Track 7
Brilliance	100	110	120	112,5	110	122,5	107,5	102,5	120	100	100
Sharpness	107,5	120	145	110	115	130	107,5	110	120	100	100
Quality	100	90	65	100	85	75	110	95	80	100	100

Figure 2: Session 1: Brilliance, sharpness, quality of high frequency reproduction in paired comparison relative to original.



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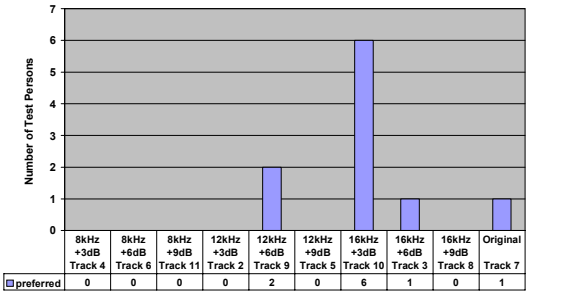
Brilliance	5	7	9	5	6	7	5,25	6	8	4
Sharpness	5,25	6,75	8,75	5,75	7	8,25	4,75	5,5	7,25	4
Quality	4,75	4,25	2	4,75	4,5	3	5,5	4,5	4	4,5

Figure 3: Session 2: Brilliance, sharpness, quality of high frequency reproduction in magnitude estimation without anchor.



	8kHz +3dB Track 4	8kHz +6dB Track 6	8kHz +9dB Track 11	12kHz +3dB Track 2	12kHz +6dB Track 9	12kHz +9dB Track 5	16kHz +3dB Track 10	16kHz +6dB Track 3	16kHz +9dB Track 8	Original Track 7
preferred	0	0	0	0	2	0	6	1	0	1

Figure 4: Session 3: Preferred track.

4. Listening Test "Midrange"

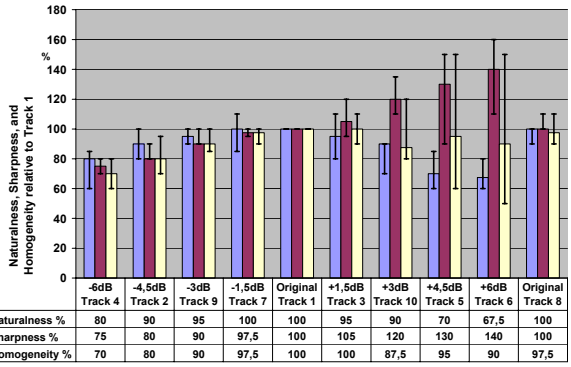
For investigating the necessary sound pressure level round 3.5 kHz several tracks were created by decreasing and increasing the level at 3.5 kHz with a Q-factor of 0.7 in a range of -6 dB to +6 dB in steps of 1.5 dB. The nine tracks were also estimated in three separate sessions as the investigation above. Only the criteria we changed. As described in figure 1 the tracks were judged instead of brilliance according the naturalness and instead of quality of high frequency reproduction according their homogeneity.

5. Results of Test "Midrange"

The results of paired comparison in session 1 are shown in figure 5. The sharpness is increasing with higher level at 3.5 kHz. Naturalness and homogeneity have a similar course with their maximum at the original signal and worse values with smaller and higher levels.

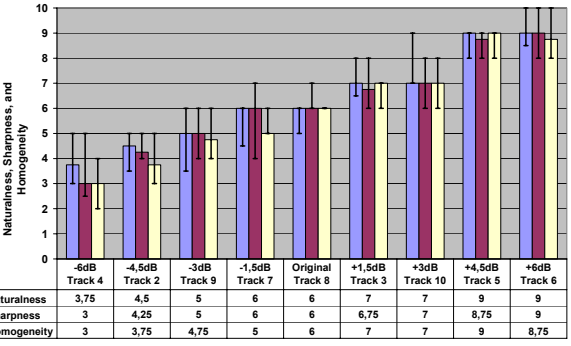
The results of session 2 represent in figure 6 also an increasing sharpness with higher level, a well-balanced sharpness is recognizable at a level of -3 dB. Naturalness and homogeneity have the best value 5 also at a level of -3 dB. With higher level the music section sounds more "aggressive" and "importunate".

In session 3, in which the best sound should be selected, the -3 dB version was preferred.



	-6dB Track 4	-4,5dB Track 2	-3dB Track 9	-1,5dB Track 7	Original Track 1	+1,5dB Track 3	+3dB Track 10	+4,5dB Track 5	+6dB Track 6	Original Track 8
Naturalness %	80	90	95	100	100	95	90	70	67,5	100
Sharpness %	75	80	90	97,5	100	105	120	130	140	100
Homogeneity %	70	80	90	97,5	100	100	87,5	95	90	97,5

Figure 5: Session 1: Naturalness, sharpness, and homogeneity in paired comparison relative to original track 1.



	-6dB Track 4	-4,5dB Track 2	-3dB Track 9	-1,5dB Track 7	Original Track 8	+1,5dB Track 3	+3dB Track 10	+4,5dB Track 5	+6dB Track 6
Naturalness	3,75	4,5	5	6	6	7	7	9	9
Sharpness	3	4,25	5	6	6	6,75	7	8,75	9
Homogeneity	3	3,75	4,75	5	6	7	7	9	8,75

Figure 6: Session 2: Naturalness, sharpness, and homogeneity in magnitude estimation without anchor.

6. Conclusion

The results indicate, that independent of the used investigation procedures a tweeter loudspeaker frequency response should have a small level increase of about 3 dB at 16 kHz with a Q-factor of 0.7. At 3.5 kHz however the paired comparison gives the original sound the preference, while with the magnitude estimation and in a separate third session a level decrease of 3 dB was preferred by the test persons. For general declarations certainly more experiments with different music sequences and Q-factors have to be executed.