

Correlation between the distortion parameters and perceived sound quality of loudspeakers

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Abstract: This work is to investigate relationship between subjective quality and objective distortion quantities for loudspeakers, for the aim of predicting perceived quality with physical parameters. The measured distortion parameters included: duration of initial transient, duration of final transient, harmonic distortion and frequency response. Subjective evaluation test was conducted to give the perceived sound quality described with six adjective words. Based on the correlation analysis between the distortion parameters and the sound quality psychological scales, it found that softness is mainly correlated with the duration of initial transient and the harmonic distortion. The clarity is correlated with the harmonic distortion; the fullness is influenced by the duration of initial transient.

Key words: distortion; subjective evaluation; correlation; sound quality

扬声器失真评价参数与主观音质评价参数的关系

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摘要: 本文探讨了扬声器的失真参数与主观音质评价参数的关系。其中可测量失真参数包括: 前沿瞬态时间、后沿瞬态时间、谐波失真和频率响应。通过主观评价实验得到了不同音质评价术语的等级量表。在失真参数与声品质心理尺度的相关分析基础上, 发现柔和度主要与前沿瞬态时间和谐波失真有关, 清晰度与谐波失真有关, 丰满度受到前沿瞬态时间的影响。

关键词: 失真; 主观评价; 相关性; 声品质

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1 INTRODUCTION

Although nearly 80% of loudspeakers of the world are produced in China, sound quality of most products is unsatisfactory presently. With the increasing requirement of loudspeakers, the competitive abilities of loudspeaker enterprises should be enhanced, and as a consequent, the improvement of sound quality of loudspeakers becomes neces-

sary. On one hand, sound quality of loudspeakers is usually determined by subjective evaluations, and on the other hand, objective parameters are generally used to maintain the quality of loudspeakers by manufactures. For the sake of this, improving sound quality by establishing some relations between the subjective sound quality and objective parameters would be a good choice.

There are many studies on subjective evaluations of loudspeakers and the techniques of loudspeaker measurement have been well developed

recently. However, very few researches on relationship between the sound quality and the objective parameters had been carried out, and the frequency response is usually used as an objective parameter of loudspeakers in these studies. The perceived sound quality of loudspeakers is affected not only by the frequency response but also by many other parameters, such as transient response, phase response, distortions and so on^[1]. It is essential to find out more objective parameters that correlate with sound quality, in order to get a better sound quality of loudspeakers. This paper presents a preliminary analysis on correlation between distortion parameters and subjective auditory evaluation of some local loudspeakers.

2 DISTORTION PARAMETERS OF LOUDSPEAKERS

The distortion parameters included duration of initial transient, duration of final transient and harmonic distortion were measured in an anechoic environment and the definitions of distortion parameters were as follows:

The duration of initial and final transients could be measured by tone burst test. The length of tone burst was 20 circles. The tone burst emitted by loudspeakers could be transferred into energy curve as shown in Fig.1. The length of energy curve from zero to steady state was called the duration of initial transient for this frequency. The length of ener-

gy-time curve decayed by 10 dB from steady state was called the duration of final transient for this frequency.

The harmonic distortions of loudspeakers were measured and all the results of distortion parameters are displayed in Fig.2.

3 SELECTIONS OF SUBJECTIVE EVALUATION TERMS

On the basis of some investigations on the evaluation experiments, it found that in many experiments fidelity, impact, softness, clarity, fullness, brightness and spaciousness were usually used as subjective evaluation terms.

Some investigations on experts of acoustics and sound engineers with a large number of adjectives were carried out. The results were shown in Table 1, the percentage means the ratio of each term that was selected by subjects in investigations. It shows that fullness, clarity, brightness, and softness were most frequently used as the subjective evaluation terms of loudspeakers.

Table 1 Results of investigations

No.	1	2	3	4	5
Terms	Fullness	Clarity	Brightness	Softness	Mellow
Percentage	100%	85%	85%	85%	77%
6	7	8	9	10	11
Close	Balance	Fidelity	Wooden	Transparent	Thickness
69%	69%	62%	46%	46%	46%
12	13	14	15	16	17
Roughness	Flatness	Scatter	Warm	Shrink	Hollow
38%	38%	38%	38%	31%	31%

As introduced in^[3], the perceived sound quality of loudspeakers, headphone, and hearing aids was investigated in the form of subjective evaluation with the purpose to find out the meaning of relevant dimensions in perceived sound quality. There were 55 adjectives for the experiment chosen on the basis of result from questionnaires to 40 sound engineers. And the sound quality of loudspeakers was interpreted as clearness, feeling of

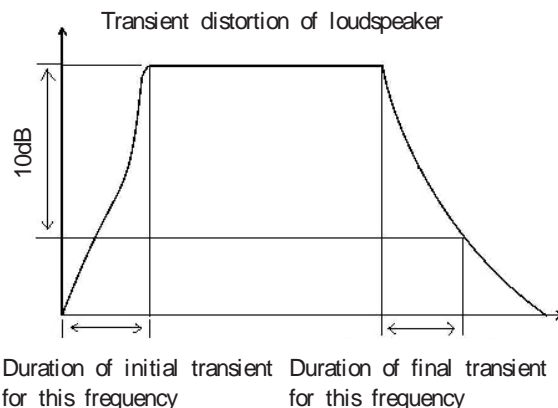


Fig.1 Energy envelope of tone burst

space, nearness, sharpness, hardness-softness, brightness-darkness and noise.

According to these works, the clarity, brightness, softness, impact, fullness and fidelity were selected as subjective evaluation terms of loudspeakers.

4 EXPERIMENTS OF SUBJECTIVE EVALUATIONS

A standard listening room and equipments were prepared according to IEC 268-13 "sound system equipment-part 13: Listening tests on loudspeakers". Paired comparison method was used and all the subjective evaluation experiments of loudspeakers were monophonic. In the experiments, three classical music sections with different styles were used. The music sections were as follows:

(1) Felix Mendelssohn: Songs Without words op. 19: No. 3 In A Major 'Hunting Song' for 16s. There are some piano solos including treble and bass.

(2) Stravinsky: The beginning of The Rite of Spring Glorification of the Chosen Victim in Part : The Sacrifice for 14s. In this section brasses and percussions are mainly included.

(3) Richard Strauss: Music from Concerto for Oboe and Small Orchestra in D major Allegro for 20s and all the violinists are playing in unison.

In order to avoid the influence of sound pressure level (SPL), the SPL which was approximately 80dB(A) in audience area was maintained invariable during subjective test. By this means, the influence of variable SPL to the result of experiments could be ignored.

In the experiment, each evaluation terms was definitely defined and the subjects had an identical comprehension with them. The definitions of subjective evaluation terms were explained as follows:

Clarity: The reproduction sounds clear, distinct, pure and you can clearly hear and distinguish different instruments and voices within complex or-

chestra, in contrast to a sound that is inarticulate, blurred and diffuse.

Brightness: It refers to the brightness of the sound in contrast to a sound that sounds dullness and darkness.

Softness: The reproduction sounds soft and gentle in contrast to a sound that is sharp, hard, keen and shrill.

Fullness: It is favored by a broad frequency range and more emphasis on lower frequency in contrast to a sound that is thin.

Impact: The reproduction sounds impact and more powerful in contrast to faint and weakness.

Fidelity: It describes how closely the reproduced sound approaches your impression or recollection of the original sound.

In the experiments only 2 people were permitted each time and 22 subjects who were postgraduates of acoustic were selected and the subjective scales of loudspeakers based on the evaluation experiments were shown in Fig.4.

5 CORRELATIONS BETWEEN DISTORTION PARAMETERS AND PERCEIVED SOUND QUALITY OF LOUDSPEAKERS

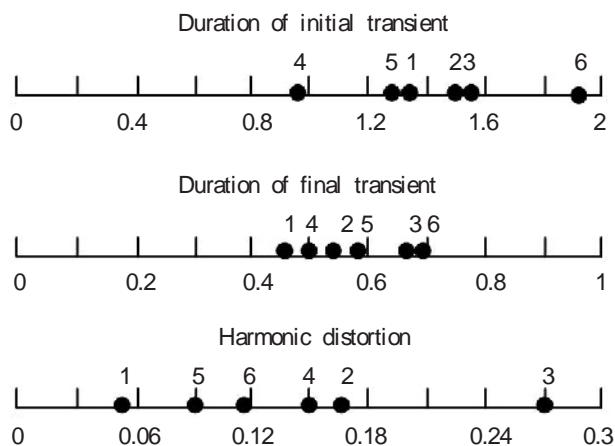


Fig.2 Results of objective measurement for loudspeakers

The scales of different distortion parameters of loudspeakers are shown in Fig.2, in which the identify number of loudspeakers is marked over the

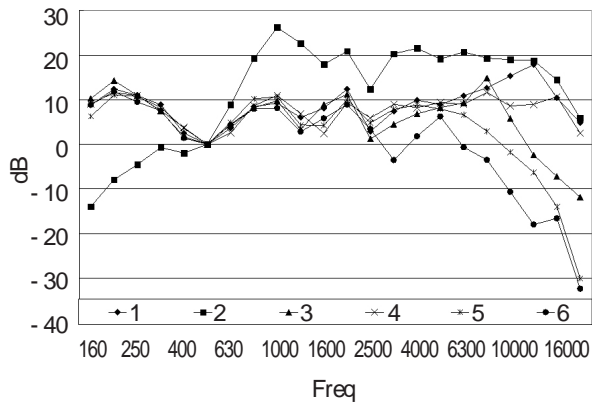


Fig.3 The frequency response of loudspeakers

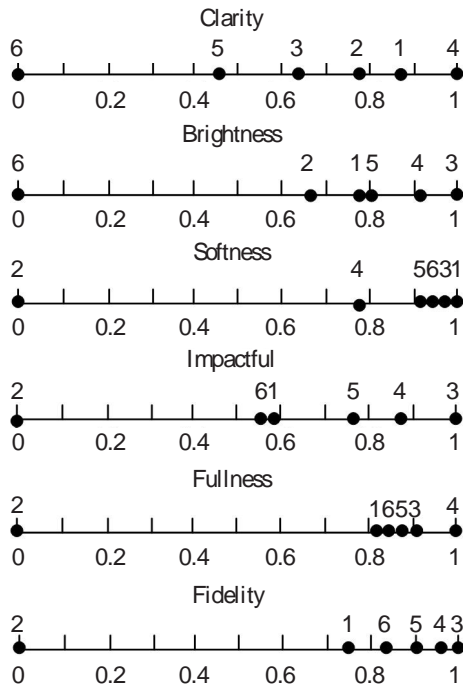


Fig.4 Results of subjective evaluation of loudspeakers

scales with corresponding value of the distortion parameters marked under the scales. As seen from Fig.2, all the values of duration of initial transient are larger than the values of final transient. The harmonic distortion and duration of initial transient have more differences than the duration of final transient among loudspeakers and the value of duration of final transient is mainly between 0.4 and 0.7.

The frequency responses of loudspeakers measured in an anechoic room are shown in Fig.3. The frequency response of loudspeaker No.2 has decayed at frequencies below 1000Hz obviously and the frequency response of loudspeaker No.6 has decayed at frequencies above 3000Hz.

In Fig.4 the results of subjective evaluations are shown and the rating scales for different evaluation terms have been indicated. On the top of these scales the number of loudspeakers had been marked. The loudspeaker of No.6 has the worst sound quality in clarity and brightness and the loudspeaker of No.2 has the worst sound quality in softness, impact, fullness and fidelity. It seems that clarity and brightness are related to the high frequency response that is above 3000Hz and softness, impact, fullness and fidelity are related to low frequency response that is below 1000Hz. It is in agreement with previous studies^[4,5] on the affection of frequency response to loudspeakers.

The sound quality of loudspeaker No.2 is not very good in clarity and brightness and its sound quality in softness, impact and fullness is the worst. Then the fidelity of loudspeaker No.2 is worst; The sound quality of loudspeaker No.3 is better than any other loudspeakers in brightness, softness, impact and fullness. Then there is a better sound quality in fidelity of the loudspeaker No.3. Therefore the fidelity is affected by clarity, brightness, softness, impact and fullness simultaneously and the fidelity is an overall rating of sound quality.

In Fig2 and Fig4, the sequences of loudspeakers are demonstrated. If a distortion parameter has some relationship with evaluation terms, there will be some correlations between their sequences too. From this point a simple correlation analysis had been accomplished and a matrix of correlation coefficients was shown in table 2.

Table 2 Correlation coefficients between distortion and evaluation terms

	Duration of initial transient	Duration of final transient	Harmonic distortion
Clarity	0.37	0.26	0.71
Brightness	0.43	0.14	0.31
Softness	0.83	0.03	0.71
Impact	0.26	0.54	0.09
Fullness	0.60	0.14	0.43
Fidelity	0.54	0.03	0.66

The clarity has some correlations with the harmonic distortion of loudspeakers. Softness is influenced by duration of initial transient and harmonic distortion simultaneously. On the basis of correlation coefficients, it seems that the duration of initial transient has more affection to the softness than the harmonic distortion of loudspeakers. A correlation is found between the duration of initial transient and fullness.

All the correlation coefficients between the duration of final transient and evaluation terms of sound quality are below 0.6 as shown in table 2, it seems that the correlations between them are not very strong. Maybe there are two reasons for this interpretation: In the aspect of evaluation terms, the sound quality described with six adjective words has few correlations with the duration of final transient in deed; Fig.2 shows the values of the duration of final transient ranged from 0.4 to 0.7, whether these differences among the duration of final transient are audibility or not need more experiments on it. The correlation coefficient between the clarity and the harmonic distortion is the same as that between the softness and the harmonic distortion. Therefore the harmonic distortion should have significant influence on sound quality compared with other objective parameters.

6 DISCUSSIONS

Some preliminary relations between the sound quality and distortion parameters are found via the analysis of the experiments. The harmonic distortion has the primary affection to the sound quality, the

duration of initial transient has the secondary affection to the sound quality and the relations between the duration of final transient and the sound quality are still not found out. The clarity has a significant correlation with the harmonic distortion; the softness is affected by the duration of initial transient and the harmonic distortion at the same time, but the duration of initial transient has more affection to it; the fullness is influenced by the duration of initial transient. If some quantitative relations between the distortion parameters and the sound quality can be found out via some advanced studies, they will contribute greatly to the improvement of sound quality.

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