STUDY OF SOUND QUALITY EVALUATION FOCUSED ON EFFECTS FROM DIFFERENCE OF MEDIA TO PLAYING SYSTEM

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Today, some audiophiles sometimes discuss about the difference of sound quality between different medias. Moreover, some production groups focus on the sound quality and developed new media. But, there aren't any techniques to evaluate sound quality except for subjective methods. We researched about it focused on spaciousness and noise floor level and considered that the playing system may be affected from the difference of media from result. So, added with noise floor level and spaciousness researched last year, we considered methods of analysis to show the difference of sound quality objectively with focusing on interaural cross-correlation (IACC), jitter of a compact-disc (CD) player while playing a CD. Regarding IACC, we checked IACC while playing different CD using dummy head to explain spaciousness more objectively than last year researching. Regarding jitter, we measured jitter from Sony/Philips digital interface (S/PDIF) coaxial output and carried out experiment to research whether jitter could be recognized from listeners by adding jitter to the CD player deliberately. From these analysis, we consider how to check the difference of sound quality between different media and applicability another source.

Keywords: sound quality evaluation, auditory impression

1. Introduction

For some of today’s music media, which includes CD, DVD-audio, and BD-audio, only the data is being sold. Therefore, audiophiles sometimes discuss the differences in sound quality between different medias that have the same music. In addition, sales of CDs are decreasing in Japan in general as shown in Fig. 1[1]. This trend is same as in the U.S[2].

To combat this tendency, CD suppliers have tried making CDs that have better sound quality to add value to their products. We will call those CDs “high quality CDs” in this paper. Audiophiles also discuss the sound quality differences between discs that have the same format but different materials or differ in how they are made, as well as between completely different media.

There are many studies that consider the causes of differences of sound quality. In Hioki’s research[3], an attempt was made to improve the sound quality by optimizing the material of the disc, color of the label printing, the shape, etc. The cause of the decreasing sound quality was found to be jitter; therefore, we need to strengthen the power supply system and construct a jitter-free playing system.

Nishimura et al.[4] proposed two approaches to detect the differences of sound from media constructed from different materials. First, to eliminate the influence of jitter, they compared the root
mean square values of the recorded signal waveforms with a synchronized clock between the player and the recorder. Second, they surveyed the time-variation properties by comparing the phases between two signal waveforms in the absence of synchronization. They were able to clarify that there are no differences in sound quality caused by the CD media in the target player.

Furthermore, there is some evidence suggesting a difference in the apparent source width between conventional and high-quality CDs\(^5\).

Therefore, we cannot say that the causes producing differences in the sound quality from different CDs are identified.

This study reinvestigates the difference in the apparent source width between conventional and high-quality CDs and considers the causes of sound quality differences, mainly focusing on jitter.

2. **CD media**

In this research, we compared conventional CD, “Ultimate Hi-Quality CD” (UHQCD), and “Pre-Master CD” (PMCD).

PMCD is a CD format that includes the original source used to produce conventional CDs for purchase. They are made using the same materials as conventional CD\(^6\).
UHQCD, which is a type of high quality CD, is made using a photopolymer, but a special alloy is employed as the reflection film. Because of that, UHQCDs succeed in getting a higher transfer ratio of the stamper than conventional CDs\cite{6}, as shown in Fig. 2.

3. **Interaural cross correlation measurement**

Previous research compared the apparent source width between high quality and conventional CDs in terms of the interaural time difference (ITD). It concluded that the high quality CD has wider apparent source width than conventional CD\cite{5}. However, it has been reported that the human can recognize a 9\mu s ITD\cite{7}. In other words, we think that it is necessary to check the apparent source width regarding the interaural intensity difference, in addition to ITD, thus checking the apparent source width difference between high quality and conventional CDs again. In this section we show how to check the apparent source width between these CDs.

3.1 **Interaural Cross Correlation (IACC)\cite{8}\**

When the signals are measured by binaural microphones, the interaural cross correlation (IACC) is measured from the interaural cross-correlation function (IACF), defined as,

\[
IACF(\tau) = \frac{\int_{t_1}^{t_2} x_1(t)x_2(t + \tau)dt}{\sqrt{\int_{t_1}^{t_2} x_1^2(t)dt \int_{t_1}^{t_2} x_2^2(t)dt}}
\]

IACF is a function in the range [-1,1] and gives a measure of the correlation between the received signal \(x_1\) and \(x_2\) within the integration limits \(t_1\) and \(t_2\) as a function of the time delay \(\tau\).

Then, IACC defined as shown,

\[
IACC = \max |IACF(\tau)|
\]

The smaller IACC is, the better the apparent source width could be felt by a human.

3.2 **Measurement method**

IACC from each CD and each track was calculated and the signal recorded with a dummy head in an anechoic chamber. The CDs used in this experiment have the same music in all tracks. The recording environment is shown in Fig. 3. We compared the maximum, minimum, mean value, and standard deviation of IACC from these CDs.

![Figure 3. The experiment system for IACC measurement](image-url)
3.3 Results

The maximum, minimum, and mean value of IACC from each CD are shown in Fig. 4 and the standard deviation in Fig. 5. Both figures show that the values for UHQCD are the smallest of these CDs. Thus, we note the possibility that the difference in materials in the same media format affects the apparent source width.

Fig. 6 shows the distributions of IACC from these CDs. Though these distributions are tested in ANOVA, there are no significant differences. However, the number of samples might be too small to test ANOVA (statistical power $\beta = 0.128$). Hence, it is necessary to get more samples to compare in more detail.

4. Jitter measurement

Jitter is the variation in time of a digital signal. In a digital audio environment, jitter effects the analog signal waveform and the sound quality [9]. Therefore, we assumed that the jitter effects the apparent source width and measured the jitter from each CD. In this section we show how to measure the jitter.

![Figure 4. Maximum, minimum and mean value of IACC from each CD](image)

![Figure 5. The standard deviations of IACC from each CD](image)
4.1 Measurement method

A CD player (ESOTERIC K-07) and an audio analyzer (Audio Precision APx555) are connected and PMCDs, UHQCDs, and conventional CDs are played with a 44.1kHz clock synchronization from the analyzer. In this situation, the jitter from the Sony/Philips Digital Interface (SPDIF) coaxial output on the CD player is measured in the analyzer. However, because of the player characteristic, this CD player produced a jitter decline as time proceeded. Hence, we believe that this CD player is easily affected by aging. Thus, we compared the standard deviation of the jitter between each CD. The jitter was sampled at 32 Hz and each CD was played around 70 minutes.

4.2 Result

The standard deviation of the jitter from each CD is given in Fig. 8. Just like in section 3, Fig. 8 shows that the UHQCD value is the smallest among these CDs. This result was obtained regardless of which order we played the CDs. Because of aging, no statistical test could be performed. However, the standard deviation of the jitter from UHQCD is the smallest for all orders of playing the CDs. Therefore, we note the possibility that the difference of materials in the same media format affects the jitter distribution.

5. Possibility of jitter discrimination

According to sections 3 and 4, UHQCD has the smallest IACC standard deviation of and jitter among these CD. However, it is not clear that the differences in these standard deviations of the jitter effect the sound quality, including the apparent source width. Thus, it is necessary to check whether
the difference between these standard deviations of jitter can be discriminated. This section shows the test theory, experimental method, and results about jitter discrimination.

Figure 8. The standard deviations of jitter from each CD

5.1 Two-point identification test

The two-point identification test\(^{[10]}\) is applicable to research to understand the ability of subjects to discriminate between two things. Before the identification, the null hypothesis \(H_0\) is put forward. When \(H_0\) is defined as “subjects cannot discriminate,” the probability level \(p\) equals 1/2,

\[
H_0: p = \frac{1}{2} \tag{3}
\]

If \(H_0\) is the correct hypothesis, the number of times \(x\) the correct answer is chosen follows the binomial distribution with \(p = 1/2\). Thus, in \(n\) repetitions, the probability \(P(x)\) that the subjects can make correct answers \(x\) times is,

\[
P(x) = nC_x p^x (1 - p)^{n-x} \tag{4}
\]

When we substitute \(p = 1/2\),

\[
P(x) = nC_x \left(\frac{1}{2}\right)^x \left(1 - \frac{1}{2}\right)^{n-x}
= nC_x \left(\frac{1}{2}\right)^n
= \frac{n!}{x!(n-x)!} \left(\frac{1}{2}\right)^n \tag{5}
\]

Thus, the probability \(P\) that subjects can provide correct answers \(x\) times in \(n\) trials is,

\[
P = P(x) + P(x+1) + \cdots + P(n-1) + P(n) \tag{6}
\]
When this has a 5% level of significance, i.e. if $P \geq 0.05$, $H_0$ is not rejected, and when $P < 0.05$, $H_0$ is rejected.

5.2 Test method

The two stimuli ripped from a UHQCD, one with added jitter (maximum 40 ns from a jitter generator, Audio Precision APx555) and the other without added jitter, are evaluated by a single-blind test. We had 15 participants and carried out 4 tests per participant. In this test, because the CD player has a re-clock circuit, the jitter from the S/PDIF coaxial output had a maximum around 4 ns. Table 1 shows that the standard deviation of the jitter from these two stimuli have a larger difference between the standard deviations of the jitter than in Fig. 8. The order of playing stimuli is shown in Table 2. To investigate whether the participants can discriminate among these stimuli we employed the two-point identification test, with a 5% level of significance. Fig. 9 shows the test system.

![Test system for jitter discrimination](image)

**Table 1. The standard deviation of jitter and stimuli definition**

<table>
<thead>
<tr>
<th>Stimuli</th>
<th>Jitter addition</th>
<th>Standard deviation of jitter(ps)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>✕</td>
<td>41.5</td>
</tr>
<tr>
<td>B</td>
<td>○(Max 40ns)</td>
<td>53</td>
</tr>
</tbody>
</table>

**Table 2. The order of playing stimuli**

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Order</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>B→A</td>
</tr>
<tr>
<td>2</td>
<td>A→B</td>
</tr>
<tr>
<td>3</td>
<td>A→B</td>
</tr>
<tr>
<td>4</td>
<td>B→A</td>
</tr>
</tbody>
</table>

5.3 Result

Table 3 shows the result of this experiment. According to Table 3, this test could not determine a significant difference between these stimuli. This shows that the difference in standard deviation of the jitter between these two stimuli does not affect the auditory impression among the participants. We conclude that the differences in the standard deviation of the jitter between conventional CDs, UHQCDs, and PMCDs has little possibility to affect the auditory impression.
### 6. Conclusion

We have reinvestigated the difference in the apparent source width between conventional and high-quality CDs and considered the cause of sound quality differences by focusing on jitter. We compared the apparent source width of conventional and high-quality CDs by measuring IACC in section 3. We considered how the difference of CD materials affects the apparent source width. However, we had too few samples to draw any conclusions. Therefore, it is necessary to collect more samples of IACC from these CDs.

In section 4, the jitter from the CDs are compared and we found that UHQCD has a smaller standard deviation of jitter than conventional CD, showing that a difference in the materials of the CD affects jitter distribution.

A jitter discrimination experiment was carried out in section 5. The relation between the standard deviation of jitter and sound quality was not confirmed. It is possible that the different CD materials affects the apparent source width and jitter distribution, but we are unable to find a correlation between jitter and sound quality.

In the future, we will investigate the causes that affect the apparent source width from the difference in CD materials. Furthermore, it is necessary to collect more samples to make a more detailed statistical analysis and compare IACC between the two stimuli to determine the relation between jitter and apparent source width.

### REFERENCES