Fundamental Subjective Attributes for Sound Fields from a Model of Auditory-Brain System

Yoichi Ando
Graduate School of Science and Technology, Kobe University, Rokkodai, Nada, Kobe 657 Japan

Abstract: This paper describes subjective responses for sound fields from a model of auditory-brain system.

MODEL

A model may be proposed as shown in FIGURE 1 (Ando, 1985; Ando 1998). Based on this model, we can describe qualities of sound fields in term of processes of the auditory pathways and the brain. Together with the mechanisms of the interaural crosscorrelation and the autocorrelation as well as the specialization of human brain, fundamental subjective attributes may well be described as mentioned below.

FIGURE 1. An auditory-brain model.

FUNDAMENTAL SUBJECTIVE ATTRIBUTES BASED ON THE MODEL

1. Spatial Subjective Attributes in Relation to the Interaural Crosscorrelation Function

A. Subjective Diffuseness

In order to obtain the scale value of subjective diffuseness, paired-comparison tests with bandpass Gaussian noise, varying the horizontal angle of two symmetric reflections have been performed. Listeners judged which of two sound fields were perceived as more diffuse. A remarkable finding is that the scale values of subjective diffuseness are inversely proportional to the IACC, and may be formulated in terms of the 3/2 power of the MCC in a manner similar to the subjective preference, i.e., (Ando and Kurihara, 1980)

\[ S = \alpha (IACC)^{\beta} + \gamma (WIACC)^{\theta} \]

where \( \alpha = -2.9 \), \( \beta = 3/2 \), \( \gamma = 0 \), and \( \theta = 0 \).

Definitions of the IACC and WIACC are shown in FIGURE 2.

FIGURE 2. An interaural crosscorrelation function, and definitions of the IACC, WIACC and \( \tau IACC \).

It is worth noticing that \( \tau IACC = 0 \), for the frontal sound image which is required for the preferred condition of sound fields.
B. Apparent Source Width (ASW) in Relation to the IACC and the WIACC

The ASW may be well described by both factors, IACC and WIACC such as Equation (1), putting $\alpha = -1.64$, $\beta = 3/2$, $\gamma = 2.44$, and $\theta = 1/2$ (Sato and Ando, 1997).

2. Temporal Subjective Attributes in Relation to ACF of Source Signals

A. Missing Fundamental

A typical example of demonstrating the ACF model is phenomenon of missing fundamental, which may not be explained by the spectrum of source signals. Experiments were performed on the pitch matching tests for the complex tones with 600, 800, 1000, 1200 and 1400 Hz sinusoidal waves (Sumioka and Ando, 1996). The two wave forms of complex tones in phases, and random phases were applied as test stimuli. The ACF of these two stimuli are the same with a period of 5 ms (200 Hz). Results of the tests indicates that the matching frequencies for both stimuli are similar with the dominant pitch of 200 Hz which is not included in the spectrum nor in the real wave form of random phases, but the period in the ACF.

B. Subjective Effects of a Single Reflection

Results of subjective preference as an over all psychological response for sound field with a single reflection indicated that the most preferred delay of the reflection may be found by the envelope curve of ACF,

$$[\Delta t]_p = \tau_p$$

such that

$$|\phi(\tau)|_{envelope} = kA^\tau_c, \text{ at } \tau = \tau_p$$

(2)

where $A$ is the pressure amplitude of the single reflection, $k = 0.1$ and $c = 1$. If the envelope of ACF is exponential, then the above equation is simply expressed by

$$[\Delta t]_p = (1 - \log_{10}A)\tau_c$$

(3)

where $\tau_c$ is the effective duration defined by the ten percentile delay of the ACF-envelope (Ando, 1985).

Such a relationship also holds for other basic subjective responses in relation to the temporal factor. For example, the constants $k$ and $c$ may be obtained for each subjective response to sound fields, based on the ACF of source signals as listed in TABLE 1.

<table>
<thead>
<tr>
<th>Subjective attributes</th>
<th>In Equation (2)</th>
<th>Delay time to be obtained</th>
<th>Range of amplitude examined [dB]</th>
<th>Source signals</th>
<th>Authors investigated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preference of listeners</td>
<td>0.1</td>
<td>1</td>
<td>Preferred delay time</td>
<td>Speech &amp; music Gaussian noise</td>
<td>Ando (1977)</td>
</tr>
<tr>
<td>Coloration</td>
<td>$10^{-5/2}$</td>
<td>-2</td>
<td>Critical delay time</td>
<td>Speech</td>
<td>Ando &amp; Alrutz (1982)</td>
</tr>
<tr>
<td>Threshold of perception of reflection</td>
<td>2</td>
<td>1</td>
<td>Critical delay time</td>
<td>Speech</td>
<td>Seraphim (1961)</td>
</tr>
<tr>
<td>50% echo disturbance</td>
<td>0.01</td>
<td>4</td>
<td>Disturbed delay time</td>
<td>Speech</td>
<td>Haas (1951); Ando et al. (1974)</td>
</tr>
<tr>
<td>Preference of musicians</td>
<td>2/3</td>
<td>1/4</td>
<td>Preferred delay time</td>
<td>Music</td>
<td>Nakayama (1984)</td>
</tr>
</tbody>
</table>

This study was supported by the Grant in Aid for Scientific Research (C) 9838022, 1997.

REFERENCES