3-D sound field reproduction based on forward emphasis for HRTFs with the head-enclosed loudspeaker-array

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1 Introduction

The sound field reproduction is useful to represent acoustic contents with high-realistic sensation. The semitransaural system[1] which has been previously proposed can easily design the inverse filter for the spatial transfer function. However, the conventional system has the problem that the back and forth confusion disturbs the sound image localization. In this paper, we propose the 3-D sound field reproduction based on forward emphasis for head-related transfer functions (HRTFs) with the head-enclosed loudspeaker-array.

2 Proposed method

In this paper, we propose a new 3-D sound field reproduction system based on forward emphasis for HRTFs with the head-enclosed loudspeaker-array. Figure 1 indicates the flowchart of the proposed method in left side of human head. Head-enclosed loudspeaker-array consists of six loudspeakers around human head. As shown in the Fig. 1, in first step, the binaural sound source is designed by convolving the dry sound sources and HRTFs recorded in horizontal plane. In second step, the forward emphasis is applied to the binaural sound sources. The forward emphasis is defined as amplification for the power spectrum in 300 to 500 [Hz] frequency band (lower frequency band; LFB) and 3.15 to 5 [kHz] frequency band (higher frequency band; HFB)[2]. In third step, the emphasized sound sources are convolved with the inverse filter which is pre-designed. The single input multiple output (SIMO) inverse filters are designed with multiple-input/output inverse-filtering theorem (MINT)[3]. The SIMO inverse filters correct the spatial transfer functions from each loudspeaker to the listeners' ear. Equation (1) indicates the output signals $Y_i(z)$ which are emitted from loudspeaker i.

$$Y_i(z) = W_L(z) \cdot X_L(z) \cdot \hat{H}_i(z) + W_H(z) \cdot X_H(z), \quad (1)$$

where $X_L(z)$, and $X_H(z)$ are the input signals on frequency z, and $W_L(z)$, and $W_H(z)$ are the coefficients to emphasize the LFB and HFB, $\hat{H}_i(z)$ is the designed SIMO inverse filter.

3 Subjective evaluation experiment

The evaluation experiments were carried out to indicate the effectiveness of the proposed method. We employed white noise as sound sources. We also employed

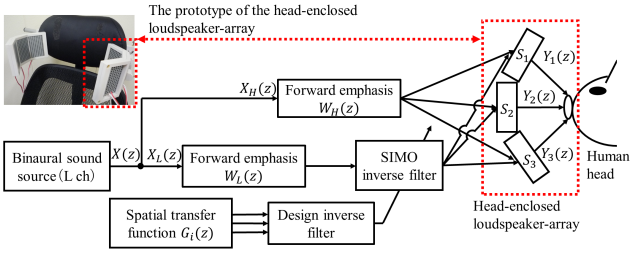
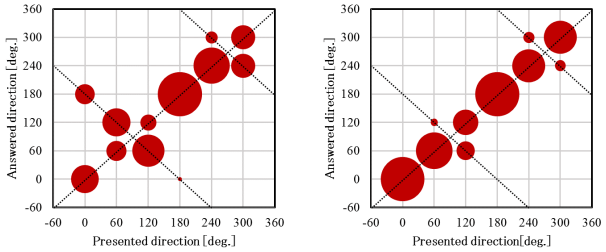


Fig. 1　Flowchart of the proposed method (left side)



(a) w/o the forward emphasis　(b) w the forward emphasis

Fig. 2　The experiment results on sound localization

personal HRTFs as HRTFs in the proposed method. The personal HRTFs were recorded in horizontal plane (0, 60, 120, 180, 240, 300 [deg.]). The subjects were four students. Figure 2 indicates the results of the evaluation experiments. As a result, we confirmed that the proposed method was able to decrease the back and forth confusion and improve the performance of sound image localization.

4 Conclusions

In this paper, we proposed the sound field reproduction system based on the forward emphasis with the head-enclosed loudspeaker-array. As a result of evaluation experiment, we confirmed the effectiveness of the proposed method. We intend to evaluate the experiment under the condition that subjects move their heads.

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