Improving sound field reproduction in a small room based on higher-order Ambisonics with 157-loudspeaker array

T. Okamoto[1], D. Cabrera[2], M. Noisternig[3], B. FG Katz[4], Y. Iwaya[1] and Y. Suzuki[1]
[1]Tohoku University, Japan, [2]The University of Sydney, Australia, [3]IRCAM, France, [4]LIMSI-CNRS, France

1. Introduction

For realizing high definition 3D sound field reproduction, we have developed a 157 loudspeaker array system [1,2] in a small room based on higher-order Ambisonics [3]. The features of this system are

1. no loudspeaker is installed on the floor
   and
   the arrangement is on rectangular grid
2. 157 channels are controlled by 4 PCs
3. reverberation time of this room is 0.2 s

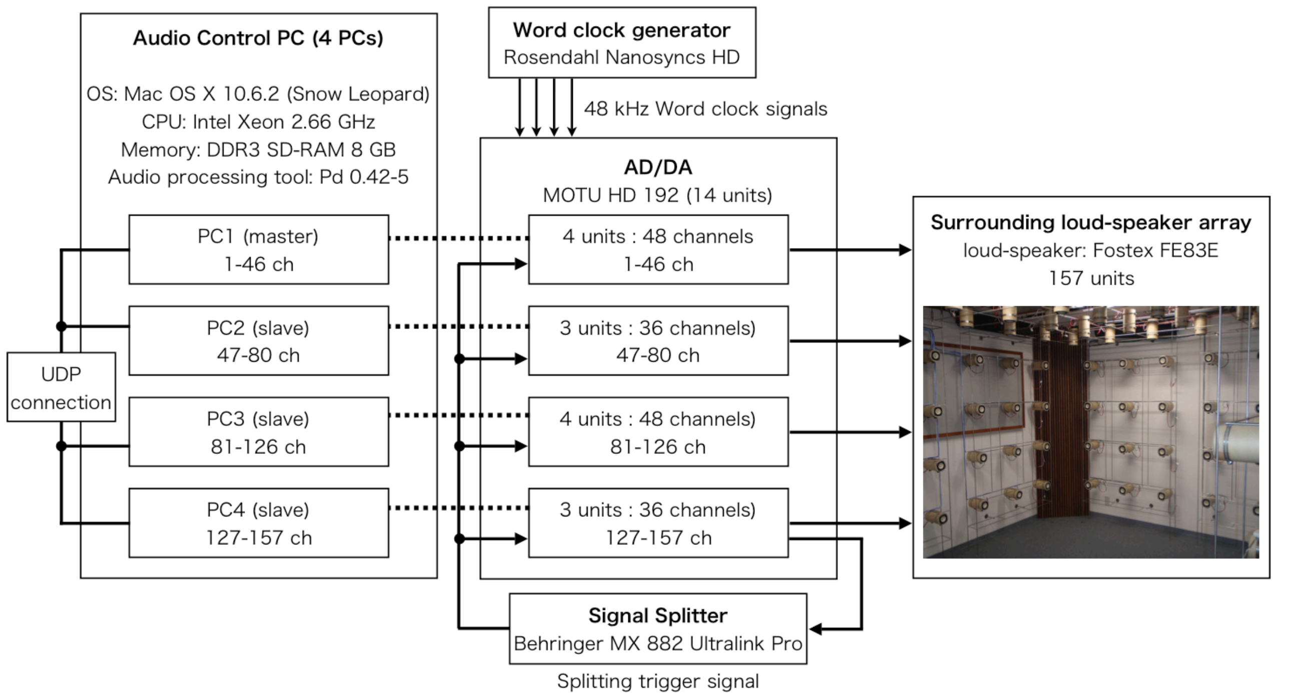
Therefore, we discuss about

1. appropriate decoding order
2. inter-channel synchronicity
3. acoustics of the reverberation

for realizing more precise sound field reproduction.

[1,2] T. Okamoto *et. al* 2007 and 2009

[3] M. A. Poletti 2005

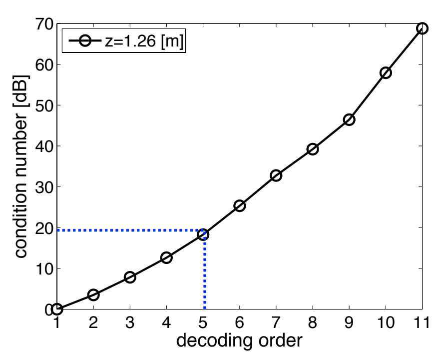


Surrounding 157 loudspeaker array system using 4 PCs, 14 units of A/D D/A and splitter

2. Appropriate decoding order

The general Ambisonics approach is defined by a spherical harmonics expansion of the free field without taking the radial solutions of the wave equation. The decoding matrix $\mathbf{C}^{+}$ is calculated from the set of spherical harmonics between the sweet spot and each loudspeaker position. The sweet spots is located in the center of the room for a seated person's ear height with z=1.26 m. The accuracy of the decoding matrix was estimated from the condition number of Eq. (1). We implemented HOA of order 5 which represents an over-determined system, i.e. it can be solved by singular value decomposition (SVD) / pseudo-inverse.

$$\mathbf{C}^{+} = \begin{pmatrix} Y_0^0(\theta_1,\phi_1) & Y_0^0(\theta_2,\phi_2) & \cdots & Y_0^0(\theta_K,\phi_K) \\ Y_1^{-1}(\theta_1,\phi_1) & Y_1^{-1}(\theta_2,\phi_2) & \cdots & Y_1^{-1}(\theta_K,\phi_K) \\ \vdots & \vdots & \ddots & \vdots \\ Y_N^N(\theta_1,\phi_1) & Y_N^N(\theta_2,\phi_2) & \cdots & Y_N^N(\theta_K,\phi_K) \end{pmatrix}^{+} \quad (1)$$

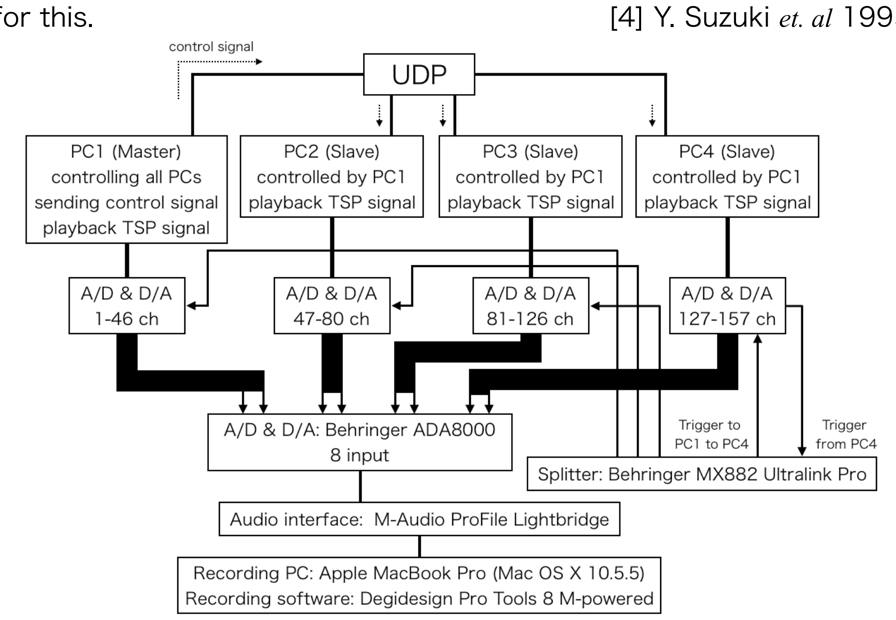


The relationship between condition number of Eq. (1) and HOA decoding order

3. Synchronization

The latency was measured using a Time Stretched Pulse (TSP) signal [4], a variant of the swept-sinusoid. Deconvolution of the TSP signal from the recorded signals for each channel provides an impulse whose temporal position is equivalent to the delay. The results show that the output signals from all D/A channels from the same PC were completely synchronous at the 1-sample level. However, the output signals between different PCs were not synchronous at the 1-sample level and the delay timing varies. The unsigned maximum latency was 51 samples (= 1.1 msec), requiring additional delays to compensate for this.

[4] Y. Suzuki *et. al* 1995



System latency measurement process using TSP signal

4. Acoustics of the reverberation environment

HOA reproduction requires free field condition. However, the measured mid-frequency reverberation time RT30 of the reproduction room is about 0.2 s. Therefore, additional sound absorption material was installed and the reverberation time was reduced a point where it could not be measured. Moreover, by adapting a measurement method that is normally used for qualifying anechoic rooms, we found the reproduction room was nearly free field within a 1 m radius from the sweet spot [5].

[5] D. Cabrera *et. al* 2010 (that will be presented at the International Symposium on Room Acoustics (ISRA) in Melbourne on Aug. 2010)

Acknowledgements: This study was partly supported by the GCOE program (CERIES) of the Graduate School of Engineering, Tohoku University and Grant-in-Aid of JSPS for Specially Promoted Research (19001004).