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The fast measurement of loudspeaker responses for all azimuthal directions using the continuous measurement method with a turntable.

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ABSTRACT

This paper proposes a method for the fast measurement of loudspeaker impulse responses for all azimuthal directions using the continuous measurement method with a turntable. The loudspeaker radiates all azimuthal directions with a constant angular velocity as the turntable rotates, and a measuring microphone records the related radiation sound. In our continuous measurement method, we use a maximum length sequence (MLS) as the excitation signal, record the received signal using a measuring microphone placed in the anechoic room away from the target loudspeaker, and feed them, along with the MLS signal, into a PC so that impulse response can be extracted for all azimuthal directions. This paper describes the concept of the method. Further, some results of the proposed method are verified using physical realization and empirical measurements.

1 Introduction

The frequency response of a loudspeaker differs depending on its position in relation to the sound-receiving point.

However, to observe the differences in frequency response depending on the position of the sound receiving point in detail, it is necessary to adjust the position of the loudspeaker and the microphone each time, which is a time-consuming and laborious measurement process.

In this paper, we propose an efficient method for measuring frequency characteristics at various directivity angles in the horizontal plane while continuously changing the direction of the sound source using a turntable to improve such conventional measurement methods.

This paper proposes a method for the fast measurement of loudspeaker impulse responses for all azimuthal directions using the continuous measurement method with a turntable. The loudspeaker radiates all azimuthal directions with a constant angular velocity as the turntable rotates, and a measuring microphone records the related radiation sound. In our continuous measurement method, we use a maximum length sequence (MLS) as the excitation signal, record the received signal using a measuring microphone placed in the anechoic room away from the target loudspeaker, and feed them, along with the MLS signal, into a PC so that impulse response can be extracted for all azimuthal directions. This paper describes the concept of the method. Further, some results of the proposed method are verified using physical realization and empirical measurements.

2 Concept and Methods

The method proposed in this study applies the method proposed by Fukudome et al.[1] for measuring HRTFs (HRIRs) to measuring loudspeaker characteristics using the reciprocal method. The characteristic feature of this method is that MLS (Maximum Length Sequence) signals are used as the measurement signals.

Recently, swept sine signal is often used as a source signal for loudspeaker characteristics measurement. However, the instantaneous frequency of the swept sine signal varies with time. The MLS signal is a pseudo-random signal and is considered to contain a sufficiently broadband component even at a particular time.

MLS signal is a periodic and deterministic signal, which means that the autocorrelation function is a perfect impulse with a finite length (one period), without assuming an infinite length like white noise. If the period L of the MLS is set to a level where time aliasing does not occur, the impulse response can be obtained by cross-correlating between input and output for one period of the signal.

Fig.1 shows an example of the calculation of the impulse response.

In an anechoic chamber, a loudspeaker was placed on a turntable and rotated at a constant angular velocity while being driven by a repetition of short-period MLS signals. Fig. 2 shows this concept.

Fig.3 shows a conceptual diagram of the section from the measurement signal to the signal used for the cross-correlation calculation.

In this paper, a measurement microphone was placed at a point 1 m away from the center of the turntable, and the MLS signal radiated from the loudspeaker was

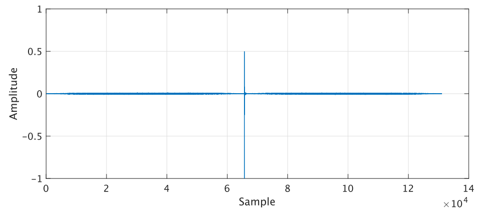

Fig. 1: An example of the calculation of the impulse response.

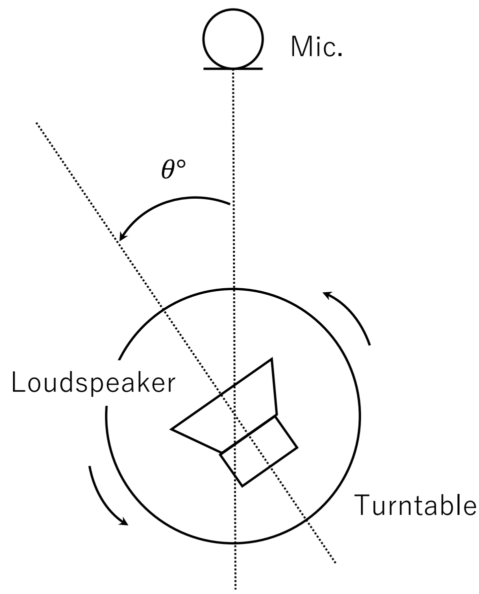

Fig. 2: Concept of Proposed Measuring Method.

continuously recorded. The impulse response of the direction in which the loudspeaker was facing at that time was obtained by trimming the signal at the appropriate time by the length of the MLS and calculating the cross-correlation with the driven MLS signal.

In this paper, a 16th-order MLS signal is used as the measurement signal, and the sampling frequency during playback and acquisition is 44.1 kHz. The rotational speed of the turntable was set to 144 s/R to take into account the effects of angular variation and Doppler effect per signal period.

Fig.4 shows a photograph of the measurement.

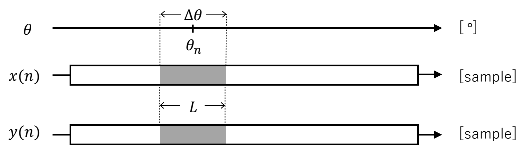

Fig. 3: Conceptual Diagram of the Section from the Measurement Signal to the Signal Used for the Cross-Crrelation Calculation.

3 Results

Fig.5 to Fig.8 show the characteristics of a loudspeaker obtained from the continuous measurement method proposed in this paper and an example of analysis of amplitude characteristics measured by the conventional method.

4 Discussion

The characteristics of the loudspeaker obtained by the proposed method is considered to be accurate enough for practical use. However, it fluctuates by a few dB compared to the method measured in a stationary state(conventional method). A further advantage is that the time required for the measurement can be significantly reduced.

The proposed method is considered suitable for measuring the characteristics of loudspeakers whose frequency response varies with the directional angle, such as a distributed mode loudspeaker(DML).

5 Summary

In this paper, a fast method for measuring the directivity-frequency characteristics of a loudspeaker is proposed. Examples of measurements are shown and the effectiveness of the proposed method is confirmed. The measurement parameters, such as the length of the MLS signal and the rotational speed of the turntable, will be subject of future work.

References

[1] Fukudome, K., Suetsugu, T., Ueshin, T., Idegami, R., and Takeya, K., "The fast measurement of head related impulse responses for all azimuthal directions using the continuous measurement method with a servo-swiveled chair," *Applied Acoustics*, 68(8), pp. 864–884, 2007, ISSN 0003-682X, doi:10.1016/j.apacoust.2006.09.009.

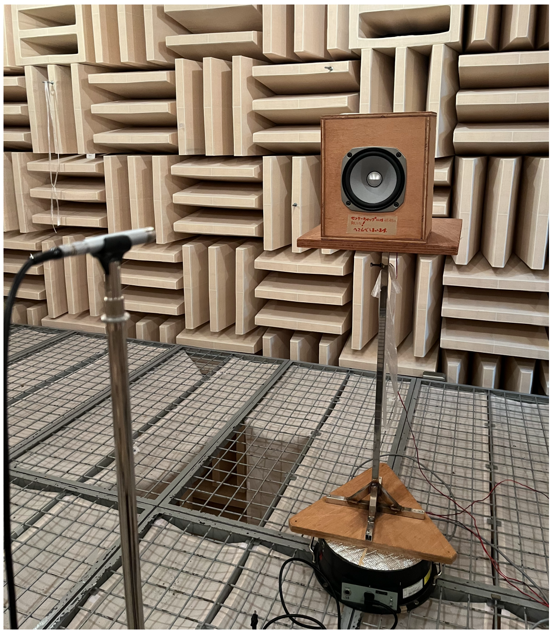

Fig. 4: Photograph of the Measurement in the Anechoic Room at Ohashi Campus, Kyushu Uninversity.

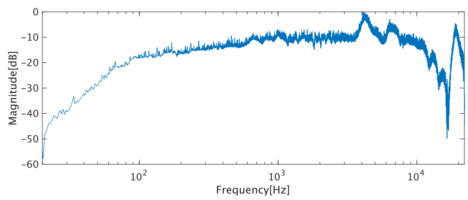

Fig. 5: The Characteristics of a Loudspeaker obtained from the Continuous Measurement (0 degree direction).

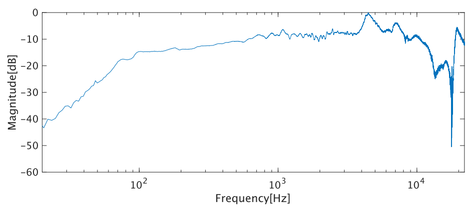

Fig. 6: The Characteristics of a Loudspeaker obtained from the Conventional Method (0 degree direction).

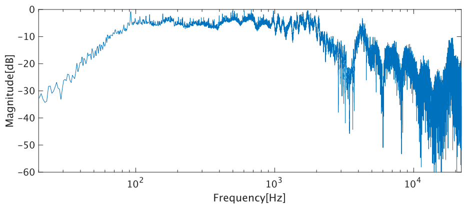

Fig. 7: The characteristics of a Loudspeaker Obtained from the Continuous Measurement (90 degree direction).

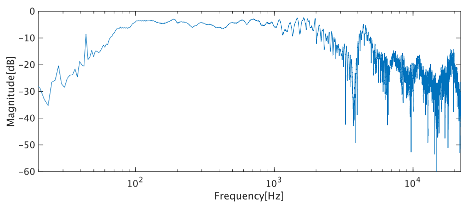

Fig. 8: The characteristics of a Loudspeaker Obtained from the Conventional Method (90 degree direction).