EXPERIMANTAL VERIFICATION OF MULTIPLE COHERENT OUTPUT DIVIDED SPECTRUM BY EXPANSION OF THE MULTIPLE SPECTRUM ANANLYSIS.

Instrumentation and techniques for noise measurement and analysis

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ABSTRUCT

The influence of the sound radiation from the room each surface is examined for the purpose of the prediction of Structure-Borne Sound as design technique. The level of Structure-Borne sound due to the environmental ground vibration is decided by the Multiple Coherent Output Spectrum of the inputs. This paper show the idea of Multiple Coherent Output Divided Spectrum (MCODS) of the inputs, and the result of the verification experiment by using six loudspeakers system.

1. INTRODUCTION

Our purpose of the research is to clarify the contributions of the walls that composes the room when the Structure-Borne sound is indoors generated from an environmental ground vibration. As the near research laboratories, Yasuoka 1] is proposing the sound radiation model intended for the space of the room in the under when the floor board vibrates for the floor impact sound. However, the examination in the state that all surfaces of the room vibrate is not performed. Moreover, Hashimoto 2]3]4] divides the vibration board into a detailed element virtual, makes these elements a piston movement board which has the infinite baffle board, calculates the radiation sound, and is proposing the method of measuring the sound radiation ratio by the combination with the vibration measurement. In this method, being thought excelling, and assuming the verification object at present no dependence on the measurement environment of the sound are the experiment models by whom the sound radiation side is made one side.

It is time when target it by this research radiates the sound room each respect vibrates to the close space. It is necessary to consider all information in board vibration, transmission system (space information), receiving sound part to request contribution in each respect. In the meaning, contribution to the radiation targeted here will have the different sense with the sound radiation ratio.

Up to now, the input had been examined in already reported, and the vibration in respect and the output were assumed to be a sound pressure and the basic relations between Input/Output were examined by using the Ordinary Coherent Function (O.C.F). The purpose is to clarify the relation between the vibration and the sound radiation in respect on the spectrum. It was shown that the vibration in respect when the Structure-Borne sound was prediction as a result was represented by the vibration response in a central part. In addition, it examines it experimentally obtaining Partial Coherent Function (P.C.F) which is the parameter proposed by the multiple spectrum analyses 5] and Multiple Coherent Function (M.C.F) to clarify the contribution element in each respect in the state which contains the influence of the sound field. Fig.1 shows multiple input/single output system which becomes assumption of a multiple spectrum analyses. It becomes Ui by input signal's Xi passing transfer function Hi, and the synthesis of Ui and the turbulence noise becomes output signal Y. P.C.F is coherence to which the element which can be linear expressed between the input signals is deleted from the input signal and the output signal and requested to show the relation between specific input signal and output Y. M.C.F shows the coherence of input signal X all and signal Y of the output.

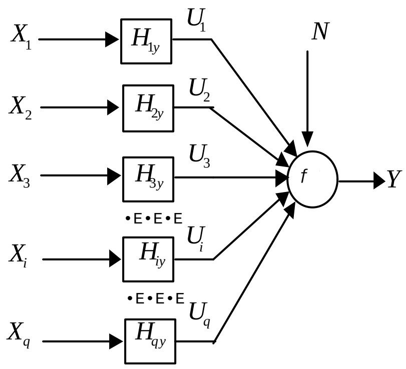
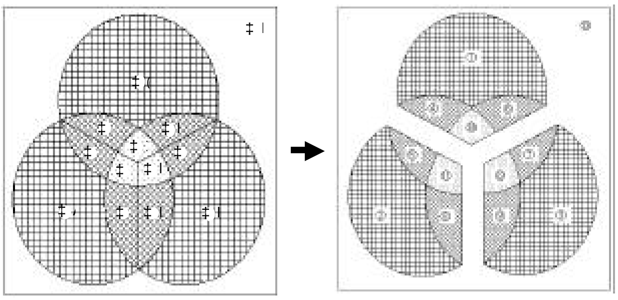


Fig.1 Multiple input/single output system

P.C.F was used to evaluate a peculiar contribution element though it was not strict correspondence, and M.C.F was used to evaluate a common contribution element. In addition, Multiple Coherent Output Spectrum (M.C.O.S) was a spectrum composed only of a linear element of output signal Y for input signal Xi, and it used it for M.C.O.S to evaluate the contribution element. As a result, the thing decided at a spectrum level whose common element of the input is a principal ingredient became clear by the research in the past as well as the result as for the Structure-Borne Sound generated by the vibration propagated from the outside of the building. The thing for the Structure-Borne Sound prediction when contribution in room each respect is clarified in this research, and all surfaces of the room radiate the sound to tie to the design technique is a purpose. Then, it is necessary to divide M.C.O.S into room each respect to clarify contribution in each respect. In this report, the M.C.O.S division theory is examined, and the idea of the indoor sound pressure by contribution in room each respect is shown.

2. DIVISION CALCULATION OF M.C.O.S

Fig.2 shows the image of the division value of M.C.O.S. It is the one having been included for the common element of which the input takes charge in a peculiar element and the multiple input of a certain input. In a multi-dimensional and spectrum analyses, it is shown that in the multiple input system, there is a common element to a peculiar element and all input at each input. It is the one to develop the idea in addition, and to subdivide a common element in figure for instance like "4. Charge of 1ch in a common of 1ch and 2ch element" and to obtain the division value of M.C.O.S in this research by the thought thing. Multiiple input / single output system which obtains the Structure-Borne Sound from the input by the vibration in room each respect as an output has already shown folding in input Xi and transfer function Hi in Fig.1 as Ui. Here, Ui is the one having been included for the common element of which a peculiar element and this input of which arbitrary input Xi takes charge take charge, and it becomes the division value of M.C.O.S. In this research, the M.C.O.S division value is shown Multiple Coherent Output Divided Spectrum (M.C.O.D.S). If do the clarification of Hi in the system which shows in Fig.1, M.C.O.D.S can be obtained. On the other hand, multiple input / single output system which removes the correlation element between the input is shown by the model of Fig.3.



1. Peculiar element of 1ch input
2. Peculiar element of 2ch input
3. Peculiar element of 3ch input
4. 1ch element of common of 1ch and 2ch element inside
5. 2ch element of common of 1ch and 2ch element inside
6. 1ch element of common of 1ch and 3ch element inside
7. 3ch element of common of 1ch and 3ch element inside
8. 2ch element of common of 2ch and 3ch element inside
9. 3ch element of common of 2ch and 3ch element inside
10. 1ch element of common of 1ch and 2ch and 3ch element inside
11. 2ch element of common of 1ch and 2ch and 3ch element inside
12. 3ch element of common of 1ch and 2ch and 3ch element inside
13. Turbulence noise element

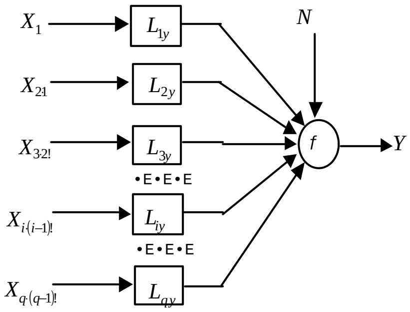
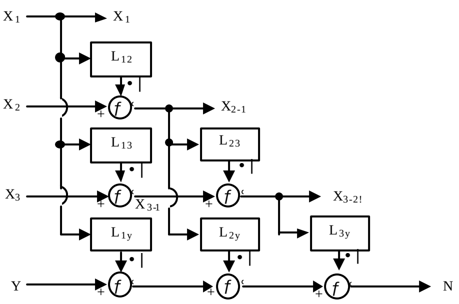


Fig.2 The image of the division value of M.C.O.S. (Left)
Fig.3 Multiple input / single output system which removes the correlation element between the inputs (Right)

$X_{i\cdot(i-1)!}, i = 1,2,\cdots,q$ means that the liner effects of records 1,2,...,i-1 have been removed from the ith record. $L_{iy}, i = 1,2,\cdots,q$ means the transfer function between $X_{i\cdot(i-1)!}$ and Y. Y means output signal. N means noise signal. Then,

$$Y = \sum L_{iy} X_{i\cdot(i-1)!} + N \qquad ...(1)$$

Linear removal element $X_{i\cdot(i-1)!}$ is calculated from the calculation process of showing in Figure 4.



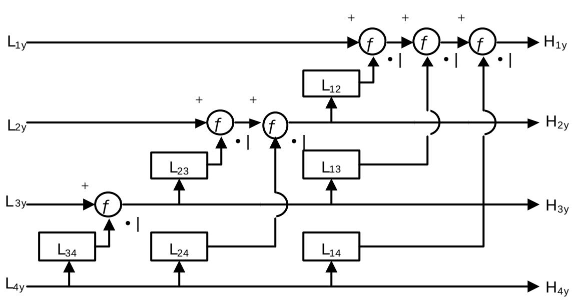


Fig.4 Calculation process of linear removal element $X_{i\cdot(i-1)!}$ (Left)

Fig.5 Relation of Hi and L_{iy} (Right)

Here, a relation of transfer function Hi and L_{iy} is shown in Fig.5, it becomes an Equation (2. MCODS can be obtained from the Equation (3) by repeating and calculating from this relation for each input signal for transfer function Hi.

$$H_{iy} = L_{iy} - \sum L_{ij} H_{jy} \qquad \text{...(2)}$$

When parameter q is 3,

$$H_{3y} = L_{3y}$$

$$H_{2y} = L_{2y} - L_{23} H_{3y}$$

$$H_{1y} = L_{1y} - L_{12} H_{2y} - L_{13} H_{3y}$$

$$M.C.O.D.S_i = U_i = H_i X \qquad \text{...(3)}$$

3. EXPERIMENTATION

Multiple inputs (X_i, i=1,2, …. 6)-single output (=Y) model to show in the Figure 6 is presumed in this experiment. And the six loudspeakers and the one microphone are installed in the anechoic room shown in the Figure 6. An experiment is based on the measuring system of the Figure 7. In the first place, a sound source shown in the Table1 is inputted in order from the each loudspeaker No.1 to No.6. And the sound pressure level (=MCODS) from the each loudspeaker is measured. Next, all sound source is inputted in the all loudspeakers at the same time. And the sound pressure level (=Y) from the all loudspeaker is measured. *MCODS* for six inputs–one output model is analysed from the each input signal X_i (before amplify) to the loudspeaker and all output signal Y. The analysis condition, sampling frequency is 11025Hz, FFT data number is 8192, average is 30 times and FFT window is hanning. When compared with the analysis value of *MCODS* to the sound pressure level of each loudspeaker. If they correspond to each other, it is judged that theory is correct. Table 1 includes the several condition of sound source. Where Type1, Type2 and Type3 are the pseudo-random signals that set up the amplitude ratio of the common element and conditioned element optionally by the maximum length sequence, Type4 is the velocity signal that it was measured on the room wall surface of the building structure.

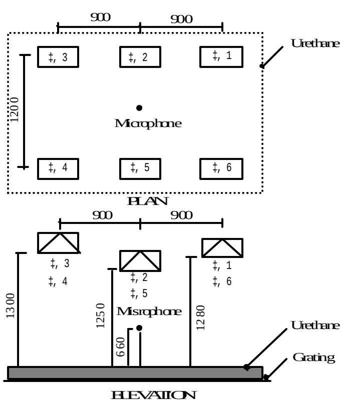


Fig.6 Installation of experiment system

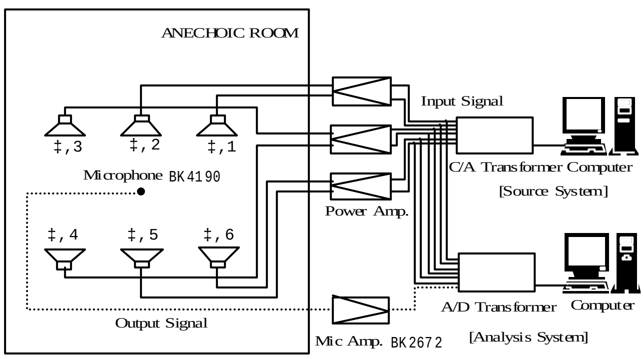


Fig.7 Measurement and Analysis system

How to make a pseudo-random signal is shown in the following. First, the maximum length sequence m(u) of 25 bits is made. Next, the eight correlation-less signals, $m_0(t)$, $m_1(t)$, $m_2(t)$, $m_3(t)$, $m_4(t)$, $m_5(t)$, $m_6(t)$, $m_7(t)$ are taken out from m(u). Here, $m_0(t)$ is the common element and $m_1(t)$ to $m_7(t)$ are the conditioned elements. Therefore, input signal $X_i(t)$ and noise signal n(t) are shown by Equation 4 and Equation 5.

$$x_i(t) = a_i \cdot m_0(t) + b_i \cdot m_i(t) \quad ...(4)$$

$$n(t) = a_7 \cdot m_0(t) + b_7 \cdot m_7(t) \quad ...(5)$$

Where, $a_i \;\; (i = 1.2...6)$ shows the amplitude coefficient of common element, $b_i \;\; (i = 1.2...6)$ shows the amplitude coefficient of conditioned element.

Tab.1 Experiment Signal

		Speakers					
		No.1	No.2	No.3	No.4	No.5	No.6
Type1	*a*	1.0	1.0	1.0	1.0	1.0	1.0
	b	0.1	0.1	0.1	0.1	0.1	0.1
Type2	*a*	0.1	0.1	0.1	0.1	0.1	0.1
	b	1.0	1.0	1.0	1.0	1.0	1.0
Type3	*a*	0.1	1.0	0.1	1.0	0.1	1.0
	b	1.0	0.1	1.0	0.1	1.0	0.1
Type4	Velocity	WallA	WallB	WallC	WallD	Ceilling	Floor

4. EXPERIMENTAL RESULTS

Figure 8 shows the results of comparison between the analysis value and measured value. Here, for example, the result of loudspeaker No.1 is shown. Figure 8 a) is the result of sound source Type1. Type1 signal can separate the contribution by the *Ordinary Coherent Function* because this set up is composed with conditioned element bigger than common element. From the result, output value from the single loudspeaker corresponds to the *MCODS* in the nature of things. And this result shows that *MCOD*S can separate the contribution in this condition.

Figure 8 b) is the result of sound source Type2. Type2 signal can not separate the contribution by Ordinary Coherent Function because this set up is composed with conditioned element smaller than common element. And this signal set up is similar condition about the condition of input element of structure-borne sound. From the result, output value from the single loudspeaker corresponds to the *MCODS* and *MCOD*S can separate the contribution in this condition.

Figure 8 c) is the result of sound source Type3. This set up condition makes a difference between the loudspeaker No.1.3.5 and the loudspeaker No.2.4.6 concern with the amplitude ratio of the conditioned element and the common element. This analysis condition is different input character concern in the *Partial Coherent Function* and the *Partial Coherent Output Power Ratio* that is given by the Multiple Spectrum Analysis. The *Partial Coherent Function* shows the correlation of the conditioned input to the conditioned output. Here, conditioned input is the signal that removed the common element of the mutuality input. The *Partial Coherent Output Power Ratio* shows the ratio of the conditioned input to the all output. A result can get *MCODS* properly, though the input condition is very complex. Figure 8 d) is the result of sound source Type4. From the result, output value from the single loudspeaker corresponds to the *MCODS* and *MCOD*S can separate the contribution in this condition, though this experiment use the vibration velocity got in the room wall surface. From the above results, It is shown that *MCODS* is analyzed properly.

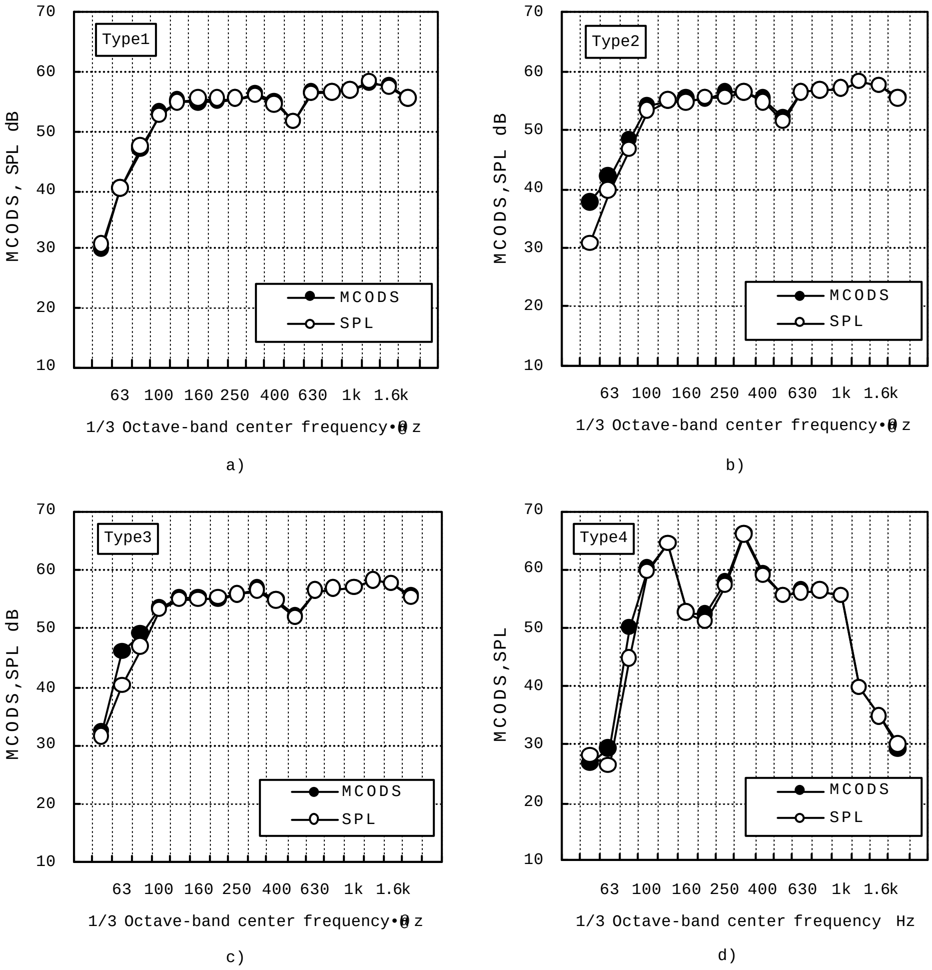


Fig.8 Relations between MCODS and SPL

5. CONCLUSION

It proposed the becoming it M.C.O.D.S index which developed a multiple spectrum analyses to show contribution in each respect where the indoor sound pressure was composed to establish the prediction technique of the Structure-Borne sound by an environmental ground vibration, and the Equation was used and shown about the physical meaning. And the analysis theory of MCODS is suitable because the results that corresponded could get MCODS and SPL of single loudspeaker from six loudspeakers system experiment.

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