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Proceedings of Symposium on Ultrasonic Electronics, Vol. 32 (2011) pp. 87-88
8-10 November, 2011

Non Contact Acoustic Contour Imaging Method using Phase Difference in Extremely Shallow Underground
極浅層地中における位相差を用いた非接触音響輪郭映像法

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1. Introduction

Extremely shallow underground imaging has been studied by measuring vibration velocity distribution of the ground surface using a Scanning Laser Doppler Vibrometer (SLDV) [1-3]. Non-contact acoustic imaging can be realized by using an airborne sound as a vibratory source. Although the detection and the identification of the buried objects can be possible by using their response band, only the amplitude component of the vibration velocity spectrum are used conventionally [4-5]. Therefore, we study about the contour imaging method using phase information of the velocity spectrum.

2. Phase Difference Imaging Method

2-1. Calculation Method of Phase Difference

The phase data (real part, imaginary part) of each scan point by SLDV are output every frequency, the phase of the specific frequency can be calculated by this phase data. When the phase difference between two adjacent scan points shows the value that is more than π or less than - π, it is necessary to correct the phase difference value because an aliasing phenomenon occurs. The phase difference correction is calculated by

$$|\Delta\theta| > \pi \quad \begin{cases} (0 < \theta_1 < \pi,\ \ \pi < \theta_2) & \cdots \ \ \Delta\theta = \theta_1 - (\theta_2 - 2\pi) \\ (\pi < \theta_1,\ \ 0 < \theta_2 < \pi) & \cdots \ \ \Delta\theta = \theta_1 - (\theta_2 + 2\pi) \end{cases}$$

2-2. Image Construction by the Phase Difference

The outline of image construction by the phase difference is shown in **Fig.1**. For explanation, 3 x 3 scan point (total 9 scan point) is assumed here. At first, each phase difference is calculated using two adjacent points. The calculated phase difference is arranged between the actual scanning points as shown in **Fig.1(a)**. Then, in the position of an original scanning point, it will become an empty because there is no data as the phase difference.

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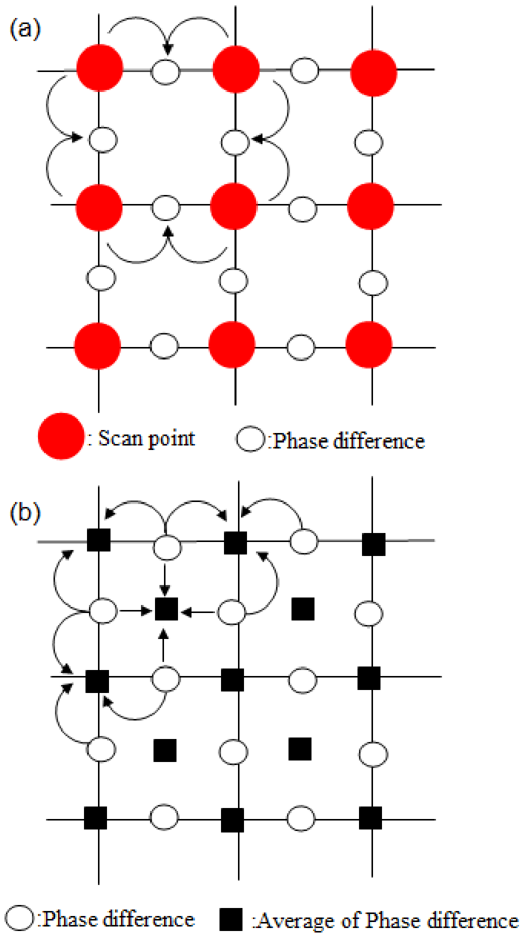

Fig.1. Outline of image construction by the phase difference imaging method is as follows. (a) First step, calculation of phase difference, (b) Second step, makes dummy points.

Still, making to the image will be possible, to make a clearer image, mean value of the adjacent phase difference is arranged to an empty point as shown in **Fig.1(b)**. Therefore, the number of the data increases more than an actual number of scanning points.

The phase difference shows the approximately same value in the small frequency range. Therefore, to improve SN ratio of the measurement data, ±2.5Hz of an arbitrary center frequency (11 frequency) are averaged. Because the value of the phase difference depends in calculation order (calculate from the left to the right and from the upper part to under part in this study), when calculating from the opposite direction, the sign will be reversed. Therefore, the absolute value is used in the resultant image.

3. Experiment using the Phase Difference Method

3-1. Experimental Setup

Fundamental setup is shown in **Fig.2**. The sand tank (110×135×50 cm^3) is filled with sand of uniform particle size (200 - 300 um). Flat speakers (FPS Corp., 2030M3P1R) are used as the vibratory sources. A SLDV (Polytec Corp., PSV400-H4) is measured the vibration velocity of sand surface two dimensionally. The scan area size and number of scan points are 27×31.5 cm^2 and 195 (13×15), respectively. Sinusoidal burst wave (0.2s) is used. A hollow plastic container (11×11×6cm^3, 80g) and a hollow steel can (diameter 8.5×8 cm^3, 70g) are used as a buried object (buried depth is 2cm).

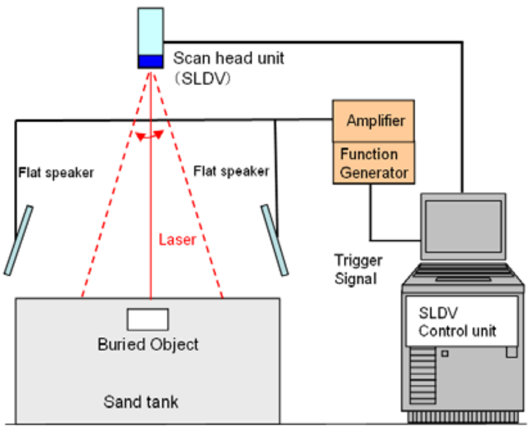

Fig.2 Experimental setup for Phase difference method.

3-2. Experimental Result

Experimental imaging results are shown in **Figs. 3-4**. In each figure, (a) shows the position confirmation image with CCD camera, (b) shows the resultant image by phase difference method. The frequency is chooses the frequency band that the response of the buried object is the strongest in. From these figures, we can confirm the clear response of the buried object, and we understand what this method has a possibility of the contour extraction of the target.

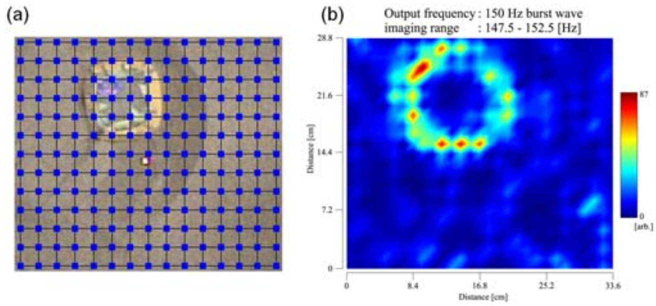

Fig.3 Imaging result of a hollow plastic container by phase difference imaging method.
(a) Buried position of a hollow plastic container.
(b) 150Hz burst wave result, imaging range: 147.5 - 152.5Hz

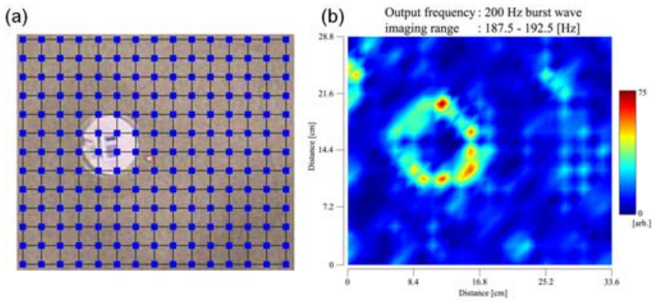

Fig.4 Imaging result of a hollow steel can by phase difference imaging method.
(a) Buried position of a steel can.
(b) 200Hz burst wave result, imaging range: 187.5 - 192.5Hz

4. Conclusions

We confirm the feasibility of the buried object detection using phase difference method. From the experimental result, this method is thought to be applicable for the contour image of the buried object. In addition, this method may perform more clearer image by combining the OFR method that using only the amplitude component of the velocity spectrum. As the future task, we will examine the effectiveness of this method for other materials.

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