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Real time monitoring of the vortex wind field based on the transmission and reception of the coded acoustic wave signals between parallel array elements

平行アレイ間符号変調音波送受信による渦風速場のリアルタイム監視

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1. Introduction

Acoustic travel time tomography system has been studied for the monitoring of the vortex wind flow velocity profile by placing multi-channel acoustic transmitter/receiver pairs along the opposite sides of monitoring region.[1,2] Based on the simulating indoor test appratus, capablity has been shown to measure the time varing vortex wind field at every second time rate. However, the number of transmitter/receiver channels used in the previous experiment (4 ch.) [3] were too small to show the potential capability of the proposed method. In this paper, the test equipment was upgraded to the 8 channel system, experiments were conducted to verify the estimation precition and real time monitoring capability of the vortex wind field.

2. Problem statement

2.1 Data observation method

As shown in **Fig.1**, a number of sound wave transmitter/receiver facing pairs were arranged on both side of the target wind fields monitoring region. In the present study, 8 channel test apparatus were constructed, where 16 facing pairs of microphone and speakers were aligned at both side of target measurement region (they were aligned with spacing d=70 mm over the aperture W=490 mm and separated with facing distance L=500 mm). Dual directional time lag ΔT were measured along the paths between the multiple combination of the facing transmitters and receivers. To accomplish the collections of data in a short period of time, coded signals were emitted from the group of transducers at once. Where, sinusoid wave with frequency f=20 kHz was modulated with different 8 bit Kasami code sequences (length N_K=255) for each transmitters. Value {1,-1} of Kasami code was assigned to the phase {0, π} of the N_{sin}=2 period of sine waves. Upon receiving data at particular receiver, component emitted from the requested transmitter can be extracted from the correlation calculation between them.

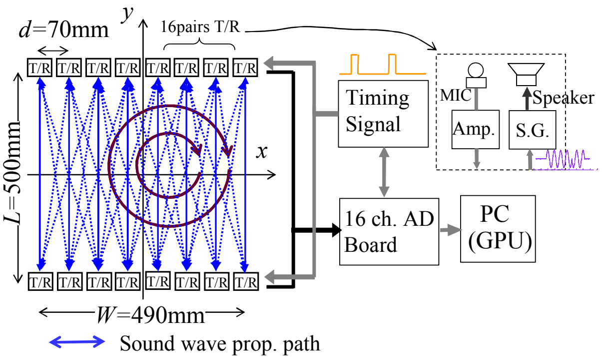

Fig.1 Multi-channel tomographic wind flow measurement system.

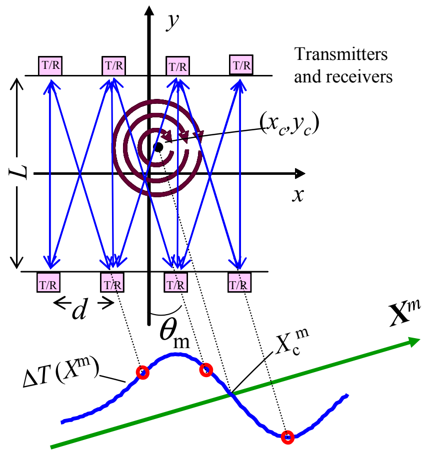

Fig.2 Relationship between sound observation paths and position of the vortex wind field.

2.2 Reconstruction of the vortex wind flow fields based on the different view travel time data

As shown in **Fig.2**, dual directional travel time difference data are collected along the different view observation paths between the arbitrary combination of the transmitter/receiver pairs. They are grouped into the data ΔT_m having different sound wave propagation angle θ_m, where m is the index related with θ_m as

$$\theta_m = \tan^{-1}\left(\frac{md}{L}\right), \quad -M \le m \le M$$

Consider that origin of the original coordinate (x, y) is shifted to the center of vortex wind field (x_c, y_c), and rotated with θ_m to obtain new coordinate (X, Y). Travel time data with m-th propagation angle θ_m and receiver position X are then denoted as $\Delta T_m(X)$. We note here that $\Delta T_m(X)$ for different propagation angle should be same over the transformed coordinate axis X. That is, $\Delta T_m(X)$ can be fitted to the true travel time difference curve $\Delta T(X)$ by virtue of the rotation symmetry of the vortex wind field. On this basis, most likely fitted true travel time curve $\Delta T(X)$ is searched, which is a function of center position (x_c, y_c), diameter D and maximum wind velocity v_{max} of the vortex wind field. From the optimally fitted curve, vortex wind field parameters (x_c, y_c), D and v_{max} were estimated.

3. Simulation test

We assumed that a vortex wind passes through the monitoring region along horizontal y-direction. To this end, x-directional center position was changed between x_c=-10 and 10 mm, under the fixed y-directional center position at y_c=-10,-5,0,5,10 mm. Other parameters of the wind

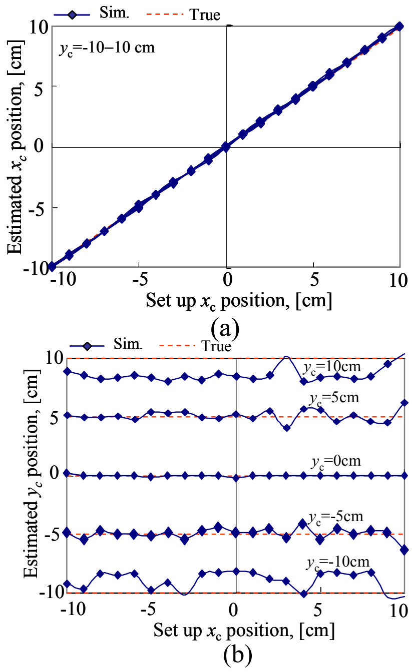

Fig.3 Simulated results of the estimated center position of vortex wind fields, where (a) is estimation for x_c and (b) for y_c.

field were determined as D=190 mm and v_{max}=5 m/s. Theoretical travel time difference ΔT_m were calculated for the observation view number N_V=5 (m=-2,-1,0,1,2). Using the synthesized data, localization precision of the vortex wind field were tested. Estimated center positions x_c and y_c as a function of predetermined x_c positions were shown in **Fig.3**. The results show that precision in y-direction is somewhat worse than those in x-direction. However, they are good on the whole, taking consideration of the extremely limited observation conditions of the small view angles in y-direction.

4. Experiment test

Experiment test was conducted using the present 8ch. measurement apparatus. As a wind source, electric fan with diameter 190 mm was prepared. Other experimental conditions are same as described in Fig.3. Localization results are shown in **Fig.4**. It can be recognized that the results show same tendencies to those in Fig.3. The experiment estimation errors of y_c are larger compared to the simulation. This is due to the fact that there were relatively large deviation errors in the travel time observation data.

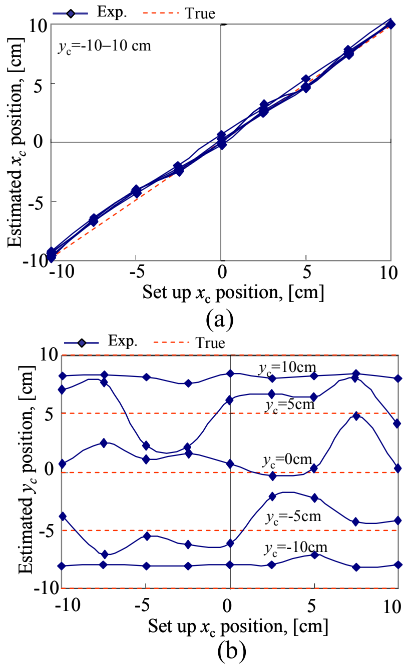

Fig.4 Experimental results of the estimated center position of wind velocity fields.

References

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