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

符号変調音波の平行アレイ間多チャンネル同時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 for the monitoring of vortex wind flow velocity profile has been studied, where multi-channel parallel acoustic transmitter/receiver pairs are placed along an opposite sides of monitoring region.[1] For real time high speed collection and computation of data, simultaneous transmission technique by using pseudo noise code modulation signal was adopted,[2] as well as incorporation of graphics processing unit. Using an 8 channel indoor test system,[3] vortex wind fields was monitored at a frame rate of around one second. A wind source was mounted on an automated slider actuator. Tracking capability for the moving vortex wind field was examined. The results showed feasibility of the method for the monitoring of outdoor moving vortex wind field.

2. Method of the acoustic tomography

2.1 Outline of test system

As shown in Fig.1, 8 channel test system 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 each side of speakers at once. For instance, transmitter signals were generated by 16 arbitrary waveform signal generators (8bit, 0.5MPS DAC). Simultaneous excitations and receptions were carried out for forward and reverse directions separately, to avoid the mixture of the waves from same side of speakers. To this end, forward and reverse timing pulses were delivered separately for the synchronization of the transmitter and receiver signals. Data received by both sides of microphones were digitized in parallel using 16 ch. A/D converter boards (Contec: AI-1204Z). Finally, they were transferred to a personal computer (Intel: Core i5 3.2GHz CPU), and demodulation calculations were made using GPU (NVIDIA: GeForce GTX 690). Travel time lag data along the propagation paths $\Delta T(X_m)$ for N_{path}=34 propagation paths (N_v=5 observation views) were obtained and used for the wind velocity field tomographic calculation. A electric fan with diameter D_v =0.19 m was used as a vortex air flow source. It was mounted on an automated slider actuator (Oriental motor ELSM4XD070K-A, max speed 400 mm/s). Changing the frequency of pulse signal to the motor controller (EDR36-K), moving speed of the slider was changed from one to ten scale.

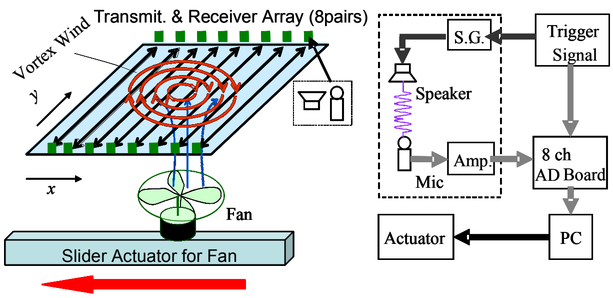

Fig.1 Multi-channel tomographic wind flow measurement system.

3. Test experiment

3.1 Contents for discussion

Moevement speeds of tornados spawned in Japan is mostly distributed from 10 km/h to 30 km/h. The validity of the present mehod assuming actual movement of tornado, equivalent experiments were conducted using a small sized indoor test system under the 1/200 scale transformation for slider movement speed (dimension of test system is 1/200 smaller with respect to the dimention of required outdoor monitoring region).

3.2 Test for tracking capability

Wind source was moved along horizontal x-axis with constant moving speed in the monitoring

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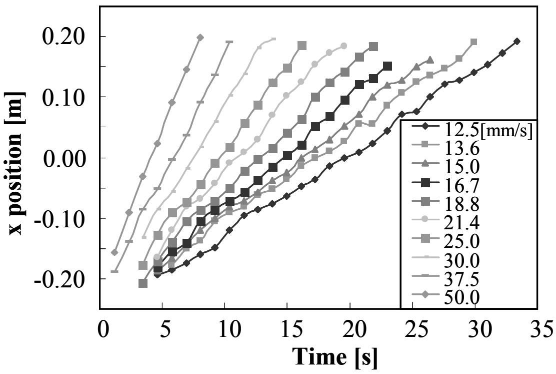

Fig.2 Measured x position of wind source as a function of movement elapsed time.

region. Fig.2 shows the variation of measured x-axis center position of wind field as a function of average moving elapesed time. Note that data were sampled at every 1.2 s on an average. From slopes of fitted straight lines to the data in Fig.2, moving speeds of the wind source were measured. In addition, setup moving speed of the wind source was obtained from sended pulse frequency to the motor controller. The results were compared with setup values of moving speed as shown in Fig.3. Similar comparisons were made between measured x-positions of wind source and its setup values as shown in Fig.4. We can see that they were in good agreement regardless of movement speed condition.

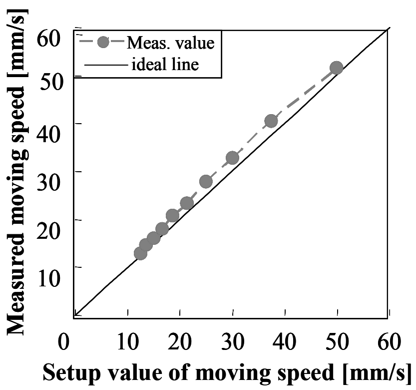

Fig.3 Measured moving speed of vortex wind field v.s. setup moving speed ordered to the motor controller.

Other than x-axis center position, wind field parameters such as dimension of wind field and maximum wind velocity can be estimated all together. Fig.5 shows results of measured diameter of vortex wind field as a function of moving elapsed time. We can see that results agree with true diameter of D_v =0.19 m on an average. Occasionally, we can see some large deviation errors near the beginning and termination measurement time. This is due to the fact that part of vortex wind field locates out of measurement region. As a result, failed local minimum solutions of the optimization problem were obtained.

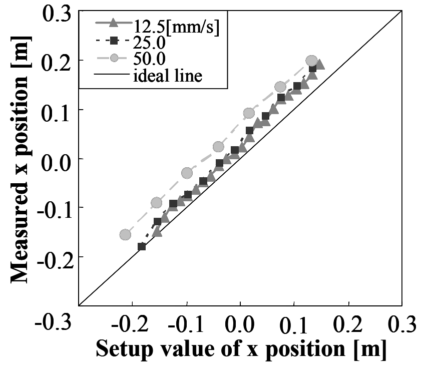

Fig.4 Comparison between measured x-position of wind source and setup x-position.

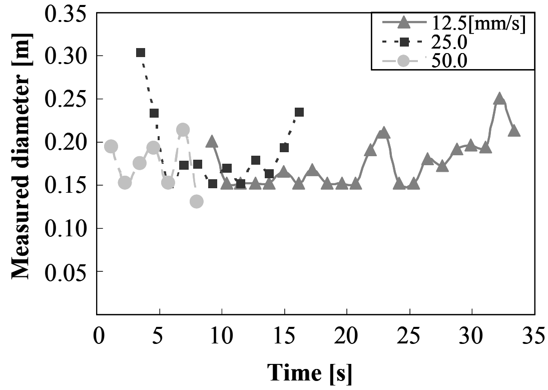

Fig.5 Measured diameter of the vortex wind filed as a function of movement elapsed time.

4. Conclusion

From the examination using small size indoor test system, real time tracking capability of the proposed system was demonstrated which can come up with actual movement speed of tornado.

References

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