論　文　の　要　旨

題　目

Application of Acoustic Tomography System for Monitoring Streamflow and Suspended Sediment Concentration in a Mountainous River and Tidal Estuary

（山地河川と感潮河口域における河川流量と浮遊土砂濃度のモニタリングに対する音響トモグラフィーの適用）

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Estimation of direct and continuous discharge passing through a cross section of river accurately remains a fundamental problem in the water-resources engineering field. Currently, the most-often classical approach adopted in estimating the river discharge is the Rating curves (RC). Nevertheless, establishing of ratings curves equations to cover the wide range of flows and processes going on in rivers has been a challenging task due to several factors contribute to the imprecision in discharge data (e.g. inaccurate stage measurement, low time-resolution in the stage recording, etc). Moreover, when the river reach is hydraulically influenced by backwater effects, such as dams, lakes or the sea, a single-parameter rating (stage for example) is impossible to be established. In recent years, several innovative velocity-monitoring systems were applied to streamflow monitoring. Acoustic Doppler Current Profilers (ADCPs) are the most common instruments used for this purpose and can be divided into two groups: moving-boat ADCPs and fixed ADCPs. The main disadvantage of a moving-boat ADCP is that it cannot measure the streamflow continuously. Fixed ADCPs not only have limitations in wide and shallow rivers but also entail complex post-processing methods, to compute the river discharge. This study demonstrates the application of the Fluvial Acoustic Tomography System (FATS), which overcomes the restrictions of the previous methods.

The first experiment presents one-month measurements of flow velocity and river discharge performed by FATS in a mountainous shallow river. The effect of suspended sediment concentration on the FATS signals was also investigated and a primary attempt was made to estimate the cross sectional averaged suspended sediment concentration <SSC>. The flow velocity varied between 0.5 m/s to 1.6 m/s in low- and high-flow conditions, respectively. Similarly, the streamflow ranges from 50 m^3/s to 260 m^3/s, where the minimum and maximum mean water depths were 0.6m and 1.42 m, respectively. The results of streamflow were compared to the RC method. The relative error was less than ±20 % and the root-mean-square of the residual (RMSR) was 9.42 m^3/s. It was observed that the SSC has a direct influence on the Signal to Noise Ratio (SNR) of the FATS. At low concentrations, when the observed turbidity was less than 2 FTU, the corresponding SNR of upstream and downstream stations were 25 dB and 35 dB, respectively. Whereas, at the high concentration, when the observed turbidity exceeded 45 FTU, the SNR decreased dramatically to 6 dB and 12 dB, respectively. A new equation was introduced to convert the SNR of FATS to <SSC>. The results showed that the maximum <SSC> reached 0.1 kg/m^3 in this period and proportionally the Suspended Sediment Flux (SSF) exceeded 20 kg/s^{-1}. The comparison of SSC measurement by FATS and other methods, such as Optical Backscatter Sensor (OBS) and ADCP, showed that the accuracy of SSC measurement by FATS is low, because the SNR does not only depend on the turbidity but also other factors such as water depth, accumulation of weeds and bottom shape.

In the second experiment reported in this thesis, the efficiency of the high-frequency (53-kHz) FATS was examined. Furthermore, a new solution using cross configuration FAT systems was proposed to estimate the angle between FATS transmission line and the flow direction. The results showed that the 53-kHz FATS have better velocity resolution and it can be operated in the shorter ranges than the 30-kHz FATS. An ADCP was used to validate the angle measurement obtained from FATS. The estimated angle by FATS varied from 12 to 18 degrees, as well, the coefficient of determination (R^2) between the ADCP and proposed method was 0.78. Then, the river discharge was estimated by both FAT systems and compared to the RC method and moving-boat ADCP estimates. The relative error of the FATS discharge measurements was less than 10%. In this experiment, an interesting phenomenon was observed. Although this experiment was performed in a freshwater river and the acoustic signals were not influenced by salinity, the signals of FATS were divided by two groups. The ray simulation showed that the river bathymetry affected the propagated signals and the second group arrived about 0.4 ms after the first group.

The last observation was made in the Ota Estuary, where the tidal currents and river discharge collide. A numerical model was applied to estimate the flow velocity and compare with the velocity measurement obtained by FATS. The flow velocity varied between -0.2 m/s and 0.85 m/s to the landward and seaward, respectively. It was concluded that the FATS is a reliable instrument to be used as a boundary condition input of the numerical models.