(Ⅱ −22) ON THE POSSIBILITY OF SMALL TIME SCALE MEASUREMENT OF RAINFALL INTENSITY BY SOUND ANALYSIS

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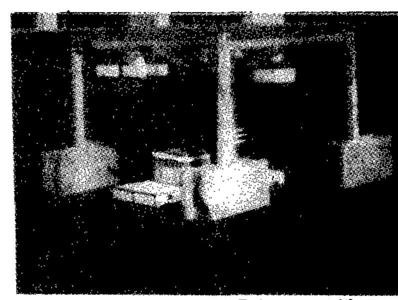
1. INTRODUCTION

Recent days, the inundation of low lands in urban river basin becomes more serious as the concentrated land usage and the thorough development of drainage system in surrounding areas make the rainfall run-off faster and sharper. As a result, an estimation of a rainfall intensity averaged in a short duration corresponding to the reduced run-off time becomes an important factor for the flood forecasting, the development of run-off models and the design of downstream channels of urban rivers. For this reason, it is required to develop a system for the rainfall measurement with a fine time resolution. This paper presents a result of a preliminary experiment for the development of a new measurement device which estimates the rainfall intensity in a short time scale by analysing "rain-sound".

2. EXPERIMENTS

A series of rain-sound is recorded by a mini-disk recorder put in a tin plated can. At the same time rainfall intensity is measured by a normal rain gauge in order to verify the output of rain-sound analysis. A water collector of funnel-shape is fixed with the normal rain gauge to accumulate more rain water so that the frequency of the counter increases per unit time and the rain gauge becomes more efficient (Pic. 1).



Pic. 1 Tin plated can and Rain gauge with a funnel-shaped water collector

3. ANALYSIS

The time series of rain sound is transformed into a series of instantaneous spectrum in order to estimate a time variation of the power of the sound (Fig. 1). By setting a proper value for the time increment of spectrum analysis, a time series of "sound pulses" has been constructed in which each pulse is assumed to correspond to each rain drop (Fig. 2).

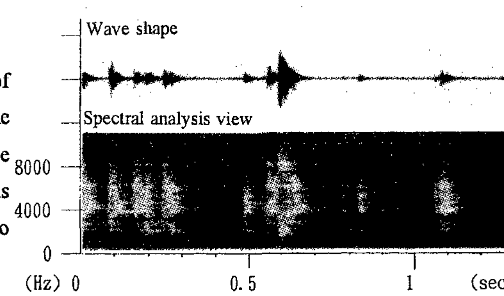


Fig. 1 Wave shape and Spectral analysis view

It seems to be a reasonable assumption that the pulse intensity (I) is a function of the volume of each rain drop (r). The relation is assumed to be a power function herein.

$$r = \alpha I^{P} \quad (1)$$

where α and P are constants which must be determined so that the integration of the rain drop volume becomes equal to an amount of rainfall measured by a normal rain gauge. Taking the time average,

$$R(\tau) = \alpha \Sigma (I^{P}) / \tau \quad (2)$$

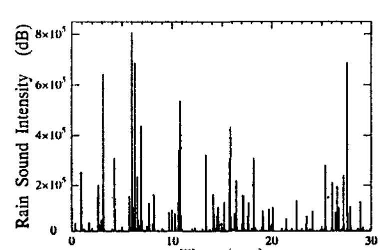


Fig. 2 Time series of rain sound intensity

where $R(\tau)$ is rainfall intensity averaged in a duration τ which is set as 30 sec in the following analysis.

The least square method is applied to determine the value of α for an assumed value of P. Then, the relative residual $E=Z/\alpha^2$ is estimated for each value of P as shown in Fig. 3 where the optimum P is suggested to be as 0.6.

After this calibration, the sound analysis successfully reproduces the time variation of rainfall intensity. Fig. 4 shows an example of the comparison between the output of sound analysis (Eq. 2) and the rainfall intensity measured by the normal rain gauge.

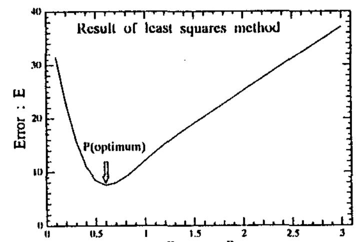


Fig. 3 Relation between the parameter P and error E

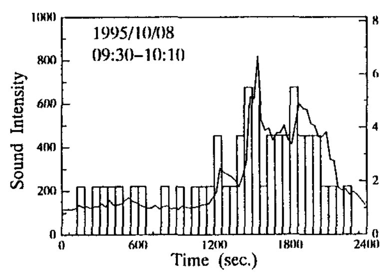


Fig. 4 Comparison between the time series of rain sound intensity I^{**} & rainfall intensity

4. DISCUSSION

It is considered to be a reasonable assumption that the intensity of each sound pulse is proportional to the kinetic energy of each rain drop. This assumption is supported by a result of a laboratory experiment as shown in Fig. 5. Therefore,

$$I \propto D^3 V^2 \quad (3)$$

where, D is the rain drop diameter and V is the falling velocity. Eq. (1) and (3) enables us to estimate the relation between the falling velocity and the rain drop diameter as follows,

$$V \propto D^{1.5(1/P-1)} \quad (4)$$

If $P = 0.6$

$$V \propto D \quad (5)$$

Fig. 6 shows a relation of the falling velocity proposed by Best [1] which proves the direct proportion of Eq. (5) in a wide range. Therefore, the value of P which was empirically determined in section 3 seems to be reasonable in the dynamical point of view.

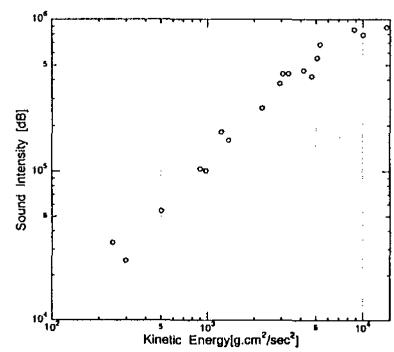


Fig. 5 Relation between kinetic energy and sound intensity

5. CONCLUSION

In this study the recorded rain sound is analysed in order to estimate the rainfall intensity in a short time scale. The result shows that the variation of rainfall intensity in a short time can be estimated very well by calibrating the parameters in eq. (2). The calibration result is also consistent with the result of existing studies on the falling velocity. This fact indicates the possibility to develop an advanced device which can measure rainfall intensity with fine time resolution.

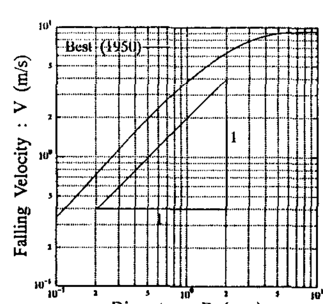


Fig. 6 Relation between the drop size and falling velocity

REFERENCE

1) A.C.Best:Empirical formula for the terminal velocity of water drops falling through the atmosphere,Quart.j.Roy.Meteor.Soc.,76,pp.302-311,1950.