10.8 RIVER FLOW INFORMATION SYSTEM WITH RF CURRENT SENSORS

Yoshinori Kimura*, Satoshi Iida, Hiroaki Mori
Yokogawa Denshikiki Co., Ltd

1. Introduction

A geological condition makes rivers short and rapid in Japan. As a result, rainfall rushes into the sea in a short time. It is necessary to overcome these geological difficulties for the prevention of disasters like flooding and debris-avalanche and water resource control with state of art technologies. It includes data acquisition and analysis of hydrological data like rainfall, water level of a river, and flow and water quality on a scale of a river basin.

The current river management system uses the following two methods for a hydrological data acquisition. (1) The measured data by water gauge is sent via telemeter every ten minutes. Then the flow is derived from the water level - flow relation based on the past accumulated data. (2) The flow calibration is executed at the pre-determined period or at high flow. The water level - flow relation curve is renewed by this calibration. At the calibration the flow is measured by injection type velocity meter or float drifting time. The latter method is only for the sake at high flow because a rapid flow and lots of drifting make the direct measuring of flow impossible.

However the flow measurement using floats has the following weak points. (1) Many crews (usually 3 to 5 persons) are required. (2) Most important measurement at high flow is the peak flow measurement. However this method may fail to set up whole procedure before the peek flow. (3) Basically it is not continuous measurement. (4) If the float was drifting off from the measurement line, it causes an error increase. (5) A real time flow data is not available because of calculation delay after water velocity measurement.

We developed a river flow measurement system to overcome the above mentioned weak points. It gives real time data of river flow with use of ease and safe. The measured data is transferred to a remote management office via standard Ethernet network with images of the river.

* Corresponding author address: Yoshinori Kimura
Yokogawa Denshikiki Co., Ltd.
500, Soya, Hadano-shi, Kanagawa, 257-8502, Japan
e-mail: Yoshinori_Kimura@ydk.yokogawa.co.jp

2. The motivation of the development

The development targets to advance the river management system from the water level measurement to the real time flow measurement. For the purpose, continuous measurement, safe operation, real time data acquisition, easy maintenance, wide band application for variety of rivers and remote data handling via network are required.

We solved the challenge items (1) to (4) mentioned before by using the RF current sensor.

It is desirable to install arbitrary number of sensors according to the width of a river for the construction of suitable flow observation system without additional hardware. For that reason a multi-dropping system is employed so that sensors up to 20s can be connected to one cable in parallel.

There are such parameters that are different depending on installation place or that varies when time goes. It is necessary to take into a consideration that the data structures are flexible for easy handling and maintenance remotely. A cross-sectional area required for real time flow calculation is one of such data. The data is surveyed before installation and then stored at a table in the flow calculation unit. Thanks to this structure, the table data can be easily changed by the survey data after floods. The necessary cross-sectional data in this table is referenced with the data of water level and the installation point. The cross-sectional flow is calculated by multiplying flow velocity to the data.

The observatories for river management should be placed at the key points from the upstream to the downstream of a river. In the case of large river, the observatories are scattered broadly. From disaster prevention point of view, it is required to integrate those scattered datum in real time via network. The river flow information system adopted the Field information server (Fis) as a data-processing unit. The Field Information Server is a name of our system products; this system collects the scattered information widely over the vast area in a reliable way, processes them and gives information via network to users [2].

3. Flow observation using the RF current sensor

3.1 Principle of the RF current sensor

The RF current sensor measures the surface velocity by the Doppler effect of microwave. The frequency difference between radiation wave and reflection one (i.e. the Doppler frequency) shows the surface velocity of flow. The RF current sensor employs the states of art technologies for signal processing to realize a reliable flow measurement. Those are high resolution A/D conversion, Fast Fourier Transformation and spectrum analysis in frequency domain.

As far as Doppler application to the flow measurement concerned, there had been a few intrinsic weak points to be solved. (1) Concentric ring waves made by raindrops on water surface give adverse effect to the Doppler signal. (2) The sensors installed on a bridge pick up vibration signal by traffic. (3) The waving of plants at riverbed in dry season gives noise to the Doppler signal. The influences of such disturbances were reduced by optimizing the algorithm of spectrum analysis.

The surface velocity is also influenced by wind. As a consequence, the RF current sensor picks up a flow signal with an overlapped noise by wind. This error is compensated in a way that the true flow is calculated subtracting wind velocity from RF current sensor data. The compensation method is based on the experimental result which was jointly conducted with the Public Works Research Institute. This experiment showed a relation between wind velocity and surface velocity of flow [3].

Table 1 shows specifications of the RF current sensor.

RF	CW 10.525GHz 0.1W
Antenna	0.3m diameter parabolic antenna
Velocity Range	0.5 to 20.0 m/s
Angle	20 to 45 deg. (Vertical) 0 to 20 deg. (Horizontal)
Measurement time	1sec, 2sec, 5 sec, 10sec, 20sec, 30sec, 60sec, 120sec
Smoothing time	10sec, 20sec, 30sec, 60sec, 120sec, 300sec, 600sec
Interface	RS-485
Cable length	1km maximum
Supply	48Vdc 110mA maximum

Table 1 Specifications of RF current sensor.

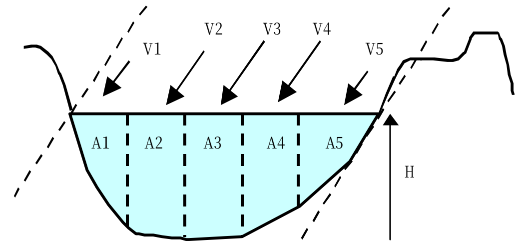

Fig.1: Cross section and velocity and water level.

3.2 The calculation of flow

A river flow is derived as a product of a cross-sectional area (*A*) of river and its velocity (*V*) to downstream. It is usual to divide a cross section into some partial cross sections to get an accurate integral result from a survey data. Fig.1 shows an example with five partial cross sections.

The river flow (*Q*) is given in equation (1).

$$Q = f \sum V_n A_n \ . \tag{1}$$

In equation (1), f is a compensation factor.

Fig.2 shows a flowchart of river flow calculation. The velocities are measured by the FR current sensors. Each of these sensors corresponds to a part of cross section (measurement line) and independently measures surface velocity. The wind data are commonly used to compensate the effect of wind to surface velocity.

The water level is measured by a level gauge. If the river is single channel, only one level gauge could be installed. If the river has the shallows or multi-channels, necessary number of level gauges should be installed.

The numerical data of corresponding cross section is taken out of a table in a flow module. These numerical data are generated from a survey data of a river and referenced with a water level as a parameter. The data means real water cross section corresponding to water level at each sensor part. It serves to 20m depth water (table 2).

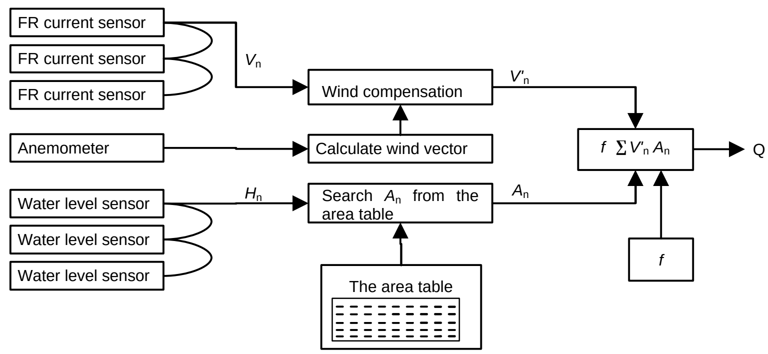

Fig.2: A flowchart of river flow calculation.

Water level (cm)	Area 1 (m^2)	Area 2 (m^2)	- - -	Area n (m^2)
0	$A_{1,0}$	$A_{2,0}$	- - -	$A_{n,0}$
1	$A_{1,1}$	$A_{2,1}$	- - -	$A_{n,1}$
2	$A_{1,2}$	$A_{2,2}$	- - -	$A_{n,2}$
:	:	:		:
H_m	$A_{1,m}$	$A_{2,m}$	- - -	$A_{n,m}$
:	:	:		:
1999	$A_{1,1999}$	$A_{2,1999}$	- - -	$A_{n,1999}$

Table 2: The area table. The data means real water cross section corresponding to water level at each sensor part.

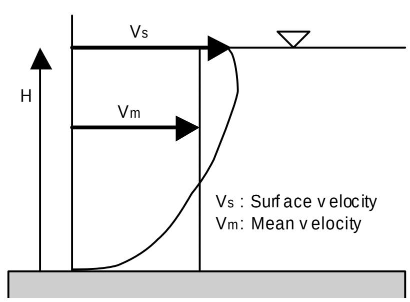

Fig.3: The velocity profile of the depth.

A flow is calculated using each data acquired in the above procedure by the formula (1) in real time.

The compensation factor f in the formula (1) is a coefficient which substitutes the surface velocity for the mean flow velocity of the river. The velocity profile from the surface to the bottom is shown in Fig.3. The coefficient f has been proved as it is from 0.8 to 0.9 in a series of experiments in variety of rivers [1].

4. The system configuration of a river flow information system

Fig.4 shows a configuration of the river flow information system. The RF current sensor can be connected in parallel up to 20 units to a bus cable and their spatial interval is arbitrary depending on each river. Each RF current sensor has unique address and is connected to the flow module with RS-485 bus. The flow module is continuously polling each RF current sensor to acquire the latest velocity data.

Water level sensors are also hooked up to another bus and finally connected to the level module. The level module continuously acquires a water level data from a water level sensor via a bus.

An anemometer is used to compensate fluctuating surface velocities by a wind-generated wave. The signal of the anemometer is converted and processed by the wind module.

A Web camera sends real time images of river at the observatory via the network.

The flow module calculates river flow by using collected data of velocity, water level, wind direction, and

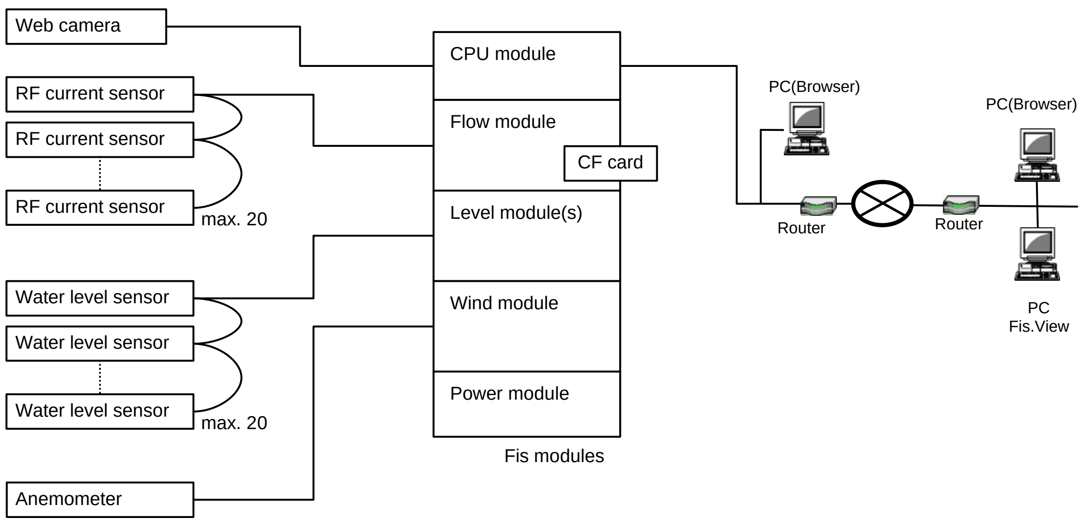

Fig. 4: Configuration of the river flow information system.

wind speed. And all data are recorded onto a Compact-Flash card for on-site storage in the module.

The CPU module collects data of flow, velocity, water level, wind direction, wind speed, and camera pictures at constant cycle and accumulates them. And those datum are transmitted to an external network via Ethernet or RS232C. Users can easily access to the observation data in real time by a browser in their PC.

The dedicated software "Fis.View" is prepared for the purpose of long-term storage of observation data, statistics processing yearly or monthly and integration of observatory data more than two.

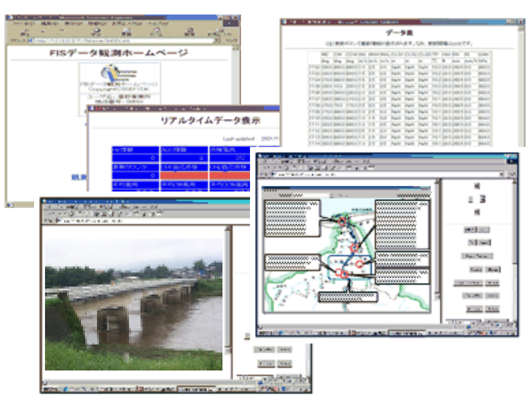

Fig.5: The integrated data image of Fis.View.

5. The example of installation and observed data

The river flow observation system with the RF current sensors is used in over twenty river observatories in Japan. Here, the observation data in Yattajima observatory of Tone River supplied by Tone River Upstream Work Office is shown. The river basin of Tone River is the largest in Japan, and the river width at Yttajima observatory is about 920m. Fig.6 shows Tone River and the RF current sensor.

In this observatory, the river flow is measured using 10 units of RF current sensor and 2 units of ultrasonic level sensor. Fig.7 shows the cross section of the river and location of sensors.

Fig.8-(1) shows observation datum October in 2004.

Fig.6: Yattajima observatory of Tone River and RF current sensor.

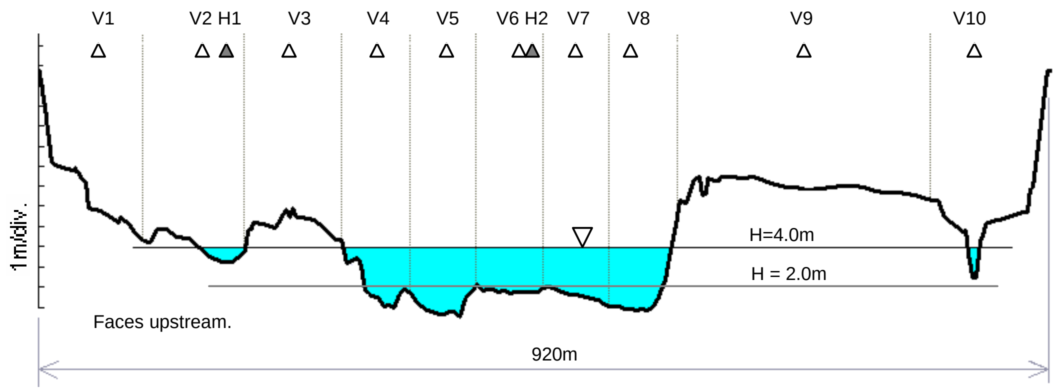

Fig. 7: Crossing and layout of sensors in Yattajima observatory. V1 to V10 are RF current sensors, H1 and H2 are ultrasonic level gages.

The water level values H1 and H2 are different because the height of river bottom is different. (The difference comes from the difference of zero basis.) Although the flow datum obtained by the conventional method using floats is discrete in time, the flow datum obtained by this system is continuous like this graph at any time.

On October 9 and 10, there were much rainfall by the autumnal stationary front and the typhoon No. 22. For the reason, the observed flow data reached to over 2000 m^3/s. And, the rise of a high flow and the two peak datum of flow were clearly observed. Fig.8-(2) shows the relation between water level and flow. Fig.8-(3), (4) show the relation between water level and velocity.

Since the observation datum is processed in real time to convenient format for the river management stuff, they can make right and prompt decision based on accurate information.

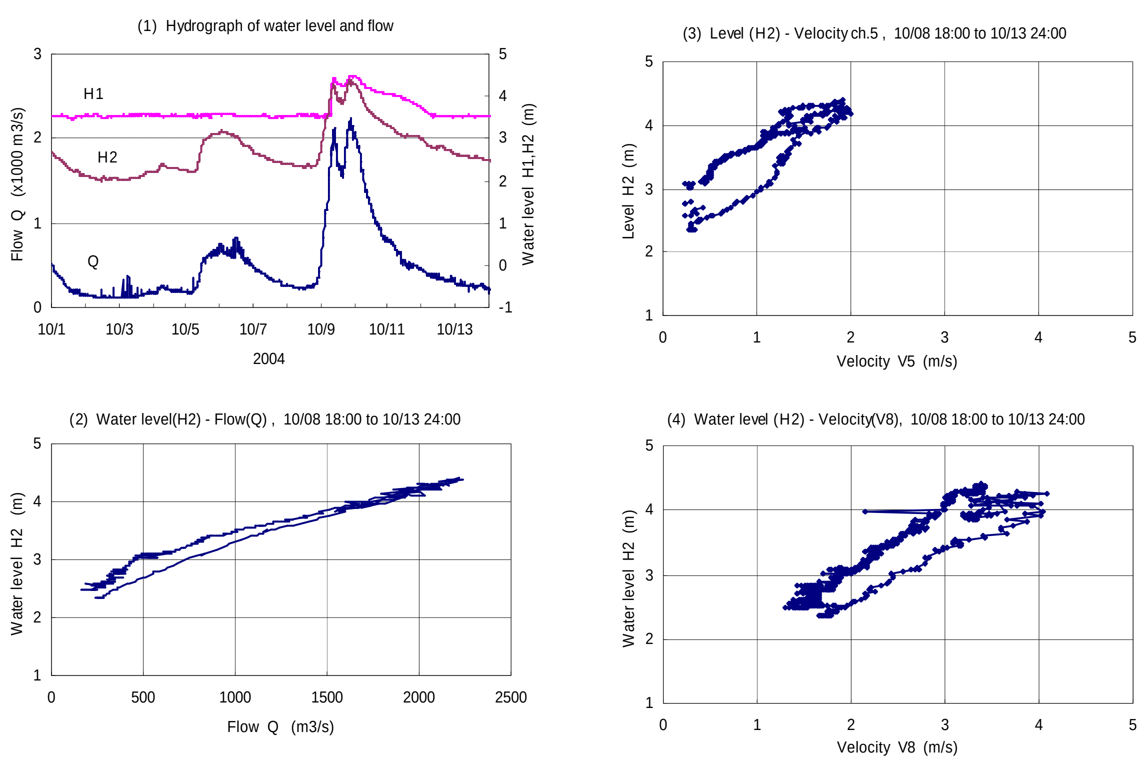

Fig.8: Graphs of observation datum in Yattajima observatory October in 2004.

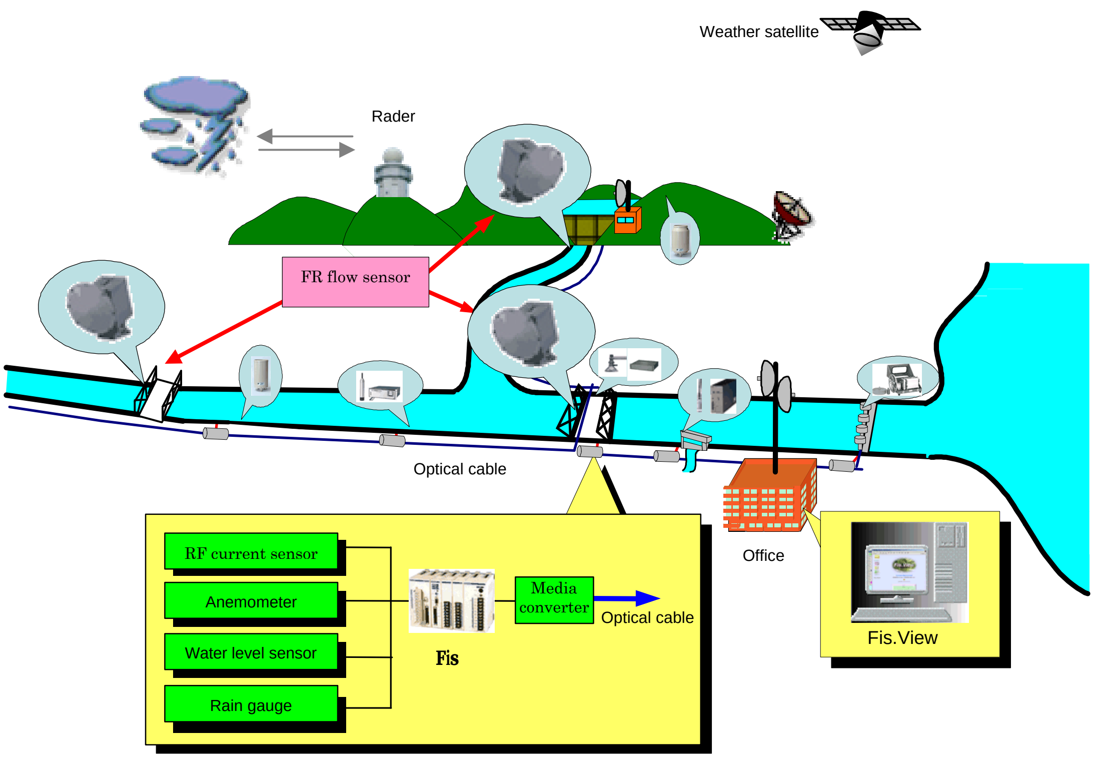

Fig. 9: An advanced river management system.

6. A future development plan

Fig.9 shows an advanced river management system. Many kind of meteorological and hydrological sensors are allocated in the river basin to acquire necessary information for the river management. For instance, rain gauges are installed in the upper river basin to acquire water volume which will come into the river and RF flow sensors are installed to acquire a real river flow in some points of the river. In this system all information about a river basin is sent to the management office and is integrated there for the easy understanding of the river situation. Using this system, officers in the management can grasp the real time situation of the river and predict the flow in the river in advance from the precipitation information. The more information of a relation between the precipitation and the flow is acquired, the better prediction would be given from the improved relation formula. It is the same as in the relation between the upstream flow and the downstream flow. This system will become a powerful tool for the river management to prevent disasters.

7. Conclusion

The following results were recognized by using the river information system with RF current sensors.

- Flow data can be measured in real time.
- Image data is obtained with observation data at the same time, it is useful to prevent disaster.
- The information at various situation of a river can be stored by continuous observation.
- The flow observation work has been achieved to be automated. As a result, the dangerous work for staff at flooding could be eliminated.
- The river information can be accessed from anywhere via the network. It is useful for the river management staff to make a prompt decision.
- The new flow information system is proved to be adaptive from small to large river.
- The remote sensing instrument including RF current sensors realized the remote failure diagnosis and easy system maintenance.

8. Acknowledgments

The authors would like to thank the staff of Public Works Research Institute for advice to this work and the observation datum offered is courtesy of the staff of Tone River Upstream Work Office.

9. Reference

[1] Yamaguchi T, 2002: The flood velocity and flow observation. Journal of Japan Society of Hydrology and Water Resources, Vol. 15, No. 6, 625-635.

[2] Yoshimura A. et al., 2004: FIELD INFORMATION SERVER. 20th Conference on Interactive Information Processing Systems (IIPS) for Meteorology, Oceanography, and Hydrology, 84th American Meteorological Society Annual Meeting.

[3] Public Works Research Institute, 2002: Report of joint research "Development of velocity measuring method without contacting the water."

[4] WEATHAC, "Water special number.", 2004: Yokogawa Denshikiki Co., Ltd.

*coauthor information

Satoshi Iida: Satoshi_Iida@ydk.yokogawa.co.jp

Hiroaki Mori: Hiroaki_Mori@ydk.yokogawa.co.jp