Implementing IoT in Water Level Management: Reservoir Monitoring and Flood Mitigation

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***Abstract*— The present study investigates the monitoring of reservoir water levels to help prevent floods by accurately measuring and controlling the water flow through the reservoir's door. The system uses multiple technologies, such as the OTT C31 Universal Current Meter, float level switches, and the Yagi-Uda antenna, to gather real-time data from substations and main stations around the dam. The data collected includes water level before and after the dam door, and water velocity at the dam door. Ensuring the efficiency and security of data transmission, the system employs an HT12E encoder and HT12D decoder, which are used to encode and decode data for secured transmission. The data was processed in Arduino Mega 2560 and sent to Raspberry Pi due to its ability to connect to Wi-Fi, which could host a website providing users with real-time data and reducing the damage caused by flooding. The real-time data transmission allows the system to significantly improve the capability for proactive flood management, making it a vital tool for protecting public safety and infrastructure. The simulation and experimental results demonstrate the effectiveness of the proposed system in both controlled and real-world environments. Key findings include the performance of the Yagi-Uda antenna at 433 MHz and the water velocity measurement through varied cross-sectional dam doors.**

Keywords—water level, velocity of water flow, Float Level Switch, Yagi-Uda antenna

I. Introduction

According to the World Bank, "The total damage and losses from the 2011 floods in Thailand amounted to THB 1.43 trillion (USD 46.5 billion) [1], with losses accounting for 56 percent of the total." Flooding is one of the most common natural disasters in Thailand. It results in loss of life and damage to personal property and critical public health infrastructure. Recently, there has been frequent flooding happening throughout Thailand, leading to loss of life and destroying families. Dam failure could lead to a severe threat to life and property; and is one of the major contributors to flooding in Thailand. Therefore, a liquid-level detector system planted in the dam is necessary to prevent flooding.

Today there are around 4 main devices used to inform the water level: Float Switches [2], Conductive (or Electrode) Level Sensors, Ultrasonic Level Sensors [3], and Capacitive Level Sensors. Nonetheless, each of the methods has its advantages and disadvantages. One of the common dam water level detectors is ultrasonic water level. It is used due to its ability to perform non-contact measurement, accuracy, and ability to function in harsh conditions; however, ultrasonic sensors can be affected by temperature fluctuations, dust, and other environmental conditions: for example, when it rains the surface of the water being measured by the ultra-sonic water level could be inaccurate as using the ultrasonic water level sensor requires a still surface of the liquid.

Another common reservoir liquid level detector is the pressure transducer. Pressure transducers are used in many reservoirs to monitor the water level to measure deeper water levels. This device operates by detecting the pressure exerted by the water at various depths, providing accurate and reliable measurements. This device is commonly used due to its ability to function in submerged conditions, making it essential for application in deep water. However, it requires direct contact with water, which can lead to issues such as sensor inaccuracy, the need for maintenance, and high costs.

Float switches, then, are the most common choice for water level monitoring in reservoirs due to their simple principle, accuracy, and cost-effectiveness. Float switches use floating components that rise when the liquid surface reaches the switch, requiring no complex electronics. This therefore makes them highly durable and easy to maintain in a harsh environment. Float switches are particularly well suited for this paper where direct contact with water is acceptable. Their simple mechanical nature allows them to precisely send data about the water level. Unlike other techniques mentioned earlier, they are not affected by any environmental conditions such as temperature fluctuations, surface turbulence, and high maintenance costs. Additionally, the ease of installation makes them an attractive option for large-scale reservoir management systems, highlighting their accuracy and durability.

II. Principle

A. Application of Float Type Level Switches for Reservior System Analysis

Float level switches are used in many locations where liquid levels must be detected. This paper utilizes the operating principles of float type level switches and uses the principle for real life implication; the principle of the devices used in the paper is based on the buoyancy of the liquid as the float moves up and down. As the surface of the liquid carries the float up from its original position, a reed switch in a stem is actuated by a magnet in the float, and outputs detection signal as shown in Fig. 1.

Float type level switch is being utilized specifically in this paper to measure the system of the reservoir by placing the float level switch device: before (S_1), on (M), and after (S_2) the reservoir is shown in Fig. 2. The paper aims to collect data about the reservoir system, leading to its improved utilization.

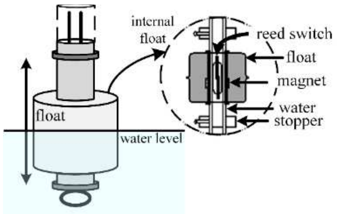


Fig. 1. Float Level Switch

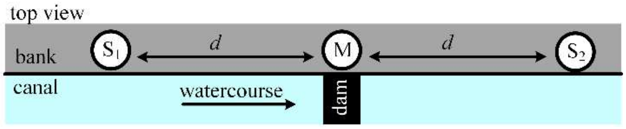


Fig. 2. Reservoir water stability system

B. The OTT C31 Universal Current Meter

The OTT C31 Universal Current Meter [4] as shown in Fig. 3, simply referred to as the current meter, is commonly used in the field of hydrology (the study of Earth's water movement) because the instrument measures the velocity of water flow. The current meter is crucial for flood forecasting; justifying its use in this paper. Determining the water flow in the reservoir helps calculate the discharge —or the volume of water passing through the reservoir per unit of time. The current meter functions on the principle of mechanical flow measurement. The setup of a complete flow monitoring station consists of propeller, sounding weight, hoisting and electrical connection, ground, and a fin for stabilizing that is actuated by the flow of water, causing the propeller to spin. The rate at which the propeller spins is directly proportional to the velocity of the water. A calibration factor converts the number of propeller revolutions, counted by a reed switch within the device, into a velocity measurement.

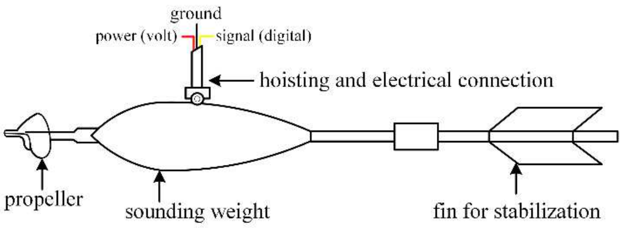
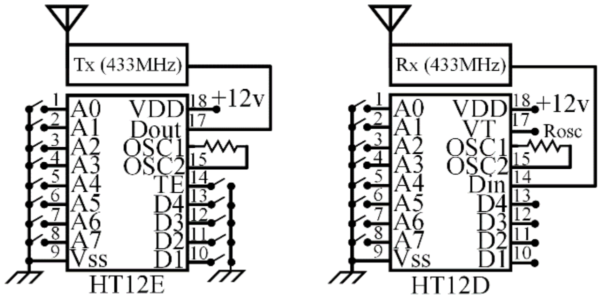


Fig. 3. OTT C31 Universal Current Meter

C. Radio Frequency 433MHZ Radio Control Using Ency

Radiofrequency (RF) communication systems [5] such as the 433MHz RF module, are widely used for remote control systems, wireless data transmission, and industrial automation, though, its main purpose is for data transmission. This paper delves into the implementation of the HT12E encoder and HT12D decoder inside this system to allow efficient wireless communication as shown in Fig. 4. The HT12E encodes 12-bit parallel data into a serial format, allowing transmission from RF modules, while the HT12D decodes the received data back into its original form. By using address and data bits, this system guarantees data accurate and secure data transfer, even in convoluted environments with multiple receivers. This setup is particularly beneficial for transferring critical water level data and control signals within dam systems, increasing the overall score of the system's responsiveness and reliability.



(a.) HT12E (b.) HT12D

Fig. 4. Encoder & Decoder ICs

D. Yagi-Uda antenna

The Yagi-Uda antenna or Yagi antenna, widely used in radio, TV, and wireless communication [6–8], focuses signals on a specific direction with high gain, enhancing signal strength and accuracy. It consists of a driven element, a reflector, and a director. The driven element controls signal input [9], the reflector focuses the signal by bouncing back unused waves, and the director strengthens the signal in the desired direction. Adding more directors increases signal directionality and gain.

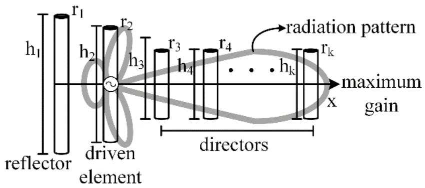


Fig. 5. Structure of Yagi antenna

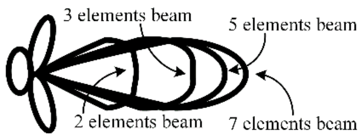


Fig. 6. Radiation patterns of Yagi Antennas with varying elements.

The number of elements in a Yagi antenna affects how well it focuses and amplifies signals. Fig. 6. shows how the antenna's signal pattern changes with 2, 3, 5, and 7 elements. More elements make the pattern more focused, and the signal can reach farther. The 7-elements antenna has the narrowest pattern and the highest directivity and gain, which means it sends and receives signals more effectively over long distances. This research involves designing and simulating a 7-element Yagi antenna for a frequency of 433 MHz The lengths of each part (Reflector, Driven Element, Directors) are calculated using the wavelength eq:

$$\lambda = c/f \tag{1}$$

where c is the speed of light (3.00×10^8 meters per second) and f is the frequency in Hertz (Hz). The calculations for the lengths and distances are shown in Table I.

TABLE I. THE DIMENSIONS OF THE DESIGN

Element	Length(m)	Spacing	Length (m)
h_1	0.448λ	r_1	0.184λ
h_2	0.52λ	r_2	0.080λ
h_3	0.4λ	r_3	0.088λ
h_4	0.384λ	r_4	0.104λ
h_5	0.368λ	r_5	0.104λ
h_6	0.352λ	r_6	0.104λ
h_7	0.336λ	-	-

E. *Flow of Water through a Sluice Gate Valve*

Sluice gate valve is essential for the management of water in rivers, lakes, and bodies of water in irrigation systems. The structure of a Sluice gate valve is shown in Fig. 7, These types of doors can be adjusted depending on the level of water, this characteristic is crucial for water level management, flood prevention, farming, prevention of corrosion in the canal and body of water. The flow of water can be divided into two main categories, Free Flow and Submerged flow, shown in Fig. 8.

Fig. 8a shows free flow which occurs when the downstream water level is lower than the upstream level. In this scenario, the water flows naturally, controlled by the difference in water levels (head) between upstream and downstream. In contrast, Fig 8b depicts submerged flow, where the downstream water level is higher than the upstream level, exerting pressure on the flow and causing it to slow down or stop.

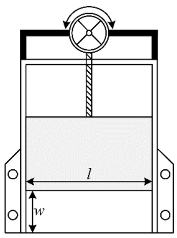
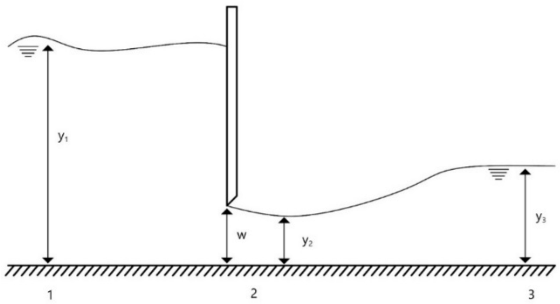
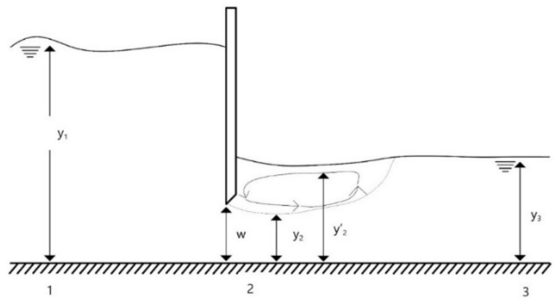


Fig. 7 structure of a Sluice gate valve



(a.) Free Flow



(b.) Submerged Flow

Fig 8 Flow of Water through a Sluice Gate Valve

This type of flow is influenced by both the difference in water levels and the pressure from below. As a result, the volume of water passing through the gate decreases as the downstream water level rises. Submerged flow is common during high floods when controlling water levels is critical to prevent flooding or erosion. The volume of water can be calculated using the Energy-Momentum Method, where E_1 (initial energy-momentum) equals E_2. (final energy-momentum). The cross-sectional area in Fig. 8 can be expressed by the following eq:

$$y_1 + \frac{q^2}{2gy_1^2} = y_2 + \frac{q^2}{2gy_2^2} \quad (2)$$

Assuming energy loss is negligible between points 1 and 2 because the friction between the water and the gate is too small to have an effect. $q = Q/l$ where Q is total flow rate at the cross- sectional of the water channel, l is width of the gate, g is acceleration of freefall, y_1 is depth of the water on top of the sluice, and y_2 is depth of water at which compression occurs [10]. This is shown in (3)

$$q = y_1 y_2 \sqrt{\frac{2g}{y_1 + y_2}} \quad (3)$$

This formula shows the function of the flow $v = \sqrt{2gy_1}$, where w is height of the gate, C_d is flowing coefficient, and therefore the rate of flow can be calculated using (4):

$$q = C_c w \sqrt{2gy_1 \frac{y_1}{y_1 + y_2}} = C_d w \sqrt{2gy_1} \quad (4)$$

C_c is compression coefficient depending on the shape. The total compression coefficient is the factor that points out how much the flow has been compressed when flowed through the dimensions of the gate (w). C_d is the flow coefficient.

F. *Application Layer*

The Application Layer, an abstraction layer, is primarily used to take care of network communication, and receiving data from sensors. It acts as a medium between the user and the application, ensuring that the data collected is accurately represented on the website in this research paper. The application layer gathers data from float-level switches from 2 substations – S_1 and S_2 – and the OTT C31 universal current meter from the main station. In this research, the website will display critical information such as the water levels before and after the dam door, and the velocity of the water (*m/s*). Additionally, the application layer allows the system to alert citizens by displaying real-time data, enabling them to monitor any rapid water level increase.

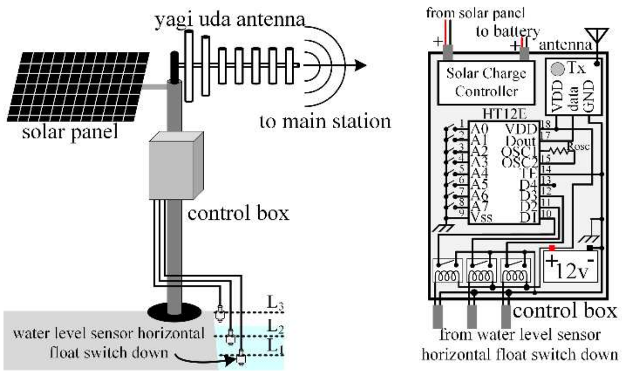
III. Proposed Methods

This paper proposes a method for measuring the water levels at the two substations and the water velocity at the main station to calculate the volume needed to stabilize the reservoir. The proposal will be divided into three subsections: substations, main station, and display. As illustrated in Fig. 2, substations S_1 and S_2 are positioned on either side of the main station, which is essential for data collection and analysis. The worker will adjust the dam's angle according to the analysis made in the main station. However, this system of display is not limited to workers alone —the display is also accessible to the general population, allowing them to make informed decisions, including planning for evacuation, if necessary, which is also applicable for agriculture purposes.

A. *Substations*

Substations S_1 and S_2 are essential for monitoring water levels in the reservoir. Each substation is equipped with a solar panel, shown in Fig.9(a), where sunlight is the main source of energy. The energy collected is managed by a solar charge controller, which charges a battery that powers the system of the substation. Another component of the substation is the control box, seen in Fig.9(b), which includes a circuit relay that is activated when the surface of the water reaches the float switch and elevates the device, the relay circuit is short to the ground and sends signals to D1, D2 and D3. To transmit this data, the encoder requires a matching address with the main station for both the transmitter and receiver on the main station end. This data modulated into radio wave and transmitted through Yagi-Uda antenna due to its low cost, light weight, and most importantly its ability to withstand harsh environmental condition, ensuring accurate and reliable information transfer to the main station for an effective water level management system.

Fig.9 illustrates the use of 3 float switches. Each are placed at different heights within the reservoir to monitor the water level. When any of the levels are activated, the relay circuit to the ground (GND) closes, sending binary data "1" - default is sending binary data of "0". The lowest level L_1 is positioned beneath the average level to ensure that the system is working, the middle switch L_2 is place at the average water level in the reservoir, while the highest float switch level shows that the water level is placed above average water level, and some adjustment needs to be made. Using the mechanics of substations described in the paragraphs above, the system can detect these varying water levels and transmit the information to the main station above the dam. This enables workers to make precise adjustments to the dam's angle, thereby stabilizing the water level in the reservoir.



(a) Substation (b) Control Box
Fig. 9 Diagram of Substations and Control Box

B. Main Station

The main station is the most essential part for monitoring water level and overall preventing flooding. It receives radio signals from the substations with the Yagi-Uda antenna and is designed for communicating at the frequency of range 433 MHz, in which tasks are continued inside the control box, shown in Fig.10. The control box consists of data from substations, receivers, a 12V battery, a solar charge controller, a river flow meter, Arduino Mega, HT12D, and Raspberry Pi as shown in Fig.11. As data is contrived, the data demodulates the receivers which send data to the HT12D in ciphertext. The HT12D then decodes this ciphertext, converting it into plain text, which is subsequently sent to D1, D2, and D3. These data are then sent forward to Arduino Mega 2560, which handles analog input from A1 to A6. Furthermore, Arduino Mega 2560 processes pulse frequency data from the river flow meter, which is used to calculate the velocity of the water flowing through the dam. Finally, these data are then transferred to Raspberry Pi allowing an internet connection; allowing the user to access these data through a website.

For any system to work, there must be an energy supply. In this paper, the main station contains a solar cell, well known for being an efficient and reliable source of energy, which is connected to the control box by using a solar charge controller. The solar cell provides a reliable energy source for the 12V battery, allowing the system to run smoothly.

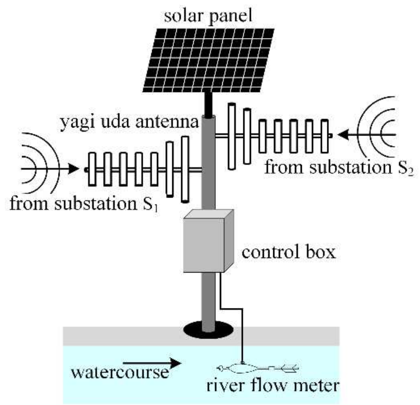


Fig.10 Structure of main station

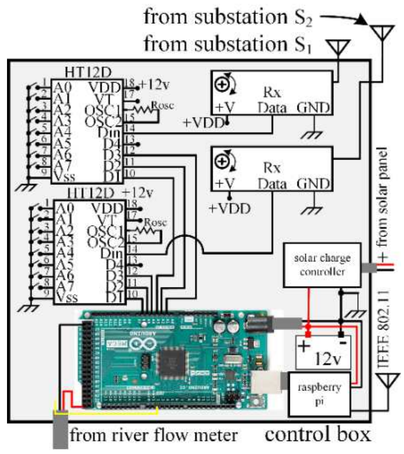


Fig.11 Control box of main station

C. Display Data

The Data measured by sensor will be sent to Arduino, which then would send these data to Raspberry Pi. Then, it will be processed into useful information. In this research, the website will be hosted on Raspberry Pi. The data will be refreshed every 10 minutes.

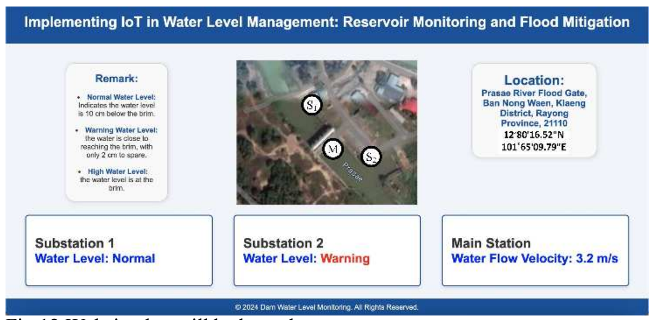


Fig.12 Website that will be hosted

The website uses HTML and CSS to show the location where these data are gathered from (substation 1, substation 2, and the main station). Additionally, it shows the water level in substation 1 and 2, and water velocity from Main Station. An example of the web page is shown in Fig. 12.

IV. Simulation and Experimental Results

From constructing these stations, experimental results were used to assess the accuracy of methodologies. This section presents the findings in two key areas: first, the performance of the Yagi-Uda antenna in both simulated and real-world environments; and second, the measurements of water velocity obtained using the flow meter with varied cross-sectional dam doors.

A. *Yagi-Uda's performance*

This antenna simulation was carried out using CST Microwave Studio Suite for modeling, changing, and analyzing the antenna's performance. Fig. 13 shows the design model of the antenna created in the CST software.

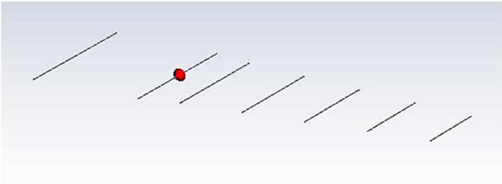


Fig.13 Element Yagi antenna on CST

Installation of the designed antenna and the SMA feed connector are shown in Fig.14,

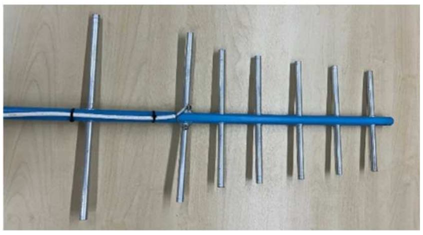


Fig. 14 Designed Yagi antenna

The S11 value or reflection coefficient measures how much signal is reflected from the antenna. It ranges from 0 dB (all signals reflected) to -∞ dB (no signal reflected). A value below -10 dB is considered good and means that the antenna is well matched with the feed line. Fig.15 shows a comparison of the S11 values for the Yagi antenna, both simulated and constructed for practical use at a frequency of 433 MHz It was found that the measured S11 is -22.7089 dB, which also shows low reflection, but is slightly less efficient compared to the simulated value of -28.7629 dB. The difference could be due to various factors, such as manufacturing tolerances, environmental conditions.

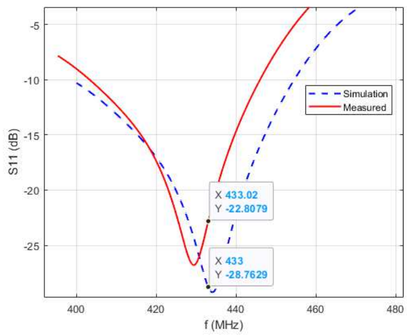


Fig. 15 S11 parameter

Fig. 16 shows the relationship between VSWR (Voltage Standing Wave Ratio), gain, and frequency. VSWR measures how good the antenna matches the feed line, with a value of 1.0 indicating perfect matching and no reflected signal. A higher VSWR means some signal is reflected. At 433 MHz, the VSWR is 1.07, showing excellent matching and minimal signal reflection. The graph shows that the VSWR increases at frequencies lower or higher than 433 MHz. This antenna works best at 433 MHz. Moreover, the antenna has a gain of 9.188 dB, indicating it performs well in focusing the signal. The gain increases up to 433 MHz and then drops, meaning the antenna is best at this frequency. This makes it great for applications needing strong and clear signals at 433 MHz.

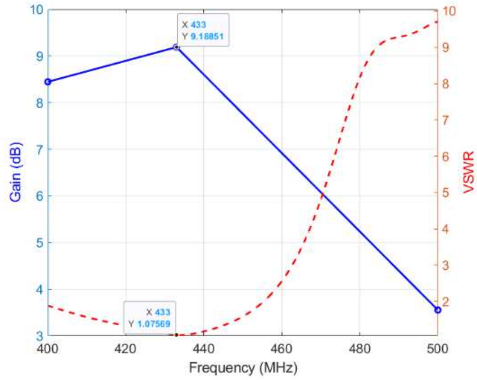
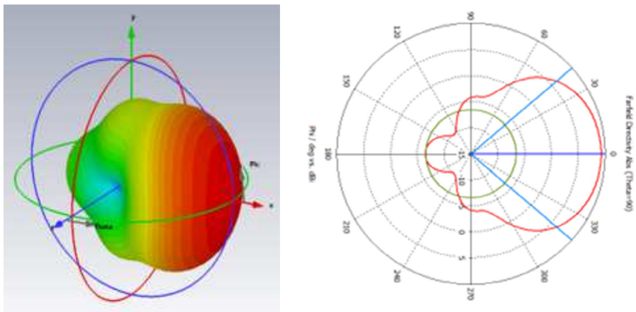


Fig. 16 VSWR and Gain

Fig. 17(a.) shows a 3D image with a radiation pattern of the Yagi antenna at 433 MHz. The red areas indicate the highest energy concentration (up to 9.19 dBi), while the blue and green areas show lower energy levels. The antenna is directional, focusing its energy primarily along the y-axis. Fig. 17(b.) shows a 2D image of the radiation pattern where theta = 90˚. It highlights the main lobe with maximum energy at roughly 0.10 dBi, pointing to 0º. Side lobes, having much lower intensity (-15.7dB) show reduced energy in unwanted directions, indicating good interference reduction.



(a) 3D radiation pattern (b) 2D radiation pattern (Theta = 90˚)

Fig. 17 Radiation Pattern of The Yagi Antenna at 433 MHz

B. *Hydroflow dynamic*

The flow meter placement was determined using Computational Fluid Dynamics (CFD). A 2D model, based on actual dimensions, was created as shown in Fig 18. The sluice gate outlet is 0.5 meters. Numerical calculations were used to optimize the grid size, balancing accuracy and computational efficiency. The grid structure is defined as rectangular.

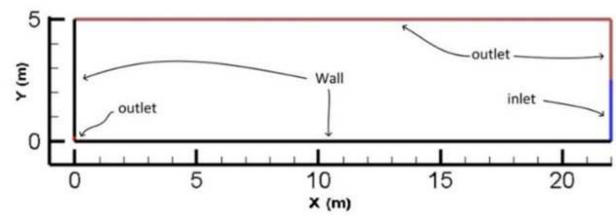


Fig.18 Geometry of the computational domain

Fig. 19 shows the change in water velocity through the sluice gate with varying grid sizes. As the number of grids increases, the velocity changes more rapidly. Beyond 298,000 cells, the velocity stabilizes with less than a 0.5% variation. Therefore, a grid size of 298,000 cells was chosen to balance accuracy, cost, and processing time.

This study used a Volume of Fluid Model to analyze the turbulent flow characteristics of water and air. To ensure precise results, equation accuracy was set to below 10^{-3}.

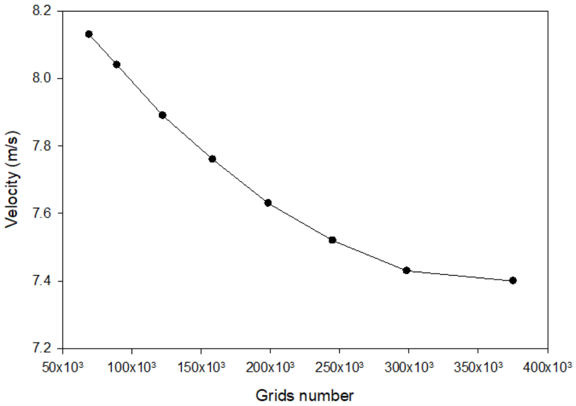


Fig. 19 Grid independence analysis of the velocity variation.

The position for installing the flow meter was determined using Computational Fluid Dynamics in which the model analyzed the flow characteristics of water at depths of 2.5 meters and 3.0 meters above the sluice gate, with the gate open to 0.5 meters, as shown in Fig. 20. Fig. 20(a1)-(a2) shows the flow patterns. This change in flow pattern is due to water vortices at the surface. Fig. 20(b) shows these vortices at a depth of 3 meters above the gate. The vortices rotate clockwise with centers located at 0.4 meters and 1.6 meters from the gate horizontally and vertically. These vortices cover a wide area where water and air mix together (colored green). Therefore, based on Fig. 20, installing the flow meter in areas with these vortices is not suitable.

Therefore, when comparing the water velocity measured by the flow meter to the numerical calculation results at a depth of 3 meters above the gate, and at distances of 10 to 15 meters from the sluice gate, with heights of 1.6 and 1.8 meters from the ground (as shown in Fig. 21), experimental data was found to be consistent with the calculations. This slow decrease in speed is caused by the flow pattern as shown in Fig. 20 (a1-a2), where water slows down as it approaches the sluice gate and forms surface vortices.

V. Conclusion

This research introduces the Real-Time IoT System for Reservoir Monitoring, aimed at improving water level accuracy and stability, crucial for flood forecasting and management. By integrating technologies like the OTT C31 universal current meter, float level switches, and the Yagi-Uda antenna along with HT12E/HT12D encoders/decoders, the system delivers real-time data on water levels and flow velocities. This information is vital for effective water management, particularly in flood mitigation and agricultural applications. The system's capability to measure water levels and velocity before and after the sluice ensures prompt, informed decision-making to stabilize water levels. The Yagi-Uda antenna operating at 433 MHz guarantees reliable data transmission, even in harsh environmental conditions, making the system versatile for various settings. Simulation and experimental results validate the system's performance, demonstrating its accuracy in both controlled and real-world environments. The close alignment of measured water velocities with simulated data confirms the system's effectiveness. Additionally, a web-based platform hosted on Raspberry Pi allows real-time data access, enhancing its utility for both technical personnel and the public. This system not only aids in flood management but also serves as a valuable resource for broader water management practices.

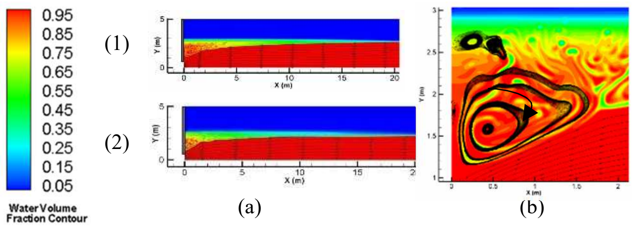


Fig. 20 show the water flow streamlines and the water-air mixing contours (Water Volume Fraction Contour).
(a1) shows the water flow pattern at a depth of 3 meters,
(a2) shows the water flow pattern at a depth of 2.5 meters, and
(b) shows the vortices between water and air at a water depth of 3 m.

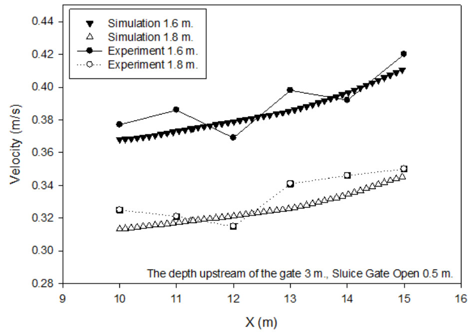


Fig. 21 The relationship between water flow velocity and a height of 3 meters at a distance of 10 to 15 meters from the sluice gate, with heights from the ground of 1.6 and 1.8 meters.

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References

[1] N. Poaponsakorn, P. Meethom, "Impact of the 2011 Floods, and Flood Management in Thailand", ERIA Discussion Paper Series, pp.1-72, Nov. 2013.

[2] Y. R. Hais, E. Saputra, A. T. I. Zk, and A. Raboula, "Design and Development of a Flood Detection Device for Drainage Systems Utilizing Float Switch Water Level Sensors," Circuit: Journal Ilmiah Pendidikan Teknik Elektro, vol. 8, no. 1, pp. 69–86, Mar. 2024.

[3] K. S. Varun, K. A. Kumar, V. R. Chowdary, and C. S. K. Raju, "Water Level Management Using Ultrasonic Sensor (Automation)," International Journal of Computer Sciences and Engineering, pp. 799-804, June 2018.

[4] Yamaguchi and K. Niizato, "Flood Discharge Observation Using Radio Current Meter," Doboku Gakkai Ronbunshu, vol. 1994, no. 497, pp. 41–50, Aug. 1994.

[5] C. Franzen et al., "Microwave and radio wave supported drying as new options in flood mitigation of imbued decorated historic masonry," Journal of Cultural Heritage, vol. 21, pp. 751–758, Sep. 2016.

[6] H. Karbalaee, M. R. Salehifar and S. Soleimany, "Designing Yagi-Uda antenna fed by microstrip line and simulated by HFSS," 2012 6th International Conference on Application of Information and Communication Technologies (AICT), Tbilisi, Georgia, 2012, pp. 1-5.

[7] H. -C. Huang and P. Hsu, "A planar reconfigurable Yagi-Uda antenna with end-fire beam scan," 2009 Asia Pacific Microwave Conference, Singapore, December 2009, pp. 1914-1917.

[8] Kannan, P. & Reji, M. & Ramamurthy, Swaminathan. "Design of reduced dipole yagi – Uda antenna". IOP Conference Series: Materials Science and Engineering. 2020.

[9] Balanis, C. A. Antenna Theory: Analysis and Design (4th ed.). Wiley, 2016.

[10] A. J. Clemmens, M.ASCE, T. S. Strelkoff, M.ASCE, and J. A. Replogle, F.ASCE, "Calibration of submerged radial gates." Journal of Hydraulic Engineering, Vol. 129, No. 9, pp. 680–687.