



Prototype of Flood Monitoring System Based on River Turbidity Using Optical Fiber Sensor and Raspberry Pi 3 B+

Muhamad Iqbal, Aldo Novaznursyah Costrada and Harmadi Harmadi

EasyChair preprints are intended for rapid dissemination of research results and are integrated with the rest of EasyChair.

September 25, 2021

Prototype of Flood Monitoring System Based on River Turbidity Using Optical Fiber Sensors and Raspberry Pi 3B+

Muhamad Iqbal¹, Aldo Novaznursyah Costrada², and Harmadi¹

¹ Department of Physics, Faculty of Mathematics and Natural Science, Andalas University, Padang, 25163, Indonesia

² Department of Physics, Faculty of Mathematics and Natural Science, Bandung Institute of Technology, Bandung, 40132, Indonesia
harmadi@sci.unand.ac.id

Abstract. A prototype of a flood monitoring system based on river turbidity has been developed using an optical fiber sensor and the Raspberry Pi 3B+. The prototype of this flood monitoring system consists of 3 units, such as a unit of electrical energy source, a transmitter unit, and a receiver unit. The electrical energy source unit has a function to produce energy from sunlight and to activate the transmitter unit. The transmitter unit has a function to measure the water turbidity and transmits the measurement result to the receiver unit. The receiver unit has a function to receive the river water turbidity data from the transmitter unit, manages and display data in a graph, save the data, and gives an early warning using a buzzer when the flood has occurred. The optical fiber sensor is used to measure the value of water turbidity by utilizing the change in the voltage output of the OPT101 photodiode. The result of the test and data analysis that have been recorded in Raspberry pi 3B+ will be sent from transmitter unit to receiver unit by using the nRF24L01+ transceiver. The maximum distance from data transmission of the nRF24L01+ was 739 m without obstacle and 318 m with an obstacle. The threshold of turbidity value used to determine the potential for flooding in this prototype was 467 NTU. This prototype has a sensitivity of $-1.3074 \text{ mV} / \text{NTU}$ and the average relative error percentage of this prototype is 21.56% compared to the turbidity meter TU-2016.

Keywords: OPT101 Photodiode, Transceiver nRF24L01+, Raspberry Pi 3B+.

1 Introduction

Indonesia is traversed by the equator so that the region has a tropical climate with two seasons, the rainy season and the dry season [1]. The rainy season triggers various disasters such as landslides, hurricanes, and floods. A Flood disaster is an event when water inundates an area that is usually not flooded for a certain period of time and is characterized by continuous rain for a long time, the water discharge increases, and the water becomes cloudy after the rain [2].

The government has made efforts to reduce the impact of the flood disaster by implementing a Flood Early Warning System (FEWS) installed around residential areas, but FEWS is still limited because the price is very expensive and the procurement is also not evenly distributed in every region of Indonesia.

Several studies have been conducted to become alternative solutions for pre-flood mitigation, as has been done by Yuzria et al [3]. designed an early warning tool for flood disasters based on water level using the ultrasonic sensor HC-SR04. The research that has been carried out by Yusriza needs other indicators that can indicate a flood disaster will occur.

Ammari et al.[4] designed a prototype for flood early warning using a turbidity meter sensor SEN1089 to measure the level of turbidity on the surface of river water with an error percentage of 29.48%. From these results, a sensor is needed that can minimize the percentage of errors. One sensor that has a good response and measurement accuracy is an optical fiber sensor. Optical fiber has advantages such as very fast measurement response, precision, and high accuracy [5].

One method of making fiber optic sensors is the evanescent method. The evanescent method is a method of developing a hybrid fiber optic sensor by utilizing the effect of attenuating the intensity of light that senses the outside environment. The cladding is peeled so that the core directly interacts with the outside environment and the cladding's refractive index function is automatically replaced by the refractive index of the sample (river water) [6],[7].

Deswilan et al [8] and Costrada et al. [9] developed a flood and landslide monitoring system with a JSN sensor as a flood level measuring sensor and an optical fiber sensor as a landslide shift sensor. This system uses SIM 900A as a data sending unit. Data storage in this system uses a Personal Computer which requires a large amount of power in the field so it is necessary to use power-saving devices and sources of electrical energy that can be used in the field.

Based on the description above, it is necessary to make a prototype of a flood disaster monitoring system based on the turbidity of river water using fiber optic sensors and Raspberry PI 3B+. Raspberry PI 3 B+ can manage and display data into a graph in real-time and saved in a comma-separated value (.csv) format file (Salim et al [10]). The system is divided into three units, namely an electrical energy source unit, a transmitter unit, and a receiver unit. The electrical energy source unit utilizes energy from sunlight and generates electricity to activate the transmitter unit. The transmitter unit measures the turbidity of river water and transmits data using the Transceiver nRF24L01+ to the receiver unit. The receiver unit processes the data received from the transmitter unit and saves the data into a file in real-time. The receiver unit can determine whether there is a potential for a flood disaster or not based on water turbidity data and the turbidity threshold value for a flood disaster.

2 Method

2.1 The test of electric source of monitoring system

Testing of electrical energy sources is shown to determine the ability of the power source to be used in the monitoring system. The processes contained in the electrical energy source include the process of absorption of solar energy, the process of energy storage, and the process of converting voltage. The process of absorption of solar energy aims to convert sunlight energy into electrical energy. The tools used for this process are solar panels and multimeters.

The energy storage process aims to store energy that has been absorbed and converted into electrical energy in the process of absorbing solar energy. Electrical energy from the solar energy absorption process will be conditioned using a solar charge controller and then stored using a 12V deep cycle battery. The voltage conversion process aims to change from DC voltage to AC voltage. The process of changing this voltage is done because the required voltage at the transmitter unit is AC voltage with a value range of 110V-220V.

2.2 Design of overall experiment of flood monitoring system

Testing of the flood early warning system is carried out at Batu Busuk River, Padang. The increased turbidity of the water is one of the factors that the overall test of this system can be carried out. An overview of the overall system testing is shown in the form of a block diagram in Fig 1.

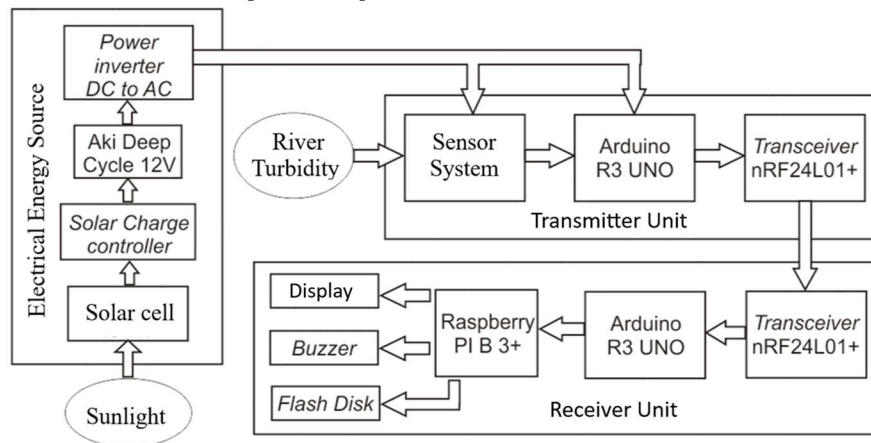


Fig. 1. The block diagram of flood monitoring system

The electrical energy source unit and the transmitter unit are placed upstream of the river. The electrical energy source unit generated by the solar panel is partly stored in a 12 V deep cycle battery and partly used for the transmitter unit. The transmitter unit consists of a sensor system measuring the turbidity level of the water and the turbidity

value data will be sent to the receiver unit downstream of the river. The measurement of river water turbidity is measured dynamically and the measured water turbidity value will be sent in real-time to the receiver unit. The receiver unit processes the data received from the transmitter unit. The receiver unit will save to the storage media and display the value of river water turbidity on a monitor downstream of the river. The schematic of this flood monitoring system is shown in Fig 2.

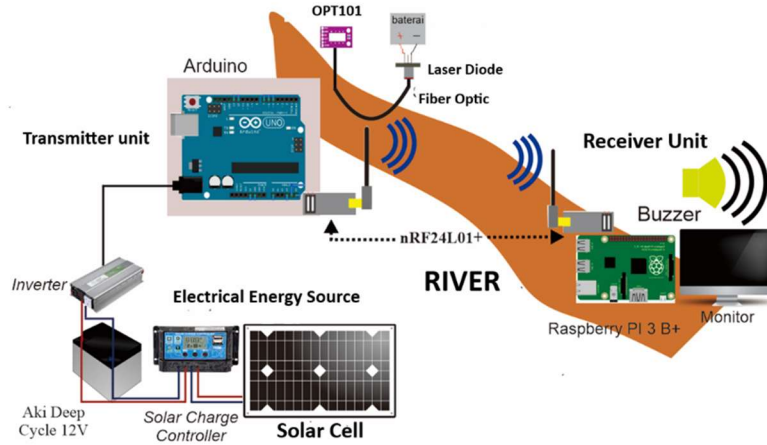


Fig. 2. Scheme of overall monitoring system of flood

The flood monitoring system will warn when the turbidity value of the water in the upstream river crosses the threshold value of the turbidity. The test is carried out by making turbidity with rocks and sand from the river, the turbidity is poured into the river flow so that it is mixed with river water. Data on the turbidity value of water that exceeds the threshold is processed on the Raspberry PI 3 B+ receiver unit so that the buzzer turns on and the monitor displays the words "FLOOD" as an early flood warning. The flood early warning will turn off automatically and the monitor will display the words "NORMAL" when the rain subsides followed by the turbidity of the water returning to normal. Data on turbidity values above and below the turbidity threshold will be stored on storage media using a Raspberry PI 3 B+ receiver unit.

2.3 Data Analysis

Data analysis is a process to find out the accuracy of the measurement system. The accuracy is the suitability level of measurement result toward the correct value. The accuracy of the system is determined from the error percentage between the correct value with the measurement value. The error percentage of the measuring instrument is determined with Equation 1

$$e_n = \frac{Y_n - X_n}{Y_n} \times 100\% \quad (1)$$

Y_n is the correct value of the comparison instrument and X_n is the measured value of measuring instrument. The comparison instrument used was a TU-2016 Turbidity meter.

3 Result and Discussion

3.1 The testing of solar panels as a source of electrical energy

Testing of solar panels aims to ensure that solar panels can be used as a source of electrical energy in the monitoring system. The test is carried out by measuring the DC voltage generated by the solar panel which is then converted into AC voltage. The solar panel test data is presented in Table 1.

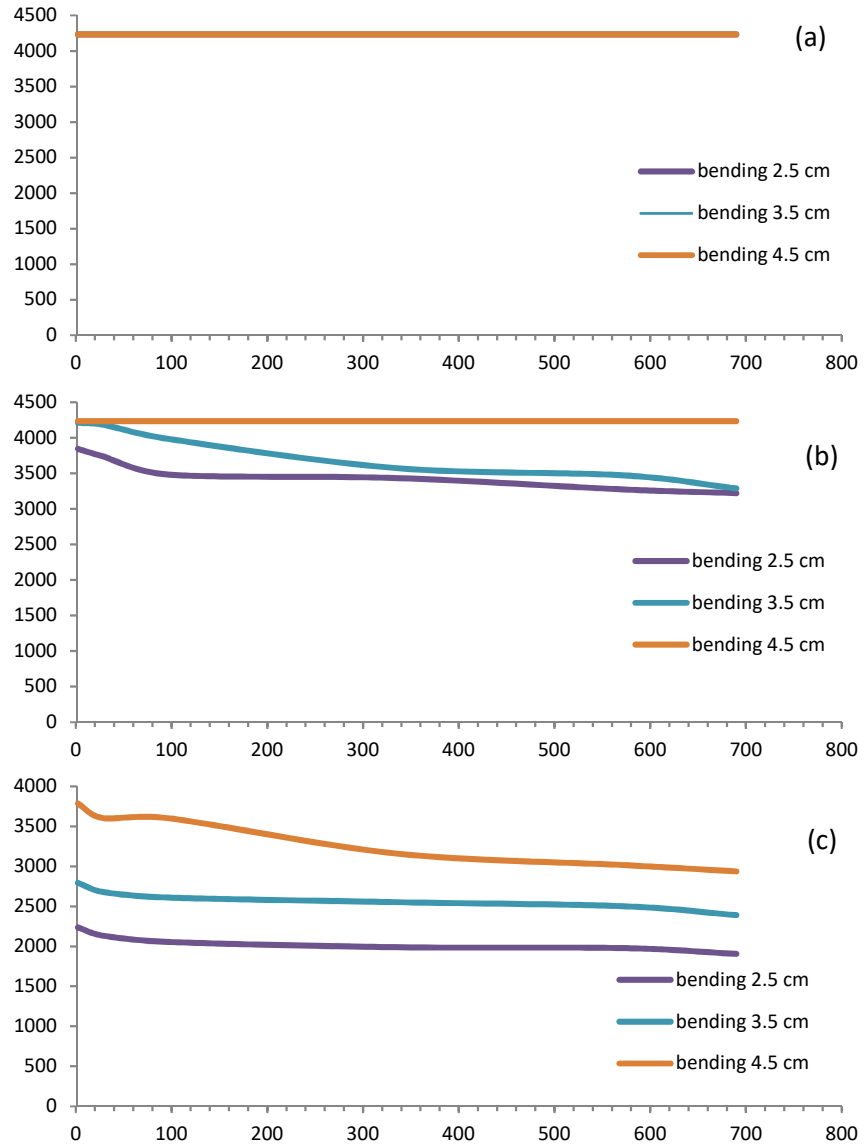
Table 1. The test data of solar panels as a source of electrical energy

Procces	Output Voltage	
	Device	Datasheet
Prodeuced by solar panels (DC voltage)	8,19 V	0 -16.8 V
Saved to baterry (Listrik DC)	12.2 V	11.7 -12.8 V
Converted to AC voltage by power inverter	206 V	110- 220 V

Table 1 shows that the solar power plant test was successfully carried out where the equipment used could run properly. This is based on the output voltage within the range of capabilities of each device by the datasheet.

3.2 The Characterization of Optical Fiber Sensor as Turbidity Flood Sensor

Characterization was carried out to make optical fiber able to measure water turbidity. The optical fiber is treated with evanescent wave attenuation so that the optical fiber can work as a sensor. The peeling of the jacket and cladding is varied in length 1cm, 2cm, 3cm, 4cm, 5cm. This characterization also looks at the effect of optical fiber bending on the accuracy of measuring water turbidity with a radius variation of 2.5 cm, 3.5 cm, and 4.5 cm. The results of the characterization applied to the flood disaster monitoring system are fiber optic sensors with a coefficient of determination close to 1 and high sensitivity. The results of the characterization in Figure 1 are a graph of the relationship between turbidity (NTU) and voltage (mV).



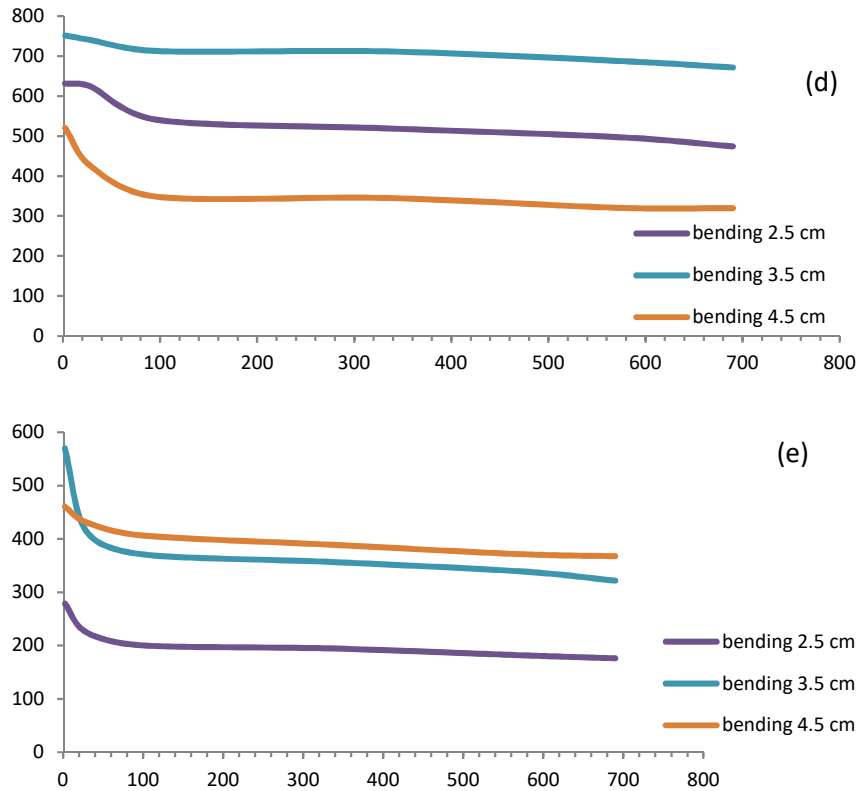


Fig. 3. The characterization of fiber optic with peeling: (a) 1 cm, (b) 2 cm, (c) 3 cm, (d) 4 cm, (e) 5cm.

Based on Fig. 3, there is a difference in output voltage between variations in cladding peeling and the bending radius of optical fiber. Peeling of 1 cm cladding in all variations of bending and peeling of 2 cm cladding with a radius of 4.5 cm did not change the stress due to total internal reflection which can maintain the intensity of the guided light in the optical fiber. The evanescent attenuation area that is too narrow causes light loss to have little effect on the performance of the fiber optic sensor

The effect of water turbidity on the output voltage read by the photo-detector shows a trend of decreasing voltage with an increase in water turbidity. Characterization of optical fiber with variations in peeling and bending radius of optical fiber obtained the best results at 2 cm peeling and bending radius of 3.5 cm with a coefficient of determination of 0.9537 and a sensitivity value of -1.3074 mV/NTU.

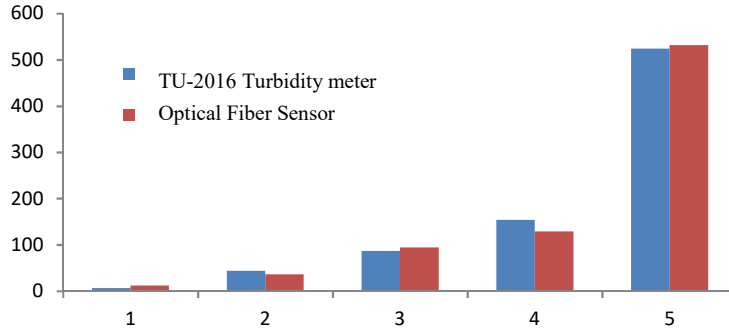


Fig. 4. The data analysis of optical fiber sensor compares with TU-2016 turbidity meter

The test of the optical fiber sensor as turbidity flood sensor also compares measurements using optical fiber sensor with the TU-2016 turbidity meter which is a water turbidity measurement instrument. The measurement of river water turbidity is carried out simultaneously. Comparison of measurements between TU-2016 and fiber optic based on the image produces an error percentage of 21.56%. This is because there are errors caused by external factors such as strong river flows and errors caused in the manufacture of fiber optic sensors that cause the electronic components of the device to become unstable. The data analysis of optical fiber sensor compares with TU-2016 turbidity meter shown in Fig 4.

3.3 Overall Testing of Flood Monitoring System

Overall testing is carried out to ensure hardware and software are running so that the prototype can work according to its function. The full prototype test was carried out in 2 conditions, namely below the flood turbidity threshold value and above or equal to the flood turbidity threshold value. The prototype of flood monitoring system shown in Fig.5.

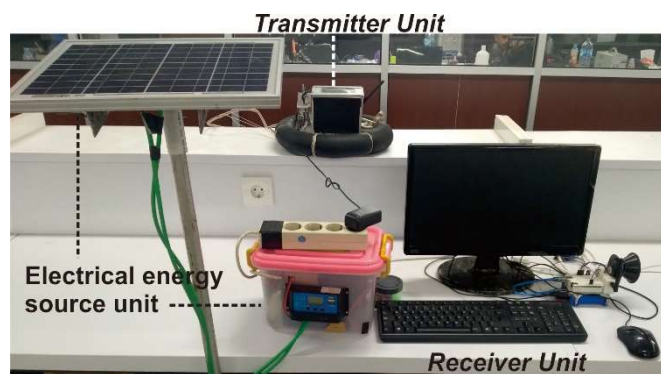


Fig. 5. The prototype of flood monitoring system

The flood turbidity threshold value used in this prototype is 467 NTU. This value is used based on the reference value of flood turbidity which has been measured by (LIPI, 2010) in the Citarum River, Purwadana Village, Jambe Bay, Karawang, West Java. The test results are recorded and attached in Table 2.

Table 2. The data of overall testing of flood monitoring system

No	The Turbidity of TU-2016 (NTU)	The turbidity of optical fiber sensor (NTU)	Condition (safe/flood)	Buzzer ON/OFF
1	6.07	12.02	Safe	OFF
2	43.92	36.5	Safe	OFF
3	86.76	94.22	Safe	OFF
4	153.89	128.9	Safe	OFF
5	524.2	531.6	Flood	ON

Based on Table 2, the tool as a whole can work with its function. The sensor system located in the transmitter unit can measure the turbidity of river water and send it to the receiver unit. The receiver unit of the device as a whole can receive the turbidity of river water sent from the transmitter unit so that it can be processed. The tool can give a warning if the turbidity of the river water is the same and exceeds the flood threshold value of 467 NTU which is indicated by the buzzer on.

4 Conclusion

The best fiber optic sensor from the characterization results is 2 cm of cladding peeling and a bending radius of 3.5 cm and a coefficient of determination (R²) of 0.9537. The prototype designed has a sensitivity of -1.3074 mV/NTU with an average error percentage of 21.56%. The data on the turbidity value of river water has been successfully transmitted from the transmitting unit to the receiving unit using the nRF24L01+ transceiver with a maximum distance of 739.61 meters without barrier and 318.69 meters with trees as a barrier. The prototype designed can work in a river and each unit works according to its respective function.

5 Acknowledgement

This research is supported by The Directorate of Research and Public Service, Deputy of Affirmation Research and Development Sector, The Ministry of Research and Technology / National Research and Innovation Agency (commission contract of public service program number: 163/SP2H/AMD/LT/DRPM/2020).

References

1. BMKG Homepage, <https://www.bmkg.go.id>, last accessed 2021/1/21.
2. Jica Homepage, <https://www.jica.go.jp/project>, last accessed 2021/1/2021.
3. Yuzria, H.O., Pesma, R.A., Dahlan, D., Harmadi, Shadri, M., Wildian.: Rancang Bangun Sistem Peringatan Dini Banjir Menggunakan Telemetry Nikabel Dengan transceiver nRF24L01+. *Jurnal Ilmu Fisika* 9(1), 57-67 (2017).
4. Ammari, S., Wildian, and Harmadi.: Rancang Bangun Sistem Peringatan Dini Banjir Berdasarkan Tingkat Kekeruhan Air Hulu Sungai dengan Turbidity Sensor SEN0189 dan Transceiver nRF24L01+. *Jurnal Fisika Unand* 8(3), 240-244 (2019).
5. Zulaichah, S.: Pengukuran frekuensi getaran menggunakan serat optik. ITB, Bandung (2014).
6. Fidanboyu, K. dan Efendioglu, H.S.: *Fiber Optic Sensors and Their Applications*, 5th International Advanced Technologies Symposium., Karabuk, Turkey (2009).
7. Frederick, A.: *Fiber Optic Hand Book for Engineers and Scientist*, Mc Graw-Hill, United States. (1990).
8. Deswilan, S., Costrada, AN., & Harmadi.: Prototipe Pengukuran Intensitas Curah Hujan Menggunakan Linear Sensor Array CCD TSL1401CL. *JURNAL ILMU FISIKA* 13(1), 18-25 (2021).
9. Costrada, AN.: Karakterisasi Desain Ekstensometer Serat Optik Tikungan Ganda untuk Sensor Tanah Longsor. *JURNAL ILMU FISIKA* 13(1), 1-7 (2021).
10. Salim, T. I., Haiyunnisa, T., & Alam, H. S.: Design and Implementation of Water Quality Monitoring for Eel Fish Aquaculture, In 2016 International Symposium on Electronics and Smart Devices (ISESD), IEEE, pp. 208-213 (2016).