RSSI Analysis on CSS Modulation in the 433 MHz Frequency Band Using Lora in Flood Sensor

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Abstract *– Long Range (LoRa) low power is a transmission technology capable of connecting multiple sensors to the Internet of Things in the future. LoRa uses Chirp Spread Spectrum (CSS) frequency modulation which promises to achieve remote connectivity at very low power. More specifically, this paper focuses on the analysis of Receive Signal Strength Indicator (RSSI) on CSS modulation on flood sensors. This paper presents a detailed model of using LoRa on flood sensors, showing that LoRa is capable of transmitting sensor data over long distances with perfect RSSI values. The results showed the potential for a close communication range with a narrow band network at a frequency of 433 MHz and an average RSSI of -50 dB at a maximum distance of 600 meters without obstruction. Although LoRa communication uses CSS modulation and has good RSSI values, in long-distance communication with data in the form of video or large sensor data, this toughness is not sufficient due to long distances and large bandwidth usage, while in this study LoRa type Ai Thinker Ra- 02 SX 1278 can only be set up to 125 KHz according to the datasheet. The disadvantages of using large sensor data over long distances and a larger footprint make CSS vulnerable to other, possibly larger, resources.*

Keywords*: LoRa, CSS, RSSI, frequency, flood sensor.*

1. Introduction

As technology advances in the Internet of Things (IoT), remote transmission systems with low power and capable of accommodating many sensors are needed in today's development of wireless communication technology. Unlike traditional cellular networks, IoT networks aim to maintain low-level long-distance communication. For this reason, Many Low Power Wide Area Network (LPWAN) or Long Range (LoRa) technologies are required. most of this technology operates in Industrial, Scientific, and Medical radio bands (ISM bands). The spectrum usage in the ISM band is limited to 1% for uplink and 10% for downlink (duty cycle) [1]. The main advantage of this technology is that the equipment setup is very cheap and less energy consuming [2]. In recent years, several technologies have been presented in order to perform LPWAN such as Long Range (LoRa), Sigfox [3], Weightless [4], Narrow band IoT (NB-IoT) [5], Ingenu RPMA, Telensa, Qovisio, Nwave and Waviot [6], [7]. LoRa usage frequency recommended by the LoRa developer, Semtech is 433 MHz for Asia, 868 MHz for Europe and 915 MHz for North America [8].

LoRa modulation is a patented technology that belongs to Semtech which is not fully open. LoRa uses Chirp Spread Spectrum (CSS) modulation which was originally intended for radar use in 1940 [9]. With CSS modulation, it will certainly be possible to transmit data over long distances with low power consumption through the ISM (Instrumentation Science and Medical) bandwidth. In this paper, we will focus on RSSI (Receive Signal Strength Indicator) analysis on sensor data transmission using CSS modulation by LoRa, especially in the 433 MHz frequency range, where in previous studies there have been similar studies related to "RSSI Fingerprinting-based Localization Using Machine Learning in LoRa Networks". in the study it was said that placing the transmitter device at the appropriate place and height will have a major influence on the signal strength received by the receiver in LoRa communication [10]. RSSI is a signal received by a receiver in a communication system and has been mixed with noise and interference or the overall signal power received by the user in dBm units [11].

2. Research Methods

2.1. Research Methods and Steps

Research on making a flood sensor by utilizing LoRa type Ai Thinker Ra-02 SX 1278 using CSS modulation for RSSI value analysis as a test tool to obtain an analysis of an effective transmission system in LoRa communication is included in the realm of research and development (R&D). This is indicated by the results of the research in the form of technological products that are carried out through technical steps. The research step in this implementation refers to project work procedures, meaning that the sequence of work is planned according to the simplest design and continues to increase into a complex product. The research steps are as shown in Figure 1.

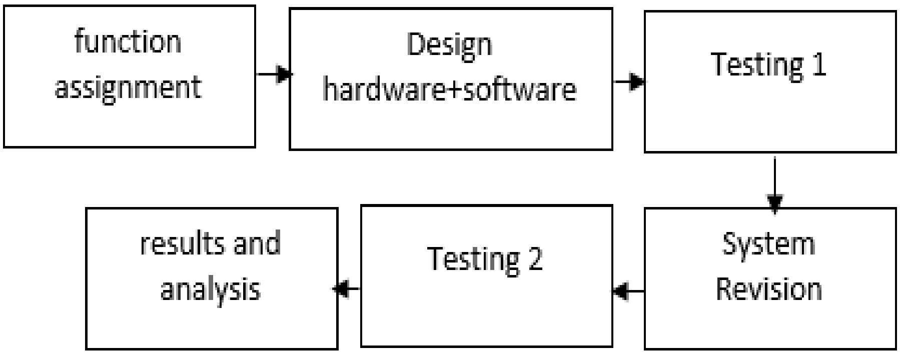

Figure 1. Workflow diagram of a flood sensor using CSS modulation.

2.1.1. Object of Research

The object of this research takes the theme of RSSI analysis on CSS modulation in the 433 MHz frequency band using LoRa in flood sensor, resulting in tool work in accordance with the design idea. It is hoped that the results of RSSI research and analysis in this study can be functionally useful and add to the repertoire of electronics science, especially in the telecommunications field. Data processing is determined by the program design for the flood sensor in executing incoming data as a variable which will later be transmitted using LoRa.

2.1.2. Research Models and Schemes

This study uses a research and research model development (R&D). It is based on data that will be presented empirically with the aim of testing the truth of the theory embodied in the realization of a system real communication, namely LoRa applications, modulation techniques, transmitter and receiver circuits and the RSSI magnitude that can be measured, assessed or expressed in one quantity.

The research scheme for making flood sensors by utilizing CSS modulation at LoRa frequency of 433 MHz refers to the deductive research scheme presented in Figure 2. This is based on research development starting from the theoretical level then to the concept level and continued to the operational level.

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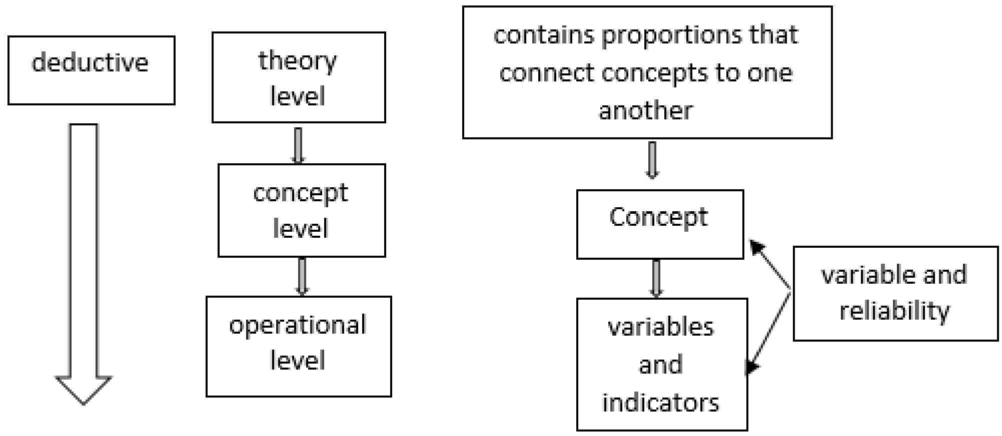

Figure 2. Schematic frame of mind.

2.1.3. Testing Methods and Instruments

The testing method on the flood sensor using CSS modulation to get the results of the RSSI analysis is carried out separately in the main parts. To see the performance of the tools that have been made, testing must be done. Before testing the tool will be calibrated with a similar instrument as a reference. This test is to determine the character, pattern value, unit, magnitude, working principle of the transmission system on the flood sensor.

This sensor is actually measured based on the ability to work on reading water level data in detecting floods, the speed and distance of data transmission, the accuracy of the flood sensor readings and the range. Furthermore, the results of the test will be analyzed based on theory. each test requires an instrument (measurement tool) to knowing the value of a system according to the amount in order to analyzed. In the research of making this flood sensor, several instruments are needed, including: breadboard, jumper cable, 2.4 GHz antenna (Tx and Rx) and AVOmeter.

2.1.4. Data Collection and Data Analysis Techniques

Data retrieval is carried out through measurements using a serial monitor as a reference for readings and sensor accuracy. Measurement or data retrieval in RSSI analysis research on CSS modulation at a frequency of 433 MHz in this flood sensor is focused on measuring software and performance results. Data retrieval to determine accuracy, precision, range and response is carried out by measuring various different conditions. The testing process is carried out repeatedly, and the measurement data from several conditions are averaged as the final result. Data obtained from the results of trials conducted with a minimum of 2 repetitions.

Data analysis in this study was carried out quantitatively [12]. This is done by calculating the measurement results and then comparing them with the theoretical analysis results. The results of this analysis is a combination of the measurement results and theoretical calculations. From this data analysis, conclusions will be drawn from what has been formulated.

2.1.5. Conclude Research Results

Concluding the results of the study was carried out after analyzing the data that was considered sufficient and then concluded. The conclusions of this study are related to the formulation of the hardware design of the flood sensor device, RSSI on LoRa which is used as a receiver, and the performance of RSSI analysis results on CSS modulation. The conclusion of the design of the tool can be seen from the measurement results obtained from the results of data collection. After the data is collected according to the quantity, then the data can then be processed to determine the value of the LoRa transmission system capability, precision, range and response time.

2.2. Flood sensor design chart using LoRa frequency 433 MHz

To get the results of the design of a flood sensor using LoRa with a frequency of 433 MHz, it is done by combining several electronic circuit systems. Some of these systems are connected in a breadboard so that the system can work as a whole. The arrangement of relationships between systems can be seen in Figure 3.

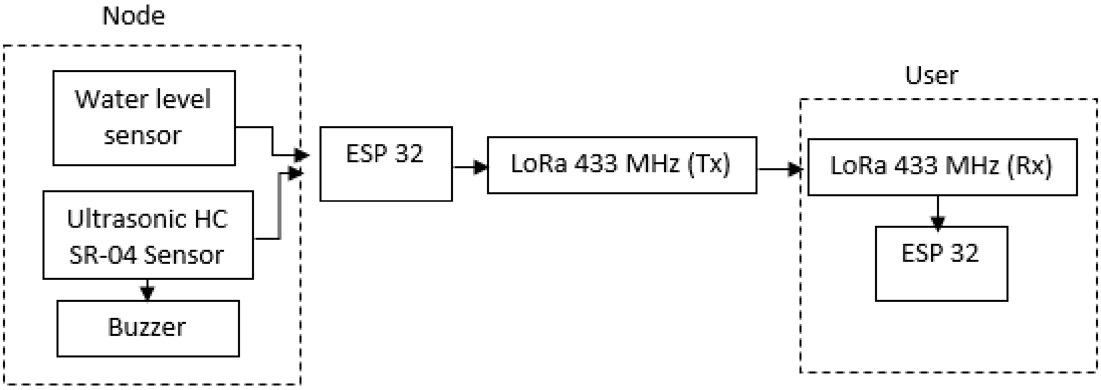

Figure 3. The flood sensor system to be designed.

The desired parameter observed by LoRa transmission using CSS modulation is the RSSI value at the receiver. The sensor output is still in the form of raw data in the form of voltage, then extracted by the perception section with a signal conditioning strand in the form of a comparator so that digital signals are produced with TTL (Transistor Transistor Logic) standards. The digital signal is then processed by the microcontroller ESP 32 is based on a knowledge base programmed in the microcontroller so that an action command is generated [13]. This command is further processed by the planning and transmission subsystem so that finally the transmitter part in the form of a 433 MHz LoRa module and antenna sends sensor reading data according to the command. Thus the receiver is expected to be able to receive the sensor readings in real time.

3. Results and Analysis

3.1. Implementation Design

The flood sensor circuit uses Chirp Spread Spectrum (CSS) modulation on LoRa which is designed to be implemented in Figure 4.

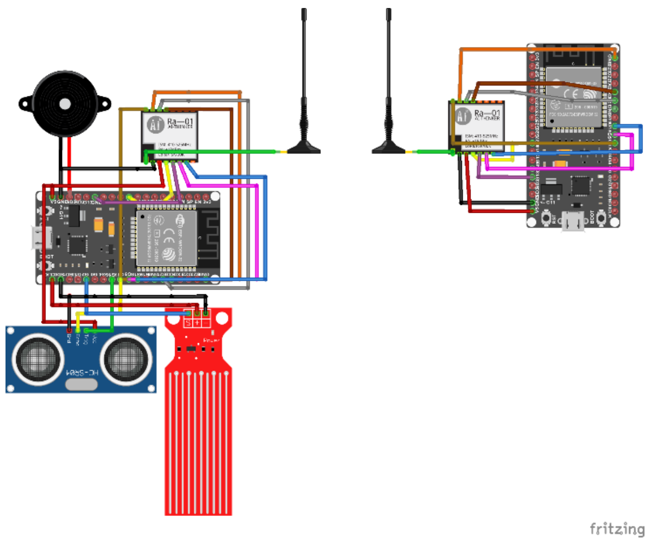

Figure 4. Electronics design.

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LoRa which is used for transmitting and receiving signal modulation uses LoRa type Ai Thinker Ra-02 SX 1278 with a frequency range between 410 - 425 MHz and uses a voltage of 3.3V as input. This study follows the frequency regulation recommended by Semtech in the Asian region, which is 433 MHz. In the designed flood sensor, a water level sensor is used to detect the water level so that the resulting water level monitoring data in flood-prone areas and the ultrasonic sensor HC-SR 04 which detects the water level when the water level sensor is completely submerged in flood water. if the water level has reached 50 cm from the ultrasonic sensor, the buzzer sensor will sound loudly warning that the water has started to get high and the sensor will not work because it is completely submerged in water. based on the datasheet on LoRa type Ai Thinker Ra-02 SX 1278 in the 433 MHz frequency range will have receive sensitivity as shown in Table 1.

Table 1. Receive Sensitivity in 433MHz.

Frequency	Spread Factor	SNR	Sensitivity
433 MHz	7	-7	-125
	10	-15	-134
	12	-20	-141

Keep in mind that the data above is measured by the Semtech Laboratory of Shenzen with the current conditions of the test: power output of 20 dBm and bandwidth of 125KHz

3.2. Physical Layer LoRa Parameters in CSS Modulation

In this study, the amount of bandwidth in LoRa modulation is set at 125 KHz. while for the Spreading Factor (SF) the LoRa physical layer parameters cannot be separated from two things, namely, the number of chips in each symbol is 2^{SF} and the number of bits that can be encoded by LoRa in the SF symbol. while the code rate (CR) to handle Packet Error Rate (PER) due to interference can be formulated using the equation 1.

$$CR = \frac{4}{(4+n)} \tag{1}$$

where n is {1, 2, 3, 4}. dividing the power of two from SF to bandwidth (BW) will produce the symbol duration (TS) with the formula as in equation 2.

$$TS = 2^{SF/BW} \tag{2}$$

the reciprocal of the duration of this symbol is the symbol rate (RS)

$$RC = RS\ X\ 2^{SF(\frac{Chip}{Sec})} \tag{3}$$

so that it will produce the equation

$$RC = BW \tag{4}$$

because in this study using a bandwidth of 125 KHz, when LoRa does CSS modulation it can reach 125,000 chips/second. LoRa has a Forward Error Correction Code by determining the Code Rate (CR) with the equation 1. for the bit rate can be formulated with the following equation:

$$RB = SF\ X\ RS\ X\ CR = SF\,\frac{BW^{SF}}{2}\ X\ \frac{4}{(4+n)} \tag{5}$$

In this study, BW is set at 125 KHz with a large SF according to the LoRa data sheet type Ai Thinker Ra-02 SX 1278 of 7 and CR 4/5, it will produce a bit rate of RB = 5.5 kbps. lowering the Code Rate (CR) value will cause a decrease in the Packet Error Rate (PER) from the appearance of interference. for example a packet sent with a CR of 4/8 will tolerate interference more than a CR of 4/5 [14].

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3.3. RSSI Analysis in Flood Sensor Circuits Using CSS Modulation

The results of the flood sensor testing using CSS modulation on LoRa 433 MHz Robot is carried out by taking water level data and RSSI values for each sensor data reception. We took the location of flood-prone puddles in Karawang for data collection and the test results can be seen in Figure 5.

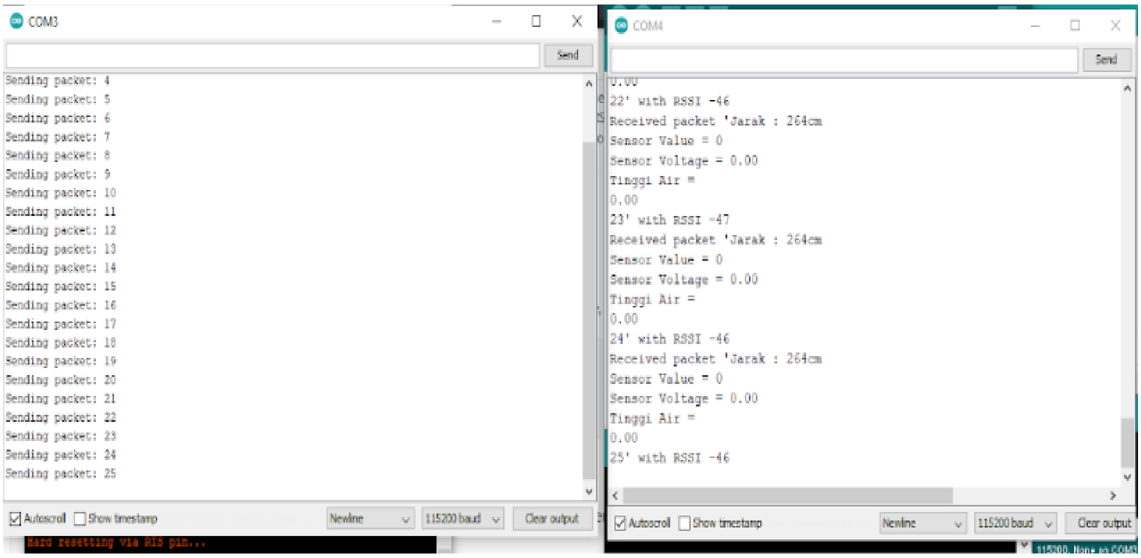

Figure 5. Serial data monitor testing tool.

From the results of testing and data collection, the performance of the tool can be analyzed. Based on the performance analysis data above, the flood sensor tool with the use of CSS modulation at LoRa 433 MHz is declared to have a fairly good level of performance if judged by the RSSI amount for each sensor data transmission. Data collection 7 times is presented in Table 2.

Table 2. RSSI data value retrieval.

Triar to -	RSSI (dBm)	Distance Tx to Rx (m)
1	-46	300
2	-47	350
3	-46	400
4	-55	450
5	-55	500
6	-47	550
7	-54	600

The core program performs the tasks of sensor reading, processing sensor data, and transmitting sensor reading data using the LoRa communication system. The sensor data transmission base is based on the method used by the LoRa transmission medium to use CSS modulation, namely transmission in the 433 MHz frequency range. for samples sending sensor data and receiving sensor data can be seen in Figure 6 and Figure 7.

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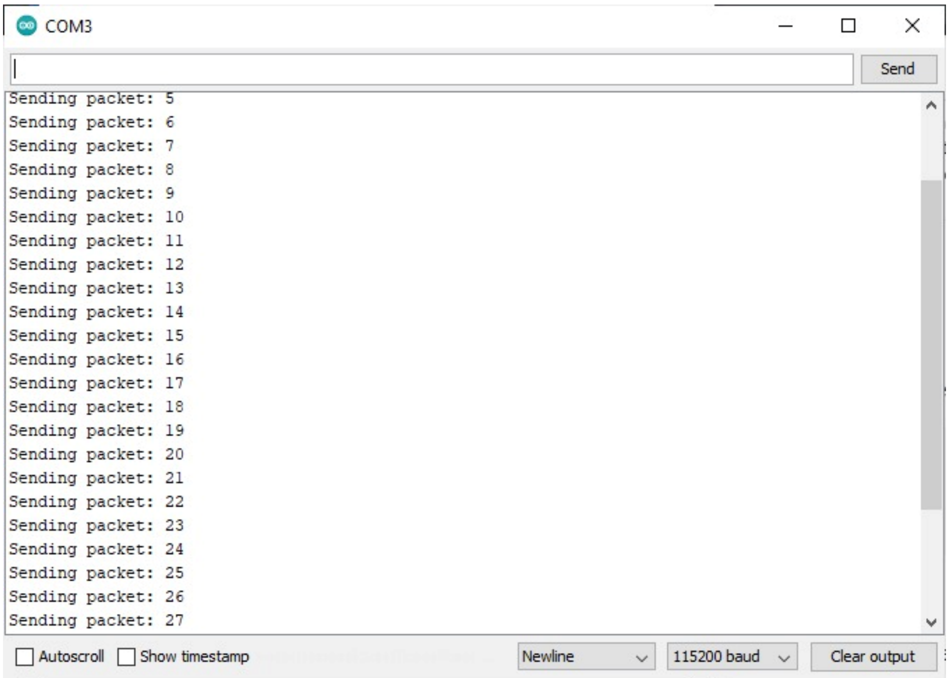

Figure 6. Transmitter.

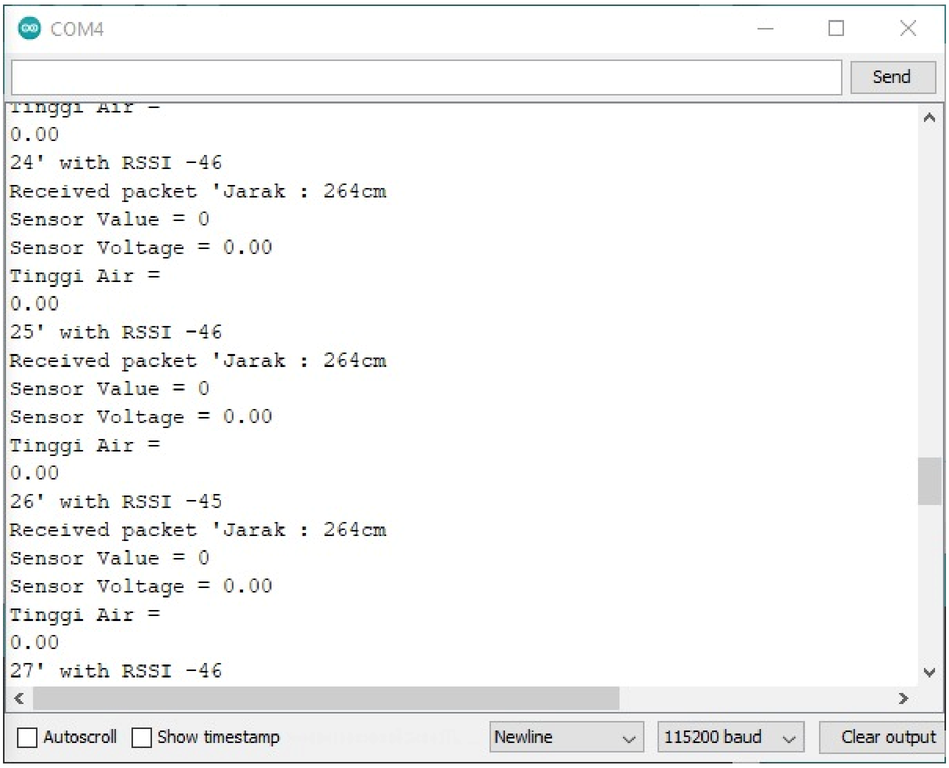

Figure 7. Receiver.

4. Conclusion

The design of the flood sensor using CSS LoRa 433 MHz modulation must be carried out in a structured, functional, dimensional and analytical way to select components to produce good RSSI values in unobstructed conditions. Based on the results of testing on the RSSI, the average RSSI for data collection for 7 sensors is -50 dBm at a maximum distance of 600 meters. so it can be said that the quality of sensor data transmission using CSS modulation technique is quite good considering the bit rate emitted by LoRa type Ai Thinker Ra-02 SX 1278 during the experiment was 5.5 kbps with a set bandwidth of 125 KHz

Acknowledgements

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