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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 that allows multiple sensors to connect to the Internet of Things in the future. LoRa uses chirp spread spectrum (CSS) frequency modulation, which promises remote connectivity with very low power consumption. In particular, this paper focuses on the analysis of Received Signal Strength Indicator (RSSI) for flood sensor CSS modulation because a good flood sensor is a flood sensor that has high accuracy in conveying information so that the signal power received is in good condition. This white paper presents a detailed model of using LoRa with flood sensors and shows that LoRa can send sensor data over long distances with full RSSI values. The results show the possibility of a narrowband network with a frequency of 433 MHz and a short range of coverage using an average RSSI of -50 dB at a maximum unobstructed distance of 600 meters. LoRa communication with CSS modulation and good RSSI values is not sufficient for long-distance communication with data in the form of video or large sensor data due to the use of long distances and wide bandwidth, preferably, the use of the LoRa module as transmission is carried out in an area that does not have too many obstacles so that the quality of the RSSI produced during modulation has good results. But LoRa is sufficient for this study. According to the Type Ai Thinker datasheet, the Ai Thinker Ra- 02 SX 1278 can only be set up to 125KHz. The drawbacks of using large sensor data over long distances and large footprints make CSS vulnerable to other potentially large resources.

Keywords: LoRa, CSS, RSSI, Frequency, Sensor

1. INTRODUCTION

With the advancement of Internet of Things (IoT) technology, the development of today's wireless communication technology requires a low-power, long-distance transmission system that can support many sensors. Unlike traditional cellular networks, IoT networks aim to maintain low levels of long-distance communication. This requires many low power wide area network (LPWAN) or long range (LoRa) technologies. Most of this technology operates in the industrial, scientific, and medical (ISM) radio bands. Spectral use in the ISM band is limited to 1% on the uplink and 10% on the downlink (duty cycle) [1]. The main advantage of this technique is that the structure of the device is very cheap and consumes less energy [2]. In recent years, to run LPWAN, Long Range (LoRa), Sigfox [3], Weightless [4], Narrow Band IoT (NB-IoT) [5], Ingenu RPMA, Telensa, Qovisio, Nwave, Waveot [6] , [7]. LoRa developer Semtech recommends LoRa frequencies of 433 MHz in Asia, 868 MHz in Europe, and 915 MHz in North America [8].

LoRa modulation is a technology patented by Semtech and is not completely open. LoRa uses chirp spread spectrum (CSS) modulation originally intended for use in radar in the 1940s [9]. CSS modulation ensures low power consumption and long-distance data transmission over the ISM (Instrumentation Science and Medical) bandwidth. This article focuses on Received Signal Strength Indicator (RSSI) analysis of sensor data transmission using CSS modulation with LoRa, especially in the 433 MHz frequency range. Similar research related to "RSSI-Fingerprint Base" is being

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conducted here. Through machine learning on the LoRa network. " According to this study, placing the transmitter in the right place and height has a significant impact on the signal strength received by the receiver in LoRa communication [10]. RSSI is the total signal power (in dBm) received by the receiver of the communication system, mixed with noise and interference, or received by the user [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.

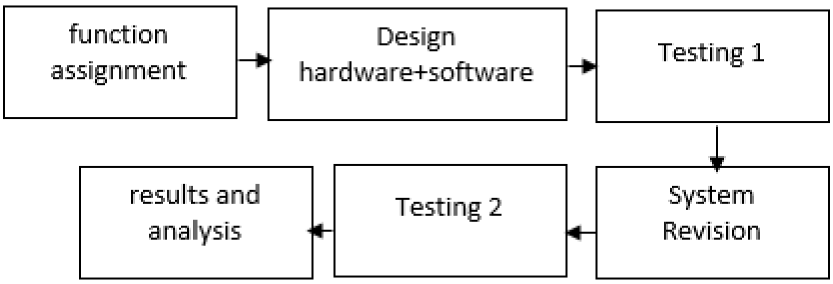

Figure 1 . Workflow diagram of a flood sensor using css modulation

2.2 Object of Research

The subject of this study is the topic of RSSI analysis on CSS modulation in the 433MHz frequency band using LoRa in flood sensors, which brings tool work in line with design ideas. The results of RSSI research and analysis in this study are functionally useful and are expected to expand the electronic science repertoire, especially in the field of telecommunications. Data processing is determined by the flood sensor's program design by executing the received data as variables and later transmitting it using LoRa.

2.3 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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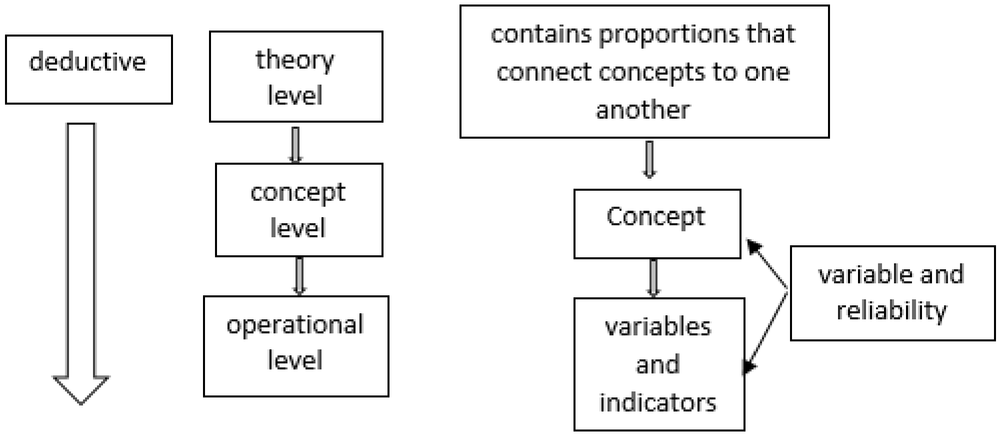

Figure 2 . Schematic frame of mind

2.4 Testing Methods and Instruments

The flood sensor testing procedure using CSS modulation to obtain the results of RSSI analysis is performed separately in the main part. To verify the performance of the manufactured tool, you need to run a test. Prior to testing, the tool will be calibrated using similar equipment as a reference. This test is to determine the characteristics, sample values, units, size, and operating principle of the flood sensor transmission system.

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.

2.5 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.

2.6 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

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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.

2.7 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.

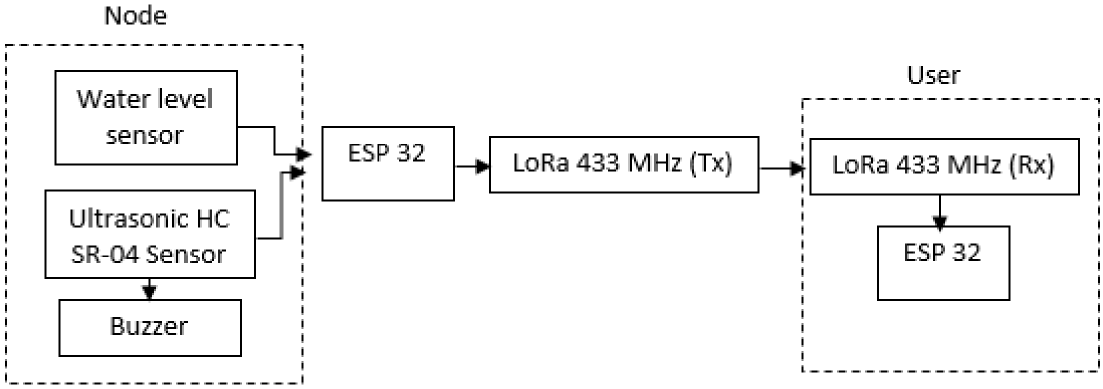

Figure 3 . The flood sensor system to be designed

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. RESULT 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 below.

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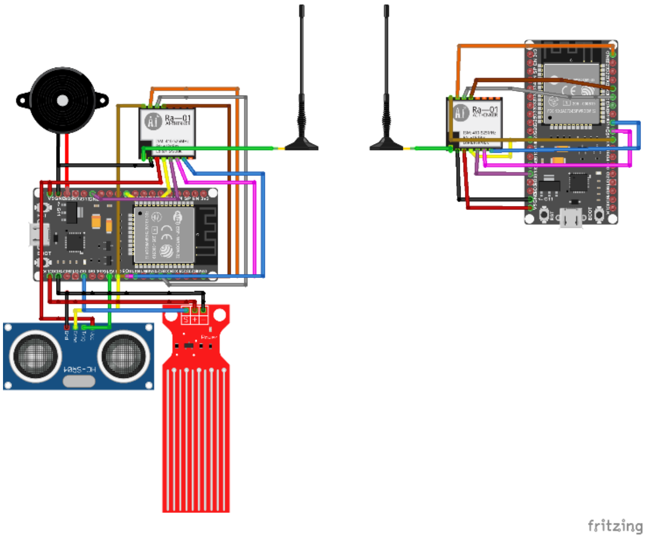

Figure 4 . Electronics design

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

Frequency	Spread Factor	SNR	Sensitivity
433 MHz	7	-7	-125
433 MHz	10	-15	-134
433 MHz	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 2SF 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.

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

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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)

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

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].

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 below:

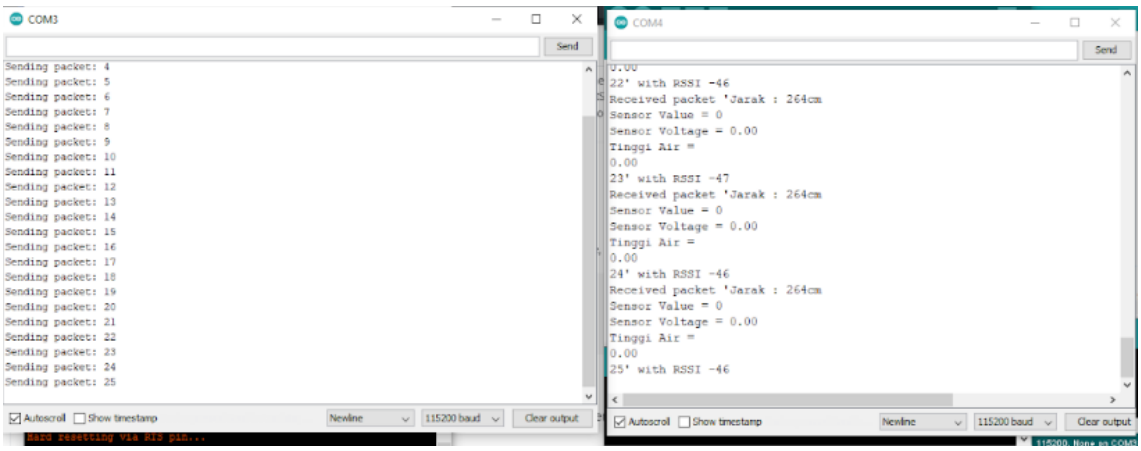

Figure 5 . Serial data monitor testing tool

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

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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 below:

Table 2 RSSI data value retrieval

Trial 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.

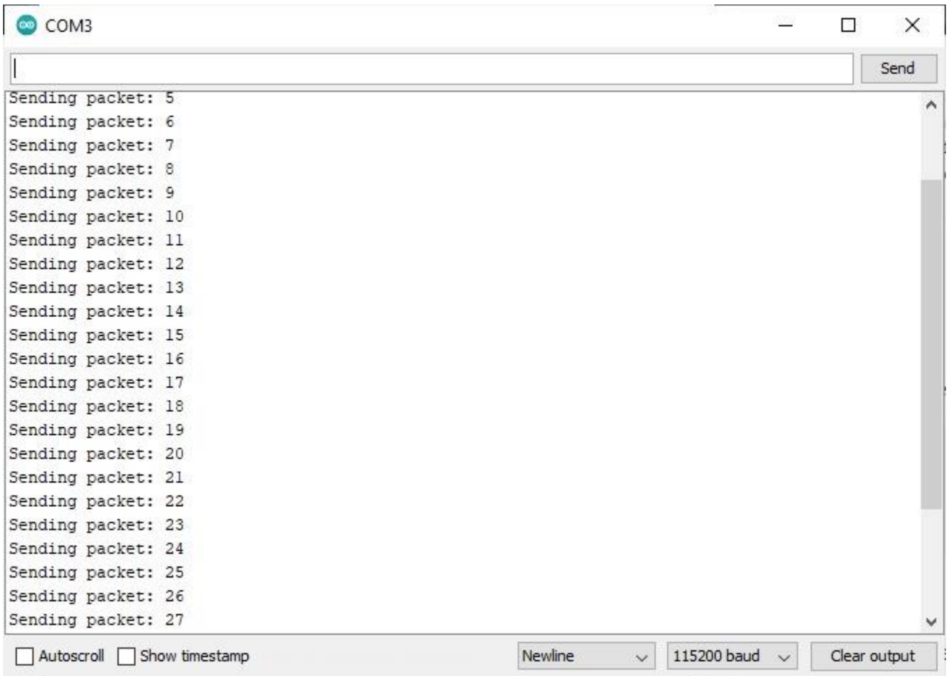

Figure 6 . Transmitter

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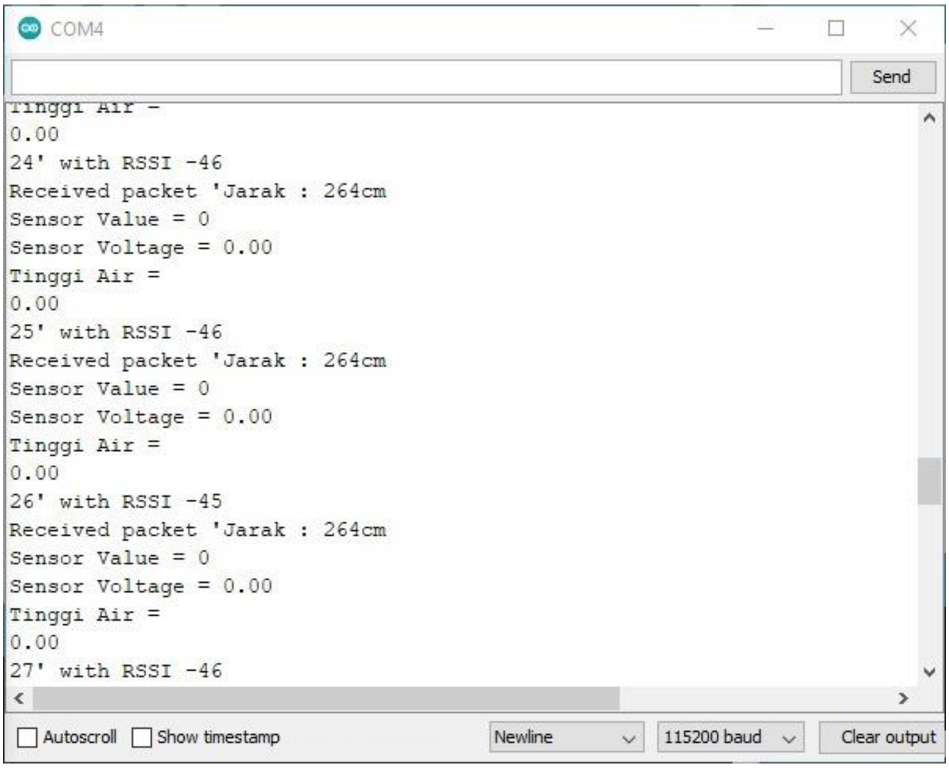

Figure 7 . Receiver

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.

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