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DESIGN OF FREQUENCY CONTROLLER SYSTEM FOR UHF RADIO WAVE RECEIVER DEVICE

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Abstract

Frequency is fundamental in data communication for transmitter and receiver stations. The most common problem found in the data communication is the signal quality measurement. A LoRa module, as one of the wireless devices with UHF (Ultra High Radio) frequencies, has extended range frequencies and signal strength parameters (RSSI, Received Signal Strength Indicator). RSSI parameter on signal bandwidth and the distance between stations. However, there is no supporting research in terms of the RSSI quality and short-distance variations. In line with this, this study aims to design a frequency control system of a LoRa module and to investigate the effect of short-distance and frequency differences on RSSI. The system consists of a transmitter, a LoRa SX1278 module, and push buttons as frequency control buttons. The system's performance was tested by receiving data over various distances from 0 to 1.25 m. The results show that the system works efficiently in controlling the frequency (ranging from 433 – 525 MHz) with good flexibility and accuracy. The system maintained an RSSI level > -120 dBm using a constant power supply and varied distances. The highest RSSI level is found at the shortest distance (0.2 m) with a higher frequency (525 MHz). There is a significant correlation between distance, frequency variations, and RSSI levels ($R^2 > 0.75$). It can be concluded that the LoRa SX1278 module can be used as a short-distance-based data communication with moderate quality (average RSSI levels are about 80 - 120 dBm). Higher frequencies provide better RSSI levels due to increased transmission energy.

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INTRODUCTION

Long Range (LoRa) is an electronic device that sends and receives data through frequency signals. LoRa has a long-range, low power consumption, and secure data transmission[1-2]. The reason LoRa is often utilized as a remote wireless sending and receiving device in various prototypes, such as air quality monitoring devices [3], earthquake early detection [4], and smart farming [5]. In the process of receiving or sending data, interference from other transmitter frequency waves often occurs and reduces signal strength or RSSI (Received Strength Signal Indicator)[6-8]. RSSI is a parameter that shows the quality of the signal received by the receiver at a certain point [9]. Factors that affect the decrease in signal strength are distance, obstructions, reflections, and frequency differences between the transmitter and receiver [10].

The frequency difference between the transmitter and receiver will affect the data received or sent. Research conducted by Utami (2017) [11] using LoRa as an ultra high frequency wave transmitter in observing the percentage of T-CD4 cell production. The problem faced is the difficulty of equalizing the frequency between the transmitter and receiver, causing the data received to be different from that sent. Another factor is that LoRa operates in the free frequency spectrum, so it will experience interference from other devices or transmitters that have working frequencies, such as LoRa [12].

Research conducted by Esyaganitha (2021) [13] implements continuous authentication with tokens to avoid frequency collisions on LoRa. The use of tokens is used to recognize the receiving device and determine the time of data reception. The method was successfully used to reduce interference from other devices. It is necessary to develop a simpler and more efficient system.

LoRa is an electronic device that can operate at a frequency of 433 - 915 MHz, which is categorized as ultra-high frequency [14]. Besides being able to facilitate as a communication device, radio wave transmitter devices can have a negative impact on human health due to exposure to electromagnetic wave radiation over a long period and significant intensity and energy [15-16]. Some disorders of the immune system due to exposure to radiowave radiation are vertigo, insomnia, white blood cells, etc [17]. In order to avoid this, it is necessary to make a control system on high-frequency transmitters in order to avoid direct contact with radiation exposure.

Based on this background, there is a need for the development of a LoRa frequency-matching operation system in the form of a frequency control system. This control system will provide a solution for using LoRa devices more effectively. The control system is designed by pressing a button to equalize the frequency used by the transmitter and receiver. However, in the use of frequency-based devices, the range gets interference from the surrounding environmental conditions that cause a decrease in the quality of the signal strength. Therefore, this study aims to design a frequency control system and investigate the effect of distance variation and frequency difference on RSSI.

RESEARCH METHODS

This study used LoRa SX1278 modules as the primary data communication system. These modules were varied into a transmitter and a receiver. Both of these modules have several buttons for the frequency controller. The frequencies were varied into f_1 (433 MHz), f_2 (455 MHz), and f_3 (525 MHz). These controllers were generated using a pull-down method with resistors (10 kΩ) and a stable power adaptor (5 Volt).

The distance was varied to 0 m, 0.25 m, 0.5 m, 0.75 m, and 1 m to investigate the effect of distance on signal quality. This distance variation is used to see the impact of short distances on signal strength quality. Previous research conducted testing at long distances in the range of 5 m - 1 km [18-20]. In testing LoRa performance, prior research used the success rate method [21], SNR [22], & transmit power [23]. This research uses the RSSI method as a parameter to see the quality of the signal strength received by the receiver.

The type of research used is quantitative research with an experimental approach. Quantitative data used is the result of measuring the signal strength received by the receiver from the transmitter. The variables in this study are the frequency and distance between the receiver from the transmitter included in the independent variable, as for the dependent variable in the form of RSSI. Data collection is done indoors.

RSSI, or Received Strength Signal Indicator, is a parameter that shows the receiving power of all signals in the frequency band of the channel used [24]. The closer the RSSI value is to 0, the better the signal. The RSSI value is expressed in dBm and is a negative value. A negative value indicates that the received signal has a lower strength; the minimum value of RSSI is -120 dBm [25]. The standardization of signal strength according to TIPHON is shown in Table 1 [26].

Table 1. RSSI Standard Value [26]

Category	RSSI (dBm)
Very Good	>-70
Good	-70 s/d -85
Fair	-86 s/d -100
Less Good	-100

RSSI is a parameter to determine the quality of a communication signal. Factors that affect the measured RSSI include obstructions (interference), distance (d), and frequency (f). Changes in these parameters will affect wave energy (E), wave power (P_R), and intensity (I). The RSSI value is an indicator of the signal strength received by the receiver from a particular point, so mathematically, RSSI can be expressed by the following equation:

$$RSSI = -10\log\frac{P_R}{P_{reff}} \tag{1}$$

P_R s the power strength, in watts received by the receiver at a certain point, P_{reff} Is the power strength in watts received at the reference point [27], RSSI can be described by how strong the signal received by a device is or called signal intensity. Signal intensity can be expressed in watts per unit area as the following equation:

$$I = \frac{P_R}{A} \tag{2}$$

Where I is the signal intensity or energy emitted or absorbed per unit time per unit area (W/m^2 or $J/s\ m^2$), P is the power (W), A is the surface area (m^2). Signal intensity describes the amount of energy carried by a wave per unit time, so equation 3.2 can be expressed as follows:

$$I = \frac{E}{t} = E = \frac{P_R}{A.t} \tag{3}$$

E is the energy carried by the wave per unit time (J), and t is the time (t) with A and t constant [28].

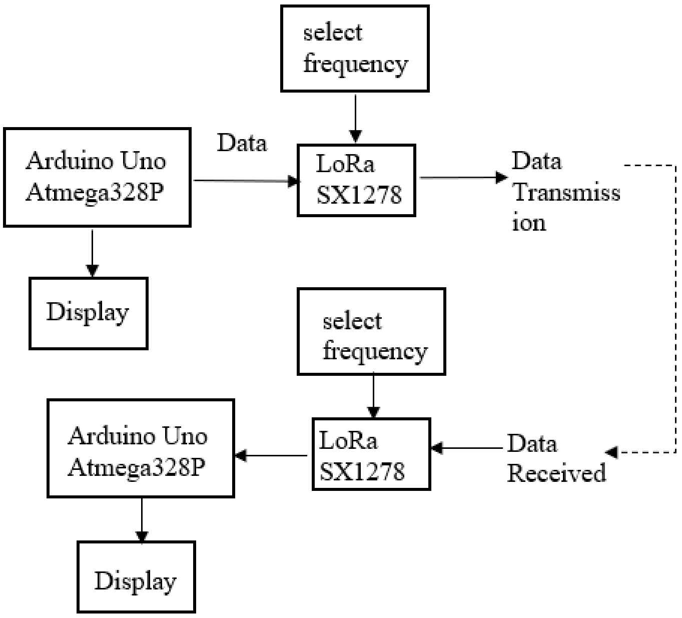

Figure 1. Instrumentation System Diagram

The system examination was carried out to see the suitability of the functions of the design and implementation results. This method determined the performance of the designed system. Performance testing identified the delay time of the sending and transmitting data throughout the varying quality of the signal strength received by the receiver (RSSI). This test was conducted in several distance variations to test the performance of data transmission, delay time, and RSSI (Received Signal Strength Indicator): 0 to 1.25 m and 433 MHz, 455 MHz, and 525 MHz. All measurements were taken for 60 seconds with a five-second time interval.

RESULT AND DISCUSSION

The use of LoRa as a device that transmits data remotely in wireless sensor network (WSN) systems is often done. Even many authentication methods have been developed such as Time Division

Multiple Access (TDMA)[29] and Fiege-Fiat-Shamir (FFS) Identification Scheme [30]. However, it still ranges from experiencing interference by other frequencies and connected unauthorized devices. The system design in this research focuses on the ease of LoRa authentication. The system consists of data sending and receiving devices, a frequency control system and a data viewer controlled using an Atmega 328P microcontroller or Arduino Uno module. Fig. 2 shows the system that has been designed in this research.

Figure 2. Frequency Controller System Design

The frequency controller system uses push buttons to adjust the frequency to authenticate LoRa SX1278 devices as signal receivers and senders. The buttons change the frequency quickly according to the environment or communication needs. This method increases the flexibility and responsiveness of the LoRa device in various applications. In addition, the use of buttons also reduces the risk of frequency setting errors that can occur when using manual configuration methods. Frequency selection provides convenience, increases efficiency, and reduces the possibility of errors in the use of LoRa technology.

The system testing aims to determine the performance of the system in receiving data and the quality of the signal received by the receiver based on variations in distance and frequency used. Sampling data from a distance of 0 m, 0.25 m, 0.5 m, 1 m, and 1.25 m at frequencies of 433 MHz, 455 MHz, and 525 MHz. The resulting data were processed using Microsoft Excel in the form of graphs to see the characteristics of the data obtained. The following figure interprets the experimental results.

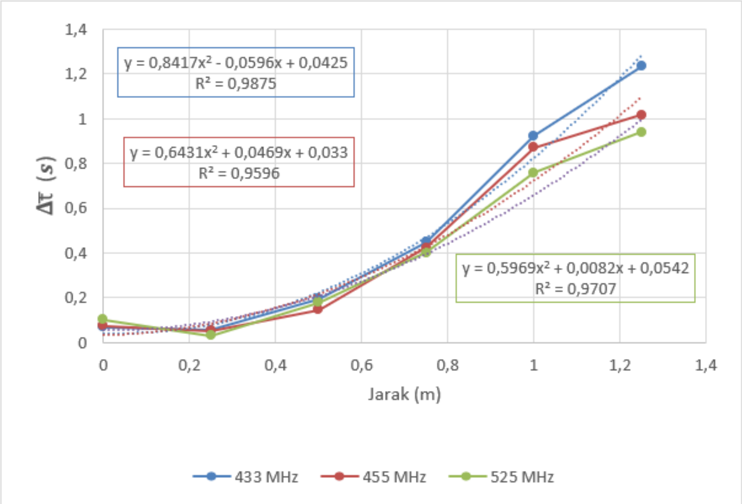

Figure 3. Graph of Time Relationship to Distance Variation

The measurement results of the time responses (Δt) by Andreini (2024) et al. [18] in the distance range of 0 m – 195 m in outdoor conditions of 2.09 seconds. Figure 3. shows the results of time response to distance. There is an increase in delay time as the receiver distance increases. The results show that the use of 525 MHz frequency at close range is more recommended because it has a better data transfer rate than 433 MHz and 455 MHz frequencies. Measurement of delay time at a distance of 0 m has a more significant delay value than at a distance of 0.25 m. From these results, it can be seen that a distance of 0 m is the minimum distance of LoRa performance. These results are well interpreted in Fig. 3, which shows a good regression coefficient ($R^2 > 0.75$). Figure 3 also illustrates the significant relationship between time delay and distance variation. In addition to time delay measurements, signal strength (RSSI) measurements were taken to see the quality of signal strength received by the receiver.

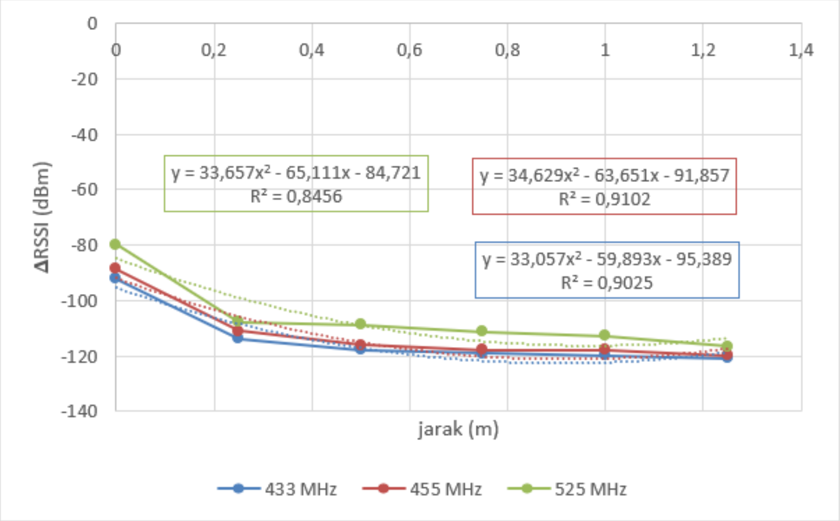

Figure 4. RSSI Relationship Graph against Distance Variation

The signal strength quality test was done by varying the receiver distance and the frequency used. The graph in Fig. 4 depicts the characteristics of each frequency. The signal strength (RSSI) received by the receiver decreases as the distance increases. In the use of frequency 433 MHz, the RSSI value decreases more than the other frequencies. The difference in these results may be influenced by the use of the 433 MHz frequency, which is prone to having the same frequency as other wireless devices, causing interference. The results of the graph test also show that the regression coefficient is good ($R^2 > 0.75$) at each frequency. These results prove that the high-low RSSI value produced is based on the near/far distance of communication. The use of the 525 MHz frequency is highly recommended for short-distance conditions. RSSI also indicates the amount of signal energy received by the receiver. A stronger signal means the receiver captures more energy. Fig. 5 explains the amount of power received by the receiver based on the frequency used.

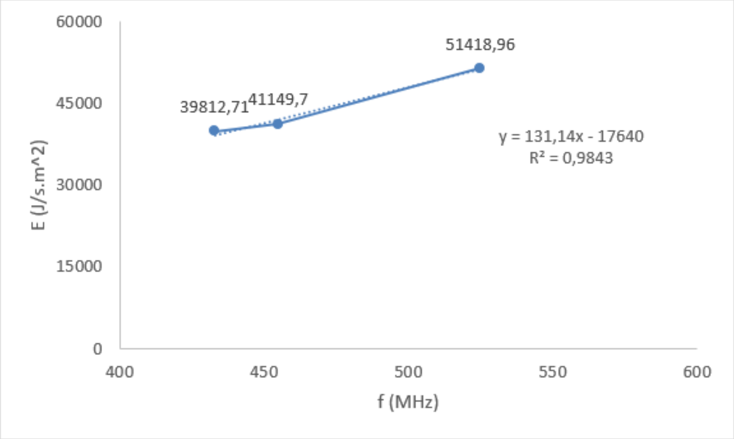

Figure 5. Energy to Frequency Relationship Graph

The energy received by the receiver at frequencies of 433 MHz, 455 MHz, and 525 MHz was 39812.71 $J/s.m^2$; 41149.7 $J/s.m^2$ dan 51418.96 $J/s.m^2$, respectively. The results show that the energy obtained is directly proportional to the frequency. The greater the frequency used, the greater the energy carried by the waves; this is in accordance with the equation $E = h.f$

CONCLUSION

The use of a constant power supply and varied distances generates RSSI level > -120 dBm. The highest RSSI level is found at the shortest distance (0.2 m) with a higher frequency (525 MHz). There is a significant correlation between distance-frequency variations and RSSI levels ($R^2 > 0.75$). It can be concluded that the LoRa SX1278 module can be used as a short-distance-based data communication with moderate quality (average RSSI levels are about 80 - 120 dBm). A higher frequency has a higher transmission energy, resulting in a better RSSI level.

REFERENCES

[1] P. Seneviratne, "*Beginning LoRa Radio Networks with Arduino: Build Long Range, Low Power Wireless IoT Networks*," USA: Aprees, 2019, pp. 1-289.

[2] A.A Bahashwan, M. Anbar, N. Abdullah, T. Al-Hadhrami, S.M Hanshi, "Review on Common IoT Communication Technologies for Both Long-Range Network (LPWAN) and Short-Range Network," *Proceedings of ICACIn 2020,* vol 1188, pp. 341-353, 2021, doi: 10.1007/978-981-15-6048-4_30F.

[3] M. I. Munabbih, E. D. Widianto, Y. E. Windarto, and E. Y. Indrasto, "Rancang Banagun Sistem Pemantau Kulaitas Udara Menggunakan Arduino dan LoRa Berbasis Jaringan Sensor Nirkabel, " *Transmisi: Jurnal Ilmiah Teknik Elektro*, vol. 22, no. 1, pp. 6-14, 2020, doi: 10.14710/transmisi.22.1.6-14 .

[4] A. B. Siregar, E. Ezwarsyah, H. M. Yusdartono, and F. A. Nasution, "Rancang Bangun Sistem Peringatan Gempa Menggunakan Sensor Adxl 345 Berbasis Lora Dengan Esp 32," *J. Energi Elektr.*, vol. 11, no. 2, pp. 8-14, 2022, doi: 10.29103/jee.v11i2.10066.

[5] D. P. Sari, "Prototype Alat Monitoring Suhu, Kelembaban dan Kecepatan Angin Untuk Smart Farming Menggunakan Komunikasi LoRa dengan Daya Listrik Menggunakan Panel Surya," *Kilat*, vol. 10, no. 2, pp. 370–380, 2021, doi: 10.33322/kilat.v10i2.1376.

[6] E. Murdyantoro, I. Rosyadi, and H. Septian, "Studi Performansi Jarak Jangkauan LoRa OLG01 Sebagai Infrastruktur Konektivitas Nirkabel IoT," *Dinamika Rekayasa*, vol. 15, no. 1, pp. 47-56 2019.

[7] I. Asep and A. Harimawan, "Studi Awal Teknologi Wi-Fi Untuk Diimplementasikan Pada Pembuatan Prototipe Sistem Remote Terminal Unit Multi Sensor Dengan Energi Mandiri Preliminary Study for Wifi Technology Prototyping System Implemented In Remote Terminal Units Multi Sensor With Indep," *Bul. POS dan Telekomun.*, vol. 10, no. 3, pp. 225–240, 2012, doi: 10.17933/bpostel.2012.100306 .

[8] P. Dani, P. Adi, and M. Efendi, "Evaluasi Kinerja LPWA Berbasis Internet of Things Menggunakan Radio Frekuensi LoRa 915 MHz dan 920," *Seminar Keinsinyuran Program Studi Program Profesi Insinyur (PSPPI) Ke-1 2021*, vol. 1, no. 1, pp. 60–72, 2021.

[9] H. Fitriawan, R. C. Rohman, H. Herlinawati, and S. Purwiyanti, "Pengukuran RSSI Jaringan Sensor Nirkabel Berbasis ZigBee pada Berbagai Topologi," *J. Rekayasa Elektr.*, vol. 16, no. 2, 2020, doi: 10.17529/jre.v16i2.15750.

[10] R. Al Alawi, "RSSI based location estimation in wireless sensors networks," *ICON 2011 - 17th IEEE Int. Conf. Networks*, pp. 118–122, 2011, doi: 10.1109/ICON.2011.6168517.

[11] I. Utami, R. Wirawan, A. Budianto, and E. D. Wara, "Pengaruh Paparan Gelombang Elektromagnetik Jenis UHF (Ultra High Frequency) Terhadap Produksi Sel T-4 (CD4) Dalam Darah," *ORBITA*, vol. 4, pp. 1–6, 2017.

[12] F. Hamid, E. Ratuloli, A. Setia Budi, and A. Bhawiyuga, "Implementasi Skema Anti-Collision Menggunakan Metode TDMA dan TPSN pada Sistem WSN Berbasis LoRa," *J. Pengemb. Teknol. Inf. dan Ilmu Komput.*, vol. 5, no. 1, 2021.

[13] R. Y. Esyaganitha, A. Bhawiyuga, and K. Amron, "Implementasi Continuous Authentication dengan Token pada Wireless Sensor Network (WSN) berbasis LoRaWAN," *Jurnal Pengembangan Teknologi Informasi dan Ilmu Komputer,* vol. 5, no. 1, pp. 319–326, 2021.

[14] G. Zhu, C. H. Liao, M. Suzuki, Y. Narusue, and H. Morikawa, "Evaluation of LoRa Receiver Performance under Co-technology Interference," *2018 15th IEEE Annual Consumer Communications and Networking Conference (CCNC)*, pp. 1-7, 2018, doi: 10.1109/CCNC.2018.8319183.

[15] B. O. Anyaka and U. B. Akuru, "Electromagnetic wave effect on human health: Challenges for developing countries," *Proc. 2012 Int. Conf. Cyber-Enabled Distrib. Comput. Knowl. Discov. CyberC 2012*, pp. 447–452, 2012, doi: 10.1109/CyberC.2012.81.

[16] A. Ahlbom, A. J. Bridges, René De Seze, L. Hillert, J. Juutilainen, Mats-Olof Mattsson, G. Neubauer, J. Schüz, M. Simko, and K. Bromen, "Possible effects of electromagnetic fields (EMF) on human health--opinion of the scientific committee on emerging and newly identified health risks (SCENIHR).," *Toxicology*, vol. 246, no. 2–3, pp. 248–250, 2008, doi: 10.1016/j.tox.2008.02.004.

[17] Y. Stein and I. G. Udasin, "Electromagnetic hypersensitivity (EHS, microwave syndrome) – Review of mechanisms," *Environ.* Res., vol. 186, pp. 109445, 2020, doi: 10.1016/j.envres.2020.109445.

[18] L. Andreini, A. Y. P. Wardoyo, H. A. Dharmawan, M. Nurhuda, and A. Budianto, "A design of fine particle concentration measurement system based on a near field wireless radio communication," *AIP Conf. Proc.*, vol. 2296, pp. 1-8, 2020, doi: 10.1063/5.0031172.

[19] I. N. A. Prahara and I. R. Widiasari, "Implementasi Metode Received Signal Strength Indication dan Quality of Service Terhadap Analisis Kualitas Jaringan Wireless di CV Java Media Perdana Pati," *J. JTIK*, vol. 7, no. 4, pp. 528–535, 2023, doi: 10.35870/jtik.v7i4.1025.

[20] M. N. Gani, H. Ludiyati, R. Hanifatunnisa, E. Mozef, and R. N. Ananti, "Sistem Pemantauan Kelembaban Tanah Jarak Jauh Berbasis LoRa Menggunakan Sensor pH dan Kelembaban," *Jurnal Teknik: Media Pengembangan Ilmu dan Aplikasi Teknik*, vol. 22, no. 02, pp. 153–161, 2023, doi: 10.55893/jt.vol22no2.564

[21] H. Arijuddin, A. Bhawiyuga, and K. Amron, "Pengembangan Sistem Perantara Pengiriman Data Menggunakan Modul Komunikasi LoRa dan Protokol MQTT Pada Wireless Sensor Network," *J. Pengemb. Teknol. Inf. dan Ilmu Komput.*, vol. 3, no. 2, pp. 1655–1659, 2019.

[22] F. N. Aroeboesman, M. H. H. Ichsan, and R. Primananda, "Tampilan Analisis Kinerja LoRa SX1278 Menggunakan Topologi Star Berdasarkan Jarak dan Besar Data Pada WSN," *J. Pengemb. Teknol. Inf. dan Ilmu Komput.*, vol. 3, no. 4, pp. 3860–3865, 2019.

[23] M. Bor, J. Vidler, and U. Roedig, "Lora for the internet of things," *Int. Conf. Embeded Wirel. Syst. Networks*, pp. 361–366, 2016, doi: 10.5555/2893711.2893802

[24] Yamamoto B, A. Wong, P.J. Agcanas, K. Jones, D. Gaspar, R. Andrade, and A.Z. Trimble, "Received signal strength indication (RSSI) of 2.4 GHz and 5 GHz wireless local area network systems projected over land and sea for near-shore maritime robot operations," *Journal of Marine Science and Engineering*, vol. 7, no. 9,pp. 290, 2019, doi: 10.3390/jmse7090290.

[25] R. Islam, M. W. Rahman, R. Rubaiat, M. M. Hasan, M. M. Reza, and M. M. Rahman, "LoRa and server-based home automation using the internet of things (IoT)," *J. King Saud Univ. - Comput. Inf. Sci.*, vol. 34, no. 6, pp. 3703–3712, 2022, doi: 10.1016/j.jksuci.2020.12.020.

[26] ETSI. "TS 101 329-2 - V1.1.1 - *Telecommunications and Internet Protocol Harmonization Over Networks (TIPHON); End to End Quality of Service in TIPHON Systems*; Part 2: Definition of Quality of Service (QoS) Classes." European Telecommunications Standards Institute, 2000.

[27] G. Aishah, S. Suroso, and S. Soim, "Pengkajian Kualitas Sinyal Dan Posisi Wifi Access Point Dengan Metode Rssi Di Gedung Kpa Politeknik Negeri Sriwijaya, " *Prosiding SNATIF (2017)*, pp. 0-5, 2015.

[28] A. Mikrajuddin, *Fisika Dasar II.* Bandung: Institut Teknologi Bandung, 2017, pp. 1-863.

[29] Ahmad Ridwan, R. Ferdian, and Rahmadi Kurnia, "Optimization of the LEACH Protocol to Increase Stability on the Wireless Sensor Network," *J. RESTI*, vol. 4, no. 1, pp. 192–200, 2020, doi: 10.29207/resti.v4i1.1514.

[30] A. F. Septano, A. Kusyanti, and R. A. Siregar, "Implementasi Feige-Fiat-Shamir Identification Scheme untuk Autentikasi antara Node dan Gateway pada Module Lora," *Jurnal Pengembangan Teknologi Informasi dan Ilmu Komputer*, vol. 5, no. 7, pp. 2961–2967, 2021.