Design of linked sirens for tsunami early warning system using telecontrol system (case study at PUSDALOPS PB BPBD of Cilegon city)

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Abstract. Cilegon is an industrial city located near and facing the Megathrust Sunda Strait Subduction Zone. Around the Sunda Strait is Mount Anak Krakatau which is the most active mountain in the world. So that, it has the potential for a tsunami to cause a catastrophic failure of technology along the coast of Cilegon. In this study, TEWS (Tsunami Early Warning System) is made in the form of sirens that are connected in parallel (linked sirens), can be controlled from the PUSDALOPS room of BPBD in Cilegon City. Communication system used by GSM and amateur radio. The test is carried out using a BPBD repeater with a radius of 146 km. The results of the study prove that the delay in the GSM communication system is 14.5 seconds, whereas the delay in the RF system is 6.4 seconds.

1. Introduction

Based on statistics from BNPB (National Disaster Management Agency), Indonesia has many areas prone to natural disasters, from 2012 to 2017 there have been 11,712 times of natural disasters with 15,221,886 fatalities (died, lost, injured, suffering, and displaced), including earthquakes and tsunamis that occurred 122 times with 200,590 fatalities [1]. One of the provinces in Indonesia with high risk class is Banten Province according on the disaster risk index of BNPB. During the last 5 years from 2012 to 2017, there were 241 natural disasters that occurred in Banten Province with 643,223 fatalities (died, missing, injured, suffering and displaced) [2].

Cilegon City is one of the city of 6 cities with high risk of natural disaster in Banten Province, at least 11 natural disasters that occurred in the city from 2012 to 2017. Cilegon City geographically, geologically, hydrologically and demographically has a vulnerability to natural disasters [3]. Cilegon City is known as an industrial city that has a long coastline of 40.88 km or 43.6% of the total area of Cilegon City [4]. One of the industrial areas in the Cilegon City, PT. KIEC (Krakatau Cilegon Industrial Estate) has a total area of 625 hectares [5].

The industrial area of Cilegon City is the most threatened area of the tsunami because it is close to the segment of the Sunda Strait megathrust, which in the last three hundred years there have been no earthquakes with scale such as the megathrust earthquake in 1833 and 1861 that occurred in the region. If the industrial zone in Cilegon is hit by a tsunami, it is feared that a secondary disaster will occur in the form of technological failure such as the spread of dangerous chemicals that can threaten the community [6]. The Sunda Plate is a very active plate, because the subduction movement reaches
an average of 7 cm per year under the Eurasian plate [7]. The result of the subduction process is to make the area often shaken by large shallow earthquakes that can cause tsunamis [8-10]. Besides that, Cilegon is near the Krakatoa volcanic complex which can cause volcanic earthquakes and tsunami [11].

The EWS (Early Warning System) according to the National Disaster Management Agency (BNPB) is a series of activities to inform the public as soon as possible about the possibility of a disaster occurring somewhere by an authorized institution [12]. The accuracy of EWS is not only assessed technically, but the community needs to understand the risks of the disaster that is or will occur, with the ultimate goal of conducting disaster prevention or mitigation, so that the risk of death, injury, damage and loss can be reduced [13, 14]. Early warning systems that have been installed in Indonesia, that is InaTEWS (Indonesian Tsunami Early Warning System) [15], GITEWS (German-Indonesian Tsunami Early Warning System), ICDN (Indonesian China Digital Network), and JISNET (Japan Indonesian Seismic Network) [16].

The PUSDALOPS PB (Center for Disaster Management Operations) is an implementing element in BNPB or BPBD (Regional Disaster Management Agency) which is tasked to organize disaster management information and communication systems [17]. Disaster information is not only related to disaster events, but also make efforts for disaster management by various parties during pre-disaster and post-disaster [18]. Cilegon City already has two EWS installed in Ciwandon sub-district and Grogol sub-district, but both EWS are in damaged condition. In 2018, the Cilegon City Government planned to repair one of that existing EWS, but this plan was not continued. According on this explanation, this study discusses sirens linked for EWS which is operated from the RUPUS (PUSDALOPS room) BPBD of Cilegon City as a preventive measure that is useful to reduce the risk of fatalities.

2. Methodology

This research designs and makes linked sirens for TEWS using remote control system. Linked sirens is a control system for several sirens that are spread in the area of Cilegon which is operated from RUPUS.

![Diagram of sirens communication system](image)

**Figure 1.** Linked sirens communication system.

Figure 1 shows the sirens communication system is connected by using two communications, GSM and VHF, the communication serves as a medium for sending control commands and receiving control information. Control command is data sent from the transmitter system to the receiving system, while the control information is feedback data that is used to notify that the receiving system has finished executing the command.
Figure 2. Block diagram of sirens remote control system.

The block diagram in figure 2 shows how the sirens can be controlled by the GUI on the PC located at RUPUS. The GUI can activate or deactivate sirens and can find out which sirens have been activated. Remote control uses two communication media. The function of each component is as follows; PC, as a sirens controller center; Arduino Nano, as the sender of the command; Intel Galileo Gen 2, as the recipient of the command; TCM3105NL, as VHF Modem FSK; VHF Transceiver, as a tool for sending and receiving for VHF communication; SIM800L, as a GSM Modem and a device for sending and receiving for GSM communication; LED indicators (Serial LED, GSM LED and VHF LED) as process indicators; Relay, as a sirens switch; ON / OFF button, as manual sirens controller; and sirens, as a sound source.

3. Results and Discussion

Laboratory testing test is carried out to test and ensure that the transmitter system and receiver system can work properly and accordingly, before RUPUS testing. First test, operators in the RUPUS control the PC (Personal Computer) by selecting communications to be used and control commands contained in the GUI (Graphical User Interface) that aim to control the sirens. Receive bias on VHF modems is adjusting because it is very important in VHF modems that are used as determinants of modem VHF demodulation results. This test makes adjustments when the receive bias value is at the upper, lower, and middle limit values. The results of this test can be seen in Table 1.

| VHF Modem              | Min (V) | Max (V) | Receive bias used (V) |
|------------------------|---------|---------|-----------------------|
| Receiver System 1      | 1.92    | 2.62    | 2.25                  |
| Receiver System 2      | 1.83    | 2.60    | 2.25                  |
| Transmitter System     | 2.44    | 2.57    | 2.50                  |

According to Table 1, the VHF modem on receiver system 1, receiver system 2, and the transmitter system have different results. Receive bias used is the result of the middle value between min and max, because when the receive bias value is close to the min or max value, the results of receiving control commands obtained often fail, and if the min and max limits are exceeded, the demodulation process fails. Bias value is too large or too small, the baudrate rises to 2000 bps which should have
been 1200 bps, this has resulted in a failure to receive control commands. The signal results in the process of adjusting the receive bias can be seen in figure 3.

![Signal results of VHF modem](image)

**Figure 3.** Signal results of VHF modem, (a) receiver system at 12.25 V; (a) modulation; (b) demodulation.

The second test is to test the results of modulation and demodulation of signals when the process of sending or receiving. The PC sends command to the transmitter system, then RUPUS recognizes the command, and if it can be identified, the transmitter system sends control commands to the receiver system via GSM or VHF communication.

Modulation is when the Arduino Nano sends a command to activate the sirens (radios1_on) to the VHF modem, while demodulation is when Intel Galileo Gen 2 receives control commands from the VHF modem. Figure 4 is showing when the digital signal is logic 1 or high, the frequency is 1200 Hz, whereas if logic 0 or low then the frequency is 2200 Hz, when no digital signal is sent the frequency is 1200 Hz. The baudrate used is 1200 bps. The 1 bit time obtained is 0.83 ms.

| No | Serial Binary | ASCII Binary | Character | No | Serial Binary | ASCII Binary | Character |
|----|---------------|--------------|-----------|----|---------------|--------------|-----------|
| 1  | 0 010011101   | 01110010     | r         | 6  | 0 110011101   | 01110011     | s         |
| 2  | 0 100001101   | 01000001     | a         | 7  | 0 100011001   | 00110001     | l         |
| 3  | 0 001001101   | 01100100     | d         | 8  | 0 111110101   | 01011111     | –         |
| 4  | 0 100101101   | 01101001     | i         | 9  | 0 111101101   | 01101111     | o         |
| 5  | 0 111101101   | 01101111     | o         | 10 | 0 011101101   | 00110110     | n         |

Based on Table 2 the serial binary results correspond to ASCII binary. Transmitting serial binary starts from the rightmost or LSB (Least Significant Bit) binary in the ASCII (American Standard Code for Information Interchange) binary, and has a start bit (logic 0) and stop bit (logic 1).

The third test, the receiver system receives a control command, if the command is recognized, the receiver system controls the sirens, and if the command is not recognized, the receiver system does not take action. Testing is done to determine the communication performance when controlling sirens at a distance of 2.5 meters for the transmitter system with receiver systems 1 and 2. This test aims to determine the performance of the device with close or near distance remote control before far distance remote control is carried out.

| Command    | $Td_0(s)$ | $Td_1(s)$ | Mean $Td_{0−1}(s)$ | Mean $Td_p(s)$ | Information success (%) |
|------------|-----------|-----------|---------------------|-----------------|-------------------------|
| Sirens 1 on| 1.7       | 2.2       | 6                   | 2.1             | 100                     |
| Sirens 1 off| 1.7      | 2.2       | 6                   | 2.1             | 100                     |
| Sirens 2 on| 1.7       | 2.2       | 6                   | 2.1             | 100                     |
| Sirens 2 off| 1.7      | 2.2       | 6                   | 2.1             | 100                     |

Based on table 3, each control command is sent 20 times, all test get control information with an mean $Td_{0−1}$ or the average total time when sending control commands to successfully receiving control information is 6 seconds. $Td_0$ or the processing time when transmitting control commands on transmitter system is 1.7 seconds, while $Td_1$ or the processing time of receiving control information is on receiver system 2.2 seconds, then the mean $Td_p$ or the average processing time when on air
transmitting and data processing on receiver system is 2.1 seconds. The success rate of receiving control information obtained is 100% from 20 data.

The fourth test is the testing of remote sirens control, this test is carried out to determine the performance of the device when installed far apart. Before conducting this test a VHF coverage simulation is needed, to find out the maximum radius, simulation using Radio Online Cellular Web Software. The receiver system sends control information to the transmitter system through communication that has been previously chosen if it has controlled the sirens. The simulation results can be seen in figure 4. Coverage of the VHF Communication almost all areas in the Cilegon City, except for the Districts of Pulomerak, Grogol, and Ciwandan with antenna height is 1.75 m, while for antenna height of 20 m, only Pulomerak District is out of radio coverage. The power of transmitter is 17 W, with elevation 20 m and the antenna height 1.75 m and 20 m.

![Figure 4](image-url) VHF coverage based on altitude of antenna, (a) ± 1.75 m; (b) ± 20 m.

This test is carried out in 5 times with the interval of 10 seconds of transmitting time, based on figure 5, a distance of 1.28 km and 1.73 km obtained when the antenna height is 1.75 m. The farthest distance is 5.82 km with an antenna height of 20 m. All control commands can be received by the receiver system and successfully control the sirens.

![Figure 5](image-url) Remote control testing based on height of antenna.

The results (Table 4) obtained when the distance of 1.28 km, the transmitter system gets control information with an average delay time of 6.4 s, whereas if the control information is not received the delay is unknown, when the distance of 1.73 km the transmitter system does not get control information, because the transmit power of the receiving system is less than 5 W, while the transmit power of the transmitter system is 17 W.

| Command            | Time Difference (s) | Receiving Control | Receiving Feedback |
|--------------------|---------------------|-------------------|--------------------|
|                    | 1.28 km | 1.73 km | 5.82 km | Command | 1.28 km | 1.73 km | 5.82 km |
| Sirens 2 is off    | 5       | -      | -      | Success  | Success | Failed  | Failed  |
| Sirens 2 is on     | 7       | -      | -      | Success  | Success | Failed  | Failed  |
| Sirens 2 is off    | 7       | -      | -      | Success  | Success | Failed  | Failed  |
| Sirens 2 is on     | 6       | -      | -      | Success  | Success | Failed  | Failed  |
| Sirens 2 is off    | 7       | -      | -      | Success  | Success | Failed  | Failed  |
The fifth test, the transmitter system receives control information, then immediately sends the control information to the PC and displays it in the GUI. The GSM remote control test is carried out at a distance of 1.28 km and 1.73 km according to the location in the VHF remote control test.

**Table 5.** GSM remote control test results.

| No | Command | Time Difference (s) | Feedback | No | Command | Time Difference (s) | Feedback |
|----|---------|---------------------|----------|----|---------|---------------------|----------|
|    |         | 1.28 km | 1.73 km | 1.28 km | 1.73 km | 1.28 km | 1.73 km | 1.28 km | 1.73 km |
| 1  | ON      | 13      | 14      | Yes     | Yes     | 6       | OFF     | 38      | 13      | Yes     | Yes     |
| 2  | OFF     | 13      | 14      | Yes     | Yes     | 7       | ON      | 12      | 13      | Yes     | Yes     |
| 3  | ON      | 15      | 13      | Yes     | Yes     | 8       | OFF     | 13      | 13      | Yes     | Yes     |
| 4  | OFF     | 14      | 13      | Yes     | Yes     | 9       | ON      | 13      | 14      | Yes     | Yes     |
| 5  | ON      | 13      | 13      | Yes     | Yes     | 10      | OFF     | 13      | 14      | Yes     | Yes     |

This test (Table 5) sends control commands 10 times. the results obtained are all control commands get control information on the transmitter system and the receiver system successfully controls the sirens according to the control command. The average delay obtained is 14.5 seconds.

After laboratory testing, then carried out testing at RUPUS BPBD Cilegon City. BPBD Repeater Cilegon is located in Mount Cipala. This simulation uses Software Radio Mobile Online. Based on figure 6 the results of the coverage of the antenna are obtained with a radius of 48422 km2, the antenna used is Diamond X700H which has a gain of 9.3 dB, uses 25 W of power, antenna height of 50 m, and has an elevation of 500 m. The frequency used is 155,050 MHz for the transmitter, and 156,050 MHz for the receiver.

![Figure 6. Coverage of Antenna VHF at BPBD Repeaters in Cilegon City.](image)

The transmitter system that had been tested before in laboratory testing was installed in the Cilegon City RUPUS BPBD, the control commands sent from RUPUS was sent to the Cilegon BPBD repeater, then the repeater was sent back to the receiver system, so that the maximum radius could be increased, if not using a repeater, Pulomerak and Ciwandan Subdistricts are not accessible by the VHF communication radius. Installation of the transmitter system at RUPUS can be seen in figure 7(a).

Testing to control the TEWS owned by BPBD of Cilegon City in Ciwandan and Grogol Subdistricts cannot be done because the TEWS still in a damaged condition. The TEWS owned by BPBD in Cilegon City can be seen in figure 7(b) and figure 7(c).
Figure 7. BPBD tsunami early warning system Cilegon city, (a) transmitter system; (b) Ciwandan district; (c) Grogol district.

4. Conclusion
Based on the results of this study, the tsunami early warning system using a remote control system can be concluded as follows: sirens can be activated or deactivated remotely from RUPUS BPBD Cilegon City and the controller will get feedback using VHF and GSM communication. Maximum radius of remote control using VHF communication which is 5.82 km with 17 W power and antenna position at ± 20 m height. Delay time to receive control information by sending control commands using GSM communication which is 14.5 seconds, while VHF communication is 6.4 seconds.

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