Waveform Evaluation of Seismic Network in The Aceh Province by Using Power Spectral Density and Probability Density Function

Maryana, Andrean V. H. Simanjuntak, Marzuki Sinambela, Noviana Sihotang, Naikson Fandier Saragih, Mendarissan Aritonang, Asaziduhu Gea, Eva Darnila

***Abstract*— Waveform evaluation of seismic networks is important to know the station's performance. The monitoring must be carefully checked and routinely evaluated to capture some seismic activities from active faults and an unknown active fault. We develop and evaluate the seismic network in Aceh Province from three stations, namely LHMI, MLSI, and KCSI stations. We applied machine learning approaches to classify the seismic waveforms and features in the time-frequency domain and figure the power spectral density and probability density function (PSDPDF) in the time-frequency domain. The results, the characteristics of the PSD are normal and the sensor condition is in good condition. The recorded signal was well-analyzed in the 19 times segmentations and figure no significant noise the vertical component. High frequency (> 10 Hz) has a low noise percentage and low signals < 0.1 Hz. A parallel trend can be found at the low frequency content and an overlapping trend at the very high frequency content. That was usually comes from ordinary equipment interference in the centering and thermal conditions. The overlapping is very meaningless because it was only located in one segment. In general, the recorded signal is suitable with the amplitude tolerance of the pole-zero seismometer configuration, so the determination of the body-wave phase signal (P and S) in the higher frequency is effective.**

***Index Terms*— wave form, seismic network, power spectral density, probability density function**

Maryana, Department of Mathematics Universitas Malikussaleh, Aceh, Indonesia. (e-mail: maryana@unimal.ac.id).

Andrean V H Simanjuntak, Meteorological Climatological and Geophysical Agency of Indonesia, Banda Aceh, Indonesia. (e-mail: andreansimanjuntak@gmail.com).

Marzuki Sinambela, Meteorological Climatological and Geophysical Agency of Indonesia, Banda Aceh, Indonesia. (e-mail: sinambela.m@gmail.com).

Noviana Sihotang, Meteorological Climatological and Geophysical Agency of Indonesia, Banda Aceh, Indonesia. (e-mail: novianasihotang@gmail.com).

Naikson Fandier Saragih, Faculty of Computer Science, Universitas Methodist Indonesia, Medan, Indonesia. (e-mail: saragihnaikson@gmail.com).

Mendarissan Aritonang, Faculty of Computer Science, Universitas Methodist Indonesia, Medan, Indonesia. (e-mail: rissanaritonang@gmail.com)

Asaziduhu Gea, Faculty of Computer Science, Universitas Methodist Indonesia, Medan, Indonesia. (e-mail: asaziduhugea@gmail.com)

Eva Darnila, Department of Informatics, Universitas Malikussaleh, Aceh, Indonesia. (e-mail: eva.darnila@unimal.ac.id)

I. Introduction

BADAN Meteorologi Klimatologi dan Geofisika (BMKG), the government agency to monitor earthquake activities, has deployed many seismic stations. After the last decade, the new mini region network was deployed to capture the microearthquake activities that were previously not captured. Seismically, the earthquakes are mostly distributed along Sumatra Fault Zone (SFZ) that are generated by horizontal lateral, as shown in Fig. 1 [1]. Historically, some earthquakes from active faults have occurred, such as 1964 from Seulimeum fault with M 6.4 [2], 1996 Kutacane from Tripa fault with M 6.1 [3], 2013 Bener Meriah from Central Aceh fault with M 6.3 [4], [5], and last in 2017 Pidie Jaya M 6.5 [6], [7].

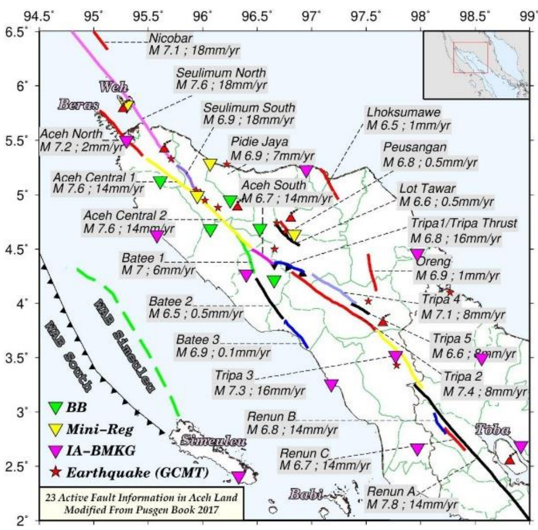

Fig. 1. The tectonic map that shows 23 active faults with potential magnitude and geodetic slip rate in the Aceh Province. The highest magnitude can be found in the northen part of Seulimeum fault with M7.6 with 18 mm.yr^{-1} slip rate. The triangles are the seismic station distribution with broadband (green), mini regional with shor period seismometer (yellow) and existing stations (purple) while historical devastating earthquakes (red star) from active fault are compiled from Global Centroid Moment Tensor (GCMT).

In the last decade, several research has been studied to figure out the tectonic process in the Aceh Province, for example, probabilistic and deterministic seismic hazard [8], [9], the detailed structure of tectonic system geodetical analysis with GPS measurements, tsunami modelling, site condition effect, and statistical analysis. In this study, we

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figure out the station performance by evaluating the waveform pattern and features by using machine learning that figure the power spectral density and probability density function (PSDPDF) in the time-frequency domain [1], [10]–[13].

A global and very local monitoring system is needed to detect local earthquake events and must be routinely evaluated. The new mini region station at the end of 2019 had been deployed and worked. The new mini region station can detect a very local earthquake in April 2020 from Aceh Tengah fault and Pidie Jaya fault. Detection is very important to the mitigation study and plans to reduce loss and victims in the future. From Fig. 2, we can see if the mini region with station BUSI, TPSI, GPSM, SISM and GESM are located very close and capture the local events with a small azimuthal gap.

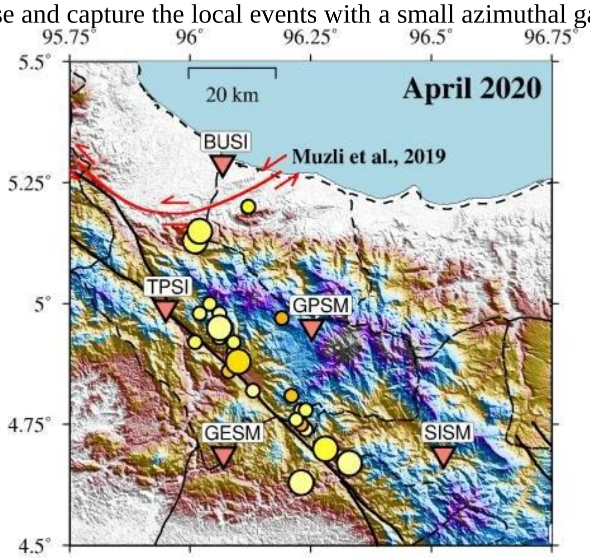

Fig. 2. The seismic activities in April 2020 in the Pidie Jaya region, the red line is Pidie Jaya fault that has generated M6.3 in the December 2016 with massive loss and damage.

The seismic observation uses machine learning to get event detection that is needed a very clear waveform with low noise. A well-computerized one will give a good detection and precise location. Therefore, our study will provide important information to evaluate the seismic network and can be used to calibrate the sensor due to the power spectral density and probability density function report.

II. DATA AND METHODS

In this study, we used ~1 hour (10:14:56 to 11:01:56 in January 1, 2021) recording from KCSI in the Kutacane region, LHMI in the Lhoksumawe city and MLSI in the Meulaboh city. All stations are located in a dense population that is needed an evaluation. The dense population activities may generate some noise effect. Therefore, we selected the three sensors station with the information shown in Table I. Table I, shows the location and kinds of row data of the seismic station. Waveform data produced vertical (SHZ) and the horizontal component (SHE and SHN).

The digitizer type is Quantera 330S+ which is compatible with all major data acquisition platforms and can be operated in ultra-low power (~0.75W for three channels, including recorder and GPS) with high-resolution data harvesting. The seismometer type is Streckeisen Seismic Instrumentation (STS-2) with a frequency range 120 s (8.33 mHz) - 50 Hz, sensitivity 1500 Vs/m in standard and low power while 20000 Vs/m in high gain version, and the dimension 235 mm x 260 mm, 12 kg (9.25" x 10.2", 26.4 lbs).

TABLE I.
SENSOR TYPE AND LOCATION IN THE ACEH PROVINCE

Station	Lat	Lon	Satellite	Digitizer	Type
KCSI	3.52	97.77	VSAT	Q330S+	STS-2
LHMI	5.22	96.94	VSAT	Q330S+	STS-2
MLSI	4.26	96.40	VSAT	Q330S+	STS-2

Several studies have conducted a PSDPDF approach to report and evaluate the seismic network throughout a wide period [14], [15]. In this study, we use the PSDPF technique in eq.1 to evaluate. It shows the waveform recorded in one hour for the broadband seismometer. PSDPDF approach can available to figure out the information high-quality of waveform performance in miniSEED format file. Furthermore, the seismometer instrument response must be removed to avoid the gain effect by dividing the PSD on instrument transfer function to acceleration from eq (1) [16].

$$P_a = P_a.\omega^2 , P_k = P_v , \left(\frac{\left({}^{m}/_{s^2}\right)^2}{H_z}\right) \tag{1}$$

where the power spectral density estimate, and for direct comparison of the low noise model and high noise model using, the PSD estimate is converted into decibels (dB) concerning acceleration. The general methods in this study based on the PSDPF method can show in Fig. 2. The PSDPDF method can perform the new mini region station.

III. RESULT AND DISCUSSION

The results figure clearly the PSDPDF profiles from three stations (KCSI, LHMI, and MLSI). Each station will provide different waveform characteristics due to the site condition and give a unique PSDPDF profile with different amplitude ranges and noise percentages. We first analyse KCSI station, as shown in Fig. 3 and Fig. 4.

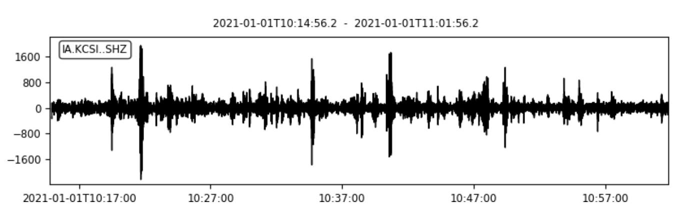

Fig. 3. Seismic waveform recording in the KCSI station in vertical component with 40 Hz sampling rate. The time length is ~1 hour that can be used in the PSPDF analysis. The seismic waveform is still in the velocity domain.

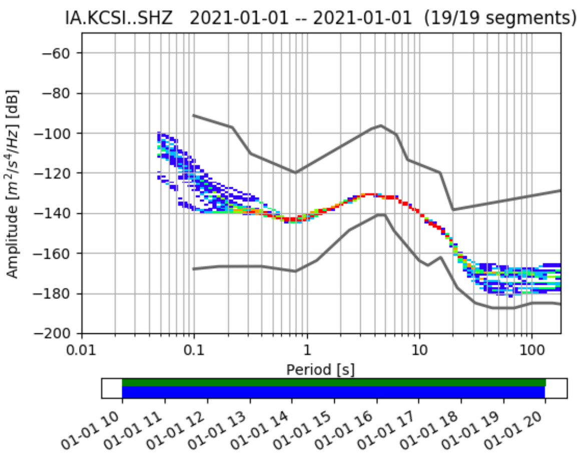

Fig. 4. The power spectral density for KCSI station in the vertical component. The amplitude-time domain has 19 segments waveform that is used to compute the PSDPDF. The amplitude level is set in the range -200 to 80 dB, while the waveform amplitude is located in the middle range in normal conditions. The low period has low noise percentage (<10%), which is very important for capturing micro-earthquakes with high-frequency content.

The SHZ component with 40 sampling rate per second (sps) on the vertical component is the highest sampling in seismic monitoring at BMKG, providing high-resolution analysis. KCSI station waveform data was downloaded for 1 hours on January 1, 2021. The analysis was carried out on component Z because of the most important component in determining the quick location of earthquakes.

From the PSD analysis, the characteristics of the PSD are in normal condition and very good. Nineteen segments in the recorded signal are well-analyzed and have no significant noise. High signals above > 10 Hz have a small percentage noise, as well as low signals < 0.1 Hz. The waveform amplitude range is also located in the middle of the given range. The recording signal is within the amplitude tolerance of the pole-zero seismometer configuration, so determining the P signal is very effective [17].

We continue to analyze the MLSI station as shown in Fig. 5 for the waveform recording while in the Fig. 6 for the PSDPDF profile. The waveforms are noisy with the amplitude pattern is almost similar. The noisy waveform influences the PSDPDF result that figure the overlapping trend in the low period range. The site condition may influence the overlapping because the site stands on the basin sediment with alluvial material. Furthermore, the waveform length must be enlarged to figure more clearly the PSDPDF.

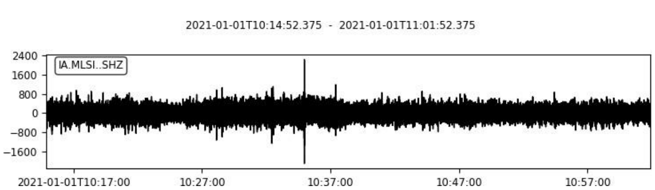

Fig. 5. Seismic waveform recording in the KCSI station in vertical component with 40 Hz sampling rate. The time length is similar to KCSI station in ~1 hour, which can be used in the PSPDF analysis. The seismic waveform is still also in the velocity domain.

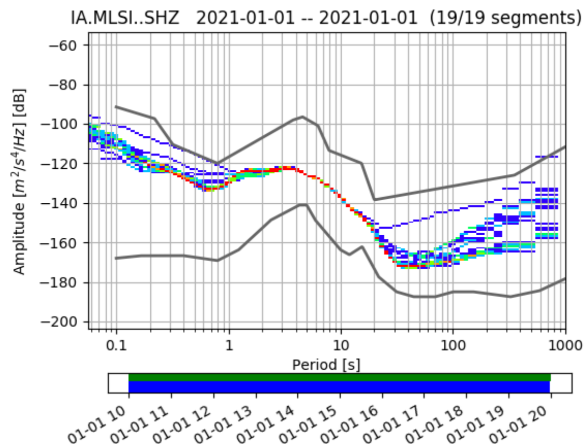

Fig. 6. The power spectral density for MLSI station in the vertical component. The amplitude-time domain has a similar segment with 19 segments used to compute the PSDPDF. The amplitude level is set in the range -200 to 80 dB, while the waveform amplitude is located in the middle range, which is in normal conditions. The low period has a low noise percentage (<10%), which is very important for capturing micro-earthquakes with high-frequency content. At the low period, an overlapping trend in the -140 – 100 dB can influence the P phase and microearthquake detection.

Similar to the KCSI and MLSI stations, the signal from the LHMI station was downloaded for 1 hour on January 1, 2021. The analysis was also carried out on the Z component because it is the most important component in the rapid determination of earthquake locations and body wave phases. We can see the waveform recording in Fig. 7 while the PSDPDF in Fig. 8. The waveform condition is also noisy, giving an overlapping trend in the PSDPDF profile.

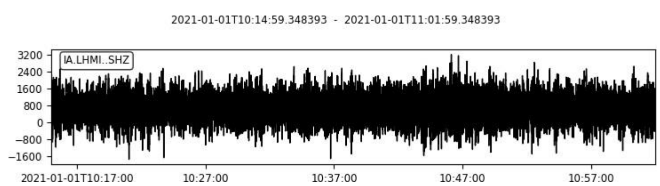

Fig. 7. Seismic waveform recording in the LHMI station in vertical component with 40 Hz sampling rate. The time length is ~1 hour which can be used in the PSPDF analysis. The seismic waveform is still in the velocity domain.

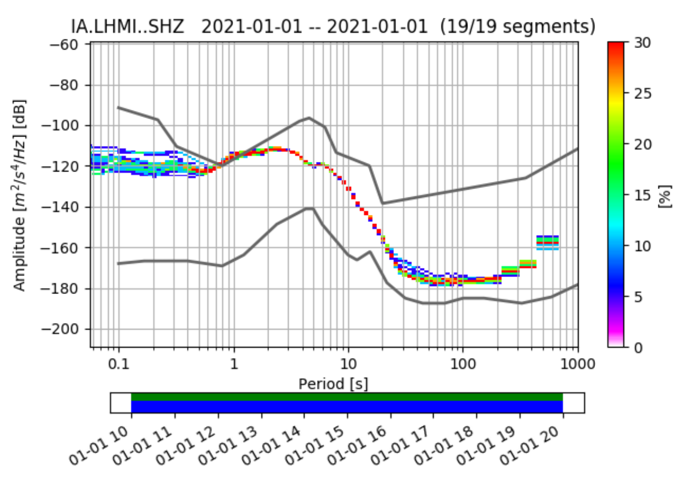

Fig. 8. The power spectral density for LHMI station in the vertical component. The amplitude-time domain has a similar segment with 19 segments used to compute the PSDPDF. The amplitude level is set in the range -200 to 80 dB,

while the waveform amplitude is located in the middle range, which is in the normal condition. The low period has low noise percentage (<10%), which is very important for capturing micro-earthquakes with high-frequency content. There is an overlapping trend in the -120 – 110 dB at the low period, which can influence the P phase and microearthquake detection.

The PSD analysis on the LHMI station shows that the PSD characteristics are normal, even if overlapping can be found. Nineteen segments in the recorded signal are well-analyzed and have no significant noise, for high signals above > 10 Hz have a small percentage and low signals < 0.1 Hz. There is a parallel trend at the low frequency and an overlapping trend at the very high frequency. This usually comes from ordinary equipment interference in centring and thermal conditions, but it is very meaningless because it is only one segment.

In general, the recorded signal is within the amplitude tolerance of the pole-zero seismometer configuration, so the determination of the P signal is effective. Similar to the previous station, the signal from the LHMI station was downloaded for 1 hour on January 1, 2021. The analysis was carried out on the Z component because it is the most important component in quickly determining an earthquake's location. The effect of noise in the low range is relatively high, almost beyond the pole-zero tolerance. It may come from the device's condition but does not interfere with the recording because local earthquakes generally play at a high frequency. Furthermore, the routine evaluation will be important to earthquake early warning systems that may reduce losses and victims generated by major earthquakes. The evaluation is also important for the relocation and 1-D seismic velocity model.

IV. Conclusion

In this study, we figure the three-stations PSDPDF has similar specifications and seismometer. All stations have good PSDPDF profiles but MLSI and LHMI have an overlapping trend. The KCSI station has a better result than MLSI, and LHMI with the amplitude is located precisely in the middle of the upper and lower amplitude range. At the low period, the MLSI stations have an overlapping trend in the -140 – 100 dB, influencing the P phase and microearthquake detection. Similar results are also found on the LHMI station at the low period. An overlapping trend in the -120 – 110 dB can influence the P phase and microearthquake detection. All stations have a low noise percentage that is usually in normal condition. Overall, three stations have a good evaluation which is very important for earthquake monitoring. Furthermore, the future evaluation can use more length time data and include all stations in the Aceh Province. This result can also be used for the next evaluation by comparing the amplitude range and noise percentage in the different time recordings.

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