Seismometer's Performance Monitoring during an Intensive Field Measurement

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Summary

We propose in a simple way to monitor the performance of several seismometers using spectral ratio between seismometers during a microseismic or passive seismic survey. Ideally, a seismometer must be calibrated beforehand before being used for field measurement. Among the usual techniques for the calibration of seismometers is by using a shaking table and electromagnetic calibrator method to determine the response of seismometer. However, it is not practical to apply in a survey conducted intensively in field with a limited survey time. The average spectrum of sets of seismometers using simultaneously during a field survey can be used to test and monitor the performance of the individual seismometer from time to time by means of comparing it with the spectrum of each sensor. It can be simply used to see if there is a technical problem on the sensor or not. This is very useful for avoiding errors in processing involving the spectral analysis of seismograms such as the HVSR method.

Introduction

Recently a seismometer is not only used for continuous monitoring installed in a specific place (permanent stations), but is often used for a rover instrument (e.g. a microseismic mapping of earthquake hazard mitigation purposes, passive seismic survey etc.). An intensive use of the seismometer in the field is likely to cause a decline in performance of the sensor due to the effects of fatigue from the mechanical and electrical part. Thus, the results of measurements using these tools become no longer valid and in general affects the quality of the measurement results.

In this paper we propose in a simple way of how we can monitor the performance of seismometers during an intensive field measurement using spectral ratio between seismometers. Therefore, prevention efforts can be made when it was found that a seismometer changes their performance with an intensive examination in the mechanical and electrical systems of the sensor before being used for measurements in other places. Ideally, a seismometer must be calibrated before being used for the field measurement. Calibration is a way to adjust the seismometer by measuring the properties of the transfer function and express it in a complex frequency response as described in a more detailed by Wieland (2012). Among the usual techniques for the calibration of seismometers are (1) to use a shaking table and (2) electromagnetic calibrator method to determine the response of seismometer. However, it is not practical way to apply this calibration technique in a survey conducted intensively in field with a limited time project.

Method

We do a comparison between the spectrums of each component of each sensor with the average spectrum from all seismometers used for measurement. For this purpose, we conduct a noise measurement using all sensors that placed close together to ensure that they record the same signal. In this study, we performed measurements for at least 1 hour during this calibration process. Furthermore seismogram from each sensor is calculated for their spectrum using the Fourier transform. The spectrum is then averaged to obtain the average spectrum for each component (N-S, E-W and Vertical).

The average spectrums of each component are then used for the comparison to each spectrum from each instrument (Eq. 1).
Figure 1 The measurement locations (red dots) consist of seven areas separated by more than 100 km. Each area consists of about 40 measurement points.

\[
R_x = \frac{X_i(\omega)}{X(\omega)}
\]  

(1)

Where \(R_x\) is the spectral ratio, \(X_i(\omega)\) is the E-W spectrum of sensor \(i\) and \(X(\omega)\) is the average spectrum of all sensors using for measurement. For other component (i.e. \(R_y\) and \(R_z\)) the same procedure is applied.

**Results**

We conduct a field measurement from September 2013 to November 2013 using six short periods, three components seismometers type TDV-23S with TDS-4A data logger at seven different locations in Indonesia (Figure 2).

**Figure 2** A short period, three components seismometers type TDV-23S with TDS-4A data logger.
Figure 3 An example of time series record of the noise of about 3 hours. It can be noted that although the waveform are equal, but the amplitude is slightly different.

The first location is at the East Borneo, we fly from Jakarta to a small island Tarakan for about 2.5 hours, and continued with a speed boat to a small island (Bunyu Island) for about 1 hour. The second location is at Central Borneo, reached by a speedboat, airplane and off-road car. The total time for mobilization from Bunyu Island to Central Borneo is about 8 hours. The Third location is in Lamongan East Java; the fourth is Cepu, Central Java; Brebes Central Java; Lirik, South Sumatera; and Aru-Langkat, North Sumatera. The distance between each area is more than 100 kilometres and mostly reached by using all types of transportations, from aircraft, ship boats or cars (Figure 1). In each location, we have about 40 measurement points of microseismic data spending about three weeks of acquisition time. In some locations, the field condition is very extreme (road condition, extreme topography) that the sensors is experiencing great shock. Unfortunately those kinds of instrument (sensors) are not equipped with clamps.

Before being used for measurements, firstly the seismometers were calibrated with the procedures described above. We measure at the same location the ambient noise using six sensors simultaneously for about three hours. Figure 3 shows the time series of the recorded ambient noise during calibration at the Aru Langkat North Sumatera Area. The results of the calculation of the ratio spectrum for each component are shown in Figure 4-6 below.

Figure 4 The spectral ratio of the E-W component for each sensor to the average spectral ratio of the same component.

From Figure 4-6 it is shown that the performance of each sensor can be monitored from time to time.
From the first location (Jakarta, Indonesia) up to the second location in Central Borneo, the sensors seems to have constant performance, except the sixth sensors (TDS-06) for the N-S component (Figure 5).

**Figure 5** The spectral ratio of the N-S component for each sensor to the average spectral ratio of the same component.

We found at that time that the sixth sensor has a mechanical problem and it can be fixed during field measurement. It is interesting that although the entire sensor and also the datalogger is the same, but the relative amplitude is different. The first sensor (TDS-01) has the higher relative amplitude of about 1.9 It can be seen that in October 2013, (at the survey area of Lamongan, East Java, Indonesia), one sensor (TDS-05) behave differently as the spectral ratio characteristic changes. The spectral ratio values for all components changed drastically.

After seeing these anomalies, we then check the mechanical and electrical condition of the sensors of TDS-05. It was found that the connection spring with the mass on the sensor is bad. It is also found that the best way to bring the seismometer during the trip is by flipping it 180 degrees, so that the top is placed upside down.

**Figure 5** The spectral ratio of the vertical component for each sensor with the average spectral ratio for the same component.

**Conclusions**

The average spectrum of sets of seismometers can be used to test and monitor the performance of the individual seismometer from time to time by means of comparing it with the spectrum of each sensor. It can be simply used to see if there is a technical problem on the sensor or not. This is very useful for
avoiding errors in processing involving the spectral analysis of seismograms such as the HVSR method. We also found that the way to bring a sensor of this type is by inverting the sensor 180 degrees so that the bottom of the sensor reversed upwards (at the top) and vice versa. This causes the load mass in the seismometer can sit well and are less affected by shocks during the transportation process.

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References