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Processing The Ground Motion Signal Recording Using Correction Instrument Method

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ABSTRACT (10 PT)

The instrument correction method is a way to eliminate interference with the signal from the recording instrument response. Signal processing by the instrument correction method using the inverse filter method created using the MATLAB program. This research uses Honshu earthquake data, Japan with Mw 7.4 (dated September 5, 2004) recorded by the MERAMEX seismometer type L4C-3D type short seismometer and Japan Tohoku-Oki earthquake with a strength of Mw 9.0 (March 11, 2011). The data are from four seismic stations in Padang, West Sumatra with a DS-4A type short-period seismometer. From the research known, the signal can clearly show the phase of the P and S waves. This can help to determine the parameters of the hypocenter, receiver function, moment tensors, studies of $^{v_p}/_{v_s}$ *. The surface wave phase can be reconstructed well. This is very useful for studies using surface wave data, moment tensor solutions, seismic wave dispersion studies. Based on the amplitude of the instrument correction results compared with theoretical data, the gain or amplification is* $1 \times 10^5 m/s$.

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1. INTRODUCTION

Some of the signal processing methods continue to develop, which is the filtering method until the algorithm is used to generate the original signal or actual input and can eliminate noise in actual ground motion. The effect of the recording instrument used can also cause changes in waveforms. The recording in Figure 1 is an earthquake event that took place in the Fiji Islands (an island country south of the Pacific Ocean) recorded by the German Graefenberg (GRF) seismological station network with an epicenter distance of 151 °. Fiji earthquake recordings have a different form of a signal if recorded using different instruments (LPZ, BBZ, SPZ), The PKP dan pPKP wave phases are different signal characteristics (LPZ Long-period seismometer signals, SPZ short-period signals, and broadband BBZ) The PKP phase is a wave that propagates in the earth's core, while the pPKP is a surface reflection's. This is because the seismogram is the result of recording the output of the data logger so that the resulting seismogram still contains information on the characteristics of each instrument used [1]. Literature review that has been done author used in the chapter "Introduction" to explain the difference of the manuscript with other papers, that it is innovative, it is used in the chapter "Research Method" to describe the step of research and used in the chapter "Results and Discussion" to support the analysis of the results [2]. If the manuscript was written has high originality, which proposed a new method or algorithm, the additional chapter after the "Introduction" chapter and before the "Research Method" chapter can be added to explain briefly the theory and/or the proposed method/algorithm [3].

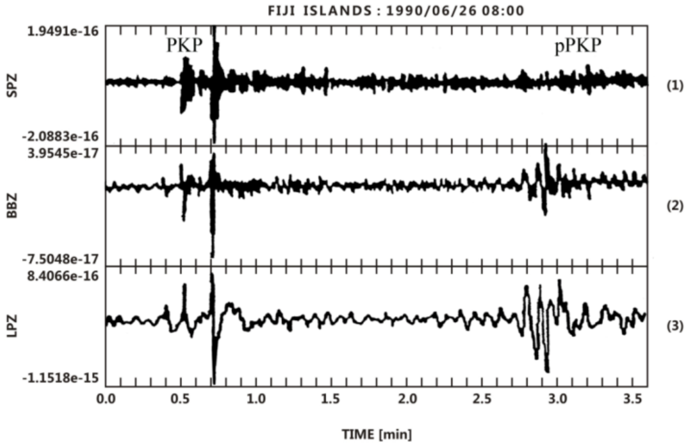

Figure 1. Fiji island earthquake records in the vertical component recorded by Kirnos BB seismometer [4]

Here is also research to determine the actual ground motion, [5] defines the displacement of actual land movements by implementing several theories of algorithm calculation. The Data used in the research was footage of the land movement of the accelerometer on the earthquake that took place in Parkfield, California (July 28, 1966). The results of the progress of the soil movements are shown in Figure 2.

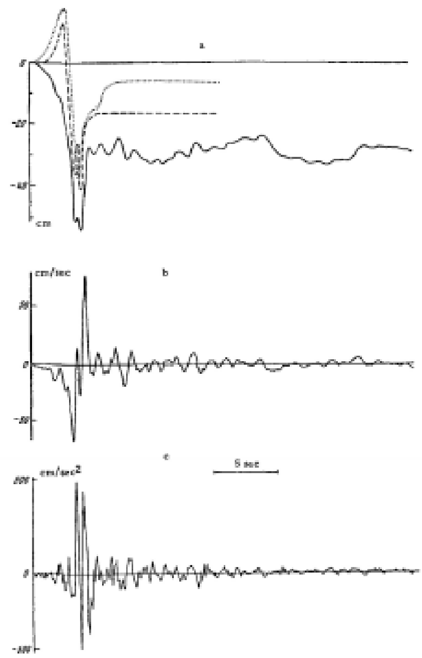

Figure 2. displacement of the [solid] accelerogram, [dashed line] the displacement calculated based on the N. Haskell theory, [point-line] the displacement calculated in a method by Hartzell, b) Calculation of the velocity value, c) Calculation of the acceleration value [5]

The recording from Accelerogram is a parameter of the accelerating movement of the land, to obtain the value of its transfer, it is necessary to double integral or twice on the recorded results of the Accelerogram. Thus the movement of land movements of The earthquake event can be determined.

[3] Specifies the value of the amplitude of the digital seismometer by applying correction instruments to the seismogram. The Data in his research was a shallow volcanic earthquake (type B) footage of the Krakatau mountain Boy recorded by the L4-C seismometer. The seismogram footage of The earthquake event is shown in Figure 3. The original Seismogram recording on the volcanic earthquake of the Krakatau mountain Boy recorded by an L4-C seismometer (Figure 4) with a unit of amplitude is *count*. Thus, information regarding the magnitude of the volcanic earthquake is not yet usable for further analysis. Therefore it is necessary to perform the conversion of amplitude unit in *m/s*. Recorded volcanic tremor from the son of Krakatau volcano recorded by an L4 seismometer after the correction of the instrument then the amplitude unit on each component is *m/s* (Figure 2.3)on the element N-S has a maximum Magnitude of $0{,}9 \times 10^{-4} m/s$ and minimum $-1 \times 10^{-4} m/s$, on the E-W component Maximum Magnitude value is $0{,}1 \times 10^{-4}$*m/s* and minimum $-1{,}9 \times 10^{-4}$*m/s*, and on Z component of maximum Magnitude $1{,}2 \times 10^{-4}$*m/s* and minimum -1×10^{-4}*m/*s

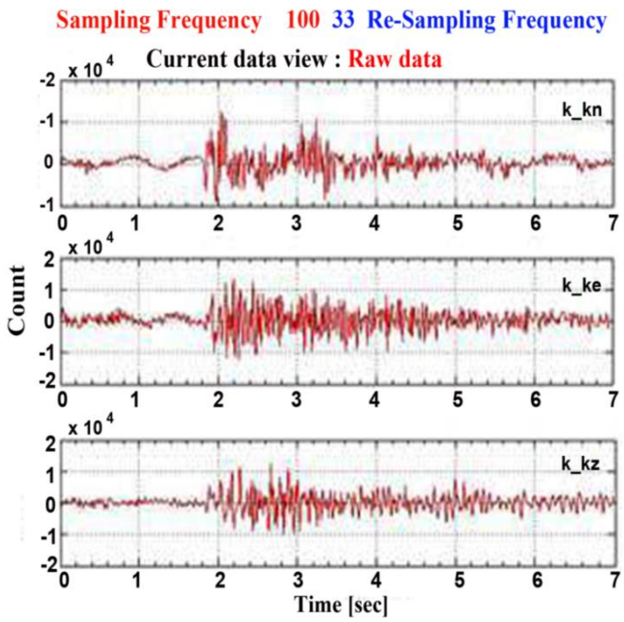

Figure 3. Recording VB Mount anak Krakatau before Correction (Gunawan, 2008)

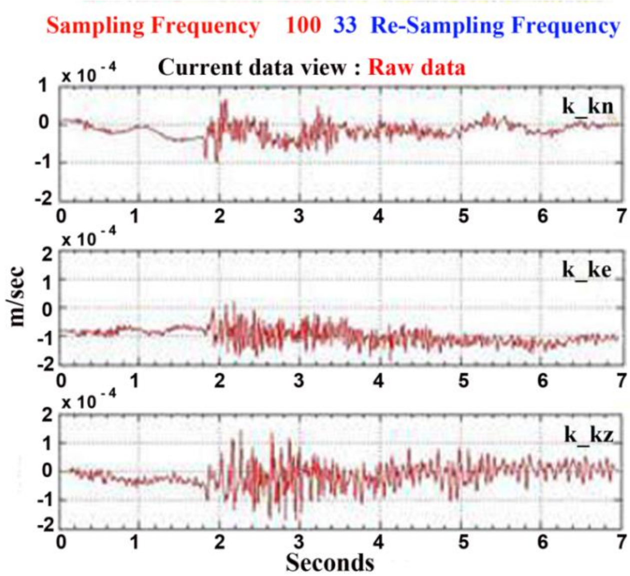

Figure 4. Recording VB Mount Anak Krakatau after correction (Gunawan, 2008)

The amplitude value Parameter to find SEISMIC moment determination and VB earthquake magnitude. The corrected record results integrated, resulting in an earthquake recording in-unit *Displacement* (maximum amplitude $2 \times 10^{-5} m$)

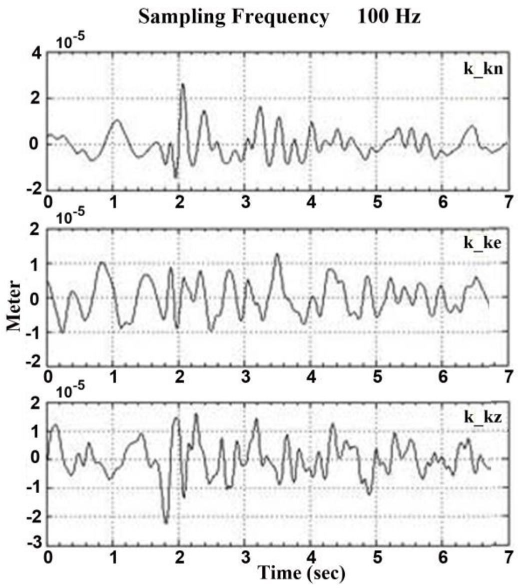

Figure 5. Recording VB Anak Krakatau after integrated with amplitude unit in meter *(Gunawan, 2008)*

(Haney, M., et al, 2012) conducted studies on instrument correction on short-period and *broadband* seismometer record data to obtain actual ground movements. The Data used in his research was a recorded volcanic earthquake in Mount Spurr volcano, Alaska (Fig 6)

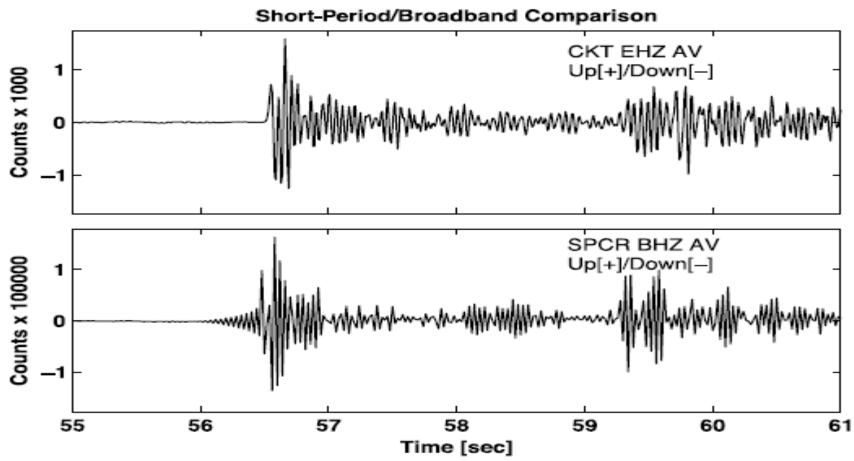

Figure 6. Seismograms [original] instrument recorded by the short-period and *broadband* seismometer on a volcanic earthquake in Mount Spurr, Alaska**.**

Bilinear transformation to design filter instruments in *Z* region that can interpolate and oversampling data to get the correction result of the accurate in Correction Instrument. The broadband Seismometer record and the short period will be matched and compared to both recordings having the same form of signal and band frequency. Thus, if the short-period Seismometer recording has similarities with the *broadband* recording, then the recorded result is the actual recording of the land movement. The instrument Correction results from the recorded earthquake can be visible in figure 7.

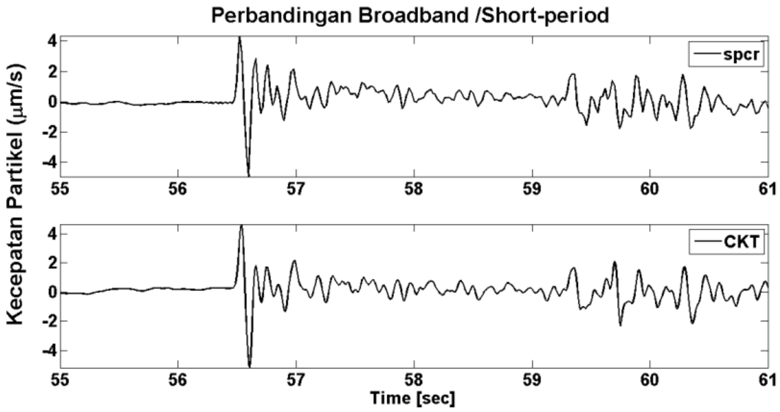

Figure 7. Signal Correction results of the instrument

In the application of the transformation method bilinear, the parameter that plays a crucial role is the *pole-zero* value. From the results of research, The recording signal of the current period of the characteristics of the waveform and the same frequency as the *broadband* signal, so that the recording is the real land movement of the earthquake event, considering the broadband recording signal is a representation of the actual land movements. Thus the method of correction of instruments formed by Haney, etc. (2012)can eliminate the influence of the recording instrument and can produce actual ground movements. This thesis will be performed a method of instrument correction to signal the recording results of different types of seismometers.

To find out the real ground vibration required information about the characteristics of an instrument. So that the seismogram recording will have the same signal shape characteristics, even though different instruments record it. This research will be conducted on the effect of the characteristics of seismometer type instruments on the recorded seismic signals

2. RESEARCH METHOD

The application of the instrument correction method is using the MATLAB program. The most crucial thing in instrument correction is designing a digital filter design using the pole and zero response provided by the seismometer. The poles and zero parameters of the seismometer are responses to the region s, thus to design a digital filter design a bilinear transformation method is needed to transform from the s (analog) region to the digital z region [4]

The case used in this research was the japan Tohoku-Oki earthquake event and the Japan Honshu earthquake event. the earthquake recording data that took place in Tohoku, japan was obtained from the *short-period* seismometer record ds-4a on four seismic stations (sp2, sp4, sp5, and sp6) at geophysics station Padang, West Sumatera.

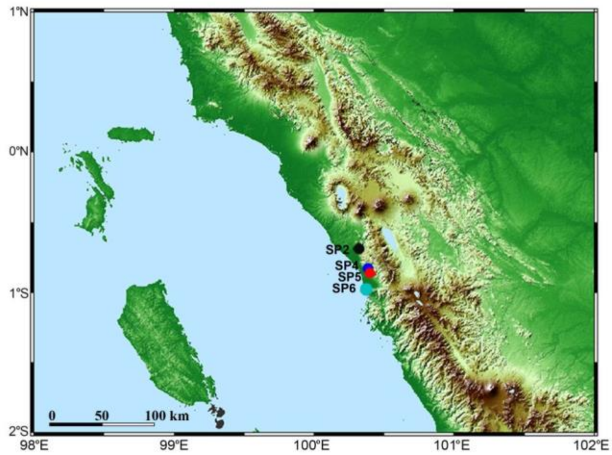

Figure 9. The Location Map Seismic StationTPadang, Sumatera Barat

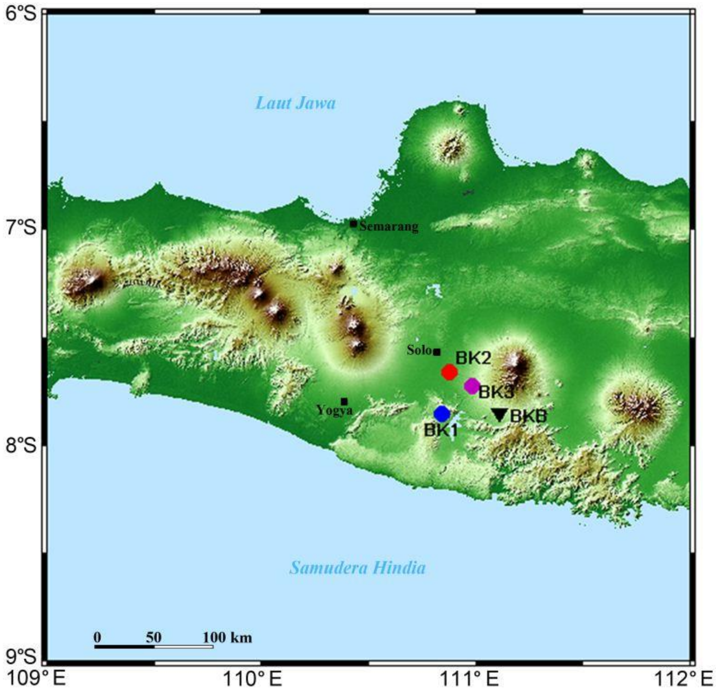

Figure 10. The location map of the seismic station placement on the MERAPI Amphibious Experiments (MERAMEX) seismometer network installed in and around Central Java

The earthquake event that occurred in Honshu, Japan on September 5, 2004, was recorded by the Merapi Amphibious Experiments (MERAMEX) seismogram network installed in central Java and its surroundings. The recording instrument used was an STS-2 Broadband seismometer with BKB station code, as well as three L4C-3D short-period seismometers with station codes BK1, BK2, and BK3 in Figure 9

Frequency Response

To find out the response or characteristics of a seismometer can be analyzed by the input and output relationships in the frequency region by using the Fourier transform [7]. A Fourier transformation in the equation

$$X(f) = \int_{-\infty}^{\infty} x(t) e^{-j2\pi f t}\, dt, \qquad (1)$$

$X(f)$ is a function frequency Hz, $x(t)$ time function second

When using the angular frequency ω in (rad/sec) then, the relationship between ω and f, X (ω) and X (f) according to Press et al. (2002) is

$$\omega \equiv 2\pi f,$$
$$X(\omega) \equiv [X(f)]_{f=\omega/2\pi.} \qquad (2)$$

T (jω) is a frequency response function of the seismometer. So the frequency response function

$$T(j\omega) = \frac{Y(j\omega)}{X\,(j\omega)}, \qquad (3)$$

Transfer Function

The frequency response function is closely related to the concept of moving functions, to prove the relevance of the idea [2] resolves the seismometer equation

$$f(s) = \int_{-\infty}^{\infty} f(t)e^{-st}dt. \quad (4)$$

With the complex frequency variable s = σ + j, then in the seismometer equation $\ddot{x} + 2\varepsilon\dot{x}_r(t) + {\omega_0}^2 x_r = -\ddot{u}_{,g}(t)$ becomes

$$(s^2X_r(s) + 2\varepsilon sX_r(s) + \omega_0^2X_r(s)) = -s^2U_g(s), \quad (5)$$

or can be writing

$$(s^2 + 2\varepsilon\omega s + \omega_0^2)X_r(s) = -s^2U_g(s) \quad (6)$$

so the transfer function of the seismometer equation is:

$$T(s) = \frac{X_r(s)}{U_g(s)} = \frac{-s^2}{s^2 + 2\varepsilon s + \omega_0^2}. \quad (7)$$

Poles and Zero

Pole-zero is a graphical representation of a rational transfer function in a complex field that can help to convey the response or character of a system. Pole is the value (Laplace variable in region s) of the root of the equation of the transfer function denominator, which can cause the value of the infinite transfer function. While zero is the root of the comparison of the transfer function system numerator that causes the value of the transfer function to be zero [2].

The poles parameter parameters of a seismometer are known from the quadratic equation. A seismometer response equation is

$$T(j\omega) = \frac{\omega^2}{\omega_0^2 - \omega^2 + j2\varepsilon\omega}, \quad (8)$$

Or can be writing

$$\omega_0^2 + j2\varepsilon\omega + \omega^2 = 0, \quad (9)$$

so obtained

$$\begin{aligned} p_{1,2} &= -\varepsilon \pm \sqrt{\varepsilon^2 - \omega_0^2}, \\ &= -h\omega_0 \pm \omega_0\sqrt{h^2 - 1} \\ &= -\left(h \pm \sqrt{h^2 - 1}\right)\omega_0. \end{aligned} \quad (10)$$

3. RESULTS

The instrument correction method produces a signal form that has a waveform similarity between a broadband recording with a short period. The P, S wave, and surface waves phases of each recorded signal are visible.

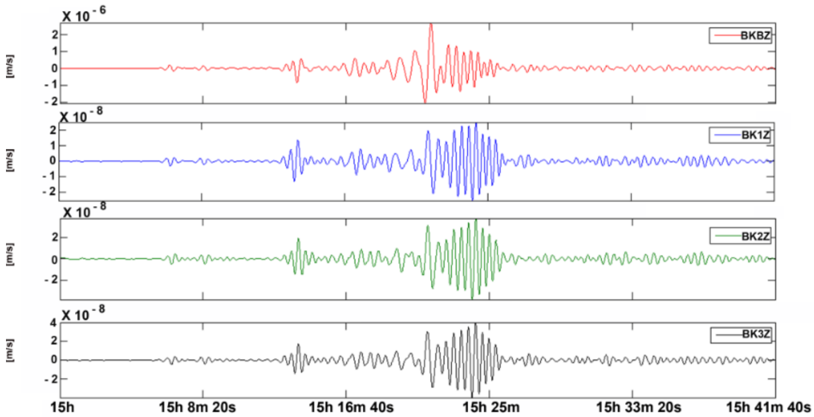

Figure 14. The instrument correction results on the recorded signal from each instrument have the same signal shape characteristics. [red; broadband signal], [blue: BK1 short period], [green: BK2 short period], [black: BK3 short period].

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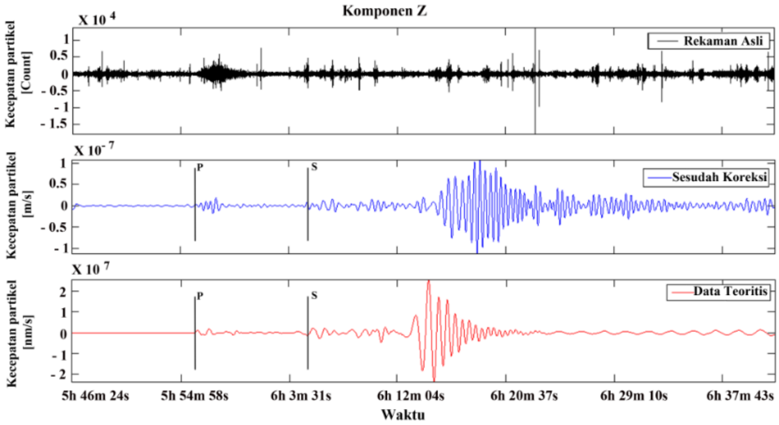

Figure 15. SP 2 Seismic Station; Seismogram [Black], Instrumen Corretion Results [Blue], and synthetic data [Red]

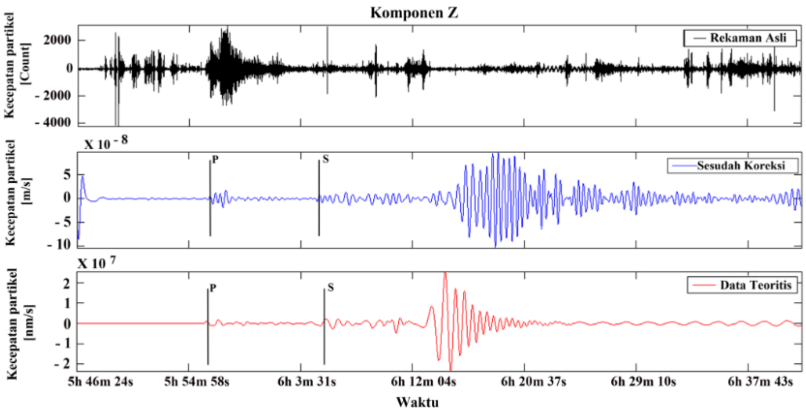

Figure 16. SP4 Seismic Station; Seismogram [Black], Instrumen Corretion Results [Blue], and synthetic data [Red]

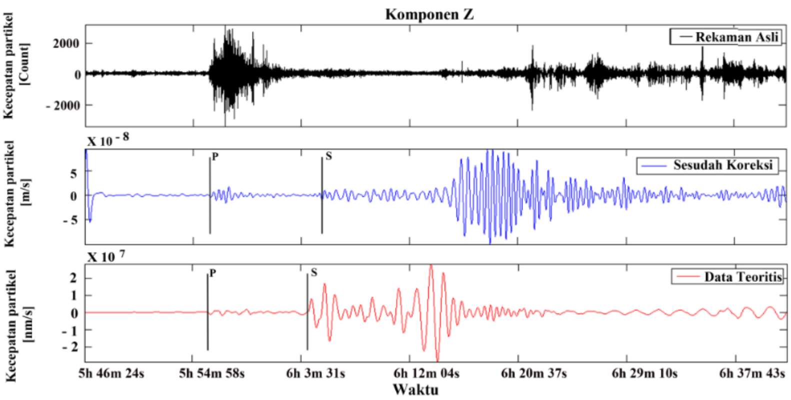

Figure 17. SP5 Seismic Station; Seismogram [Black], Instrumen Corretion Results [Blue], and synthetic data [Red]

4. CONCLUSION

The results of the instrument correction on the seismogram signal recording from four seismic stations in Padang, West Sumatra gave very significant results with the original seismogram signal recording.

1. The signal can show clearly the phase of the p and s waves. This can help to determine the parameters of the hypocenter, receiver function, moment tensors, studies of v_p/v_s, etc.

2. The surface wave phase can be reconstructed well. This is very useful for studies using surface wave data, moment tensor solutions, seismic wave dispersion studies, etc.
3. Based on the amplitude of the instrument correction results compared with theoretical data, the gain or amplification factor is $1 \times 10^5 m/s$.

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