Influence of Amplitude on the Value of Noise in Sinusoidal Signal

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Abstract

In expressing sinusoidal waves mathematically with the addition of the amplitude parameters, the equation becomes $x(n) = \Sigma An \sin 2\pi fnt$. Signals in the form of sinusoidal waves can experience interference when getting frequency readings. This interference is caused by the presence of noise in the sinusoidal wave signal. In this study, the amplitude of sinusoidal signal and noise will be compared to determine how much noise affects frequency readings. The method adopted to transform discrete data x(n) into frequency is the Discrete Fourier Transform. Based on the results obtained, when the amplitude value in discrete data is greater than the noise value, frequency readings are defined and clear. Noise value double the value of the amplitude value can still yield frequency readings from a structure; however, results are barely comprehensible.

Keywords
Amplitude, noise, frequency, signal, sinusoidal waves.

1. Introduction
The general expression of a sinusoidal wave involves frequency and time parameters. Expressed graphically, its equation will yield peak points. These peak points are also known as amplitude. By definition, the amplitude is the farthest distance or deviation from the equilibrium point in a sinusoidal wave. The amplitude does not affect the frequency value of the sinusoidal signal (Lai, 2003). In the form of a mathematical equation the equation of a sinusoidal wave with the addition of a parameter of amplitude, namely $x(n) = A_n \sin 2\pi f_n t$ (Bolton, 2021; Muscas, 2016).
Signals in the form of sinusoidal waves can experience interference in reading frequency values. This is caused by noise in the sinusoidal wave signal (Ahmad, 1990). Noise is unwanted interference in an electrical signal (Motchenbacher, 1993). The noise produced by electronic devices varies greatly because it is produced by several different effects (Kapoor, 2017; Aburuotu, 2021). In communication systems, noise is an unwanted error or random interference of a useful signal.

In a structural vibration test, reliability and accuracy of the collected signals is very important, as they are contaminated with noise. The noise embedded in the signal could put limits on detection of small defects by affecting the accuracy and reliability of the results (Yi, 2012). Noises causes the emergence of new amplitude points on a sinusoidal wave signal with a random pattern (Liu, 2012; Juarez-Salazar, 2017). In this study, it will be taken into account how much the noise value will affect the reading of the frequency value in the sinusoidal signal. The parameters that will be compared are the amplitude value of the sinusoidal signal and the noise value given to the sinusoidal signal.

2. Methods
The flow chart of the effect of the amplitude value of the sinusoidal signal on the frequency value is shown in Figure 1. The values of the amplitude of the sinusoidal signal used as the base of this analysis are 1, 1/10, 1/100, and 1/1000. In conducting a study of the effect of the sinusoidal signal amplitude on frequency, the frequency value, sample rate, and standard deviation of the noise that has been determined are accounted for. The frequency value used consists of the frequency value objectives, namely (fn) = 2 Hz, 3 Hz, 4 Hz, 5 Hz, 6 Hz, 7 Hz, and 8 Hz. The sample rate used is

(fs) = 32 Hz and the total number of samples is N=256. The noise input data uses the noise standard deviation with a value of noise σ_{noise} =0.5.

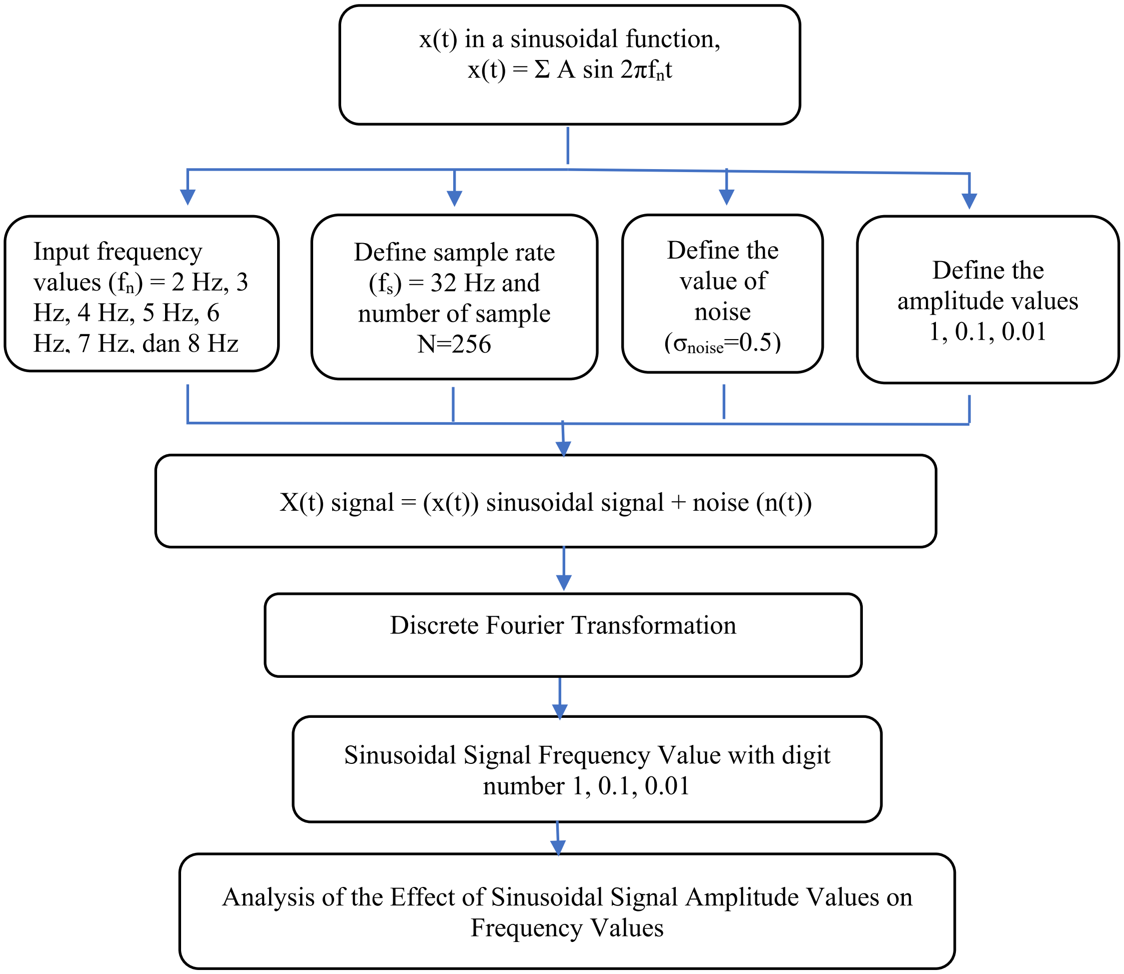

Figure 1. Analysis of The Effect of Sinusoidal Signal Amplitude Values on Frequency Values Diagram

3. Results and Discussion

The study was conducted to determine the effect of the value of the sinusoidal signal amplitude on the frequency value of the structure. The specified frequency values are 2 Hz, 3 Hz, 4 Hz, 5 Hz, 6 Hz, 7 Hz, and 8 Hz. While the amplitude value for each frequency is varied with the three models, namely 1, 0.1, and 0.01. The standard deviation of the noise used is 0.5.

3.1 Effects of Amplitude value 1 with Noise 0.5

Based on Figure 2, the wave pattern of discrete data x(n) versus time and discrete data with added noise, X(n) versus time. Discrete data, x(n) appears to have a periodic pattern from t=0 seconds to t=8 seconds. Meanwhile, discrete data that has been mixed with noise (σ=0.5) is seen to have experienced non-uniform vibration patterns (non-periodic).

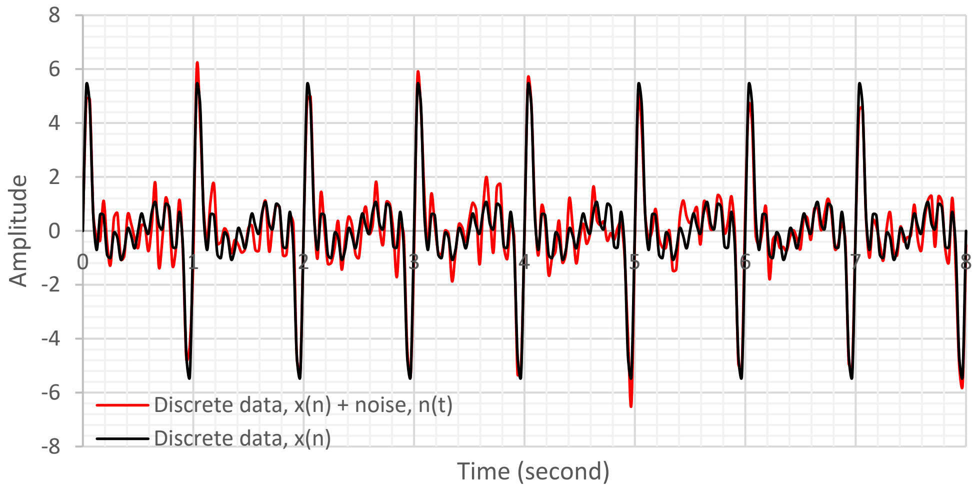

Figure 2. Comparison of Discrete Data and Discrete Data + Noise 0.5 for Amplitude 1

Discrete data with an amplitude of 1 with an added 0.5 noise, X(n) is transformed into the frequency domain using the Discrete Fourier Transform. By using the number of data N = 256 with a value of k=0,1,2,……..,255. The results of the calculation of the Discrete Fourier Transform analysis are shown in the form of a graph as shown in Figure 3.

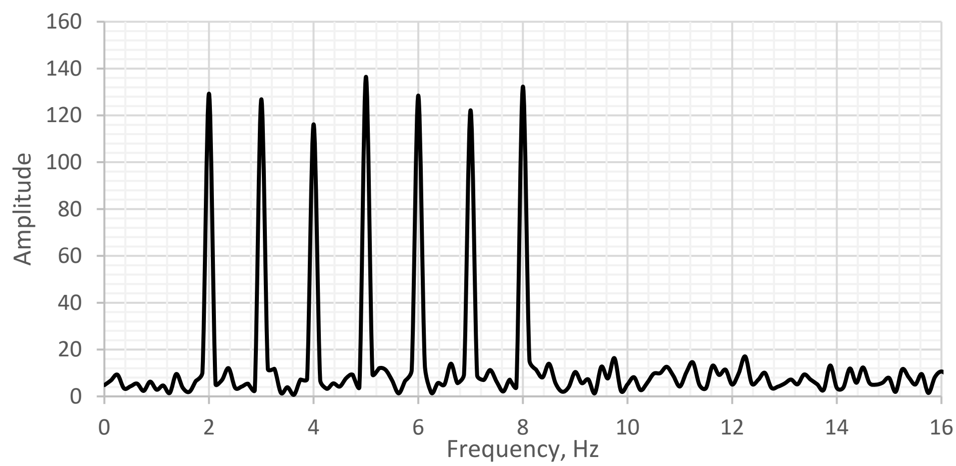

Figure 3. Frequency Graph of Amplitude =1 and Noise σ = 0.5

Based on Figure 3, the seven frequency values (2 Hz, 3 Hz, 4 Hz, 5 Hz, 6 Hz, 7 Hz, and 8 Hz) can still be read clearly. From the graph above, it can be seen that there are small peak points from a frequency of 0 Hz – 16 Hz whose pattern is random. The small peak points are a description of the noise in discrete data with a noise value of 0.5. By using an amplitude value of 1 and a noise of 0.5, it can be concluded that the noise has not interfered with the reading of the value of the structure frequency.

3.2 Effects of Amplitude 0.1 with Noise 0.5

Figure 4 represents discrete data with amplitude 0.1, x(n), and discrete data with added noise 0.5, X(n). Discrete data, x(n) appears to have a periodic pattern from t=0 seconds to t=8 seconds. Meanwhile, discrete data that has been mixed with noise (σ=0.5) shows a non-periodic vibration pattern and the amplitude value of discrete data with 0.5 noise added is much larger than discrete data with an amplitude of 0.1.

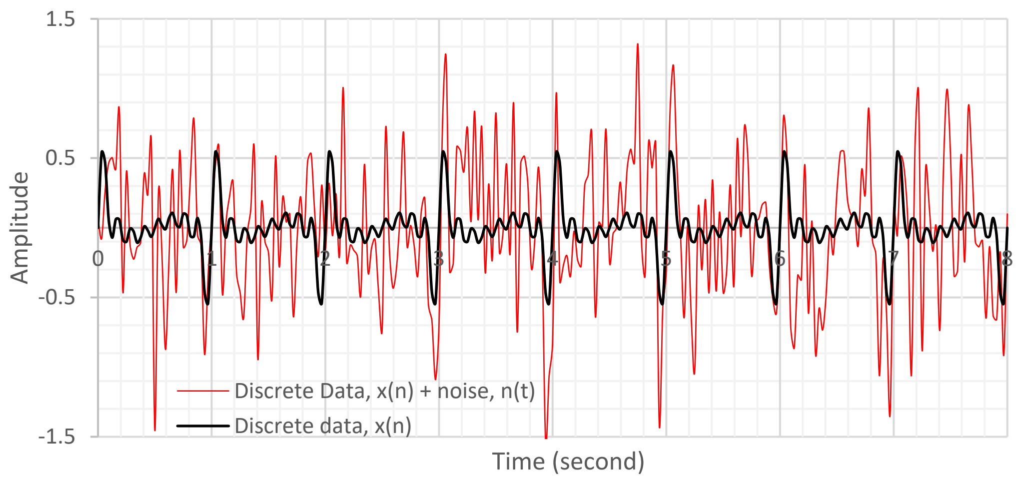

Figure 4. Comparison of Discrete Data and Discrete Data + Noise 0.5 for Amplitude 0.1

Discrete data with an amplitude of 0.1 to which 0.5 noise has been added, X(n) is transformed into the frequency domain using the Discrete Fourier Transform. By using the number of data N = 256 with a value of k=0,1,2,……..,255. The results of the calculation of the Discrete Fourier Transform analysis are in graphical form as shown in Figure 6.

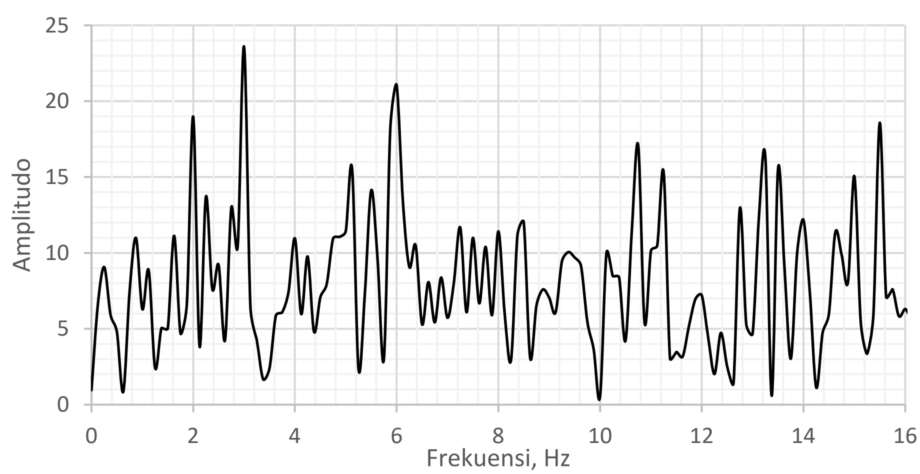

Figure 5. Frequency Graph for Amplitude = 0.1 and Noise σ=0.5

Based on Figure 5, the seven frequency values (2 Hz, 3 Hz, 4 Hz, 5 Hz, 6 Hz, 7 Hz, and 8 Hz) are not comprehensible. The amplitude peaks of the 0 - 16 Hz frequency domain have many peaks that are not of the seven specified frequencies. By using an amplitude value of 0.1 and a noise of 0.5, it can be concluded that noise has interfered with the reading of the value of the structure's frequency.

3.3 Effects of Amplitude 0.01 with Noise 0.5

Figure 6 represents the amplitude of 0.01, x(n), and discrete data with added noise 0.5, X(n). Discrete data, x(n) appears to have a periodic pattern from t=0 seconds to t=8 seconds. While discrete data that has been mixed with noise (σ=0.5) shows a non-periodic vibration pattern and the amplitude value of discrete data with 0.5 noise added is very much larger than discrete data with an amplitude of 0.01.

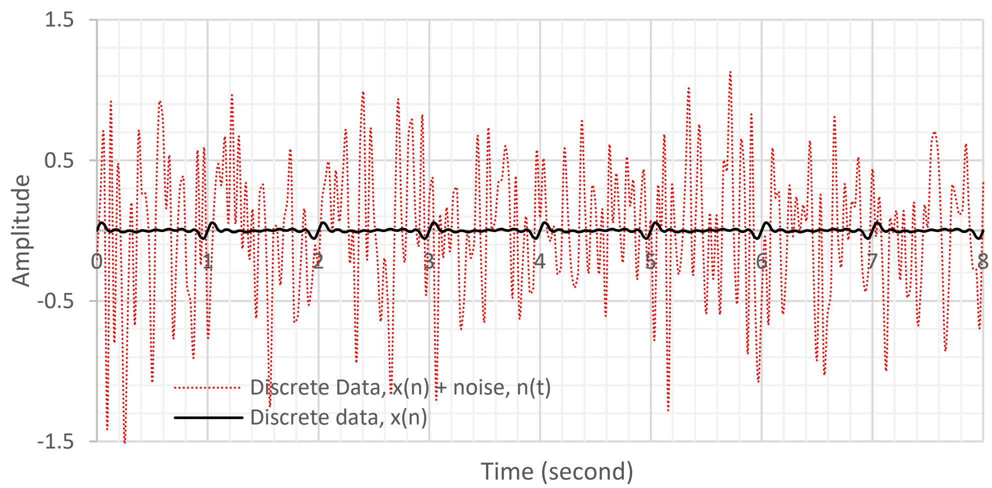

Figure 6. Comparison of Discrete Data and Discrete Data + Noise 0.5 for Amplitude 0.01

Discrete data with an amplitude of 0.1 to which 0.5 noise has been added, X(n) is transformed into the frequency domain using the Discrete Fourier Transform. By using the number of data N = 256 with a value of k=0,1,2,……..,255. The results of the calculation of the Discrete Fourier Transform analysis are in graphical form as shown in Figure 7.

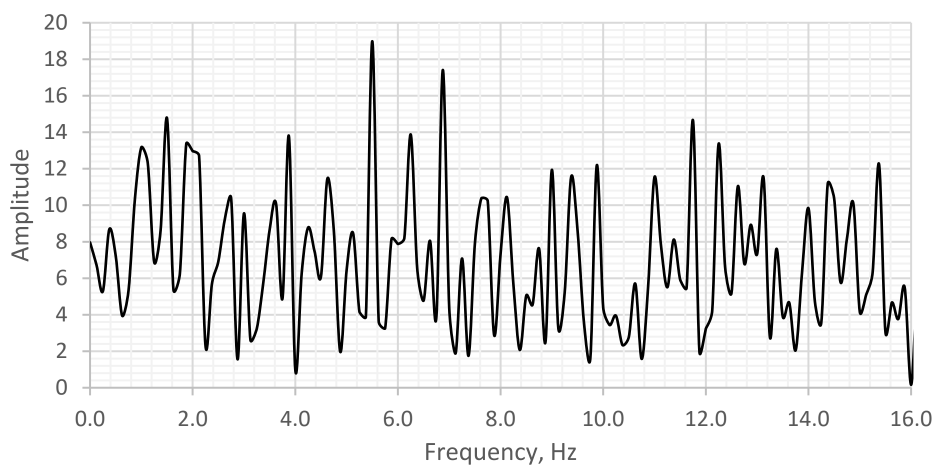

Figure 7. Frequency Graph for Amplitude = 0.01 and Noise σ=0.5

Based on Figure 7, the seven frequency values (2 Hz, 3 Hz, 4 Hz, 5 Hz, 6 Hz, 7 Hz, and 8 Hz) are no longer comprehensible. The amplitude peaks of the 0 - 16 Hz frequency domain have many peaks that are not of the seven specified frequencies. By using an amplitude value of 0.01 and a noise of 0.5, it can be concluded that the noise has interfered with the reading of the value of the structure frequency.

3.4 Comparisons of Amplitude values 1, 0.1, 0.01 dengan Noise 0.5

Figure 8 represents the frequency data taken from the readings of discrete data with varying amplitude values: 1, 0.1, and 0.01 with an added noise of 0.5. Discrete data with an amplitude of 1 read the seven frequency values clearly, namely the frequencies of 2 Hz, 3 Hz, 4 Hz, 5 Hz, 6 Hz, 7 Hz, and 8 Hz. Meanwhile, discrete data with amplitudes of 0.1 and 0.01 cannot be read clearly for the seven frequency values. The conclusion from this result is that the amplitude value in discrete data which is greater than the noise value gives clear frequency readings. For the amplitude value of discrete data which is smaller than the noise value, the frequency value reading is difficult to read. This is because the noise content in the discrete data is larger and disrupts the vibration pattern of the original discrete data.

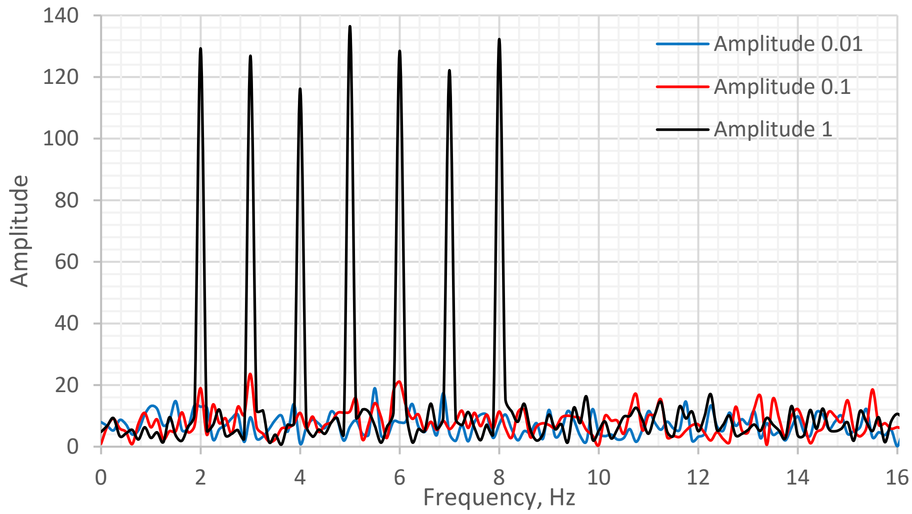

Figure 8. Comparisons of Frequency Values with Amplitude 1, 0.1, 0.01 and Noise 0.5

Based on the results of the preceding graph, when the noise value is larger than the amplitude value, an interference in the reading of the frequency value occurs. Using 0.1 amplitude of discrete data and 0.5 noise causes the frequency value to be read clearly.

3.5 Effects of Amplitude 0.1, 0.01 with Noise 0.3, 0.2 and 0.1

Discrete data with an amplitude of 0.1 with varying noise values are used, namely 0.3, 0.2 and 0.1. Based on the results in Figure 9 with noise 0.1 and 0.2, the readings for the seven frequency values can be read clearly. However, higher peak points started to show with an added noise of 0.2 to discrete data with an amplitude of 0.1 when compared to discrete data with 0.1 noise. For discrete data with 0.3 noise, the reading of the frequency value has begun to be disturbed due to the presence of high peak points. From these results, it can be concluded that the noise content with twice the amplitude value can still read the frequency value of the structure. For noise content that is more than 2 times the amplitude value of discrete data, it causes interference in reading the structure frequency value.

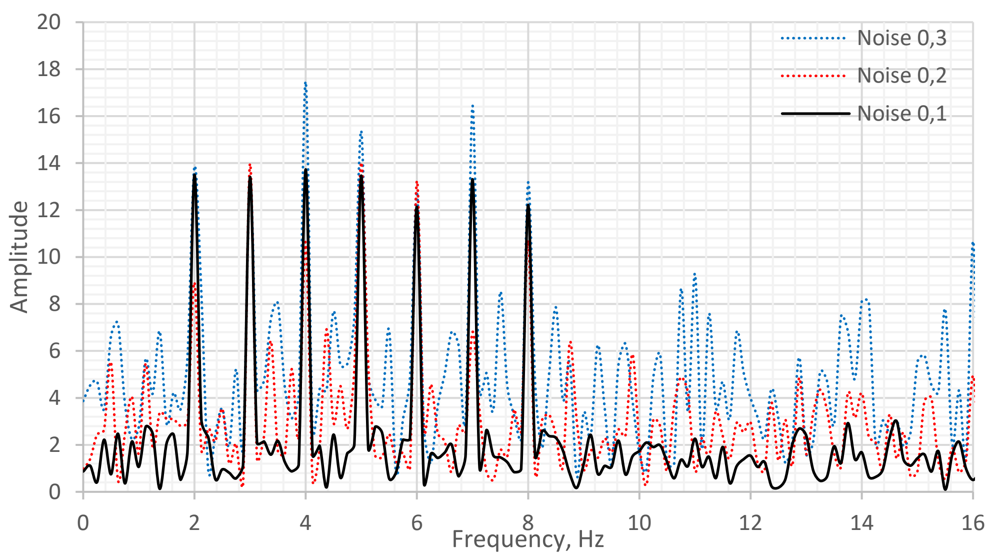

Figure 9. Comparison of Frequency Values with Amplitude of 0.1 and Noise 0.3, 0.2 dan 0.1

The same result is also shown in discrete data with an amplitude of 0.01 with a noise of 0.03, 0.02 and 0.01. The noise content with twice the amplitude value can still read the frequency value from the structure. This result is proven by the graph obtained in Figure 10 in the following. For noise content that is more than 2 times the amplitude value of discrete data, it causes interference in reading the structure frequency value.

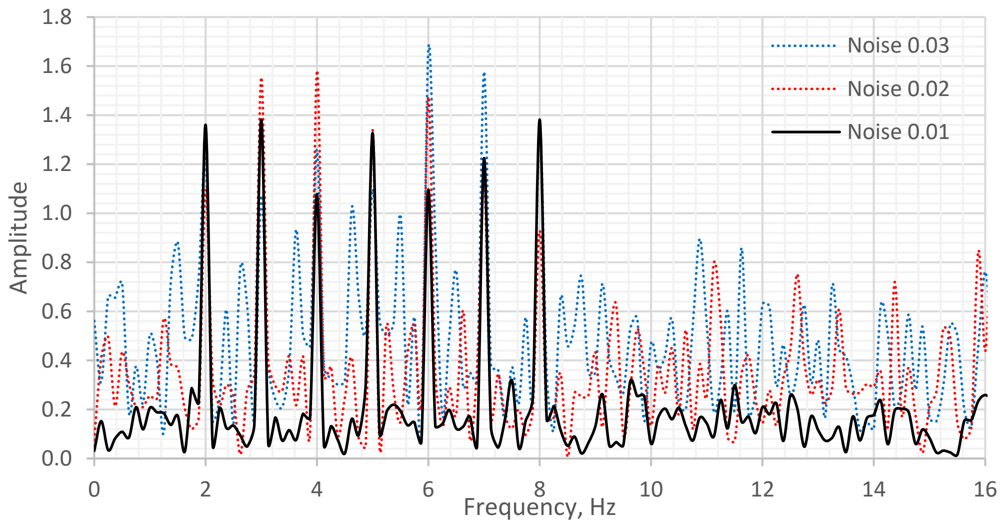

Figure 10. Comparison of Frequency Values with Amplitude 0.01 and Noise 0.03, 0.02 and 0.01

4. Conclusion

After conducting this study, it can be concluded:

- The amplitude value of 1 and the noise 0.5 can be concluded that the noise has not interfered with the reading of the value of the structure frequency
- The amplitude value is 0.1 and the noise is 0.5, it can be concluded that the noise has interfered with the reading of the value of the structure frequency
- The amplitude value of 0.01 and the noise of 0.5 can be concluded that the noise has interfered with the reading of the value of the structure frequency
- Amplitude value in discrete data which is greater than the noise value gives clear frequency readings
- Noise value with twice the amplitude value can still read the frequency value from the structure
- The noise value is 2 times greater than the amplitude value, causing difficulty in determining the reading of the frequency value.

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