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Identification of the PLTA JELOK TUNTANG Rapid Pipeline (Penstock) Based On the Spectra Response of the Microtremor Method

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Abstract:
Background*: There are many cases of pipe leakage caused by the construction of a public works project in an area. In the process of working on it, many obstacles were faced, such as unknown subsurface conditions.Therefore,weneedamethodthatcanbeidentifiedthesubsurfaceconditions,oneof which is the microtremor method.*
Materials and Methods*: This research was conducted through the JelokTuntang hydropower pipeline using the HVSR method. (Horizontal to Vertical Spectral Ratio), namely the comparison of the horizontal component spectra to the vertical component spectrum of the microtremor wave. With 31measuringpointsdividedinto5trackswith10 minutesof takingateachmeasurementpoint.*
Results*: Based on the correlation of the dominant frequency and amplification on each path, it can be characterized that the pipeline has a frequency of 0.13 - 8.86 Hz and an amplification of 1.04 - 8.39 because the pipelineislocatedatashallowdepth,itisnecessarytomeasureatleast1pointdirectlyabovetheline. pipe.Then,basedonthecorrelationofeachline,oneofthepipelinesoftheJelokTuntanghydropower pipeline can beidentified.*

Key Word*: Pipe, HVSR, dominant frequency, amplification*

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I. Introduction

In the last few years, there have been many cases of pipes that have leaked due to work on a public works project in an area, such as what happened in the Cimahi area in October 2019. PT Pertamina's pipeline leak in Cimahi was caused by a project to work on the Jakarta-Bandung fast train line [1]. In the process, there were many obstacles is not known to affect the project sustainability process especially the unknown underground conditions. Therefore, we need a method that can map the subsurface conditions, one of which is the microtremor method. The microtremor method is a relatively fast, non-destructive, low-cost method. The microtremor method is also a vibration that comes from nature or activity human [2]. One of the microtremor data processing is the HVSR method. The principle of the HVSR method is the comparison of the horizontal component spectra to the vertical component spectra [3]. According to [4] the microtremor method can detect pipe leaks by recording the leak signal on the geophone trajectory that is placed on the ground. The results of this study indicate that the random source of the leak can be shown using the 2D vicoacoustic equation and using the cross-correlation method.

Based on previous research conducted [5] regarding the correlation of the HVSR peak frequency with the object model buried in the sediment layer, it was stated that the frequency-dependent site amplification was known from the presence of waves trapped in the sediment layer, so that the waves occurred superposition between waves. If the waves have relatively the same frequency, a resonant wave process will occur which causes the waves to reinforce each other. Research with the HVSR method was also carried out to determine the pipeline in the Kalidoh area which showed a circular pattern at amplification of 1.4-1.5 [6]. The amplification contour obtained is lower than the surrounding area because the object under study is a pipe filled with fluid.

Based on the above case, it is important to detect subsurface conditions in project work, such as pipelines, one of which is by using the microtremor method. Therefore, this research was carried out in one of the sections in the JelokTuntang hydropower plant area to detect a rapid pipeline (penstock). This study examines the relationship between the HVSR response for the existence of pipelines and the response spectra.

The response spectra can be extracted from the HVSR curves arranged in a linear path configuration form a frequency-amplification profile.

II. Material And Methods

This prospective Microtremor is also called soil vibration with an amplitude of displacement of about 0.1-1 micron with an amplitude of velocity of 0.001-0.01 cm / s [7]. Microtremor or ambient noise is a vibration originating from the ground with a certain amplitude which can describe the geological condition of the area caused by natural or artificial events, such as wind, vehicle vibrations or ocean waves [8]. In microtremor research based on the parameters of the dominant frequency and amplification, it can be seen the characteristics of the soil layer [9].

Horizontal to Vertical Spectral Ratio (HVSR) method is a method available for microtremor data processing by comparing the horizontal component spectra to the vertical component spectra. The Horizontal to Vertical Spectral Ratio method is based on the assumption that the horizontal and vertical spectrum ratio of surface vibrations is a function of displacement. The processing result of this method is an H/V curve whose peak shows local information (site effect) in the form of the predominant frequency value and the amplification factor of the recorded waves in the soil [10].

The amplification factor of the spectra of the horizontal component and the spectra of the vertical component on the soil surface in direct contact with the bedrock in the basin area is denoted by T_H and T_V. The magnitude of the horizontal amplification factor T_H can be stated as follows [11].

$$T_H = \frac{S_{HS}}{S_{HB}} \tag{1}$$

whereS_{HS} is the spectra of the horizontal component at the soil surface and S_{HB} is the spectra of the horizontal component in the bedrock. The magnitude of the vertical amplification factor
T_V can be stated as follows:

$$T_V = \frac{S_{VS}}{S_{VB}} \tag{2}$$

S_{VS} is the spectrum of the vertical component at ground level and S_{VB} is the spectrum of the vertical component in bedrock.

The microtremor data is composed of several types of waves, but the main one is Rayleigh waves that propagate in the sedimentary layer above the bedrock. The effect of Rayleigh waves on the microtremor recording is the same for the vertical and horizontal components in the frequency range (0.2-20.0) Hz, so that the ratio between the spectra of the horizontal component and the spectrum of the vertical component in bedrock is close to the value of one.

$$\frac{S_{HB}}{S_{VB}} \approx 1 \tag{3}$$

Then rounded up to

$$\frac{S_{HB}}{S_{VB}} = 1 \tag{4}$$

rounding is done because of the result close to one.

Because the spectrum ratio between the horizontal component spectra and the vertical component spectrum in the bedrock is close to the value of one, so there is only an influence caused by the local geological structure or site effect (T_{SITE}). T_{SITE} shows the amplification peak at the fundamental frequency of a location. From equations (1) and (2), the amount ofT_{SITE} is :

$$T_{SITE} = \frac{T_H}{T_V} \tag{5}$$

By entering equation (4) into equation (5), we get the following equation:

$$T_{SITE} = \frac{S_{HS}}{S_{VS}} \tag{6}$$

Equation (6) becomes the basis for calculating the horizontal to vertical spectral ratio (HVSR) as follows:

$$HVSR = T_{SITE} = \frac{\sqrt{{S_{NS}}^2 + {S_{EW}}^2}}{S_V} \tag{7}$$

Dominant frequency is the frequency value which appears often recognized as the frequency of rock layers in the region. The dominant frequency has a close relationship with the thickness of the sediment (bedrock) [12]. As was also stated by [13] and [14] that the deeper the bedrock, the lower the dominant frequency. Conversely, the shallower the bedrock, the higher the dominant frequency. The value of the dominant frequency of an area is influenced by the thickness of the weathered layer (h) and the subsurface velocity (Vs).

Amplification of a wave can occur when an object that has its own frequency is disturbed by another wave with the same frequency. Amplification is an enlargement of seismic waves that occurs due to significant differences between layers, in other words, seismic waves will experience enlargement, if they propagate from one medium to another that is softer than the initial medium in which it is passed. The greater the difference, the greater the magnification experienced by the wave [12].

There are two devices used in research, namely hardware and software, The hardware device are Geophone 3 Axial VHL Vs-2B, Global Positioning System (GPS), Geological Compass, Data Logger DI 710 and Data Logger GL (840 and 240), Laptop. The software used is Geopsy, Microsoft Excel 2016, Notepad ++, Windaq, Surfer, and Google Earth Pro.

III. Result

The measurement results of this study are the dominant frequency and amplification values. The dominant frequency values are expressed in the color gradation contours shown in Figure 1, while the amplification values are shown in Figure 2.

The dominant frequency values in the study area range from 0.13 to 8.86 Hz with a dominant frequency of less than 4 Hz which dominates the research area. Based on the value of the frequency distribution in one of the sections in the JelokTuntang hydropower plant area, high frequency values are found at measurement points B1, B4, B5, D1, and E4 of 6.30 - 8.86 Hz marked in yellow to red. The other measurement points have a low dominant frequency marked in purple to blue, 0.13 - 1.83 Hz. The low frequency values represent the thick sedimentary layer of the area. The thickness of the sediment layer can describe the subsurface layer in the study area. The lower the value of the dominant frequency, the thicker the thickness of the sediment layer, so that the depth of the bedrock is also getting deeper. Conversely, if the higher the value of the dominant frequency, the thinner the thickness of the sediment layer, so that the depth of the bedrock also getting shallower.

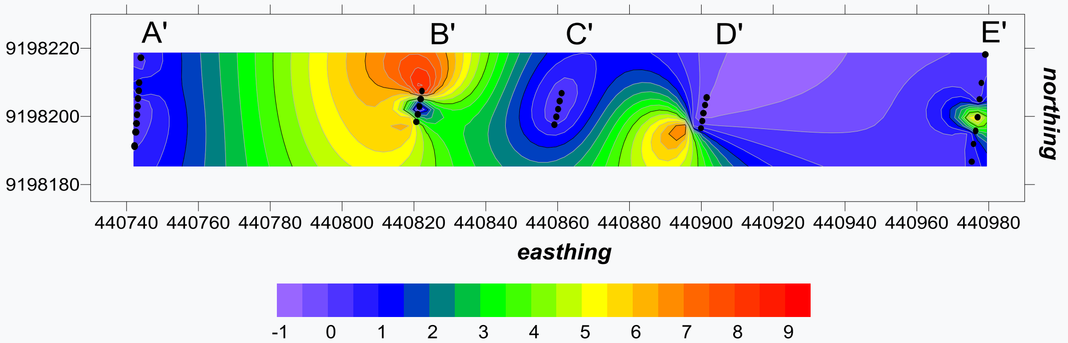

Figure 1. Dominant frequency contour (f_o) of the study area

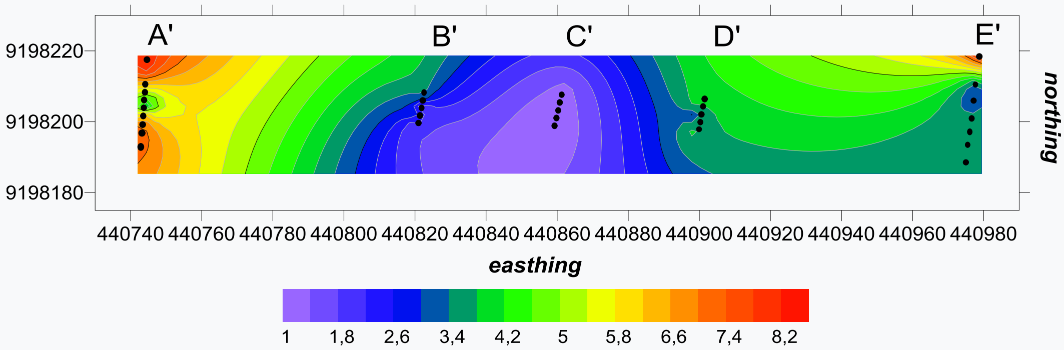

Figure 2, Contours of the amplification of the study area

Based on Figure 2, the value of the amplification factor around the pipeline ranges from 1.04 to 8.39. The highest amplification factor values are found at measurement points A6, A7, A8, A9, and E7 of 6.48 - 8.39 marked in yellow to red, while the other measurement points have the lowest amplification factor value of 1.04 - 4.66 is marked purple to green. A high amplification value indicates a low impedance contrast between layers, meaning that the inter-layer passages are also low, while a low amplification value is found in dense rock because the impedance contrast of the area is high. The dominant frequency and amplification values are not related to each other as in the C line. The C line has a low dominant frequency and low amplification because the factor that affects the dominant frequency is the thickness of the sediment layer, while the amplification factor of the sediment thickness does not really have an effect.

IV. Discussion

Line A is a path that is used as a reference in indicating the existence of a pipeline. The amplification value on path A ranges from 1 to 7,8. From this line an indication of the existence of a pipeline is at point A2 which has low amplification which is marked in purple. In Figure 3, it can be seen that the amplification factor value of point A2 is 2.75 with a dominant frequency value of 0.14 Hz.

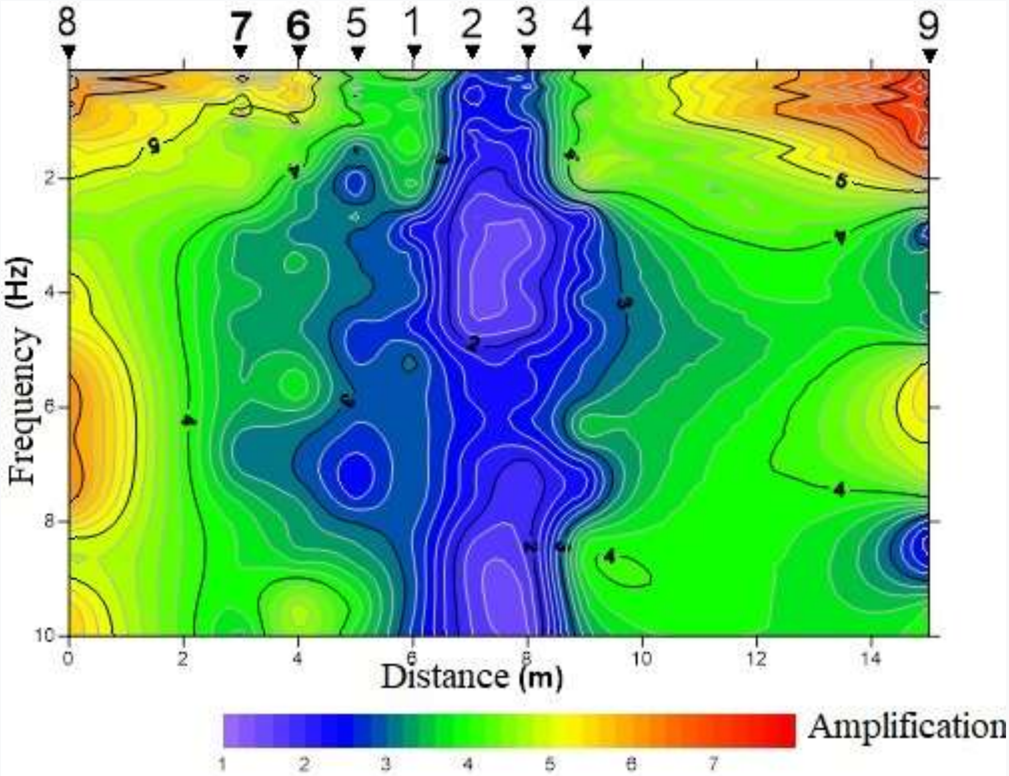

Figure 3. Trajectory profile A of the study area

The next line is line B. From this line, an indication of the existence of a pipeline at point B3 has a dominant frequency of 6.12 Hz with an amplification factor value of 1.48.

The C line has the lowest amplification value compared to the other lines. The profile of the C path can be seen in Figure 5. The low amplification factor of this path is due to the compactness or density of the sediment layer which accelerates the duration of the wave propagating in this path and the high impedance contrast value of this path. If the impedance contrast value is high, the amplification value is low because it is inversely proportional. The indication of the existence of a pipeline on line C, namely at point C3, is marked in purple. point C3 has a dominant frequency value of 0.35 Hz with an amplification of 1.22.

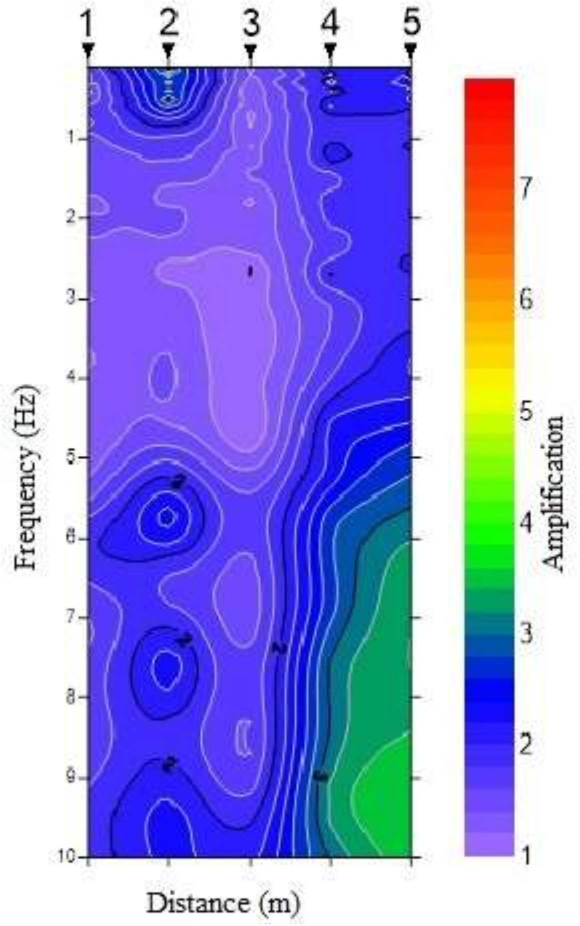

Figure 4. Trajectory profile A of the study area

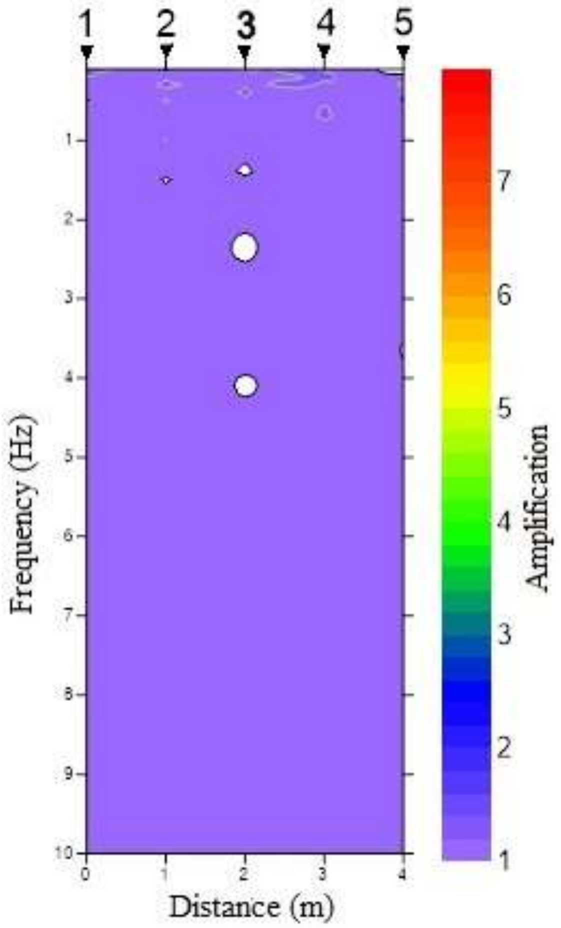

Figure 5. Trajectory profile A of the study area

The indication of the existence of a pipeline on line D is located at point D3 with low amplification marked in purple. Point D3 has a low dominant frequency value of 0.24 Hz with an amplification of 3.04. The pipe diameter on this track is the same as the other tracks, which is 2 m.

The last path is the E line with 7 measurement points. The E trajectory profile can be seen in Figure 7 which has an amplification range of 1 - 7.8 marked in purple to red. The indication of the existence of a pipeline on this line, namely at point E4 is marked with green. The amplification value at point E4 tends to be greater than the other points because there is a layer of soft sediment above the bedrock at this point. Point E4 has a dominant frequency value of 6.98 Hz with an amplification of 3.88.

Based on the correlation of the dominant frequency and amplification on each path, it can be characterized that the fast pipeline (penstock) has a frequency of 0.13 - 8.86 Hz and an amplification of 1.04 - 8.39. Then, based on the correlation of each line with the HVSR curve, it can be identified that one of the sections of the JelokTuntang hydropower pipeline can be seen in Figure 8

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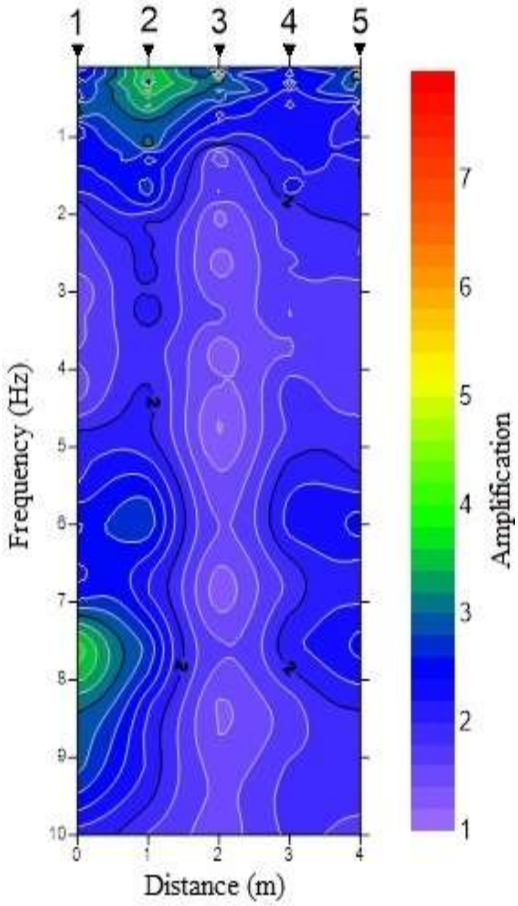

Figure 6. Trajectory profile D of the study area

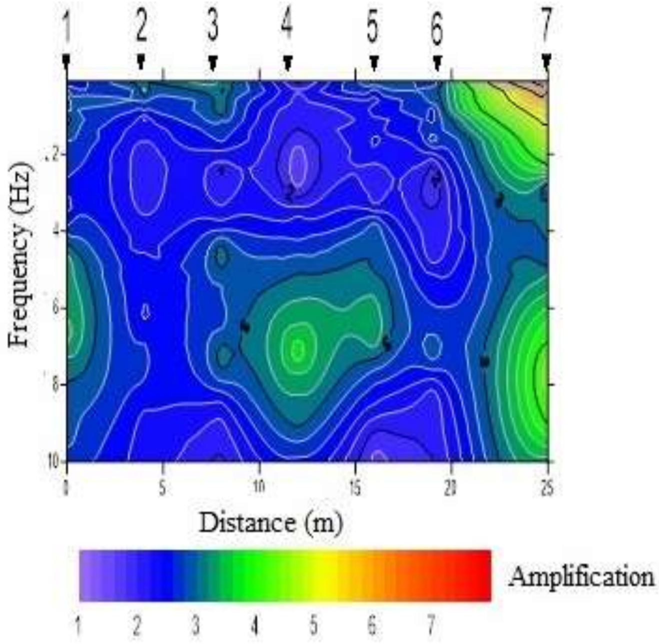

Figure 7. Trajectory profile E of the study area

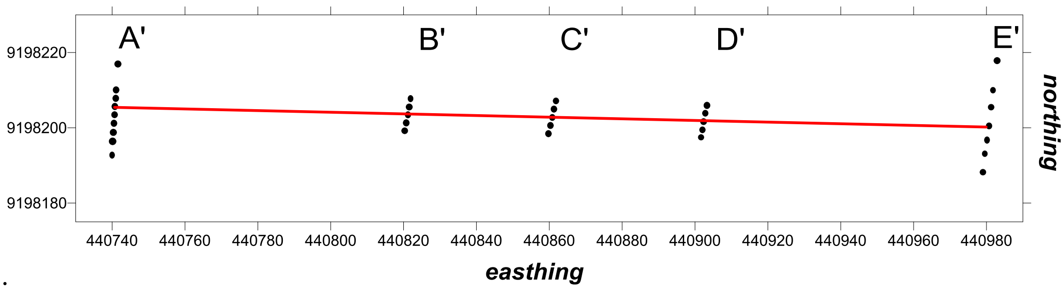

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Figure 8, The pipe line indication is marked with a red line extending from line A to line E

Correlating the location of the measurement point with the pipeline indication can be done through spatial analysis of the measurement point. On track A according to the modeling results using a surfer, the measuring point A2 is estimated to be right above the rapid pipeline. The first spatial analysis was carried out on path A between measurement points A8 and A9 without including measurement point A2, the results can be seen in Figure 9.From the figure below the indication of the existence of a pipeline is not clearly visible as in Figure 9.

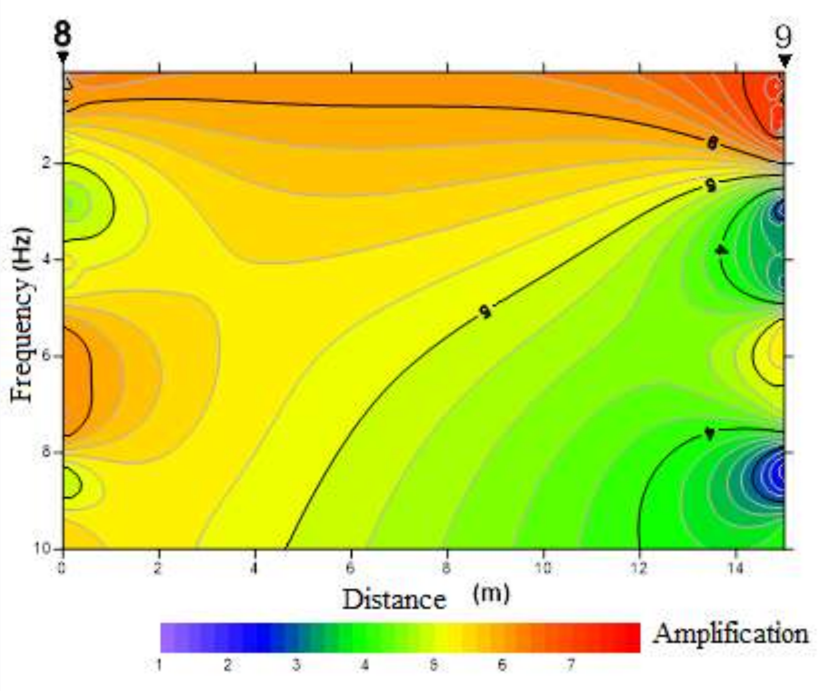

Figure 9. Spatial analysis of path A with 2 measurement points, at point 8 and 9.

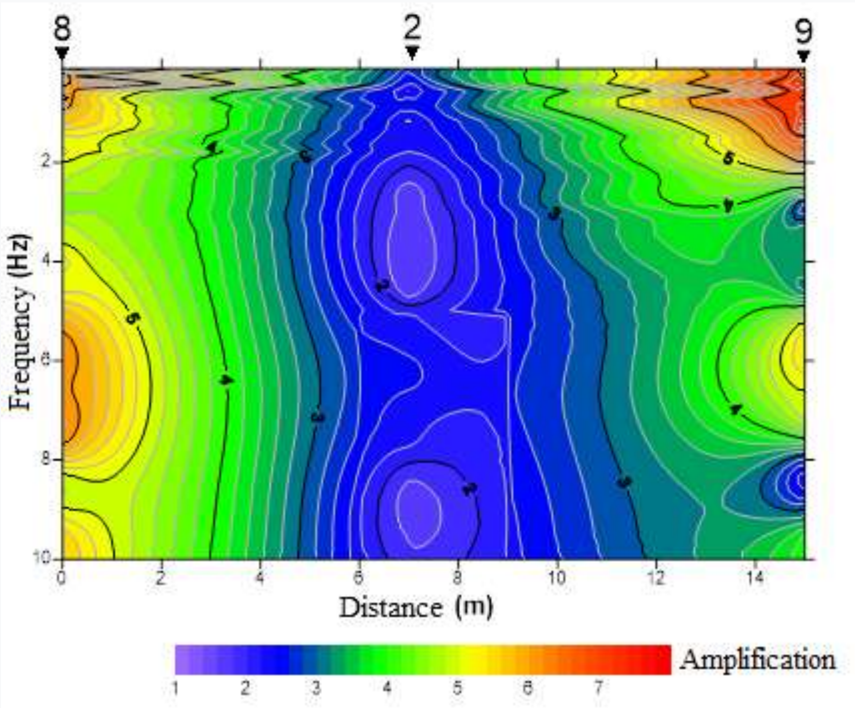

Figure 10. Spatial analysis of path A with 3 measurement points, at point 8, 2 and 9.

Then the second spatial analysis on line A, namely by using measurement points A2, A8, and A9, modeling can be seen in Figure 10.From Figure 10, it is clear that the indication of a rapid pipeline is due to the A2 measurement point which is directly above the pipeline . From the two spatial analyzes above, it can be concluded that in identifying shallow buried objects such as rapid pipelines, there is at least 1 measuring point right above the object or rapid pipeline.

V. Conclusion

From the results of research that has been carried out in one of the sections in the PLTA JelokTuntang area, Semarang Regency with a number of points of 31 measurement points, it shows the sensitivity of a certain frequency and amplification to the existence of a pipe line at the dominant frequency (0.13 - 8.86) Hz and amplification of (1.04 - 8.39) because the pipeline is located at a shallow depth, it is necessary to measure at least 1 point directly above the pipeline. Then, based on the frequency correlation, amplification, and spatial analysis of each track, one of the pipelines in the PLTA JelokTuntang hydropower plant can be identified.

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