

Performance of Elliptic Filter on Multi-Spectral Signal Based on Divided Zone

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Abstract— A multispectral signal fluctuation pattern is a signal pattern with fluctuations numbering more than one wave or frequency. This paper uses the HHF (High-High Fluctuation) matrix pattern of the chemicals H₂O and H₂O mixed with HCl, which was obtained through Capacitive Multispectral Mechanism acquisition on the previously mentioned substances. It is known that the resulting data is very large, thus needing a method to enhance or read the special characteristics of the fluctuation pattern produced. The method used in this paper is called the Divided Zone, which will divide the HHF matrix data into two parts and divide each into two more parts, giving six parts. Every part that has been divided will be called zones. After, the result of the method will be divided into two parts. The first will be used as a comparison, and the second will be applied low-pass elliptical filtering, which will be done using Python programming. The comparison observed that the highest amplitude point from every zone differs between the first and the second method. Where the first method has multiple highest amplitude points, the second has only one. And the highest amplitude point from the original data is more than either. This paper succeeds in seeing the characteristics of the original data using the methods used.

Keywords— *multispectral, divided zone, elliptic filter*

I. INTRODUCTION

A signal fluctuation pattern is the shape of the frequency of a signal. One form of a signal is a multispectral fluctuation signal where the signal has more than one wave or frequency. A multispectral signal pattern is one of the results of signal processing, and sometimes the pattern produced needs a method to analyze the data better. One such method is to divide the pattern into different zones. This study is related to processing multispectral signal patterns, which resulted from data acquisition using a capacitive sensor on the materials H₂O and H₂O mixed with HCl from the previous study [1].

The materials H₂O and H₂O mixed with HCl were used in a previous study that produced a multispectral signal fluctuation as its output. The previous study used a Multispectral Capacitive Sensor data acquisition on the two materials to produce their multispectral signal pattern. Fluctuation patterns are divided into Low Fluctuation (LF), Medium Fluctuation (MF), High Fluctuation (HF), and High-

High Fluctuation (HHF). This study uses the HHF pattern, which was in the form of a matrix[1], [2].

But there is not many useful information that can be read from the data in matrix form. This is because the pattern produced is complex and needs more advanced information processing. This paper uses the Divided Zone method. The divided zone method is used to look at large data information by dividing the data into smaller zones, which was already used in aerial imaging, the spray application in an industrial robot, and others [3]–[5]. After going through data processing, a filter will be applied to the resulting data.

on the previously mentioned solutions There are various types of filters used in signal processing [6]. In this study, the type of filter used is an elliptic filter. The elliptic or Cauer filter has equiripple behavior in the passband and stopband. This filter generally satisfies the filter requirements of the lowest order, where the elliptic filter minimizes the transition width of the passband ripple and the stop band ripple [6]. There is also an advantage to the elliptic filter, namely its ability to produce the fastest transition compared to other filters. This filter also can show ripple gain in both the passband and the stopband. More specifically, the elliptic filter used in this study is the low-pass elliptic filter. This filter has various uses that have been applied by other studies, including filtering noise signals, image restoration, etc. [6]–[9]. A filter is needed in this study to see the pattern of multispectral fluctuations more clearly.

As opposed to the previous research [10], which analyzed the pattern of HF, this study analyzes the HHF pattern in H₂O and H₂O mixed with HCl. This research is also a follow-up study of [1] by applying an elliptic filter and the divided zone method to analyze the pattern of HHF obtained. An elliptic filter is used to reduce the noise present in the signal. Evaluation of signal quality was also carried out using Signal-to-Noise Ratio (SNR), Standard Deviation (STD), and Power Spectral Density (PSD). Following this, the difference between the results of the divided zone method is analyzed before and after applying the elliptic filter.

II. RESEARCH METHOD

A. Divided Zone Method

The divided zone method in this study is a method that divides a pattern or matrix data into several parts or zones. This method is used to examine data that is too large in more detail by dividing the data, signal, or image into smaller parts that can be examined more individually. This method can be used in various situations, which can be seen in the following studies [3], [4], [11].

B. Elliptic Low-pass Filter

The elliptic filter is a development of the Chebyshev filter. The main characteristic of this filter is that there are ripples in both the pass and stop bands. It is called an elliptic filter because it uses the elliptic function, which is usually used to calculate the locations of zeros and poles. Sometimes this elliptic filter is called a Causer filter or a Chebyshev Rational filter. Compared to Butterworth and Chebyshev, this Elliptical filter requires a smaller order with the same specifications [11].

The error criterion of the elliptic filter fits perfectly with how the filter specifications are often given. The elliptical (as well as Butterworth and Chebyshev) analog low-pass filter transfer functions are constructed from zeros and poles in second-order factor form [12]:

$$H(j\omega) = \frac{1}{\sqrt{1 + \varepsilon^2 R_k^2(\xi \frac{\omega}{\omega_p})}} \quad (1)$$

Where R_k is the rational elliptic function order, ω is the transmission frequency, ω_p is the passband frequency, ε is the ripple factor and ξ is the selectivity factor.

C. Signal to Noise Ratio

In digital and analog communications, the signal-to-noise ratio or SNR is a measurement of signal versus noise. This ratio is generally measured in decibels (dB) using the signal-to-noise ratio formula. If the power of the input signal measuring microvolts is V_s , and the noise level, which is also measured in microvolts, is V_n , the signal-to-noise ratio is given the following formula [6]:

$$SNR = 20 \log_{10} \left(\frac{V_s}{V_n} \right) \quad (2)$$

If $V_s = V_n$ then $SNR = 0$. In this situation the signal cannot be measured because the level of noise is too large.

D. Standard Deviation

Standard deviation is defined as the most widely used measure of the distribution of data. The variable x will have a large value if the spread is very large to the average value. On the other hand, when the data spread is very small to the average value, the x value will be small. The following equation can calculate the standard deviation:

$$\sigma_x = \sqrt{\frac{\sum_{i=0}^n (x_i - \bar{x})^2}{n-1}} \quad (3)$$

Where σ_x is the standard deviation, n is the sample size, \bar{x} is the average value and x_i is the sample value.

E. Power Spectral Density

A signal's power spectral density (PSD) describes the power present in the signal as a frequency function per unit frequency. In general, PSD is expressed in watts per hertz (W/Hz). PSD also represents a measure of signal power intensity in the frequency domain. In practice, PSD is calculated from a signal's Fast Fourier Transform (FFT). PSD provides a useful way of characterizing the amplitude with the frequency of a random signal [12]:

$$\Phi(\omega) = \sum_{k=-\infty}^{\infty} R(k) e^{-i\omega k} \quad (4)$$

Where $\Phi(\omega)$ is the PSD function, $R(k)$ is the autocovariance order and ω is the frequency sample.

F. Research Process

The processes carried out in this research are the data acquisition process, zone separation process, program implementation, and data analysis, as seen in Fig. 1. Previous studies on chemical materials using capacitive sensors have carried out the data acquisition process. The study resulted in three types of fluctuations, namely MF, HF, and HHF, in the form of a matrix. This research will use HHF-type data from pure water (H₂O) and pure water (H₂O) mixed with HCl. Fig. 1 shows one form of the pattern of H₂O material fluctuations before being zoned and filtered.

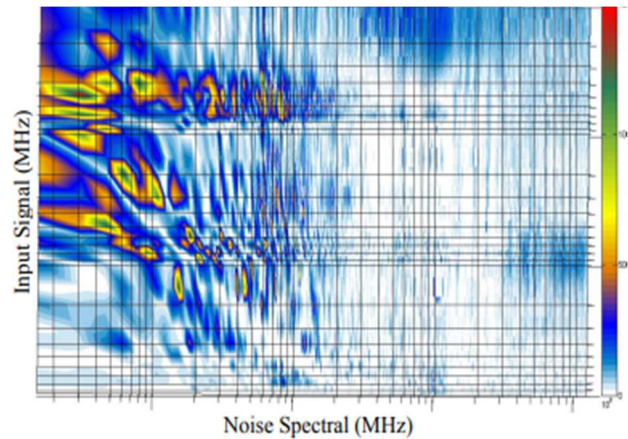


Fig. 1. HHF Pattern of H₂O [1].

This study uses Python programming to show and analyze the HHF pattern obtained from previous studies on H₂O and H₂O mixed with HCl. The data is a sampling of data obtained from previous studies in the form of excel data, and this data is then processed manually using the Microsoft Excel 2019 program.

Furthermore, the data processing is carried out using the Divided Zone method, which divides the data with a size of 31x8192 into two zones with two different sizes, namely the data size of 15x8192, which is called zone 2A, and the size of 16x8192 which is called zone 2B. Still using the Divided Zone method, Zone 2A and 2B will be divided into two zones so that there are four zones, namely zones 4A and 4C with the size of 15x4096 and zones 4A and 4C with the size of 16x4096.

The next step is low-pass elliptic filtering. The divided zone process results are then passed through an elliptic filter. Elliptical filtering uses Equation 1. The elliptic filter design considers the filter order, frequency sampling, and cutoff frequency. The results and values of the SNR, STD, and PSD signal parameters were also measured. Filtering and searching for parameter values is done using a Python program.

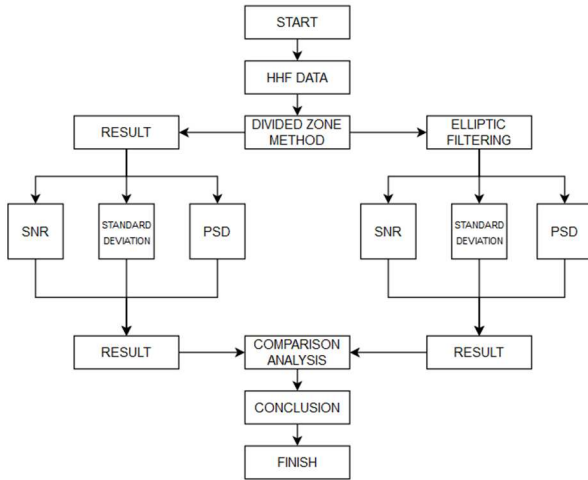


Fig. 2. Research Steps.

To see the effect of the low-pass elliptic filter in the signal data filtering process, this study compares the H₂O and H₂O mixed with HCl multispectral fluctuation signal data before and after filter application. The research steps can be seen more clearly in Fig. 2.

III. RESULTS AND DISCUSSION

A. Results And Analysis Of The Divided Zone Method

The previous study resulted in a large number of HHF data samples [1]. This paper chooses from that, three random data samples named D1, D10, and D100. After going through the initial data processing, the data is divided into six parts. Zones 2A and 2B are the zones produced by dividing the initial data into two parts, where zone 2A is the left part of the initial data matrix, and 2B is the right part. Zones 4A, 4B, 4C, and 4D are zones that separate the initial data into four parts where zone 4A is the upper left part of the matrix, 4B is the upper right part of the matrix, 4C is the lower left part of the matrix and 4D is the lower right part of the matrix.

Fig. 3 shows that the highest amplitude value of D1 data is in zones 2B and 4B, with a value of 4120. Fig. 4 shows that the highest amplitude value of D10 data is in zones 2A and 4A, with a value of 5367. Furthermore, Fig. 5 determines that the highest value of D100 data is found in zones 2A and 4A, with a value of 4400. After seeing the highest amplitude, this study conducted a parameter analysis using the SNR, STD, and PSD parameters.

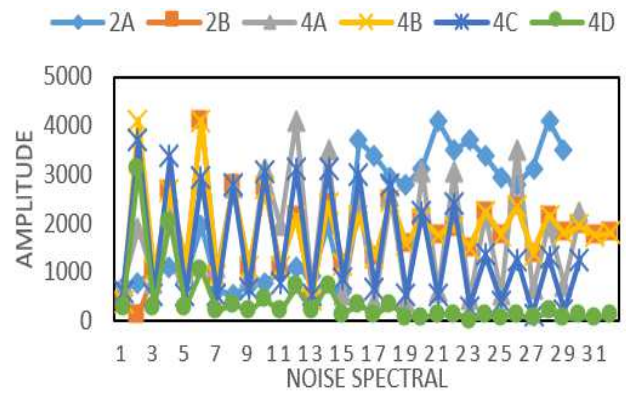


Fig. 3. Highest Amplitude Value of D1 H₂O Data after the Divided Zone Method.

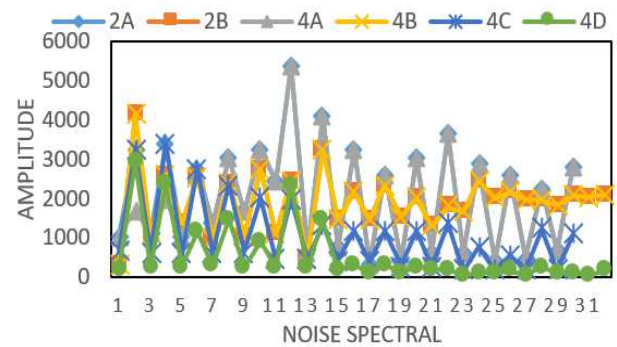


Fig. 4. Highest Amplitude Value of D10 H₂O Data after the Divided Zone Method.

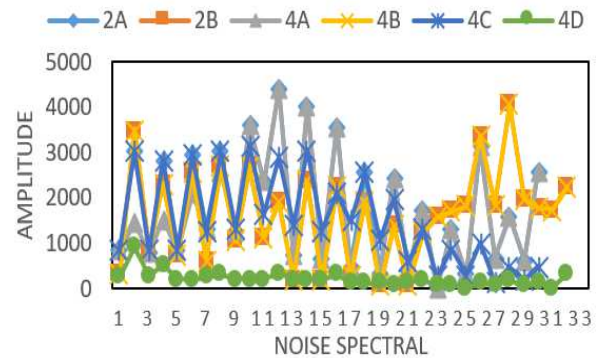


Fig. 5. Highest Amplitude Value of D100 H₂O Data after the Divided Zone Method.

The highest SNR value is 224,251 dB in zone 4A data D100 and the lowest SNR value is -1.325 dB in zone 4D data D100. The highest value of STD is 222.393 in zone 4D data D100 and the lowest value is -1.106 in zone 4A data D1. The resulting PSD graph can be seen in Fig. 9. The PSD graphs do not change shape because there is no change in the spectral density due to the method used.

There are also the results of H₂O mixed with HCl were similar to the previous H₂O material, from 100 H₂O mixed with HCl HHF patterns obtained by previous studies, which are used three random data named D1, D10, and D100. The amplitude graph of the pattern can be seen in Fig. 6, Fig. 7, and Fig. 8.

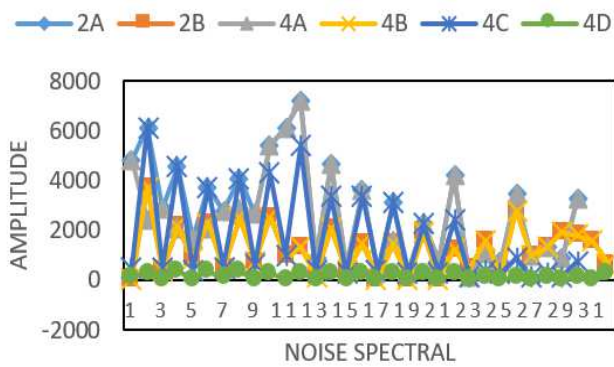


Fig. 6. Highest Amplitude Value of D1 H2O Mixed with HCl Data After the Divided Zone Method.

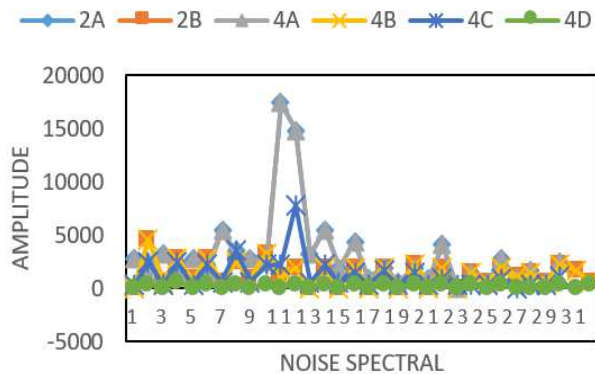


Fig. 7. Highest Amplitude Value of D10 H2O Mixed with HCl Data After the Divided Zone Method.

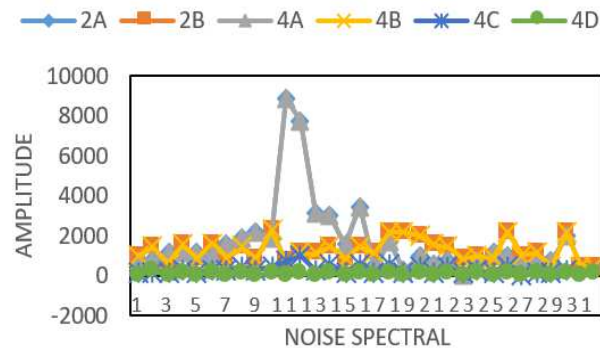


Fig. 8. Highest Amplitude Value of D100 H2O Mixed with HCl Data After the Divided Zone Method.

Fig. 6 shows that the highest amplitude value of D1 data is in zones 2A and 4A, with a value of 7225. Furthermore, Fig. 7 shows that the highest amplitude value of D10 data is in zones 2A and 4A, with a value of 17359. Then, fig. 8 shows that the highest value of D100 data is found in zones 2A and 4A, with a value of 8871. After seeing the highest amplitude, this study analyzed the SNR, STD, and PSD parameters.

The highest SNR value is 236,897 dB in zone 4A data D100, and the lowest SNR value is -1.223 dB in zone 4A data D10. The highest value of STD is 167,579 in zone 2B data D1, and the lowest value is -1.364 in zone 4A data D100. The PSD graph can be seen in Fig. 10. The PSD graph does not change shape because there is no change in the spectral density that occurs due to the method used.

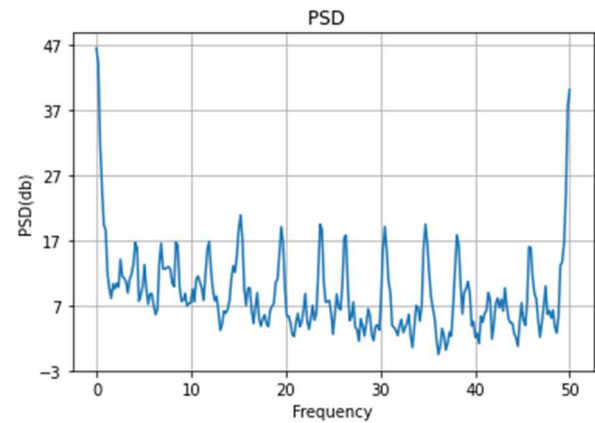


Fig. 9. PSD Graph of H2O Data.

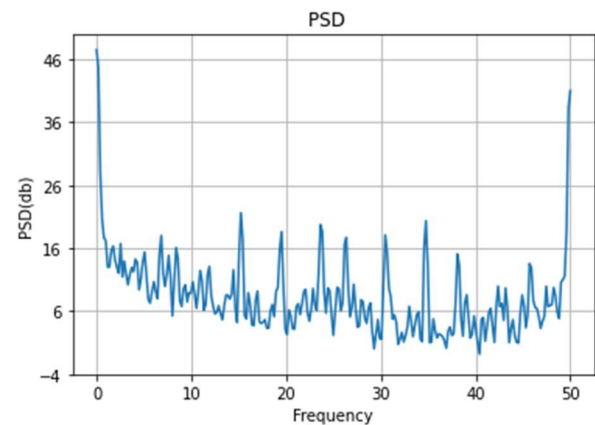


Fig. 10. PSD Graph of H2O Mixed with HCl Data.

B. Results And Analysis After Elliptic Filtering

The results of this method are obtained by programming, and the type of filter used is an elliptic low-pass filter. After screening the initial data, screening is also carried out on zoned patterns. Then the highest amplitude of each zone is measured, as can be shown in Fig. 11, where the highest amplitude value of each zone after the filter is applied to the H2O material is shown.

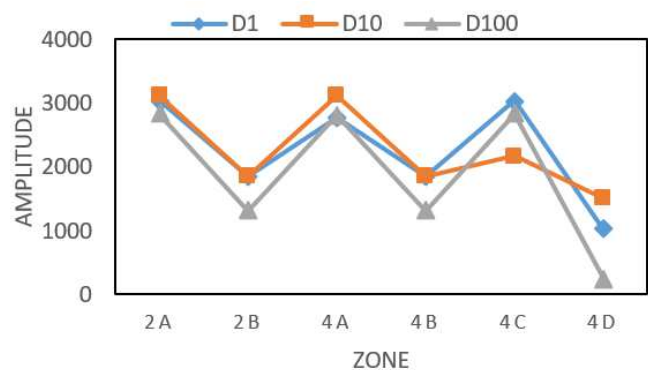


Fig. 11. Highest Amplitude Value of H2O Data After Filter Application.

It can be seen in Fig. 11, where the y-axis shows the amplitude of the data and the x-axis shows the zones, that the highest amplitude of the D1 data is in zones 2A and 4C, with the value of 3037 while the lowest is in zone 4D with 1020. In the D10 data, the highest amplitude values are in zones 2A

and 4A at 3111, and the lowest are in zone 4D at 1020. In the D100 data, the highest amplitude values are in zones 2A and 4C at 2834, and the lowest is in 4D at 261. It can also be seen that the highest amplitude of all initial data is in zone 2A and 4A data D10, and the lowest is in zone 4D data D100.

After obtaining the highest amplitude values, all H2O material data were analyzed with several signal parameters, namely SNR, STD, and PSD. The highest SNR value is 228.324 dB in zone 4A data D1, and the lowest SNR is -1.364 dB in zone 4D data D1. The highest STD value is 218,459 in the 4D data zone D1, and the lowest is -1.192 in the D1 data 4D zone. The PSD graph does not change shape because there is no change in the spectral density due to the method used. After analyzing the H2O material, the same analysis was carried out on the H2O material mixed with HCl.

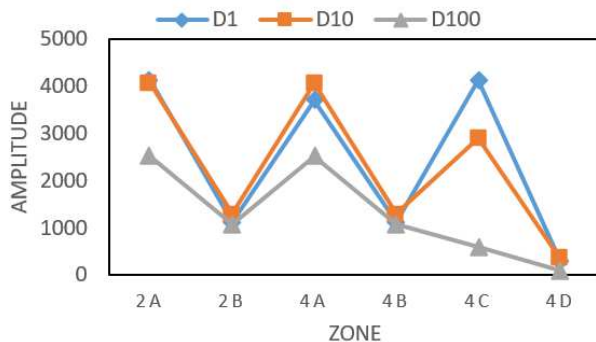


Fig. 12. Highest Amplitude Value of H2O Mixed with HCl Data After Filter Application.

As highlighted in Fig. 12, the y-axis shows the amplitude of the data and the x-axis shows the zone, that the highest amplitude of the D1 data is in zones 2A and 4C with the value of 4123, and the lowest is in zone 4D with 288. In the D10 data, the highest amplitude values are in zones 2A and 4A at 4071, and the lowest are in zone 4D at 334. In the D100 data, the highest amplitude values are in zones 2A and 4A at 2513, and the lowest is in 4D at 89. It can also be seen that the highest amplitude of all initial data is in zones 2A and 4C data D1, and the lowest is in zone 4D data D100.

After obtaining the highest amplitude values, the data were analyzed with several signal parameters, namely SNR, STD, and PSD. The highest SNR value is 178,632 dB in zone 4A data D100, and the lowest SNR is -1,084 dB in zone 4A data D10. The highest value of STD is 137,034 in zone 4B data D1, and the lowest value is -1.297 in zone 4A data D100. The PSD graph does not change shape because there is no change in the spectral density that occurs due to the method used.

C. Comparison of the Results Before And After Elliptic Filtering

Comparison of the results of the zoned pattern before and after being filtered as the last step of the research.

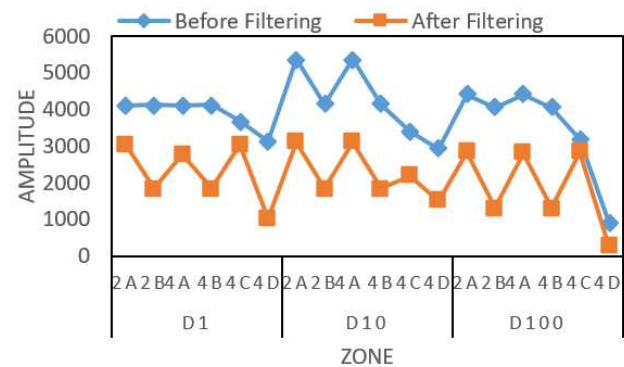


Fig. 13. Comparison of the highest Amplitude Value of the H2O Data before and after filtering.

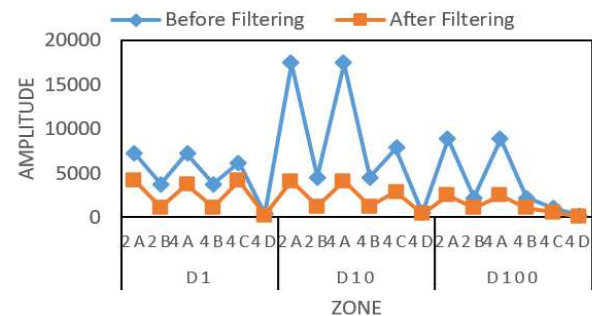


Fig. 14. Comparison of the highest Amplitude Value of the H2O Mixed with HCl Data before and after filtering.

Finally, Fig. 13 and Fig. 14 present the ratio of the highest amplitude of each data from the two materials used, where the x-axis shows the zone, and the y-axis shows the amplitude value. It can be seen that the amplitude of the data is higher in the first method, the method before filtering. This is due to the use of a low-pass elliptic filter which filters out higher fluctuations.

IV. CONCLUSION

This study has successfully applied a low-pass elliptic filter to multispectral signals based on the Divided Zone Method. The multispectral fluctuation pattern is divided into zones and produces six different patterns from each sample of data used. The highest amplitude from the H2O sample was at the value of 5367 while the H2O mixed with HCl sample was at 17359. The Low-pass Elliptical Filter succeeded in suppressing noise resulting in lower amplitude value where the H2O sample highest amplitude is 3111 and H2O mixed with HCl is at 4123. The highest amplitude value before and after filtering shows that the value is lower after filtering. Further research can be done to analyze the Divided Zone method using different filters.

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