Recognizing Human Emotion patterns by applying Fast Fourier Transform based on Brainwave Features

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***Abstract*— The natural ability of humans to receive messages from the surrounding environment can be obtained through the senses. The senses will respond to stimuli received in various conditions including emotional conditions. Psychologically, recognizing human emotions directly can be assessed from several criteria, such as facial expressions, sounds, or body movements. This research aims to analyze human emotions from the biomedical side through brainwave signals using EEG sensors. The EEG signal obtained will be extracted using Fast Fourier Transform and first-order statistical features. Monitoring of EEG Signals is obtained by grouping based on four emotional conditions (normal, focus, sadness and shock emotions). The results of this research are expected to help improve users in knowing their mental state accurately. The development of this kind of emotional analysis has the potential to create wide applications in the future environment. Research results have shown and compared frequency stimuli from normal emotions, sadness, focus and shock in a variety of situations.**

Keywords—Emotion, Electroencephalography (EEG), Fast Fourier Transform (FFT), Brainwave

I. INTRODUCTION

Humans have the natural ability to use all their senses in receiving messages in a conscious state. Through these senses, humans can feel emotional states when they get a stimulus [1][2]. Recognizing human emotions directly can be assessed from several criteria, such as facial expressions [3], sounds [4], or body movements [5][6]. Other criteria for identifying human emotions can also be based on data recorded on human brain activity, better known as Electroencephalography (EEG) [7].

EEG is a tool used to view electrical activity in the human brain. EEG signal change turns into a model and by examining it gives a successful method to group the EEG signal. In general, EEG signal comprises of wave parts, separated by their frequency domain such as Delta (0.1-4Hz), Theta (4-8Hz), Alpha(8-13Hz), Beta(13-30Hz) and Gamma (40-80Hz) [8][15][16][17]. Table 1 displays the oscillation frequency of brainwave signals.

TABLE I. BRAINWAVE OSCILLATIONS BASED ON NEUROSKY

Brainwave Type	Frequency range	Mental states and conditions
Delta	0.1 – 3 Hz	Deep, dreamless sleep, non-REM sleep, unconscious
Theta	4 – 7 Hz	Intuitive, creative, recall, fantasy, imaginary, dream
Alpha	8 – 12 Hz	Relaxed, but not drowsy, tranquil, conscious
Low Beta	12 – 15 Hz	Relaxed yet focused, integrated
Midrange Beta	16 – 20 Hz	Thinking, aware of self & surroundings
High Beta	21 – 30 Hz	Alertness, agitation
Gamma	30 – 100 Hz	Motor Functions, higher mental activity

In this study, we will use Neurosky Mindwave Mobile which is equipped with a sensor on the forehead and noise filter in the form of an ear clip mounted on the left ear to observe and record brainwaves [9]. Mindwave measures the voltage between sensors placed on the forehead and sensors that clamp the left ear (ear clip) as *ground*. More precisely, the position on the forehead is Fp1, as determined by the International System. Besides, this tool already has Noise Cancellation Technologies that can eliminate noise frequencies from other sources such as muscle movements and electrical devices. This filter removes electrical interference that varies from 50 Hz to 60 Hz depending on geographical location [10].

The type of the EEG output is in the way of electrical signals in the brain in the form of a graph with brainwave voltage on the time or frequency that can be seen using a computer [11]. Brainwave graphs on EEG vary depending on the condition of the human brain at the time of recording. It can be influenced by the presence of internal stimuli when experiencing an emotion (sad, surprised and thinking/focus) [12].

In this study, the spectrum analysis method based on Fast Fourier Transform (FFT) used in characterizing EEG output brainwaves is used to analyse the existence of brainwave differences between emotions and standard in a person [13].

II. RESEARCH METHODS

A. *Neurosky Mindwave Mobile*

This study applied four versions of EEG sensor: the NeuroSky MindSet headset, NeuroSky MindBand, NeuroSky MindWave headset, and NeuroSky MindWave Mobile headset. Mindwave version measures the voltage between the sensor placed on the forehead and the sensor that clips the left ear (ear clip) as *ground* [14]. More precisely, the position on the forehead is Fp1, as determined by the International System. The ThinkGear is the EEG technology within each NeuroSky products that safely measure and generate the EEG power spectrum. Both the eSense™ Meters (attention and meditation) and raw brainwaves are calculated on the ThinkGear Chip [15].

B. *Stimulus*

Before starting the experiment, preparation time is needed to install the Neurosky Mindwave and adjust the position of the subject to be comfortable during activities, the processing time is unpredictable because it depends on how long the subject takes to complete a stimulus[16]. A psychologist gives justification to validate the stimulus used in this study**:** listening to songs, watching videos or reading books. The stimulus serves to find out whether the subject of emotion is when he is given a song, video or work [17].

C. *Fast Fourier Transform*

The Fast Fourier Transform method requires around 10,000 mathematical algorithm operations for data with 1000 observations, 100 times faster than the previous method. The discovery of Fast Fourier Transform and the development of personal computers, the Fast Fourier Transform technique in the data analysis process became popular and is one of the standard methods in data analysis. One form of transformation commonly used to convert signals from the time domain to the frequency domain is the Fourier transform [18].

Correlation is a term commonly used to describe whether or not there is a relationship with something else [19][20]. In simple terms, that is precisely what understanding correlation means. Correlation analysis is a method or method to determine whether or not there is a linear relationship between variables. If there is a relationship, the changes that occur in one of the variables X will result in a difference in the other variable (Y). The term is said to be a causal term, and the term is a characteristic of correlation analysis — the Fast Fourier Transform algorithm equation in equation (1).

$$f_j = \sum_{k=0}^{N-1} w_N^{k_j} f_k \qquad (1)$$

Suppose that N can be divided into two so that the equation below divided into two parts, namely for even k and odd k. Then given a new variable with equation (2):

$$M = \frac{N}{2} \qquad (2)$$

So that equation (3) is obtained:

$$f_j = \sum_{k=0}^{M-1} w_N^{2k_j} f_{2k} + \sum_{k=0}^{M-1} w_N^{(2k+1)_j} f_{2k+1} \qquad (3)$$

Where N is the amount of data, then equation (4) is what is known as FFT:

$$M = \frac{N}{2} M = \frac{N}{2}; w_N = e^{\frac{-2\pi i}{N}}; w_M = e^{\frac{-2\pi i}{M}}; k, j = 0,1, \dots, N-1. \qquad (4)$$

The above equation is used to find *sine* and *cosine* correlation on Fast Fourier Transform. A correlation that occurs between two variables is not always in the form of an addition to the value of variable Y if the variable X increases, a correlation like this is called a positive correlation. Sometimes it is found that there is a relationship where if one of the variable values increases the other variable decreases, a relationship like this is called a negative correlation. Not only positive and negative correlations, but also sometimes found cases where the relationship between variables is fragile, and even no correlation founded.

D. *Research Tools and Materials*

The main tools and materials used, and their functions can be seen in Table 2.

TABLE II. RESEARCH TOOLS AND MATERIALS

Research Tools and Materials	
Tools and Materials	***Information***
Personal Computer	To design and simulate the MATLAB program using the FFT method
EEG Neurosky Mindwave	Brain ware recording
Bluetooth Adapter	As a device to connect Neurosky Mindwave with a Laptop
Stimulus	Used to get the brainwave parameters of each subject
MATLAB	Used for brainwave feature extraction using the FFT method.

E. *Block Diagram*

To simplify the process of making the script, this time, the research needs to make systematic steps. The existence of levels in this study is expected to guide in formulating research problems. The design flow can be seen in Figures 1 and 2.

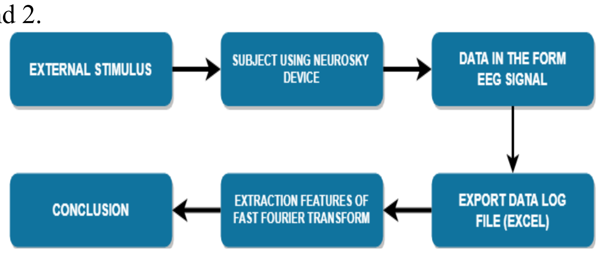

Fig. 1. System Design Block Diagram

The subject will be given a stimulus in the form of music, video and books with Neurosky placed on the head to record the EEG signal. The signal then will get pre-processed to generate the average signal and erase the baseline to get the signal output. The results were then analyzed using Fast Fourier Transform to obtain a noise-free EEG signal to extract all essential frequency components from EEG signals of alpha, beta, gamma, delta, and theta. Separation of the frequency of the wave part of the EEG signal for grouping the features of a subject's brainwaves that will carry out tests based on certain level signals. Fast Fourier Transform is used for gathering and detecting brainwaves which provides different features. The results of the selection of prominent EEG signals from brainwave signals in identifying features result in the identification of data classification.

Fig. 2. Hardware Design Block Block Diagram

The block diagram above, it can be seen that Bluetooth adapters function as communication protocols between laptops with Neurosky Mindwave. The data sent is in the form of brainwave record values measured using Neurosky Mindwave and will be posted periodically according to how long the recording process is.

F. System Testing

In this study, the subject will be given a stimulus in the form of listening to music, watching a video or reading a book while using the *Neurosky* sensor so that an EEG signal is obtained.

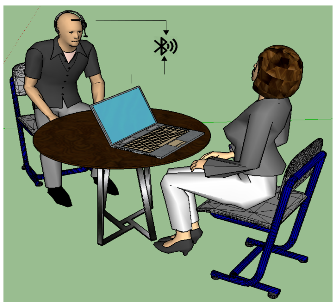

Fig. 3. Ilustration of System Testing

The results of the EEG signal pre-processing were generated using Fast Fourier Transform (FFT) to obtain a noise-free EEG signal to extract all essential frequency components such as alpha, beta, gamma, delta, and theta. Separation of the frequency of the wave part of the EEG signal for grouping the features of a subject's brainwaves that will carry out tests based on certain level signals. Fast Fourier Transform is used for gathering and detecting brainwaves where these brainwaves provide different features. The results of the selection of prominent EEG signals from brainwave signals in identifying features result in the identification of data classification.

III. Result and Discussion

In this study, the test results will be divided into several stages. The first stage is testing brainwave conversion from RAW data into a Fast Fourier Transform (FFT) spectrum. Second is testing for brainwave analysis when under normal circumstances and in certain emotions using FFT.

A. Converting RAW data into FFT on Brainwave Recordings

The process of converting raw data into FFT is done by using the Matlab software where the data input is RAW data output from Neurosky. For the results that have been running in the form of Neurosky amplitude waves and FFT frequency waves. The results obtained from running the program will be shown in Figures 4 (a) and 4 (b) below.

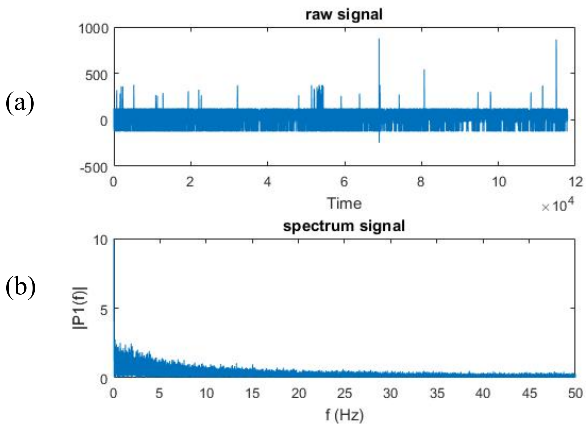

Fig. 4. The result of running the program conversion from the RAW signal (a) to the FFT spectrum (b)

From the picture above shows the difference between Neurosky data in the form of RAW data from the subject and the Fast Fourier Transform signal spectrum from a subject data. The result of running the program is that there are two forms of signals, namely Neurosky wave signals in the form of a neurosky amplitude and wave in the form of frequency, while in figure 5 (a), raw signal is raw data obtained from Neurosky waves that are tested on subjects that are thinking complicated things and can see a high amplitude from 0 to 1 $\times 10^5$. Figure 5 (b) shows a Neurosky wave frequency signal spectrum which was tested on subjects in a state of thinking about complicated things. There are frequencies of 0 to 50 Hz which have different amounts at each frequency. The results of the signal spectrum will be different for each stimulus given to the subject.

B. FFT Spectrum Analysis of Individual Regular Brainwaves and Emotions

FFT spectrum analysis process is carried out between regular and specific emotional waves. The picture below explains the results of running programs for subjects with the FFT method in figure 5, 6, and 7.

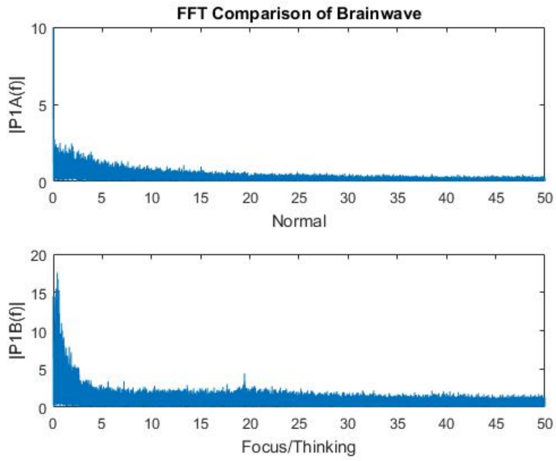

Fig. 5. FFT Result when Normal and Focused (Thinking)

It can be seen that the first subject brainwave has a difference where at regular times it has the highest amplitude of 2.86 at a frequency of 0 - 50Hz, while at a time of focus/thinking has the highest amplitude of 17.57 at a frequency of 0 - 50Hz.

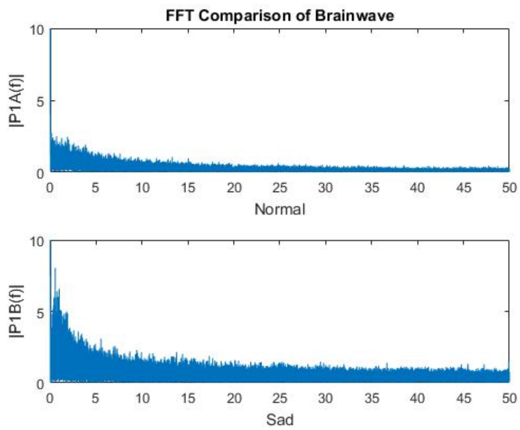

Fig. 6. FFT Result when Normal and Sad

The second subject's brainwaves have differences were at regular times they have the highest amplitude of 2.86 at a frequency of 0 - 50Hz, while at a time of sad have the highest amplitude of 8.04 at a frequency of 0 – 50 Hz.

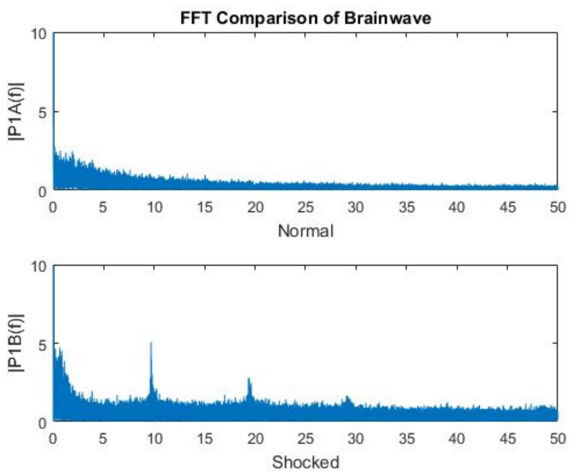

Fig. 7. FFT Result when Normal and Shocked

It can be seen that the second subject's brainwaves have differences were at regular times they have the highest amplitude of 2.86 at a frequency of 0 - 50Hz, while at a time of shock have the highest amplitude of 6.27 at a frequency of 0Hz.

From the results of the comparison of three subjects when the state of focus, sad, and shocked, can be seen the results of the FFT spectrum between the three there are differences where at the time of focus state has a higher amplitude value than when the state of sad and shocked. But in a state of shock, there are several amplitude surges in the frequency range 0-5Hz, 9-10Hz, 19-20Hz and 29-30Hz.

C. The Results of the Comparison of the amount data in each emotion

The highest amount of data is collected from each frequency to compare the values obtained from each emotion, and the process is carried out in MATLAB to retrieve the most top data from 0 - 4Hz with a range of 0.25Hz. The results obtained can be seen in Figure 8, Figure 9, Figure 10, and Figure 11.

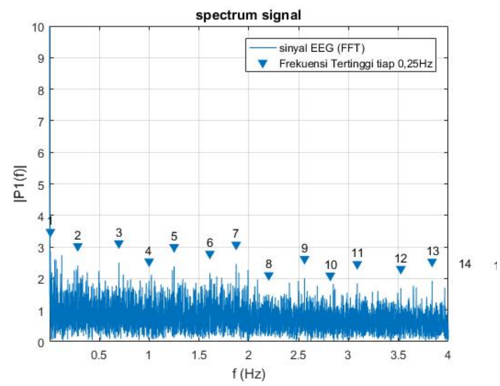

Fig. 8. Signal spectrum of “normal” emotions

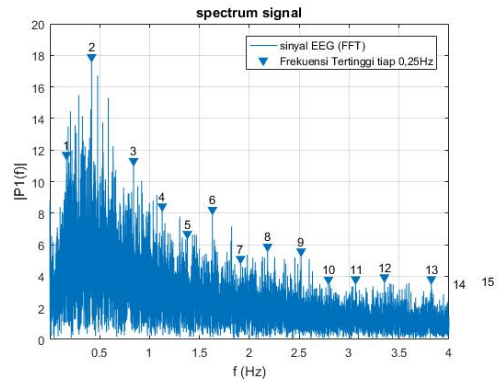

Fig. 9. Signal spectrum of “focused” emotions

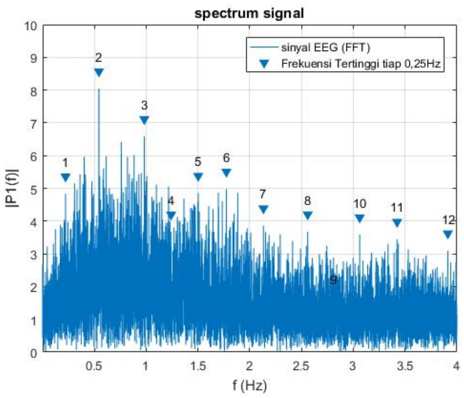

Fig. 10. Signal spectrum of "sad" emotions

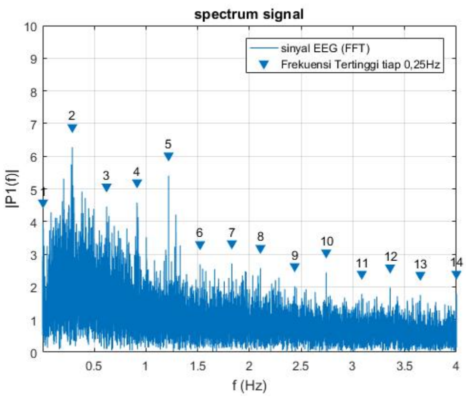

Fig. 11. Signal spectrum of "shocked" emotions

In figure 8, 12 different data obtained in each frequency from 0 - 4Hz with a range of 0.25Hz, emotional graph output is very different starting from the highest that is Focus, Sad, Shocked and the lowest is normal. This is based on an analysis obtained from psychology where the effect on interference and pressure makes the brain performance higher so that the correlation of brainwaves to the subject with the stimulus will be in line. Then proceed to take the value of each frequency contained in Table 3.

TABLE III. THE MAXIMUM PEAK OF ALL TYPES OF EMOTIONS BASED ON SPECTRUM SIGNALS

No	Emotion Types (Hz)			
	Normal	***Focused***	***Sad***	***Shocked***
1	2.8665	11.3798	4.8353	3.9660
2	2.4131	17.5746	8.0422	6.2746
3	2.5042	10.9925	6.5860	4.4555
4	1.9288	8.1166	3.6707	4.5811
5	2.3847	6.3706	4.8527	5.4052
6	2.1723	7.8941	4.9804	2.6893
7	2.4603	4.7945	3.8608	2.7143
8	1.4927	5.5629	3.6754	2.5726
9	2.0089	5.2621	1.2591	2.0168
10	1.4789	3.4735	3.5842	2.4372
11	1.8456	3.4978	3.4489	1.7841
12	1.6929	3.621	3.0951	1.9765
Average	**2.1041**	**7.3783**	**4.3242**	**3.4061**

By looking on the table 2, the results obtained from the values of each frequency from 0-4Hz with a range of 0.25Hz and obtained 12 data from each brainwave that has been processed using FFT, then the results of the table are compared in the form of a line chart in Figure 9.

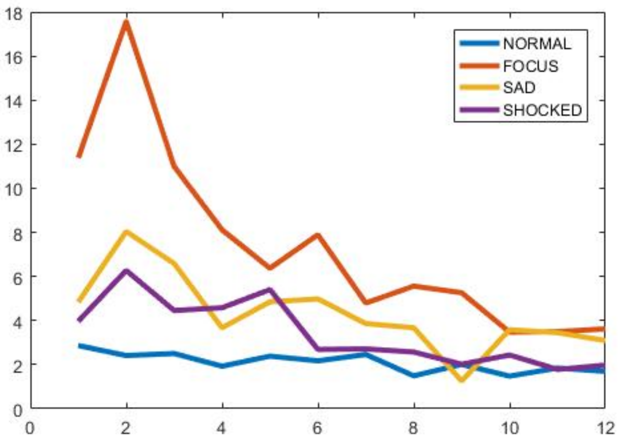

Fig. 12. Result Comparison of All Types of Emotional Frequencies

The results of the comparison of brainwaves in table 3 made into the form of a line chart in Figure 12 seen a significant difference between each brainwave that has been processed from raw data into FFT where there is a difference in correlation between each emotion with the average value the highest meanings are in Emotion Focus (7.3783), Sad (4.3242), Shocked (3.4061), Normal (2,104).

Table 4 shows the extraction results based on statistical features of the maximum peak signal. Based on the characteristics obtained, it can be seen that the type of emotion that is very dominant in providing the stimulus provided is focus. Focus gives 88.54 (43%) of other emotions, namely sad with 25%, shocked 20%, and normal 12%.

TABLE IV. BRAINWAVE STATISTICS FEATURE

Features	**Emotional Types**			
	Normal	*Focused*	*Sad*	*Shocked*
Mean	2,1041	7,3783	4,3242	3,4061
Standard Error	0,1258	1,2115	0,5015	0,4286
Median	2,0906	5,9668	3,7681	2,7018
Standard Deviation	0,4356	4,1967	1,7371	1,4848
Sample Variance	0,1898	17,6126	3,0175	2,2046
Kurtosis	-0,8763	2,0476	1,3216	-0,6754
Skewness	0,0508	1,4273	0,6482	0,7494
Range	1,3876	14,1011	6,7831	4,4905
Minimum	1,4789	3,4735	1,2591	1,7841
Maximum	2,8665	17,5746	8,0422	6,2746
Sum	**25,2489 (12%)**	**88,54 (43%)**	**51,8908 (25%)**	**40,8732 (20%)**

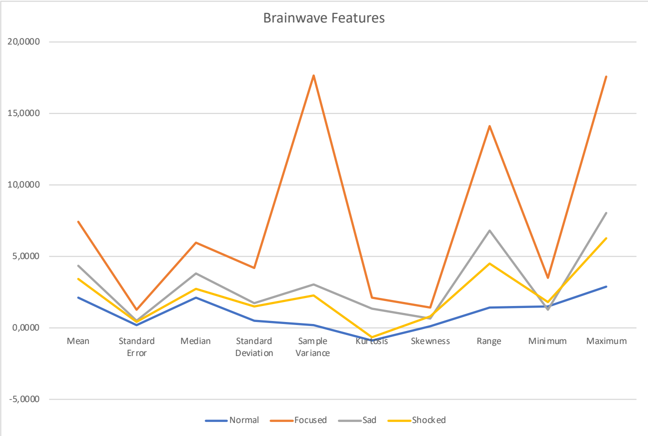

Fig. 13. Statistical features of the maximum peak brainwave signals

From Figure 13 it can be seen that the results of the focus emotions graph are above that of other emotional graphs. This shows a good mental state. The use of stimulation is very influential in determining this mental state. Things to note are sad emotions that have a relatively high yield after focused emotions. Regulations on sad emotions are needed to help improve productivity and mental health conditions.

IV. Conclusion

Based on the results, it showed that each subject has its brainwave pattern based on the stimulus given, so that the subject is in a particular emotional state. While it can be seen the shape and value of the brainwave frequency spectrum using Fast Fourier Transform from each recorded brainwave. From the results of the comparison of the average for each emotion there is still a slight difference between normal and shocked emotions compared to focus and sad, therefore still needed to take more brainwave data records and expand its scope as reviewed in terms of age, gender, and others so that the results of the shape or value of the FFT spectrum can be more accurate and detailed.

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