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Design and Implementation of EEG Signals Analysis on FPGA

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Abstract*: In today's world our life style accumulates too much of stress. This stress is major factor for deteriorating health. To reduce the stress level, meditation is one of the ways. The Electroencephalography (EEG) is characterized by five signals they are Alpha, Beta, Gamma, Delta and Theta. This paper focuses on the analysis of EEG signals of meditating and non-meditating persons. The signals are analyzed using Matlab and Verilog Xilinx 14.7 on FPGA. It was found that the variation of alpha wave in a person who is meditating regularly was less and delta wave density is more compared to a person who is not meditating.*

Keywords: EEG, Delta wave, FFT, FPGA, Heartfulness, Meditation.

1. Introduction

Meditation is the process where by focusing on one thought or thing, we can achieve control over the mind. So meditation helps in reduction of stress. Meditation on a regular basis will reduce the number of symptoms in various illnesses.

Heartfulness meditation is the Heart based meditation in which we are focusing on our Heart. As the heart is center for functioning of the all the organs of the body, meditating on the heart has positive impact on the health of mind and body.

The electrical activity of the brain is mapped using EEG. The EEG highlights brain activity during various actions done.

So measuring EEG we can analyze the effects of meditation on mental health of a person. ref. [5] EEG has been classified into different signals like Alpha, Beta, Gamma, Delta and Theta.

The Alpha signal ranges from 8 to 12 Hz. It signifies relaxed, non-agitated, but not drowsy, conscious state of mind. It physiologically co-relates to relaxed or healing condition. The alpha signal is sub divided into two sub bands as, Low alpha of frequency 8-10Hz: It is mainly associated with inner-awareness of self, mind/body integration. High alpha of frequency: 10-12Hz. It is mainly associated with centering, healing, mind/body connection.
Deals with results and discussions. The paper is concluded in section V.

2. Related Work

Prajakta F ulpatil [1] described the effect of meditation for stress relief. The study of EEG signals was done using the Wavelet transform. The signal recording, filtering and decomposing into different frequency bands was explained in detail. ref. [1]

Jeffrey L [2] explained about different frequency range of the brain signals, and the advantages and disadvantages of training particular frequency signal for the improvement.
For example ,Gamma brain waves are related with mental ability and help to improve memory and perception, whereas, increase in Gamma will results in negative effects such as , becoming more tensed, nervousness and some time even over anxious. ref. [2]

Sivaramakrishnan Rajaraman [3] explained the different types of meditation. The study on brain and heart signal showed that the meditation results in good health and the long time meditation will bring the functional modification in the human organs and will

save approximately $200 per month on the clinical visit of individual health. Both the quantitative and qualitative methods were used to find the solutions for the practical clinical research. ref. [3]

Sun K. Yoo et al [4], explained as to how the attention status are dependent on the performance and how the attention undergoes changes in terms of autonomic and central nervous system by analyzing the EEG and HRV signals and also demonstrated the relationship between brain and heart signals during attention. ref. [4]

Thomas F. Collura, [5] explained about what is EEG, How they are distinguished into different signals of particular frequency, what are their distribution areas, subjective feeling states , the behaviours and tasks associated with them ,and also explained about how the effect of training to a particular signals will result. ref. [5]

Erik Andreas Larsen [6] explained brain computer interface, how the NeuroSky device is made as Brain computer interface, what the brain activities are and how they are measured, what the different patterns of the brain activities are and how they are identified. It is also explained about the EEG signal analysis and the different approach to classify EEG signals, use of FFT and band powers. ref. [8]

3. METHODOLOGY

The real time signals are acquired and processed using Matlab. The EEG signals of different age groups are taken. The signals are recorded before, during and after meditation. The samples are recorded for 3 minutes duration. The processed brainwave signals are converted into frequency domain using FFT because of its symmetric nature. Equation (1) shows the FFT of the signal. Then brainwave signals were separated using Butter worth low pass filter of the order 4 with cutoff frequency 4Hz for delta wave, 8-10Hz for alpha1, 10-12Hz for alpha2 and 0-100 units for Meditation level. Figure 1shows the flow diagram of the EEG signal processing.

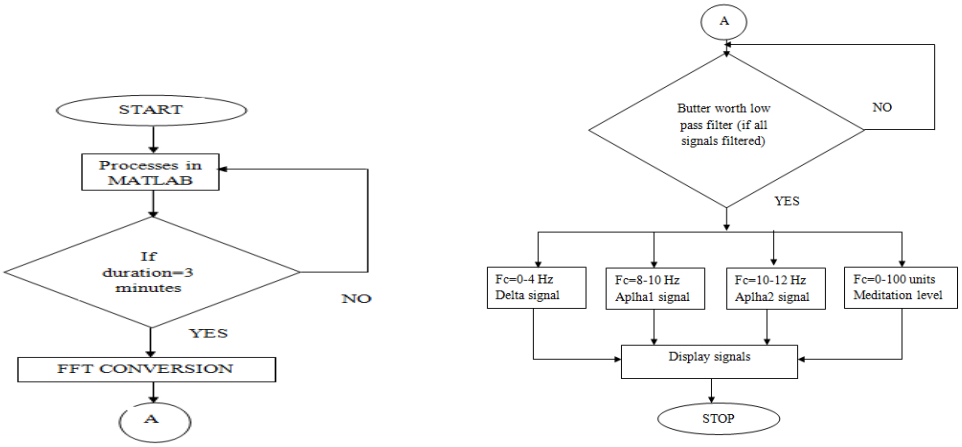

Figure 1: Flow Chart of EEG Signal Processing.

$$X(k) = \sum_{j}^{N} x(i)\omega_N^{(j-1)(k-1)} \quad (1)$$

$$x(j) = (1/N)\sum_{k=1}^{N} X(k)\omega_N^{-(j-1)(k-1)}$$

Where,

$$\omega_N = e^{(-2\pi i)/N} \quad (2)$$

is the root of unity.

The frequency domain converted signals are then filtered using FIR Butterworth low pass filter of the order 4 and in the pass-band and stop-band.

The obtained EEG signal results from the Matlab are then used to implement on an FPGA using verilog code in Xilinx 14.7, by means of doing Erosion, Dilation and Peak valley ref. [17].

The following is algorithm used for the operation of erosion, dilation and peak valley is as shown in figure 2.

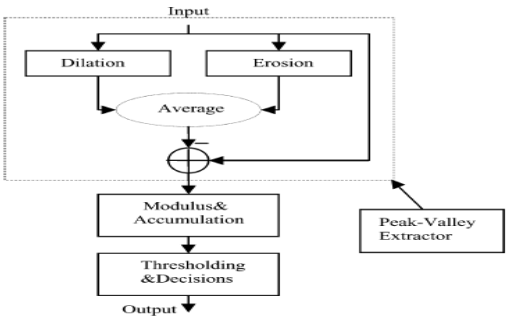

Figure2: Algorithm used for the operation of erosion, dilation and peak valley

$$\text{Dilation}: f \oplus g(n) = \max_{(i)}[(f(n-i) + g(i)] \quad (3)$$

$$\text{Erosion}: f\Theta g(n) = \min_{(i)}[(f(n+i) - g(i)] \quad (4)$$

The erosion and dilation are the morphological mathematical operations they are based on the f(n) is a single dimensional, g(n) is a structural elements.

The opening and closing arte the two extended morphological operations based on the erosion and dilation and are formulated as flowingly.

$$\text{Opening}: f \circ g(n) = (f\Theta g) \oplus g(n) \quad (5)$$

$$\text{Closing}: f * g(n) = (f \oplus g)\Theta g(n). \quad (6)$$

The opening and closing work as the morphology filters with the clipping effect. Resulting in cutting down and filling up the peak valley.

4. RESULTS ANALYSIS

The brainwave signals of 60 samples belonging to different age groups, non-Meditator, Meditator's with varying years of meditation practice were analyzed.

EEG signals of non-Meditator, before, during and after meditation were recorded. A non-meditator was made to meditate for 5 minutes for the analysis purpose. It was found that there was a significant rise in delta wave in youths in the age group of 20-25years and significant dip in the delta wave in the age group of 40 years and above. It clearly shows that the youths are more relaxed compared to the adults in the age group of 40 years and above having family and other responsibilities.

The brainwave analysis of a meditator before, during and after meditation is as shown in Figure 3 and that of Non-Meditator before, during and after the meditation is shown in Figure 4.

The histogram of each signal was plotted to analyze the effect of meditation on brainwave signals.

The Histogram comparison of meditator and Non-meditator was done by considering Aplha1 and Alpha2 signals which range from 8-10Hz and 10-12Hz respectively and are as shown in Figure 5.

From the obtained result, it was found that regular meditator had fewer thoughts as compare to that of a non-meditator. The relaxed state of a person is indicated by the delta wave.

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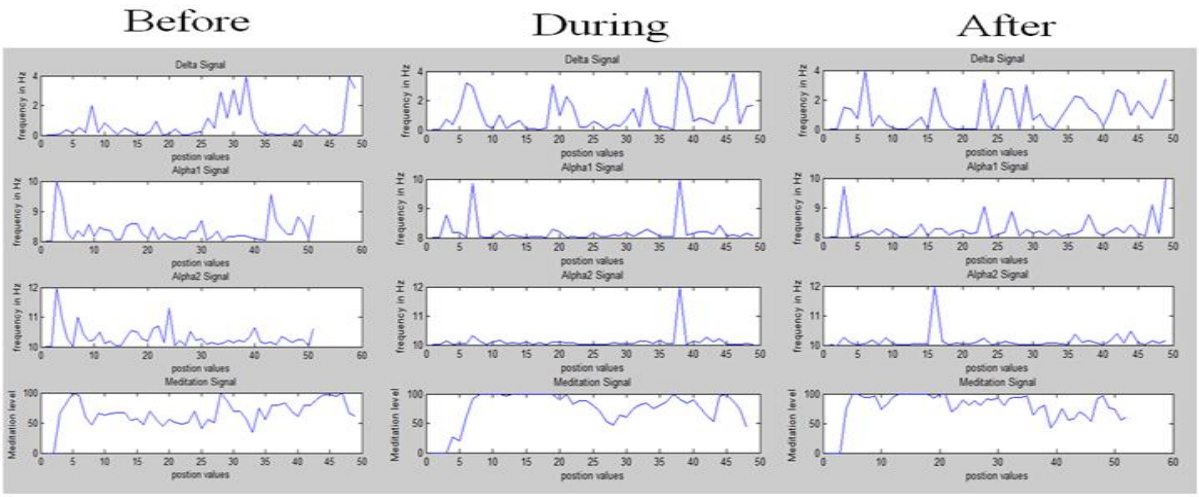

Figure 3: EEG signal analysis of Meditator.

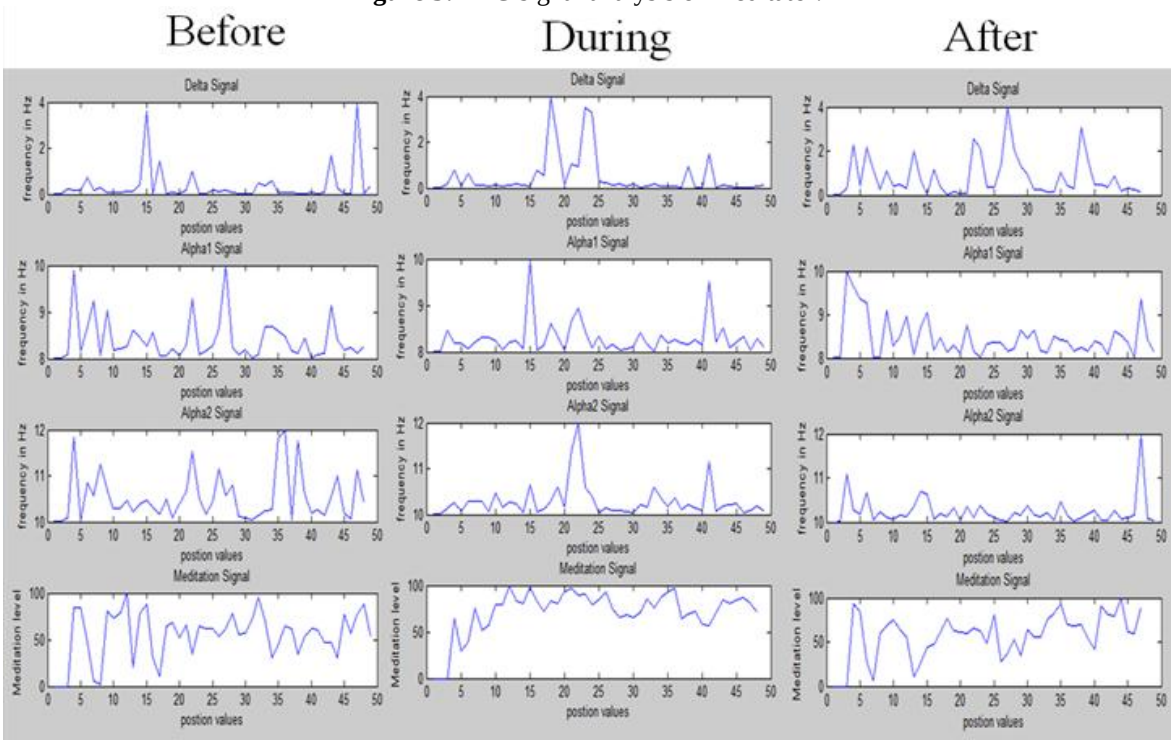

Figure 4: EEG signal analysis of Non- Meditator.

The Histogram results are obtained to compare and analyze the effect of meditation on both Meditator's and Non-meditator in the 3 conditions such as before, during and after meditation.

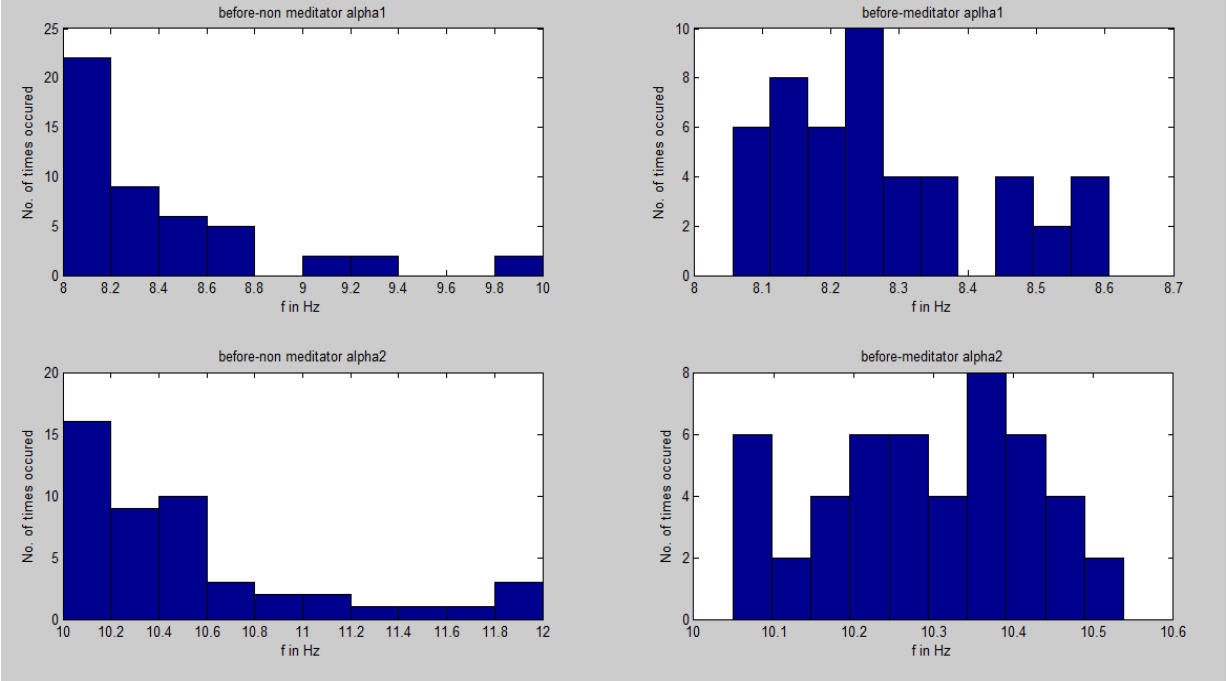

Figure 5: Histograms of Alpha1 and Aplha2 signals of Meditator and Non-Meditator, before Meditation.

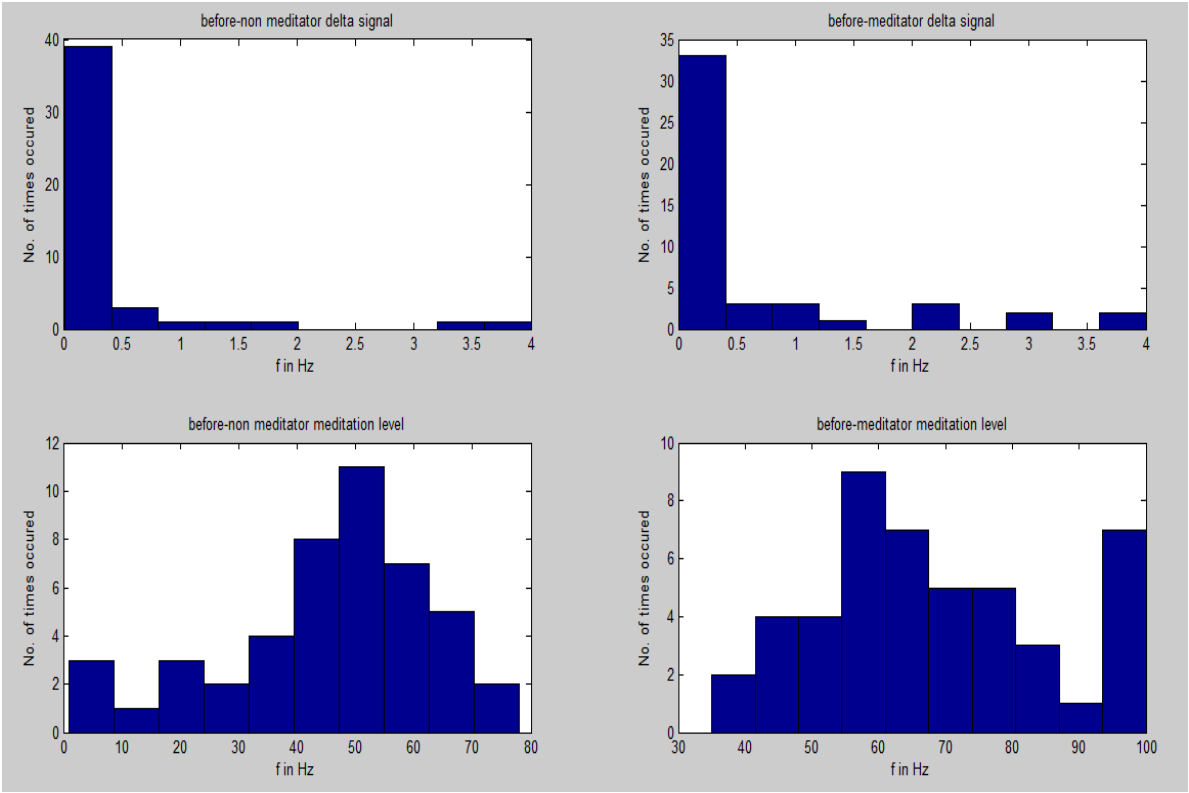

Figure 6: Histograms of Delta wave and Meditation levels of Meditator and Non-Meditator, before Meditation.

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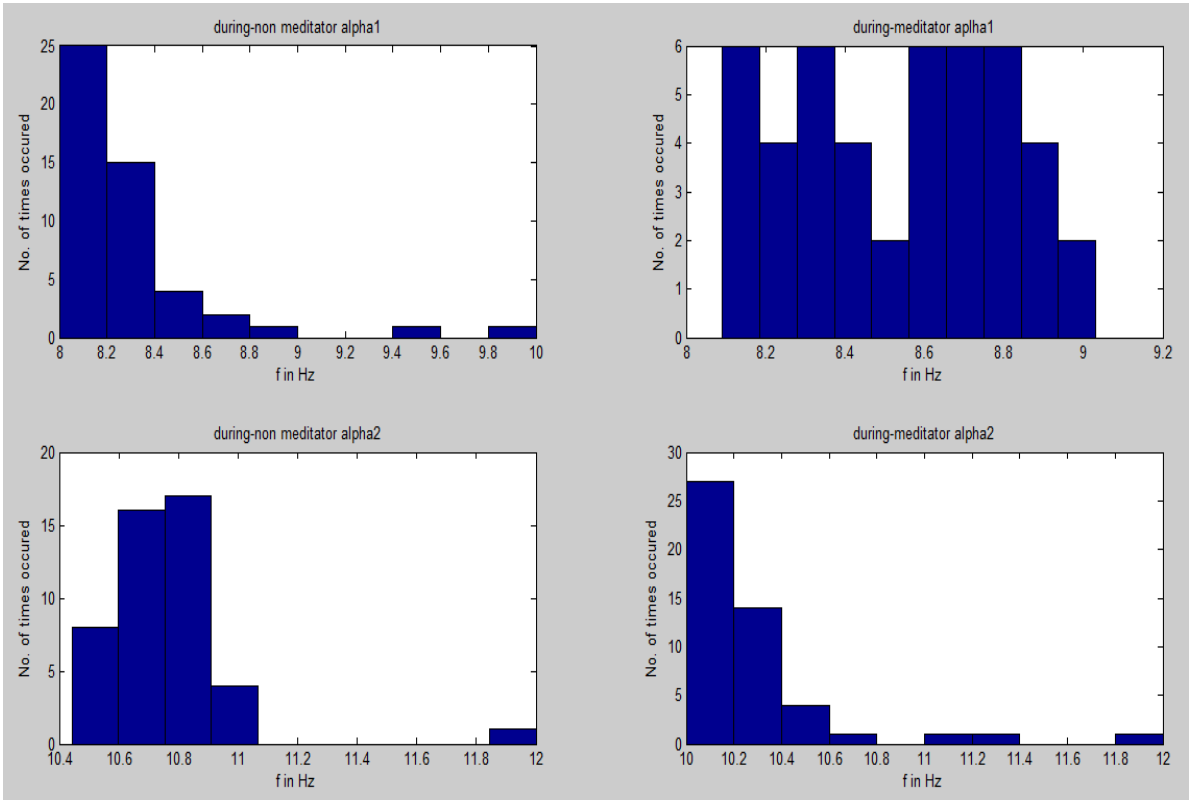

Figure 7: Histograms of Alpha1 and Aplha2 waves of Meditator and Non-Meditator, during meditation

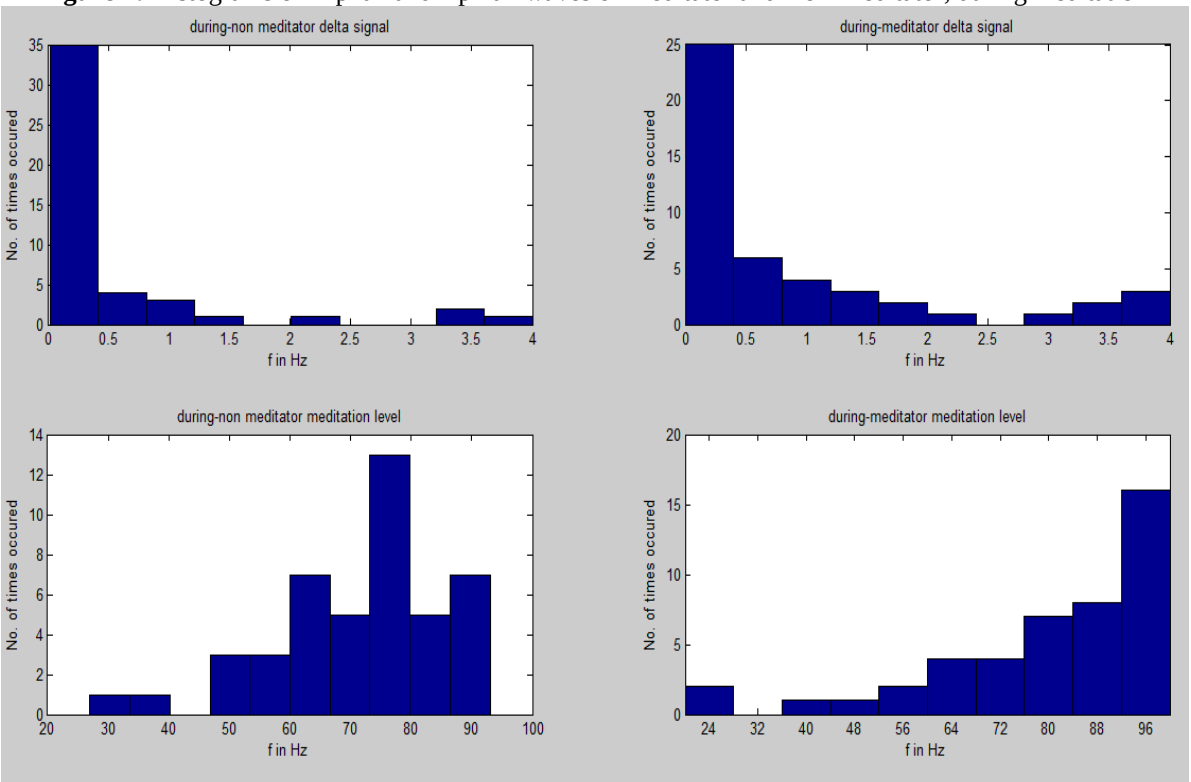

Figure 8: Histograms of Delta wave and Meditation levels of Meditator and Non-Meditator, during meditation

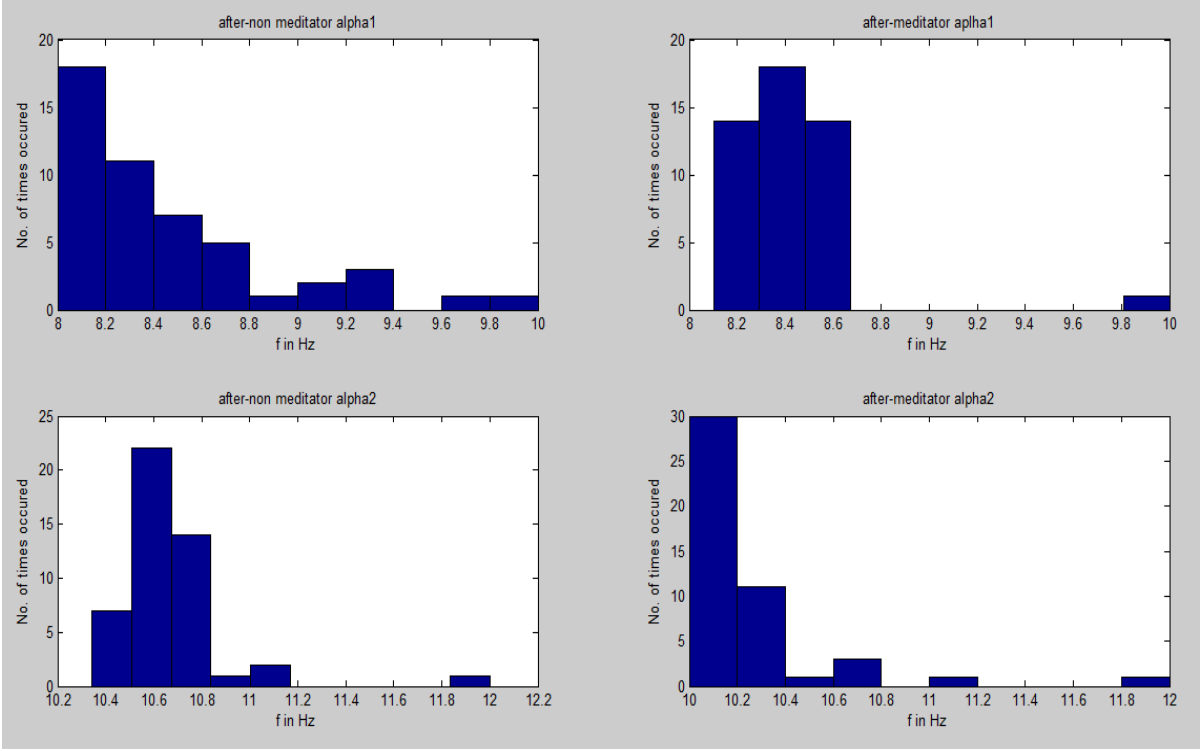

Figure 9: Histograms of Alpha1 and Aplha2 waves of Meditator and Non-Meditator, after Meditation

Frequency	**Non-Meditator**			**Meditator**		
	Before	**During**	**After**	**Before**	**During**	**After**
Alpha1: 8-10 Hz	Max No. Times	Max No. Times	Max No. Times	Max No. Times	Max No. Times	Max No. Times
	8.2-22	8.2-25	8.2-17	8.2-6	8.2-6	8.2-14
	9.4-3	8.4-15	8.8-4	8.25-10	8.3-6	8.4-17
	10-3	8.6-4	9.4-3	8.6-4	8.8-6	8.6-14
		10-1	10-2	No values occurred beyond 8.6 Hz	9-2	10-2
Alpha2: 10-12Hz	10.2-16	10.5-7	10.4-6	10.1-6	10.2-26	10 to 10.2-30
	11-2	10.7-16	10.6-22	10.35-8	10.4-14	10.4-10
	12-3	10.8-17	10.8-14	10.5-2	11.4-1	11.2-1
		12-1	12-1	No values occurred beyond 10.5 Hz	12-1	12-1
Delta: 0-4 Hz	0 to 0.5-39	0 to 0.5-35	0 to 0.5-24	0 to 0.5-33	0 to 0.5-25	0 to 0.5-16
	0.8-2	0.5-4	1-6	1-3	0.8-5	2.5-3
	2-1	3.5-2	2.5-4, 3.5-1	2.5-3	3.5-2	3.5-3
	4-1	4-1	4-1	4-2	4-3	4-3
Meditation Level 0-100	50-11	65-7	60-10	60-9	80-6	75-7
	60-7	75-13	70-9	65-7	88-9	85-8
	75-2	90-7	80-6	100-7	100-17	100-23
			100-4			

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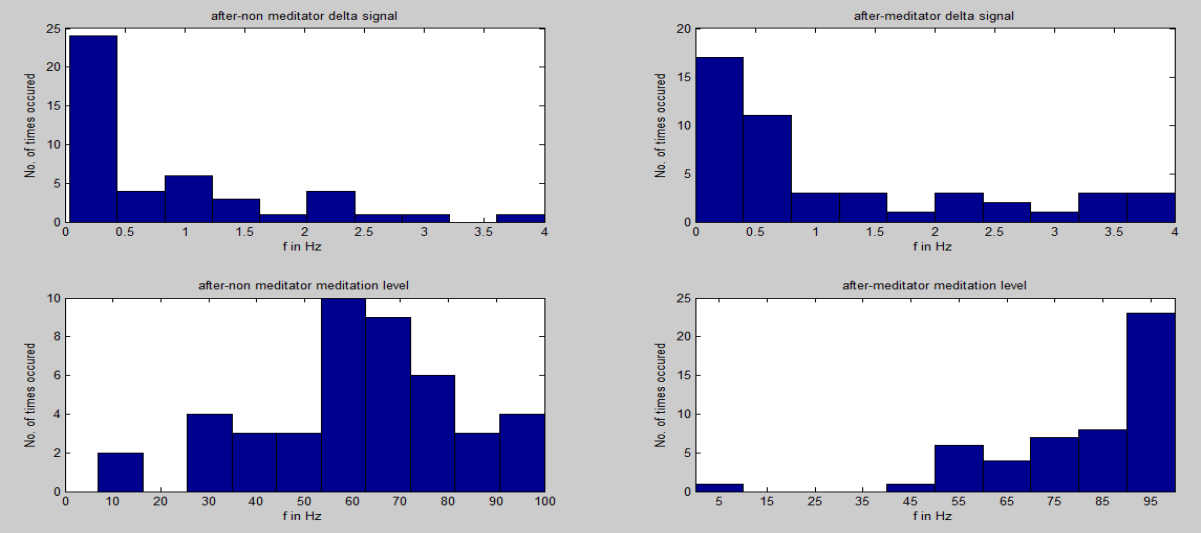

Figure 10: Histograms of Delta wave and Meditation levels of Meditator and Non-Meditator, after Meditation

The obtained Histogram values are tabulated for the comparison results with oneself and the other and are as shown in table1.

Table1: Tabulation of Histogram results

The obtained results are verified, simulated using verilog Xilinx 14.7 and implemented on FPGA Spartan-3 using Chipscope. The Chipscope result of Delta signal after meditation is as shown below figure11.

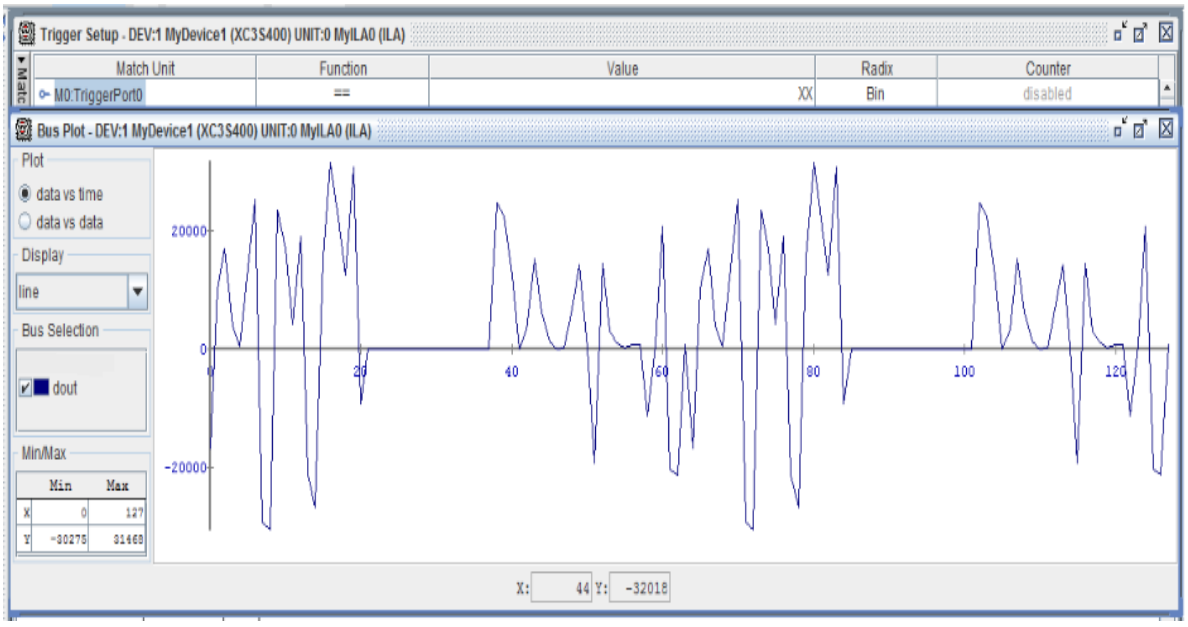

Figure11: The peak valley of obtained delta signal after meditation.

The meditation levels of a meditator and non-meditator before meditation were compared and it was found that a meditator remains in balanced state maintaining same meditation level due to regular practice of meditation.

It was also found that there was a significant rise in delta wave of a meditator compared to that of a non-meditator. From the above figures, it was found that a meditator is better relaxed and less influenced to stress.

As the signals are taken for the short period of time, some of the Meditator and Non-Meditator found to have 3% and 15% respectively more thoughts during meditation because of awareness of the device and the surrounding noise and the thought level in meditator is much less compared to that of non-meditator as shown in figure 7.

It is also found that, there is a significant rise in delta wave and much improvement in the relaxed state during meditation, both in Meditator and Non-Meditator as shown in Figure 8.

In comparison with above two conditions, before and during meditation, there was a significant fall in the Alpha wave after meditation, which clearly indicates the reduction in the number of thoughts after meditation indicating that the mind is more regulated as shown in Figure 9.
After Meditation the Histogram results comparison of Delta and Meditation level signals of Meditator and Non-Meditator are shown in the figure 10.

From above all condition it is best conclude that after meditation both Meditator and Non-Meditator attained the good meditation level and relaxed condition. And hence it is definite that the meditation has very good impact in our health improvement.

The obtained Histogram result values are well comparable to all the conditions with individual and the other. Hence in the above table1 the values are considered in way that, it becomes the self explanatory for comparing the results and analyzing the state of the both Meditator and Non-Meditator.

In the table1 it is observed that the Non-Meditator before meditation the aplha1 which is usually referred to thinking or self/surrounding consciousness.

As observed the aplha1 around 8.2 Hz has occurred 22 times and 10Hz which is maximum value of alpha1 has occurred 3times, during meditation 8.2Hz occurred 25 times , 8.4 Hz 15 times ,10Hz 1 time and after meditation the 8.2Hz occurred 17 times 10Hz occurred 2 times , So comparing the alpha1 of non-meditator it is found that the non-meditator though meditated for the first time the thought level were reduced around 20%, and in comparison with after meditation the thought level is reduced around 7 %.

Similarly aplha2 is also analyzed. In case of Mediator due to regular practice of meditation the thoughts levels were found to be more reduced during and after the mediation, In states such as before, during, after meditation there is good amount of difference in alpha1 and alpha2 of Non-Meditator and Meditator, around 30 % at aplha1 and 50% in case of alpha2 are reduced, as alpha signals are as related to kind of intense thinking or even deep consciousness of body or surrounding.

As mediation mainly results in relaxation which is analyzed from the delta signal and it is found that the both Meditator and Non-Meditator delta signal levels were increased. In case of meditator the regular practice gave a good result in this short period, after observing the table1 the delta signals maximum frequency which is 4Hz, its occurrence is increased 3 times during and after meditation. Even in case of non-meditator the delta signal of 3.5Hz occurred 2 times and 4Hz occurred once. Hence both Non-Meditator and Meditator are found to be better relaxed after meditation.

The meditation level from the simulation and histogram it is very clear that the meditation level in both meditator and non-meditator start becoming steady during and after meditation. In case of meditator they could continue to maintain it even after the meditation.

From above all condition it is best conclude that after meditation both Meditator and Non-Meditator attained the good meditation level and relaxed condition. And hence from the above description it is clear that mediation helps one to become more relaxed, have less thoughts and hence results in high focus, good health of mind and body.

5. CONCLUSION

Today our life style is leading to the high stress, hence heath is measure concern. As Heartfulness meditation is one of way of mediation, this method is leading to the benefit of health improvement. By means of analysing the biomedical signals such as EEG of Meditating and Non-Meditating people it is found that meditation leads to more relaxed condition. Hence it is the one of the scientific approach of proving the benefit of Heartfulness meditation on health improvement, by analysing the EEG signals using Matlab and Verilog Xilinx 14.7 and implementing the signals on FPGA using Chipscope.

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