B. TECH. PROJECT REPORT

ON

STUDY OF THE EFFECTS OF CHANTING ON EEG SIGNAL RHYTHMS

BY

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DISCIPLINE OF ELECTRICAL ENGINEERING

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STUDY OF THE EFFECTS OF CHANTING ON EEG SIGNAL RHYTHMS

A PROJECT REPORT

Submitted in partial fulfilment of
the requirements for the award
of the degrees
Of

BACHELOR OF TECHNOLOGY in ELECTRICAL ENGINEERING

Submitted by:
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Guided by:
Prof. Ram Bilas Pachori, IIT Indore

INDIAN INSTITUTE OF TECHNOLOGY INDORE
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CANDIDATE'S DECLARATION

I hereby declare that the project entitled **"Study of the effects of chanting on EEG signal rhythms"** submitted in partial fulfilment for the award of the degree of Bachelor of Technology in 'ELECTRICAL ENGINEERING' completed under the supervision of **Prof. Ram Bilas Pachori, IIT Indore** is an authentic work.

Further, I declare that I have not submitted this work for the award of any other degree elsewhere.

Pankaj Verma

CERTIFICATE by BTP Guide

It is certified that the above statement made by the students is correct to the best of my knowledge.

Prof. Ram Bilas Pachori

IIT INDORE

Preface

This report on “Study of the effects of chanting on EEG signal rhythms" is prepared under the guidance of Prof. Ram Bilas Pachori.

The present study examined the brain dynamics of oscillatory changes after Hare Krishna maha mantra (HKM) meditation using Fourier Bessel series expansion (FBSE) based rhythms separation method from electroencephalogram (EEG) signals. The main motivation of this study is to show the potential role of mantra meditation in offering relaxation. This research may help to clarify meditation and encourage people who think it as beneficial practice. In this work, I have focused on channel specific alpha rhythm which is associated to relaxation as the outcome of mantra meditation.

I have tried to the best of my abilities and knowledge to explain the content in a lucid manner. I have also added graphs and figures to make it more illustrative.

Pankaj Verma

B. Tech. IV Year

Discipline of Electrical Engineering

IIT Indore

Acknowledgements

I would like to express my sincere gratitude to my supervisor Prof. Ram Bilas Pachori for constantly supporting and motivating me throughout the project and for always giving me new ideas and guiding me in the right direction.

I would like to thank Ph.D. scholar Mr. Kritiprasanna Das for all his valuable guidance.

I would also like to thank my family and friends for always being there with me and for being a source of constant motivation.

I would like to extend thanks to IIT Indore for giving me the golden opportunity to work in fully functional labs and providing all the necessary research accessories required for the project.

It is their help and support, due to which I became able to complete the project. Without their support this report would not have been possible.

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Abstract

Hare Krishna maha mantra (HKM) is believed to be sacred mantra from the ancient time and it is chanted as meditation practice since long time. The present study examined the brain dynamics of oscillatory changes in human brain after HKM chanting. Naturally, mantra chanting produces a state of mind that has a wide-ranging effect on our opinions and actions. The electroencephalogram (EEG) signals are used to capture the state of brain. The EEG signals acquired from human are non-stationary in nature. The advanced signal processing is suitable technique to analyse these kinds of signals. In this study, 32 subjects were asked to perform HKM chanting and EEG signals were recorded with closed eyes before and after chanting of HKM. After that, rhythms (Delta, theta, alpha, beta, and gamma) are extracted in both time and frequency domain from the recorded EEG signals using Fourier-Bessel series expansion (FBSE) method. The rhythm power is calculated and power comparison is done between the rhythms obtained before and after HKM chanting to get new findings into the nature of the EEG due to chanting. The study showed an increase in alpha relative power in channels 3 and 4 after HKM meditation showing relaxation. The study shows the potential role of loud HKM chanting in offering relaxation. It gives the new viewpoint of meditation to the naïve meditators.

Keywords: HKM, EEG, Rhythms, Chanting

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Chapter 1

Introduction

1.1 Meditation

Meditation is being used to regulate willingly one's self attentiveness for relaxation or self-awareness from the ancient time. It includes variety of practices that vary according to region and tradition. Some meditation exercises involve constant focus on fixed repetitive word, phrase or sound (such as OM mantra [1]) chanted either aloud or silently such as mantra meditation. It is being used to reduce stress, anxiety, depression and to increase mental peace and well-being. Hare Krishna Maha mantra (HKM) [2] is believed to be sacred mantra from the ancient time and it is chanted as meditation practice since long time. That is why meditation with HKM is chosen for this study. The present study examined the brain dynamics of oscillatory changes after Hare Krishna Maha mantra (HKM) meditation. Hare Krishna Maha mantra in Hindi language is written as follows.

हरे कृष्ण हरे कृष्ण
कृष्ण कृष्ण हरे हरे
हरे राम हरे राम
राम राम हरे हरे॥

HKM in English language is as follows.

Hare Krishna Hare Krishna
Krishna Krishna Hare Hare
Hare Ram Hare Ram
Ram Ram Hare Hare

1.2 Electroencephalogram (EEG) signals

The electroencephalogram (EEG) is a technique to capture electrical activity of brain under definite psychological states. It is of two types: non-invasive and invasive process [3]. In non-invasive EEG, electrode cap is implanted on the brain scalp. EEG is useful technique for widespread academic research and the diagnosis of epileptic seizure, sleep disorders, coma and other mental disorders which involve abundance or lack of neural activity in certain parts of brain. EEG and functional magnetic resonance imaging (fMRI) [4] have been used as techniques for studies related to meditation and other human brain studies. EEG recording process is cheaper and it has good time resolution. EEG signals contain valuable information related to brain state, which help us to understand physiology and psychology of the human brain. That is why EEG has been used for the study [5].

1.3 Related work

In recent work, a number of studies have been done to analyse the effects of mantra meditation on human brain. Effects of mantra meditation ('OM' chanting) on alpha EEG and galvanic skin response (GSR) have been studied [6]. This study disclosed a significance increase in alpha EEG and GSR values as a result of mantra meditation which advocate the positive effect of relaxation and decrease in stress level. In another study, EEG spectral analysis on OM mantra meditation has been done [1]. In this study, twenty-three naïve meditators were asked to do loud 'OM' chanting for 30 minutes and EEG signals were recorded before and after OM chanting. This study showed an increase in theta power after meditation when averaged across all brain regions.

1.4 Motivation of the work

The main motivation of this study is to show the potential role of mantra chanting in offering relaxation. This research may help to clarify benefits of meditation and encourage people who think it as beneficial practice. Mantra chanting gives us so many benefits like better lungs function, reduction in stress and depression, increased mental peace and environmental awareness. In hospitals, it is recommended to do mantra chanting early recovery due the impressive research. There is many psychological usefulness of mantra meditation which includes reduced heart rate, decreased adrenaline and cortisol level, decreased level of tension

as well as balanced rate of blood pressure. Chanting mantra's vibrations along with a constant deep inhalation process improves the efficiency of the spinal cord and boost up blood circulation to the all body parts by providing more oxygen to the body [7,8]. The EEG signals contain valuable information related to brain state, which help us to understand physiology and psychology of the human brain. The brain state measured by EEG signals is more advantageous because it is difficult to influence electrical brain activity intentionally.

1.5 Objectives

The objective of this study is to analyse the effects of mantra chanting on human brain using Fourier Bessel Series Expansion (FBSE) based EEG signals rhythms.

1.6 Contribution

A new, suitable and effective method (FBSE for decomposition of EEG signal into different rhythms) has been used to analyse the effects of mantra chanting on human brain. The present study showed increased alpha relative power in channels 3 and 4 documenting relaxation [5,9] as an outcome of HKM chanting.

1.7 Organization of the report

The remaining portion of this report is organized as follows: In chapter 2, the method for the implementation of the project has been proposed. It involves EEG signals recording, data pre-processing, rhythm separation using FBSE and rhythm power calculation. In chapter 4, results and discussion have been provided. Finally, the whole work is concluded in chapter 5 and it also involves the direction of future work.

Chapter 2

Proposed Method

EEG signals of 32 subjects with closed eyes before and after HKM chanting is recorded. In next step pre-processing of recorded EEG signals is done. The EEG recording contains the artifacts (Electrocardiogram (ECG), eye-blink, body movement, power line interface etc.). In pre-processing stage, we remove the artifacts from the data recorded. Now pre-processed EEG signal is used to extract rhythms (Delta, theta, alpha, beta, and gamma) in time and frequency domain with FBSE method. Then we compare the power of each rhythm obtained before and after chanting. Since each rhythm has its own significance, conclusion is given on that basis. Figure 2.1 shows the block diagram of the proposed method.

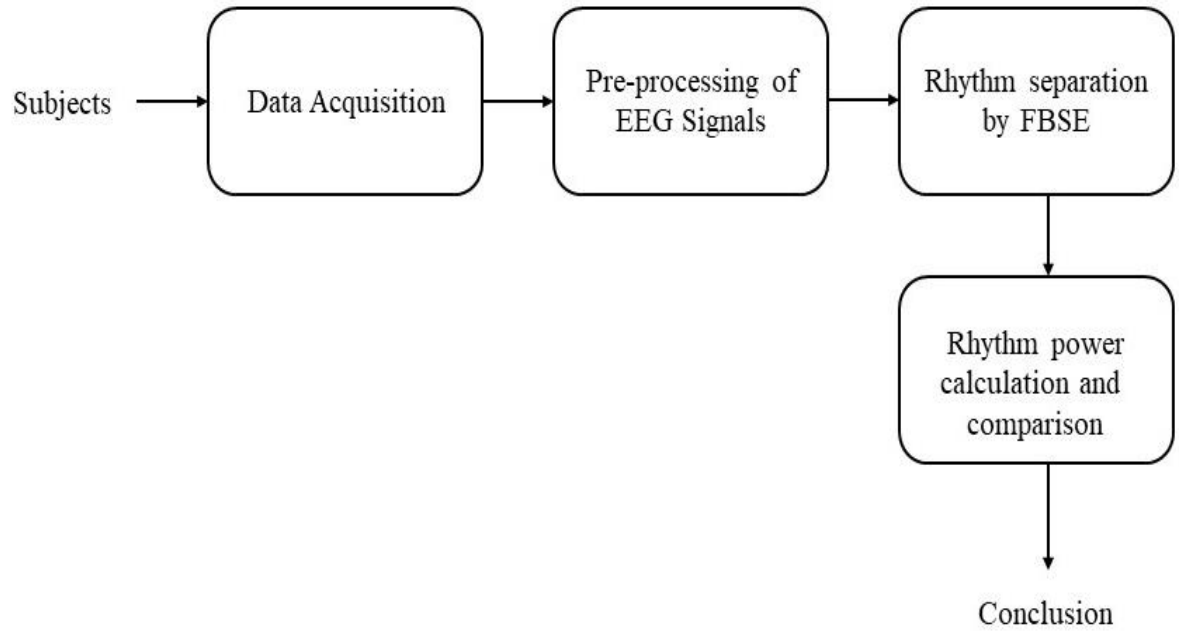


Fig. 2.1 The block diagram of proposed method

2.1 Data acquisition

HKM EEG database was created in the institute's Signal Analysis Research Lab. For acquisition of EEG signals BIOPAC MP150 (data acquisition unit) and EEG 100C (EEG amplifier module) are used. During recording signal has passed through one high pass filter

with cut off frequency of 0.1 Hz and notch filter with 50 dB reduction at 50 Hz. Amplifier gain was 20,000 [5] with sampling frequency of 1000 Hz. Subjects were introduced by the research personnel about the whole experiment after which they were given a consent form to respond voluntarily. Experimental session was started only after signing the consent form. The whole work was permissioned by institute's human ethics committee, IIT Indore.

2.1.1 Subject information

A total of 32 subjects (16 males and 16 females, age group 18-30 years) were asked to perform HKM chanting. They never did HKM chanting. They were college students and staff members. Out of 32 subjects, two of them were left-handed. They were non-smokers and none of them was habitual drinker. They did not have any history of neurological illness.

2.1.2 Experimental equipment for data recording

We use EEG electrode cap which has inbuilt metal disc electrodes, properly placed in fixed position according to 10/20 international EEG recording system [10], to record electrical

(a) (b)

(c) (d) (e)

Fig. 2.2 (a) EEG electrode cap (b) BIOPAC (MP150) data acquisition system (c) Electro-gel for conductivity (d) Disposable sponge disks (e) Disposable glove

activity of human brain. It measures voltage fluctuation of a group of neurons. BIOPAC MP150 and EEG100C are used for data acquisition and amplification. To make proper connection between scalp and metal disc electrode, Electro-gel is used. It has good conductivity. It reduces the impedance between scalp and electrodes and we get better quality of signals [5]. Disposable sponge discs are used for forehead electrodes referencing. Disposable gloves are used to avoid cross-contamination between subject and research personnel. Fig 2.2 shows different equipment and accessories used in our experiment.

2.1.3 Electrode arrangement

EEG signals were recorded using 10 differential channels with 1000 Hz sampling frequency, electrode placement was according to 10-20 international standard for electrode position [10]. The bipolar arrangement of electrodes which has been used in the study is as follows: Ch1 (Fp1-Fp2), Ch2 (F3-F4), Ch3 (C3-C4), Ch4 (P3-P4, Ch5 (O1-O2), Ch6 (F7-F8), Ch7 (T3-T4) , Ch8 (T5-T6), Ch9 (Fpz-Cz), Ch10 (Fz-Pz), GND (A1-A2). Fig 2.3 shows the electrode placement for 10/20 international system.

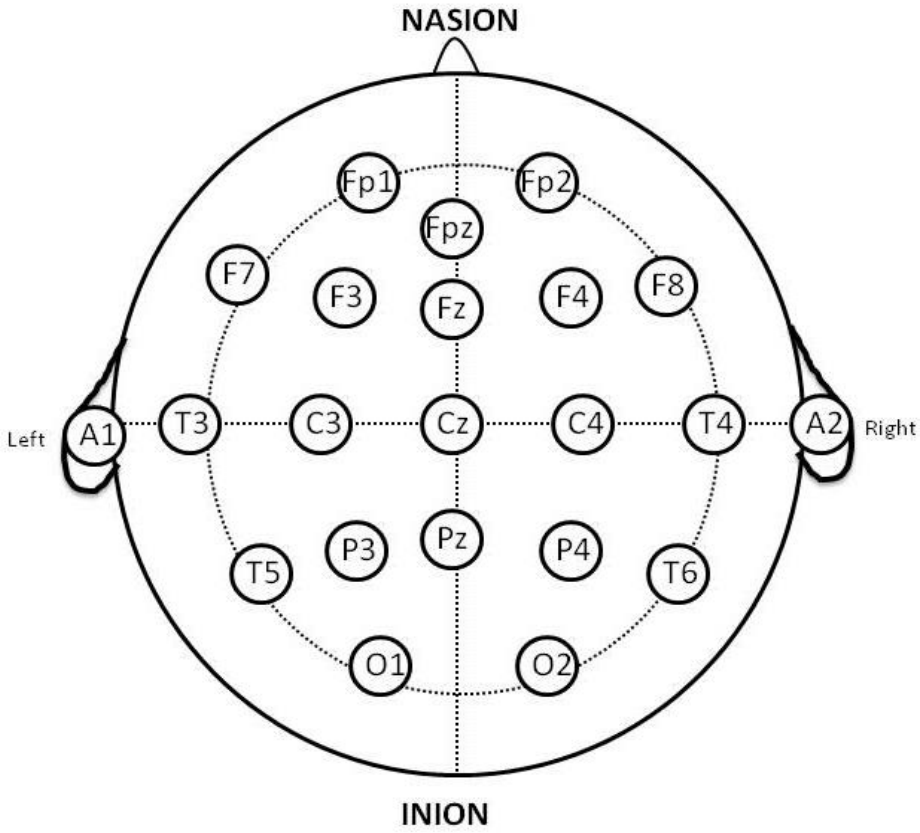
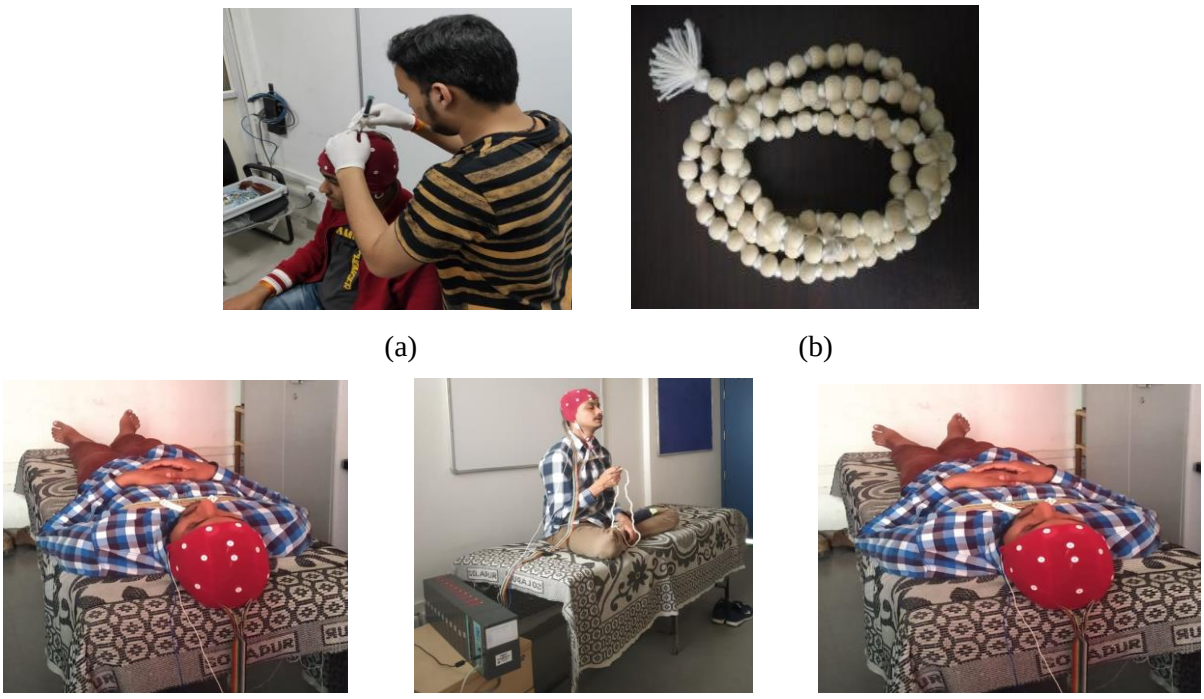


Fig. 2.3 Electrode placement 10-20 international system

2.1.4 Experimental setup for EEG recording

The experimental setup for EEG recording is as follows: At first, subject was asked to lay down while relaxing with closed eyes and no voluntary muscle movement as far as possible, during which EEG signals for 90 seconds were recoded. The recorded signals are called EEG signal before HKM chanting. After this, subject was asked to sit with spine straight, and was asked to chant one round (108 times) of HKM. Subjects were given Japa beads containing 108 beads. They had to touch each bead and chant HKM. They were asked to chant HKM loudly and concentrate on listening the mantra. Three different activities (touch, listening, speaking) simultaneously engage our brain due to that concentration increases. The subject was then asked to lay down while relaxing with closed eyes and minimal muscle movements, during which EEG signals for 90 seconds were recorded. The recorded signals are called EEG signals after HKM chanting. In this way, we get two signals from one subject. In Fig. 2.4, different steps of data acquisition have shown. The block diagram of experimental setup for recording EEG signal is shown in Fig 2.5. Fig. 2.6 shows the raw EEG data of a subject (S01) for channel 3 before and after chanting.



(a) (b)

(c) (d) (e)

Fig. 2.4 Images of experimental setup for EEG recording (a) Preparation for EEG recording (b) Japa beads (c) EEG before HKM meditation (d) HKM meditation (e) EEG after HKM meditation

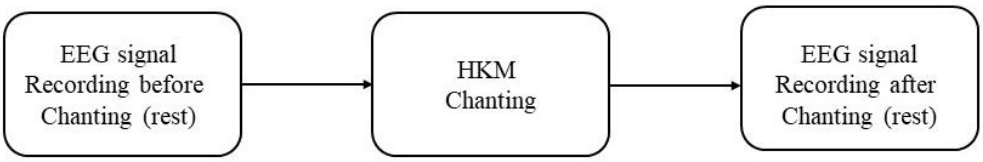
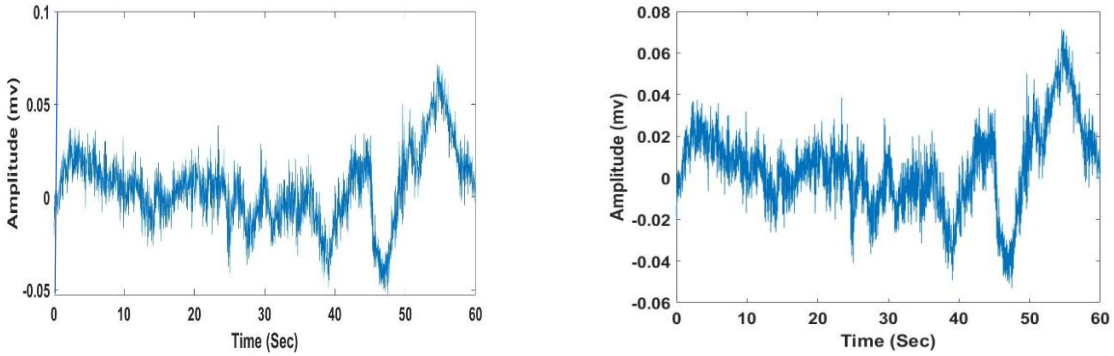


Fig. 2.5 Block diagram of experimental setup for recording EEG signal



(a) (b)

Fig. 2.6 Raw EEG signal (a) before and (b) after chanting

2.2 Data pre-processing

EEG signals captures the state of brain of subject and it contains erroneous information traced from the bodily function like eye-blinking, movements of hands, heart-beats etc. All such electrical activities corresponding to such unwanted phenomenon is called artifacts and that are to be removed since we are focused only on the information that has been aroused due to mantra chanting. In pre-processing stage, we remove the artifacts from the data recorded. Apart from this, EEG signal of first 60 seconds [1] is taken out of 90 seconds for the analysis. The EEG signal is down sampled from 1000 Hz to 250 Hz [5].

2.3 EEG rhythms and their significance

Most of cerebral signal observed in the scalp EEG falls into the range of 0.1-100 Hz [5]. This frequency range is subdivided into bands called as delta, theta, alpha, beta and gamma which are known as rhythms. The significance of different brain rhythms are as follows [5,9].

Delta: It is associated with the mental states deep, dreamless sleep, trance and unconscious. Its frequency range is between 0.1 to 4 Hz.

Theta: Theta waves appear for the mental states like intuitive, creative, recall, fantasy, dreamlike, drowsy and knowing. It lies between 4 to 8 Hz.

Alpha: This rhythm is found in relaxed, non-agitated, conscious state of mind mainly when eye is closed in the frequency range 8 to 13 Hz.

Beta: Beta rhythm is found due to alertness, focused, integrated, thinking, agitation, aware of self and surroundings. Frequency range of beta is 13 to 30 Hz.

Gamma: Thinking, integrated thought or any complex activities are the cause of gamma rhythms. Frequency lies in the range of 30 to 100 Hz.

Using FBSE, EEG signal is transformed into frequency domain and different frequency bands (rhythms) are separated. Alpha rhythm predominantly originates from the central sites (channels c3 and c4) at rest and posterior region of brain [10]. The study focuses mostly on alpha rhythm in channels 3 and 4 since it is associated with relaxation as an outcome of mantra meditation [5,9].

2.4 Rhythm separation by FBSE

Most of the natural signals are non-stationary in nature, this is true for EEG signal also. FBSE is advantageous for non-stationary signal analysis because Bessel functions which are its basis have non-stationary property. The zero-order FBSE of x(n) is expressed as follows [11,12]

$$x(n) = \sum_{k=1}^{S} C_k J_0(\lambda_k n/s), \qquad n = 0,1,2,3.... S-1 \qquad (1)$$

where, C_k are the FBSE coefficients of $x(n)$ and it can be computed by below equation

$$C_k = \frac{2\sum_{n=0}^{S-1} n x(n) J_0(\lambda_k n/S)}{S^2[J_1(\lambda_k)]^2} \qquad (2)$$

where, $J_0(\cdot)$ and $J_1(\cdot)$ are zero-order and first-order Bessel functions, respectively. The positive roots λ_k for the zero-order Bessel function $J_0(\lambda)$ with ascending order are expressed in terms of corresponding frequencies as follows

$$\lambda_k = \frac{2\pi f_k S}{f_s} \qquad (3)$$

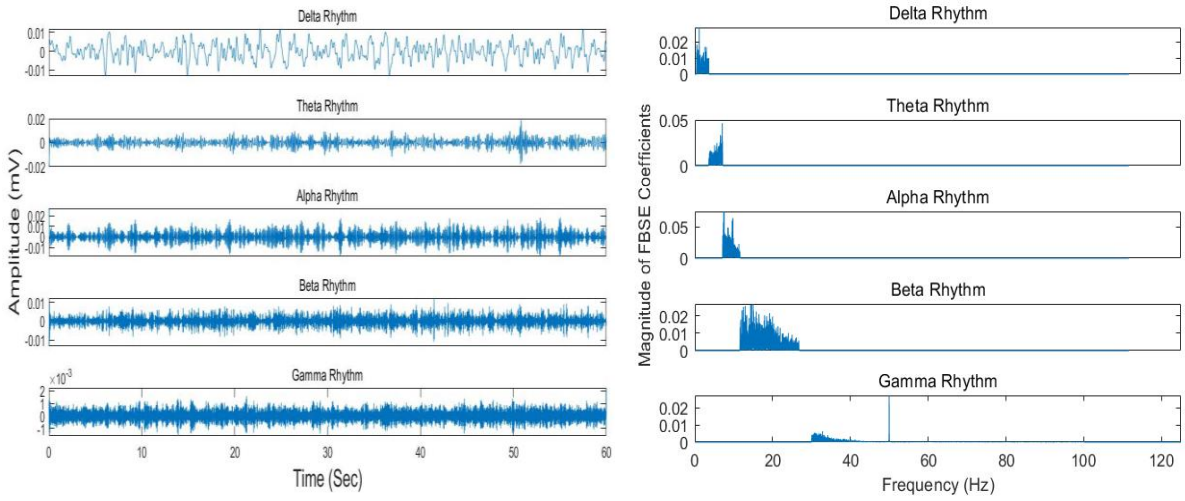
where, fs is the sampling frequency, $\lambda_K \approx \lambda_{K-1} + \pi \approx k\pi$ and $k = 1, 2, \ldots, S$. Therefore, Eq. (3) can be written as follows [13]

$$k = \frac{2 f_k S}{f_s} \tag{4}$$

In Eq. (4), the value of *k* should be varied from *1* to *S* (length of a discrete-time signal) so that it will cover the entire frequency contents of the signal. Hence, the value of *k* can be selected to obtain the coefficients C_k of FBSE corresponding to the different frequency band of rhythms (delta (0.5–4 Hz), theta (4–8 Hz), alpha (8–13 Hz), beta (13–30 Hz), and gamma (30–100 Hz)) of EEG signal. The selected coefficients corresponding to different bands (δ, θ, α, β, and γ) are used in Eq. (1) for obtaining the rhythms of the EEG signal and then Eq. (1) can be written as follows:

$$x(n) = \sum_{k=\delta_1}^{\delta_2} C_k J_0\left(\frac{\lambda_k n}{S}\right) + \sum_{k=\theta_1}^{\theta_2} C_k J_0\left(\frac{\lambda_k n}{S}\right) + \sum_{k=\alpha_1}^{\alpha_2} C_k J_0\left(\frac{\lambda_k n}{S}\right) + \sum_{k=\beta_1}^{\beta_2} C_k J_0\left(\frac{\lambda_k n}{S}\right) + \sum_{k=\gamma_1}^{\gamma_2} C_k J_0\left(\frac{\lambda_k n}{S}\right) \tag{5}$$

where, $[\delta_1, \delta_2]$, $[\theta_1, \theta_2]$, $[\alpha_1, \alpha_2]$, $[\beta_1, \beta_2]$, and $[\gamma_1, \gamma_2]$ are in the order range of 0.5–4 Hz, 4–8 Hz, 8–13 Hz, 13–30 Hz, and 30–86.81 Hz frequency bands of rhythms, respectively. The plot of these rhythms and their corresponding of FBSE coefficients can be seen in Fig. 2.6 and Fig. 2.7 for EEG signal of a subject before and after HKM chanting respectively.



(a) (b)

Fig. 2.7 (a) Plot of rhythms (delta, theta, alpha, beta, gamma respectively), (b) Corresponding magnitude of FBSE coefficient of EEG signal of a subject (S01) in channel 3 before HKM chanting

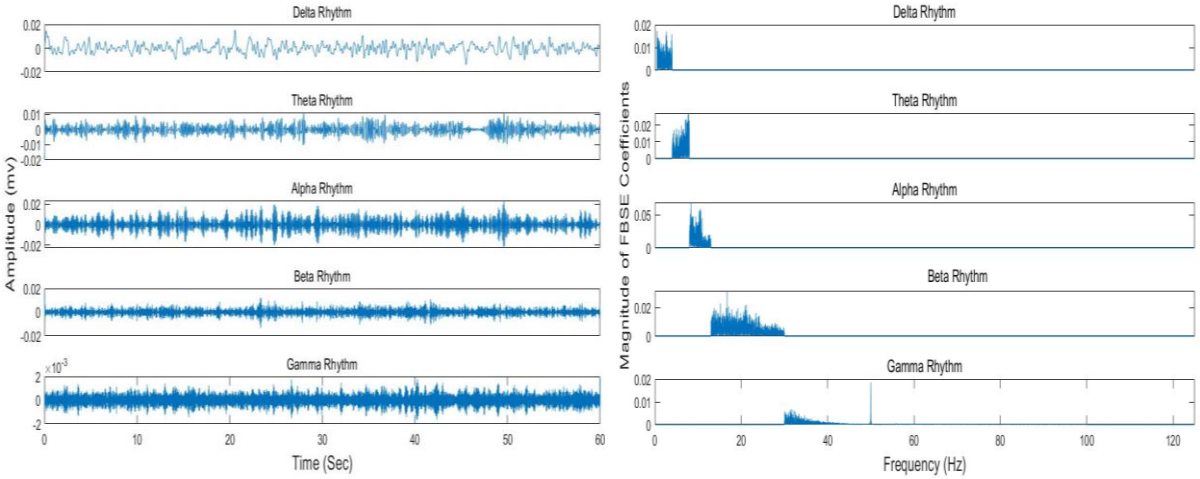


Fig. 2.8 (a) Plot of rhythms (delta, theta, alpha, beta, gamma respectively), (b) Corresponding magnitude of FBSE coefficient of EEG signal of a subject (S01) in channel 3 after HKM chanting

2.5 Rhythm power calculation and comparison

In this process, power of all rhythms obtained before and after HKM chanting is calculated. The Parseval theorem for power of the FBSE expansion be stated as [14]

$$\mathrm{P} = \sum_{k=0}^{S} n\, x^2(n)/S = \sum_{k=1}^{S} C_k^2 \frac{S^2}{2} [J_1(\lambda_k)]^2/\mathrm{S}$$

After that, relative alpha power comparison is done between rhythms obtained before and after HKM chanting [1]. The mathematical expression for relative alpha power is given as follows.

$$\text{Relative alpha power} = \frac{\sum_{k=\alpha_1}^{\alpha_2} C_k^2 \frac{S^2}{2} [J_1(\lambda_k)]^2}{\sum_{k=1}^{S} C_k^2 \frac{S^2}{2} [J_1(\lambda_k)]^2}$$

Comparison between relative power in alpha rhythms before and after chanting is shown in Table 2.1 and Table 2.2 for channels 3 and 4 respectively.

Subject	Relative power in alpha-rhythm before chanting	Relative power in alpha-rhythm before chanting
1	0.443	0.523
2	0.7	0.735
3	0.121	0.183
4	0.443	0.547
5	0.635	0.579
6	0.058	0.332
7	0.522	0.571
8	0.154	0.208
9	0.052	0.057
10	0.154	0.235
11	0.177	0.244
12	0.466	0.581
13	0.045	0.163
14	0.423	0.436
15	0.249	0.313
16	0.437	0.421
17	0.359	0.437
18	0.456	0.508
19	0.283	0.353
20	0.371	0.422
21	0.288	0.41
22	0.387	0.221
23	0.499	0.481
24	0.21	0.364
25	0.17	0.249
26	0.237	0.52
27	0.569	0.565
28	0.296	0.26
29	0.349	0.396
30	0.519	0.522
31	0.513	0.71
32	0.272	0.273

Table 2.1 Relative alpha power before and after HKM meditation for every individual (32 subjects) for channel 3 (Central -C3-C4)

Subject	Relative power in alpha-rhythm before chanting	Relative Power in alpha-rhythm after chanting
1	0.41	0.32
2	0.621	0.687
3	0.778	0.704
4	0.06	0.204
5	0.629	0.683
6	0.342	0.362
7	0.314	0.484
8	0.352	0.306
9	0.404	0.506
10	0.407	0.412
11	0.313	0.304
12	0.543	0.621
13	0.283	0.493
14	0.425	0.459
15	0.585	0.616
16	0.507	0.576
17	0.427	0.308
18	0.621	0.709
19	0.276	0.346
20	0.485	0.553
21	0.48	0.471
22	0.233	0.291
23	0.686	0.701
24	0.349	0.51
25	0.106	0.061
26	0.312	0.586
27	0.541	0.583
28	0.412	0.443
29	0.49	0.562
30	0.729	0.674
31	0.688	0.833
32	0.427	0.503

Table 2.2 Relative alpha power before and after HKM meditation for every individual (32 subjects) for channel 4 (Parietal – P3-P4)

Chapter 3

Results and discussion

Fig 3.1 shows the bar graph of channel 3 which shows comparison between relative alpha power of EEG alpha rhythms obtained before and after HKM chanting. We can clearly see that relative alpha power increases for 26 subjects out of 32 subjects.

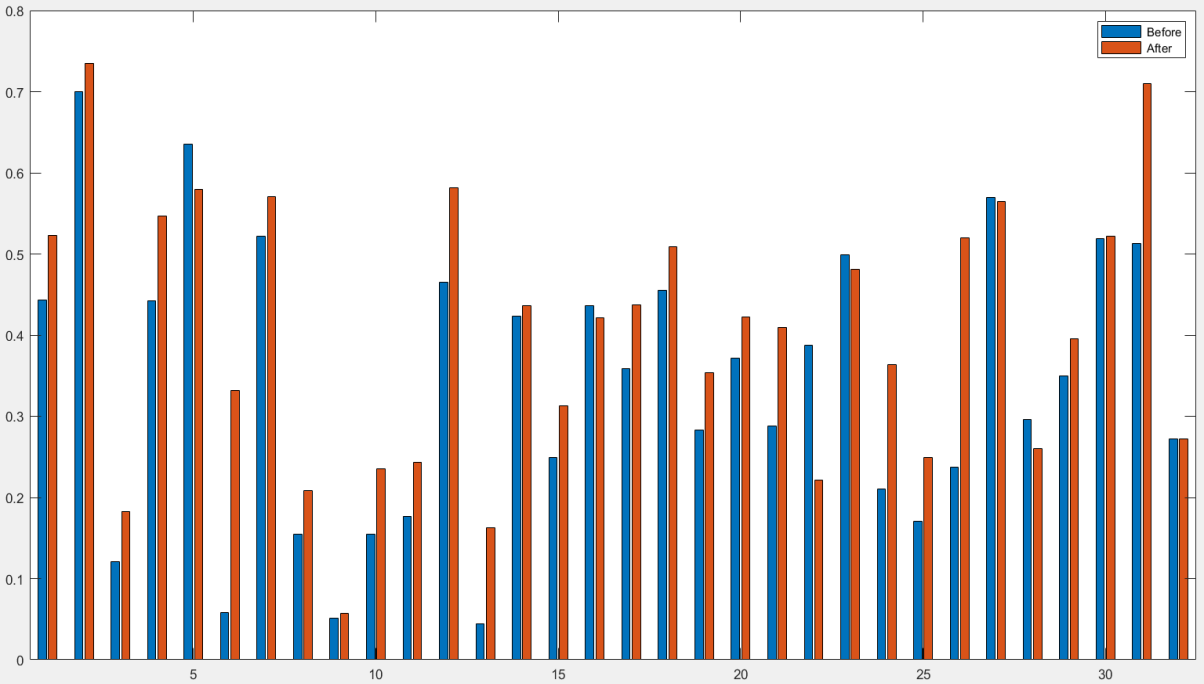


Fig. 3.1 Relative alpha Power before and after HKM meditation for every individual (32 subjects) for channel 3 (Central -C3-C4)

Fig 3.2 shows the bar graph of channel 4 which shows comparison between relative alpha power of EEG alpha rhythms obtained before and after HKM chanting. We can clearly see that relative alpha power increases for 24 subjects out of 32 subjects.

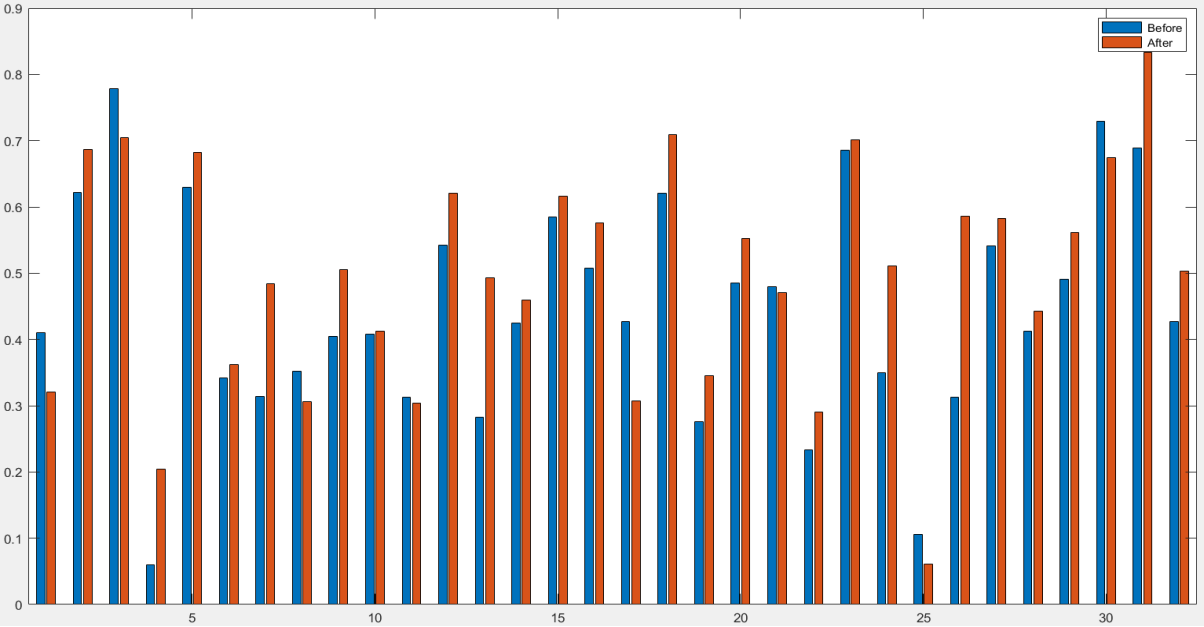


Fig. 3.2 Relative alpha Power before and after HKM meditation for every individual (32 subjects) for channel 4 (Parietal – P3-P4)

The bar graph in Fig 3.3 shows mean relative alpha power before and after HKM meditation for all 32 subjects for channel 3 and channel 4 respectively. So overall mean relative alpha power increases after HKM meditation for channels 3 and 4.

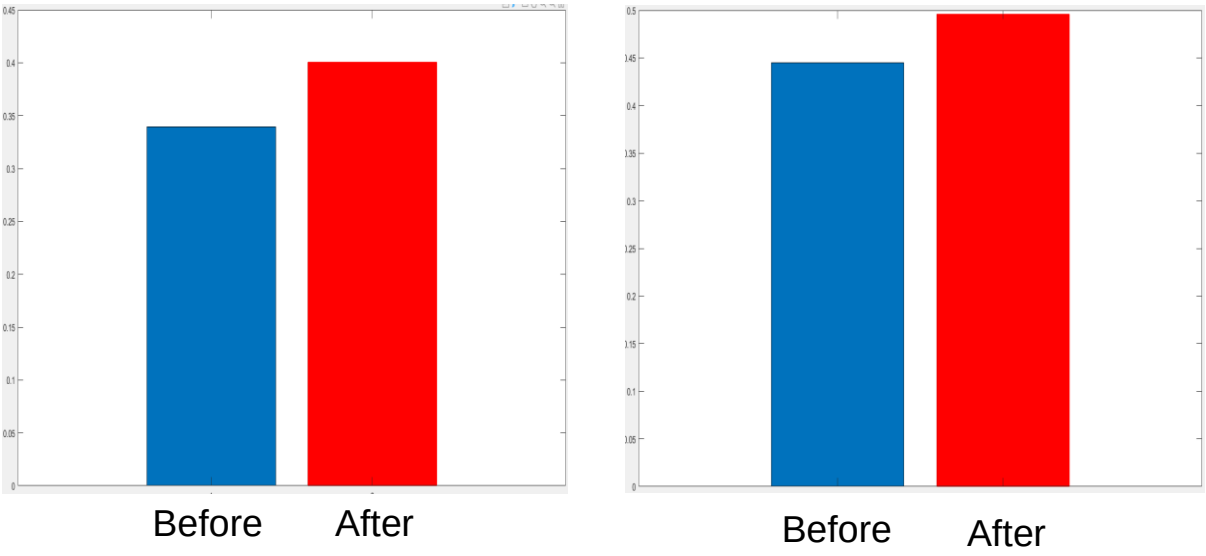


Fig. 3.3 Mean Relative alpha Power before and after HKM meditation for 32 subjects for channel 3 (Central -C3-C4) and channel 4 (Parietal – P3-P4), respectively

Chapter 4

Conclusion and future work

The effects of loud HKM chanting on human brain on the basis of EEG based rhythms obtained before and after HKM chanting were examined. The relative power of alpha rhythm increased in channels 3 and 4 which shows relaxed state [1,6] of human brain after HKM meditation. Results in the present study are based on naïve meditators. It was also seen that alpha brain wave appear with closing of the eyes and with relaxation, and diminishes with opening of eyes or mental effort [1,6].

Further studies are required in the direction of the present study where a bigger data set can be used. Effect of meditation may be shown more prominently if more than one round of HKM chanting is performed. Study can be further done to find the effect of regular chanting for long time period.

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