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Original Article

Evaluating the Changes in Alpha-1 Band Due to Exposure to Magnetic Field

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Abstract

Introduction
Increase in alpha band is observed when blood perfusion in frontal area of head decreases. The present study evaluated some changes in the alpha band particularly, alpha-1 of frontal and central areas of the head, when several areas were exposed simultaneously to magnetic field.
Materials and Methods
Five points of head (F3, F4, Cz, T3, and T4) of twenty healthy male participants were exposed to magnetic fields simultaneously by five separate coils at different frequencies of 45, 17, 10, 5, and 3 Hz, in five separate sessions. The magnetic field intensity was 100 μT at 1.5 cm distance from the coil. At the end, relative powers over these areas in common frequency and alpha-1 bands were evaluated by paired t-test.
Results
Significant reduction ($p<0.05$) in alpha-1 band was observed by exposure of local ELF magnetic field at frequencies of higher than 5 Hz in closed-eye. These reductive effects were enormous at 5 and 45 Hz frequency.
Conclusion
Observed reduction in alpha-1 band may be due to the influence of magnetic field exposure on production centers of alpha band, particularly the thalamus. Hence, increased blood perfusion in some areas is probably the cause of this reduction which requires more research.
Keywords: Alpha Band, Brain Signal, EEG, Magnetic Field

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1. Introduction

We have been exposed to electromagnetic fields in different places such as home and workplace, with the frequency usually ranging from static (DC) to GHz. As a result, many researches have been done to study the effects of extremely low frequency magnetic field (ELF-MF) on biological systems and living creatures, especially humans [1-5].

Some of the researches, paying attention to the importance of the central nervous system especially the brain, concentrated on effects of magnetic fields (MFs) upon the brain-related functions, e.g. the effects of MFs on the performance, perception [6], and memory [7-10]. They often study the possible negative effects of the MFs, especially the AC power (50/60 Hz). However, in practice, it is observed that MFs in some cases have had a positive effect on some diseases such as improving the standing balance by exposure to MF with 200 μT in the head and the neck areas [11] and reduction of tremors in the quality by exposure to MF with 1000 μT [12-14], while the negative effect of MFs in some diseases, especially epilepsy, is partly confirmed [15-17].

In investigating the effect of MFs in the head and neck areas, investigating the effect of MFs on the brain signals of people who are exposed to MFs is one of the most common methods because the EEG records are very fast, non-invasive, and inexpensive method for the diagnosis of brain responses to external stimuli. As it was said before, one approach to deal with MFs effect on the central nervous system is monitoring their possible negative effects. Therefore, there is no appropriate evidence in the evaluation of the brain signals that explain communication between changing of EEG (by exposure to MFs) and possible negative or positive effects. For example, a number of studies examined the effect of MFs on psychological disorders such as depression and anxiety without any attention to changes in the brain signals of the persons who are exposed to the field [18-22]. On the other hand, uniform MFs, usually generated by Helmholtz coils, include all parts of head. Especially, if it is used in the above-mentioned cases. As a result, all neurons and brain productive signal sources (whole brain) are exposed to MFs equally. We have recently found that changes in the brain signal after exposure to local MFs were completely different compared with the exposure of the whole head [23-26].

The brain controls blood supply through the blood vessels by expanding and contracting. Blood flow is controlled to active areas by self-regulation. Blood flow supply combined with oxygen and glucose are known as blood perfusion. Measurement of blood perfusion can be done by imaging techniques such as PET and SPECT. However, these techniques are often considered invasive due to injection of radioactive materials. Some researchers showed that the brain's electrical activity or EEG has a special relationship with cerebral perfusion which is able to show reduction of blood perfusion for example, in patients with ADD/ADHD [27]. In these cases, a reduction in alpha-1 and theta rhythms has been seen in the forehead [28]. The Exposure of magnetic field in an area of head causes changes in the alpha band seen particularly in alpha-1 band [23]. In the present study, by the exposure in several areas of the brain simultaneously, we are going to further evaluate changes in the alpha band, particularly alpha-1 band in areas of the frontal and central parts of the brain.

2. Materials and Methods

2.1. Subjects, EEG Measurement and Magnetic Field Design

Study sample consisted of randomly selected male students, from those enrolled for M.Sc. & Ph.D. program at Tarbiat Modares University. Twenty male students volunteered to participate in this research and the mean age and the standard deviation (SD) of the sample were 23.5±2.5 years. All participants were right-handed. None of them had the history of mental illness such as epilepsy and chronic headaches which lead to taking medication. None of them were addicted to drugs or alcohol and no history of smoking was given. They were prohibited to drink coffee or tea at least three hours before the recording sessions. Each person volunteered without the knowledge of exposure session, came twice to get the exposure and recording of the brain signals. The period of time between two sessions was between 2 to 7 days, depending on the time constraints of the participants. MFs were produced by using five separate coils (2 cm in diameter, 0.5 cm in height) consisting of 250 turns of copper wire No. 0.30 (wire thickness and coated rubber). Applied electrical current to the coil was such that produced MF by the coil on the main axis, distance 1.5 cm from the skin surface had an intensity of 100 μT. Selection of an intensity of 100 μT was due to observation of multiple effects of MF on central nervous system [8, 24-26, 29-31]. On the other hand, the center of each coil was fixed upon one of these points: T4, T3, F3, Cz, and F4. In order to maintain vertical state on the skull due to stability of EEG electrodes in the center of coil and the electrode wire passed under the coil, a ring of Plexiglas with a diameter of 3 mm and a gap on the stability of the electrode wires to pass through EEG were attached to the coil (Figure 1).

In order to reduce the effects of peripheral MFs, the recording of the signals was done in the Faraday cage with dimensions of 2.2×1.8×1.2 m, size of netting mesh covering the cage was 2 mm and was made of aluminum frame. Three gas lamps were used without transformer for lighting the test site. In order to record brain's signals from Flexcomp set (Thought Technology, Montreal, Canada) used by five electrodes, the activity of brain in areas T4, T3, F3, Cz, and F4 was recorded as monopole. The ground electrode was attached on the forehead. For recording EEG, 2 to 50 Hz pass filter was used as well as the notch filter in 50 Hz in order to minimize EMG noise and to remove eye movement. Sampling rate for device was 992 Hz and experiments were performed from 03.00 pm to 08:30 pm.

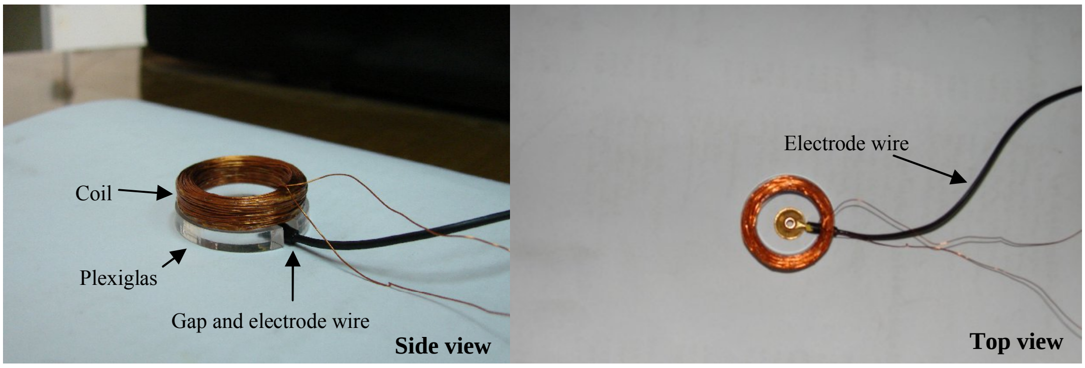

Figure 1. MFs were produced using a coil (2 cm in diameter and 0.5 cm is height). The coil was fixed to a C-shape ring of Plexiglas with 3 mm in thickness. The gap on the ring was for crossing the electrode wire of EEG.

2.2. MFs Exposure

The procedure of MFs exposure is that the signal generator produces the current with 2 sec ON and 3 sec OFF intervals. During the 2 sec, the sinusoidal MF had respectively one of the frequencies of 45, 17, 10, 5, and 3 Hz. In other words, in five-sec intervals during the exposure, 2 sec MF exposure was present.

During the three-sec pause, we had actually the recording of the EEG without noise and disturbance caused by the exposure. Total exposure and five-sec records were good enough that at least 20 healthy records (without blinking and eye movement) were removed (2 min). This action had been done for open-eye and immediately after for closed-eye state, with a twenty-sec pause to the stability of the closed-eye state (Figure 2).

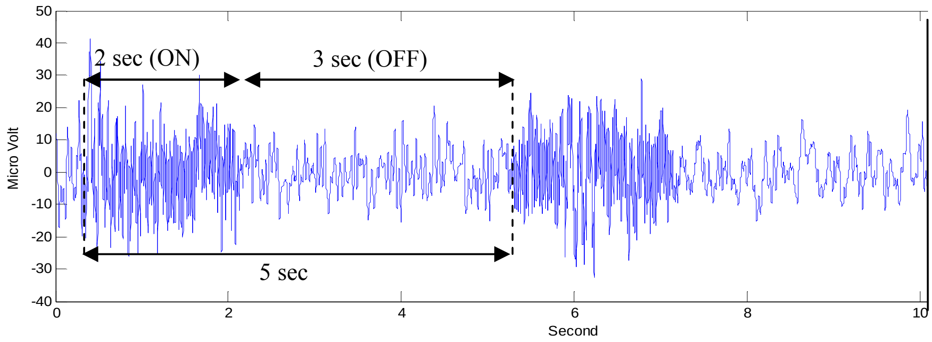

Figure 2. A typical EEG recording from the Cz point exposed to 45 Hz ELF-MFs. Vertical axis is signal amplitude in (µV) and horizontal axis is time (sec).

2.3. Procedure of Exposing and Recording

After placing the electrodes at the 5 points (T3, T4, F3, F4, and Cz), a recording protocol of 2 min of open-eye and 2 min of closed-eye was done to find out the EEG base-line for each participant. Then, the coil was randomly placed on one of the five points by a flexible band. Next, two subsequent pairs of open- and closed-eye records were done, each with 2 min duration with twenty-sec intervals. Two more records were then immediately taken concomitant with the exposure of ELF-MF. This facilitates comparison of signals recorded before and during the MF exposure. Cook and others did not confirm the existence of a significant persistent effect for more that 7 min after 15 min of ELF exposure [32]. Therefore, the next round of record and exposure were implemented after 10 min in a similar manner at another point with the respective frequency to guarantee the absence of persistent effect caused by the first record. Finally, after applying the exposure to the five points, a record was again taken in the absence of the coil, 10 min after the exposure on the fifth point, similar to the first record (Figure 3). It is worth noting that the above procedure was also implemented for the sham group sessions, but the signal generator did not produce any electrical signals thus there was no MF.

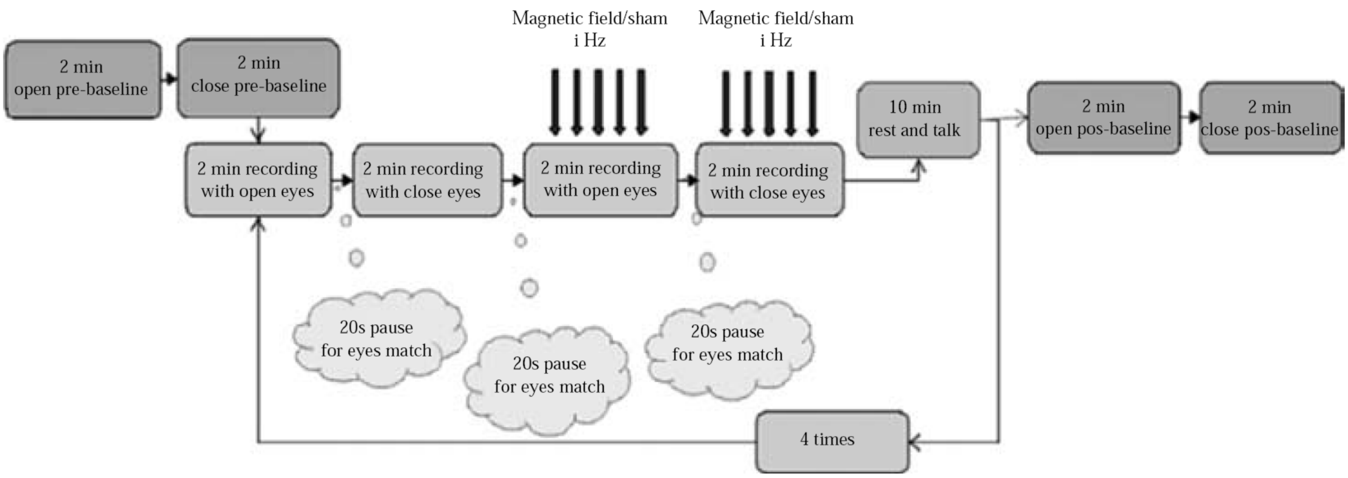

Figure 3. Each 120 min session consisted of 5 stages plus two base-line recordings prior and subsequent to them. The two-min recordings were separated with a twenty-sec pause between them.

2.4. Data Analysis

In each record, the two-sec segments, which were between the three-sec pauses (Figure 3), were extracted using MATLAB software (MathWorks, Natick, MA, USA). Twenty noiseless segments were selected for each state of open- and closed-eye as well as before and during the exposure. Moreover, for the control group who did not receive exposure, two-sec records with three-sec pauses between them were performed similar to the field exposure. Frequency analysis of the EEG was subsequently carried out using Fast Fourier Transform (FFT) along with Hanning filter. After averaging the power spectra of the 20 segments and obtaining a power spectrum with low fluctuation, contribution of each EEG band and its relative power spectrum was extracted. The analyzed frequency bands included: Delta (2.5 – 4 Hz), Theta (4.5 – 7.5 Hz), Alpha (8 – 12.5 Hz), Alpha-1(8-10 Hz), Alpha-2 (10.5-12.5), Beta (13–30.5 Hz), and Gamma (31 – 47.5 Hz). The EEG signals before and during the exposure were also compared using paired t-test at the significance level of $p<0.05$.

3. Results

In order to investigate the effect of MFs on brain signals, especially alpha-1 band, the relative power, before and during exposure, was extracted separately in the binary states in open-and closed-eye states and was investigated by paired t-test with significance level of less than $p<0.05$. The results are summarized and represented in Table 1 and Figures 4 to 10. In Table 1, the recorded places of brain's signals and frequencies of MFs exposure have been determined. In addition, the effects of relative power of the spectra can be compared before and during exposure by paired t-test and bands that had significant changes ($p<0.05$) accompanied by the standard error and mean (mean ± SE) of difference in relative power in each band before and during the exposure. Up and down arrows display increase and decrease of the related band, respectively.

Table 1. The exposure results of the five points by 100 µT ELF-MF.

Recorded point / Frequency	F3	F4	Cz	T3	T4
45	Alpha ↓ (0.055 ± 0.019) Alpha-1 ↓ (0.059 ± 0.016)	Alpha ↓ (0.055 ± 0.023) Alpha-1 ↓ (0.061 ± 0.019)	Alpha ↓ (0.063 ± 0.024) Alpha-1 ↓ (0.066 ± 0.024) Theta↑ (0.035 ± 0.011)	Alpha ↓ (0.043 ± 0.020) Alpha-1 ↓ (0.047 ± 0.019)	Delta↑ (0.037 ± 0.014) Alpha ↓ (0.052 ± 0.020) Alpha-1 ↓ (0.051 ± 0.019)
17	Alpha1 ↓ (0.037 ± 0.014) Beta↑ (0.014 ± 0.007)	Alpha1 ↓ (0.040 ± 0.016)	Alpha-1 ↓ (0.058 ± 0.017)	Alpha-2 ↓ (0.026 ± 0.010)	Alpha-2 ↑ (0.024 ± 0.010)
10	N.S*	Alpha-1 ↓ (0.035 ± 0.015)	Alpha-1 ↓ (0.040 ± 0.018)	N.S*	Theta↑ (0.031 ± 0.014)
5	Alpha-1 ↓ (0.060 ± 0.018)	Alpha-1 ↓ (0.047 ± 0.015)	Alpha-1 ↓ (0.063 ± 0.020) Delta↑ (0.020 ± 0.009)	Alpha-1 ↓ (0.054 ± 0.019)	Alpha-1 ↓ (0.029 ± 0.014)
3	Alpha↓ (0.037 ± 0.016) Beta↑ (0.014 ± 0.006) Theta↑ (0.014 ± 0.006)	Beta↑ (0.014 ± 0.006)	N.S*	N.S*	N.S*

↓Increased power spectra, ↓ Decreased power spectra, * Not significant in all defined EEG bands in context.
Significant changes of EEG bands in five measurement points are presented as Mean ± SE.

The observed changes in open-eye state were limited and according to the purpose of this article were ignored to express. In Figure 4, the relative power values of alpha band before and during MF are given In all areas (frontal and center), the relative power of alpha band was significantly decreased.

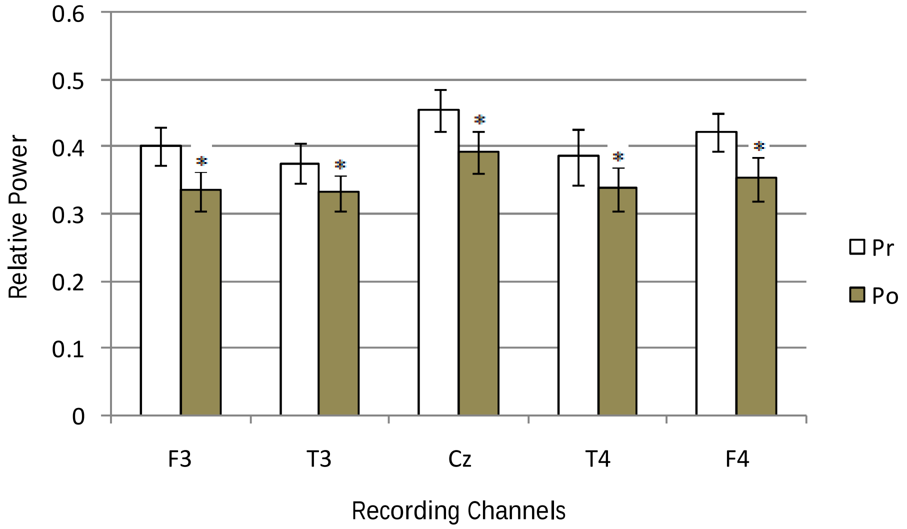

Figure 4. Relative power alpha bands of recorded EEG during (MF) and prior (Pr) to the exposure; ELF-MFs in closed-eye state (Mean ± SE) when all of F3, T3,Cz, T4, and F4 points have been exposed to 100 µT MF in 45 Hz frequency. Significant effect ($p<0.05$) is shown with "*".

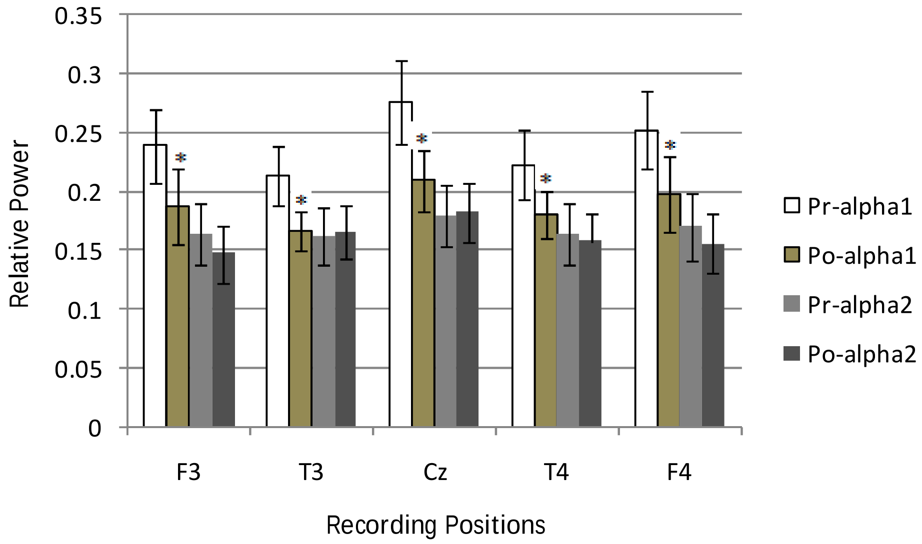

Figure 5. Relative power of alpha-1and alpha-2 bands of recorded EEG during (Po) and prior (Pr) to the exposure; ELF-MFs in closed-eye state (Mean ± SE) when all of F3, T3,Cz, T4, and F4 points have been exposed to 100 µT MF in 45 Hz frequency. Significant effect ($p<0.05$) is shown with *.

The observed decrease in the alpha band was concentrated on the low frequency band (alpha-1), which caused about 20% reduction in the alpha-1 band in all channels. The display values of the relative power in the alpha-1 and alpha-2 during and before exposure can be seen in Figure 5.

The exposure of 17 Hz MF in the closed-eye, the relative power of alpha-1 band reduced in all channels compared with the previous exposure. The mean difference of the relative power in alpha-1 band during and before the exposure MF is visible in Figure 6. In this graph, the sham group (zero intensity) is also displayed, which was not significant statistically.

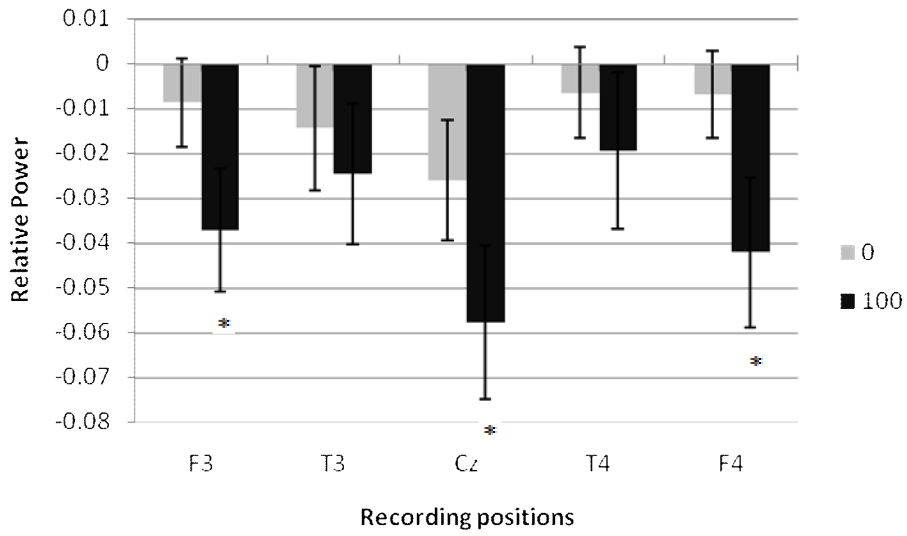

Figure 6. Subtract of relative power alpha-1 band of recorded EEG during and prior to the exposure; ELF-MFs in closed-eye state (Mean ± SE) when all of F3, T3,Cz, T4, and F4 points have been exposed with 0 (sham) or 100 µT MF in 17 Hz frequency. Significant effect ($p<0.05$) is shown with "*".

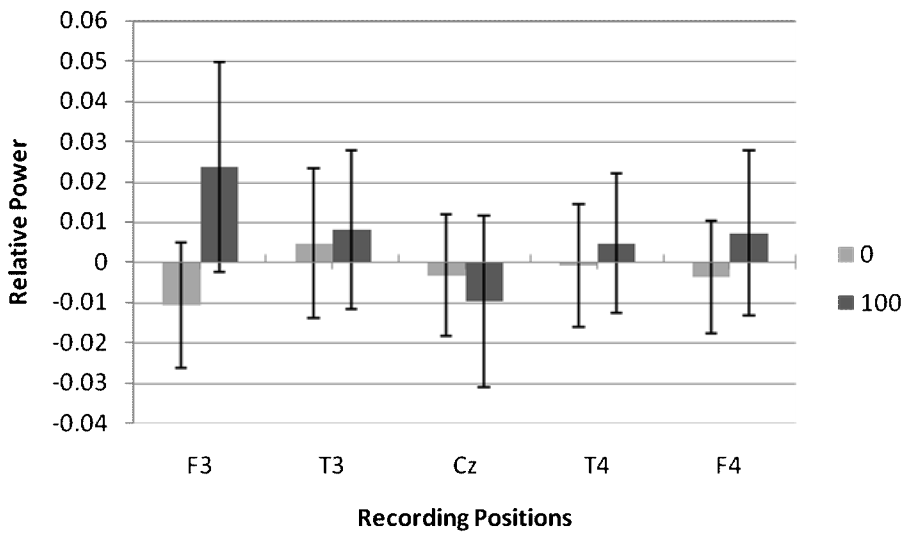

Figure 7. Subtract of relative power alpha band of recorded EEG during and prior to the exposure; ELF-MFs in open-eye state (Mean ± SE) when all of F3, T3,Cz, T4, and F4 points have been exposed to 0 (sham) or 100 µT MF in 10 Hz frequency. Significant effect ($p<0.05$) is shown with "*".

When the frequency of MF had been reduced to 10 Hz in the third stage, the relative power of alpha band during exposure and prior to the MF exposure was not changed statistically in the open-eye state.

While in the fourth stage, the five points of the brain have been exposed to the MF simultaneously with a 5 Hz frequency by five coils, the observed changes in the EEG recorded in closed-eye state were often observed in all areas through the coordinated reduction in the relative power of alpha-1 band (Figure 8). The rate of changes was very little in beta- and gamma-band and the mean difference of relative power during and before exposure is presented in Figure 9.

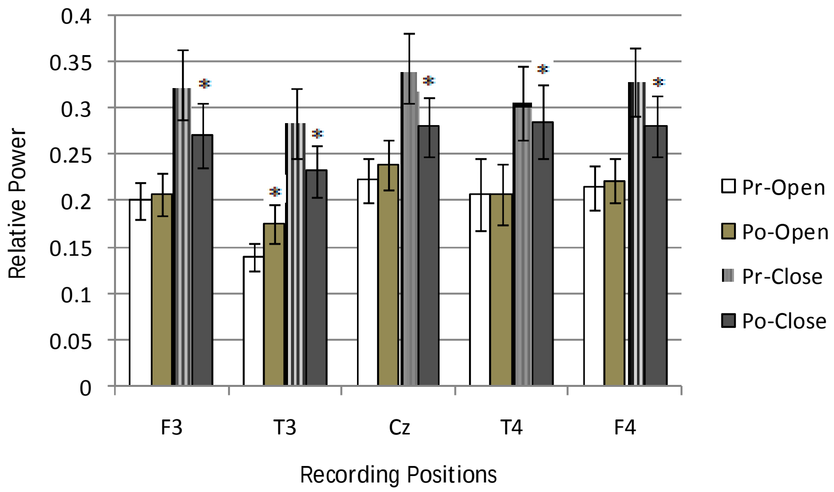

Figure 8. Relative power alpha-1 band of recorded EEG during (Po) and prior (Pr) to the exposure; ELF-MFs in open- and closed-eye state (Mean ± SE) when all of F3, T3,Cz, T4, and F4 points have been exposed to 100 µT MF in 5 Hz frequency. Significant effect ($p<0.05$) is shown with "*".

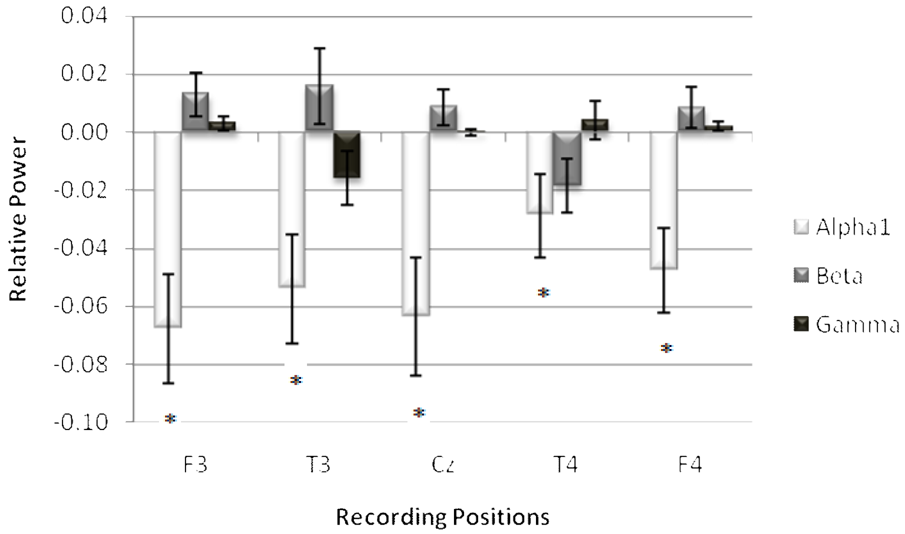

Figure 9. Subtract of relative power alpha-1, beta, and gamma bands of recorded EEG during and prior to the exposure; ELF-MFs in closed-eye state (Mean ± SE) when all of F3, T3, Cz ,T4, and F4 points have been exposed to 100 µT MF in 5 Hz frequency. Significant effect ($p<0.05$) is shown with "*".

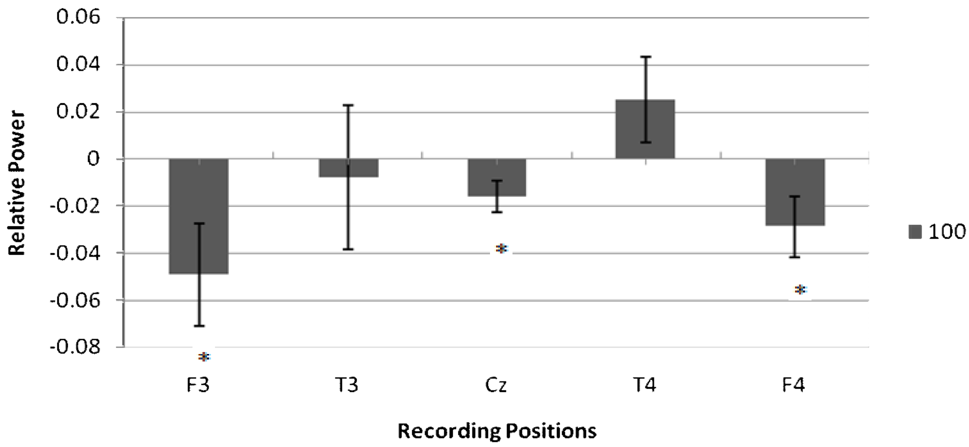

Figure 10. Subtract of relative power alpha band of recorded EEG during and prior to the exposure; ELF-MFs in open-eye state (Mean ± SE) when all of F3, T3, Cz, T4, and F4 points have been exposed to 100 µT MF in 45 Hz frequency. Significant effect ($p<0.05$) is shown with "*".

4. Discussion

MF with frequency of 45 HZ and an intensity of 100 µT reduced alpha band in the frontal and central areas in the closed-eye state (Figure 4). The observed reduction was concentrated more on low-frequency alpha band (alpha-1). This effect can be seen clearly by showing the relative power of the alpha-1 and alpha-2 during and before the exposure in Figure 5. This phenomenon, with little difference in the extent of affected area is observed in the 17, 10, and 5 Hz (Figures 6 and 8). According to some researchers' reports, alpha-1 band increases by the reduction of cerebral blood perfusion, thus maybe the reduction mechanism of alpha-1 band relative power that happened in the MF exposure can be justified by an increase in blood perfusion. Consequently, it can be suggested that the MF exposure with the above conditions to evaluate the blood perfusion can be performed using PET, SPECT, or FMRI. In addition to examining the changes in blood perfusion by the effect of MF exposure, the possible origin of these changes in the brain can be distinguished which can help to understand more areas that are more effective in the MF exposure.

In Table 1, it can be seen that the effect of the MF on alpha band in closed-eye state is mainly on the alpha-1. On the other hand, we know that at the time of activation of the sense of vision, hearing, etc., alpha band decreases. When the eyes are closed, this effect is more visible because the decrease in alpha band during visual sense activation is very strong and intense, that was named as alpha-blocking. Moreover, MF with the intensities of 100 and the frequency of 45 causes a reduction in the alpha, especially in the alpha-1 when eyes are closed, and in other frequencies also a decrease in alpha-1 in the closed-eye state were observed. Therefore, it may be concluded that an MF (unlike the other senses) is felt directly by the brain. Because in the open-eye state due to dominant blocks, the above effect of MF was not observed (Similar to the activation of the other body senses in the open-eye state). Perhaps, it can be said that the area of the brain which is affected more by the MFs, feels the MFs directly. In further confirmation of this opinion, it can be mentioned that two sources of alpha band of cortex and thalamus are considered in this case. The more different senses are activated, the more influence on the thalamus can be seen which cause a reduction in the alpha band. Reduction of alpha and alpha-1 bands are applied by exposure of MFs seems not to be from cortical origin. Because If we consider the relationship between the reduction of the alpha-1 band and disturbing the harmony of cortex neurons, beta and gamma bands should consequently increase with the same proportion in which such effect was not observed in this study (Figure 9). Besides, in our previous research, one of the mentioned areas had been exposed under MFs with the intensity of 100 µT and a reduction in alpha-1 band similar to this study has not been observed even in the exposure area [25]. Therefore, the possible reduction in the alpha-1 band is due to the influence of MF on the cortex which is very low. Therefore, the origin of changes should be connected to somewhere other than the cortex which regarding to the thalamus is another important center of the alpha-generating and MF effects directly on this area is not too far-fetched, although we require further investigation and research.

Nevertheless, some researchers report that the brain's ineffectual reception of the frequency of 20 Hz and higher [31, 33], during 45 Hz MFs, significantly changes in the brain's signals whether in open- or closed-eye states (Table 1). Unlike some researchers, no changes were observed in the resulted waves from the forehead in the MFs exposure [30, 32, 34, 35]. In the present study, significant effects were observed in areas of local exposure. The roots of this conflict can be explained by the method for applying MFs to the brain. As it was discussed in the introduction, often in investigations of MFs on the brain, MFs are used uniformly and cover the entire head.

Two mentionable phenomena that require further investigations are: firstly, no effective reception of alpha-1 was seen in the MF with frequency below 5 Hz (3 Hz), because reduction of alpha-1 in frontal and center areas has been observed in the closed-eye coordinately and equally in almost all frequencies that were more than 5 Hz (Table 1). Secondly, the wide effectiveness of brain in harmony with the reduction of alpha-1 band took place every five-point in frequencies exposure of 5 and 45 Hz.

In the open-eye state, the effect of 45 Hz MFs exposure was the reduction of beta band in the central and frontal areas (Figure 10). Inhibitory effects of beta band in open-eyed state can be important psychologically. One of the most common methods for inhibiting beta duke is the reduction of beta band in the forehead [36]. This effect can be observed in the exposure of 45 Hz MFs. Therefore, it can be suggested to investigate the effects of the exposure in 45 Hz MF to 100 µT in order to inhibit beta duke. It is essential to mention that the beta duke or the excess beta is intensive. It is also in coordinated activity with beta-band which this pattern can be seen among 10% of patients with ADD/ADHD [37], mood disorders, and bipolar disorder [36]. Moreover, it can be observed in 20% of people with epilepsy before the beginning of an epileptic attack.

5. Conclusion

Local ELF-MFs reduced relative power of alpha band in the frontal and central areas in the closed-eye state. The observed reduction was concentrated more on low-frequency alpha band (8-10 Hz). Therefore, it may be concluded that the local ELF-MFs with less than 45 Hz frequency (unlike the other senses) is felt directly by the brain. Observed reduction in alpha-1 band may be due to the influence of magnetic field exposure on production centers of alpha band, particularly the thalamus. Hence, increased blood perfusion in some areas is probably the cause of this reduction which requires more research.

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