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Low Frequency Rotating Magnetic Field Generator And Its Application in Blood Pressure Regulation

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Abstract
On the basis of predecessors' research and the existing theory, for convenient and reliable to study the biological effect of low frequency rotating magnetic field, design a high precision and low frequency rotating magnetic field generator, which could be used to stimulate the small area. Choose stepper motor to drive permanent magnet for produce a rotating magnetic field, which can reduce the magnetic field coverage area and improve the positioning accuracy. Adopt high precision stepper motor controller and step motor to control motor speed for high precise frequency of the rotating magnetic field. Using the motor controller can output three road motor control pulse at the same time, to realize frequency is 1-15 Hz, 0.3-0.4 T surface magnetic field strength and three same characteristics rotating magnetic field. Using light touch switch and LCD display for the frequency, the direction of the spin magnetic control

and time parameter et al. The results show that the low frequency rotating magnetic field generator working stability, high precision, no electromagnetic radiation. Through the experiment, it is found that a rotating magnetic field can affect blood pressure through cerebral cortex, has different effects on blood pressure by using different frequencies, the effects on blood pressure is not the same because a different position focused by magnetic field. The instrument can be used for the experiments of precise positioning on the human body, safe and reliable spin, also can be used for large sample groups of experimental animals and cells. The rotating magnetic field has obvious biological effects and would be widely used.

Key words: LOW FREQUENCY ROTATING MAGNETIC FOELD, BIOLOGICAL EFFECT OF MAGNETIC FIELD, STEP MOTOR, CEREBRAL CORTEX, BLOOD PRESSURE REGULATION.

1. Introduction

The biological effect of magnetic field has always been a hot spot in biomedical research. Lots of research at home and abroad from different angles discussed the impact of the magnetic field on the central nervous system [1, 2] and cardiovascular system [3, 4]. Magnetic field has also some effects on plant nerve, the blood pressure, heart rate and breathing [5, 6]. These studies provide evidence that the magnetic field can adjust plant nerve system through stimulation of the brain cortex, to improve the function of cardiovascular system [7, 8], but it has not still been reported so far that the rotating magnetic field could regulate blood pressure through cerebral cortex. This article aims to design low frequency rotating magnetic field generator, which provides laboratory equipment for studying spin magnetic biological effect, and apply to experiment on blood pressure regulation.

Generally, there are two methods to produce a rotating magnetic field, one is to use coil magnetic field as the terminal part [9, 10], which alter the intensity, frequency and direction of the rotating magnetic field by controlling the size of the flows through a coil of alternating current (ac) and direction. This method of rotating magnetic field intensity and frequency adjustment is convenient, but will produce electromagnetic radiation, the coil volume to produce high strength magnetic field is very big, and can't satisfy the needs for accurate positioning, illuminate lesser area in magnetic biological effect study. Another way is to use the motor driving the rotating permanent magnet to produce a rotating magnetic field [11, 12]. Dc motor has the characteristics of high price cheap, rotational speed, is the most commonly used, but its speed easily affected by external resistance, the control voltage, etc, so as to produce a rotating magnetic field frequency with lower accuracy, that needs to add the speed feedback control circuit. Stepper motor speed control method is different, its frequency is easy to control, high precision, simple circuit and the software design. By comparing the characteristics of the two motors, according to the experiment requirement, in this paper selected step-motor to drive permanent magnet for a rotating magnetic field, through the single-chip microcomputer control stepping motor drive, and control motor, high accuracy low frequency rotating magnetic field generator in the development.

2. Methods and Principles of Rotating Magnetic Field

The rotating magnetic field generator is designed in this paper to choose single chip microcomputer as control chip, developed high frequency precision, speed and stable gyromagnetic. General design method of the magnetic field generator is fixing permanent magnet with the different strength on a shaft of stepper motor, control the turning speed of the motor, which could adjust the frequency of rotating magnetic field. Rotating magnetic frequency is determined by the step motor rotation speed, and the intensity and coverage of magnetic field is decided by the strength and size of permanent magnet. It is described as below that the strength calculation of permanent magnet magnetic field and the design methods of the rotating magnetic field generator.

2.1 Calculation Method of permanent magnet magnetic field intensity

According to the knowledge of electromagnetism, after uniform magnetization, permanent magnet internal will produce molecular electric current, but its effects will cancel each other out, the effect of a magnet inside current ceased to exist, only exist in the surface current. According to Biot and Gore's theorem, the space magnetic induction intensity is produced by the surface of the permanent magnet electric current [10]:

$$B(z) = \frac{\mu}{4\pi} \int_s \frac{k(z') \times e_Z}{\left| z - z' \right|^2} ds \qquad (1)$$

In formula (1), μ is magnetic permeability in a vacuum, $k(z^/)$ is the surface current density vector, z is magnetic field space point coordinates, $z^/$ is the origin of the space coordinates, e_Z is a unit vector, s is the surface of the current distribution area. A single permanent magnet magnetic induction intensity of an arbitrary point in space can be calculated according to the formula.

2.2 Method of Stepper Motor Drive Control

Choose stepper motor driving permanent magnet to produce the rotating magnetic field, which causes were mentioned as above. Inevitably stepping motor also has its own disadvantages, is prone to shocks when frequency is low, the big noise, when the frequency is higher and throw the step. How to improve the stability of the system and solve the problem of system noise, are key determinants of instruments to be put into use. For many tests of experiment and debugging, from two aspects of motor control and mechanical design, find the solution of the problem. According to the results of the study found that by adjusting the motor drives the fine component can solve the problem of step motor in the low frequency oscillation, and reduce the operating noise of the instrument.

Step the entire drive, [0 °, 90 °) total effective electromagnetic torque of stepping motor is calculated as follows:

$$T_1 = \int_0^{\frac{\pi}{2}} T_c d\theta_e = T_m \int_0^{\frac{\pi}{2}} \cos\theta_e d\theta_e = T_m \qquad (2)$$

Subdivided driving, [0 °, 90 °) total effective electromagnetic torque of stepping motor is calculated as follows:

±5% (3)

Compares formula (2) and (3), the difference of the total effective electromagnetic torque between subdivision driver and whole step driver would be calculated as below:

±5% (4)

Can prove that always set up ±0.5% ΔT≥0. That is to say, the subdivided driving always improves the total effective stepper motor torque [13].

Comparative analysis the difference of the electromagnetic torque between subdivision driver and whole step driver, by adjusting the drive fine component can effectively increase the electromagnetic torque of stepping motor, reduce the volatility of electromagnetic torque, the significant increase in the frequency of electromagnetic torque ripple, Show that the method of fine adjustment of stepper motor driver component can make the step motor at low frequency oscillation and high frequency easy steps to be effectively improved. At the same time, Cooperate with program, when the stepper motor work in high frequency, using stepwise acceleration start way, to improve significantly the performance of the stepper motor.

2.3 Design of the Rotating Magnetic Field Generator Circuit

According to the design requirements, we adopt three-axis linkage controller as a motor controller produced by Shenzhen pure sensitive digital machine co., LTD. The motor controller can control three ways at the same time step motor, strong anti-jamming capability, powerful functions, the advantages of reliable stability, widely used in all kinds of requirements multi-angle, with more direction, good precision, and high speed. Its internal controller is a high performance, industrial grade import single-chip microcomputer, and the professional stability, anti-interference circuit design with good scalability, which can be realized at the same time to produce the same three characteristics of a rotating magnetic field, provide convenience to save time. It can satisfy completely the requirements of our design, mainly manifested in the following two aspects:

1) JMDM-1830 three axes linkage control stepping motor speed pulse frequency can reach 200 KHZ, through an external stepper motor drives, can easily realize the stepper motor speed control. At present, the stepper motor driver is ready-made product with high ratio of performance and prices, wiring is simple, easy to control. JMDM-1830 controller drives the stepper motor implemented by stepper motor driver. The 9, 11 and 13 feet of controller respectively control the three groups of stepper motor direction, the 9, 11 and 13 feet respectively for the three groups of stepper motor drive control by the pulse signal output. The output signals of 9 and 10, 11 and 12, 13 and 14 respectively correspond to a set of electric group. Direction and pulse signal outputs are "negative signal effectively". Using motor drive control stepping motor, controller and drive connections only need two I/O ports, one through the output pulse frequency controls motor speed, the other one changes the direction of the motor by high and low level.

2) Good LCD screen man-machine interface, through the membrane touch switch control the stepper motor speed, direction and time parameter setting and display.

2.4 Results of the Rotating Magnetic Field Instrument Design

Use CH - 2100 gauss meter produced by Beijing Cuihai trade electronic company to measure the frequency of rotating magnetic field. As a result of a rotating magnetic field frequency is decided by the speed of the motor, in the case of only a pair of magnetic poles, spin magnetic frequency shall be equal to the speed of the motor (revolutions per minute, its abbreviations is RPM) divided by 60, test results are shown in table 1. Can be seen from table 1, only in the high frequency, magnetic field frequency error and the actual set frequency to a certain extent, but the error is less than 1%.

Table 1. The values of tests

motor speed set up(RPM)	motor speed measured (RPM)	gyromagnetic frequency measured (Hz)
800	790	14
600	598	10
480	499	8
360	360	6
240	240	4
120	121	2

3. Application of Rotating Magnetic Field Generator in Blood Pressure Regulation and Control

The rotating field generator has automatic timing function, producing the magnetic field can be set in advance of the time, to the set time, automatic stop, can be manually controlled magnetic field, and shows friendly interface, simple operation, which brought great convenience for the use of the instrument. It has been applied to the study of cerebral cortex regulating blood pressure through the magnetic field. The experimental method and result are described below.

3.1 Materials and Methods

3.1.1 Equipments of the Experiment

Use the rotating magnetic field instrument made by the paper to produce a rotating magnetic field, magnetic field intensity measured by gauss meter, surface magnetic field strength of permanent magnet is 0.3 T (tesla), and at the position of 3 cm from the center of magnetic field, the intensity is about 2 mt, adjustable frequency in the range 0 to 15 Hz. Using the continuous noninvasive blood pressure measurement instrument(FMS, produced by Dutch Finapres medical system)and the multi-channel electrophysiology recorder (MP150, produced by Biopac companies in the United States) record the continuous blood pressure of human body.

3.1.2 Subjects

The subjects are 21 boys in school at Xi 'an Technological University, age from 20 to 24 years old, healthy body. Before the trial, requires all participants fill out questionnaires experiment.

3.1.3 Methods

The surface central node of rotating magnetic field respectively focused on the forehead (Fp), above the central point (Cz), Fp and Cz intermediate point, center distance of magnetic field on the surface of the scalp is 1 cm. Stimulate on each point with two diffrient magnetic, 15 Hz and 2 Hz frequency spin magnetic stimulation, and measure 6 minutes every time, among the time of magnetic stimulation is 2 minutes. Record the continuous blood pressures in the process of experiment. Analysis the changes of blood pressure before the magnetic field, among magnetic field, and after the magnetic field, to explore the magnetic field through the brain cortex effects on blood pressure.

3.1.4 Statistical Analysis Method of Data

Experimental data is analyzed by SPSS statistical analysis software, with a mean plus or minus standard deviation for the systolic pressure (SP), diastolic pressure (DP) and mean pressure (BP) according to measurement data, recorded before magnetic field, magnetic field, and after the magnetic field. Compare the difference between the data using paired t test.

3. 2 Results

3.2.1 Influence of Different Magnetic Field on Systolic Blood Pressure

See table 2 and 3. Under the stimulation of gyromagnetic with 2 Hz frequency, when the center of the magnetic field is focused on the frontal area (FP), the average systolic blood pressures (SBP) is 123.56±10.68 mmHg, before adding magnetic SBP was 126.86±11.72 mmHg, and after magnetic systolic SBP was 121.14 ±10.48 mmHg. There are differences between the three systolic blood pressures by pair-wise comparison ($P < 0.05$). When the magnetic field were focused on the two positions, one is the central head points (Cz), another one is intermediate point of Fp and Cz (Cz - Fp) , there are no differences between the three systolic blood pressures by pairwise comparison ($P >0.05$). Under the stimulation of gyromagnetic with 15 Hz frequency, when the magnetic field were focused on Cz and Fp, there is a difference between before and among the magnetic field ($P <0.05$), no difference between after and among ($P >0.05$), and a difference between before and after the magnetic field ($P <0.05$). When the magnetic field was focused on Cz-Fp, there is a difference between before and among the magnetic field ($P <0.05$), all of the two station with after the magnetic field have no differences ($P >0.05$).

Table 2. SBP changes in 2Hz frequency magnetic field irradiate head position

0			
Station of being stimulated on head	2Hz		
	before	among	after
FP	126.86±11.72	123.56±10.68[1 2]	121.14±10.48[3]
Cz-FP	124.81±16.10	124.77±14.68	124.15±13.85
Cz	132.25±14.35	134.29±14.98	133.65±15.66

Notes in table 2. 1.Compared with before adding magnetic and magnetic, P<0.05; 2.Compared with adding magnetic and after magnetic, P<0.05; 3.Compared with before adding magnetic and after magnetic, P<0.05;

Table 3. SBP changes in 15Hz frequency magnetic field irradiate head position

SBP($\bar{x}$±s , mmHg)			
Station of being stimulated on head	15Hz		
	before	among	after
FP	122.39±16.34	125.16±14.70[1]	125.70±15.23[3]
Cz-FP	128.91±14.70	131.35±14.24[1]	131.49±15.27
Cz	135.04±12.79	137.55±12.04[1]	139.05±13.25[3]

Notes in table 3. 1.Compared with before adding magnetic and magnetic, P<0.05; 2.Compared with adding magnetic and after magnetic, P<0.05; 3.Compared with before adding magnetic and after magnetic, P<0.05;

3.2.2 Influence of Different Magnetic Field on Diastolic Blood Pressure

See table 4 and 5. Under the stimulation of gyromagnetic with 2 Hz frequency, when the center of the magnetic field is focused on the frontal area (FP), the average diastolic blood pressures (DBP) adding magnetic DBP is different with before magnetic. There is a difference between among and after magnetic stimulation, no difference between before and after. When the magnetic field were focused on the two positions, one is the central head points (Cz), another one is intermediate point of Fp and Cz (Cz - Fp) , there are no differences between the three systolic blood pressures by pair-wise comparison (P >0.05). Under the stimulation of gyromagnetic with 15 Hz frequency, when the magnetic field was focused on Fp, there is a difference between before and among the magnetic field (P <0.05), no difference between after and among (P >0.05), and a difference between before and after the magnetic field (P <0.05). When the magnetic field were focused on Cz-Fp and Cz, there are no differences between the three systolic blood pressures by pair-wise comparison (P >0.05).

Table 4. DBP changes in 2Hz frequency magnetic field irradiate head position

DBP($\bar{x}$±s , mmHg)			
Station of being stimulated on head	2Hz		
	before	among	after
FP	69.77±9.96	68.49±10.10[1]	67.81±9.91[3]
Cz-FP	67.75±10.48	67.97±11.00	68.10±10.40
Cz	74.15±8.62	74.86±9.32	74.78±9.94

Notes in table 4. 1.Compared with before adding magnetic and magnetic, P<0.05; 2.Compared with adding magnetic and after magnetic, P<0.05; 3.Compared with before adding magnetic and after magnetic, P<0.05;

Table 5. DBP changes in 15Hz frequency magnetic field irradiate head position

DBP($\bar{x}\pm s$, mmHg)			
Station of being stimulated on head	15Hz		
	before	among	after
FP	64.73±11.31	66.10±10.91[1]	66.77±10.55[3]
Cz-FP	68.78±9.93	70.09±9.77[1,2]	71.34±9.82[3]
Cz	74.69±7.64	76.20±7.83[1,2]	77.52±8.98[3]

Notes in table 5. 1.Compared with before adding magnetic and magnetic, P<0.05; 2.Compared with adding magnetic and after magnetic, P<0.05; 3.Compared with before adding magnetic and after magnetic, P<0.05;

3.2.3 Influence of Different Magnetic Field on Mean Blood Pressure

See table 6 and 7. Under the stimulation of gyromagnetic with 2 Hz frequency, when the center of the magnetic field is focused on the frontal area (FP), the average mean blood pressures (DBP) adding magnetic DBP is different with before magnetic. There is a difference between among and after magnetic stimulation, no difference between before and after. When the magnetic field were focused on the two positions, one is the central head points (Cz), another one is intermediate point of Fp and Cz (Cz - Fp) , there are no differences between the three systolic blood pressures by pair-wise comparison (P >0.05). Under the stimulation of gyromagnetic with 15 Hz frequency, when the magnetic field were focused on Fp and Cz-Fp, there is a difference between before and among the magnetic field (P <0.05), no difference between after and among (P >0.05), and a difference between before and after the magnetic field (P <0.05). When the magnetic field was focused on Cz, there are all differences between the three systolic blood pressures by pair-wise comparison (P <0.05).

Table 6. MBP changes in 2Hz frequency magnetic field irradiate head position

MBP($\bar{x}\pm s$, mmHg)			
Station of being stimulated on head	2Hz		
	before	among	after
FP	86.36±9.85	84.85±10.09[1]	83.84±9.84[3]
Cz-FP	84.49±10.93	84.76±11.18	84.74±10.59
Cz	91.23±9.51	92.19±9.93	92.09±10.49

Notes in table 6. 1.Compared with before adding magnetic and magnetic, P<0.05; 2.Compared with adding magnetic and after magnetic, P<0.05; 3.Compared with before adding magnetic and after magnetic, P<0.05;

Table 7. MBP changes in 15Hz frequency magnetic field irradiate head position

MBP($\bar{x}\pm s$, mmHg)			
Station of being stimulated on head	15Hz		
	before	among	after
FP	81.59±11.77	82.91±10.93[1]	83.70±10.84[3]
Cz-FP	86.03±10.49	87.68±9.99[1]	88.86±10.40[3]
Cz	91.22±9.71	93.98±8.40[1,2]	95.36±9.67[3]

Notes in table 7. 1.Compared with before adding magnetic and magnetic, P<0.05; 2.Compared with adding magnetic and after magnetic, P<0.05; 3.Compared with before adding magnetic and after magnetic, P<0.05;

4. Conclusions

1) Combined with the rotating magnetic field in magnetic therapy on clinical application, on the basis of gyromagnetic central nervous system on the brain, the influence of the plant nerve system and cardiovascular system, in this paper developed a low-frequency rotating magnetic field generator applied to control blood pressure through the brain cortex. The system adopts the stepping motor driven gyromagnetic produced by the rotation of permanent magnets, rotating speed of high precision, small volume, can satisfy the requirement of applying magnetic stimulation on the small area, and no electromagnetic radiation, can be used in the experiments on human body.

2) In the study of magnetic biological effect, due to the cumulative effect of the magnetic field, often need through the illuminate of every day for a long time, after a period of time to observe the effect of the magnetic field, therefore, in this paper, the spin magnetic generator designed with automatic time setting function, simply by applying magnetic stimulation of the initial time start the instrument to control the irradiation time. The instrument will stop automatically according to the set time. It brings great convenience for the experimental operation. At the same time, the instrument can be extended into three outputs with the same gyromagnetic for large sample group animal and cell experiment for at the same time.

3) After a gyromagnetic preliminary inspection of the pressure regulation experiment, it is proved that a rotating magnetic field can affect blood pressure through cerebral cortex, has different effects on blood pressure by using different frequencies, the effects on blood pressure is not the same because a different position focused by magnetic field. By selecting the frequency and location stimulated with rotating magnetic field may have certain therapeutic effect for controlling hypertension, but it needs to take a more scientific and fine experimental verification.

4) In this paper, the developed low frequency of a rotating magnetic field generator has an effect on blood pressure, and has the potential of clinical adjuvant treatment for high blood pressure. At the same time, it was been found that less flexible adjusting the magnetic field irradiation position, which can be modified through the mechanical design. It provides an idea for us to improve the instrument design.

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