A Micro Magnetic Stimulator

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Transcranial magnetic stimulus is a non-invasive method for electrically stimulating the cerebral cortex applying squared pulses with certain frequency, during variable time intervals, over particular regions of the cranium. Some specific stimuli are able to depolarize neurons and produce measurable effects such that chains of these stimuli may modify the cortical excitability of both the stimulated zone and the related remote areas through functional anatomic connections. This allows an efficient tool on treating neurological and psychiatric conditions such as depression. In this work we present a novel stimulation architecture that allows localizing the magnetic field over small spatial regions such that the field amplitude is on the order of micro-Tesla, which is three orders of magnitude less than that used in the current technology. Besides localizing the stimuli, this novel architecture will help to reduce the secondary effects of the treatment due to the low field intensity.

Keywords: transcranial, magnetic, stimulus

Transcranial magnetic stimulus (TMS) is a non-invasive method that employs inductive electrical currents to stimulate the brain. TMS is able to stimulate and inhibit activity in localized regions of the brain by directly modifying the neural circuits. TMS has proven an unconventional, integral neuroscience tool in both research and therapeutic treatment of diverse neuropsychiatric diseases and disorders since it allows electrically influencing zones deeper than the cerebral cortex without causing pain [1].

Put simply, the current TMS procedure consists on applying electrical pulses of variable intensity with frequencies in the range of 100-300 Hz over time periods on the order of milliseconds [2]. Traditionally, the TMS architecture consists of coils disposed in circular or *eight* geometries. On one hand, the circular geometry produces a more extensive electric field, allowing for the simultaneous stimulus of both hemispheres. On the other hand, the *eight* geometry results in a more focused field [3]. Figure shows a schematic of a typical TMS device.

In general, the therapeutic effect of TMS of reducing some of the symptoms is useful in a wide variety of mental illnesses including mania, obsessive compulsive disorder, post-traumatic stress disorder, addiction, and schizophrenia [4]. Particularly, TMS has proven useful auxiliary tool in the treatment of depression, in which approximately 40% of patients present the so-called Treatment Resistant Depression (TRS) [5], since the application of TMS on both pre-frontal regions results in transitory states of sadness and joy [6].

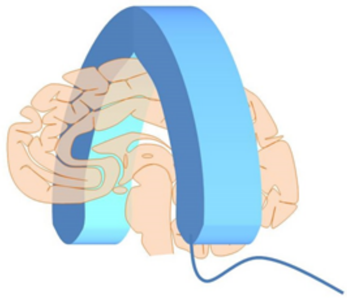

Fig. 1. Shape of micro magnetic stimulator for cerebral stimulus

TMS is considered a safe technique that follows well established safety guidelines in order to avoid harmful effects. For instance, irritation at the cephalic or cervical level, if present, has proven mild and transient. Moreover, the risk of epileptic seizures is low during the stimulus and practically negligible (not observed) after the stimulus [7]. However, due to the relatively high field intensities used in the current technology, the accessibility to deeper regions of the brain is limited and undesired, significant secondary effects are still present.

In this work, we present a novel architecture for TMS applications that allows localizing the magnetic field over very small spatial regions such that the field amplitude is on the order of micro-Tesla, which is three orders of magnitude less than that used in the current technology. Consequently, this novel architecture may help to significantly reduce the secondary effects of the treatment due to the low field intensity required.

System description

The system consists of a collection of coils disposed tangentially over the scalp of the patient, as shown schematically in figure 2. In this particular configuration, the coils are connected in series such that the electrical

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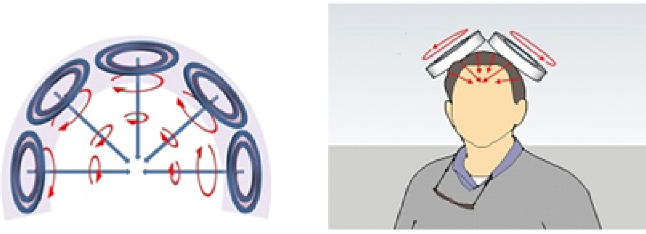

Fig. 2. Direction of electromagnetic current flow of the micro stimulator

currents generated result in magnetic fields that extend throughout the brain in a determined direction.

The distribution and location of the coils are designed to maximize the effect of the electromagnetic fields in deep layers of the brain such that the independent fields project towards the interior of the skull in a specific stimulation pattern from various points around its periphery, as shown in figure 3.

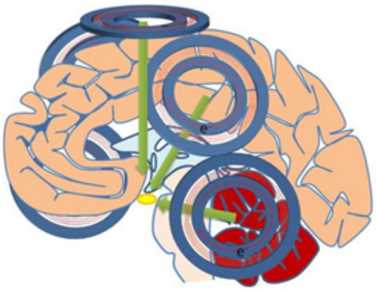

Fig. 3. Stimulus of the deep layers of the brain through the current EM generated by the micro stimulator coils

In order to promote a direct stimulus to the cerebral mass, the range of frequencies contains frequencies audible to the human ear. The signals generated (intensity, frequency, and time intervals) are pre-programmed and configured in a database loaded on a micro programmer.

These parameters are selected by the operator through an interactive interface displayed on a touch screen computer.

The eventual aim envisioned for this equipment is offering an auxiliary tool based on low-intensity field transcranial magnetic stimulus for the application in pathologies related to pain, anxiety, and depression. This system is capable to stimulate the human brain by using oscillating magnetic fields in a frequency range that depends on the current and desired mental state. The equipment can be operated only by a healthcare professional with the appropriated training.

As shown schematically in figure 4, the magnetic micro stimulator contains the following components.

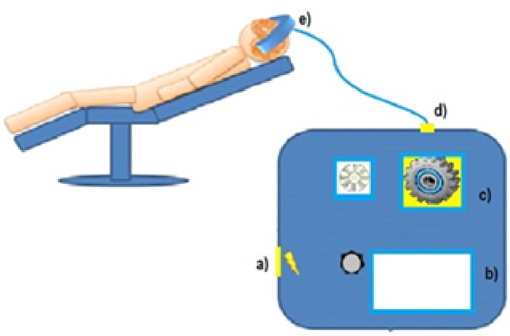

Fig. 4. Diagram of the components of the magnetic micro stimulator

a) Energy supply. This device converts the alternate voltage from the supply network into the appropriate voltages needed in the different electronic systems of the control circuit. The new voltages can be either alternate or continuous, and their supply can be controlled by switching.

b) Database of frequencies. This contains the pre-loaded database with the set of frequencies and time sequences (temporizer) that will be available, in other words, it determines for how long the magnetic field with fixed frequency will be applied. The parameters of the magnetic field (frequency, intensity and time sequence) that will be applied through a specific coil can be selected via the set of menus displayed on screen.

c) Signal amplifier. This device magnifies the amplitude of the control signal in order to provide a larger voltage capable to actually exercise the cellular stimulus.

d) Interface. This set of circuits, adapters, and connectors allows for interfacing the output of the signal generator in order to feed magnetic stimulus to the coil.

e) Coil for stimulus

The way to apply the signal for stimulus is rather simple: the operator selects a pre-programmed time sequence from the database for a specific frequency and intensity of the magnetic field, this translates into a control signal that is further sent to a pre-amplifier circuit in order to provide a magnetic field sufficiently strong at the coil to achieve cellular stimulus.

The magnetic field signal at the coil is generated by feeding an arbitrary, alternating (periodic) current signal created by the standard technique of Fourier series decomposition, the parameters of which determine the characteristics of the signal i.e. amplitude and shape. By using Fourier series decomposition, it is possible to generate arbitrary waveforms containing components of both alternating and direct voltage over well controlled periods of oscillation.

The frequency of oscillation determines the duration of the signal applied to the coil and, therefore, the duration of the magnetic stimulus applied directly to the cellular population.

Based on the typical response of ferromagnetic fluids, the intensity of the magnetic field available at the point of contact of the coil for actual delivery is in the range of 0.22 to 0.42 mili Teslas in order to ensure cellular response to the applied stimulus. Future research should aim to stimulate the limbic system surrounding tonsils, under the assumption of a positive result in the frontal-limbic circuit associated with depression.

This range of required magnetic field intensity corresponds to a net electrical current from 1 to 2.5 Amperes applied through a pulse of approximately 1 ms at the coil. This, in turn, determines that an adequate source for the entire system could be a standard DC source of 12 V and 4A.

The basic circuit of the signal amplifier in the magnetic stimulator is shown in figure 5. It can be seen that different intensities can be selected by using the switch (top in fig. 5).

Coils take many distinct shapes and sizes. All of them consist of one or more coils of copper thread completely isolated, normally within in a plastic mold. The two types of coil most commonly used are the circular and figure of eight coils. Our coil is in the form of an inverted V, as shown in figure 6. The electric field generated, and therefore the focus and penetration of the stimuli, depends on the geometry of the coil.

Stimulus with a coil with an inverted V shape consists of two circular coils that transport currents in opposite directions, and where the two coils meet, they produce a sum electric field.

The effective region of stimuli depends not only on the geometry of the coil, but also the type, orientation and the

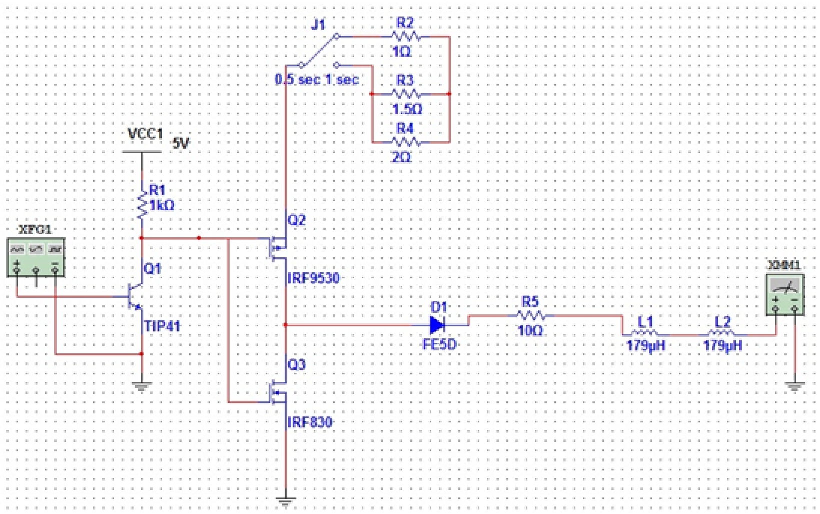

Fig. 5. Electronic circuit board.

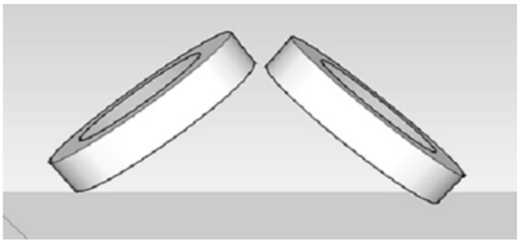

Fig. 6. Inverted V coil

level of activity of the neurons subjacent to the coil and the variability of local conductivity.

Besides the differences of focus in the induced current, the circular coils in the form of a V show a distinct affinity to stimulate for different nervous structures inside the brain.

In figure 7 the coils are shown, and their interaction with the magnetic field.

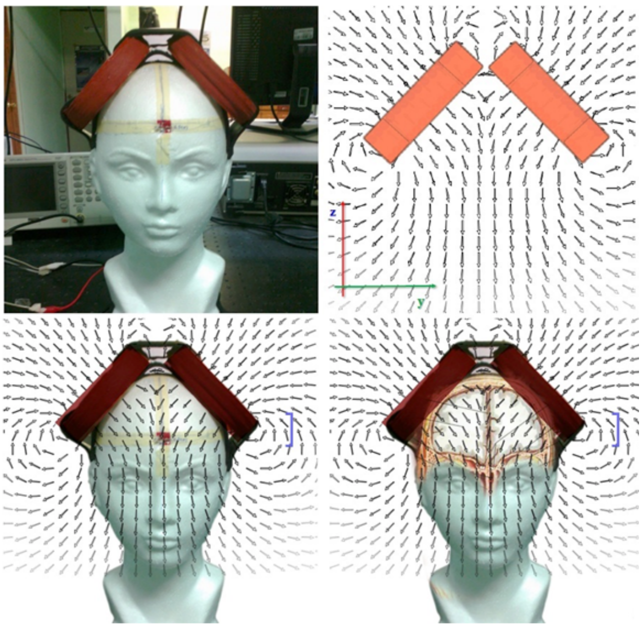

Fig. 7. Interaction with the magnetic field

A simple EMT pulse may depolarize a population of neurons and in this way evoke a determined phenomenon or perception that may alter the transitory nature of brain activity, introducing an altered nervous state in the area receiving stimuli. If the area stimulated is necessary for a given task, the execution of it should be noticeably altered.

Although TMS is a technique of extensive use in scientific applications such as in clinics, there are significant knowledge gaps in the mechanisms of neural action. It seems clear that the physiological bases that underlie the effects of EMT are distinct in regards to the effects of the real time stimulus (on-line) and delayed effects (off-line).

Developing the prototype includes an interface in which the user can select:

- PAIN
- STRESS
- DEPRESSION

In each area, certain pre-programmed frequencies are determined. It also has a manual intensity option for those who prefer.

Within RESEARCH two areas are developed:

- STRESS
- DEPRESSION

In this menu a manual frequency may be chosen, in order to select one or the other of the two menus, the frequency is a random mix of the 6 frequency options that are unknown to the user. There is the option to select intensity.

Inventory of Beck depression: The Beck Depression Inventory (BDI) [8], was initially developed, in 1961, as hetero-applied scale of 21 items aimed at assessing the severity (symptomatic intensity) of depression, with each item containing phrases for auto-evaluation.

The Beck depression test was applied to 30 (thirty) students of which 3 (three) showed a moderated depression index and, upon the use of the magnetic micro magnetic stimulator in 30 (thirty) minute sessions for 10 (ten) days, one case presented improvement (on their depression level) and remission in 2 (two) cases.

Proof is not conclusive as the fact of being students contributes to the possibility of mood change due to a variety of factors, at present this research is being conducted in a quasi-experimental form with patients resistant to medication.

Conclusions

Unlike trans-cranial magnetic stimulation, which stimulates at an approximate intensity of 1 Tesla with a variable frequency, magnetic micro-stimulation works at intensities of 20 micro-Tesla, also with a variable frequency. This is an attempt to reduce the secondary effects of this treatment, among which we find seizures, headaches and local pain, decreased hearing, among other symptoms; yet at the same time the aim is to have an equivalent effectiveness in the reduction of symptoms including stress, anxiety and depression. It has been successfully proven that among three youth of 20 ± .07 years of age with severe depression and among two with moderate depression, measured with the Beck Depression Test, the types of tests to measure depression are not conclusive but will allow a further development of research aimed at helping psicomagneticbiology. This system is in the testing stage and undergoing improvements.

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