A Micro Magnetic Stimulator

TEODORO CORDOVA FRAGA1, JOSE MARIA DE LA ROCA CHIAPAS2, HUEZTIN AARON PEREZ OLIVA1,3, MARTIN ALEJANDRO MALDONADO MORELES1, YASSER ALAYLI1, JOSE DE JESUS BERNAL ALVARADO1, DUMITRU BALEANU4,5, RAFAEL GUZMAN CABRERA6*
1Departamento de Ingeniería Física – DCI, Universidad de Guanajuato campus Leon, Lomas del Bosque 107, Lomas del Campestre, 37150 Leon, GTO, Mexico
2Departamento de Psicología – DCS, Universidad de Guanajuato campus Leon Blvd. Puente Milenio 1001, Fraccion del Predio San Carlos, 37670 Leon, GTO, Mexico
3Université de Versailles, Saint-Quentin-en-Yvelines, 10-12 avenue de l’Europe, 78140 Velizy-Villacoublay, France
4Department of Mathematics, Faculty of Art and Sciences, Cankaya University, Balgat 06530, Ankara, Turkey
5Institute of Space Sciences, 409 Atomistilor Str., 077125, Magurele, Romania
6Division de Ingenierias, Universidad de Guanajuato Campus Irapuato-Salamanca, Carretera Salamanca-Valle de Santiago, 36885 Salamanca, GTO, México

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 1 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].

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

*email: guzmanc@ugto.mx
voltages needed in the different electronic systems of the
voltage from the supply network into the appropriate
stimulator contains the following components.

Professional with the appropriated training.
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depends on the current and desired mental state. The
oscillating magnetic fields in a frequency range that
system is capable to stimulate the human brain by using
pathologies related to pain, anxiety, and depression. This
transcranial magnetic stimulus for the application in
offering an auxiliary tool based on low-intensity field
computer.

an interactive interface displayed on a touch screen
configured in a database loaded on a micro programmer.

These parameters are selected by the operator through
an interface displayed on the screen.

The eventual aim envisioned for this equipment is
offering an auxiliary tool based on low-intensity field
transcranial magnetic stimulus for the application in
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As shown schematically in figure 4, the magnetic micro
stimulator contains the following components.

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.

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
directional magnetic field sufficiently strong at the coil to achieve
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
grid of menus displayed on screen.

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 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
the desired mental state.

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,
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This range of required magnetic field intensity
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.

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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