

# Experimental Demonstration of Induction by Means of a Transcranial Magnetic Stimulator Coil Immersed in a Conducting Liquid

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# Outline

- 1 Introduction**
- 2 Orthogonal coils immersed in conducting solution**
- 3 Prototype development**
- 4 Experimental setup for prototype testing**
- 5 Experimental results**
- 6 Conclusions**

# 1. Introduction

## Transcranial magnetic stimulation: what is it?

- Transcranial magnetic stimulation (TMS) refers to a current induced in the brain by an external magnetic flux varying in time
- Depending on its intensity and direction, that induced current is able to oppose or strengthen biological currents
- TMS potentially inhibits or stimulates the central nervous system as well as any other current driven organs
- Neuronal stimulation or inhibition depends essentially on the direction and/or frequency of the current electromagnetically induced

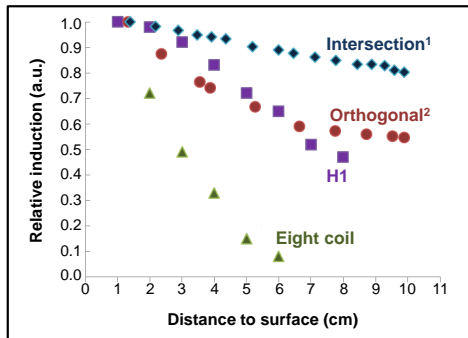
# 1. Introduction

## Motivation: potential fields of applicability of TMS

- Parkinsonism
- Alzheimer's disease
- Epilepsy
- Depression
- Sleep and mood disorders
- Stroke rehabilitation
- Pain management
- Others

# 1. Introduction

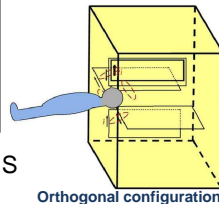
- The state of the art of deep-brain TMS



Induction ratio for several modern coils for TMS



Zangen *et al.*,  
Clin Neurophys 2005



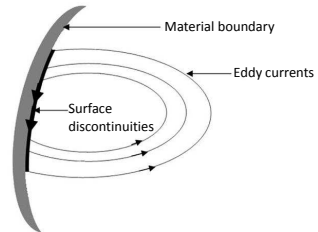
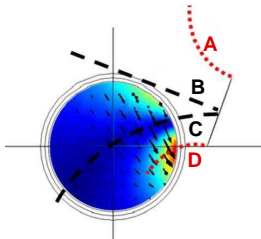
<sup>1</sup>Oliveira *et al.*, ENBENG 2012

<sup>2</sup>Dias Silva *et al.*, ENBENG 2012

# 1. Introduction

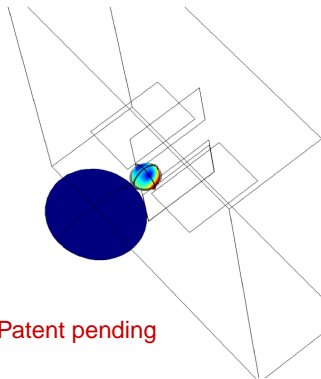
## Challenges of TMS usage in humans

- Deep-brain stimulation: loss of induction power with penetration depth
- Superficial current induction due to surface discontinuities
- Limit of current density in the retina and heart



## 2. Orthogonal coils immersed in conducting solution

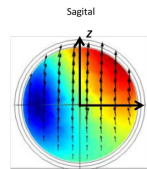
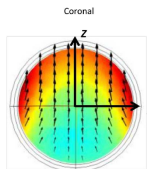
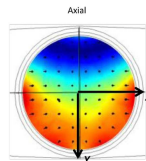
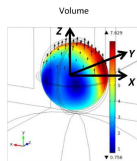
- Simulations with COMSOL multiphysics AC/DC



Patent pending

Current density distribution for the orthogonal configuration. The current density ranges between 0.756 and 7.629 A/m<sup>2</sup>. →

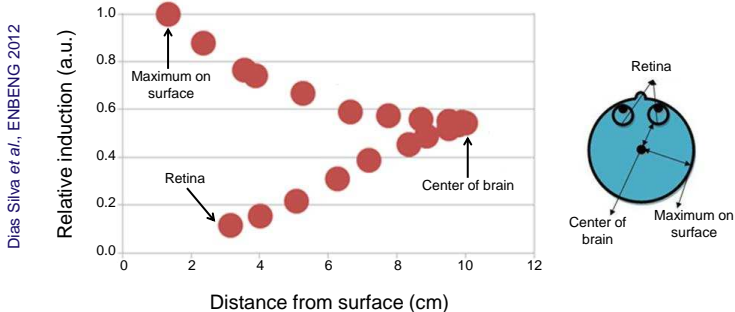
→ Volume current density distribution in a head/torso model. A conducting liquid fills the parallelogram, which in turn contains the coils and the superior region of the head. The induced current in torso corresponds to 0.001% of the maximum current induced at brain surface.



Dias Silva *et al.*, ENBENG 2012

## 2. Orthogonal coils immersed in conducting solution

- Simulations with COMSOL multiphysics AC/DC



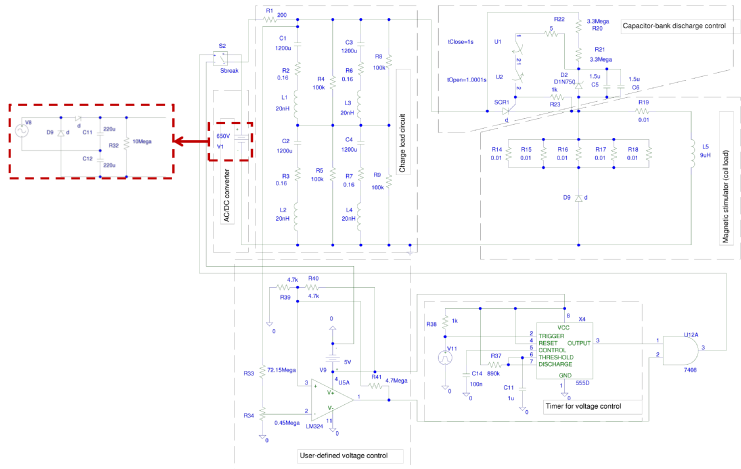
Induction ratio from maximum on superficial cortex down to brain center, and from retina down to brain center

- Induction ratio in center of brain is 53% of surface maximum
- Induction ratio in retina is 10% of surface maximum



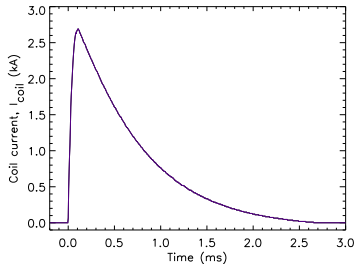
### 3. Prototype development

- Power electronics circuit implemented in PSPICE

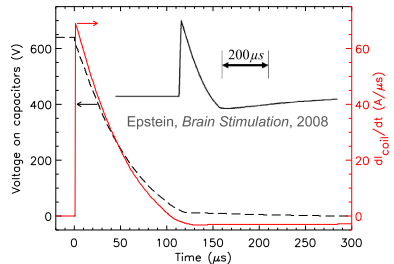


### 3. Prototype development

- Results of simulation with PSPICE



Temporal evolution of current in coil

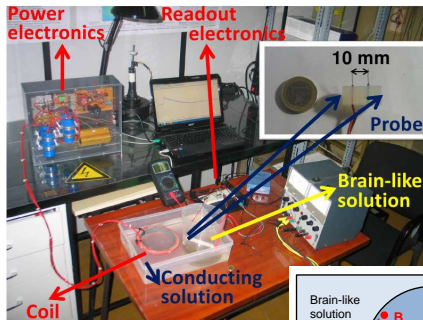


Discharge of capacitor bank  
(black dashed line)

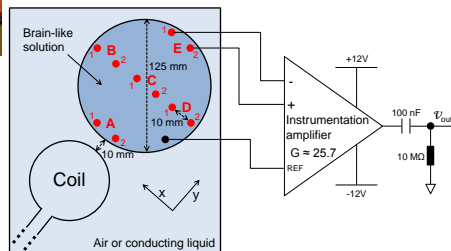
Time derivative of coil current  
(red solid line)

Stimulus with similar shape to those capable of brain stimulation

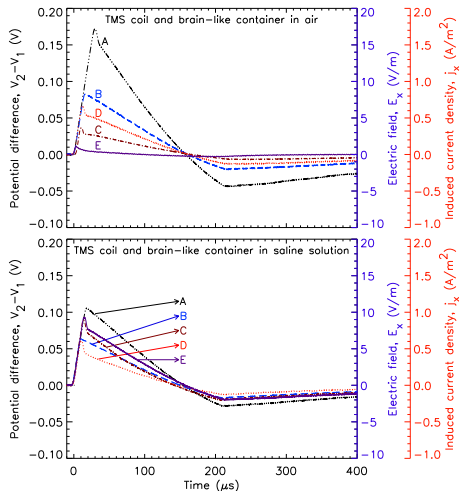
## 4. Experimental setup for prototype testing



- A container filled with an NaCl solution with conductivity with same order of magnitude than the brain was subjected to an electric field generated by the TMS system
- A, B, C, D, and E correspond to the positions where the potential difference was measured
- Coil and brain-like container surrounded by air or by an NaCl solution (with conductivity 5.5 S/m)

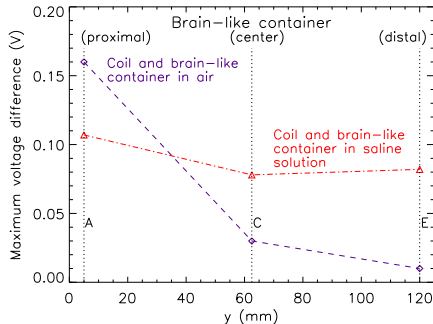


## 5. Experimental results



- *Top:* Coil and brain-like container in air
- *Bottom:* Coil and the brain-like container in conducting solution

## 5. Experimental results



Maximal potential difference for the measurements with the coil and brain-like container in air (blue) and in saline solution (red)

Ratio between the potential difference at center and at surface of the brain-like container were 0.16 and 0.76 with the setup in air and in conducting solution, respectively

## 6. Conclusions

- Development of a power electronics circuit that generates stimuli with a shape similar to those capable of TMS
- Setup in air: surface-to-center signal loss of 84%
- Setup in conducting liquid: surface-to-center signal loss of 24%
- Experimental demonstration of previous simulated conclusions: a conductive solution surrounding coil and brain strongly mitigates surface effect

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# Thank you for your attention