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Transcranial Magnetic Stimulator Coils for Stimulating Broader Areas of the Brain

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Recent clinical studies have shown that transcranial magnetic stimulation (TMS) is an effective treatment for several psychiatric and neurological diseases. Magnetic stimulators have been approved as medical devices in many countries for treatment of depression. The efficacy of TMS depends on the coil design and resulting distribution of electric fields in the brain. While many clinical studies have been performed using a figure-eight coil that delivers focal stimulation, some recently developed coils deliver electric fields to broader areas of the brain [1]. The relation between electric field distribution and therapeutic efficacy still remains to be understood. In this presentation, we discuss the potential benefits of stimulating broader areas of the brain, and describe the development and evaluation of a prototype coil [2].

To maintain the therapeutic effect, patients undergo daily TMS sessions. The position of the coil fluctuates between the sessions due to the limited reproducibility of coil navigation systems. When the field distribution is broad, the therapeutic efficacy becomes more stable. In addition, broadly distributed fields tend to penetrate deeply into the brain. Relatively weak electric fields at the scalp are beneficial for suppressing pain sensation. Furthermore, several clinical studies suggest that broad stimulations lead to increased therapeutic efficacies.

We propose a double-D coil that gives broader stimulations of the brain compared with standard figure-eight coils. This coil is equipped with parallel conductors to induce electric fields in the target area and return conductors in the circumference. The parallel conductors produce homogeneous electric fields in the target area and resulting broadly distributed fields. The electric field distributions of the double-D coil and figure-eight coil were compared using numerical simulations based on the finite element method. A prototype coil was developed based on this design. The insulator case containing double-D-shaped slits was fabricated using a 3D printer, and Litz wire was assembled in the case. The coil was filled with epoxy for electric insulation.

The numerical simulations showed that the double-D coil induced electric fields in an area of 8.8 × 4.7 mm, while the figure-eight coil induced electric fields in 6.0 × 3.3 mm. Stimulation of the human brain was performed for five healthy subjects using the developed prototype. TMS was applied at 200 positions distributed around the primary motor cortex, and the intensity of motor evoked potential (MEP) was recorded for each coil position. The full width at half maximum of the MEP was 52 × 28 mm for the double-D coil, while that for the figure-eight coil was 35 × 19 mm. This result shows that the double D coil provides broader distribution of the induced electric field, leading to stimulation effects that are more stable against displacement of the coil. These characteristics are beneficial for therapeutic applications of TMS.

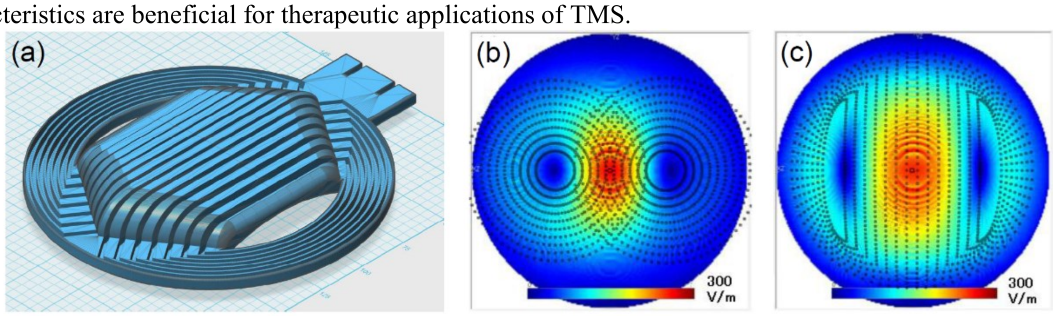

Figure 1. (a) Structure of a double-D coil. (b) Induced electric fields of a figure-eight coil. (c) Induced electric fields of the double-D coil.

References

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