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TRANSCRANIAL MAGNETIC STIMULATION (TMS) COIL DESIGNING FOR HIGH ELECTROMAGNETIC FIELD GRADIENT GENERATION

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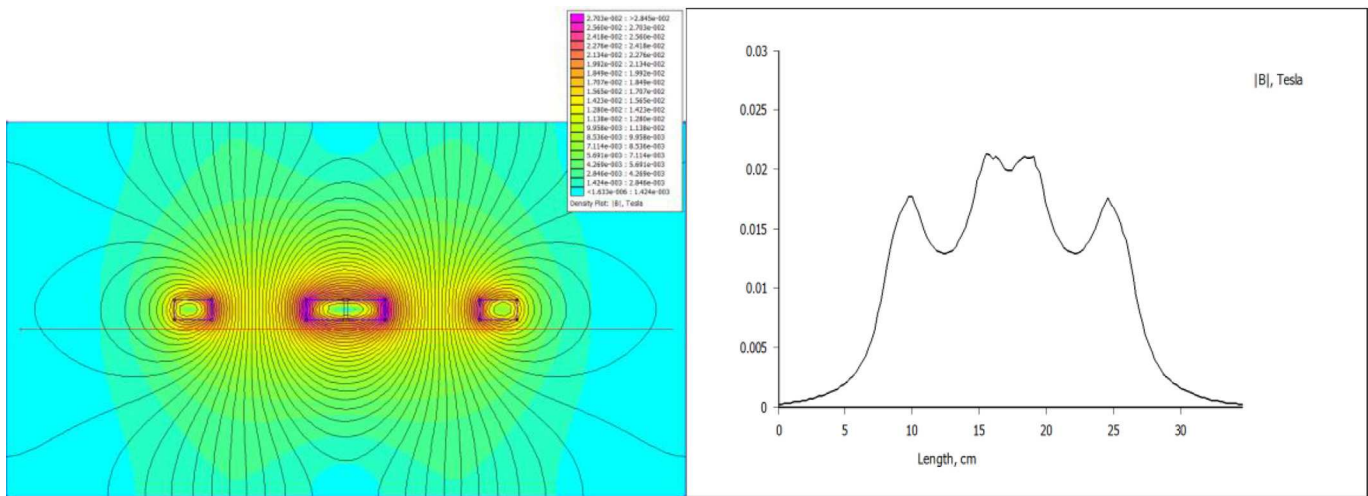
Introduction: Commercial transcranial magnetic stimulators (TMS) are designed to obtain highest transient magnetic field or induced electrical field for stimulation at desired locations, like figure-8 coil as shown in figure 1a. However, from cable equation model we know that membrane capacitor can only be charged by the **spatial gradient** of the induced electric field to reach activation threshold. New generation TMS tools will be effectively designed to produce maximized gradient electrical field instead of electrical field.

Methods: A new TMS stimulator design is proposed by using two coils, running current along opposite directions for obtaining maximized

magnetic field gradient. Since induced electric field is proportional to dB/dt , we expect that a high spatial gradient of transient magnetic field will correspondingly produce a high $grad(E)$, where E is induced electric field. Two-dimensional simulation was performed by FEMM, a finite element analysis tool. A larger radius coil and a relatively smaller radius coil, with radius ratio of 2 to 1, were top-down overlapped. By shifting the smaller coil along its horizontal direction to change their relative positions and adjust current flow ratio between them we can optimize the magnetic field gradient which is closely correlated to $grad(E)$ as discussed above.

Results: The highest magnetic field gradient was able to be achieved when the inner diameter of big coil wiring is aligned with the outside diameter of the smaller coil as figure 2a illustrates. By adjusting the current excitation in both coils, it was found that the optimized current ratio was from 1.5:1 to 1.7:1 for this case.

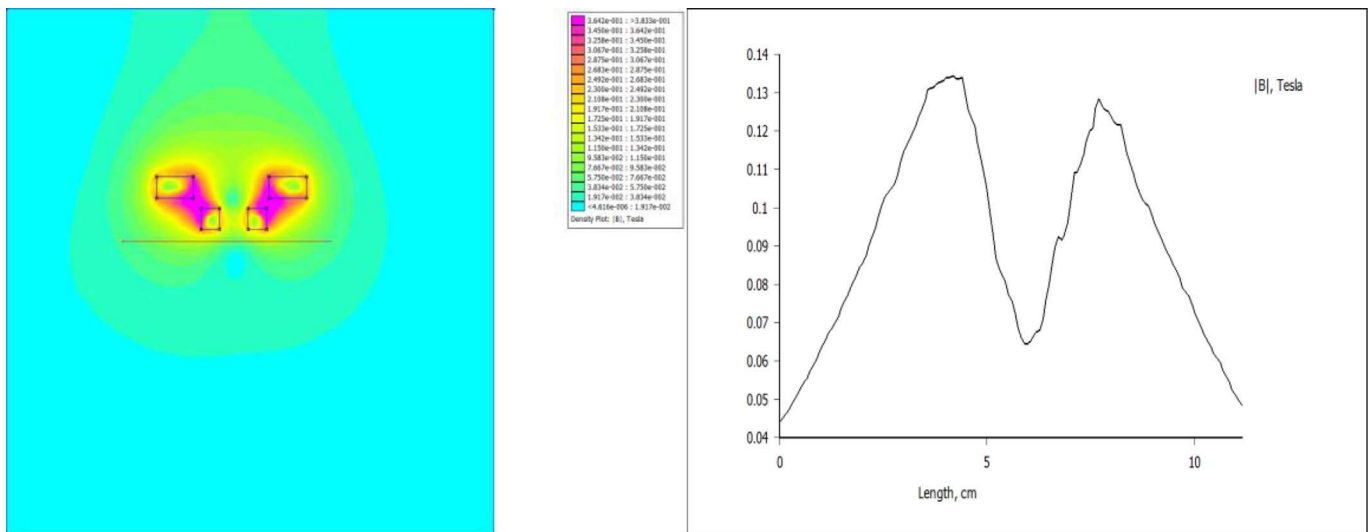
Discussion: With two coils in anti-phase operations we can achieve the same or higher $grad(B)$ amplitude at a lower total current compared with the conventional figure-8 structure. We expect new types of coil structure with optimized $grad(E)$ design will replace conventional designs in the future.



a.

b.

Figure 1a. Two-dimensional cross section view of conventional figure-8 TMS coil in FEMM and its magnetic flux density distribution; b. Magnetic flux density distribution along a cutline 0.5cm below the figure-8 coil.



a.

b.

Figure 2a. Two-dimensional cross section view of coil design in FEMM and magnetic flux density distribution (170A current load in the up-side coil and 100A current load in the down-side coil); b. Magnetic flux density distribution along a cutline 0.5cm below the down-side coil.