FAKULTA BIOMEDICÍNSKÉHO INŽENÝRSTVÍ ČVUT V PRAZE

Návod na laboratorní úlohu
Therapeutic medical devices for electrical and magnetic neurostimulation.

Název studijního předmětu: Electroceuticals for electrical and magnetic neurostimulation therapies

Vedoucí cvičení/experimentu: Doc. Ing. David Vrba, Ph.D.

Anotace cvičení/experimentu:

Transcranial Magnetic Stimulation (TMS) is a non-invasive technique. The application of TMS causes the neurons of the brain to undergo depolarization, i.e., the membrane potential becomes more positive, or hyperpolarization, i.e., the membrane potential becomes more negative. This technique relies on a brief, high-current pulse generated in a loop wire and placed in the vicinity of the skull. Inside the wire, a magnetic field with flux lines perpendicular to the wire plane is produced, followed by induction of an electric field perpendicular to the magnetic one. In homogeneous media, the electric field induces current flow parallel to the wire plane; the current is stronger near the loop wire and weaker near the center, where there is no current.

- Modeling

In this section, student will learn how to work in the SW environment and draw a simplified model of head and stimulating coil.

- Simulation

After modeling is finished another step is to set up Electromagnetic Solver. In our case we will use Magneto Quasi-Static solver. It needs to be setted up the frequency, tissue properties (electric conductivity) and current source in the loop.

- Analyzes

The evaluation of the simulation will be divided into three parts:
1. RMS B-field distribution.
2. RMS J-field distribution
3. H-field distribution

Cíle cvičení/experimentu:

This exercise (tutorial) aims to demonstrate to the students how to set up and run a neuronal dynamics simulation In this tutorial, the field in the brain is generated with a figure-eight current loop placed above the head as in [1] with this shape, the current maximum is located at the intersection of the two round wires. The exposure simulation generates information concerning the exact location of stimulation, which is important to know during TMS. The example provided in this tutorial, designed for intermediate users, is performed with the homogeneous head.

Popis použitých zařízení/přístrojů:

Výkonné pracovní stanice

[1] S. Yang, G. Xu, L. Wang, Y. Chen, H. Wu, Y. Li, Q. Yang, 3D Realistic Head Model Simulation Based on Transcranial Magnetic Stimulation, Conf. Proc. IEEE Eng. Med. Biol. Soc., 2006. Suppl.: 6469–6472.

In this exercise, the field in the brain is generated with a figure-eight current loop placed above the head as in fig.1: with this shape, the current maximum is located at the intersection of the two round wires. The exposure simulation generates information concerning the exact location of stimulation, which is important to know during TMS.

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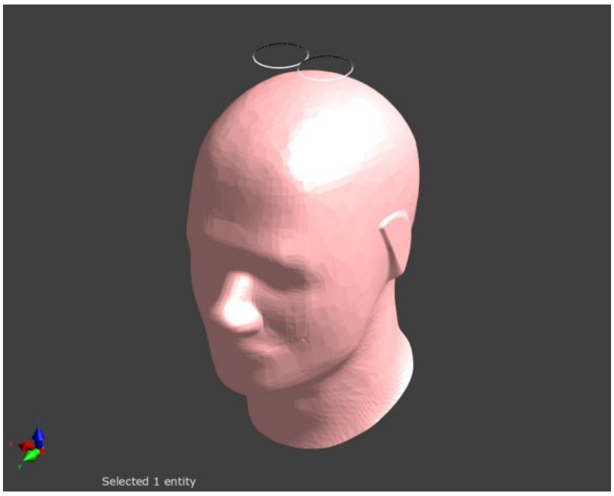

Modeling

- **Preparing the environment**
  1. Create a new project by selecting *File* | *New* from the menu.
  2. Select the *Model* tab.
  3. Select *Model* in the *Explorer* and verify that the *Model Units* in the *Options* window are *Metric/SI*, *mm* and *deg*.

- **Modeling SAM Head**
  1. Click *Imp/Export* in the ribbon and select *Import* from the group menu.
  2. Choose SAM_Head.sab from the folder.
  3. Click *Open* and then click *Import*, leaving options as default.
  4. Inside the "SAM" model group are two objects that represent the outer and inner parts of the head model, "SAM_Shell" and "SAM_Liquid", respectively.
  5. Set the *Translation* parameter inside the *Properties* window for both parts of the head model to (0, 23.5, -84.5) mm.

- **Modeling Coil**
  1. Draw a circle of radius 22.5 mm choosing *Circle* from *Sketch*
  2. Rename the circle "LF 1".
  3. In the *Properties* window, specify *Translation* values as -22.5, 0, 96.5 as the y-translation.
  4. Right click "LF 1" and select *Clone*.
  5. Rename this copy "LF 2".
  6. In the *Properties* window, change the x-component of *Translation* to 22.5.

Simulation Settings

Switch to the *Simulation* tab and click *New* | *EM LF Magneto* | *Quasi-Static*.

- **Setup**

  Inside the *Explorer* window click *Setup* and, inside the *Properties* window, insert a frequency of 10000 Hz.

- **Materials**

1. In the ribbon, click *New Settings* and rename the newly-created Material Settings inside the Explorer to “Head”.
2. In the *Properties* window, set Electric Conductivity = 0.33 S/m and Rel. Permittivity = 11000.
3. Click *Multi-Tree* in the ribbon and select the *Model* multi-tree if it is not already open.
4. Drag the “SAM” folder containing both the shell and liquid from the *Multi-Tree* | *Model* window to “Head”.

- **Current Sources**

1. Choose *Sources* under *Explorer* and select *Current Source* under *New Settings* in the ribbon.
2. Drag “LF 1” to *Wire Current Settings*.
3. Select *Current Source* under *New Settings* in the ribbon to create another settings folder.
4. Specify an *Amplitude (peak)* of -1 A under *Properties* and drag “LF 2” to *Wire Current Settings 1*.

- **Sensors**

1. By default the *Overall Field* sensor under *Sensors* is ctivated for recording the fields throughout the grid.

- **Grid**

1. Select *Grid* and click *Auto Grid Update* in the ribbon.
2. Select *SAM_Head* and *SAM_Liquid* in the *Automatic Default* grid settings group, right-click and select *New Settings* | *To Manual* from the context menu.
3. Click *Grid* again and specify the following properties:
4. *Discretization Settings*: *Manual*
5. *Maximum Step*: 12.5 mm
6. *Resolution*: 0.3 mm
7. Set *Padding Settings* to *Manual* and specify
8. *Bottom Padding*: 90 mm
9. *Top Padding*: 90 mm
10. Under *Automatic*, choose *Extremely Fine* as *Refinement*.
11. *Manual Settings*
12. *Maximum Step*: 3.1 mm
13. *Resolution*: 0.08 mm
14. A grid with ca. 1.691 MCells, The grid lines are shown in fig.3

Figure 2 Grid Setting

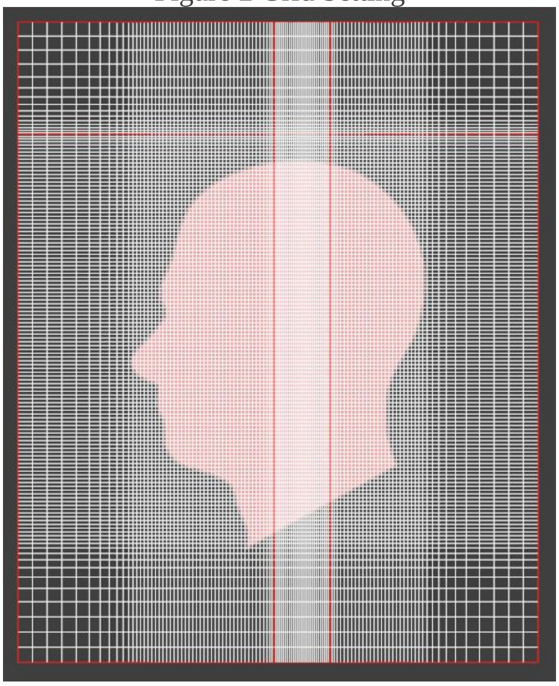

Figure 3 Visualization of grid lines in this tutorial

Voxels

1. Click the *Voxels* folder to go into the voxels settings.
2. Click *Create Voxels*, then *View Voxels* (both in the ribbon).

Solver

3. Start the simulation by clicking R*un*. A pop-up message is displayed at the bottom-right corner acknowledging submission of the simulation to the solver. All settings of the Simulation are now locked, as indicated by the symbol. To check the progress of the solver, open the *Task Manager* by clicking the icon at the bottom-right corner of the screen. In the pop-up window, unfold the last submitted task by clicking on the arrow. Click *Monitoring* to follow the progress of the solver. Another message appears when the simulation has finished.

Analysis

Once the simulation is finished, a notification will be displayed, and the results will be available for extraction in the *Analysis* environment.

1. Move to the *Analysis* tab. An object with the name of the simulation will be available.

2. Click on it, and the available sensors will be displayed in the *Output View* window.
3. Select *Overall Field*, right click and choose *Sensor Extractor*. A list of available quantities will be displayed.
4. Select *EM H(x,y,z,f0)* and click *Slice Viewer* from the *Viewers* group in the ribbon.
5. In the *Properties* window, in the *Slice Options*, choose *Plane XY* and click *Go to Max*. Select the checkbox *Smooth* in the *Visualization Options* group.
6. Press the *Refresh* button at the top of the *Properties* window. The plot should look like in fig.4.

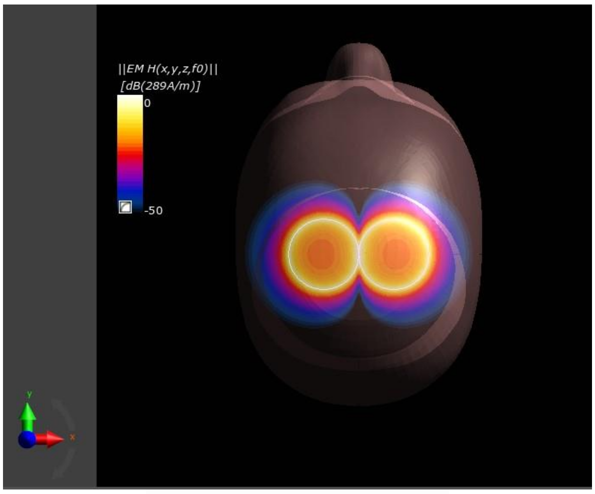

Fig.4.H-field distribution.

1. To view the B-field distribution inside the head, select *Overall Field* in *Explorer* window.
2. Select *B(x,y,z,f0)* and click *Slice Viewer* in the *Viewers* group of the ribbon.
3. In the *Properties* window, in the *Slice Options* section, choose *Plane XY* and specify 89 in the *Slice Index* field. Select the checkbox *Smooth* in the *Visualization Options* group.
4. Double click the color bar and set the *Decibel Reference* to 2.1e-07 T and click the *Apply* button.
5. The plot should look like in fig.5.

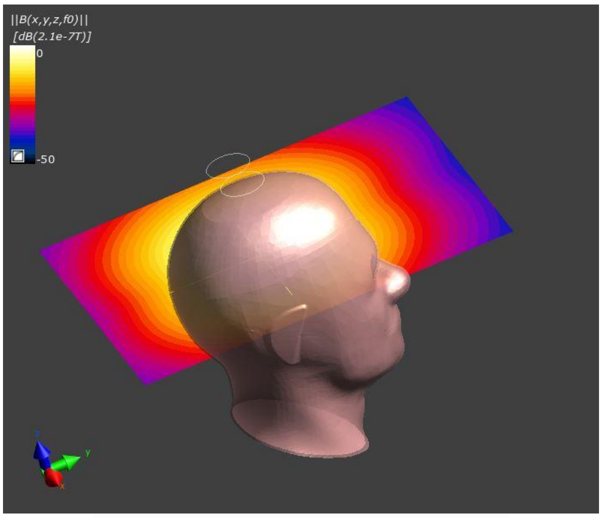

Fig. 5.Absolute B-field distribution

1. Select *Overall Field* in *Explorer* window.
2. Select *J(x,y,z,f0)* and click on the tool *Slice Viewer* from *Viewers* in the ribbon.
3. In the *Field Data Options* section of the *Properties* window, choose *Abs. Magnitude* as quantity to be displayed.
4. In the *Slice Options* section, choose *Plane YZ* and click *Go to Max*. Select the checkbox *Smooth* in the *Visualization Options* section.
5. Press the *Refresh* button at the top of the *Properties* window. The plot should look like in fig.6

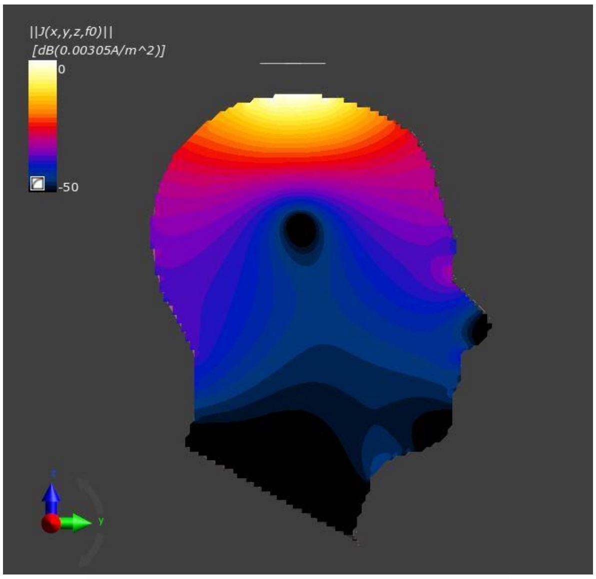

Fig. 6. Absolute J-field distribution.