Senior Design 491 - May1629
Design Document

Development of "Triple Halo Coil" for Deep Transcranial Magnetic Stimulation

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1 Project Overview

1.1 Introduction

Transcranial magnetic stimulation (TMS) is a non-invasive procedure for the treatment of neurological disorders. Producing varying magnetic fields within certain parts of the brain, transcranial magnetic stimulation can treat certain disorders, such as Parkinson's, post traumatic stress disorder. Currently only depression can be treated with TMS as the outer regions of the brain are related to the condition.

1.2 Project Purpose

It is our goal to improve upon previously developed TMS coils so that TMS can eventually be available for the treatment of many disorders.

1.3 Deliverables

- Simulated results showing improvement in depth and accuracy
- Simulated results showing structural integrity
- A new TMS coil derived of three copper coils

2 System level design

2.1 Requirements

Functional Requirement:

- Achieve a maximum stimulation of 150 V/m inside the deep region of the brain
- The peak current in the coil should not exceed 5000 A.
- The winding between the coils should be distanced at 2.5 mm from each other.
- The coil's helmet should be able to move freely as directed.
- The coil should be able to be controlled through the computer

Non-Functional Requirement:

- Accuracy - The coil must be able to achieve the consistent results
- Reliability- The coil must not decay pretty soon
- Comfortability- The coil's helmet should be comfortable when applied over patients.
- Safety- The coil should be safe to be applied over patients by maintaining optimal temperature etc.
- Variability- The coil should be able to accommodate different head sizes

2.2 System analysis

The design and components of TMS devices are relatively straightforward and universal. The whole system consists of several parts.

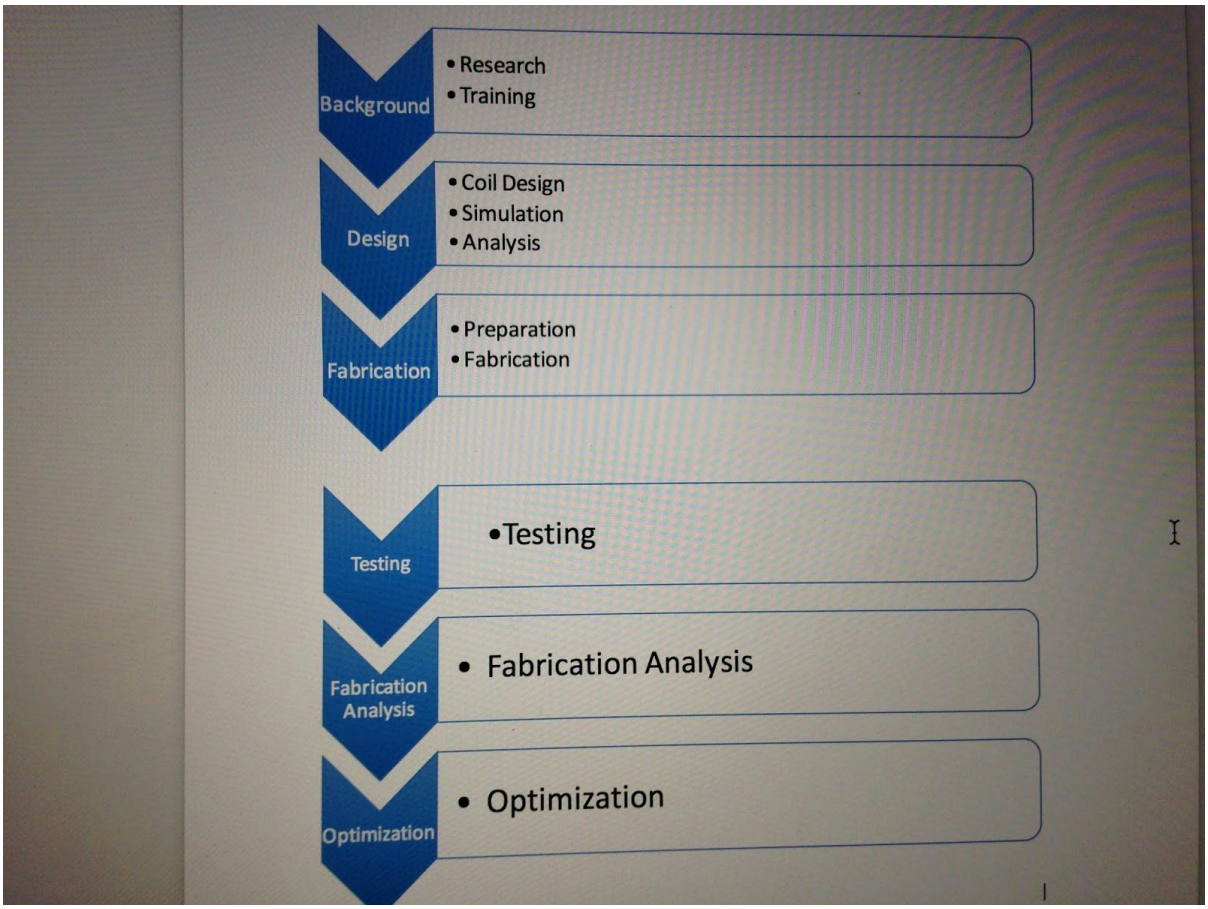
Stimulator

The Stimulator can generate either monophasic, biphasic or repetitive stimulation pulses. It will deliver reliable and accurate energy to coils. Actually it is a system power supply and will input a signal 5000A at 2500 Hz.

Coils

The stimulating coil consists of more well-insulated coils of copper wire (frequently housed in a molded plastic cover). As current passes through these coils, varied patterns of magnetic fields are generated which, in turn, generate a current in the opposing direction in any nearby conductor. Coils can be arrayed in a variety of shapes and sizes. The specific geometry of each coil determines the shape, strength, and overall focality of the resultant induced electric field, and thus of the brain stimulation.

2.3 Block diagrams of the concept



3 Detail description

3.1 Interface specifications

Coil

Triple Halo Coil:

Triple Halo Coil is going to use second generation pinning with 2 of the HV feed pins missing. Resistance and Inductance of coil will be 0.047 ohm, 22.474 microhenry. Triple Halo Coil consists three large Halo Coils.

Stimulator

The Magstim Model 200 may be operated from supplies in the range 110-120V and 220-240V.

POWER:

Voltage:	110V-120V/220-240V ac
Supply Frequency:	50-60Hz
Power Input Fuse Rating:	2 x T3.15A (Europe)
	1 x 6.3A A/S (USA/Japan)
Power Requirements:	300W
	2.5kVA peak
Leakage Current:	<100mA at 120V ac
	<200mA at 240V ac

AMBIENT TEMPERATURE:

Permissible Environmental Conditions for Transport

Ambient Temperature Range:	-40ºC to 60ºC
Relative Humidity Range:	10% to 80% Non Condensing
Atmosphere Pressure Range:	50 kPa to 106 kPa

Storage and Operating Conditions:

Operating Temperature Range:	5 ºC to 30ºC
Storage Temperature Range:	-40ºC to 60ºC
Coil Temperature Range:	5ºC to 60ºC

CAPACITOR LIFE EXPECTANCY

Life expectancy:

2 x 106 discharges at 70% power level

8 x 105 discharges at 80% power level

4 x 105 discharges at 90% power level

2 x 105 discharges at 100% power level

3.2 Hardware/software specifications

Material of coils are copper. And the thickness of copper coils should be 1 mm, and width is 5mm.

Triple Halo Coil:

Triple Halo Coil consists three large Halo Coils. The coils will be comprised of 15 turns with internal radius of the elliptical coils are 200mm and 300mm with a distance of 2.5 mm within each coil. And the gap between each Halo Coils will be 5 mm.

Circular Coil:

The Circular coil will be comprised of 14 turns with internal radius of 33.5 mm and external of 62.5mm. The distance between each coils is same as Triple Halo Coils which is 2.5mm.

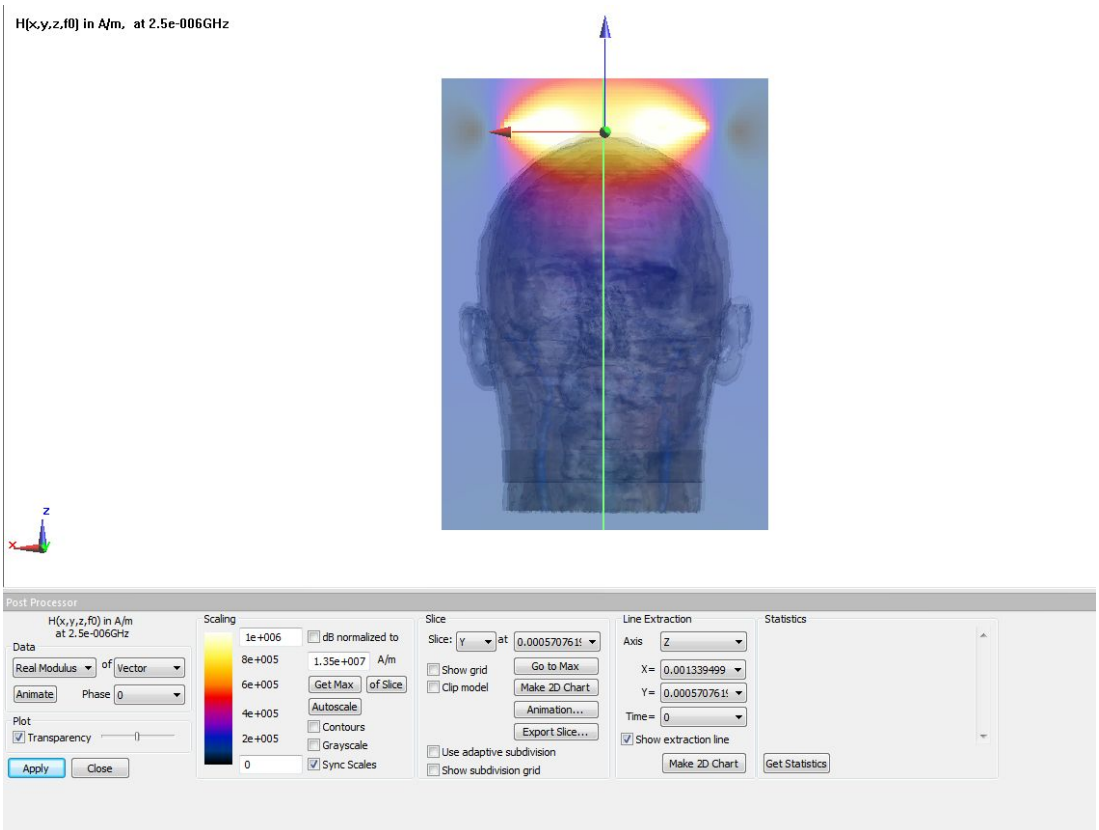
3.3 Simulations and modeling

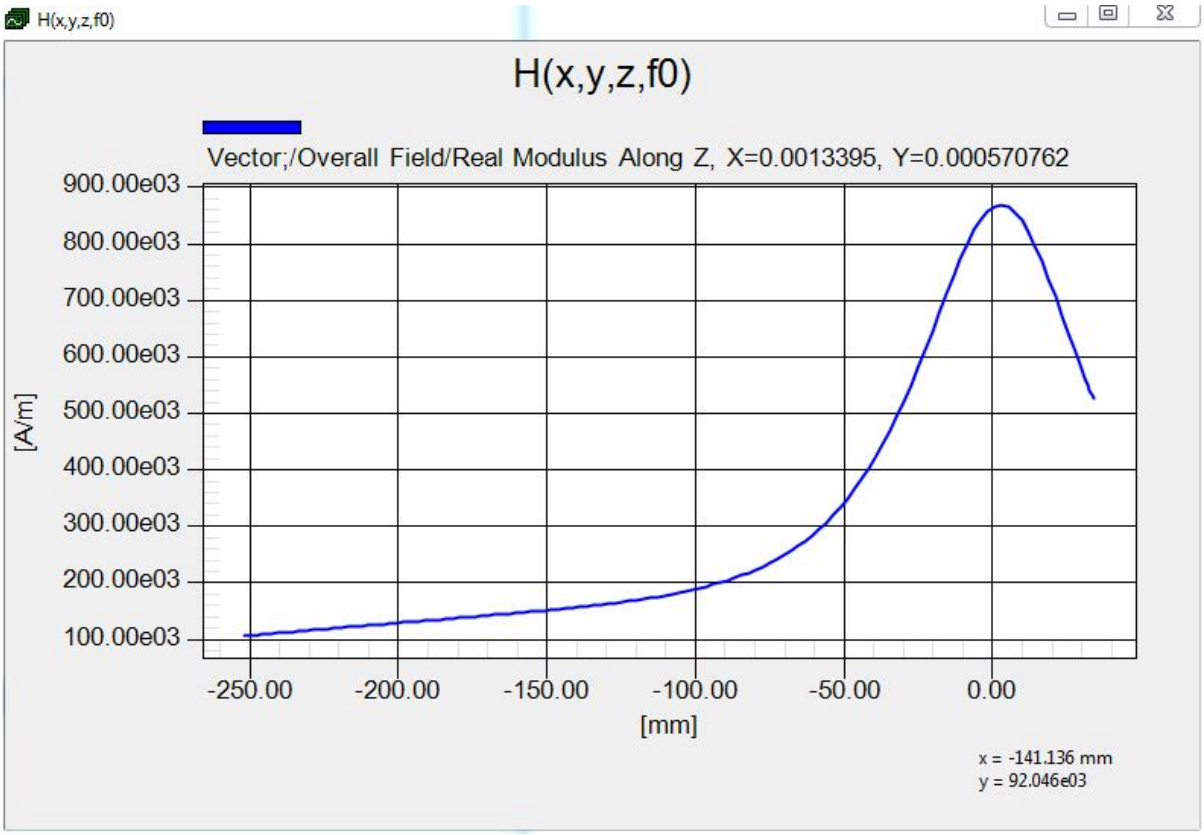
SEMCAD X

To design our coils, we used Semcad- a finite element analysis tool to study the various simulation results, and to test our designed coil.

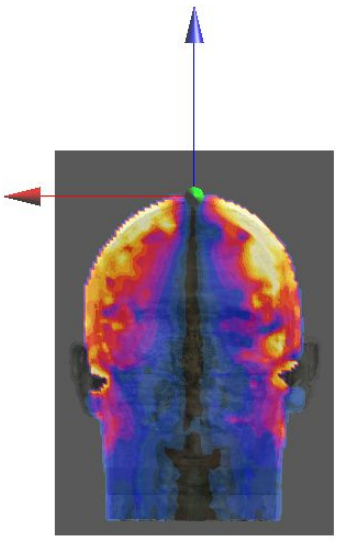
We fabricated the following design, with the attached magnetic and electric field:

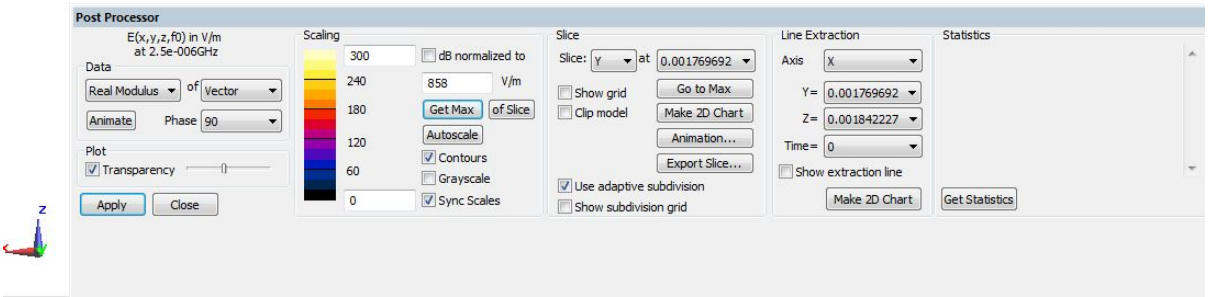
The triple halo coil, with coordinates 200 by 300: This designed coil consisted of 15 turns with starting coordinated 200 and 300, and further incrementing them with 2.5 mm. After the 5th turn, we considered a gap of 5 mm, and then continued to increament by 2.5 mm further upto 10th turn. Again, after 10th turn, we used a increment of 5 mm, and further with 2.5 mm





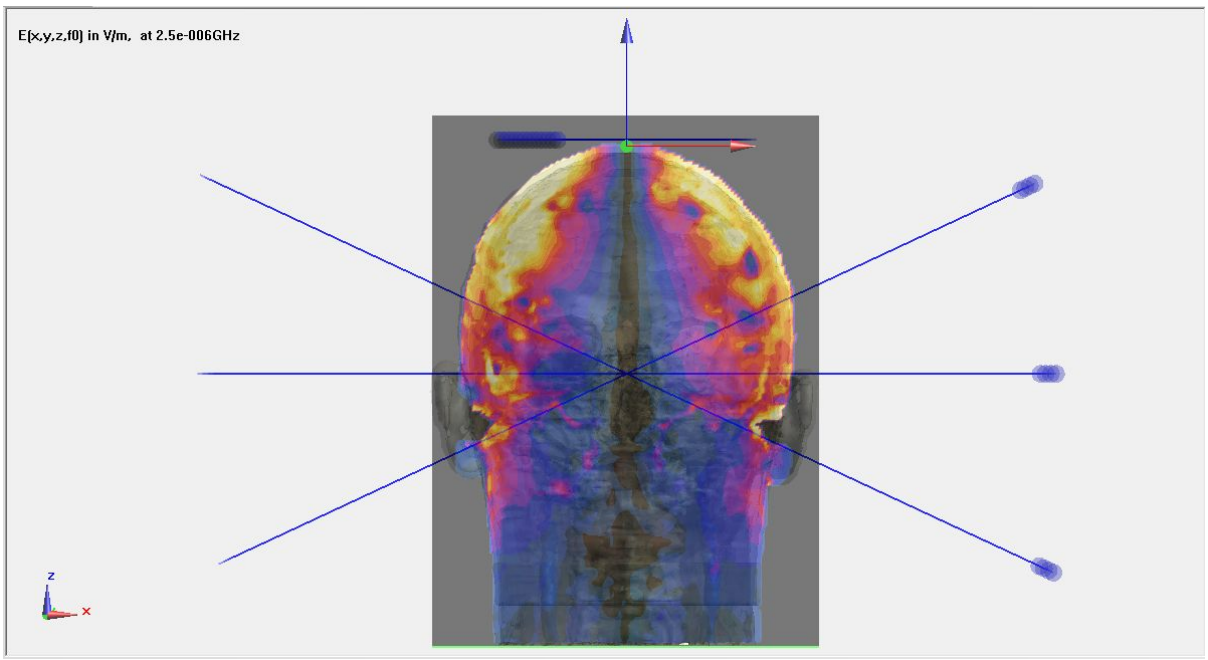
E(x,y,z,f0) in V/m, at 2.5e-006GHz



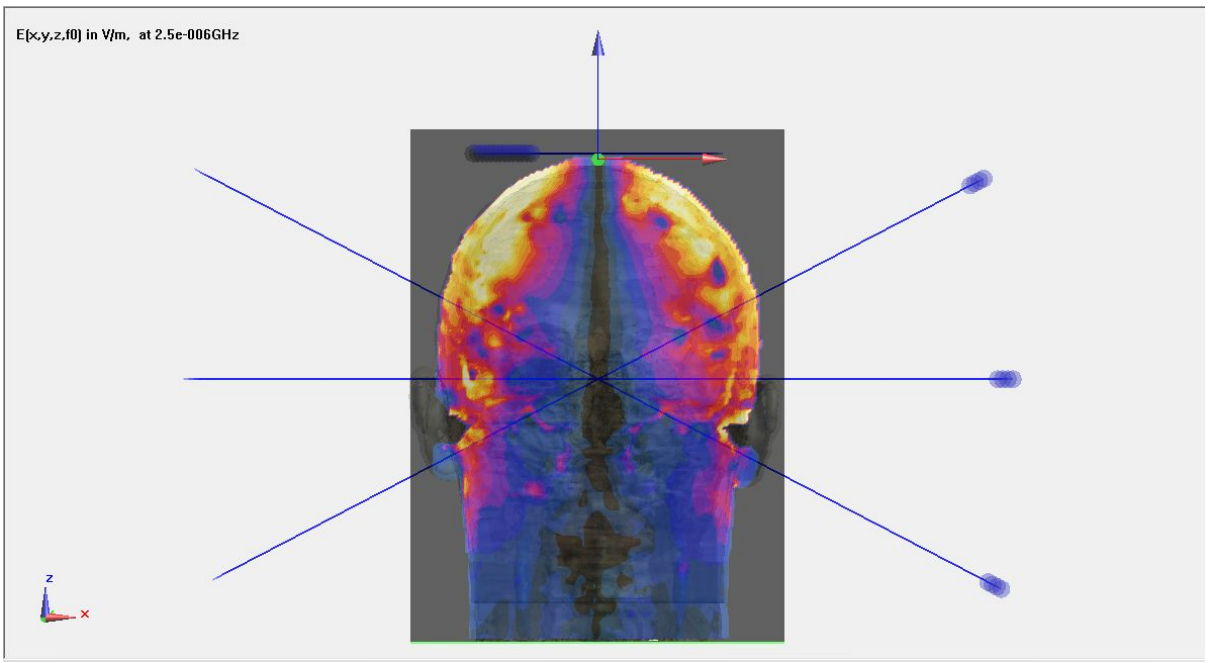


Rotation Angle

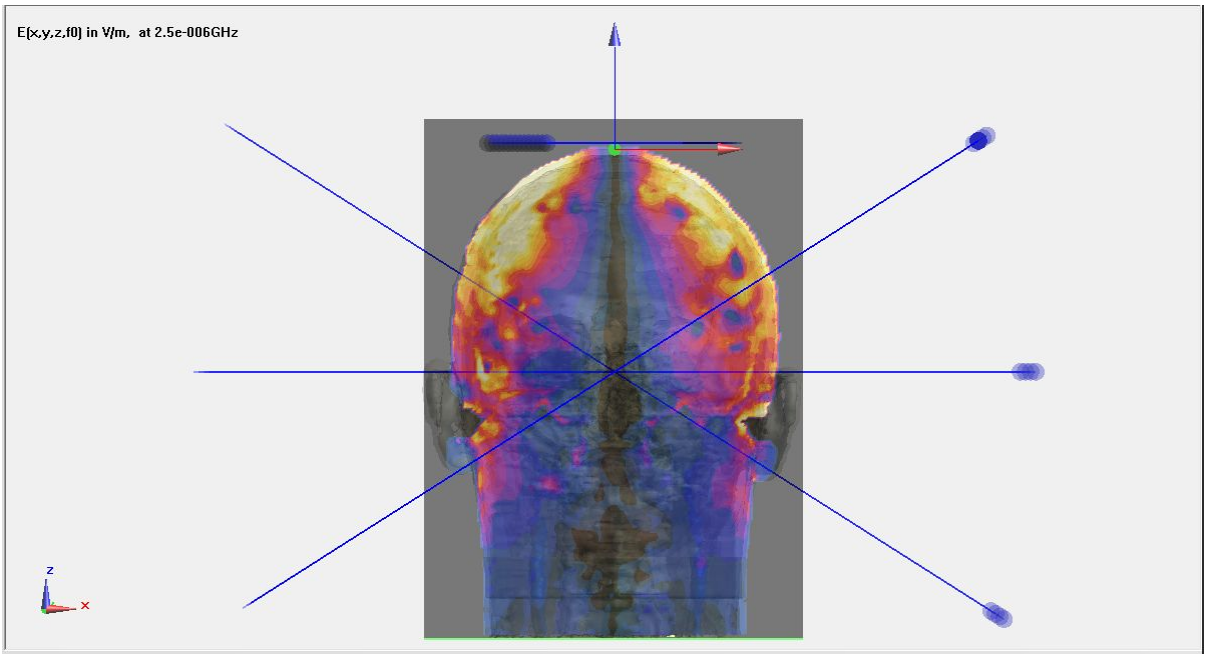
25 Degree

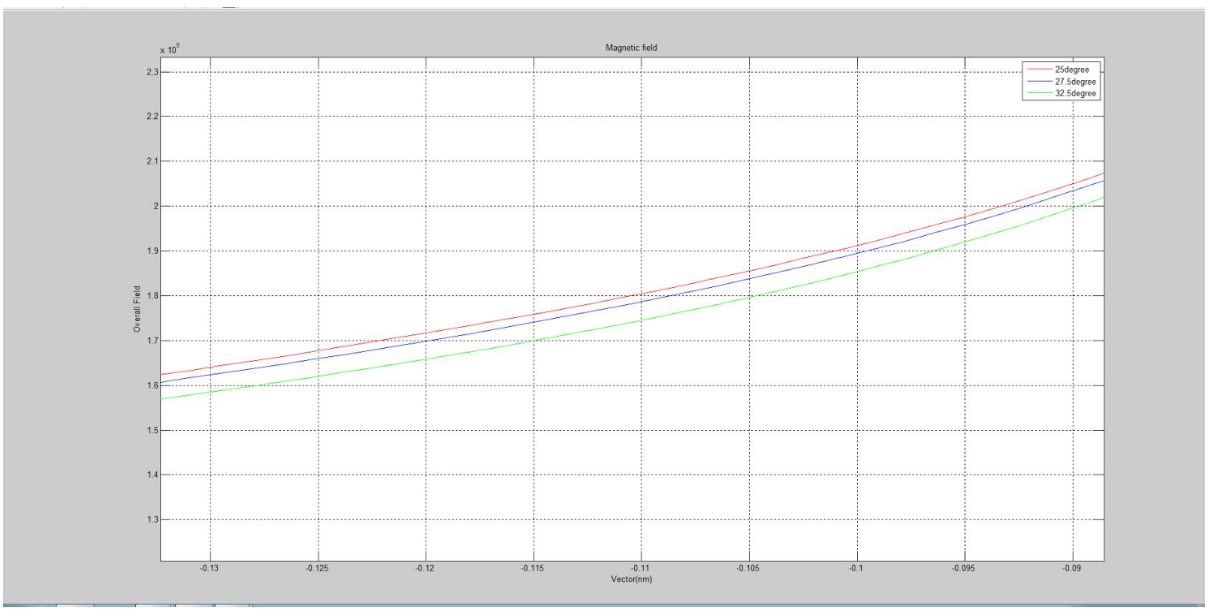


27.5 degree



32.5 degree


E(x,y,z,f0) in V/m, at 2.5e-006GHz
z
x

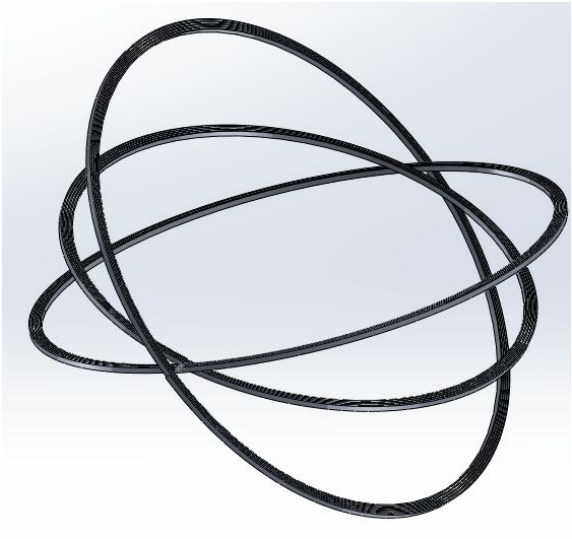

Magnetic field
x 10^5
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
Overall Field
-0.13
-0.125
-0.12
-0.115
-0.11
-0.105
-0.1
-0.095
-0.09
Vector(nm)
25degree
27.5degree
32.5degree

SolidWorks Model - Triple Halo Coil

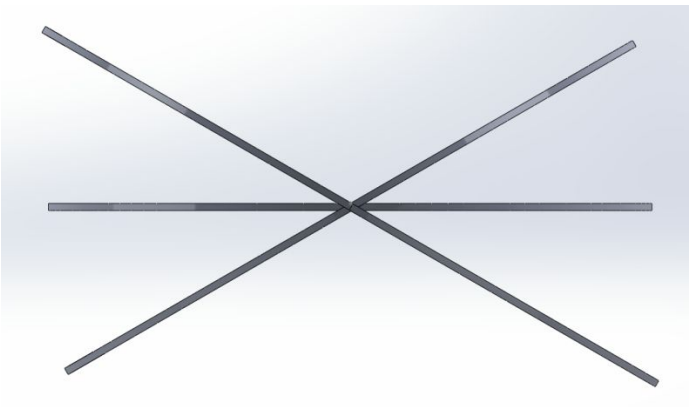
CAD software used to design a 3 dimensional model of the Triple Halo Coil

Dimensions

Inner coil	Inner radii	200mm, 300mm
	Outer radii	212.5mm, 312.5mm
Middle coil	Inner radii	218.5mm, 318.5mm
	Outer radii	231mm, 331mm
Outer coil	Inner radii	237mm, 337mm
	Outer radii	249.5mm, 349.5mm

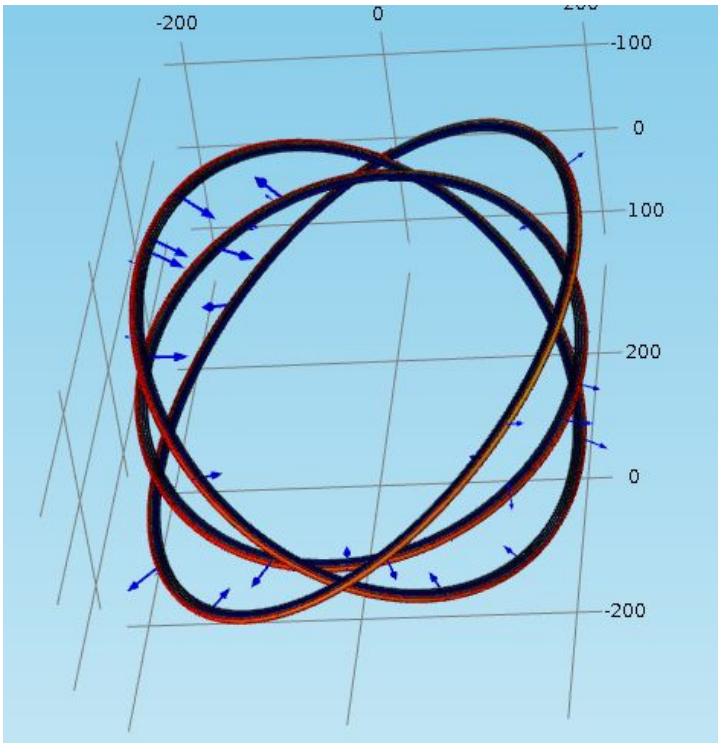


Distance between turns	1.5mm
Distance between Coils	5mm
Angle between Coils	30 degrees



COMSOL

Another finite element analysis software being used for the Triple Halo Coil simulation is COMSOL Multiphysics. Models designed in SolidWorks are imported to COMSOL for thermal and structural analysis. Joule heating and Lorentz force are two important measurements needed to ensure the stability of the design. Below is a simplified model of the Triple Halo Coil in COMSOL. (arrows represent Lorentz Force)



3.4 Implementations issues challenges

Coil Fabrication

One of the problem with the project is material of coils. Coils must use rectangular enamelled conductor of copper at right size. Have a reliable contact with right copper wire supplier company is very necessary.

Expensive Device

Many devices are very expensive such as Stimulator. In order to avoid mistakes during using stimulator, group members must take care and read instruction manual.

Tools

We need to use many new software which we haven't used it before such as SEMCAD X, Sim4life and COMSOL. It will take much for team member to get training with it and debug error.

3.6 Testing

We used the SemCAD, a finite element analysis software to test our magnetic and electric fields produced by the various coils. We used a heterogeneous head model to study the detailed effects on various materials of the brain. By using the triple halo coil with coordinates 200 by 300, and maintaining 5000 A current, with magnetic scale from 0 to 1e+006, we were able to achieve a maximum magnetic field strength of 1.35e+007 A/m.

4 Other documents

Rachana Kaul, Bridget N. Hogan, Ravi L. Hadimani, Lawrence J. Crowther, and David C. Jiles. "New Coil Designs for Deep Brain Transcranial Magnetic Stimulation Using Halo Coil Configurations"

L. J. Crowther, P. Marketos, P. I. Williams, Y. Melikhov, D. C. Jiles, and J. H. Starzewski. "Transcranial magnetic stimulation: Improved coil design for deep brain investigation" Journal of Applied Physics, 2011

L. J. Crowther, I. C. Nlebedim, and D. C. Jiles, "Developments in deep brain stimulation using time dependent magnetic fields," Journal of Applied Physics, 2012.

P. I. Williams, P. Marketos, L. J. Crowther, and D. C. Jiles, "New Designs for Deep Brain Transcranial Magnetic Stimulation," IEEE Transactions on Magnetics, 2012.

Zhi-De Deng, Sarah H. Lisanby, Angel V. Peterchev, "Electric field depth–focality tradeoff in transcranial magnetic stimulation: Simulation comparison of 50 coil designs, Brain Stimulation", 2013.

5 Conclusion

Once we are able to test it and optimize the coils, it would be sent to further research institute to verify the results, and would finally be available to the various hospitals for the treatment and beneficiary of mankind.