

UNIVERSITY OF THE SOUTHERN QUEENSLAND



NUMERICAL INVESTIGATION OF TRANSCRANIAL DIRECT CURRENT STIMULATION ON CORTICAL MODULATION

A dissertation submitted by

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Abstract

Transcranial direct current stimulation (tDCS) is a non-invasive and sub-convulsive functional stimulation technique with applications in both clinical therapy and neuroscience research. The technique provides researchers and clinicians with a unique tool capable of modulating the neural excitability in both the central and peripheral nervous system. On a clinical level, the procedure has been used quite extensively for its potential therapeutic applications in a number of neurological disorders. Despite the advantages of being safe, low cost and easy to administer, our limited understanding on interaction mechanisms between the stimulation parameters and biological materials has impeded the development and optimisation of tDCS based therapies.

The focus of this thesis is to develop a realistic finite element based human head model to address the problems involved in the forward modelling of transcranial direct current stimulation. The study explores the effects of model complexities and anisotropic material properties on field estimations. The sensitivity of electric field and current density on accurate modelling of cortical and non-cortical structures, and the influence of heterogeneously defined anisotropic electric conductivity on field parameters were analysed in an incremental manner. Using the averaged and the subject specific Magnetic Resonance Imaging (MRI) and Diffusion Tensor Imaging (DTI) data, the head models with detailed anatomical features and realistic tissue conductive properties, were developed and employed to specifically address the role of stimulation parameters, such as: morphological variations, structural details, tissue behaviour, inter-subject variations, electrode montages and neural fibre pathways for defining the site and strength of modulation/stimulation.

This thesis demonstrates the importance of human head modelling in elucidating the complex electric field and current density profiles instigated by the non-invasive

electric stimulation. The results of this study strongly support the initial hypothesis that model complexity and accurate conductivity estimation play a crucial role in determining the accurate predictions of field variables. The study also highlighted the inadequacy of scalar field maps to decipher the complex brain current flow patterns and axonal/neural polarization. With the proposed refinements, model based strategies can be employed to optimally select the required stimulation strength and electrode montage specific to individual dose requirements. Therefore, the work conducted in this study will bridge the gap between the current clinical practices and the subject specific treatments by providing accurate physiologically representative simulation.

Certification of Dissertation

I certify that the ideas, experimental work, results, analyses, software and conclusions reported in this dissertation are entirely my own effort, except where otherwise acknowledged. I also certify that the work is original and has not been previously submitted for any other award, except where otherwise acknowledged.

Signature of Candidate

Date

ENDORSEMENT

Signature of Supervisors

Date

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List of related publications

The following papers, associated with the research contained in this dissertation, have been published or submitted for publication.

JOURNAL PAPERS

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Contents

ABSTRACT	III
CERTIFICATION OF DISSERTATION	V
ACKNOWLEDGEMENT	VI
LIST OF RELATED PUBLICATIONS	VII
LIST OF TABLES	XIII
LIST OF FIGURES	XV
1. INTRODUCTION.....	1
1.1. BACKGROUND.....	1
1.2. AIM AND OBJECTIVES	2
1.3. OVERVIEW OF THE PROPOSED STRATEGY	3
1.4. SCOPE	4
1.5. THESIS OVERVIEW	7
2. ELECTROMAGNETIC STIMULATION OF HUMAN BRAIN.....	10
2.1. CLASSIFICATION OF ELECTROMAGNETIC STIMULATION	10
2.2. SIGNIFICANCE OF ELECTROMAGNETIC STIMULATION	11
2.3. INTRODUCTION TO TRANSCRANIAL DIRECT CURRENT STIMULATION	12
2.3.1. <i>Mechanism of dosage delivery</i>	12
2.3.2. <i>Dosage and its relationship with excitability</i>	14
2.4. SCOPE OF TDCS FORWARD HEAD MODELLING	16
2.4.1. <i>The forward human head model</i>	17
2.4.1.1. Analytical and simplified numerical head models	17

2.4.1.2.	Numerical volume conductor models	18
2.5.	MATHEMATICAL FORMULATION OF FORWARD HEAD MODEL	22
2.5.1.	<i>Maxwell's equations</i>	23
2.5.2.	<i>Quasi-static approximation</i>	24
2.5.3.	<i>Boundary conditions</i>	27
2.6.	NUMERICAL MODELLING FORMULATION FOR TDCS	28
2.6.1.	<i>Finite element method based formulation</i>	29
2.7.	ASSESSMENT CRITERIA FOR MODEL COMPARISON	32
2.8.	CHAPTER SUMMARY	34
3.	HUMAN HEAD MODEL DEVELOPMENT	35
3.1.	REALISTIC HUMAN HEAD MODEL CONSTRUCTION	35
3.1.1.	<i>Scalar imaging modalities</i>	37
3.1.2.	<i>Spatial image registration</i>	38
3.1.3.	<i>Spatial coregistration/transformation of scalar volumes</i>	41
3.2.	MULTIMODAL IMAGE SEGMENTATION.....	41
3.3.	ELECTRODE MODELLING	43
3.4.	MESH GENERATION	45
3.5.	CHAPTER SUMMARY	47
4.	ELECTRICAL PROPERTIES OF HUMAN HEAD TISSUES.....	48
4.1.	ISOTROPIC ELECTRICAL CONDUCTIVITIES OF HEAD TISSUES	48
4.2.	MODELLING THE ANISOTROPIC CONDUCTIVITY FOR NON-CORTICAL STRUCTURES	50
4.3.	MODELLING THE ANISOTROPIC CONDUCTIVITY OF THE BRAIN	52
4.3.1.	<i>Estimating brain anisotropic conductivity from measured diffusion tensor data</i>	54
4.3.1.1.	Diffusion tensor calculation	55
4.3.1.2.	Diffusion anisotropy by tensor parameters	58
4.3.1.3.	Artefacts in DT-MRI.....	62
4.3.1.4.	DW imaging modalities	64
4.3.1.5.	DTI data processing	64
4.3.1.6.	Translation of diffusion tensor to conductivity tensor	67

4.4.	INDUCED ELECTRIC FIELD TRACKING AND ASSESSMENT OF STIMULATION MECHANISMS ALONG FIBRE PATHWAYS.....	71
4.5.	CHAPTER SUMMARY.....	74
5.	ROLE OF MODEL COMPLEXITY ON FIELD ASSESSMENT.....	76
5.1.	INTRODUCTION.....	76
5.2.	MATERIAL AND METHODS.....	77
5.2.1.	<i>Head model design</i>	77
5.2.2.	<i>Tissue conductivity</i>	77
5.2.3.	<i>Electrode configurations and current density calculation</i>	79
5.3.	RESULTS AND ANALYSIS.....	80
5.3.1.	<i>Influence of model complexity on field assessment – impact of non-cortical structures</i>	80
5.3.2.	<i>Influence of tissue anisotropy (artificial) on field estimates</i>	86
5.4.	CONCLUSION.....	94
6.	ROLE OF REALISTIC WHITE MATTER ANISOTROPIC CONDUCTIVITY ON FIELD ESTIMATES.....	96
6.1.	INTRODUCTION.....	96
6.2.	MATERIAL AND METHODS.....	97
6.2.1.	<i>Isotropic volume conductor model construction</i>	97
6.2.2.	<i>Incorporation of WM anisotropic conductivity</i>	99
6.2.3.	<i>Tissue electric conductivity assignment</i>	100
6.2.4.	<i>Electrode configuration and current density calculation</i>	101
6.2.5.	<i>Sensitivity analysis</i>	102
6.3.	RESULTS AND ANALYSIS.....	102
6.3.1.	<i>Volume/domain analysis</i>	102
6.3.2.	<i>Volume of interest (VOI) analysis</i>	109
6.3.3.	<i>Role of anatomical variation in field distribution</i>	116
6.4.	DISCUSSION.....	119
6.5.	CONCLUSION.....	122
7.	EFFECT OF GREY MATTER AND SUB-CORTICAL ANISOTROPY ON FIELD ASSESSMENT.....	124

7.1.	INTRODUCTION.....	124
7.2.	MATERIAL AND METHODS	125
7.2.1.	<i>Isotropic head model construction</i>	125
7.2.2.	<i>Conductivity assignment</i>	127
7.2.3.	<i>Translation of diffusion tensor to conductivity tensor and electrode configurations</i>	128
7.3.	RESULTS AND ANALYSIS	130
7.3.1.	<i>Impact of brain anisotropy</i>	130
7.3.2.	<i>Electrode montage variation</i>	136
7.4.	DISCUSSION	141
7.5.	CONCLUSION.....	143
8.	EFFECT OF TISSUE ANISOTROPIC CONDUCTIVITY AND FIBRE TRACTS IN NEUROMODULATION	145
8.1.	INTRODUCTION.....	145
8.2.	MATERIAL AND METHODS	146
8.2.1.	<i>Electrode configurations and field calculations</i>	146
8.3.	RESULTS	148
8.3.1.	<i>HD vs. conventional tDCS electrode configurations</i>	148
8.3.2.	<i>Effect of anisotropic conductivity</i>	151
8.3.3.	<i>Assessment of electric field along fibre tracts</i>	158
8.4.	DISCUSSION	165
8.5.	CONCLUSION.....	167
9.	CONCLUSION AND FUTURE DIRECTION	169
9.1.	MAIN CONTRIBUTIONS	169
9.2.	FUTURE WORK AND DIRECTION	171
	REFERENCES.....	174

List of Tables

Table 4-1: Isotropic conductivity assignment	49
Table 5-1: Comparison of J_{median} across different layers	84
Table 5-2: Concentration of active regions across GM and WM	85
Table 5-3: Conductivity assignment for model comparison (conductivities are in S/m)	86
Table 5-4: Statistical variations across GM under C3-Fp2 electrode configuration..	92
Table 5-5: Statistical variations across WM under C3-Fp2 electrode configuration.	92
Table 5-6: Concentration of active regions across GM and WM	93
Table 6-1: Percentage RDM and CC across GM, WM, M1, Contralateral M1 and Supplementary motor area of averaged models. A1: Isotropic head model, A2: artificial anisotropy (radial) based head model, A3: head model based on Equivalent Isotropic Trace algorithm, A4: Model based on fixed (eigenvalues) anisotropic algorithm and A5: model based on Proportional Anisotropic Ratio algorithm	107
Table 6-2: Maximum and median values of current density for GM, WM, M1, Contralateral M1 and Supplementary motor area of averaged models. A1: Isotropic head model, A2: artificial anisotropy (radial) based head model, A3: head model based on Equivalent Isotropic Trace algorithm, A4: Model based on fixed (eigenvalues) anisotropic algorithm and A5: model based on Proportional Anisotropic Ratio algorithm.....	108
Table 6-3: Percentage RDM for two regions of interests	110
Table 6-4: Maximum and median values of current density (mA/m^2) across ROI of averaged models under consideration. A1: Isotropic head model, A2: artificial anisotropy (radial) based head model, A3: head model based on Equivalent Isotropic Trace algorithm, A4: Model based on fixed (eigenvalues) anisotropic algorithm and A5: model based on Proportional Anisotropic Ratio algorithm	111

Table 7-1: Conductivity Assignment	127
Table 8-1: Return current distribution among cathodes in HD-montages	148
Table 8-2: Strength of E-field (median values) in various regions for each electrode configuration	151
Table 8-3: Magnitude (RE) and topographic (RDM) errors in the induced electric field of the volume conductor model due to the inclusion of skull, eye muscles, muscle of mastication and brain directional electric conductivity. Electrode configuration is 4×1 high-definition with anode at C3 and four cathodes around C1, C5, FC3 and CP3	155
Table 8-4: Magnitude (RE) and topographic (RDM) errors in the induced electric field of the volume conductor model due to the inclusion of skull, eye muscles, muscle of mastication and brain directional electric conductivity. Electrode configuration is 4×1 high-definition with anode at C1 and four cathodes around Cz, C3, FC1 and CP1	156
Table 8-5: Magnitude (RE) and topographic (RDM) errors in the induced electric field of the volume conductor model due to the inclusion of skull, eye muscles, muscle of mastication and brain directional electric conductivity. Electrode configuration is conventional C3-Fp2.....	156
Table 8-6: Qualitative ranking based on the selected regions of interest	157

List of Figures

Figure 2.1: The layered structure of cerebral cortex. Source: http://chronopause.com	15
Figure 2.2: The general bioelectric problem. The domain Ω is divided into a number of sub-domains, classified by their individual electrical conductivities.	28
Figure 3.1: Isotropic finite element head model construction workflow.	37
Figure 3.2: Masks of twenty segmented tissues of the head model using T1, T2 and PD-MRI volumes of the simulated datasets (a) axial slice and (b) coronal slice.	42
Figure 3.3: Four conventional bi-cephalic electrode montages. (a) C3-Fp2 electrode configuration, (b) F3-Fp2 electrode configuration, (c) P3-Fp2 electrode configuration and (d) C3-C4 electrode configuration.	44
Figure 3.4: High-definition electrode configuration derived from the International 10–10 EEG electrode system. (a) 64 electrode positions derived from the 10–10 EEG electrode system. (b) 64 electrodes covering the brain, (c) HD montage with anode at C3 and cathode positioned at C1, FC3, CP3 and C5, and (d) HD montage with anode at C1 and four cathodes placed at Cz, C3, FC1 and CP1.	45
Figure 3.5: Tetrahedral volumetric mesh with approximately 2 million tetrahedral elements. (a) Three dimensional representation of human brain, (b) Tetrahedral volumetric mesh over the brain region and (c) Region of interest highlighting the mesh quality.	46
Figure 4.1: The three layer composition of human skull, the soft bone (spongiosa) enclosed by the hard bone (compacta). Source: (Hallez, Staelens & Lemahieu 2009; Hallez et al. 2008).	52
Figure 4.2: The complex fibre architecture (WM fibre bundles) of the human brain. Source: (http://www.vh.org/Providers/Textbooks/BrainAnatomy).	53
Figure 4.3: Nine coefficients of a diffusion tensor field. The diagonal components of the tensor are dominant indicating the positive definiteness of the diffusion tensor. 57	

Figure 4.4: Quantitative diffusion and fractional anisotropy (<i>FA</i>) maps. Out of nine, only six (three diagonal and three off diagonal) coefficients are required to represent the complete tensor field information (second rank and symmetric tensor approximation).....	59
Figure 4.5: Scalar measures derived from the diffusion tensor of the subject specific data (UCLA_0591). Eigenvalues ($\lambda_1, \lambda_2, \lambda_3$) (from high to low) and the linear, planer and spherical geometric measures illustrating the diffusion classification, the sum of which is unity.....	61
Figure 4.6: Scalar measures derived from the diffusion tensor of the subject specific data (H0351.2001). Eigenvalues ($\lambda_1, \lambda_2, \lambda_3$) (from high to low) and the linear, planer and spherical geometric measures illustrating the diffusion classification, the sum of which is unity.....	61
Figure 4.7: Different type of artefacts in DT-MRI.....	63
Figure 4.8: Effect of negative eigenvalues on the fractional anisotropy (<i>FA</i>) maps of UCLA-0591 and H0351.2001 data. (a) and (d) show the <i>FA</i> maps of individual subjects without noise compensation. (b) and (e) illustrate the regions affected by the noise artefacts in terms of <i>FA</i> values higher than 1. (c) and (f) <i>FA</i> maps after imposing the positive definiteness (the noise compensation).....	66
Figure 4.9: (a) DWI with local tensor information, (b) Spatially co-registered DWI, (c) Spatially co-registered DWI after orientation correction.....	67
Figure 4.10: Translation of diffusion tensor to conductivity tensor using the Effective Medium Approach and its derivative.....	69
Figure 4.11: The linear relationship between the conductivity tensor and measured diffusion tensor based on the Effective Medium Approach.....	70
Figure 4.12: The directionally encoded colour <i>FA</i> maps (a) Coronal, (b) Axial, (c) Sagittal plane and (d) Major White matter fibre tracts. The directionally encoded colour <i>FA</i> maps incorporate major eigenvector information for each voxel. The fibre orientation is encoded by (RGB) colour scheme i.e. Red (right – left), Green (anterior – posterior) and Blue (superior – inferior). Subject specific DWI data (MNI_0591) was used to obtain these maps.....	72
Figure 4.13: Projection of the activating function (E_p) along the fibre tracts. The electric field was induced using a conventional 5x5 cm ² electrode pads place at C3 (anode) and Fp2 (cathode).	74
Figure 5.1: Current density variation across an arbitrary straight line, (a) 1D J distribution using C3-Fp2 electrode configuration, (b) 1D J distribution using C3-C4 electrode configuration, (c) an arbitrary straight line (parallel to the xy plane) starting from x=0 (left side of the head model) to x=0.18m (right side of the head model) and passing through various regions of the head model (d) Electrical conductivity variation across an arbitrary straight line.....	81

Figure 5.2: Comparative analysis of current density distribution between 5 and 9-layer head models, C3- Fp2 electrode configuration.	82
Figure 5.3: Comparative analysis of current density distribution between 5 and 9-layer head models, C3–C4 electrode configuration.	83
Figure 5.4: (a) Topographic variation in J as a function of model complexity and (b) Correlation coefficient as a function of model complexity.....	85
Figure 5.5: 1D J distribution pattern across a straight line passing through five (conductivity wise) different head models, (a) 1D J distribution using C3-Fp2 electrode configuration, (b) 1D J distribution using C3-C4 electrode configuration.....	88
Figure 5.6: Current density distribution across the scalps of M1, M2, M3, M4 and M5 under C3-Fp2 electrode configuration.....	89
Figure 5.7: (a) Current density distribution across GMs and (b) Current density distribution across WMs, under C3-Fp2 electrode configuration.....	91
Figure 5.8: Current density distribution pattern, isotropic (M1) vs. anisotropic (M5) distribution pattern under C3-Fp2 electrode configuration.....	94
Figure 6.1: Cortical and non-cortical regions segmented from the averaged and subject specific MRI datasets. (a) Volumetric head model highlighting the scalp region of the averaged head model. (b) 3D cutaway view of the averaged head model, illustrating various cortical and non-cortical regions. (c) The skull, muscles of mastication, eye muscles, eye (sclera) and eye-lens obtained from the averaged MRI datasets. (d) GM of the averaged head model. (e) WM of the averaged head model. (f) GM obtained from the individual (MNI_0591) MRI dataset. (g) 3D WM volumetric model representation based on subject specific dataset. (h) Coronal slice of the averaged head model illustrating conductivity tensor representation in the form of ellipsoids. The distribution is produced using (A3) Equivalent Isotropic Trace algorithm. (i) Normalized conductivity tensors representation across the coronal slice of the averaged model.	98
Figure 6.2: Dorsal view of an axial slice of FA (fractional anisotropy) map obtained from the measured diffusion tensor data. Regions of high anisotropy are depicted in red and yellow colours, whereas, the contrast of blue colour indicates regions of low anisotropy. ROI illustrates conductivity tensor ellipsoids. Their shape and orientation is dictated by the procedure employed. A1, Isotropic head model; A2, artificial anisotropy (radial) based head model; A3, head model based on Equivalent Isotropic Trace algorithm; A4, model based on fixed (eigenvalues) anisotropic algorithm and A5, model based on Proportional Anisotropic Ratio algorithm.....	101
Figure 6.3: (a) Distribution of current density (magnitude) across the GM and WM of all the five models. (b) Distribution pattern of the magnitude of the normal component of current density across the cortex of model A3. (c) Selected region highlighting the strength of the normal component of current density and black arrows indicate the direction of the induced current density vector. (d) Tangential component of current density across the cortex of A3. A1, Isotropic head model; A2,	

artificial anisotropy (radial) based head model; A3, head model based on Equivalent Isotropic Trace algorithm; A4, model based on fixed (eigenvalues) anisotropic algorithm and A5, model based on Proportional Anisotropic Ratio algorithm. 103

Figure 6.4: Variation of current density distribution in terms of percentage differences across the GM of (A2-A1), (A3-A1), (A4-A1) and (A5-A1). (a) Projection of % difference in J over the cortex. Regions where the strength of J has increased is shown in red and yellow colours. Whereas regions where the magnitude of J has dropped is indicated by a contrast of blue colour (b) histogram analysis highlighting the spread of difference distribution. A1, Isotropic head model; A2, artificial anisotropy (radial) based head model; A3, head model based on Equivalent Isotropic Trace algorithm; A4, model based on fixed (eigenvalues) anisotropic algorithm and A5, model based on Proportional Anisotropic Ratio algorithm. 105

Figure 6.5: Variation of current density distribution in terms of percentage differences across WM of (A2-A1), (A3-A1), (A4-A1) and (A5-A1). (a) Projection of % difference across the white matters. For A3-A1 and A5-A1 the scale is fixed between $\pm 20\%$. For comparison A2-A1 and A4-A1 the scale is set between $\pm 150\%$ (b) histogram analyses depicting the spread of difference distribution. A1, Isotropic head model; A2, artificial anisotropy (radial) based head model; A3, head model based on Equivalent Isotropic Trace algorithm; A4, model based on fixed (eigenvalues) anisotropic algorithm and A5, model based on Proportional Anisotropic Ratio algorithm..... 106

Figure 6.6: Current distribution pattern across an axial slice of model A4 (Fixed anisotropic ratio), along with the regions of interest..... 110

Figure 6.7: Current density patterns across the ROI (Splenum of corpus callosum) under various conductivity distribution schemes, using averaged models. A1, Isotropic head model; A2, artificial anisotropy (radial) based head model; A3, head model based on Equivalent Isotropic Trace algorithm; A4, model based on fixed (eigenvalues) anisotropic algorithm and A5, model based on Proportional Anisotropic Ratio algorithm..... 112

Figure 6.8: Comparison of (a) maximum and (b) median values of the current density (J) across the GM, M1, Contralateral M1 and SMA of the averaged models. (c) Topographic variation assessment across selected regions of various models using isotropic model A1 as a comparison reference. The degree of topographic variations has been measured using the relative difference measure (RDM). (d) Correlation coefficient, highlighting the type of relationship between J_{ISO} and J_{ANISO} across the ROIs in selected models. A1: Isotropic head model, A2: artificial anisotropy (radial) based head model, A3: head model based on Equivalent Isotropic Trace algorithm, A4: Model based on fixed (eigenvalues) anisotropic algorithm and A5: model based on Proportional Anisotropic Ratio algorithm..... 113

Figure 6.9: Visualization of percentage difference in current density across an arbitrary coronal slices of averaged models under discussion. A1: Isotropic head model, A2: artificial anisotropy (radial) based head model, A3: head model based on Equivalent Isotropic Trace algorithm, A4: Model based on fixed (eigenvalues) anisotropic algorithm and A5: model based on Proportional Anisotropic Ratio

algorithm. A1, Isotropic head model; A2, artificial anisotropy (radial) based head model; A3, head model based on Equivalent Isotropic Trace algorithm; A4, model based on fixed (eigenvalues) anisotropic algorithm and A5, model based on Proportional Anisotropic Ratio algorithm..... 114

Figure 6.10: Current density distribution (magnitude) across (a) GM, (b) WM, of subject specific head models. I1, Isotropic head mode; I2, artificial anisotropy (radial) based head model (not included in sensitivity analysis); I3, head model based on Equivalent Isotropic Trace algorithm; I4, model based on fixed (eigenvalues) anisotropic algorithm; and I5, model based on Proportional Anisotropic Ratio algorithm. 117

Figure 6.11: Comparison of J_{max} and J_{median} among the averaged (A) and subject specific (I) head models. Change in (a) maximum and (b) median values of current density across the gray matters. Variations in the strength of (c) maximum and (d) median values of current density across the individual and subject specific white matters (e) topographic variations in current density distribution across DTI based (averaged and subject specific) models with respect to their isotropic models. (f) Correlation among the magnitude of J across various head models. 118

Figure 7.1: (a) The volumetric tetrahedral mesh across various regions of the head model, (b) Arbitrary coronal slice illustrating various segmented regions of the head model, (c), C3-Fp2 electrode configuration, (d) volumetric representation of skull and muscles of mastication, (e) Volumetric depiction of GM, hindbrain, eyes, eye-lens, and eye muscles, (f) white matter and hindbrain, (g) sub-cortical structures such as hippocampus, caudate nucleus, putamen, thalamus, fornix, globus pallidus par externa, globus pallidus par interna and red nucleus, (h) coronal slice representing the anisotropic conductivity distribution across GM, WM and sub-cortical regions in the form of ellipsoids, (i) Zoomed out region from (h) illustrating variation in the magnitude and degree of alignment among conductivity tensors across the GM, WM and sub-cortical regions. 126

Figure 7.2: Induced Electric field distribution across (a) brain of models I1, I2, I3 and I4, (b) E-field distribution across the selected regions of model I4, highlighting the complex distribution pattern (from left to right) in the vicinity of cathode (Fp2), anode (C3) and SMA, respectively. (c) Induced electric field distribution across the selected sub-cortical structures of models I1, I2 I3 and I4, respectively. 131

Figure 7.3: Projection of percentage differences on the brain volume (a) I2-I1, (b) I3-I1 and (c) I4-I1. Difference distribution plots; (d) I2-I1, (e) I3-I1 and (f) I4-I1..... 132

Figure 7.4: Comparison of E_{max} across selected regions of a brain using four (conductivity wise) different head models, (b) Comparison of E_{median} across selected regions of a brain using (conductivity wise) different head models, (c) Topographic assessment by comparing selected regions of each model with their respective isotropic counterparts and (d) standard deviation in E-field distributions across various regions of the selected head models. 133

Figure 7.5: Percentage difference in the strength of induced electric field across the posterior view of a coronal slice (a) I2-I1, (b) I3-I1 & (c) I4-I1..... 134

Figure 7.6: Orientation analysis, posterior view of a coronal slice, containing GM, WM, and sub-cortical regions (a) fractional anisotropy (FA) map obtained from the measured diffusion tensor data. Regions of high anisotropy are shown in red and yellow colours, whereas, contrasts of blue colour indicate regions of low anisotropy. (b) Cosine of the parallel component of E_{I4} (vector projection of E_{I4} on the principal eigenvectors of the conductivity tensor) and E_{I4} vector. Regions of strong alignment are shown in red and yellow, whereas, contrasts of blue illustrate regions of strong orthogonality (c) Projection of normalized E_{II} (blue arrows) and E_{I4} (red arrows) along the plane. (d) Projection of non-normalized E_{II} (blue arrows) and E_{I4} (red arrows) vectors along the plane. 135

Figure 7.7: Role of electrode montage and anisotropy in shaping the induced E-field, (a) C3-Fp2 electrode montage, (b) F3-Fp2 montage, (c) P3-Fp2 montage and (d) C3-C4 montage. 138

Figure 7.8: Comparison of various electrode montages across the selected regions based on (a) E_{max} , (b) E_{median} and (c) % RDM (topographic variation). 140

Figure 8.1: Role of electrode montage on the site and strength of induced electric field under anisotropic (skull, muscles, and brain) tissue conductivities. (a) Two High-Definition (4x1) and one conventional montage. In m1, anode is located at C3, whereas, in m2, anode is positioned at C1. Montage m3 is based on conventional 5x5 cm² electrode pads. In m3 anode is approximately positioned at C3 and cathode is placed at the approximate location of Fp2. (b) The depiction of induced electric field strength and distribution pattern across anisotropic brain under considered montages. (c) Anterior view of an arbitrary coronal slice, highlighting the changes in electric field strength and distribution pattern due to different electrode configurations. (d) Effect of electrode configuration on the magnitude of the component of induced electric field parallel to the fibre pathways (E_p) across the selected ROIs. 149

Figure 8.2: (a, b and c) Posterior view of an arbitrary coronal slice depicting E-field strength and distribution pattern in grayscale colours. Current distribution is highlighted by arrows, the orientation of arrows illustrates the direction of induced current and colour (RGB) signifies the strength of current density. Montage m1 and m2 are based on 4x1 HD-electrode configurations and in (a and b) field parameters (E/J) are highlighted using a common scale. Montage m3 is based on conventional C3-Fp2 configuration and its field parameters are illustrated by separate legends. In (a, b and c) the field parameters (E/J) are depicted under the influence of anisotropic skull, muscles and brain anisotropic conductivities. The coronal slices include CSF, GM, WM and sub-cortical regions. In (d–g) a single scale has been selected to indicate the changes in E-field strength and distribution pattern associated with various anisotropic regions under m1 configuration. In (h–k) each model is represented by its individual E_{max} scale under m1 configuration. Slice (d) and 3 D brain (h) illustrate E-field distribution under m1 montage using isotropic conductivities. (e and i) illustrate field distribution under the influence of skull and muscles anisotropic conductivities. (f and j) depict distribution under brain anisotropy. (g and k) projects the combined influence of skull, muscles and brain anisotropy. Posterior view of an arbitrary coronal slice, illustrating anisotropic conductivity distribution in the form of conductivity ellipsoids, (l) non-normalized,

(m) normalized. In (l and m) electrode locations are marked on the scalp using international 10-10 EEG electrode system..... 153

Figure 8.3: Absolute percentage difference in electric field magnitude across the brain due to the inclusion of skull, muscle of mastication, eye muscle anisotropy, brain directional conductivity and the overall influence of anisotropy under (a) 4×1 HD montage; m1, (2) 4×1 HD montage; m2, and (c) conventional montage (C3-Fp2) m3..... 155

Figure 8.4: Montage specific behaviour of induced electric field E and stimulation parameters E_p , $\partial E_p/\partial l$ and $\Delta E_p/2$ across (a) left corticospinal tracts, (b) right corticospinal tracts, (c) medial of corpus callosum (d) genu of corpus callosum and (e) splenium of corpus callosum under HD montages m1 and m2, respectively ($\lambda = 1\text{mm}$). 158

Figure 8.5: Montage specific behaviour of induced electric field E and stimulation parameters E_p , $\partial E_p/\partial l$ and $\Delta E_p/2$ across (a) Left corticospinal tracts, (b) right corticospinal tracts, (c) medial of corpus callosum (d) genu of corpus callosum and (e) splenium of corpus callosum under m3 (conventional) montage ($\lambda = 1\text{mm}$). 160

Figure 8.6: Single fibre level investigation using the projection of induced electric field ' E ', stimulation parameters E_p , $\partial E_p/\partial l$, $\Delta E_p/2$, fractional anisotropy index ' FA ' and conductivity distribution along the selected fibre (a-m1 and b-m1) under montage m1, (a-m2 and b-m2) under montage m2 and (a-m3 and b-m3) under montage m3. Sub-sections (a-m1, a-m2 and a-m3) illustrate E_p along the selected fibres of left corticospinal tract and (b-m1, b-m2 and b-m3) highlight the variations in electric field, stimulation mechanism, FA and anisotropic conductivity along the selected fibre ($\lambda = 1\text{mm}$). 162

Figure 8.7: Behaviour of stimulation parameters E_p and $\partial E_p G/\partial l$ in the presence of artificial bends. (a and b) montage m1, (c and d) montage m2 ($\lambda = 1\text{mm}$). 164