

Declaration

I, **Biswajit Das**, hereby declare that the present thesis, entitled “**Modeling and Simulation of Extracellular Space and its Role in Signal Transmission**”, is the record of work done by me under the supervision of Prof. Soumik Roy, Professor, Department of Electronics and Communication Engineering, Tezpur University, Tezpur. The contents of the thesis represent my original works that have not been previously submitted for any Degree/Diploma/Certificate in any other University or Institutions of Higher Education.

This thesis is being submitted to Tezpur University for the Degree of Doctor of Philosophy in Electronics and Communication Engineering.

Place: Tezpur University, Tezpur

Date: 19/06/2025

Biswajit Das

(Biswajit Das)



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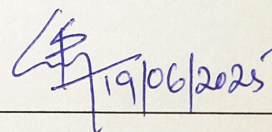
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Certificate

This is to certify that the thesis entitled, “**Modeling and Simulation of Extracellular Space and its Role in Signal Transmission**”, submitted to the School of Engineering, Tezpur University in partial fulfillment for the award of the degree of Doctor of Philosophy in Electronics and Communication Engineering is a record of research work carried out by **Mr. Biswajit Das** under my supervision and guidance.

All help received by him from various sources have been duly acknowledged.

No part of this thesis has been submitted elsewhere for award of any other degree.



(Supervisor)

Prof. Soumik Roy

Professor

Department of ECE

School of Engineering, Tezpur University



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Napaam, Tezpur-784028, Sonitpur, Assam, India

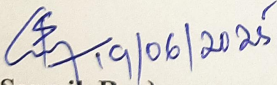
Certificate of the External Examiner

This is to certify that the thesis entitled “**Modeling and Simulation of Extracellular Space and its Role in Signal Transmission**” submitted by **Mr. Biswajit Das**, Department of Electronics & Communication Engineering, School of Engineering, Tezpur University in partial fulfilment for the award of the degree of Doctor of Philosophy in Electronics & Communication Engineering has been examined by us on 19.06.2025 and found to be satisfactory.

The committee recommends for the award of the degree of Doctor of Philosophy.

Supervisor

External Examiner


(Prof. Soumik Roy)

()

Date: _____

Date: _____

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Nomenclature

Symbols:

Na^+	Sodium Ions
K^+	Potassium Ions
Ca^{2+}	Calcium Ions
Cl^-	Chlorine Ions
C_m	Total Membrane Capacitance
c_m	Characteristic Membrane Capacitance
G_{Na}	Sodium Conductance
G_k	Potassium Conductance
G_l	Maximum Leakage Conductance
g_{Na}	Maximum Sodium Conductance
g_k	Maximum Potassium Conductance
g_l	Leakage Conductance
E_{Na}	Equilibrium Potential of Sodium Ions
E_k	Equilibrium Potential of Potassium Ions

E_l	Equilibrium Potential of Leakage Ions
I_T	Transmembrane Current
I_{Na}	Sodium Current
I_k	Potassium Current
I_l	Leakage Current
I_i	Internal Current
I_e	External Current
I_a	Axial Current
R_m	Total Membrane Resistance
R_a	Total Axial Resistance
m^3, h	Activation Variable of Sodium Ions
n^4	Activation Variable of Potassium Ions
α, β	Rate Constants
r_m	Characteristic Membrane Resistance
R_i	Volumetric Internal Resistance of the Nerve Fiber
R_e	Volumetric Extracellular Space Resistance
r_i	Characteristic Internal Resistance of the Nerve Fiber

r_e	Characteristic Extracellular Space Resistance
V_i	Internal Potential of the Nerve Fiber
V_e	Potential of the Extracellular Space
V_m	Resting Membrane Potential
A	Area
d	Myelin Thickness
ϵ	Permittivity of the Material
ϵ_0	Permittivity of Free Space
ϵ_r	Relative Permittivity
$\frac{dV_m}{dt}$	Rate of Change of Membrane Potential
D_i	Internal Diameter of the Nerve Fiber
D_e	Diameter of the Extracellular Space
l	Length of the Fiber / Physical length of the segment under consideration
V_{mnode1}	Membrane Potential of the Initial Node of Ranvier
V_{mnode2}	Membrane Potential of the Next Node of Ranvier
I_{prop1}	Current Received at the Adjacent Myelinated Segment
I_{prop2}	Current Leaving the Myelinated Segment

$I_{\text{delivered}}$	Current Delivered at the Fiber's Outlet
I_{inj}	Injected Current
I_{loss}	Propagation Loss
$R_p(V_m)$	Rescue Protein Voltage
K_{Rescue}	Rescue Protein Coefficient
$V_{m,\text{Original}}$	Membrane Potential for Non Mutated (Original) State
$V_{m,\text{mutated}}$	Membrane Potential for Mutated State

Abbreviation:

AP	Action Potential
CNS	Central Nervous System
PNS	Peripheral Nervous System
ATP	Adenosine Triphosphate
ECS	Extracellular Space
ECM	Extracellular Matrix
CSD	Cortical Spreading Depression
LFP	Local Field Potential
EEG	Electroencephalogram
EcoG	Electro-Corticogram
NCV	Nerve Conduction Velocity
H-H	Hodgkin-Huxley

MCV	Motor Nerve Conduction Velocity
MS	Multiple Sclerosis
CMV	Cytomegalovirus
OPCs	Oligodendrocyte Precursor Cells
BDNF	Brain Derived Neurotrophic Factor
GABA	Gamma-Aminobutyric Acid
BBB	Blood Brain Barrier
AIS	Axon Initial Segment
Nav	Voltage Gated Sodium Channel
CAMs	Cell Adhesion Molecules
SCN	Sodium Voltage Gated Genes
KCN	Potassium Voltage Gated Genes
MT2	Metallothionein-2
PM22	Peripheral Myelin Protein 22
ZBP1	Zipcode Binding Protein 1
GEFS+	Genetic Epilepsy with Febrile Seizure Plus