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List of abbreviations

ECG: ElectroCardioGram

EEG: ElectroEencephaloGram

ECOG: ElectroCorticOGRAM

EMG: ElectroMyoGram

IEGM: Intracardiac ElectroGram

EMF: ElectroMmagnetic Field

FN: FitzHugh Nagumo

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Abstract

This thesis deals with the dynamics of biological signal in particular an action potential propagation in nervous fibre the effects of perturbation on this dynamic . We study through the effects of some perturbation of the fibre in this dynamic and its consequences on the propagation of the nervous signal.

The main interest devoted to such investigation is that the biological signals are essential in engineering as well as in biology since they are used to propagate information between different organs of the organism.

In **Part 1**, we present some literature review on the propagation of the biological signals with particular attention in an action potential propagation.

Part 2 is focussed on the different methods used to model generation and propagation of an action potential in a myelinated nervous fibre, and the effects of external or internal defects on this dynamics of a nervous fibre. We consider an imperfections of ionic channels and the perturbation of the myelin sheath (loss or thickning) as an internal defects and exposure to electromagnetic field is consider as an external perturbation. The localized defects are modeled by a hyperbolic tangent function of space and the defects over the entire length of the fibre by a stochastic function of space.

To generate propagation in a fibre, the initial excitation inserted in the fibre is a pulse of amplitude a and width $1/k$. The domain of initial values of a and k leading to front waves generation are delineated for each type of perturbation by a system of nonlinear differential equations.

Other modelling is the propagation of wave fronts in a single electric fibre constituted of linear and nonlinear portions. we model a wave propagation in linear portion by a linear differential equation and the nonlinear part is modelled by the same nonlinear equation as those of an action potential propagation in a nervous fibre. Our goal here is to assimilate this electric line to myelinated fibre.

Part 3 deals with the presentation of all the results in this thesis and some discussions. It is found that defect in myelin sheath and imperfections of ionic channels strongly modify the velocity of propagation and can even lead to propagation failure. There is a window of conductance variation inside which propagation occurs and out of which there is propagation failure. It is found that the combined effect of defects in myelin sheath and imperfections of ionic channels could mask the acuity of the damages present in the fiber.

The domain of initial values of a and k leading to front waves generation are delineated for each type of perturbation. Links of the results to biological facts are given.

Numerical simulations in the an electric cable show that the front introduced in the nonlinear portion deforms itself in the linear portion and its propagation velocity decreases. The effects of the variation of the electrical components of the linear portion are analyzed. The application of the results to the propagation of front impulses in nervous fibre shows the decrease and increase of the velocity when the myelin sheath is affected.

Keywords: Defects, myelin sheath, Electromagnetic field, Demyelination, Remyelination, Imperfection of ionic channels.

Résumé

Cette thèse traite de la dynamique des signaux biologiques et en particulier celle du potentiel d'action sur une fibre nerveuse et les effets des perturbations que peuvent subir une fibre sur cette dynamique. Nous ressortons ici les conséquences de telles perturbations sur la propagation du signal nerveux.

L'intérêt principal consacré à une telle investigation réside sur le fait que les signaux biologiques sont essentiel aussi bien en ingénierie qu'en biologie car ils sont utiles pour la communication entre les différents organes de l'organisme.

Dans la **partie 1** nous présentons une revue de la littérature sur la propagation des signaux biologiques avec une attention particulière sur la propagation du potentiel action.

La **Partie 2** est focalisée sur les différentes méthodes utilisées pour modéliser la propagation du signal nerveux sur une fibre avec myéline et les effets des défauts aussi bien internes qu'externes à la fibre sur cette propagation. Une imperfection des canaux ioniques et un défaut de la gaine de myéline sont considérés comme défauts internes à la fibre tandis qu'une exposition de la fibre à un champ électromagnétique est considéré comme défaut externe. Les défauts localisés à un endroit bien précis de la fibre sont modélisés par une fonction de la tangente hyperbolique sur l'espace et les défauts couvrant toute la longueur de la fibre par une fonction stochastique d'espace.

Pour générer la propagation de l'influx, nous excitons la fibre avec une onde (pulse) d'amplitude a et donc l'inverse de la largeur est k . Le domaine des valeurs de a et k pouvant mener à une propagation se l'onde est établi pour chaque type de perturbation par un système d'équations différentielles non-linéaires.

Autre modèle présenté ici est celui de la propagation du signal sur une ligne électrique constituée des portions linéaires et non-linéaires. Le but ici étant d'assimiler cette ligne électrique à une fibre avec myéline.

La **Partie 3** est consacrée à la présentation de tous les résultats de des travaux de cette thèse et quelques discussions. On montre qu'un défaut de la gaine de myéline ou une imperfection des canaux ioniques modifient fortement la vitesse de propagation du potentiel d'action et peuvent même conduire à un échec de la propagation. Nous montrons aussi qu'il y a un intervalle de variation de la conductance des ions délimitant la propagation du signal. Les effets combinés d'un défaut de myéline et d'une imperfection des canaux peuvent masquer l'acuité des dommages présents sur une fibre.

pour la génération du potentiel d'action, nous montrons que le domaine des valeurs initiales de a et k pouvant générer les fronts d'onde est délimité pour chaque perturbation. Un lien de ces résultats avec la biologie est aussi donné.

Les simulations numériques faites sur le modèle du câble électrique montrent que la vitesse et la forme

du front d'onde sont modifiées dans la partie linéaire. Une modification des composants électriques de la partie linéaire est aussi analysée.

Mots clés: Défaut, Gaine de myéline, Canaux ioniques, Imperfection des canaux ioniques, Démyélination, Remyélination, Champ électromagnétique.