Modeling Dielectric Response of Biological Structures at Cellular Level

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Electrical properties of biological materials have always been considered of paramount importance in the studies related to electromagnetic effects on cells [1], [2] and are still a topic of continuous research development [3]. This is interesting not only for studies related to possible health and biological effects elicited by electromagnetic radiation [4], but more in general at the basis of the studies on the ways in which electromagnetic energy interacts with biological tissues, and in particular it finds promising applications to monitoring and diagnosis in medicine and biology. If one can think to biological tissues as micro– and nano– structured materials [5][6], it is evident how it becomes crucial to be able to describe the dielectric response starting from the molecular level, where it raises from dipolar fluctuations, up to cells and tissues.

A valuable approach, which is used to gather inside mechanisms of dielectric response and to provide the average electrical parameters of both the cell membrane and the intra- cellular and extracellular medium, is represented by the modeling one, by which it is possible to predict and explain what observed experimentally.

Non-invasive monitoring and discrimination of cell interior is one aim of dielectric spectroscopy, microdosimetric models able to accurately and realistically describe cell internal organelles like the endoplasmic reticulum can help in identifying specific experimental conditions.

Here we investigate dielectric response of a 3D model reconstructed from a real, obtained with images from an optical microscope using different staining techniques able to highlight different cell compartments elaborated like in [7]. The reconstructed images were imported in COMSOL Multiphysics® 5.3, the problem has been solved considering the Electric Currents application mode of the AC/DC module (Frequency Dependent Study). Simulations were run both in normal conditions and for the cells under electroporation effect. Here we demonstrate how it is possible to use accurate microdosimetric models (here specifically of the internal endoplasmic reticulum) to reproduce experimental quantities like the impedance at the single cell level.

Results demonstrate the ability of these models to show a spectrum of capacitive and conductive contrast in frequency domain quantitatively in line with the results in [8]. Changes in such a response due to different internal organelle shape and to an induced electroporation effect were studied.

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