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Stochastic Approach for EM Modelling of suspended Bacterial cells with Non-Uniform Geometry & Orientation Distribution

Dominique Raully*, Eric Chamberod**, Pascal Xavier*, Jean M.F. Martins**** and Jean Angelidis*****

I. INTRODUCTION

Interactions between electromagnetic (EM) fields or currents and living cells constitute a recurrent subject of interest for several decades, and their effects have been profusely discussed [1], especially for the frequency bands currently encountered in everyday life of humans. In a more restrictive domain, large number of studies have been done, focused on EM modelling of a bacteria medium, in order to predict the EM field penetration and inner induced currents in living microorganisms. Relevant information to be collected deal with level and frequency of the EM signal that may affect the development of the considered cells. The former because non-thermal effects are nowadays suspected to exist, altering cell's metabolism, the latter because it is well known that the spectral response of the living cell impedance exhibits some dispersion in relation with cell membrane behaviour and shield effects.

It appears that these parameters may be strongly sensitive to shape, dimensions and orientation of bacterial cells with regard to the applied electric field orientation. The present paper aims to examine this problem and brings a streamlined lighting. This is done through the elaboration of a simplified equivalent electric circuit, supported by a prior COMSOL™ Multiphysics analysis and a stochastic approach.

II ANALYSIS

The bacterium selected to test our approach is *Escherichia coli* DH5 α . A first model, suitable for the required level of resolution, may be a 2 μm long and 1 μm wide cylinder filled with physiological fluid and surrounded by a dielectric membrane of thickness 50 nm. The medium is considered also as a physiological fluid. Figure 1 shows the COMSOL™ model, with possible orientations for the external applied electric field, assuming that the field is provided through the application of an AC voltage between two plane parallel electrodes. A simplified equivalent circuit, similar to those explicated in the literature, can then be extracted from COMSOL™ computation, where capacitance and resistor values depend on size and orientation (Fig. 2). Next, the equivalent circuit for the overall bacterial cell is deduced, taking into account the concentration and the orientation of bacteria, as well as the electrodes/medium interface.

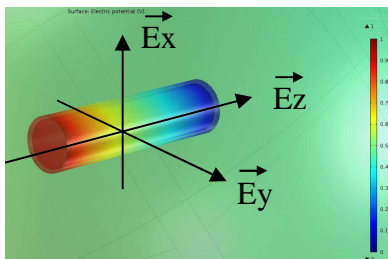


Fig.1 - COMSOL™ model of E. Coli

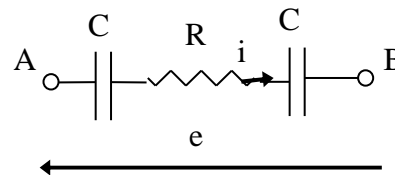


Fig.2 – Equivalent circuit for one bacterium, to be inserted in the overall circuit representing the bacterial medium. C and R values are orientation-dependent

II RESULTS

As an example of interesting result, Figure 3 shows the admittance of a bacterium longitudinally oriented with the electric field. It reveals the well-known shield effect at lower frequencies. The final paper will relate other relevant parameters as inner current in the micro-organism. Variations according to the size and orientation of bacteria will be detailed for both uniform and non-uniform media, supported by a stochastic analysis.

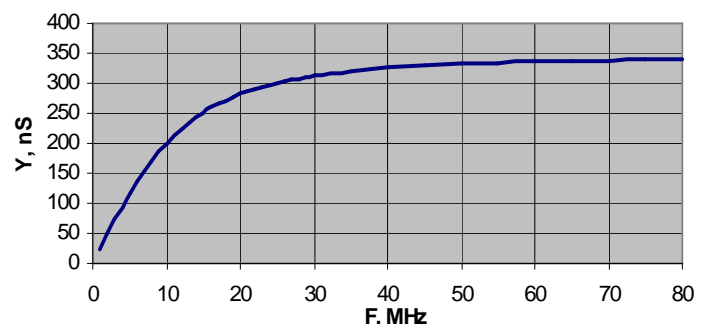


Fig. 3 – Frequency behaviour of the admittance of E. Coli

[1] M. Cifra, J.Z. Fields, A. Farhadi “Electromagnetic cellular interactions”, Progress in Biophysics and Molecular Biology, 105 (2011) 223-246

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