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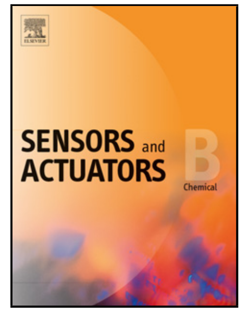

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Rational design of sensor for broadband dielectric spectroscopy of biomolecules

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Abstract

Knowledge of electromagnetic properties of biomolecules is essential for a fundamental understanding of electric field interaction with biosystems and for development of novel biomedical diagnostic and therapeutic methods. To enable systematic analysis of the dielectric properties of biomolecule solutions we presented here a method for a rational design of radiofrequency and microwave chip for quantitative dielectric sensing. At first, we estimated the primary frequency band of interest using a relaxation time of targeted molecule via the Stokes-Einstein-Debye equation. Then we proposed a microwave sensing chip for the estimated frequency band and evaluated its performance using both analytical modeling and numerical electromagnetic simulations. We fabricated the chip and experimentally demonstrated that we can extract the complex permittivity (0.5 – 40 GHz) of the water solution of alanine - one of the most common proteinogenic amino acids - without any calibration liquid and with about 20-fold smaller volume than with commercial methods. The observed dependence of extracted complex permittivity on the alanine concentration was interpreted using molecular dynamics simulations. The procedure we described here can be applied for the development of dielectric sensing method of any polar biomolecule solution.

Keywords: high-frequency biosensors, radiofrequency and microwave chips, dielectric spectroscopy, proteins, molecular dynamics

1. Introduction

Fundamental function of biomolecules is governed by a delicate balance of electric and electrodynamic forces within and among them [1–4]. The electric