Contactless measurements of liquid sample electrical conductivity for estimating specific absorption rate in MR applications.

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Introduction

Specific Absorption Rate (SAR) is the dosimetric parameter currently used as standard in the safety recommendation reports [1] for Magnetic Resonance Imaging (MRI) procedures. With the employment of MR systems with high field strengths (from 3T up to 8T), the study of the potential radiofrequency (RF) effects on the biological tissues due to higher radiofrequency, has a particular relevance [2]. Bottomley et al. [3] described a theoretical method to estimate the radiofrequency power deposition during MR exams, based on the sample geometry, the magnetic field radiofrequency, the MR sequence used (its pulse width, repetition time and flip angle) and, finally, the sample electrical conductivity. In this work we develop a liquid sample dielectric properties measurement system based on the evaluation of the resonance frequency and quality factor of a resonant circuit composed by a home-made coil. The major advantage of this method is the contactless between the liquid sample and the measurement electrode. We perform the measurement at 63.85MHz, corresponding to a 1.5T clinical MR environment, but this method can be used for measurements in the whole RF range, tuning the resonant circuit on the desired frequency.

Methods

Our measurement system is based on a resonant coil tuned at the frequency of interest (63.85MHz). The designed resonant coil is constituted by LC-circuits, where capacitors are inserted into home-made solenoids L_0 , realized using a 1 mm diameter copper wire with 6 turns on a 14 mm radius cylindrical test tube and a total capacitor C_0 of 5.6pF. The coil quality factor is evaluated in two conditions, coil unloaded (empty test tube,) and coil loaded (with the sample dielectric), using a home-made dual-loop probe consisting of two mutually decoupled pickup loops, and a network analyzer. By this values we can calculate the sample resistance *Rs* and the sample capacitance *Cs*. It is possible to express the contributions of the sample as a series combination of a resistance *Req* and a capacitor *Ceq*, calculated by means the measured parameters. So, we can calculate the loss tangent $\tan\delta$ by the definition, from which it is possible to evaluate the conductivity σ of the liquid sample.

Results

Non saline solutions

We applied our method to several standard dielectric liquid samples with known dielectric constant at frequency of interest. These samples were: ethanol, methanol, glycerol, distilled water. Fig. 1 shows the linear relationship between the calculated *Cs* values and the known ε' values; measuring the values of *Cs* for a dielectric sample with unknown ε' at the frequency of interest, the dielectric constant can be evaluated. Calculating the $\tan\delta$ by the definition it is possible to evaluate the conductivity σ of the liquid sample.

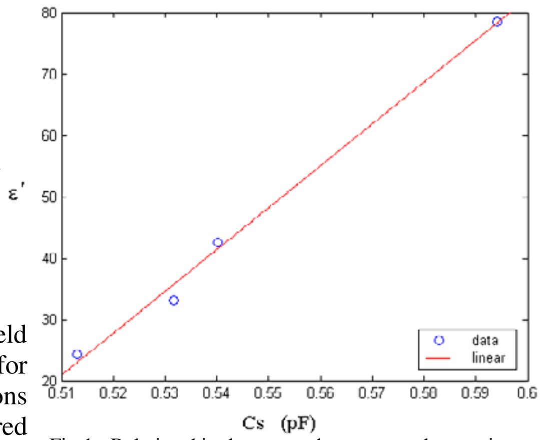

Fig.1: Relationship between the measured capacitance Cs and the dielectric constant of tested samples at resonant frequency of 64 MHz.

Saline solutions

Because the properties of ionic liquid just adjacent to test tube wall can be very different from bulk, due to a liquid structural reorganization under magnetic field action [4], we used a calibration method based on the literature values for solutions with different NaCl concentration (3.19, 5, 9 and 16 g/l). The solutions used are typical MR phantom composition. Table 1 shows the measured conductivity values at frequency of 63.85MHz and corresponding literature values.

Table 1

NaCl concentration (g/l)	Measured conductivity (S/m) at 64 MHz	Literature data for conductivity (S/m) at 64 MHz
3.19	0.58	0.71
5	0.81	0.70
9	1.29	1.44
16	2.37	2.60

Discussions

The dosimetric parameter used to analyze safety and compatibility aspects during MR procedures, is SAR: the estimation of this parameter involves the knowledge of the biological tissue dielectric properties at the specific electromagnetic field frequency. We presented a method for the measuring of liquid sample dielectric properties at 64 MHz, that can be used for experimental measurements in the whole RF range, tuning the resonant circuit on the desired frequency. We reported the results of the measurements regarding saline solutions with four different concentration of NaCl, generally used to realize MR phantom that simulate an *in vivo* situation. Considering the poor presence of data in literature at specific frequency in RF range and the disagree of the reported data, the presented method has a great relevance for studies that involve dielectric properties knowledge.

References

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