

Relationship among SAR, RF frequency and Tissue

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Abstract:

SAR is one of the most important parameters and as a guideline for MRI safety. The relationships among SAR, different tissues and different resonant frequencies have not been discussed quantitatively. In this abstract, we present some comparisons and results about this important issue.

Introduction:

The SAR for different human tissues is not easy to be measured non-invasively. As an alternative to the measurement, researchers have to do experiments of using different phantoms with different chemical contents to simulate human tissues or calculate SAR based on the existing information about the tissues [1, 2]. However, the experiments and calculation have been only limited on a several frequencies, and their data analysis of distribution of SAR is still qualitative, and sometimes, the presented data seem controversial. Here we present and discuss the relationships of permittivity, conductivity and SAR for different tissues over a wide range of RF frequency.

Methods:

For SAR simulation, it is necessary to get the dielectric constant information for different tissues. Recently, a reasonable method was introduced to measure the permittivity and conductivity for different human tissues [3]. Automatic swept frequency network and impedance analyzers were used to measure the dielectric constants for different tissues. The model based on experiment data was given [3]:

$$\epsilon(\omega) = \epsilon_{\infty} + \sum_{m=1}^4 \frac{\Delta\epsilon_m}{(j\omega\tau_m)^{1-\alpha_m}} + \sigma_j / j\omega\epsilon_0 \quad (\epsilon_0 : 8.8542 \times 10^{-12} \text{F/m}, \epsilon_{\infty} \text{ is the permittivity in the terahertz frequency range}).$$

Where, τ_m is the relaxation time, σ_j is the ionic conductivity, α_m is a constant. The ϵ and ρ were calculated at different RF frequencies. Then, SAR calculations can be obtained from the different human tissues under the different RF frequencies. The calculations are based on the following equation:

$$SAR = \frac{\sigma |E|^2}{\rho} \quad (1)$$

Results:

As shown in Fig.1(a) (b) (c), there are comparisons of frequency vs. permittivity, conductivity and SAR :

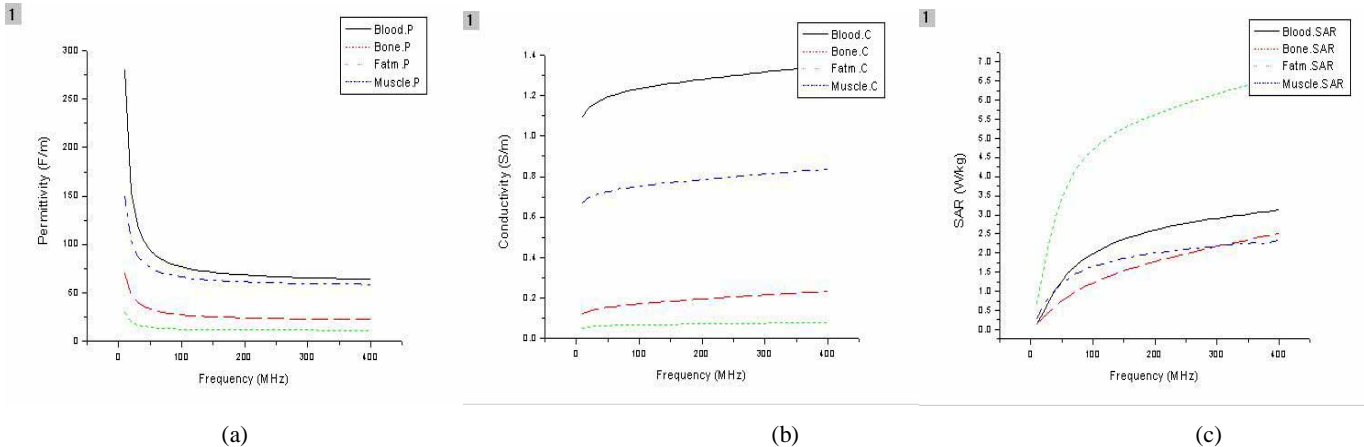


Fig. 1(a) The permittivity vs. frequency for human blood, bone, fat, and muscle; (b) the conductivity vs. frequency for human blood, bone, fat, and muscle; (c) the SAR vs. frequency for human blood, bone, fat, and muscle .

Discussion:

Based on the plots shown in Fig.1 and Fig.2, the permittivity and conductivity of tissues are highly dependent upon RF frequency at frequency below 100MHz. However, at the frequency range from 100MHz to 400MHz, the increasing rate of permittivity or conductivity of tissue is getting much slower, and is only 10-20%. The relation between SAR and frequency is different from permittivity and conductivity. When the resonant frequency is 50 MHz, the SNR for human fat is about 2.7 times higher than human blood, 4.5 times than human bone and 2.8 times than human muscle. However, if the frequency is up to 200 MHz, the SAR for the fat is 2.2 times higher than the blood, 3.2 times than the bone, and 2.8 times than the muscle. As shown in these figures, it is indicated that the SAR differences between fat and other tissues (blood, bone, muscle) become smaller at high magnetic field than at low magnetic field. It is also demonstrated that some parts of human body with more fat, such as hip, abdomen, will have much higher SAR than others. The relationship of SAR between bone and muscle will become reversal when RF frequency is higher than 300MHz. This may be caused by faster increase of bone's conductivity when frequency increases. As shown in Fig.1(c), the fastest rate of SAR occurs when the resonant frequency increases from 10 to 85 MHz, especially for the tissue of human fat.

References:

- [1] Robert L McIntosh etc. URL:<http://www.remcominc.com/pdf/mcintosh.pdf>
- [2] Christopher M Collins etc, MRM 40:847-856(1998)
- [3] C.Gabriel and S.Gabriel: "Compilation of the Dielectric Properties of Body Tissues at RF and Microwave Frequencies", Internet document; URL: <http://www.brooks.af.mil/AFRL/HED/hedr/reports/dielectric/home.html>