

Parametric Studies of Electromagnetic Compatibility between RF Hyperthermia and MR Systems

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Introduction: One of main preconditions for further development of deep-body hyperthermia (HT) therapy is a non-invasive monitoring of temperature distributions during the treatment [1]. Methods of MR thermography applied at high performance tunnel MR tomographs seem to be the most suitable solution for this [2,3]. Therefore, as far as possible interaction-free combination of the HT and MR systems is necessary [4]. The operation frequency of applicators for HT in pelvis and abdomen is near 100 MHz [5] and thus not much separated from the operation frequencies of the mid-field (1.5 T; 63 MHz) or the high-field MR tomographs (3 T; 125 MHz) giving rise to rf coupling and any kind of image distortions. The purpose of this contribution is to investigate numerically and experimentally electromagnetic interactions between the rf environments of the HT and MR systems in order to allow a combined operation.

Methods: The development of the novel 3-D phased array applicator for HT in pelvis has been performed systematically applying the numerical method of the finite-difference time-domain (FDTD) and verifying each step of development by measurements in a specially constructed quasi-anechoic chamber suitable for antenna measurements in water. As basic radiation elements coaxially and symmetrically fed tube dipoles were used which are placed inside of specially formed water-filled cassettes [6]. Tuning and matching of this short antennas was performed by end-cap rods and sliding rings. Water-immersed dipoles show smaller capacitive coupling to the shield tube. Guiding the feeding cables inside the dipole tubes also eliminates parasitary coupling. The water/air interfaces balance the antenna currents to a great extent and an additional bazooka eliminates the remaining sheath currents. These phased array elements are performed as separate modules (water cassettes) which can be placed on the circumference of the water bolus (elliptical equilateral octagon) surrounding the load (phantom or patient). In order to ensure the 3-D steering of the E-field interference these modules must cover the entire cylinder of the water bolus. They are grouped into three rings with four antennas per ring. Whereas the antennas of the two outer rings are colinearly aligned, the central ring is staggered polarly by 45°. In this arrangement the coupling between antennas is expected to be the lowest and focusing and steering of power to be optimal.

With regard to our MR body resonator (birdcage with four rods, 3 T Medspec 30/100 Bruker) there exist two opposite arrangements of the HT modules. The colinear dipole pairs can be placed in front of (**Arrangement 1**) or between the birdcage rods (**Arrangement 2**). These investigations were also performed by the FDTD method. In order to perform not only the field analysis (E-field patterns for HT, B₁ homogeneity and sensitivity for MR) but also to obtain the experimentally easier accessible network parameters (return loss, coupling, quality factor), appropriate FDTD models and approximations were developed as eg. thin-wire, thin-layer, lumped elements,

soft source generator, matching and tuning networks in virtual grid systems. Again, the most relevant of these numerical simulations were verified by measurements.

Results and conclusions: The most important results for HT antennas are the almost load insensitive return loss of less than 0.1 and coupling lower than -20 dB. The network coupling between the HT and MR systems can be slightly reduced from -23 dB for the **Arrangement 1** down to -27 dB for the **Arrangement 2**. This is still too high and therefore steep separating filters have to be used to protect the MR receiver even for the intermitting HT/MR operation. In contrary to the small effect of the polar position of HT antennas with regard to the rods of MR resonator is its impact on the B₁ homogeneity and sensitivity immense. Due to strong field coupling in **Arrangement 1** the B₁ sensitivity drops considerably. Although the B₁ sensitivity in **Arrangement 2** increases, is the B₁ field very inhomogeneous.

Acknowledgement: This work was supported by Deutsche Forschungsgemeinschaft (Sfb 273).

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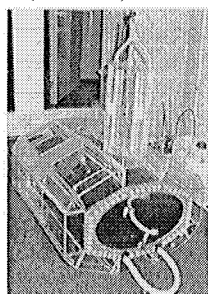


Figure 1. The MR compatible experimental 3-D HT applicator..

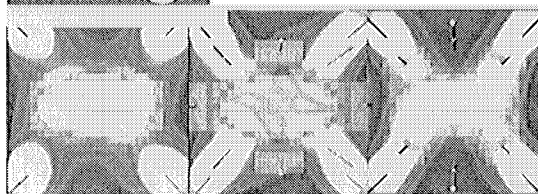


Figure 2. B₁ distributions in tissue equivalent phantom without (a), under Arrangement 1 (b) and 2 of HT antennas (c).