

High B1 dutycycle in bilateral breast imaging at 7T

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Introduction

Contrast enhanced (CE) MRI had a very high sensitivity in the detection of breast cancer, however specificity is limited. Although techniques like diffusion weighted MRI, MR spectroscopy and high resolution morphologic imaging have shown to improve specificity, their limited SNR reduces sensitivity. Intrinsic SNR increases at higher field strength, like 7T, but at higher frequencies SAR limits the RF pulse duty cycle and consequently the SNR per unit of time. RF surface coil transceivers have shown to provide a high efficiency in RF duty cycle per unit of SAR. They therefore effectively improve SNR per unit of time, as is shown in the human breast at 7T[1]. Although the FOV of these surface coils were restricted to a single breast and provide non uniform B1 fields, RF coil designs have been shown to enable bilateral MRI at relatively uniform B1[2]. However, all of these designs have a significantly lower B1 efficiency particularly per unit of local SAR, therefore compromising sensitivity. Here we propose to use a pair of efficient surface coils to excite both breasts simultaneously using inductive decoupling, without losing energy in the rest of the body. Using Ernst angle excitation at the lowest B1 level in the breasts based on the short T1 of the contrast agent, the high B1 duty cycle can provide a relatively uniform sensitivity, but very high sensitivity in both breasts simultaneously.

Methods and results

Two unilateral quadrature RF coil designs [1] were merged using inductive decoupling to form a bilateral setup (Fig 1). The RF coils were interfaced to multi-transmit 7T MR systems (Philips 7T in Utrecht and Siemens 7T in Essen) using RF power constraints based on FDTD simulations on 5 different breast models (Fig 2). Without RF shimming, 3D FFE images were obtained from a healthy volunteer using a nominal flip angle of 10° and TR of 8ms (fig 3).

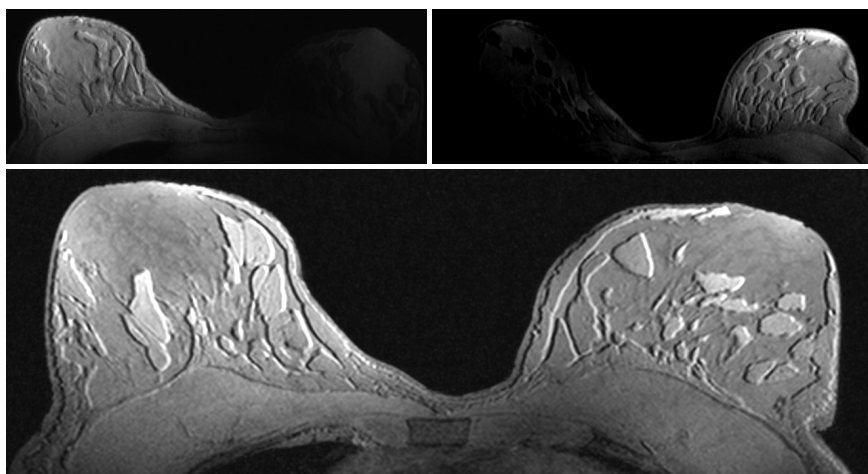


Fig 3. Non-lipid-suppressed breast MRI obtained from a healthy volunteer using the 4 channel RF surface coil. A fixed quadrature phase setting was applied between 1-2 and 3-4. Even when receiving with all elements, while transmitting with element 1-2 (left) or 3-4 (right) very low RF coupling is observed between the pairs. Therefore when combined (below) a good image uniformity is maintained.

At an RF power of 4kW for a single breast, the B1 field in the center of the breast was 40uT but non uniform, while the sensitivity can be uniform as calculated from the B1 map (fig 4). Indeed, strong T1 weighting can be applied, boosting sensitivity in the detection of breast cancer (fig 5).

Conclusion

Bilateral breast MRI at 7T can boost SNR in CE-MRI when using efficient RF surface coil arrays for transmitting high density of strong flip angles.

References: [1] Korteweg MA et al. Invest Radiol 2011;46:370-376. [2] Vaughan et al. MRM 2009;61(1):244-248.

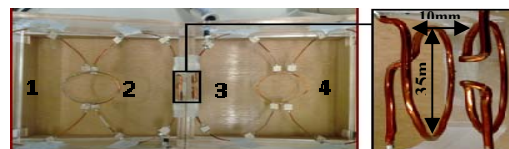


Fig 1. 7T bilateral breast coil without covers showing 4 cylindrical elements, each at an angle of 90 degree between its neighbor including inductive decoupling: horizontal coil overlap between element 1-2 and 3-4 and a vertical cross coupling between 2-3 (right).

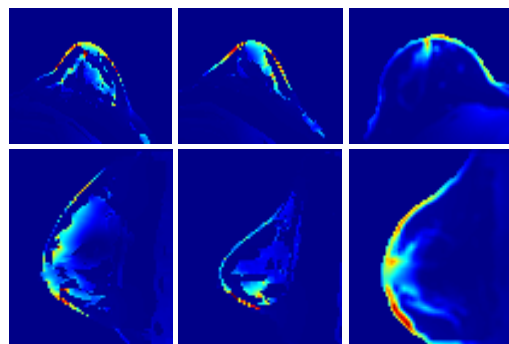


Fig 2. Local SAR calculated with FDTD using five different breast models obtained from MRI datasets resulting in an effective field of $3uT \pm 0.2uT$ in the center of the breast normalized to a maximum local SAR of 10W/kg (see red spots for these locations).

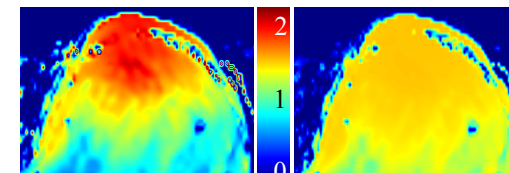


Fig 4. Relative B1 map obtained from a single breast (left) showing strong non uniformity in AP direction. However, when used as a transceiver and using strong T1 weighted MRI at a high flip angle duty cycle, the sensitivity profile is uniform (right).

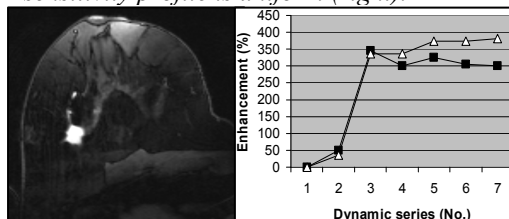


Fig 5. CE-MRI of a patient with breast cancer at 7T, using a high density of strong (40uT) RF pulses (20 degrees binomial water selective excitation at a TR of 5ms) resulting in strong T1 weighting (left): more than 3-fold signal enhancement in the tumor (right).