High SNR bilateral breast MRI with a dual transmit, 26-channel receive RF coil with simultaneous ^{31}P CSI at 7 tesla

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Introduction: 7 tesla MR systems have great potential to increase the sensitivity and specificity in the detection and characterization of breast cancers. The increase of field strength, and therefore SNR, cannot only be used to obtain higher spatial and temporal resolutions in contrast kinetics, but also to obtain ^{31}P MRS for detailed information on choline metabolism. However, so far RF coils are only optimized for either high SNR of ^{31}P using closely positioned relatively large elements or with high density closely positioned ^{1}H receiver arrays for increased SENSE and thus resolution. Merging of the two setups without compromising efficiencies is challenging at 7T due to different field patterns and thus coil couplings between 298MHz and 121MHz, particularly when considering bilateral MRI and MRS. In this study we have used a single decoupling loop tuned between the two frequencies to decouple both ^{1}H and ^{31}P elements independently. This enables maximized efficiency of quadrature ^{1}H excitation, ^{31}P transceiver of each breast independently, while simultaneously receive with 26 receiver elements as demonstrated in patients with breast cancer.

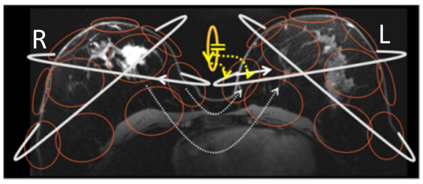

Figure 1: Diagram of the RF coil. White: Quadrature T/R-coils tuned at 121MHz (31P) and 298MHz (1H). Orange: 26 small element receiver coils tuned at 298MHz. Yellow: Decouple loop tuned at 123MHz.

Methods: Two dual tuned unilateral quadrature RF coils[1] were placed next to each other and connected to a 7 tesla MR system (Philips, Cleveland, OH, USA). When performing ^{1}H experiments, each quadrature coil was driven by an independent 4kW amplifier. Reception of the signal was done with 26 independent receive coils including preamplifier decoupling. For ^{31}P experiments one 4kW amplifier was used to drive both quadrature RF coils, which were used in T/R-mode with both receive lines connected to a separate receiver. An additional loop tuned above the ^{31}P Larmor frequency was placed between the two quadrature coils for independent decoupling of the coils at the ^{31}P frequency, while maintaining decoupling at the 1H frequency; the remaining inductance induced from one coil to the other is counteracted by the decoupling coil (figure 1). Coil couplings between all elements at both frequencies have been measured with a network analyser.

Two patients with suspicious cancer in the right breast have been scanned with the coil setup. Amongst others, a B_1 map (dual TR), a dynamic contrast enhanced scan with a 0.7mm^3 isotropic imaging sequence (using 5x2.5 fold SENSE) and an adiabatic ^{31}P CSI protocol[2] (with 2-fold SENSE due to the independent receive lines) have been obtained (2cm resolution).

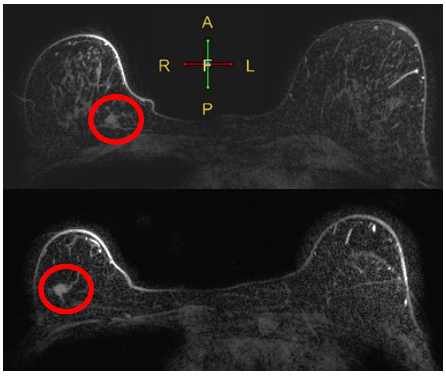

Figure 3: Two slices of a CE scan of a patient with invasive ductal carcinomas. 3D scan with 0.7mm isotropic voxels, a SENSE acceleration of 5x2.5 (RLxFH), FA 15°, and a compensating RF pulse for optimizing B1 inhomogeneities.

Results: Coil couplings were less than -15dB at both frequencies. Using the dual transmit, essential B_1 shimming between breasts can be performed (Fig 2). Figure 3 shows two slices of a post contrast scan of a patient with two invasive ductal carcinomas, where the high resolution is enables visualization of spiculations. Figure 4 shows the ^{31}P spectra of both breasts, where clearly levels of phospolipids can be detected distinct from inorganic phosphte (Pi) .

Conclusion: A dual tuned bilateral breast RF coil for 7 tesla has been developed with maximized MRI and MRS performance in one setup. This facilitates highest resolution MRI merged with phospholipid detections to aid characterization of breast lesions.

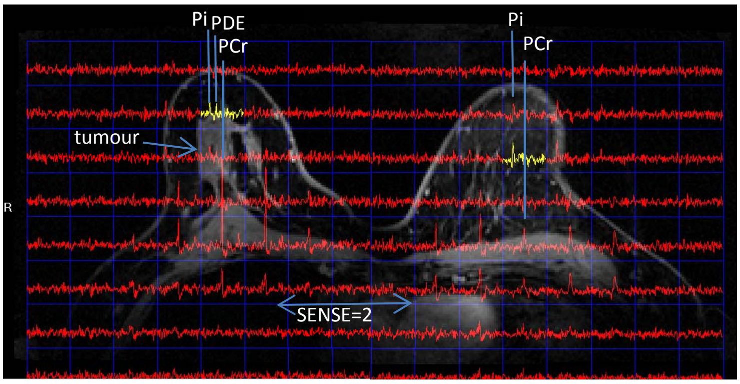

Figure 4: ^{31}P spectra of both breast in a patient with an invasive ductal carcinoma. Implicit SENSE encoding was used by connecting the two ^{31}P RF-coils to separate receiver lines. Note the low concentrated but elevated phospholipids (PDE) at the tumour area.

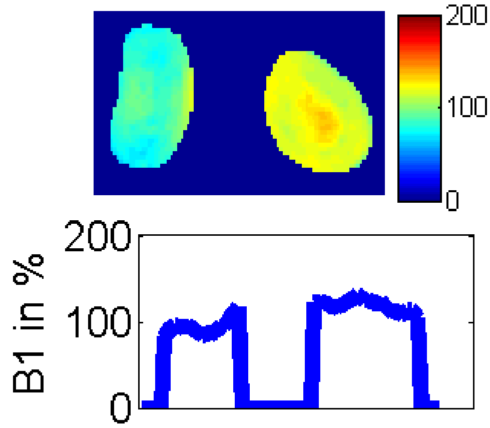

Fig 2: B1+ field map obtained in vivo with the coil driven at equal RF power prior to B1+ shimming.

References:
[1] D.W.J. Klomp et al. NMR in Biomedicine, 2011
[2] W.J.M van der Kemp et al. NMR in Biomedicine, 2013