Developing an RF Coil for MRI and MRS of Human Breast Tissue

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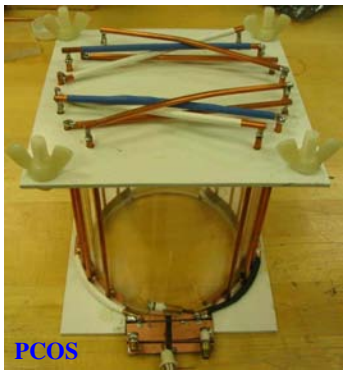
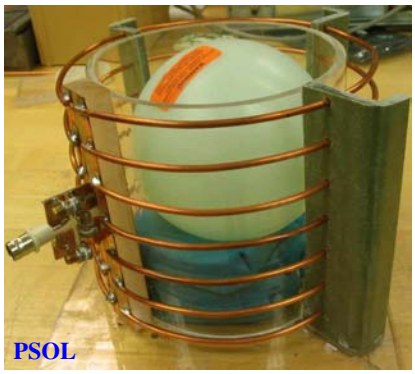
Introduction. High-field human magnetic resonance imaging (MRI) and spectroscopy (MRS) requires innovative RF coils designs to reduce imaging artifacts due to dielectric effect. For breast MRI/MRS, the problem may be resolved using small transmit/receive coils at 3T and 7T magnets when the organ size is relatively small, as compared to the RF wavelength. When employing the Sel-MQC (Selective Multiple Quantum Coherence transfer) techniques for MR spectroscopic imaging (MRSI) of breast cancer, it is important to achieve homogeneous B_1 RF magnetic field and excellent signal-to-noise ratio for absolute quantification of breast tissue metabolites. In this project, we have constructed proton PCOS breast coils and parallel-solenoidal RF coils (PSOL) and demonstrated their effectiveness in MRI/MRSI on a GE 3T human MR scanner. Images showed no obvious dielectric effect in phantoms and in human tissue.



Methods. *PCOS breast coil design*: Parallel cosine (PCOS) coil was designed to achieve homogenous B_1-field (Fig. 1).[1,2] A highly homogeneous transverse magnetic field in a long cylinder can be produced by surface currents in the axial direction proportional to the cosine of the azimuthal angle. *PSOL Breast Coil Design*: The parallel solenoidal (PSOL) coil has a much simpler geometry as compared to PCOS coil. With several copper loops parallel to each other, the coil creates a uniform magnetic field. The inductance L of the coil is $N\mu_o A/l$, where l is the length of one loop of the solenoid, N is the number of loops, and A is the area of the loop. This geometry reduces the coil inductance by a factor of N compared to the regular solenoid.



Results. Both PCOS and PSOL coils produced excellent MRI images in phantom and in human breast tissues. When using the coils as receivers and the whole-body GE coil as a transmitter at 3T, the MRI images showed typical dielectric effect (Fig. 1a,b,c). The dielectric effect disappeared when the PSOL or PCOS coil were used as transceivers (Fig. 1d,e,f). The PSOL coil generated better B_1-homogeneity with excellent signal detection sensitivity and chest wall penetration (Fig. 1c,d,e). The PSOL coils also produced excellent MRSI data from Sel-MQC detection of lactate and polyunsaturated fatty acids (PUFAs) in phantoms and in human tissue (Fig. 1g,h). PSOL coils have simple geometry as compared to PCOS coils. PSOL also has an advantage over a simple solenoid for reduced coil inductance linearly related to the number of RF loops. In addition, PSOL design provides a large range of tuning resonant frequencies from a combination of loop spacing and additional capacitor distributions symmetrically throughout the coil.

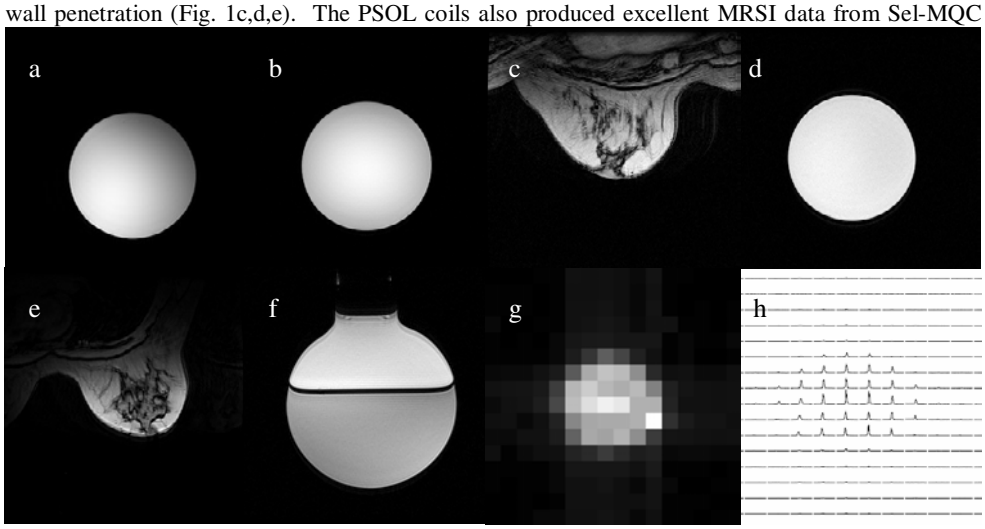


Figure 1. Imaging and spectroscopy data obtained using PCOS and PSOL coils. *(a)-(c)* Coils were in receive mode. *(d)-(f)* Coils acted as transceivers. *(a)* Cross-section of a spherical breast phantom taken with PCOS in 1.5T field; some inhomogeneity present *(b)* Cross-section of a spherical breast phantom taken with PSOL in 3T field; better homogeneity, presence of dielectric effect; *(c)* Human breast tissue image taken with PSOL at 3T; magnetic field extending far into the tissue; *(d)* Cross-sectional image of spherical sample with water taken with PSOL as transceiver at 3T – no dielectric effect; *(e)* Another human breast tissue image taken with PSOL as transceiver at 3T; *(f)* Sample used for spectroscopy (40mM lactate in H_2O) *(g),(h)* Spectroscopy data of lactate obtained using PSOL as transceiver at 3T

Conclusions. PSOL and PCOS transceiver coils were constructed for high-field MRI/MRSI studies of breast cancer and demonstrated no obvious dielectric artifacts at 3T. Among the PSOL, PCOS and the birdcage breast coil previously reported[4], PSOL coil presents superior quality for breast MR imaging and spectroscopic imaging at high fields. It is easy to construct and provides excellent B_1-homogeneity and signal sensitivity. We are currently expanding the PSOL coil for 7T breast MRSI of breast cancer.

<u>*References:*</u>

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