A Quadrature Volume Transmit Coil for Breast Imaging and Spectroscopy at 7 Tesla

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Introduction

Performing magnetic resonance imaging (MRI) and spectroscopy (MRS) at 7T enables higher SNR and improved spectral resolution as compared to standard clinical 1.5T or 3T fields. The benefits of increased field strength facilitate detection of metabolic biomarkers, a research area for diagnosis of malignant tumors and monitoring of therapy response. However, design and fabrication of RF coils for use at 7T is challenging because of electric field effects that become more prevalent as field strength increases. The ability for a coil to transmit a uniform B_1 field, tune with different loads, and minimize power losses all become more difficult to achieve at 7T [1]. Furthermore, inhomogeneous B_1 fields, as well as increased power to compensate for losses, can present a patient safety concern by creating electric field hot spots that increase local SAR. This work discusses a unilateral ^{1}H quadrature volume transmit breast coil utilizing “Forced Current Excitation” (FCE), electric field shielding techniques, and quadrature excitation to address these challenges.

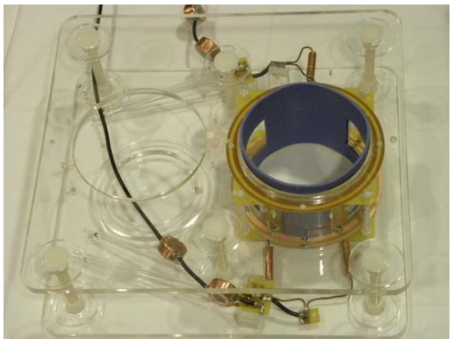

Figure 1 – Quadrature volume breast coil, utilizing the FCE technique, mounted in an acrylic glass and nylon former

Materials and Methods

A Helmholtz-saddle coil configuration was designed for quadrature excitation of the pendant breast. The Helmholtz coil was constructed from two identical loops (i.d. 16.0cm, o.d. 17.2cm, co-axial spacing 8.0cm) to produce a B_1 field in the *y*-direction. The saddle coil (diameter 15.3cm, length 8.7cm, aperture angle 120°, conductor width 0.6cm) was constructed from two elements, affixed on opposite sides of a cylindrical former, and centered inside the Helmholtz coil, producing a B_1 field in the *x*-direction. All four coil elements were fabricated from industry-standard copper-clad FR-4 PCB and segmented by 11 ceramic capacitors. Each element was also surrounded by a parallel shield (conductor width 0.4cm, spaced 0.4cm from element) to mitigate undesirable electric field effects [2]. FCE was implemented separately for the Helmholtz and saddle coils; both elements in each coil connected to a common voltage point through quarter-wavelength coaxial cables. This technique “forces” an equal current at the feed point of both elements, irrespective of both 1) unequal input impedances, stemming from asymmetric loading, and 2) element-to-element coupling, consequently producing a homogeneous B_1 field [1,3]. Traps integrated in the quarter-wavelength cables ensured current suppression on the outside of the coaxial shield [4]. Each coil’s match/tune circuit was connected to its common voltage point through a length of coaxial cable designed to transform the coil’s input impedance to facilitate matching to 50Ω. Two identical coaxial cables with traps connected the quadrature coil to the MR system.

B_1 homogeneity was evaluated from S_{21} measurements with a loop probe and subsequently verified with B_1 mapping with a phantom in the scanner. Homogeneity comparisons were made to a conventional parallel-fed (non-FCE) Helmholtz-saddle coil. Q factors were calculated for the Helmholtz and saddle coils, based on the -7dB width of the S_{11} response [5-6]. Imaging of volunteers was performed under local IRB approval on a whole-body 7T scanner (Achieva, Philips Medical Systems, Cleveland, OH, USA).

Preliminary Results and Discussion

A photograph of the coil is shown in Figure 1. Bench measurements and B_1 mapping with a phantom validated the anticipated homogeneity of the FCE coil. Asymmetries caused by uneven loading and cable routing made the conventional coil difficult to tune, a potential problem in the clinical environment, and prevented a stable quadrature configuration. A comparison of profiles between FCE and conventional coils is shown in Figure 2; the profile is notably more homogeneous with the FCE coil. Loaded and unloaded Q measurements were 37/108 for the Helmholtz coil and 110/147 for the saddle coil. The lower Q factor ratio, Q_L/Q_{UL}, for the Helmholtz coil suggested tissue losses were dominant, corroborated by B_1 mapping that indicated approximately 1cm penetration into the chest wall.

This FCE ^{1}H coil design has been validated at 7T, enabling a highly homogeneous, quadrature field. Future work includes optimizing SNR by including a switching network for individual receive elements. Additionally, a second-nuclei transmit/receive coil with LC traps will be incorporated, with this quadrature transmit ^{1}H coil providing proton decoupling [7].

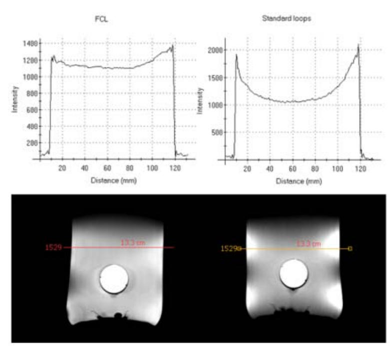

Figure 2 – Phantom profiles for FCE (left) and conventional (right) coils.

Acknowledgement

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