Active Decoupling of RF Coils: Application to 3D MRI with Concurrent Excitation and Acquisition

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Introduction: In conventional MRI, RF excitation and data acquisition is time-interleaved, and transmit and receive circuitry are separated electronically by transmit-receive (T/R) switches and detuning circuits. Interleaved acquisition leads to unwanted dead times, which severely limit the detection of tissue with ultra-short T2*. Concurrent excitation and acquisition (CEA) would allow detecting the MR signal without dead times, but CEA is difficult to achieve due to saturation of the MR receivers by the high RF transmit signals. Recently, CEA was implemented by combining geometric decoupling with destructive interference decoupling using two separate transmit coils [1,2]. In this work the method was tested for 3D CEA imaging of an *ex vivo* animal in a 3T clinical MRI system.

Materials and Methods: In a CEA experiment the acquired MR signal, $s(t)$, is the sum of the FID convolved with the RF excitation, and a frequency-dependent leakage component $h(t)*B_1(t)$, which is the remaining B_1-induced voltage due to imperfect decoupling [3]:

$$s(t) = FID * B_1(t) + h(t) * B_1(t)$$

The leakage can be determined experimentally from the system response h(t), which is the time-dependent response of the data acquisition system to the B_1-induced signal voltage. Using a second decoupling transmit coil with low transmit power, the leakage signal can be minimized [1,2].

All CEA experiments were conducted on a clinical 3T MRI system (Tim Trio, Siemens) with an 8-channel parallel transmit unit. The CEA coil setup consisted of a primary transmit coil (Tx coil-1), a decoupling transmit coil (Tx coil-2), and a receive coil (Rx coil) (Fig. 1). Circular RF coils with (diameters: 5 cm and 10 cm) were used. To maximize decoupling between the Tx coils, and between Tx coil-1 and the Rx coil, the following measures were taken:

1. Tx coils 1 and 2 were decoupled capacitively [4].
2. Tx coil-1 and the Rx coil were decoupled geometrically by placing the coil planes orthogonal to each other [5].
3. The remaining B_1-induced current of Tx coil-1 in the Rx coil was cancelled by adjusting the phase and amplitude of the transmit field from Tx coil-2 (PA decoupling).

Due to the low input power applied to Tx coil-2, the flip angle in the sample is mainly determined by the RF transmit field of Tx coil-1, and an MRI signal can be detected with the Rx coil during RF excitation. The orthogonal placement not only reduces the RF signal coupling, but also noise coupling to the Rx coil.

To demonstrate that the setup can be used for tissue differentiation, an *ex vivo* adipose APOE mouse (65 g Body weight) was imaged. Low noise amplifiers HD24388 (gain: 23 dB, NF: 0.7 dB) and HD29980 (gain: 36 dB, NF: 1.0 dB) (HD Communications Corp, NY) were connected at both transmit channels. 3D CEA MR data was acquired with a radial pulse sequence with concurrent excitation using 100000 radial spokes acquired during a chirp RF excitation (frequency range: 40 kHz, duration: 4 ms) at a TR = 20 ms resulting in a total acquisition time of 33 min. CEA data were reconstructed to a 512^3 Cartesian grid using a Gaussian kernel. For anatomical reference a 3D FLASH data set was acquired with FOV = 120 mm, TR = 7 ms, TE = 2.21 ms, 400 Hz/px bandwidth, 0.4 mm resolution and 0.5 mm slice thickness was applied.

Results and Discussion: In Fig. 2 central slices of the FLASH and CEA data are shown. Anatomical details in the abdomen such as the kidneys and the liver are visible in both data sets, but the CEA images appear more blurred. The contrast of the CEA images is different from that of the FLASH images which can be explained by the adiabatic inversion of the magnetization during the CEA experiment. Time-varying leakage signals could cause some of the artifacts, which would necessitate the re-acquisition of $h(t)*B_1(t)$. In a clinical application this is hardly feasibly, and other options need to be investigated such as numerical scaling or real-time RF measurements. These preliminary results show the feasibility of CEA in abdominal tissues in an *ex vivo* setting which opens new possibilities for CEA imaging.

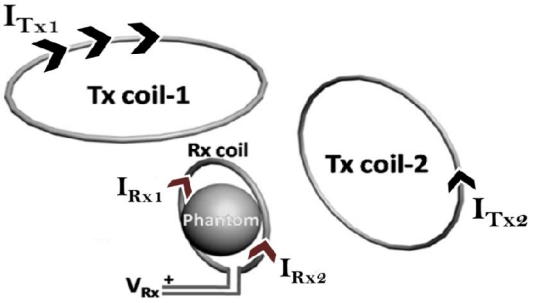

Fig. 1: Tx coil-1 and the receive coil are placed orthogonally. Tx coil-1 is driven by a current I_{Tx1}, which induces I_{Rx1} on the receive coil. Amplitude and phase of Tx coil-2 are adjusted so I_{Rx2} cancel I_{Rx1}l, which significantly reduces the total B_1-induced voltage V_{Rx}.

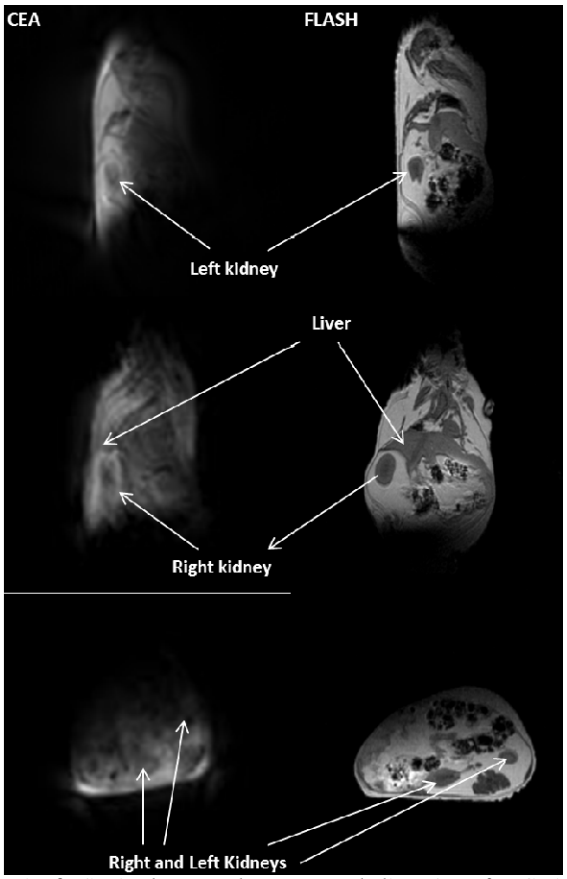

Fig. 2: Sagittal, coronal, transversal slices from 3D CEA and FLASH MRI of ex vivo mouse. FLASH shows the anatomical details (0.4mm in-plane resolution). Major structures are visible in CEA image such as the kidneys and the liver.

References: [1] Ozen AC, Ertan NK, Atalar E. ISMRM 2012: 2295. [2] Ozen AC, Atalar E. ISMRM 2013: 767. [3] Idiyatullin D, et al. J Magn Reson **220**:26-31 (2012) [4] Lee RF, et al. Magn Reson Med **48**(1):203-213 (2002) [5] Bloch F, Hansen WW, Packard M. Phys Rev **70**(7,8):474-485 (1946) **Acknowledgements:** This work was funded in part by the Helmholtz Alliance ICEMED - Imaging and Curing Environmental Metabolic Diseases, through the Initiative and Network Fund of the Helmholtz Association.