Local Coil versus Conventional Body Coil Transmission for Cardiac MR: B1+ Efficiency Improvements and Enhanced Blood Myocardium Contrast for 2D CINE SSFP Imaging at 3T

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Target audience: Clinical scientists, radiologists, cardiologists, RF coil engineers, highfield experts and applications specialists interested in highfield cardiac MR.

Introduction: In current clinical cardiac MR (CMR) practice large volume/body RF coils are commonly used for RF excitation (TX) together with local multi-channel receive (RX) coils. When moving to higher magnetic fields ($B_0 \geq 3T$) some of the signal-to-noise (SNR) and contrast-to-noise (CNR) gain is offset by specific absorption rate (SAR) constraints which limit the flip angle (FA) range used for routine clinical CMR [1,2]. Realizing these challenges and recognizing the SAR benefits of local transceiver (TX/RX) coils it is conceptually appealing to pursue CMR at 3T using local TX/RX arrays. To meet this goal this study examines the applicability of a 4 channel local TX/RX array for CMR at 3.0 T. For this purpose, transmit field (B_1^+) homogeneity and efficiency of the proposed array are explored. The feasibility of the proposed transceiver coil design for high spatial resolution 2D CINE imaging of the heart at 3T is demonstrated.

Methods: Phantom and volunteer studies were performed on a 3T MR system (Verio, Siemens Healthcare, Erlangen, Germany). The 4 channel local TX/RX coil [3] consists of an anterior and a posterior section each equipped with 2 loop elements (Fig 1). To find a uniform excitation pattern relative phase maps with a virtual reference [4] were acquired *in vivo* using a parallel TX system. The transmit setting Φ_1 maximizes the B_1^+-homogeneity within a ROI accommodating the heart without taking local SAR considerations into account. To balance local SAR with B_1^+-homogeneity a second transmit setting Φ_2 was determined by maximizing the target-function $\sigma(B_1^+)/\max(SAR_{10g})$ using EM field simulations (CST GmbH, Darmstadt, Germany) and the voxel models Duke and Ella (Virtual Family). This approach requires an ultra-fast computation of 10g averaged local SAR [5], which was accomplished with pre-calculated 4x4 SAR matrices (SimOpTx, Vienna, Austria) [6,7]. B_1^+-phase shimming was facilitated using phase shifting cables. The local 4 channel TX/RX coil was benchmarked against a 4 channel RX only coil with identical geometry in conjunction with a body coil used for excitation. To adjust the transmitter reference amplitude U_{Ref} and to quantify the flip angle (FA) distribution (mean and standard deviation) across the heart cardiac gated B_1^+-field mapping of the heart was conducted with a 2D Bloch-Siegert approach [8] (4kHz off-resonance Fermi-pulse, τ_{RF}=4.5ms, T_{acq}=12s). For cardiac imaging a 2D CINE SSFP technique (spatial resolution=(1.8x1.8x6)mm³, T_{acq}=15s, TE/TR=1.2/2.8ms) was applied using a standard four chamber view (4CV). For each TX regime the FA used in SSFP was adjusted to hit the $SAR_{normal\ mode}$=100% limit while keeping all other imaging paramters identical.

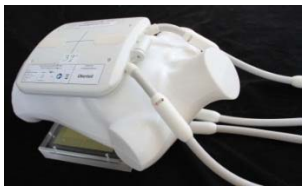

Fig.1) Anterior and posterior section of the local 4 channel transmit/receive coil.

Results: Since the B_1^+-distribution was found to be non-uniform across the heart for body and for local coil transmission the transmitter was adjusted based on in vivo B_1^+-maps. This approach ensured that the nominal FA in the imaging protocol is identical with the mean FA obtained for a ROI covering the heart. The deviation between the ROI approach and the conventional global transmitter adjustment was found to be substantial (e.g. for body coil excitation: U_{Ref}=814$V_{B1\text{-}maps}$ versus U_{Ref}=510$V_{standard}$). Quantitative FA maps together with mean values and standard deviations across the heart obtained for each TX regime are shown in Figure 2 (top row). Since the transmit setting Φ_2 is tailored to balance B_1^+-homogeneity and maximum local SAR, the upper limit of the applicable RF input power was 13% higher versus Φ_1. The B_1^+-distribution across the heart obtained for $\Phi_1$and Φ_2 , however, are similar as demonstrated in Figure 2. 2D CINE SSFP imaging provided rather uniform signal intensity across the heart for all TX regimes as shown Figure 2 (middle and bottom row). Blood/myocardium contrast obtained with the local TX/RX coil was found to be superior to that derived from body coil excitation and local coil reception**.**

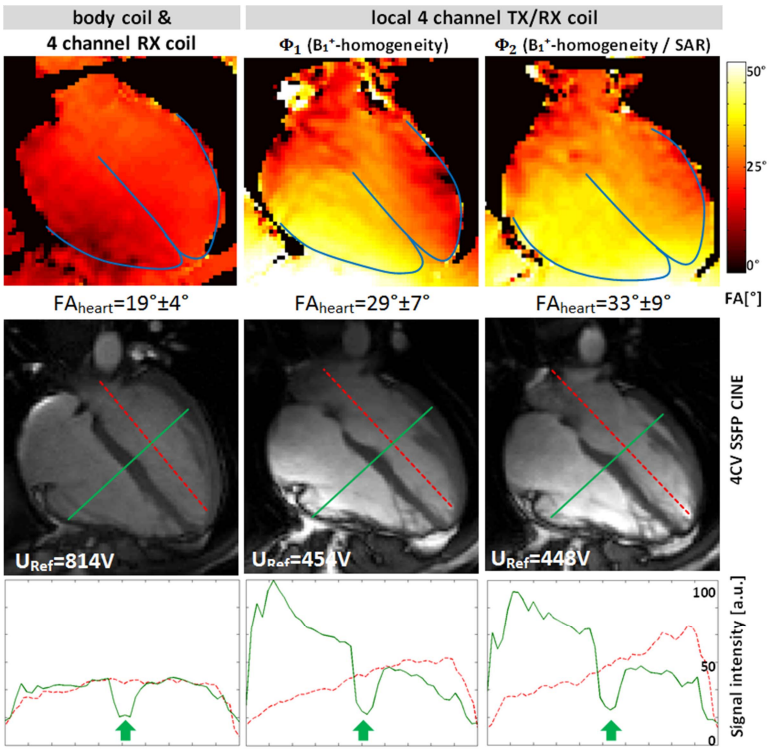

Fig. 2) Top row: In vivo flip angle maps of cardiac four chamber views for the local and volume excitation regimes used. **middle row**: Four chamber views of the heart derived from 2D CINE SSFP using maximum allowed flip angle ($SAR_{normal\ Mode}$=100%) together with the used reference amplitudes U_{Ref}. **Bottom row**: signal intensity profiles along the lines highlighted in the middle row. The arrows indicate the position of the septum.

Discussion/conclusion: Our results underline the relevance and need of adjusting the transmitter reference voltage based on in vivo B_1^+-maps rather than using the standard approach. In particular if FA quantification is required. Our results demonstrate that larger FAs can be achieved with local TX/RX coils versus body coil excitation before SAR limits are reached. This helps to improve blood/myocardium contrast for 2D CINE SSFP imaging of the heart which is instrumental for endo- and epicardial border segmentation used for left ventricular function assessment. On the downside the B_1^+-field of the local TX regime was less uniform vs. body coil transmission. This bears the risk for blood/myocardium contrast changes across the heart. To summarize, our results highlight the need and value of local SAR considerations, which help to attenuate and manage SAR hotspots and hence increase the applicable RF input power [9,10]. We anticipate extending our explorations to a larger number of TX channels which provide more degrees of freedom for $\sigma(B_1^+)/\max(SAR_{10g})$ optimization, together with SNR, CNR and parallel imaging performance enhancements [11].

References: [1]Schaer M., et al., Magn Reson Med (2004) [2]Niendorf T., Sodickson D., NMR Biomed (2006) [3]Frauenrath T., et al., p2803, ISMRM (2012) [4]Ullmann P., et al., Magn Reson Med (2005) [5]IEEE Std C95.3-2002 (R2008) [6]Zhu Y., Magn Reson Med (2004) [7]Grasslin I.,et al., Magn Reson Med (2012) [8]Sacolick L., et al., Magn Reson Med (2010) [9]Collins C., Smith M., Magn Reson Med (2001) [10]Wang Z., et al., J. Magn Reson Imag (2007) [11]Winter L., et al., Eur Radiol (2012)