Simulations of Tx-SENSE performance of a 4 channel decoupled loop array for cardiac imaging at 7T

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Introduction and Motivation

Transmit (Tx)-SENSE performance depends crucially on the reliable knowledge of the $B_1^{(+)}$-maps of the transmit coil elements. To speed up the whole imaging procedure true $B_1^{(+)}$-mapping is often avoided by using the virtual reference approach [1]. This virtual reference is constructed from the sum-of-square images of all transmit and receive channels and is assumed to be almost homogeneous. Unfortunately, at ultra-high fields this assumption is questionable, especially in body imaging. As a result, it may no longer be possible to achieve the desired excitation patterns. In order to estimate the experimental outcome of Tx-SENSE based zoomed cardiac imaging at 7T we performed FDTD simulations on a computer model of the human body. From simulated $B_1^{(+)}$- and $B_1^{(-)}$-maps of a home-built 4-channel TX/RX torso coil [2], the virtual-reference-based transmit sensitivity maps can easily be derived. This way, two complete simulations of a Tx-SENSE experiment can be compared: one based on the virtual reference approximation and one using the true $B_1^{(+)}$-maps.

Materials and Methods

FDTD simulations (XFDTD 6.4, Remcom) were performed on a 201^3 mesh of $(2\ mm)^3$ cells using a truncated body model ("Duke") from the Virtual Family data set [3]. Tissue dielectric properties were calculated for 300 MHz. The coil we are using for body imaging [2] consists of two parts, each of them is constructed as a shielded decoupled surface coil. Tuning and decoupling is achieved by adjusting the corresponding capacitors (Fig.1). All this was correctly modeled in our simulation. The four feeding ports were implemented as currents sources. Four computation runs were performed, one for each element. From steady state field amplitudes the $B_1^{(+)}$- and $B_1^{(-)}$-maps were calculated (Fig.2). RF pulse shapes were calculated according to Refs. [1,4] using either the virtual reference approach or the true $B_1^{(+)}$-maps from the FDTD simulation, but taking into account, of course, that the spin dynamics is determined by the true $B_1^{(+)}$-distributions. The target excitation pattern was a homogeneous box covering the heart. The following parameters were used for RF pulse calculation: FOV = $(400\ mm)^2$, Tx matrix size = 32 x 32, k-space: 32-turn spiral with equal arc length, RF pulse length = 2.5 ms, acceleration factor = 4.0. Flip angle maps representing the actual excitation pattern were calculated by a full Bloch Equation simulation with an intended maximum flip angle of 5 degrees. As we were interested in RF effects only, we assumed a homogeneous B_0-field and neglected any T_2^*-relaxation.

Results

The calculated $B_1^{(+)}$-maps for each coil element are depicted in Fig.2. They are consistent with experimental cardiac imaging results at 7T [2]. Thus, reasonable results were to be expected from the simulated Tx-SENSE experiments (Fig.3). When using the virtual reference approach (left column) the technique clearly fails to generate the intended excitation profile (Fig. 3a,c). For RF pulse shapes calculated from true $B_1^{(+)}$-maps the obtained excitation profile is sufficiently selective and homogeneous to perform a high quality zoomed imaging of the human heart.

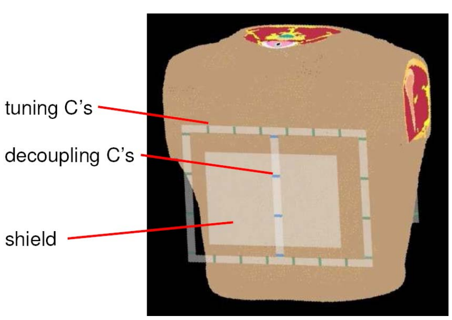

Fig. 1: Virtual torso from the human model "Duke" of the Virtual Family [3] together with one double loop of our 4-channel torso coil

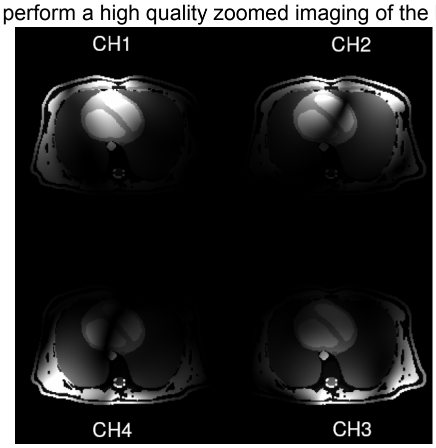

Fig.2: Simulated $B_1^{(+)}$-maps for each coil element, maps are weighted by tissue conductivity to mimic MR images

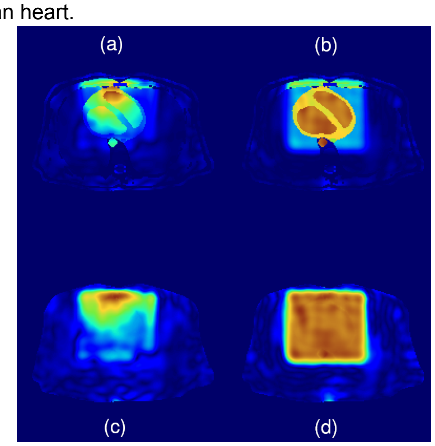

Fig.3: Simulated Tx-SENSE results. Bottom row: flip angle maps, top row: zoomed images of the heart. Left column: virtual reference approximation, right column: true $B_1^{(+)}$ maps.

Conclusions

Combining FDTD and Bloch simulations we evaluated the performance of Tx-SENSE in 7T cardiac imaging when using a 4 channel TX/RX decoupled loop array. The virtual reference based $B_1^{(+)}$ approximation, which is known to work well at 3T [1] and reasonably well in the human head at 7T, is no longer applicable for body imaging at ultrahigh fields. Using the true $B_1^{(+)}$-maps, however, very promising results are obtained. Fast and reliable $B_1^{(+)}$-mapping techniques are essential for Tx-SENSE body imaging at 7T.

References

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