B1-Shimming at 3T using an 8-Channel Transmit Array

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Introduction

The concept of B1-shimming is important for improving SNR and in quantitative MRI at high field. B1-shimming can be accomplished in hardware-only using a transmit-array with appropriately driven amplitude and phase of each array element, or using 2D/3D RF spatially selective pulses. The hardware-only solution has seen limited success in practice, mostly due to the unavailability of multi-transmit MRI systems. More recently, the transmit-SENSE method has been demonstrated to significantly reduce the pulse length of 2D and 3D spatially selective B1-shimming RF pulses[1]. We compare B1-shimming results using both the hardware and RF pulse methods on a Siemens 3T 8-channel transmit Trio-Tim MRI system.

Methods

A Siemens 3T 8-channel transmitter Trio-Tim MRI system was used with a Tx-array design (Fig.1) consisting of eight 4 x 10 cm elements evenly distributed azimuthally over a 20cm cylinder, inductively isolated with shared inductors, for a resultant isolation of better than –17dB when loaded with a high fill factor 18cm diameter cylindrical saline phantom. The excitation $B1^+$ field of each Tx-array element was simulated using xFDTDv6.3 (Remcom, USA) with a124x128x156 sized 2.5mm mesh. The 8-channel array (123.2MHz) was constructed using 1.8Ω input impedance pre-amps, active T/R switches, and cable traps and balanced matching inputs to each element. 2D RF pulses were calculated with a Matlab-based (The Mathworks, USA) least-squares inversion optimization, for a spiral gradient trajectory with 10µs gradient and 5µs RF raster time, within the gradient amplitude, slew rate and SAR limitations of the Siemens scanner. Standard FLASH images were collected (TR/TE= 500ms/10ms).

Hardware-only B1-Shimming

The goal is to drive an 8-channel Tx-array with optimized voltage amplitude and phase to produce a uniform B1+ over a transverse image plane. Although phase and magnitude variation is able to correct for azimuthally asymmetries (*Fig.1*), the best full slice shimming result is achieved from the CP-mode B1+ field still exhibiting the typical central brightening. Experimental eigenmodes [2,3] of the Tx-array are shown in *Fig.1*. By analyzing the phase distribution of the orthogonal eigenmodes of the Tx-array used (*Fig.2*), superposition of higher order modes (needed for B1-shimming) does not allow proper superposition of B1+ fields over the entire transverse plane. In order to improve the B1-shimming using such hardware-only methods, a Tx-array with both azimuthal and axial(z-axis) distribution of elements is required.

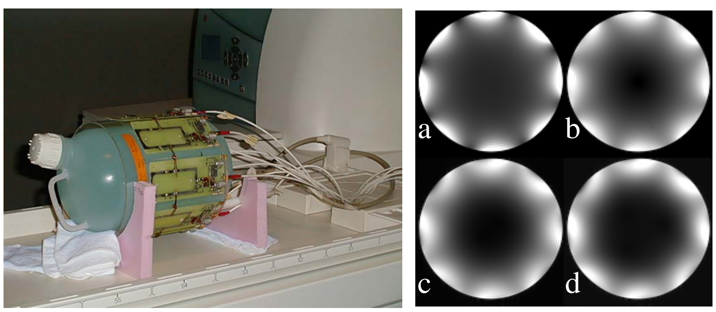


Fig. 1: Tx-array setup(left); Experimental 8-channel Rx GRE images obtained driving eigenmodes: successive phase of (a) 45°(CP), (b) 90°, (c) 135°, (d) 180°.

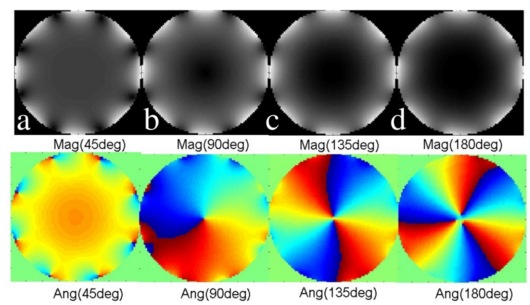
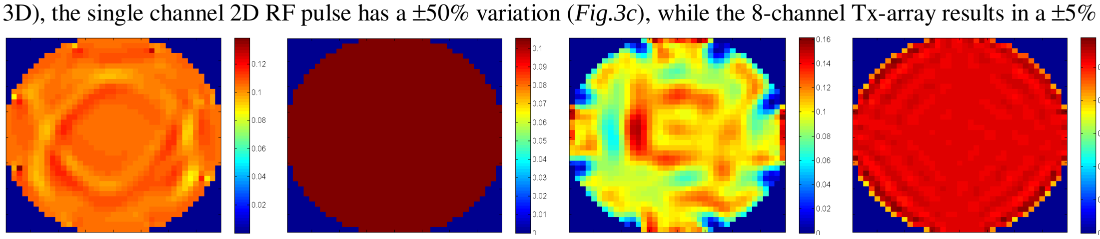


Fig.2 (a-d) Simulated B1+ eigenmodes (magnitude-top, phase-bottom) from successive phase of (a) 45°, (b) 90°, (c) 135°, (d) 180° delivered to Tx-array.

2D RF Pulse B1-shimming

An alternative method of B1-shimming involves calculation of an optimized 2D/3D RF pulse that tailors the excitation to achieve uniform flip angle distribution. For a 20 spiral trajectory, an optimized 12.2ms RF pulse shows that near perfect excitation is possible for the 8-channel Tx-array(*Fig.3b*), while the single channel mode (*Fig.3a*) has a ±20% variation in excited for a 10° flip angle. For a short 1.5ms pulse (required to extend to 3D), the single channel 2D RF pulse has a ±50% variation (*Fig.3c*), while the 8-channel Tx-array results in a ±5% variation(*Fig.3d*).



a) CP Mode, 12.2ms **b) 8-ch, 12.2ms** **c) CP Mode, 1.5ms** **d) 8-ch, 1.5ms**

Fig. 3: 2D distribution of the excited magnetization for optimized 2D RF pulses using the single channel CP-mode of the Tx-array and all 8-channel of the Tx-array.

Conclusions

B1-shimming using the hardware approach using an azimuthal distribution of array elements is unable to adequately achieve uniform excitation and therefore Tx-array coils will require elements to be placed along the axis of the coil. 2D/3D RF pulses can effectively produce uniform excitation but require Tx-arrays (Tx-SENSE) to minimize acceptable pulse lengths while maintaining excitation uniformity.

References

[1]Saekho S et al MRM 55:719-724 (2006). [2] King SB et al, Magn Reson Eng, 29B(1): 42-49 (2006). [3] King SB et al, ISMRM p.712 (2003).

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