Simultaneous multi-slice excitation by parallel transmission using a dual-row pTX head array

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Target audience: MR physicists and RF engineers

Introduction

Simultaneous multi-slice (SMS) imaging with receiver arrays allows for greatly accelerated 2D single-shot acquisitions with BOLD or diffusion-weighted EPI (1-4), and spirals (5). The commonly used SMS excitation methods require specially designed multi-band (MB) (1,2) or PINS RF pulses (6) to excite N slices. In this abstract we explore the use of parallel transmission (pTX) for SMS excitation, which can be achieved by uniquely frequency shifted slice-select pulses on subsets of pTX elements that are closets to the slices they excite. pTX has been shown to be useful for managing B_1^+ and B_0 homogeneity and SAR. Using a dual-ring 3D pTX coil design (7) and blipped-CAIPIRINHA EPI, we show that factor-2 SMS excitation with parallel transmission (pTX) can readily be achieved with conventional single-band RF pulses. Factor-4 SMS using dual-band RF pulses applied to each ring are also shown. For pTX coils with inherent TX-sensitivity encoding along the slice direction, the approach can reduce total required RF power (global SAR) compared to MB pulses with N frequency bands used on all coil elements as well as accelerating SMS multi-dimensional excitations.

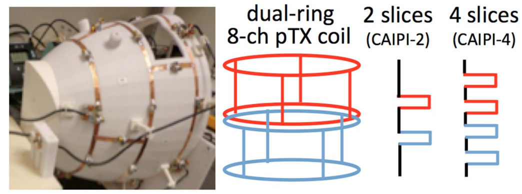

Fig 1. 8-channel dual-ring pTX coil. Like colors indicate channel selection for factor-2 and 4 pTX-SMS: Two slices were excited using single-band RF pulses on each ring at corresponding frequencies; analogously, four slices were excited using two dual-band RF pulses.

Methods

Data were acquired on a 3T Siemens with an 8-channel dual-ring pTX/RX head array, and EPI-based blipped-CAIPI (4) and 'dual-angle method' B_1^+ mapping sequences (8). Phantoms and three humans were scanned under IRB approval. The pTX coil was driven using all eight elements simultaneously or using each ring of four in two separate scans, with unique slice-select frequencies (Fig. 1), and the raw signals summed to simulate pTX. FA maps for TX on either one or both rings were acquired on a phantom (T_1~ 500ms) using EPI (64x64, 32 5mm slices, FOV 22cm, 22° and 66° non-selective pre-saturation, FA=90°, TE=25ms, TR=6s). The excitation with one ring was transmitted at half the power compared to the excitation with both rings (all elements). Analogous *in vivo* single-slice EPI scans (64x64, 32 3.5mm slices, FOV 22cm, TE= 35ms, FA=90°) were acquired with one or both rings to see the effect on image quality. Factor-2 SMS imaging with FOV/2 CAIPI shift was performed by exciting one slice of the lower/upper half of the slice-stack with the lower/upper coil ring, using standard single-band pulses. Factor-4 SMS with FOV/2 shift was done by simultaneously exciting two slices of the lower/upper half of the slice stack on each ring, using dual-band pulses (Fig 1). Flip angle readjustment was deliberately not performed, hence total scan power for the SMS scans was exactly half compared to that of single slice excitations. Aliased slices of the pTX SMS scans were separated by slice-GRAPPA in Matlab (4).

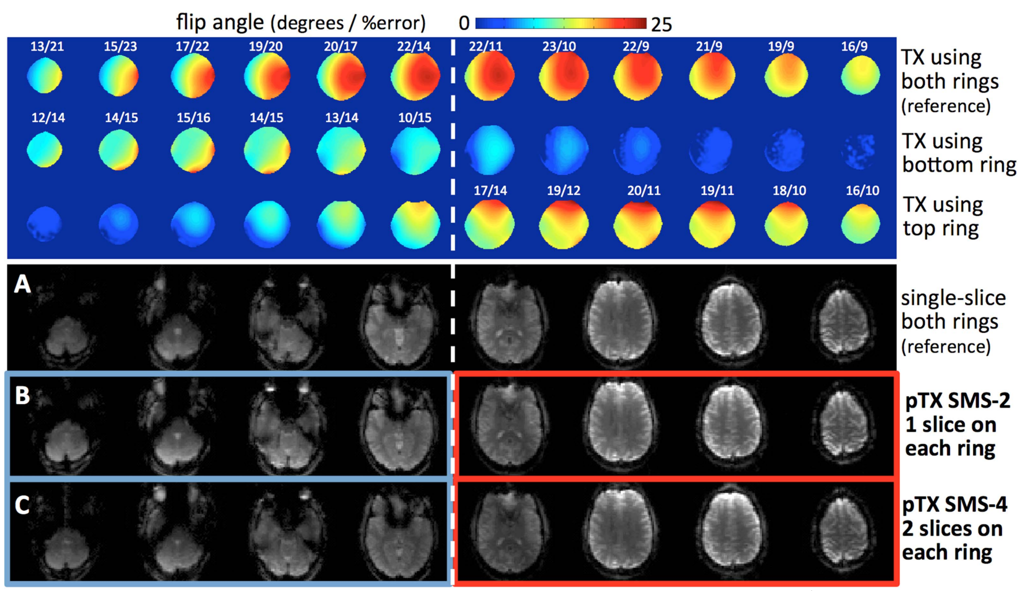

Fig 2. *Top*: FA maps for CP mode excitation on either both or individual coil rings without B_1^+ recalibration. The numbers indicate mean FA and average %deviation from the mean; the broken line is the border between rings. *Bottom*: (A) EPI images for excitation with both rings. Panel (B) shows factor-2 pTX SMS CAIPI with the lower/upper half of the slice stack excited by the lower/upper coil ring, using single-band pulses. (C) shows factor-4 pTX SMS where two slices are excited by dual-band pulses applied to each ring. Total power for SMS scans was factor two lower than in (A), but the gradient-echo EPI images do not appear much affected by the hence slightly reduced flip angles.

Results and Discussion

Flip angle maps are shown in Fig 2 (top). White numbers indicate mean FA per slice and mean %-error. Mean FA's dropped by only 17% on average (max 53%, where the rows join) despite using only one coil ring, and 50% lower power. This indicates a considerably lower power requirement even when full FA calibration is performed. Detailed SAR simulations are ongoing. The B_1^+ loss in pTX-SMS acquisitions where only one ring is used per slice was barely visible in the corresponding GE-EPI images, as evident from comparing SMS-2 and SMS-4 images in panels (B) and (C) to (A). In addition to the conceivably lower global power in pTX-SMS, exploitation of coil-sensitivity information to reduce the number of frequency bands in MB-RF pulses should strongly reduce their peak power and voltage, which readily reach hardware limits.

References [1] Larkman JMRI 13(2), 2001; [2] Moeller MRM 63(5), 2010; [3] Feinberg PlosOne 5(12),2010 [4] Setsompop MRM, 67(5), 2012; [5] Poser ISMRM 2012 #2857; [6] Norris MRM 66(5), 2011; [7] Kozlov JMR 200(1), 2009; [8] Sled MRM 43(5), 2000 **Grant support:** R01DA019912, R01EB011517, K02DA02056, DFG Po1576/1-1