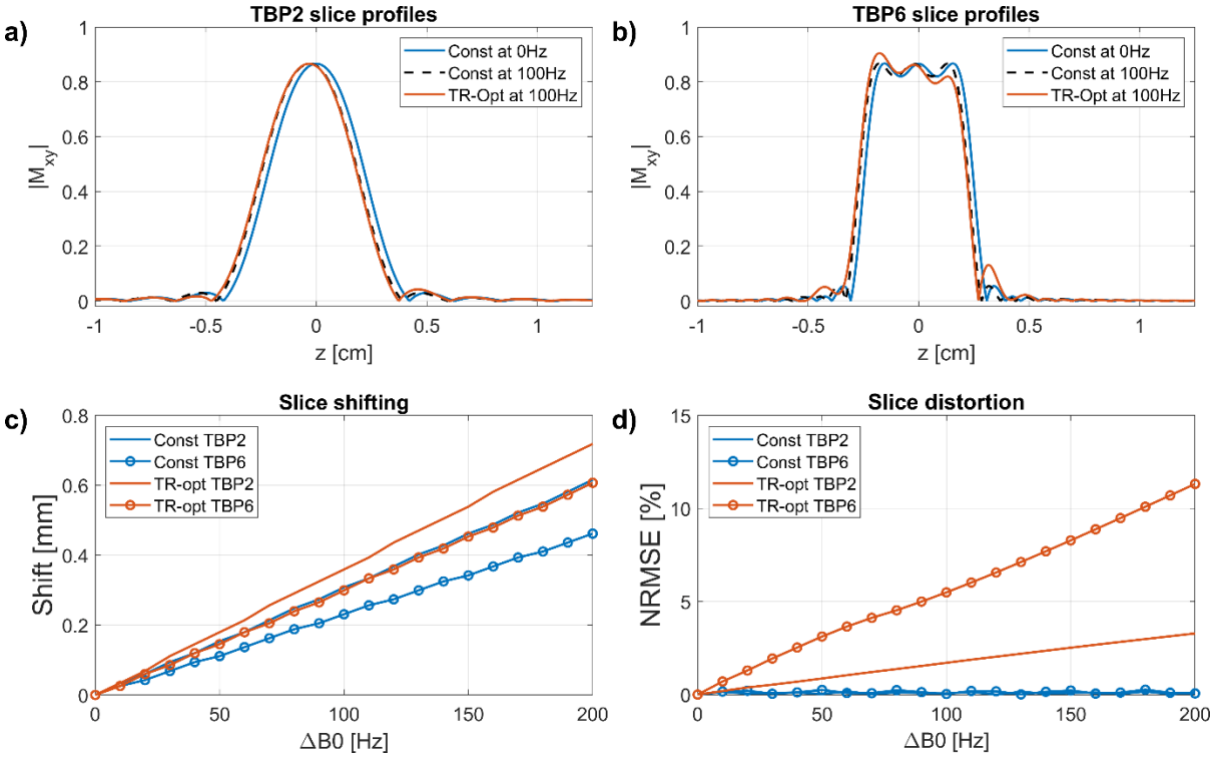
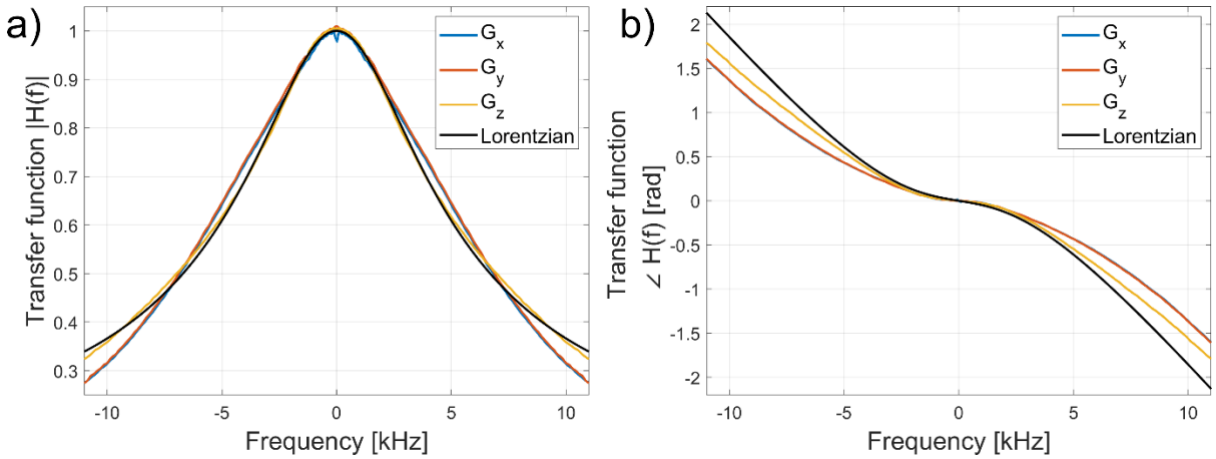
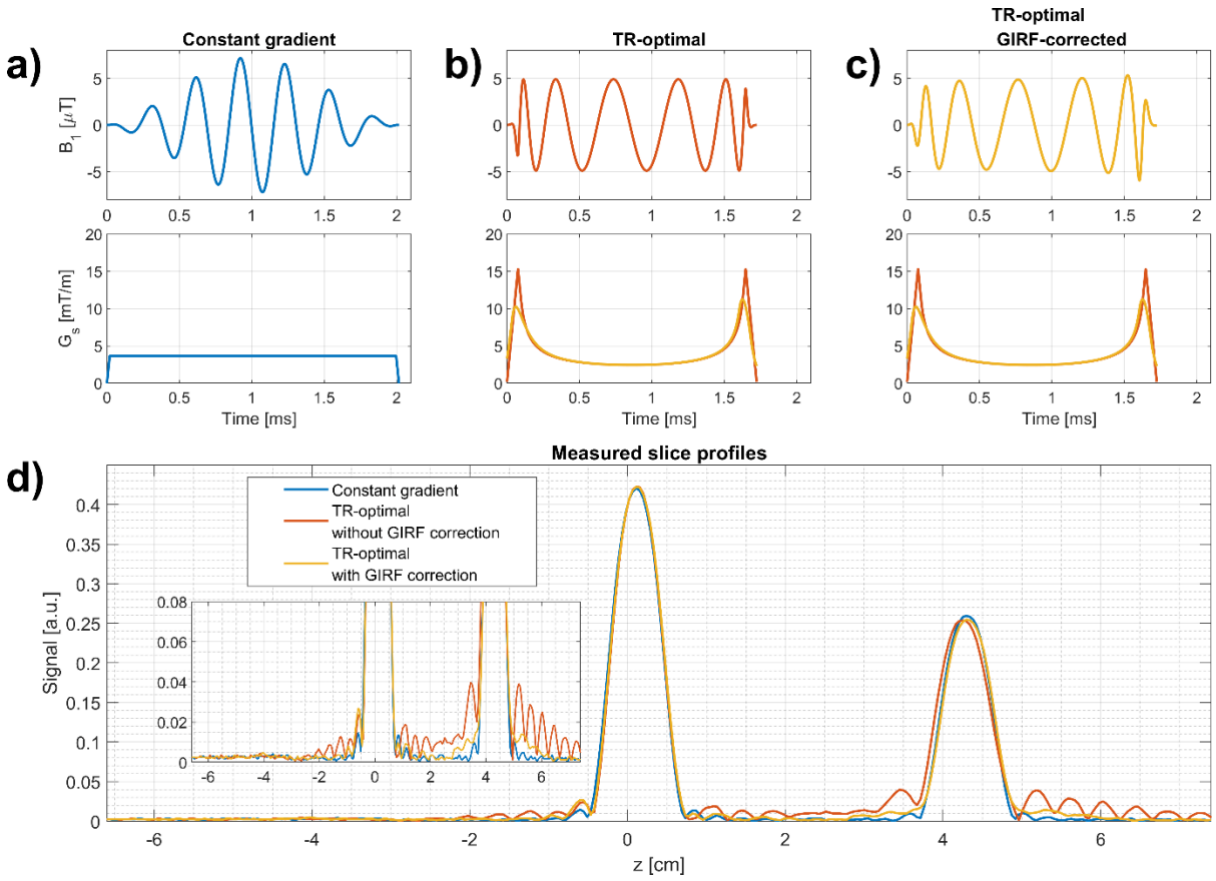
Supporting information



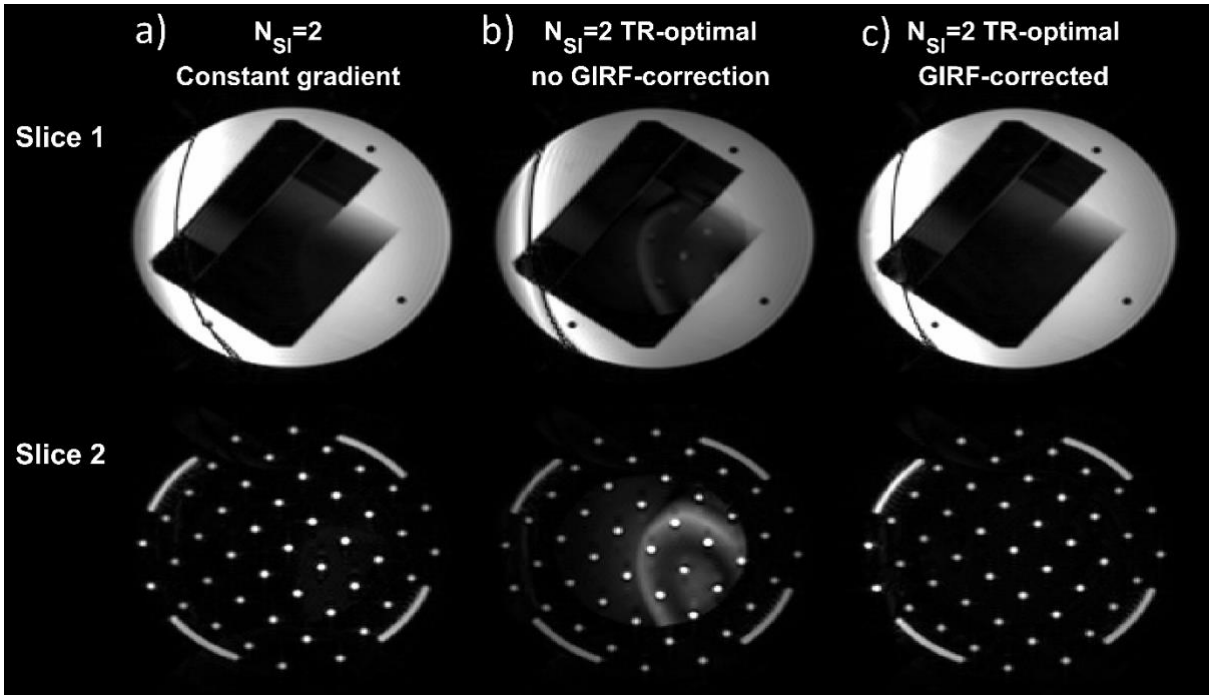
Supporting Information Figure S1: To examine off-resonance effects on the slice excitation quality, due to the use of time-variable selection gradients, off-resonance analysis was conducted using Bloch equation simulations. The spatial shift of a slice was found using cross-correlation between an on-resonance and off-resonance slice, and distortion evaluated using normalised root-mean-square error of the re-centered slice. **a)** Shows a TBP2.13 slice profile simulated at an off-resonance of 100 Hz for a constant and TR-optimal gradient solution, and **b)** shows the same for a TBP6 pulse. Both slices have a nominal thickness of 5 mm. A slight shift is noticed in both, but the TR-optimal TBP6 slice has a noticeable distortion. Subfigures **c)** and **d)** quantitatively show how slice-shifting and slice distortion vary with off-resonance frequency. The slice-shift is marginally larger for TR-optimal pulses than constant gradient versions. Constant gradient pulses also show little distortion, whilst TR-optimal show noticeable distortion which increase with TBP. This is due to the highly time-variable gradient.



Supporting Information Figure S2: Measured and estimated Gradient Impulse Response Function (GIRF) from our system (Philips 3 T Achieva), for directions X (AP), Y(RL) and Z. An image-based procedure was used to measure the GIRF (30). The curve in black shows a Lorentzian fit with time-constant 42 μs. The GIRF effectively lowpass filters the intended gradient waveform. For experimental results the estimated GIRF was used for RF-based correction, to represent results which can be reproducible without measuring a GIRF explicitly. Phantom imaging results are shown in Supporting Information figures S3 and S4.



Supporting Information Figure S3: Slice profile measurements were conducted on a 3 T Philips Achieva (Philips Healthcare, Best, Netherlands) using a cylindrical phantom containing 100 mL of saline (9 g/L) doped with 1% gadolinium contrast agent (0.5 mmol/L Gd-DOTA, Dotarem). All pulses tested were designed for a flip-angle of 45 degrees, slice-thickness of 7 mm and an inter-slice spacing (center-to-center) of 42 mm. All slices were shifted from isocenter by Δx=21 mm using the FM-shifting approach described in Connolly et al., reference (31). Slices were visualized using a 2D gradient echo sequence (TR = 50 ms, TE=8.5 ms, 0.55x0.575 mm in-plane resolution) with the read-out gradient moved to the slice-select direction.
Subfigures **a)** and **b)** show the constant and TR-optimal versions, respectively, with the addition of a predicted gradient shown in yellow. Subfigure **c)** shows the GIRF corrected RF waveform. Note that the GIRF-corrected TR-optimal gradient pulse is identical to the non-GIRF corrected one. Subfigure **d)** shows the reduction of sidelobes thanks to the correction, with some sidelobes remaining compared to the constant gradient case. This is possibly due to model inaccuracies.



Supporting Information Figure S4: The effect of using GIRF correction shown in a structural QA phantom using a multiband bSSFP acquisition identical to the in-vivo data. The column in **a)** shows the images for a constant gradient acquisition, the 2nd column **b)** shows the TR-optimal acquisition without GIRF correction, and the 3rd column **c)** the result with GIRF correction. A reduced TR in **b)** and **c)** with respect to **a)** is noted by the change in band location. The spurious out-of-slice artefacts visible in **b)** are largely eliminated in **c)**.

Supporting Information Video S1: Animation of the in-vivo dataset, containing 30 dynamics, repeated 5 times for visibility.