Improved Parallel Imaging using Small FOV Excitation on an 8-Channel Transmit Array System

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Introduction

By using numerical techniques such as SENSE or GRAPPA to reconstruct data, the FOV can be reduced to allow for faster image acquisition times and/or higher spatial resolution. This process imposes an associated g-factor, being a noise amplification term, over the imaging region, reducing overall image quality or SNR. When the ROI is small relative to the object size, a receive array can be designed specifically for improved SNR or g-factor performance [1]. Also, the effective object size can be reduced by using 2D/3D excitation RF pulses, enforcing a reduced transmit FOV (xFOV). The main concern to this approach is SAR limitations, which relates to the transmit pulse length that must be minimized when motion artifact plays a role in image quality, such as with cardiac imaging. Tx pulse length can be reduced by using a Tx array system [2], where complex 2D/3D pulse profiles can be achieved using a set of much shorter pulses. Here, we use a recently installed 3T 8-channel transmit Siemens Trio-Tim MRI system for applying 2D RF pulses to improve g-factor maps, SNR and reduce imaging time for a localized ROI.

Methods

Using our least squares inversion 2D pulse designer, any arbitrary pattern can be excited in a required slice, experimentally verified in Fig 1. To analyze the benefits of transmit SENSE, an 8-channel Tx-Rx head coil was constructed with evenly distributed 4 x 10 cm azimuthal elements around a 20 cm diameter shell. Fig. 2 depicts simulations from an 18 cm diameter phantom, where the dashed line indicates the object boundary.

The MSE for the single channel excitation of Fig 2a) is 1.5303 compared with 1.1329 when using 8 transmit channels. Of importance here is the excitation artifact signal, being within the sample but outside the blurred edges of the ROI, because aliased signals will not be unwrapped beyond the reduced FOV. If the excitation artifact signal is below the noise floor, the g-factor maps will improve, otherwise, wrap artifact exists, proportional to the excitation artifact signals. Allowing for a 5 mm blurred edge and discounting the ROI homogeneity, the MSEs would be 0.2606 and 0.0809 respectively, indicating 75% of the unwanted excitation artifact signal is removed with the 8-channel Tx array. When a 12.2 ms (20 spiral) RF pulse is used for the excitation pattern, the edge ignored MSEs become 0.1692 and 0.0174 respectively (excitation artifact signal reduced by 90%). Transmit SENSE is required to reduce the 2D pulse lengths, commonly applied to minimize motion artifact.

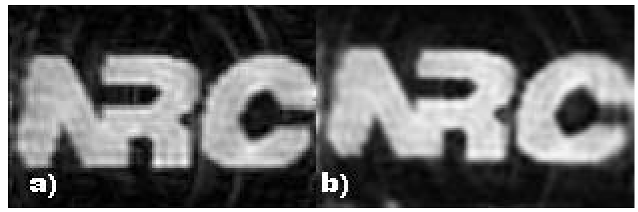

Fig. 1: Complicated CP mode 2D excitation pattern with a 8-channel Tx array verified between a) simulated fields and b) a 128x128 pixel experiment. The 12.2ms RF pulse (20 spirals) was computed for a 18 cm diameter phantom.

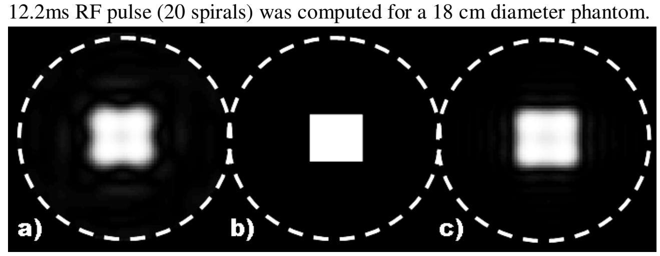

Fig. 2: Small xFOV Tx-SENSE excitation improvements based on a 1.5 ms pulse (5 spirals), displaying a) the single channel CP mode of our Tx array, b) desired excitation and c) the 8-ch Tx array optimized excitation profile.

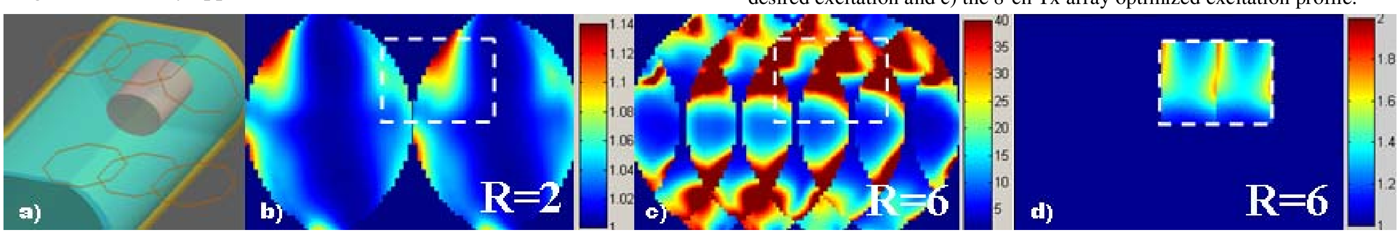

Fig. 3: a) Human cardiac torso model with 6-channel Siemens OEM receivers showing simulated g-factor maps based on b) full FOV excitation L-R, R = 2, c) full FOV excitation L-R PE, R = 6 d) perfect small xFOV excitation (1/3 of full FOV), applying R = 2, effectively making R = 6.

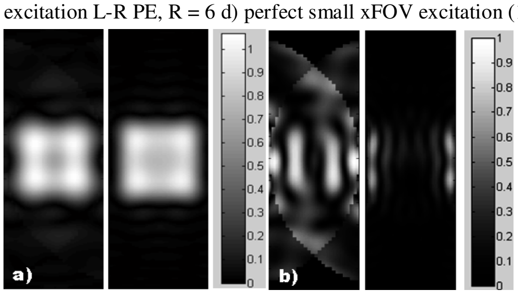

Fig. 4: Wrapped profiles of Fig 2 for 1/3 FOV depicting a) excitation superposition and b) only wrapped signals.

Next, we look at how these pulses are used for parallel imaging. Using a human torso sample and the Siemens OEM 6-channel coil arrangement of Fig 3a, L-R PE g-factor maps are compared between a full FOV image and a perfect 2D pulse excited image over the dashed cardiac region. Note that effective reduction factors larger than the number of receiver channels are possible and would be favorable with an optimized design [2]. The downside to small xFOV parallel imaging is that unwanted excitation signals will create artifacts within the resulting image that cannot easily be removed. Using the imperfect excitation profiles of Fig.2, wrapping effects are shown in Fig.4, being unity scaled to the maximum pre-wrapped signal level and the maximum wrap signal for a and b respectively. We found peak wrapped signal levels of 12.3% and 5.1%, with average levels of 7.6% and 2.7% for the CP mode and the 8-channel Transmit array respectively.

Conclusions

We enhanced parallel imaging capabilities by using 2D RF pulses to suppress sample signals outside the ROI. Transmit SENSE allows the 2D pulses to be useful for fast imaging, exciting near ideal 2D profiles to minimize excitation artifact signals.

References

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