Improved parallel imaging with N-periodic spatial banding patterns in bSSFP.

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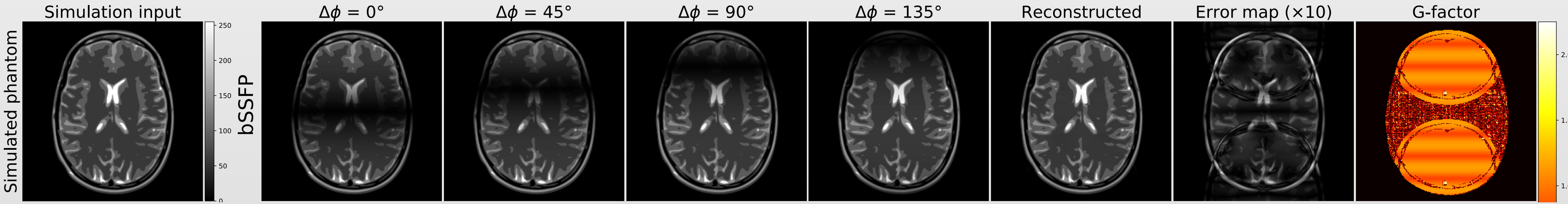
Introduction

- The balanced steady-state free precession (bSSFP) is widely used due to its high signal-to-noise ratio (SNR) efficiency[1]. However, its signal is strongly dependent on local off-resonance, and so in regions with large B_0 field inhomogeneity this results in undesirable banding artifacts.
- Via linear RF phase cycling, these patterns can be shifted across several acquisitions, which can then be combined to generate band-free images.
- In each of these bSSFP acquisitions the signal is therefore spatially modulated by both the coil sensitivity and bSSFP spectral profiles[2-3]

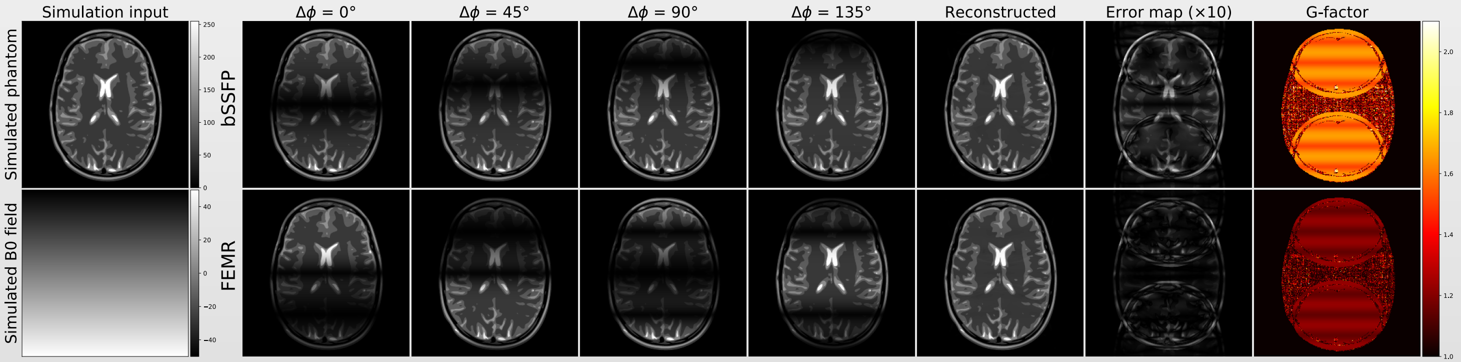


Outline of sFOV Theory with simulated phantom[2]

1) Bangerter 2004 2) Lustig 2005 3) Griswold 2002

Theory

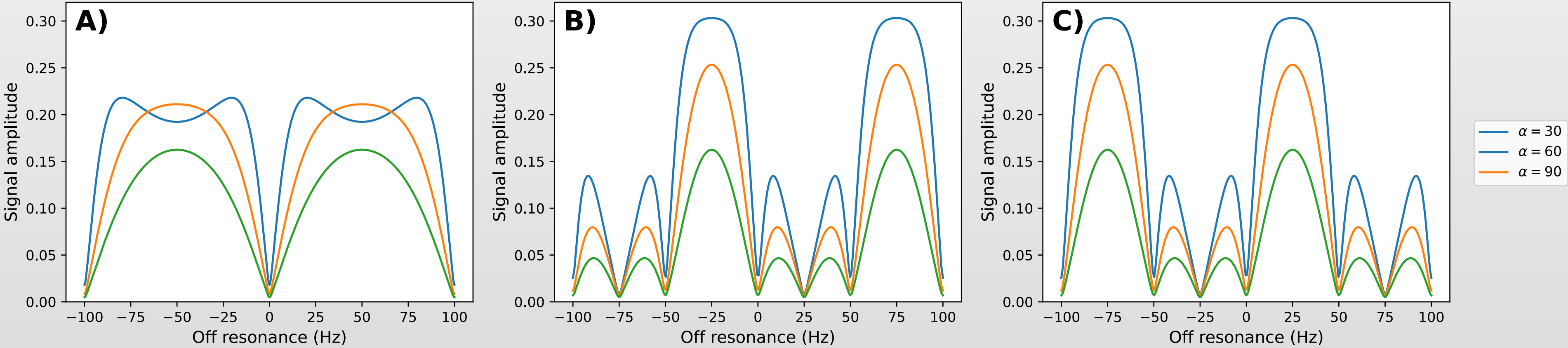
- Instead of linear phase cycling, quadratic phase cycling in bSSFP creates alternating equilibrium magnetization, resulting in more orthogonal N-periodic bSSFP profiles.
- Orthogonality improves the conditioning of parallel imaging.



Outline of sFOV Theory with simulated phantom.

Theory

- Figures A) shows the bSSFP echos
- Figures B) and C) show the FEMR echoes acquired after even and odd excitations for a single acquisition. Using a repeated RF phase scheduling of 0,90, the FEMR-acquired images have an optimal stop-band and pass-band behavior.



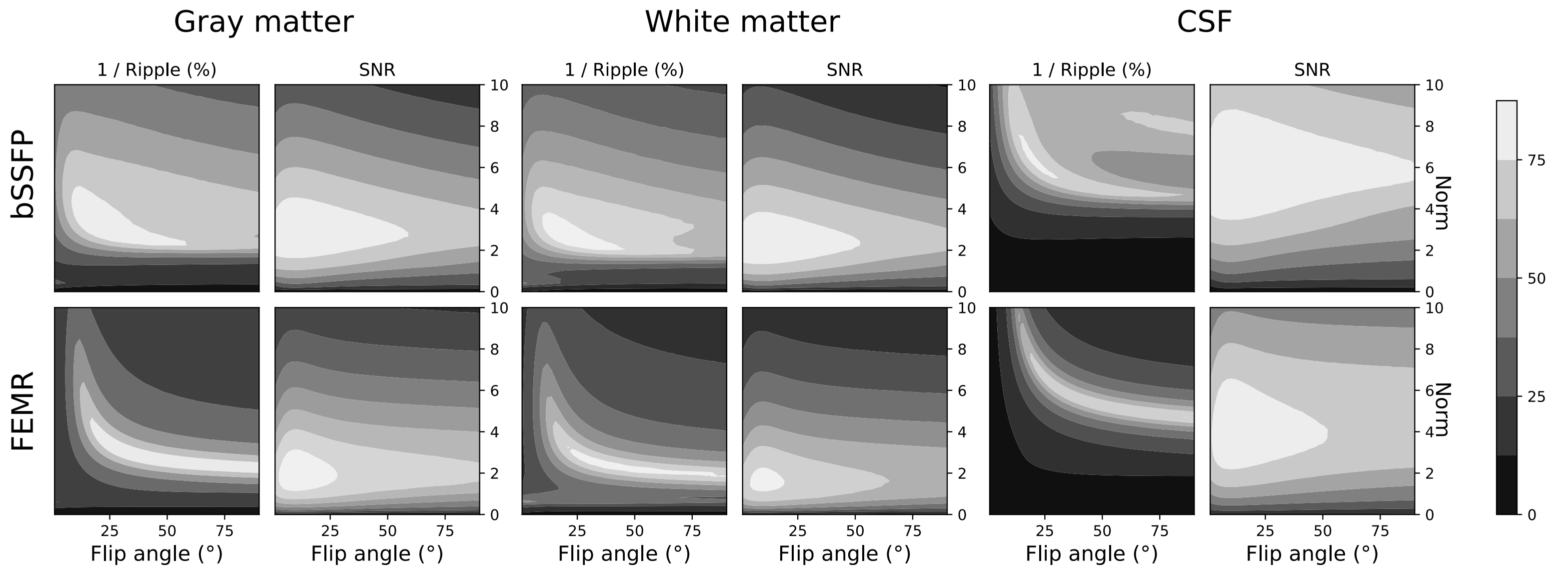
bSSFP and FEMR profiles

Methods

- Simulation
  - Bloch simulation to optimize the imaging parameters and phase cycle combination methods

- In-vivo
  - In-vivo acquisition experiment utilizing a 3T Siemens MAGNETOM Verio (Erlangen, Germany) scanner from 3 healthy subjects. This experiment encompassed the acquisition of 8 linear phased-cycled bSSFP images and 4 linear phased-cycled FEMR images.

Results: simulation

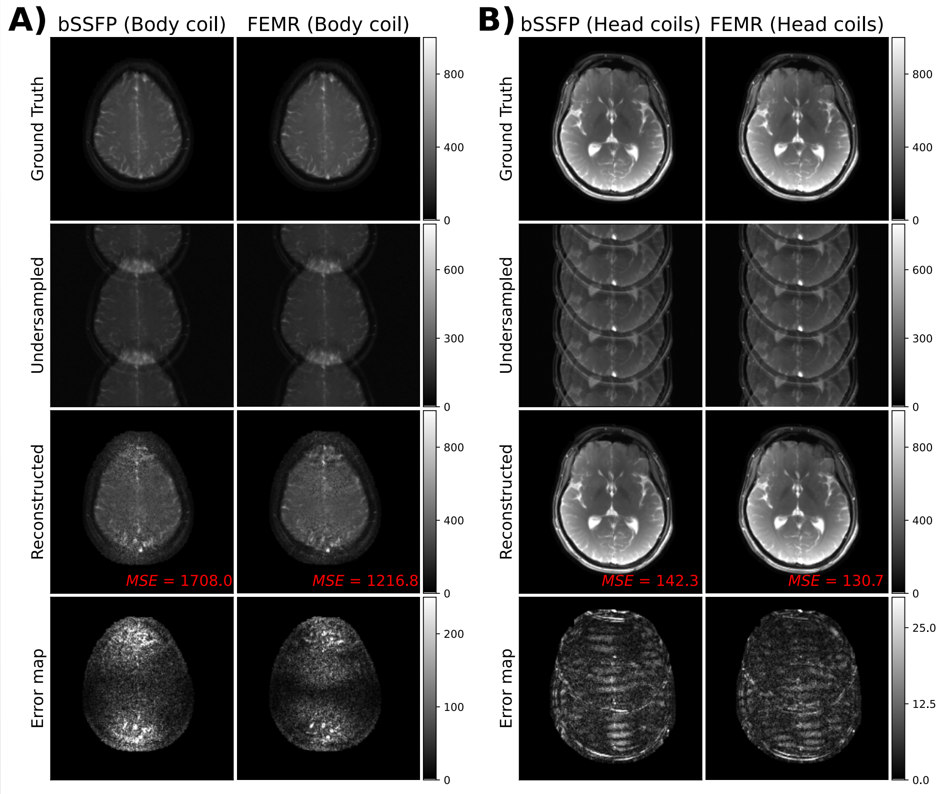


The percent ripple and SNR efficiency of bSSFP and FEMR for gray matter, white matter, and CSF.

The Bloch simulations suggested an optimal flip angle of approximately 30° and a combination norm of 2 for bSSFP. The FEMR results showed an optimal flip angle of approximately 25°.

Results: in-vivo

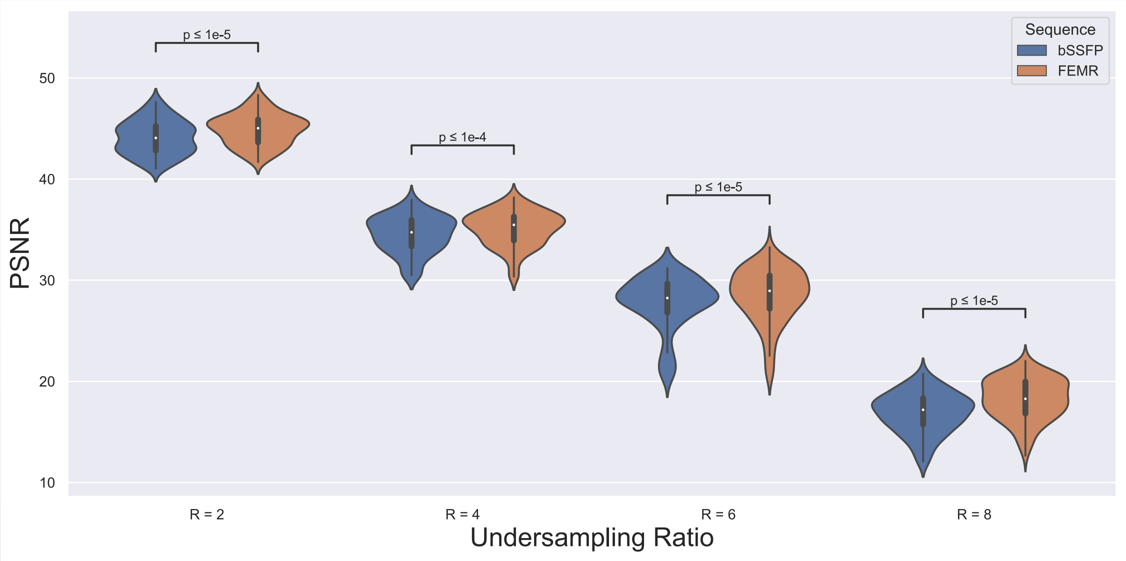
- Figure A) shows the reconstruction results with a single body coil.
- Figure B) shows the reconstruction results with head coils.
- FEMR methods shows better reconstruction results



An example GRAPPA reconstruction

Results: in-vivo

- Employing a two-sided p value threshold of 0.05, the results indicated a significant improvement in reconstructed image quality using the FEMR acquisitions.
- FEMR technique consistently outperforms bSSFP, especially at higher acceleration factors.



The PSNR values for different acceleration factors.

Discussion

- The optimal choice of flip angle and N-periodicity will depend on the specific application.
- Profile encoding methods rely on smooth B_0 field variations for spatial encoding and rapid profile changes can lead to suboptimal reconstruction results. To address this, it is necessary to either expand the auto-calibration region, or to acquire a rapid coil sensitivity calibration scan prior to the acquisition.

Conclusion

- In this work, we have shown that parallel imaging algorithms can use additional spatial encoding information that is independent of the coil geometry profile to enable simultaneous spatial encoding in SSFP acquisitions.