Transition-Band SSFP and EPI Functional MRI on a High-Performance 0.55 T Scanner

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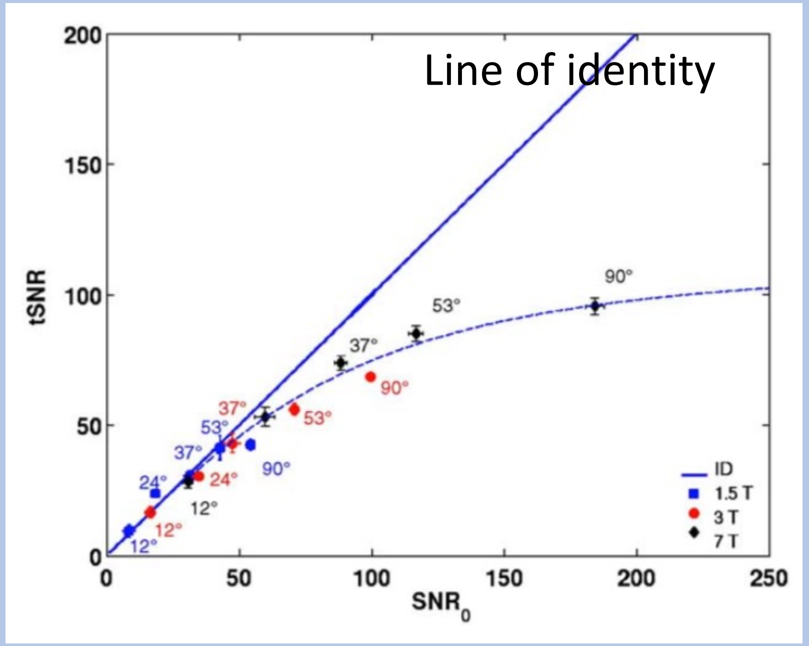
Introduction

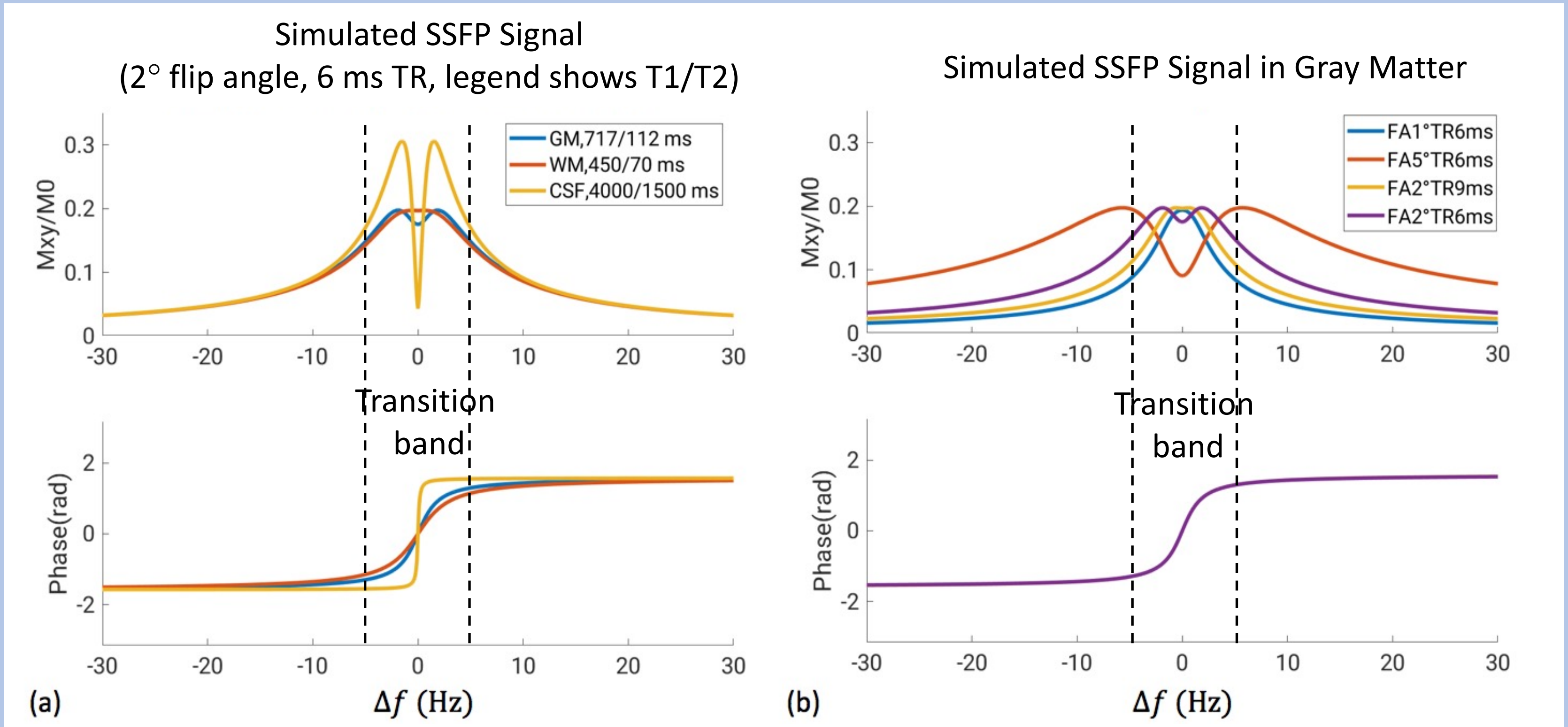
- Low-field (<1 T) MRI is advantageous in terms of cost and accessibility
- fMRI is generally considered to benefit from high field
  - Higher sensitivity to BOLD and higher SNR
  - Enable high-resolution fMRI, e.g. laminar fMRI
- However, for fMRI with a modest resolution (a few tens of mm^3 volume)
  - Physiological noise dominates thermal noise at high field
  - Difference in temporal SNR (tSNR) between high and low fields may be small
- Advantages of low-field fMRI:
  - Less signal dropout and image distortions from macroscopic susceptibility effects
  - Shorter T_1 (high efficiency)
  - Longer T_2^* (longer readout time)



tSNR dependence on image SNR
Slope decreases with increasing physiological noise
(Triantafyllou et al., 2005)

Introduction

- Transition-band Steady-State Free Precession (SSFP) fMRI
  - ➢ The SSFP signal phase is highly sensitive to frequency shift in the transition band
  - ➢ The width of the transition band is typically less than 10 Hz
  - ➢ Activation modulates voxel signal magnitude via changed intravoxel dephasing
  - ➢ Multiple experiments with varied central frequencies are needed at high field
  - ➢ May gain from the superior field uniformity at low field



Scheffler et al., 2001
Miller et al., 2003

Study Goals

- To evaluate the feasibility of BOLD fMRI at 0.55 T.
- To compare signal stability and sensitivity of SSFP and EPI based BOLD fMRI.

General Design

4-min visual stimulus experiment of each method at the same in-plane spatial resolution (3.3x3.3 mm^2) and temporal resolution (TR 1.3 s)

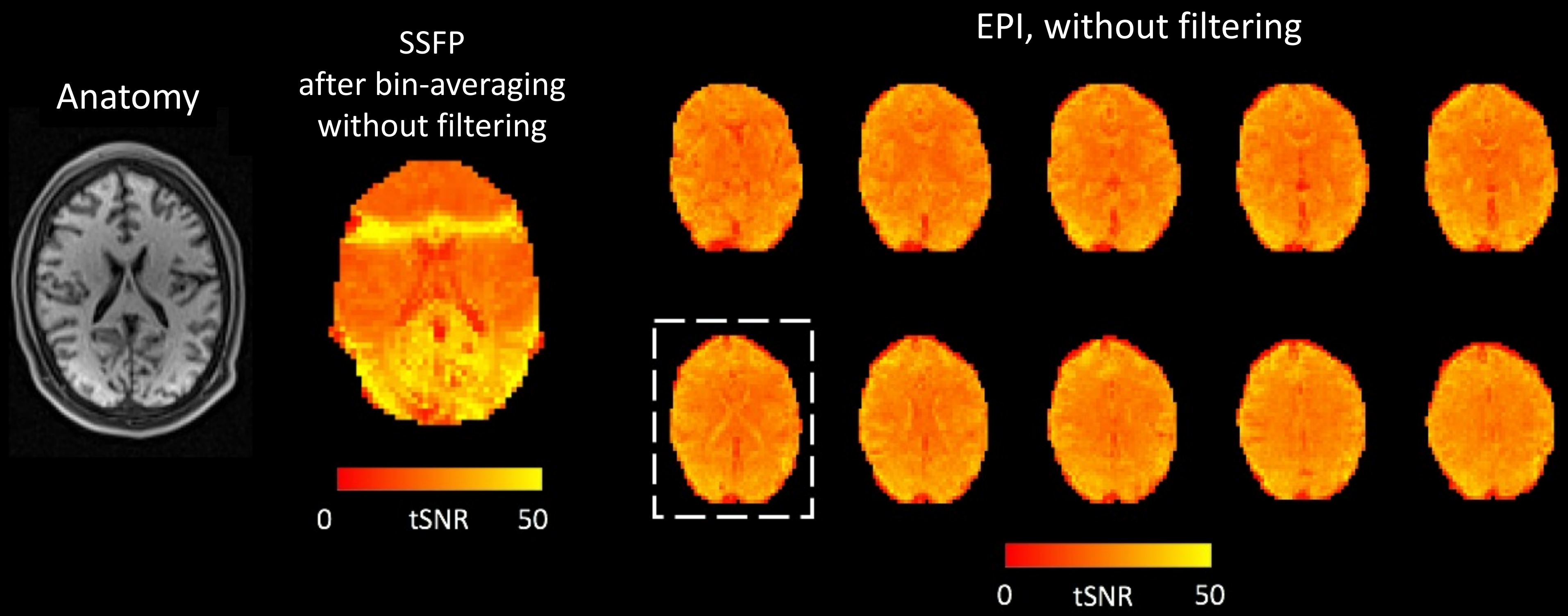
Methods

- Data acquisition from 6 healthy subjects
  - Prototype 0.55 T scanner with high-performance gradients (a ramped-down Siemens 1.5 T Aera)
  - 16-channel retuned receive array from 1.5 T
  - SSFP: 1 slice, 240×180 mm^2 FOV, 72×54 matrix size, 4 mm thickness, 2° flip angle, 6 ms TR and 3 ms TE (324 ms slice TR), 45 kHz bandwidth. Images were bin-averaged to match TR of EPI and increase tSNR (width=4).
  - EPI: 10 slices, same in-plane resolution, 3 mm slice thickness, 1.296 s TR, 80° flip angle, 85 ms TE, 60 kHz bandwidth, 1.34 ms echo spacing.
  - Concomitant fields and B_0 field drift were compensated by manual adjustment of shims and the main frequency
  - Visual stimulus paradigm: Flashing checkerboard 20.7 s on and 20.7 s off for 254 s.

- Data analysis
  - Preprocessing and analysis were based on "FEAT" in FSL (FMRIB Software Library)
  - Preprocessing included
    - Motion correction with 6 degrees of freedom using "MCFLIRT"
    - Temporal filtering (41.5 s cutoff length)
    - Spatial blurring with 5 mm FWHM (full width at half maximum)
    - Pre-whitening using "FILM" to suppress structured noise
  - General Linear Model: 1 task regressor and its temporal derivative, 6 motion regressors

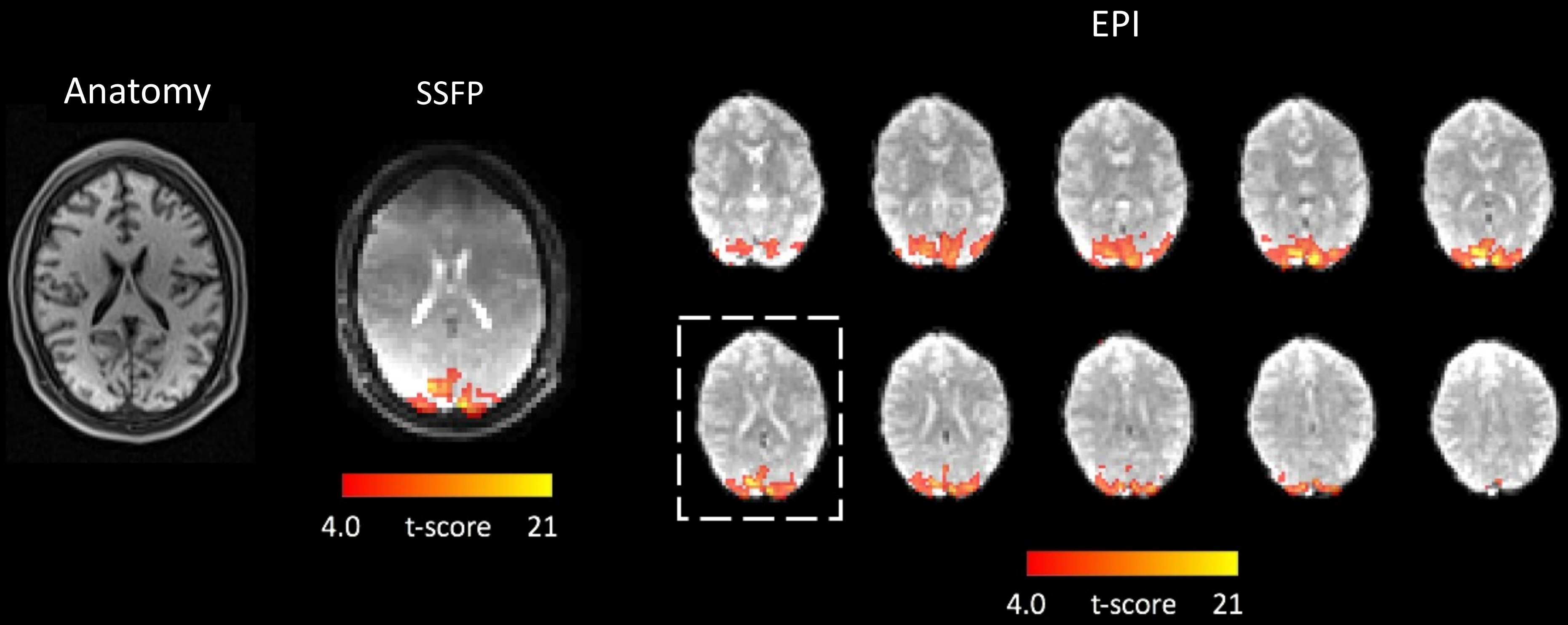
Results: Temporal SNR

- tSNR was heterogeneous for SSFP due to sensitivity to uncompensated frequency shifts e.g., no shimming in the frontal lobe, and residual concomitant field in the visual area
- tSNR was much more homogeneous for EPI
- In an occipital lobe ROI: 37±8 for SSFP and 30±6 for EPI



Results: T-statistics

- Activation was robustly detected in all 6 subjects using EPI and SSFP
- Activated voxels across subjects: 88±31 for SSFP, 107±10 for EPI at the similar slice position
- Number of the overlapped voxels was 58±10
- T score: 6.9±0.9 for SSFP and 8.0±1.1 for EPI (in their respective activated voxels)

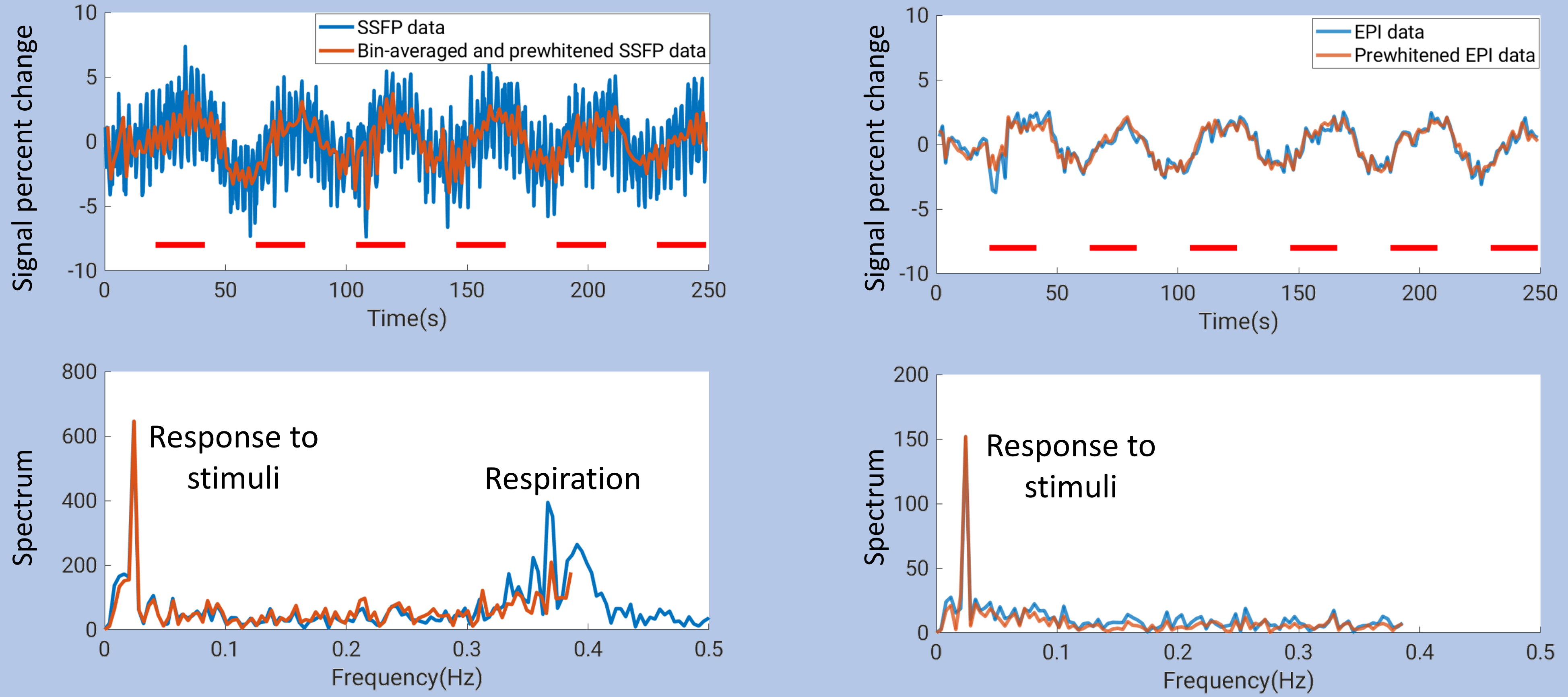


Results: Signal Characteristics

- Percent signal change over 6 subjects was 1.9±0.6 % for SSFP and 2.6±0.4 % for EPI
- Subject respiration induced strong signal oscillation in SSFP, but not in EPI
- Bin-averaging and pre-whitening helped to alleviate the oscillation

Average time courses and spectra over 69 activated voxels

SSFP | EPI



Conclusions

- Both transition band SSFP and EPI fMRI are feasible at 0.55 T
- EPI has advantages in terms of stability and spatial coverage
- SSFP demonstrated higher tSNR but slightly lower sensitivity compared to EPI
- SSFP is susceptible to small frequency changes induced by respiration, concomitant fields and scanner field drift.

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Thank you for your attention!
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