bOVOC: 200 Hz balanced One-Voxel-One-Coil MREG at 9.4T

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Target audience: Researchers interested in functional imaging, ultra-high field applications and balanced SSFP.

Introduction:

Speeding up functional brain imaging has been a major focus over the last several years with the potential goal to potentially identify activation-related MR changes faster than the time constants of the hemodynamic BOLD response function. Spatial specificity of the functional response is generated by time consuming gradient switching limiting the temporal resolution to about 0.1 to 1 second. In 2006 Hennig et. al. proposed the one-voxel-one-coil (OVOC) method which uses a single small coil for volume selection and thus in principle offers a temporal resolution of the sampling frequency of the acquisition system [1]. The OVOC acquisition is based on a FLASH-type sequence and is thus strongly T1 weighted which somewhat reduces SNR due to saturation, especially at very high fields. In this work FLASH was replaced by balanced SSFP (bSSFP) with only alternating excitation pulses (to acquire the entire signal of the coil volume), and with one spatial selection gradient (to produce a profile along that gradient). Volume selection was achieved with a tiny surface coil of 3 cm diameter.

Methods:

Measurements were performed on a 9.4 T MRI scanner (Siemens Healthcare, Erlangen, Germany) using a homebuilt 16 channel transmit array combined for excitation with a single small surface coil positioned close to the right hemisphere of the visual cortex (see Fig. a and b). Signals were acquired with a bSSFP sequence using a TR of 5 ms and TE of 2.5 ms, and flip angle of 27 deg. The volume was shimmed on-resonance corresponding to the pass-band characteristics of bSSFP. Experiments were performed either without any gradient resulting in an infinity FID with only short breaks during RF transmission, or with slice selection of 5 mm and a single balanced read out gradient along the coil axis providing a resolution of 1 mm along A-P direction (projection left-right). Visual stimulation consisted of a 13 sec rest period followed by a 3 sec checkerboard stimulation. Projection data (shown below) had a temporal resolution of 5 ms yielding 3200 sampling poins within the 13+3 sec stimulation period, which was repeated for 20 times. Time courses of the in total 64000 sampling points (with a second spatial projection dimension) were first normalized to mean zero and standard deviation of one, and subsequently detrended by applying a moving average filter with a width of 2x1000 time points and subtracting its results from the data.

Results:

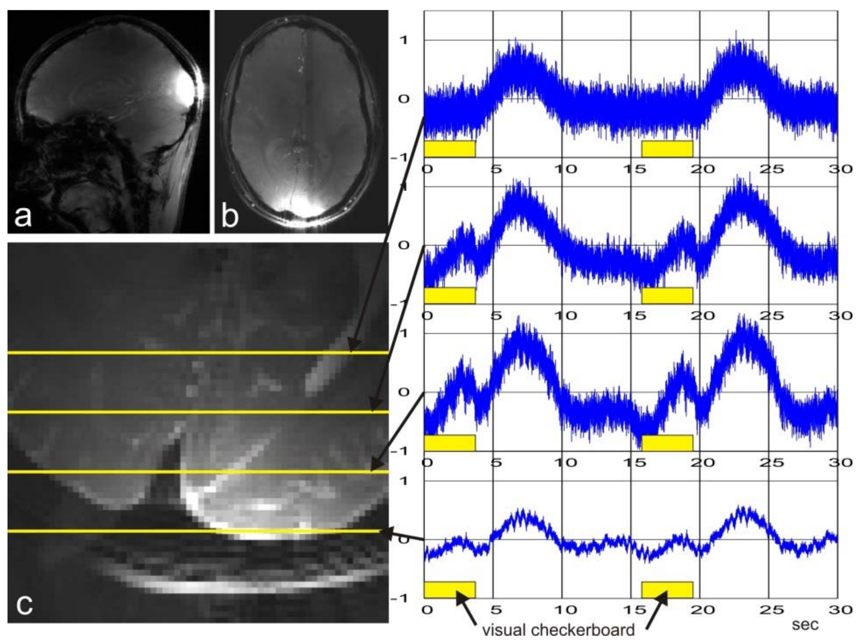

Figure a and b shows the localization of the 3 cm surface coil used for the detection of the bOVOC signal. As the surrounding 16 transceive channels were also active during this overview acquisition the entire brain is visible. Figure c represents 2D bSSFP acquisition with only the small surface coil selected. bOVOC time courses with a temporal resolution of 5 ms are shown right for different depths marked by yellow lines in Fig. c (Trial averages of 19 trials. Averaging was done over the first 30 seconds after stimulus onset of each trial.). These time courses correspond to the complex sum (projection) along left-right for increasing cortical depths. In all time courses a significant positive response is visible about 2-3 seconds after stimulus onset (and 16 sec later at 18-19 sec for the next period). Except for the deepest layer (top plot left) a further positive response is visible already about 2 sec after visual stimulus onset, which is probably a residual effect of the very strong signal component produced by heartbeat. Also, a significant increase of noise can be observed going to deeper levels due to the decreased sensitivity of the surface coil.

Discussion & Conclusion:

Measurement of functional activity using pass band bSSFP is sensitive to changes in T2*, T2 and diffusion [2, 3]. With an echo time of only 2.5 ms the T2* contribution is neglectable, suggesting a bOVOC contrast that is more related to spin echo contrast. Although the measured time courses correspond to a fairly large volume (about 4-5 cm left-right x 1 mm in read direction x 5 mm slice thickness) a high temporally resolved and reproducible signal could be detected with superior SNR compared to FLASH acquisitions.

References: [1] Hennig J, et al. NeuroImage (2007); 34:212-19. [2] Scheffler K. et. al. NMR Biomed (2001); 14, 490–496 [3] Miller K.L. MRM (2008); 60:661-673.