# Reduction of physiological noise effects in fMRI phase time series

**G. E. Hagberg[1], M. Bianciardi[2], V. Brainovich[1], and B. Maraviglia[3]**

[1]Santa Lucia Scientific Foundation, Rome, Italy, [2]LFMI, NINDS, NIH, Bethesda, MD, United States, [3]University La Sapienza, Rome, Italy

## Introduction

MRI is a phase sensitive detection system and both magnitude and phase time-series are obtained in an fMRI study. The possibility to use both image sets for the statistical evaluation of fMRI has been proposed (1-2). The raw phase values are proportional to the local voxel-averaged magnetic field and are generally dominated by Bo field inhomogeneities, that are time-dependent in the presence of physiologic and instrumental noise. Previously, it was shown that time varying noise has a greater impact on phase than magnitude images, and it was suggested that large scale fluctuations of the static magnetic are the main cause of this difference (3). Therefor the phase may be used to extract information regarding field due to respiration and heart beat instead of direct measurements (4). Here, we first characterised the noise components in the magnitude and the phase signals and then investigated the possibility of mitigating these by the use of different post-processing methods, including spatial high-pass filtering.

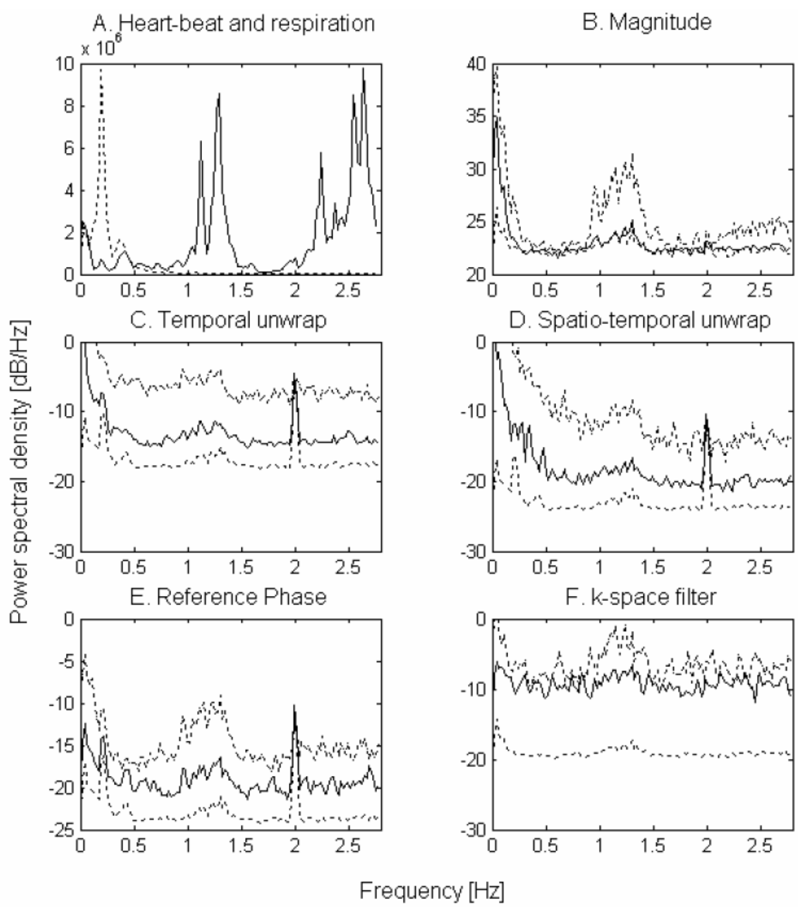
## Materials and Methods

Fourier analysis of magnitude and phase time-series was performed for CSF, grey and white matter voxels at 3T (Siemens Medical Systems) in 7 healthy subjects (26±7y) that volunteered to participate in the study, approved by the local ethics review board (ERB). They were scanned with a high-sampling fMRI protocol (gradient echo EPI, 1100 volumes, TR=180ms , TE=30 ms, slice thickness: 2.5 mm and a 50% gap between slices in plane resolution: 3x3 mm), while at rest with eyes closed in a dimly lit room. ECG and respiration belt data were acquired continuously during scanning. Motion during scan was controlled by cushioning and post-processing and one subject was excluded because of translation >0.5 mm and rotation> 0.5º. Tissue classification was obtained by segmentation of anatomical T1-weighted images in SPM2, coregistered to the EPI scans. The phase data was post-processed by four methods: C) temporal unwrap only, D) spatial unwrap (5) and temporal unwrap, E) the reference phase method (6) and temporal unwrap F) spatial high pass filtering achieved by a homodyne k-space Hamming (FWHM: 3.5 pixels) filter. Time-series were extracted and averaged across voxels prior to Fourier analysis.

## Results

Fourier analysis of ECG and respiration belt data and their relation to the MRI signal in magnitude and phase, for different post-processing methods were evaluated. In the figure results from a subject with respiration data (A. dotted line) and heart-beat (A. solid line) well localized in frequency space are shown. The prominent respiration induced variations centred at 0.18 Hz can be noted, while the first and second harmonics of the heart-beat occur around 1.2 and 2.4 Hz, respectively.

Results of Fourier analysis of the fMRI time series are shown for gray matter (solid line), white matter (dotted line), and CSF (dashed line) voxels. For the magnitude signal (B.) respiration and instrumental fluctuations cause the typical 1/f decrement at low frequencies, instabilities are also prominent in the CSF around the first cardiac harmonic. For the phase (C-F), the effect of physiologic and instrumental variations depended on the post-processing method, and the flattest profile was obtained after k-space filtering. Note the strong interference of system vibrations (C-D) caused by the Helium pump at 2 Hz that caused large scale variations of the static magnetic field and were removed by method F.




## Discussion and Conclusion

In agreement with a previous work (3) we found that the effect of physiologic fluctuations are generally more pronounced in phase than in magnitude images. Moreover we found that this is also true for temporal instabilities caused by system vibrations. The kind of post-processing method adopted will affect phase stability. Extraction of information regarding respiration and heart beat could be performed in WM voxels after application of the reference phase method. On the other hand, if the phase is to be used for statistical analysis, large-scale Bo fluctuations should be suppressed by spatial high pass filtering. Fluctuations associated with cardiac function mainly confined to vessels and the ventricles, will be unaffected by the filtering. In future studies other types of spatial filters, like for instance filters based on spline functions that have a better profile in terms of selection of spatial components, and comparison with regression techniques (RETROICOR, (7) will be considered.

## References

(1) Logan, Rowe. Neuroimage 2004;23:1078; (2) Lee et al.,. MRM 2007;57:905; (3) Hagberg et al., MRI 2008; 26:1026; (4) Hutton et al., Proc ISMRM 2008; 2458; (5) Jenkinson MRM 2003;49:193; (6) Tomasi, Caparelli. JCBF 2007; 27:33; (7) Glover et al., MRM 2000; 44:162