VibroEEG: Improved EEG Source Reconstruction By Combined Acoustic-Electric Imaging

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Summary

- VibroEEG improves significantly the source localization accuracy of EEG .
- Excitation of the vibrational modes of the cerebral cortex (CC) displaces periodically the sources of the neural electrical activity.
- The sources residing on the maxima of the induced modes will be maximally weighted in the corresponding spectral components of the broadband signals measured on the scalp electrodes.
- The intrinsic geometry of the cerebral cortex is utilized to separate sources of neural activity lying close in the sense of the Euclidean distance.

Vibrations of the cerebral cortex

- The convoluted CC forms a spring-like structure with multiple resonant frequencies
- The vibrational modes are determined mostly by the internal geometry of the cerebral cortex
- The pattern of the induced vibration can be monitored similar to MR-elastography.

The numerical experiment

- The forward EEG problem was calculated by boundary element method (BEM).
- Mechanical parameters : Youngs modulus 0.497 MPa, Poissons ratio 0.48 and density 1.14 g/cm3.
- Finite element (FE) analysis of the vibrational modes of the CC was performed using Dassault Abaqus v6.1

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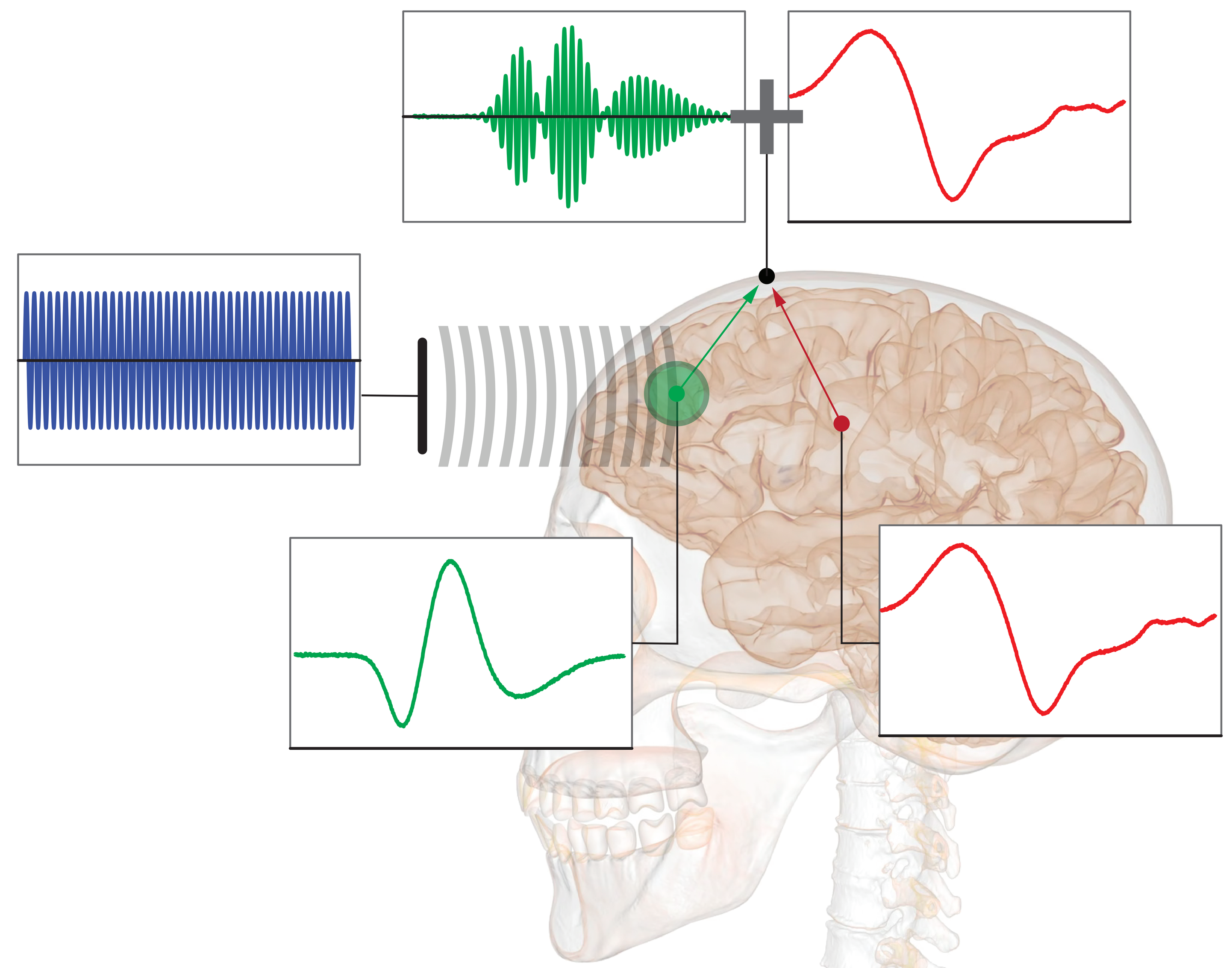
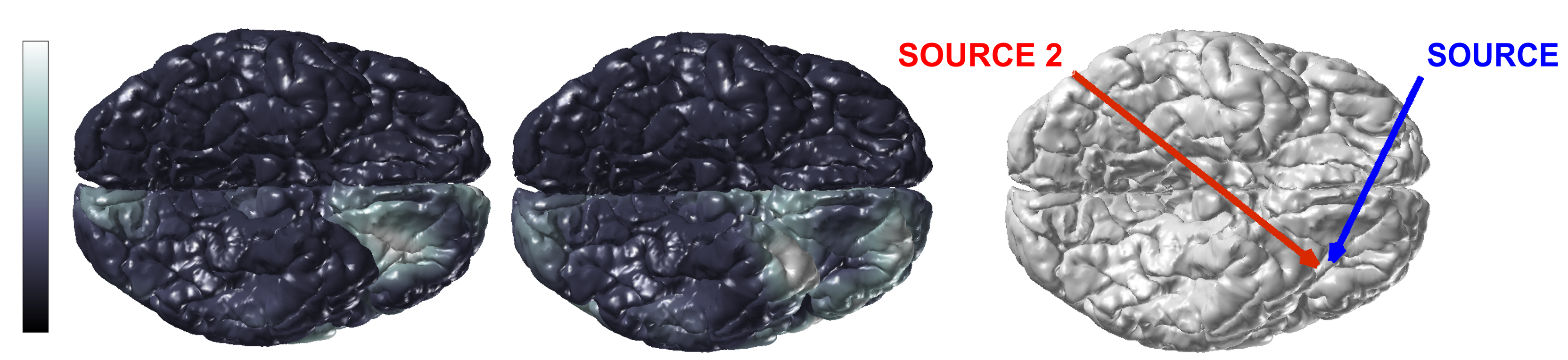


1. The brain is insonified by an ultrasound source inducing localized high-frequency vibrations. 2. The electric activity of the vibrating region is amplitude-modulated and projected onto a scalp electrode. 3. The electric activities of surrounding regions undergo no modulation and are projected onto the scalp electrode in the base band. 4. Demodulation of the scalp potential separates the signal from the localized source.



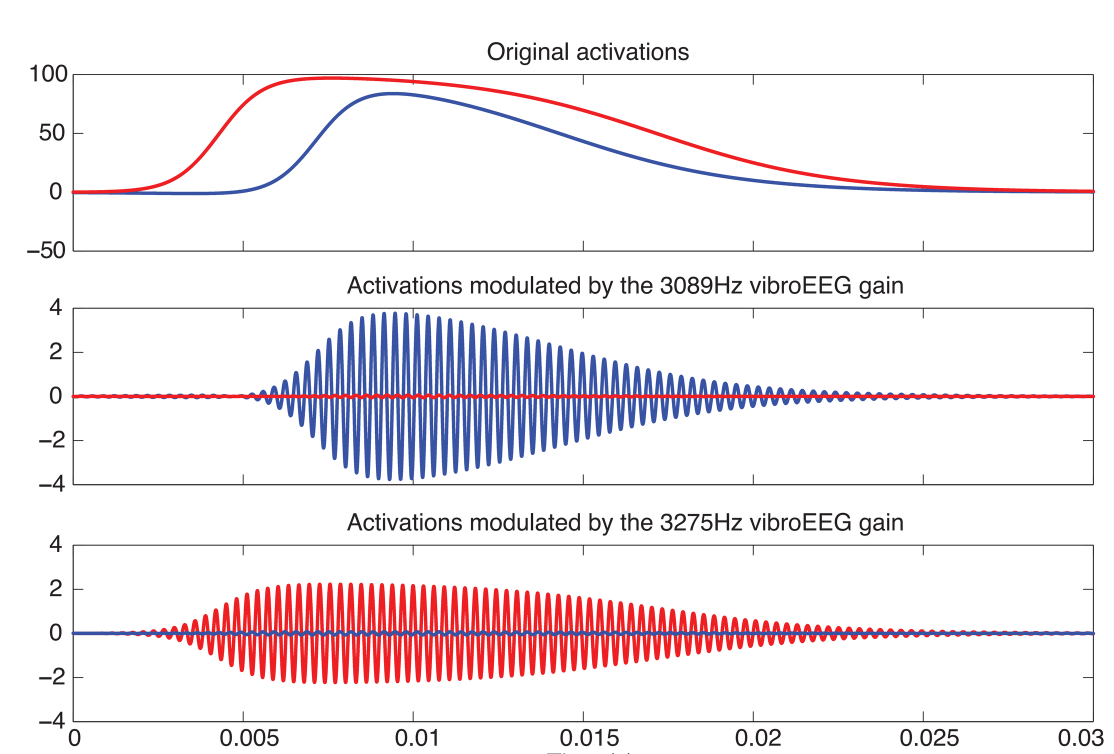


Figure 1: First row: vibrational mode of the CC for frequencies 3089Hz (left) and 3275Hz (middle), and the locations of the simulated ources on the CC (right). Second row: simulated activations of the sources (in nAm). Third and fourth rows: vibroEEG-moduldated source voltages (in microvolts) recorded at the 'Fp1' electrode for both frequencies

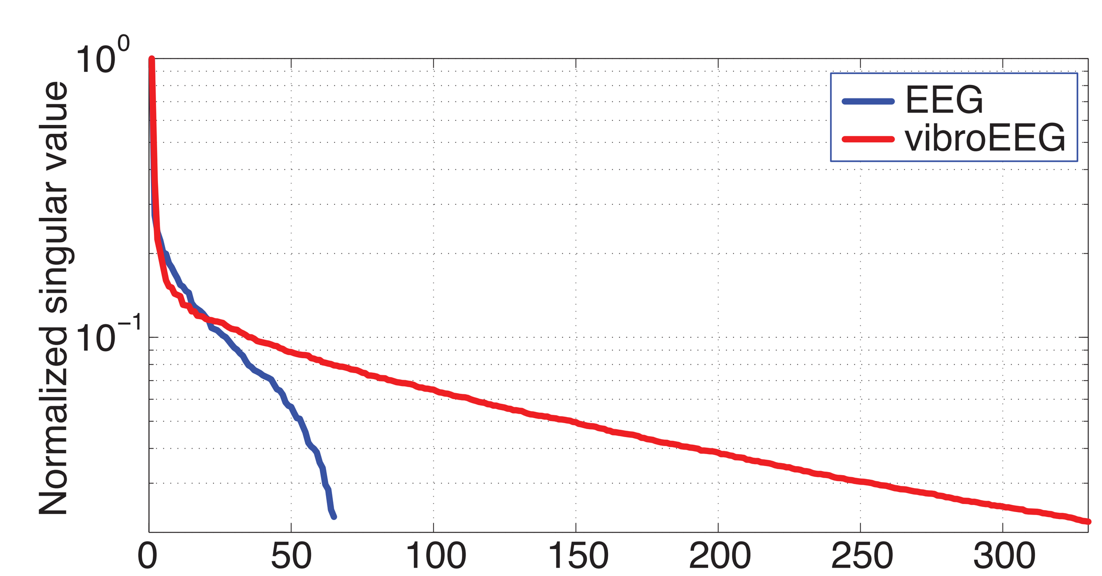


Figure 2: Singular values corresponding to the vibroEEG gain matrix (red) based on 400 modes and sampled at 65 points of the $10-20$ system vs the singular values of the corresponding EEG gain matrix (blue).

Results

- VibroEEG enriches the EEG gain matrix with new independent measurements improving its rank
- Close deep sources indistinguishable in EEG are separated in vibroEEG due to high geodesic distance between them.

Conclusion

- We have presented vibroEEG-a new combined acoustic-electric modality for brain imaging.
- When the modes are excited locally using phased arrays the neural activity can be probed at any cortical location.
- Nonlocal excitation still increases significantly the rank of the EEG gain matrix
- It seems possible to employ the vibration of the brain tissue due to blood/CSF pulsation acquiring averaged EEG signal with ECG gating.

References

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