# High-density EEG: Info-theoretic limits & algorithms

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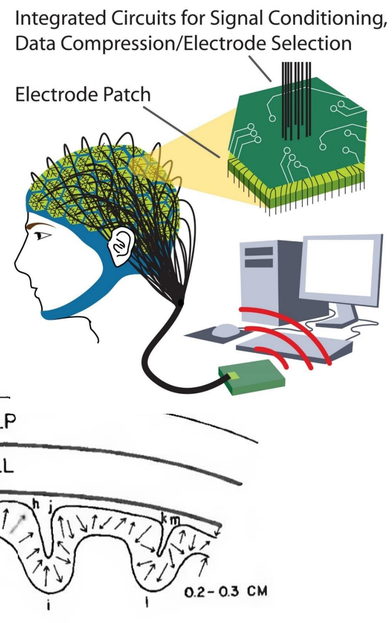
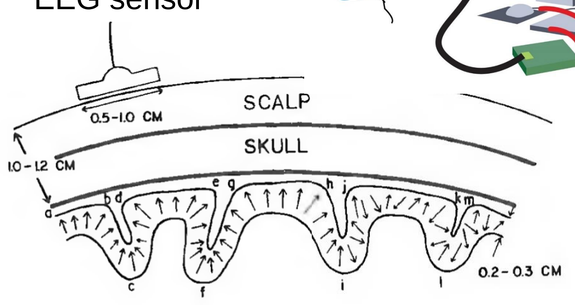
## EEG Sensing

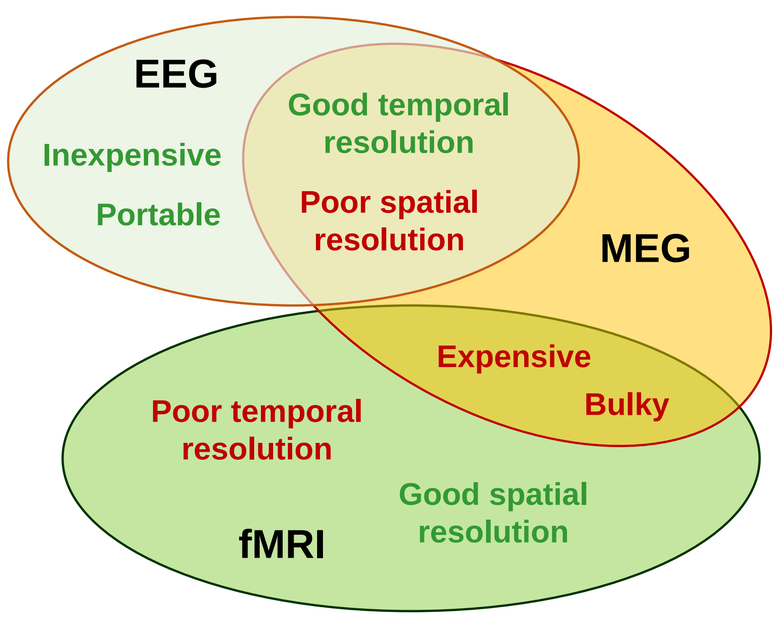
Current dipoles produce electric potentials on the scalp

Nunez, Srinivasan "Electric Fields of the Brain", Fig. 2-3



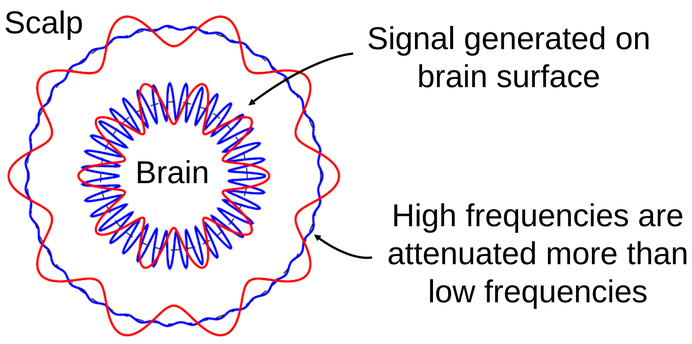

## EEG vs MEG vs fMRI



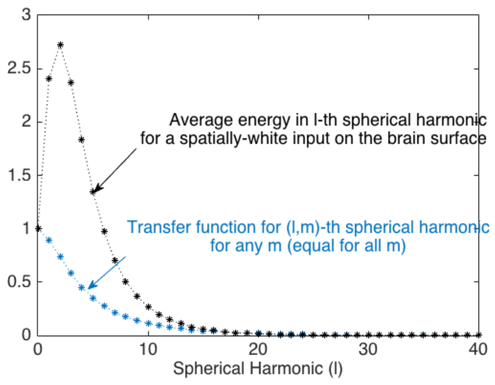

EEG would be unequivocally the best modality, if its spatial resolution could be improved!

## Spatial low-pass filtering

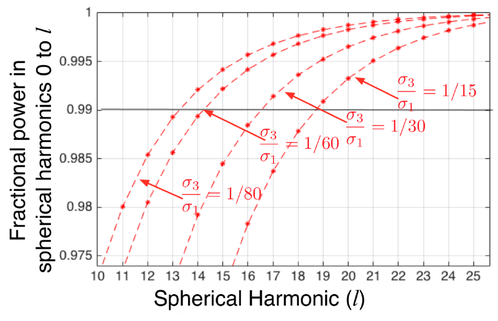
The skull and scalp act like a low-pass filter




We can compute the spatial-frequency bandwidth, and hence the Nyquist rate, for sensing the scalp potential




Find bandwidth within which 99% of signal energy is contained (Grover, Venkatesh, '17)

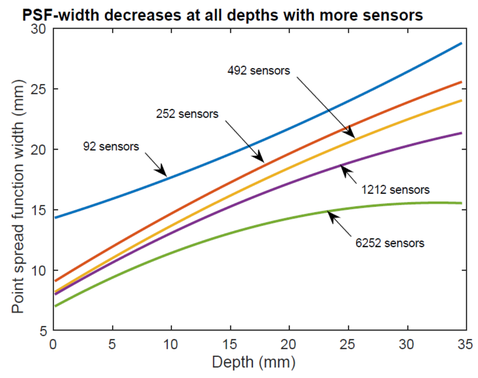



**Nyquist rate varies with skull conductivity; can be >256 electrodes!**

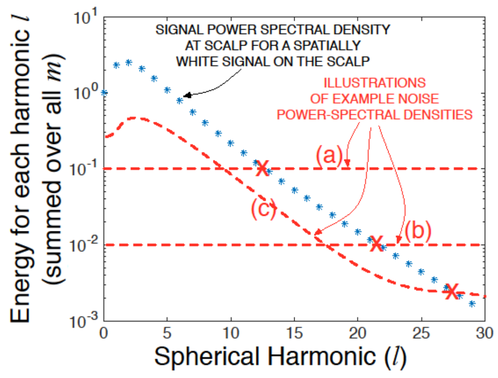
## Sensor density for imaging

**The sensor density needed for reconstructing the scalp potential is different from that needed to recover the brain signal!**

Simulation results (Grover et. al., '15)




**Without noise, source localization accuracy improves with more electrodes, even beyond Nyquist rate!**




We need to understand where the noise floor lies, and to what extent we can invert the low-pass filter

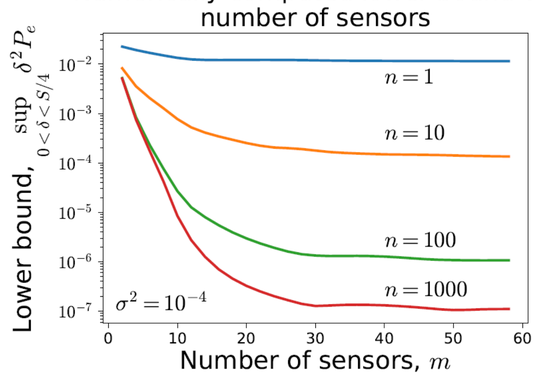
## Fundamental Limits

**What is the best attainable source localization resolution, for a given number of electrodes?**

**Minimax bounds for localizing a point source**

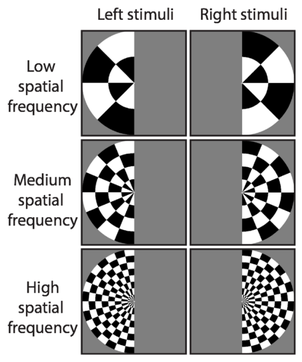
(Venkatesh and Grover, *ISIT* '17)

Numerically computed lower bound vs. number of sensors

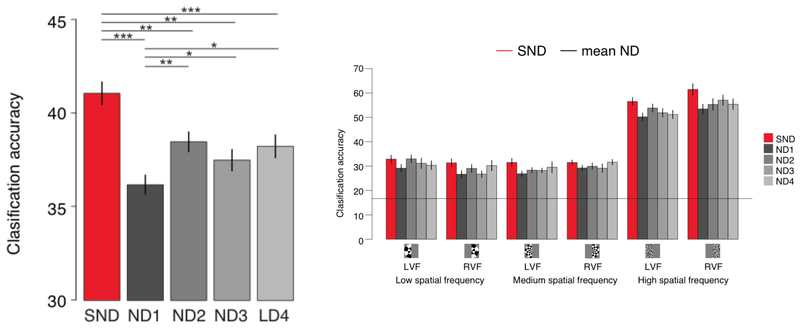



## UHD-EEG proof of concept

Experiments based on self instrumented system with **~1cm inter-electrode distance**.



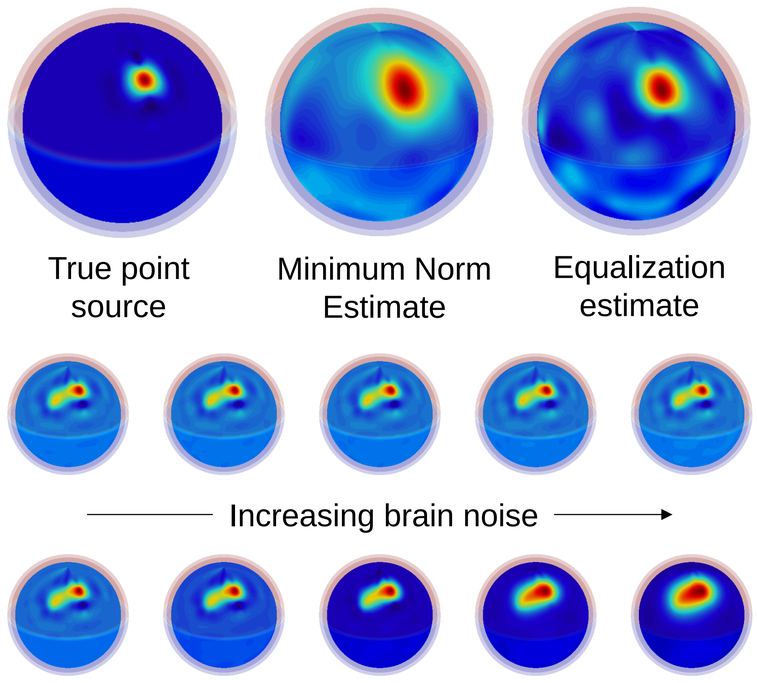

Mean classification accuracy of visual tasks is higher when using high-density EEG systems instead of low-density EEG systems.



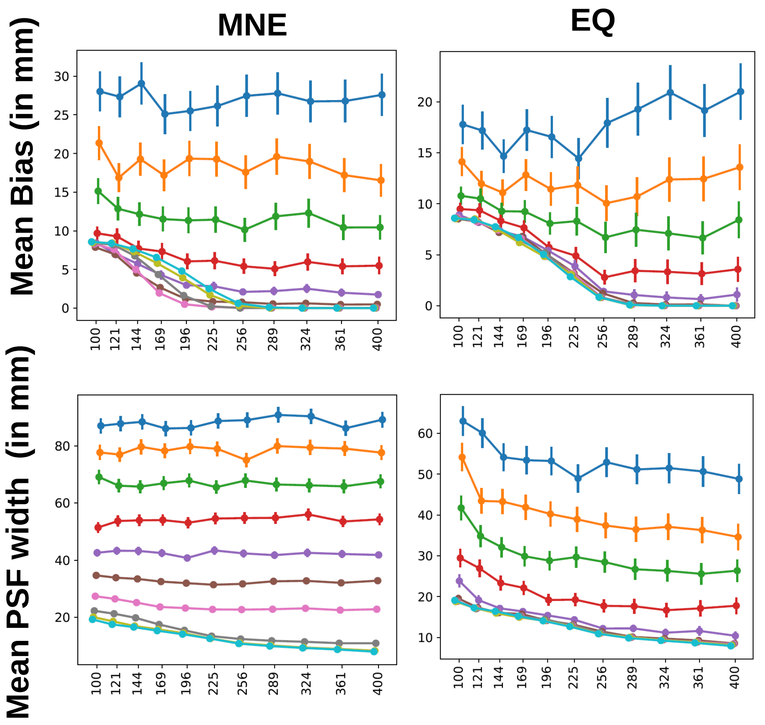

The classification accuracy gain when using HD-EEG is ***more*** when classifying the *high spatial frequency stimuli* in the left and right visual fields.

## Source Localization

Reconstructions averaged over several trials




Equalization-based algorithms are also more **robust** in the presence of **higher brain noise**

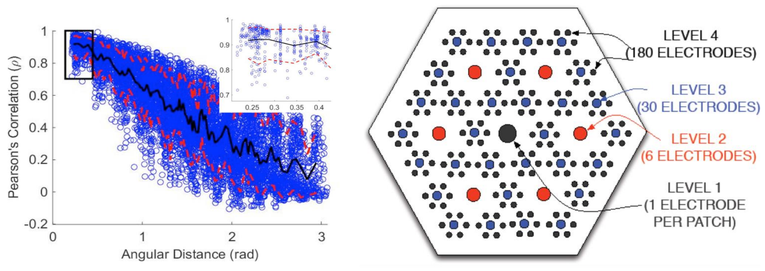



Equalization-based algorithms achieve a lower bias and lower widths of the Point Spread Function (PSF) when recovering the location of a single dipole.
*Equalization takes advantage of greater sensor density.*

## Hierarchical referencing

Information-theoretic strategy to exploit spatial correlations to reduce circuit volume and power while obtaining high-resolution signal

(Grover and Venkatesh, *Proc. IEEE* '17)




### Acknowledgements

We acknowledge support from NSF CCF-1350314, CMU BrainHUB, and SONIC, one of the six SRC STARnet centers, sponsored by MARCO and DARPA. Praveen Venkatesh is partially supported by a Henry L. Hillman Presidential Fellowship and a Dowd Fellowship from the College of Engineering at CMU. The authors would like to thank Philip and Marsha Dowd for their support and encouragement.

### References

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