Signal Processing for Medical Applications –

Frequency Domain Analyses

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LORETA – Low resolution electromagnetic tomography - 3

- Inorder to find a unique solution for the 3-dimensional distribution among the infinite set of different possible solutions, the method assumes that neighboring neurons are simultaneously and synchronously active.

- The 3D inverse solution derived here corresponds to the „smoothest“ current density capable of explaining the measured data.

- For noise-free instantaneous mesurements, the discrete problem is:

$$\min_j \left\| BWJ \right\|^2 \text{, under constraint: } \phi = K J \qquad (9.1)$$

where ϕ is a N-vector comprised of measurements (EEG and /or MEG); $J = \left(j_1^T, j_2^T, \ldots j_M^T\right)^T$ is a $3M$-vector comprised of the current densities j (3-vector) at M points with known locations within the brain volume.

- In which K is a transfer $N \cdot 3M$- matrix with the α-th row $\left(K_{\alpha 1}^T, K_{\alpha 2}^T \ldots, K_{\alpha M}^T\right)$, where K is the lead field (3-vector), which can be either electric or magnetic depending on the nature of the α-th measurement.

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- In equation (9.1) W is a diagonal $3M.3M$ - matrix with $w_{ii} = \|K_i\|$, where K_i is the i-th column of K; and B is the discrete Laplacian operator $3M.3M$- matrix.

- Specifically, let $Z = WJ = (z_1^T, z_2^T \ldots, z_M^T)^T$ where z (3-vector) is the weighted current density, and let $BZ = (I_1^T, I_2^T \ldots, I_M^T)^T$ be the corresponding discrete Laplacian.

- Then for a regular cubic grid of points (with minimum inter-point distance d) confined to the brian volume, the matrix B is such that:

$$I_i = \frac{1}{d^2}\left(6z_i - \sum_p z_p\right) \qquad (9.2)$$

$\forall p$ under constraint : $\|r_i - r_p\| = d$

where r_i denotes the position vector of the i-th grid point. With this defintion, matrix B is symmetric, non-singular and sparse.

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- For a dense grid $(M \geq N)$, if W is non-singular, the unique solution to equation (9.1) can be shown to be: $\hat{J} = T\phi$

$$T = \left(WB^T BW\right)^{-1} \times \left\{K\left(WB^T BW\right)^{-1} K^T\right\} \qquad (9.3)$$

- The estimated 3D distribution of the electrically active neural tissue is given by $\hat{J}$.

- The discrete nature of the formulation from (9.1)-(9.3) was chosen for practical reasons, although in principle, the continous version $(M \to \infty)$ could have been treated as well.

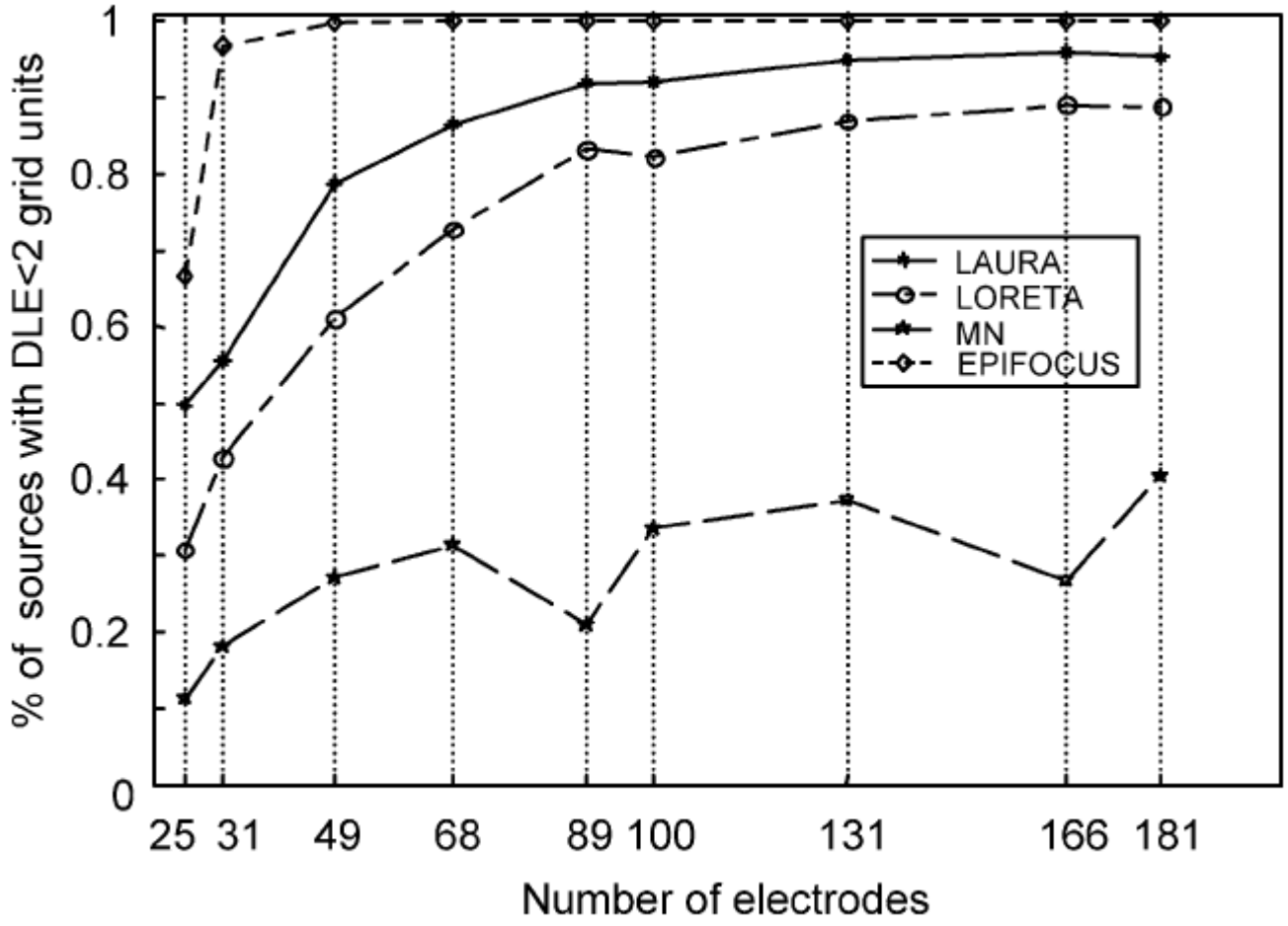
- The inverse solution is presented for electric and magnetic measurements, performed either separately or simultaneously.

- Furthermore, the solution can be applied to any physical model, with arbitary geometry and conductivity properties, as long as the appropriate solutions for the lead field matrix (matrix K) are available.

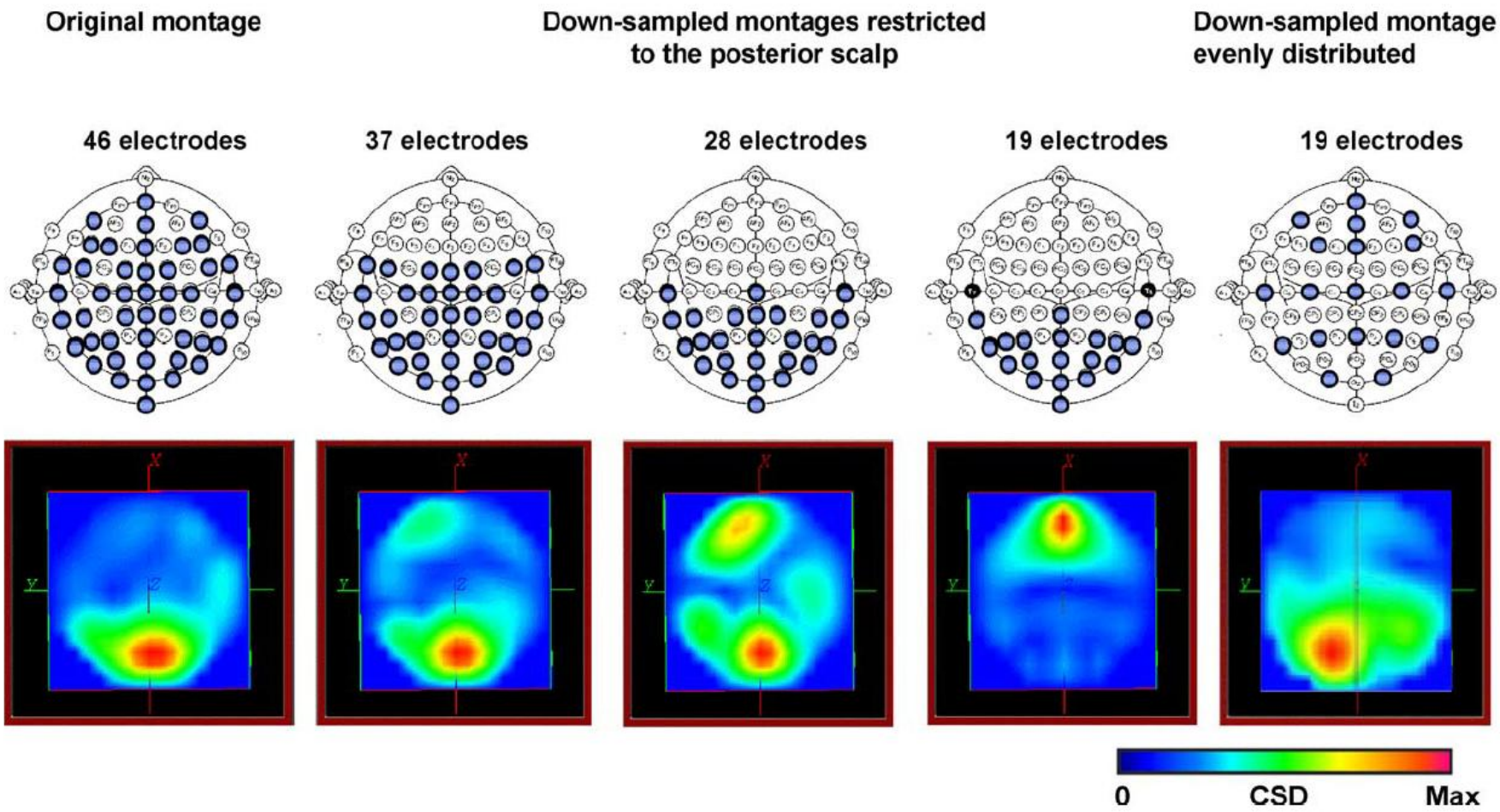
Dependance Parameters

- Number and positioning of the electrodes
  - Effect of number of electrodes on source localization
  - The choice of reference
  - Electrode positions and interpolation algorithms

Effect of number of electrodes on source localization



Effects of the electrode distribution



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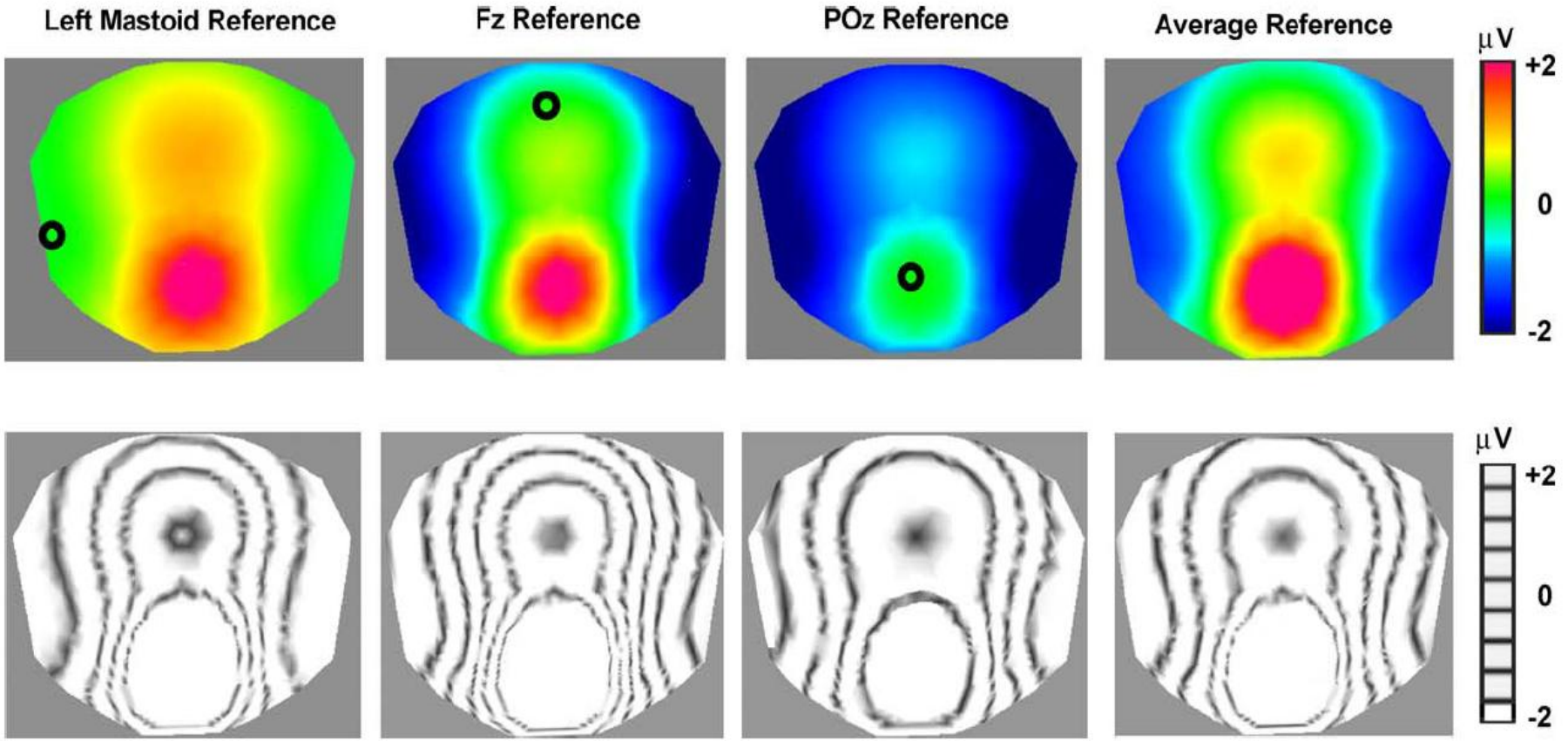
The choice of reference



Essential constraints for detecting deep sources

- Dependance of Signal to noise ratio (SNR
- Distributed sources on the cortical level
- Number of channels

Simulation I

- Required data length for cortical and sub-cortical level sources
- Required SNR for source localization

Simulation II

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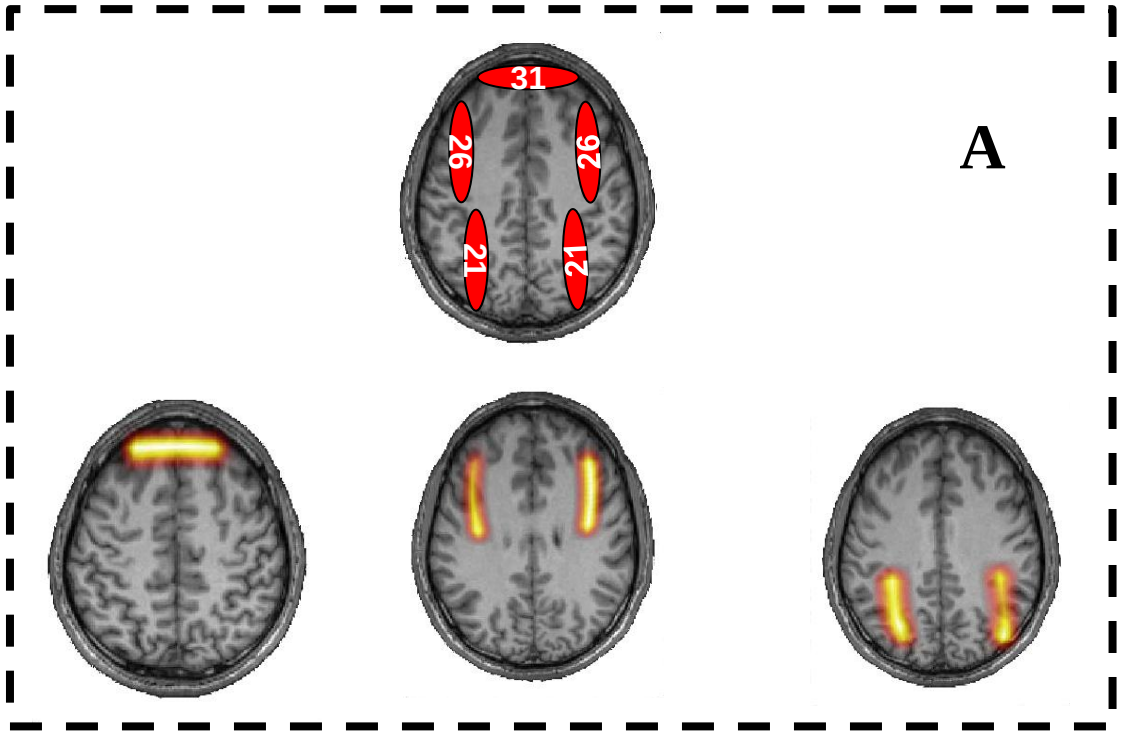
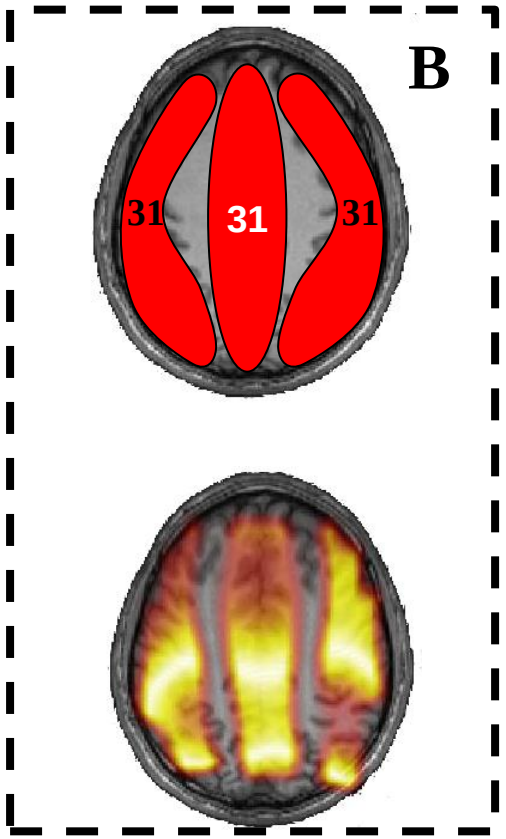
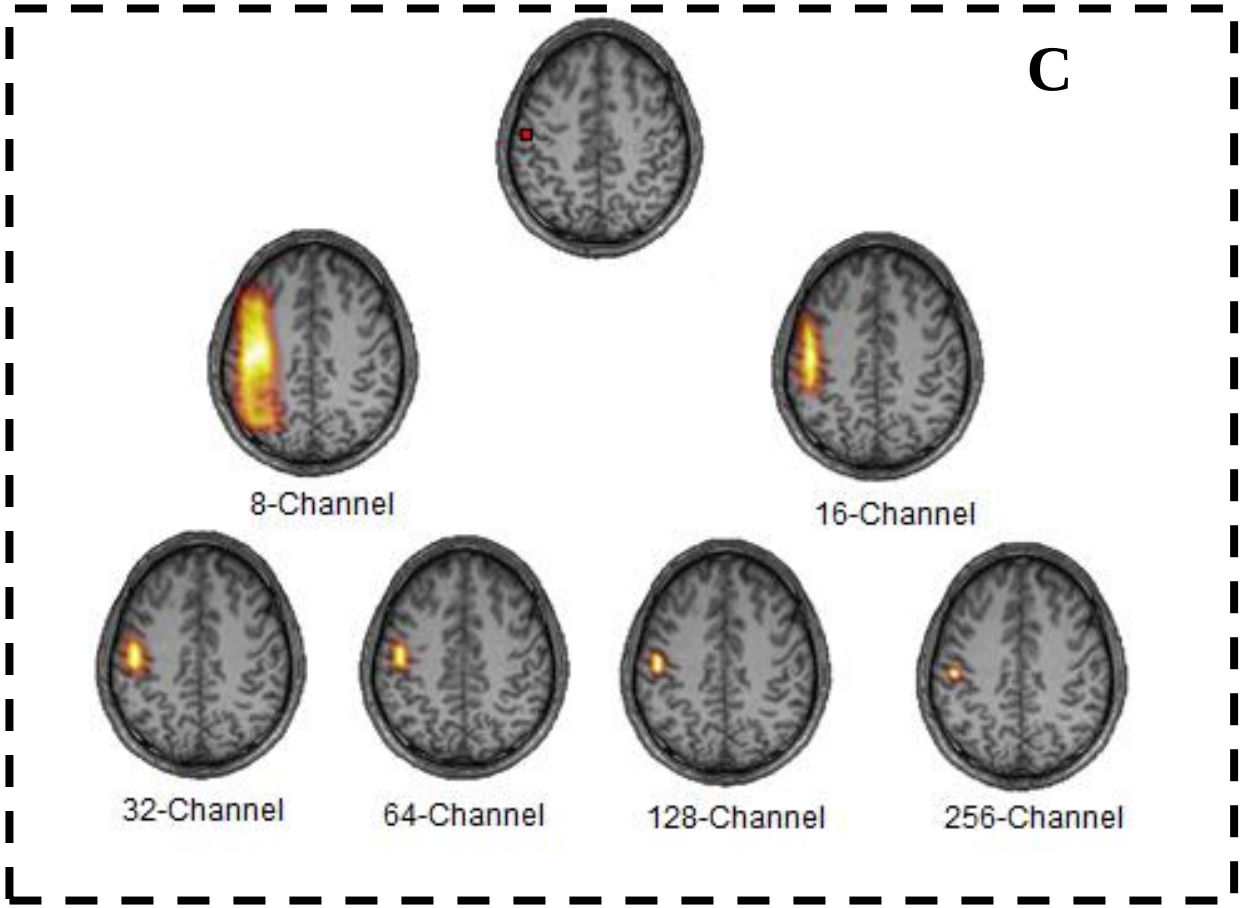
Simulation I





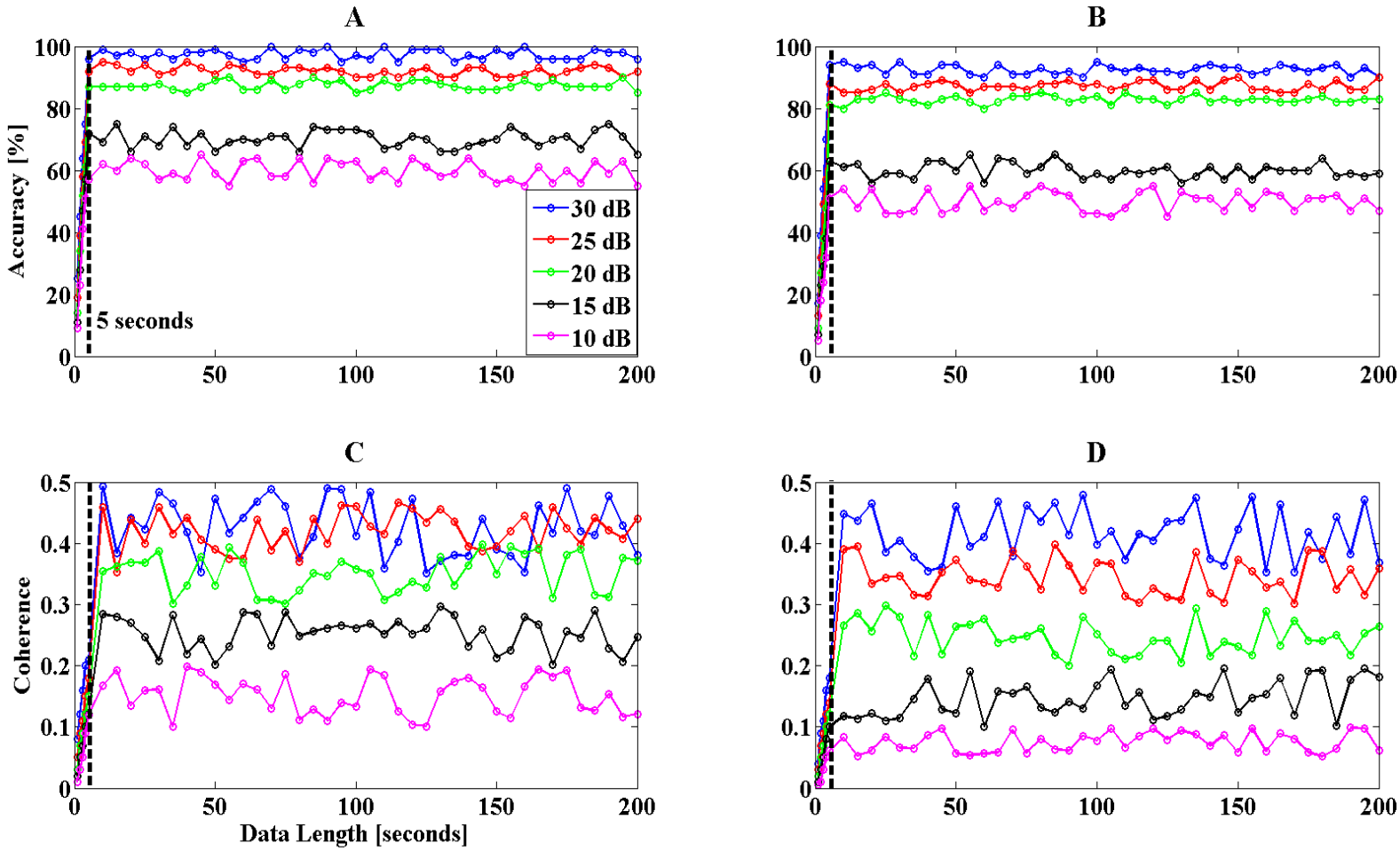
Simulation I



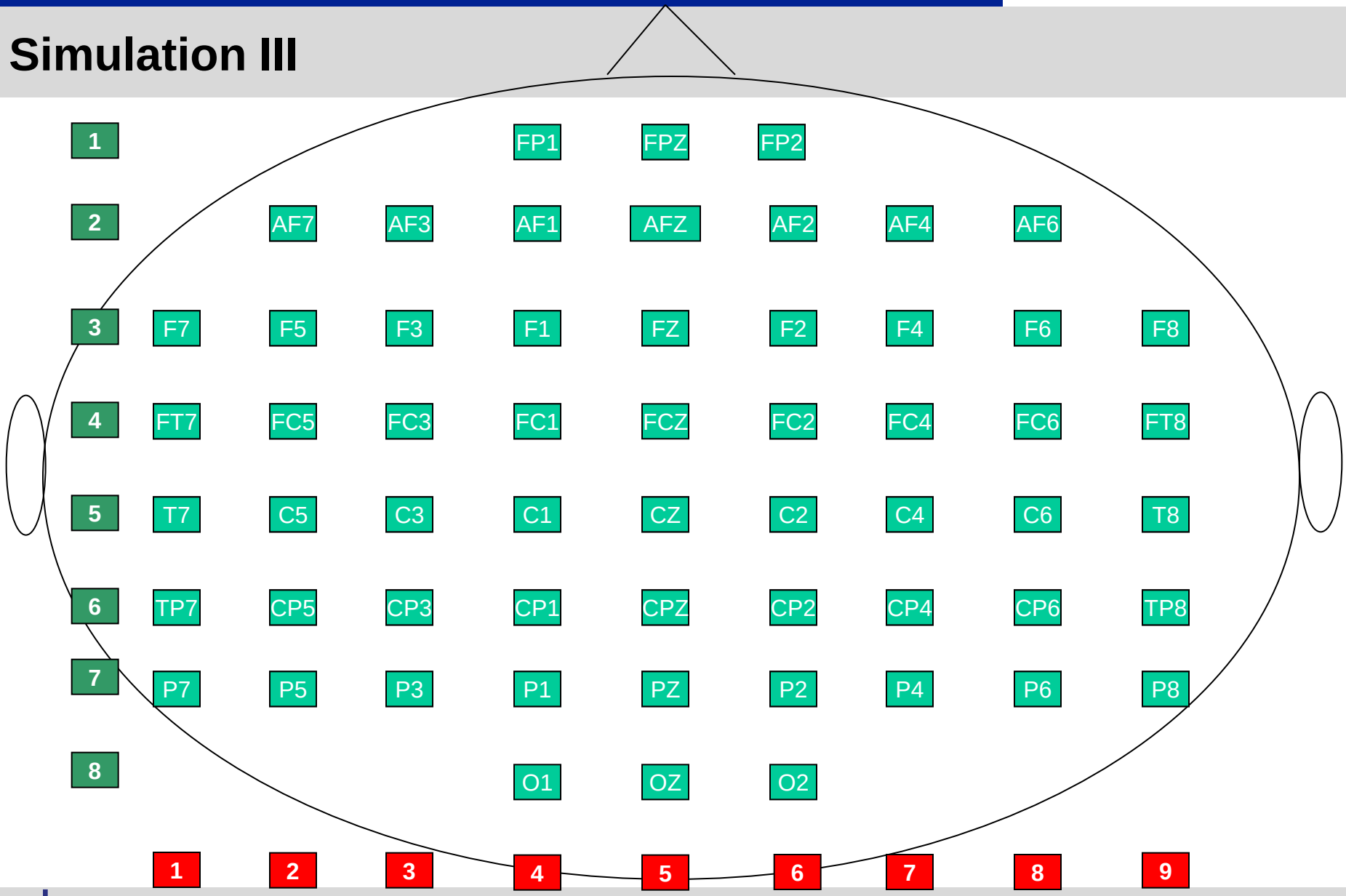
Simulation II

Contralateral Motor Cortex

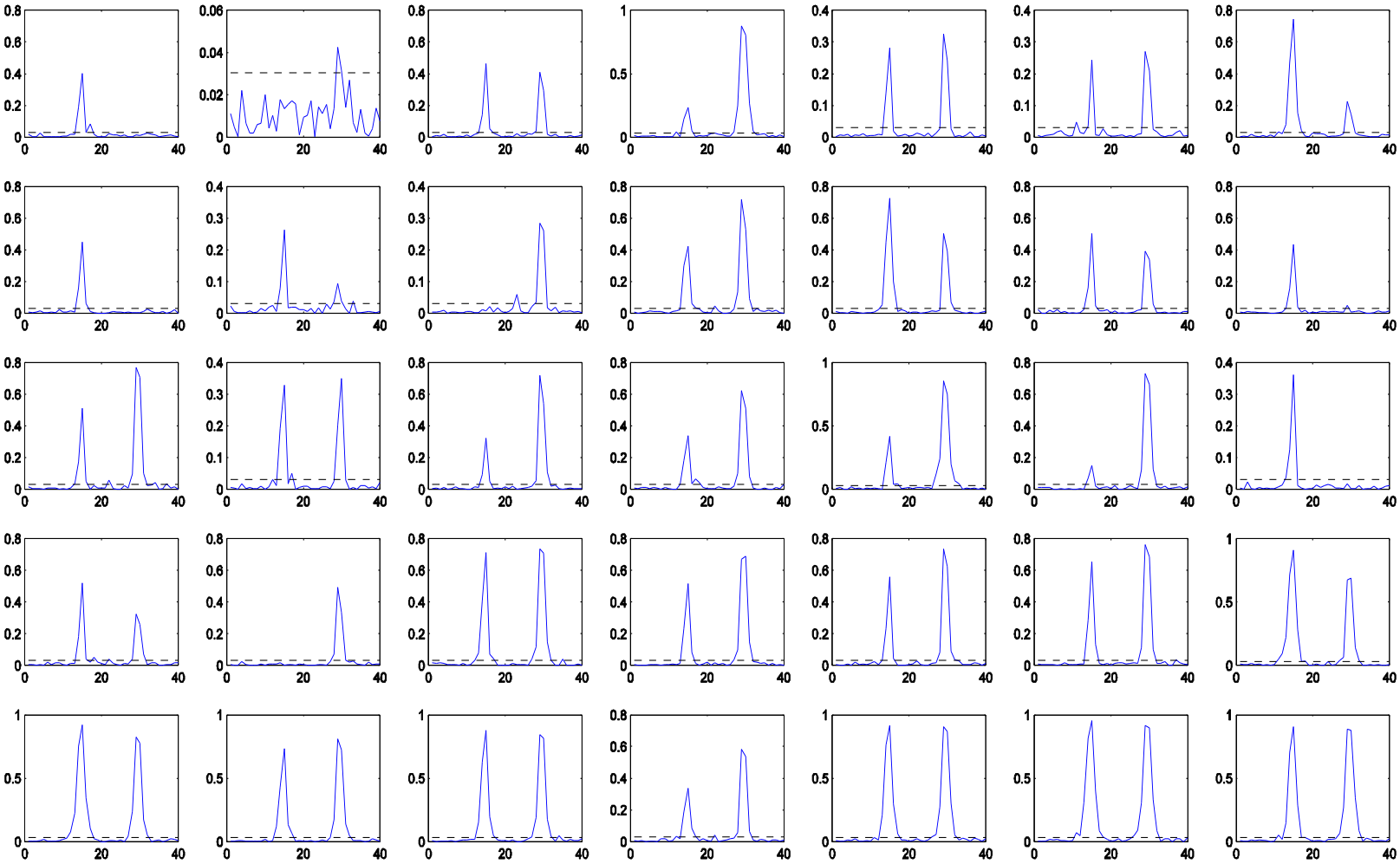
Thalamus



Simulation III



Simulation III



Simulation III

Step 1 – Systematic shuffling of electrodes on the scalp

Columns i) 1 ↔ 2, 3 ↔ 4, 6 ↔ 7, 8 ↔ 9 → No changes in the cortical and sub-cortical sources

ii) 1 ↔ 3, 2 ↔ 4, 6 ↔ 8, 7 ↔ 9 → Cortical Changes and no subcortical changes

Rows iii) 2 ↔ 3, 4 ↔ 5, 6 ↔ 7 → No changes in the cortical and sub-cortical sources

Step 2 – Random Shuffling of electrodes on the scalp

i) Adjacent electrode → No changes in the cortical and sub-cortical sources

ii) one – off electrodes → No changes in the cortical and sub-cortical sources

ii) two – off electrodes → Changes in the cortical but no significant sub-cortical sources

iii) Three-off electrodes → Changes in the cortical but no significant sub-cortical sources

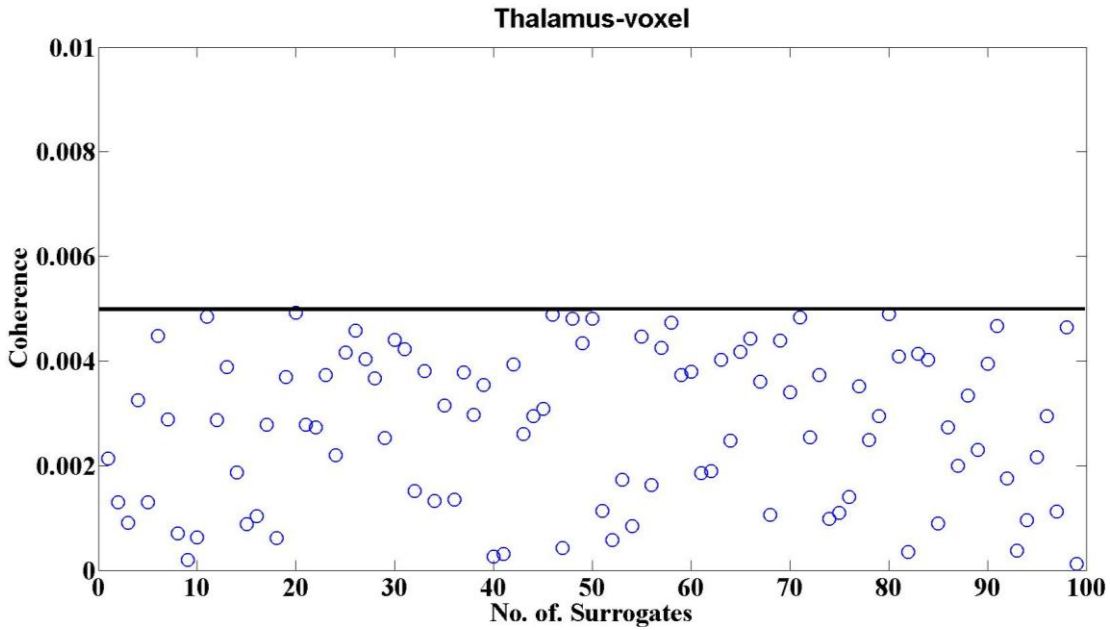
Simulation III

Step 3 – Surrogate shuffling of electrodes in the scalp

i) 99 times random two –off shuffling and getting the significance value for the deep sources – e.g: Thalamus

ii) Thalamus source signal voxel- for the coherence in the frequency 15 Hz.

iii) Maximum value of the surrogates will be taken as the significance level



Topics of Presentation

Time Slots	Dates of Presentation
9:15 – 9:30	18-01-2013
9:35 – 9:50	25-01-2013
9:55 – 10:10	01-02-2013
10:15 – 10:30	
9:15 – 9:30	
9:35 – 9:50	
9:55 – 10:10	08-02-2013
10:15 – 10:30	
13:30 – 13:45	CSR I
13:50 – 14:05	