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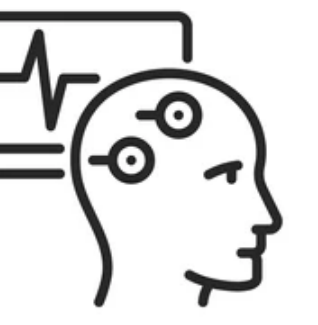
SOS-MUSIC, a subspace approach for EEG source imaging promoting Sparsity On active Sources



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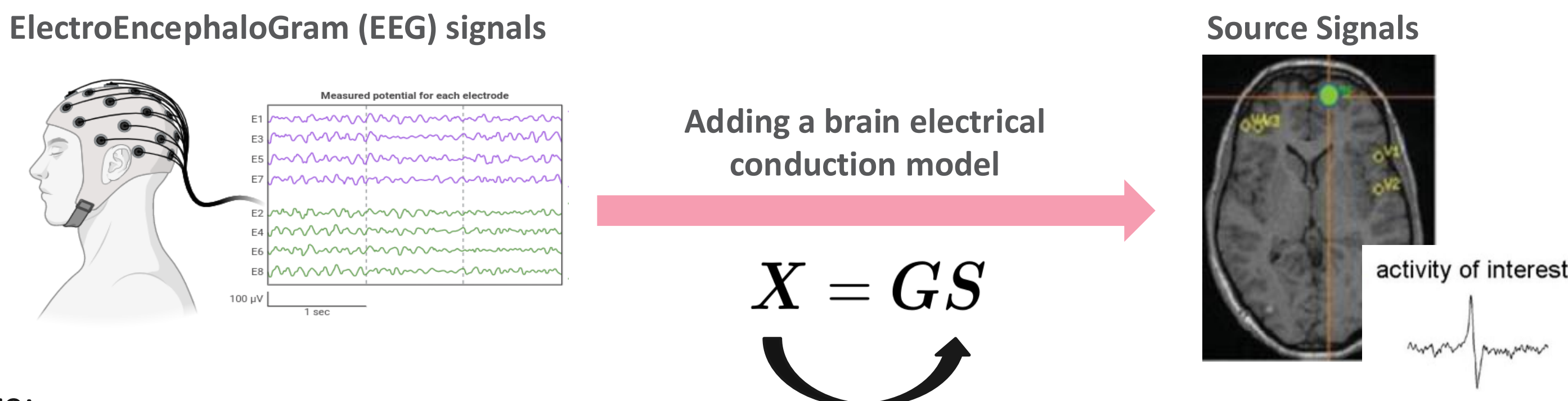


INTRODUCTION

Context

- Localizing brain epileptic sources for patients with **treatment-resistant** epilepsy (30% of cases).

Solving the EEG inverse problem



Where:

- X : the EEG data matrix of size $(N \times T)$
 - S : the signal matrix of size $(D \times T)$
 - G : the lead field matrix of size $(N \times D)$
- with
- N : The number of EEG electrodes
 - D : The number of source dipoles
 - T : The number of time samples

MUSIC (Multiple Signal Classification)[1]: a subspace approach

- Decomposition of the observed signal into **signal** and **noise orthogonal** subspaces.

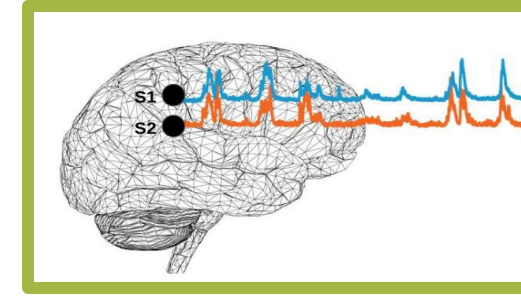
• **2-MUSIC metric**:
$$\Upsilon(g(\theta)) = \frac{g(\theta)^T E_\nu E_\nu^T g(\theta)}{g(\theta)^T g(\theta)}$$

Where:

- $g(\theta)$ is the column of G of the θ source;
- E_ν : the noise subspace;

- The θ minimizers of Υ give the epileptic sources.

METHODS



OBJECTIVE

Improve the localization of highly correlated brain sources

ASSUMPTION: SPARSITY OF THE EPILEPTIC SOURCES
There are few sources involved in the epileptic network

- A **sparse vector** v whose non-zero components select and weight the column vectors of G corresponding to the epileptic dipoles.

Our regularization problem

$$\min_{v \in \mathbb{R}^P} \Upsilon(Gv) + \lambda \|v\|_1$$

- Minimization of Υ for searching the epileptic sources.
- L1 norm** enforcing **sparsity** of the epileptic sources.
- Optimization solver : Iterative Soft Thresholding Algorithm [2].

SIMULATION SETUP

Data

- 257 channels EEG data generated from a realistic model [3].
- A three-shell realistic **head model**.
- A **source space** of 8000 dipoles corresponding to the triangles of the cortical surface mesh with orientations perpendicular to the cortical surface.

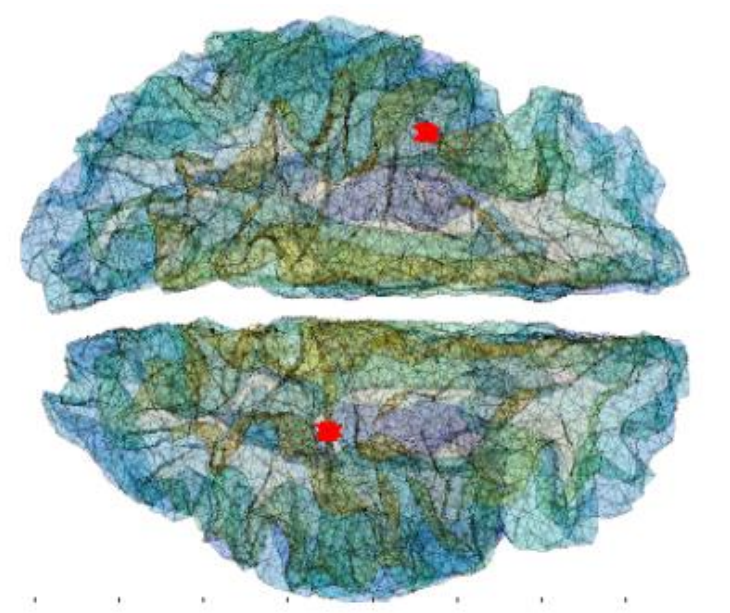


Fig 5. Frontal view of the brain mesh

Performance criteria

- Euclidean distance** between the estimate source position ($\hat{\theta}_i$) and the true position (θ_i):

$$d_{\theta_i}^{\text{Euc}} = \|\hat{\theta}_i - \theta_i\|_2$$

Scenarios

- Influence of the Signal-to-Noise-Ratio (SNR) and deepness on source localization of one epileptic source: **1a.** a surface source and in the case of **1b.** a deep source.
- Influence of the signal correlation on source localization of two synchronous epileptic sources with an SNR value of -5 dB.

RESULTS

Scenario 1.a

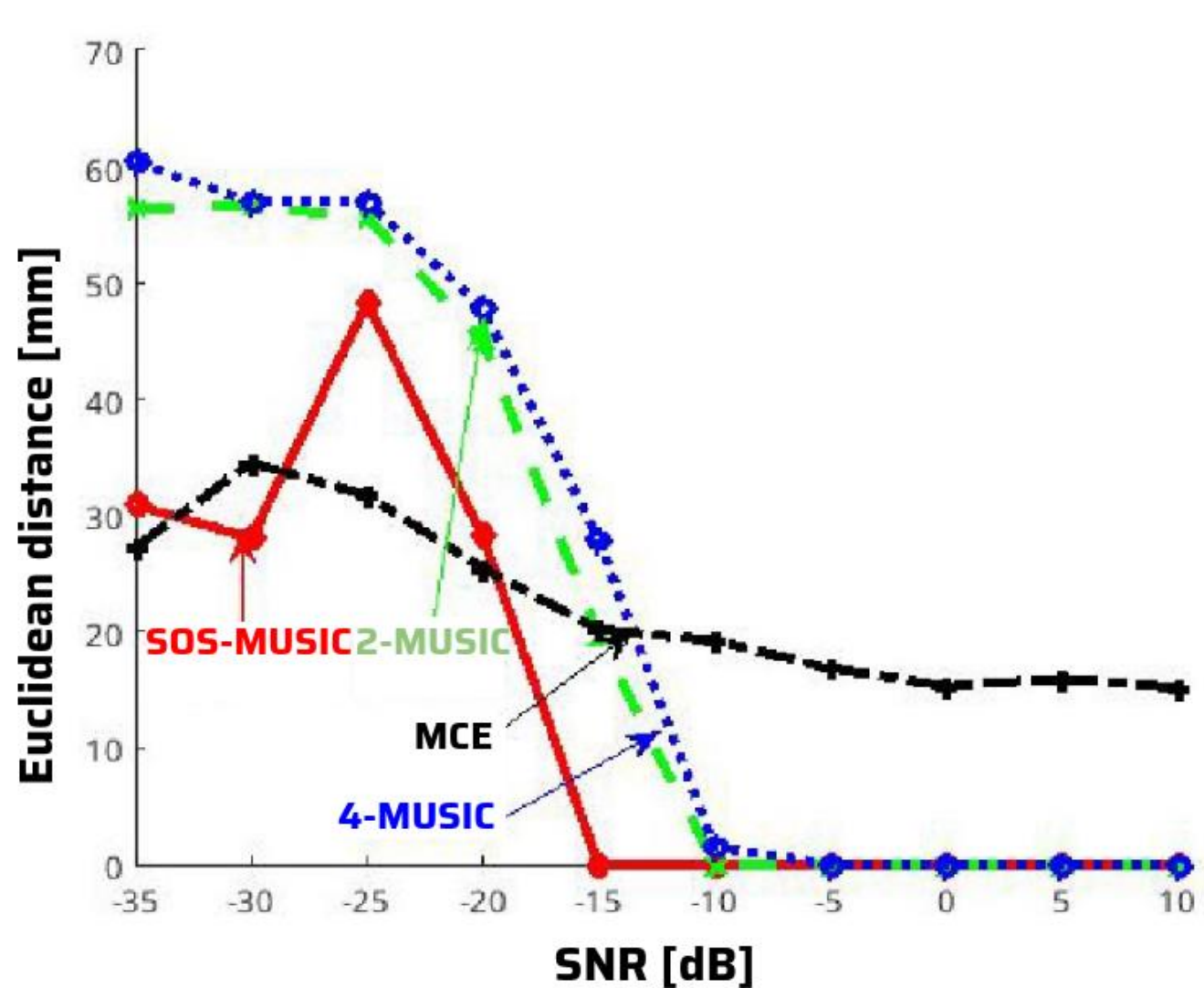


Fig 1. Localization error in mm for one surface epileptic source

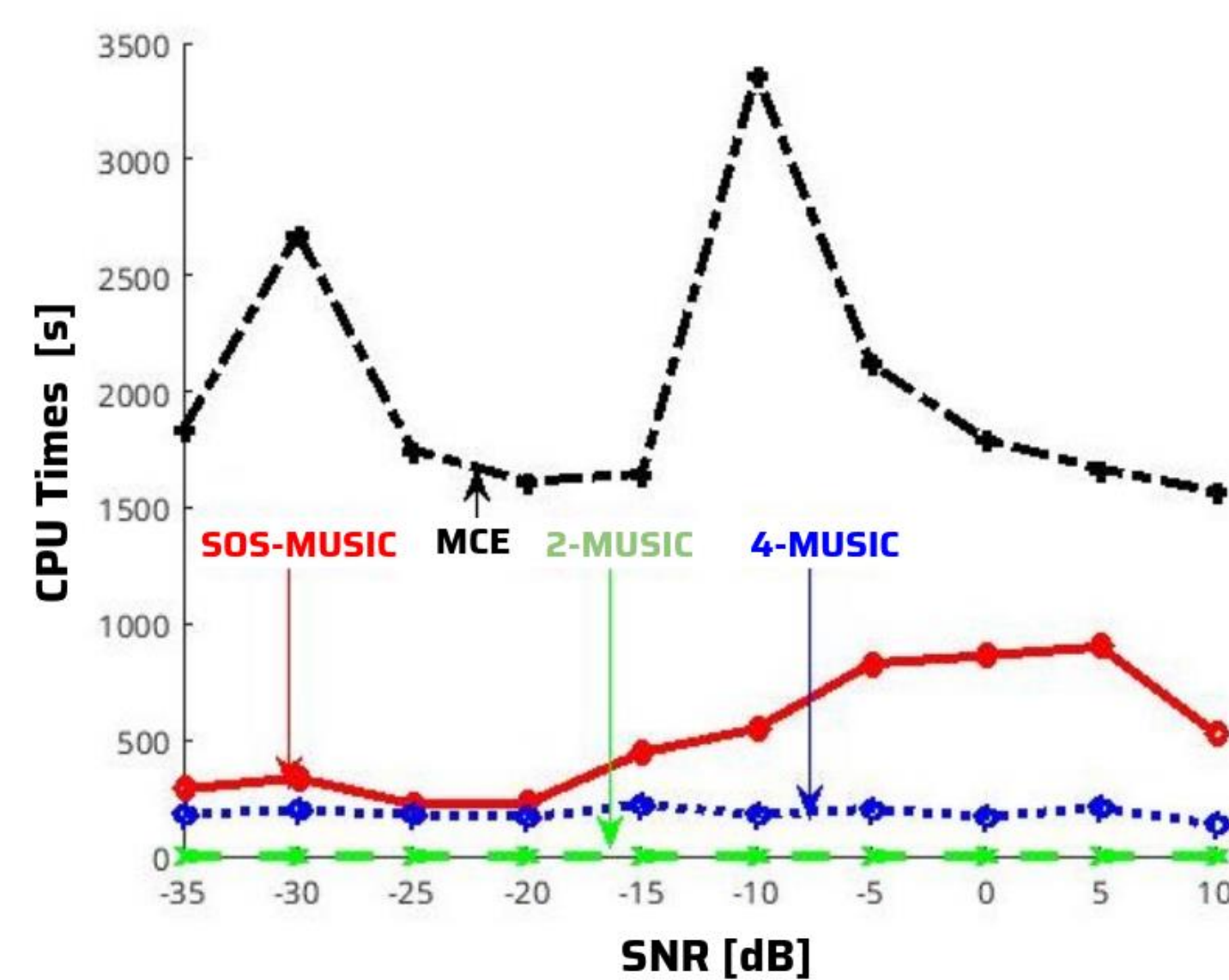


Fig 2. CPU time in seconds for one surface epileptic source

Scenario 1.b

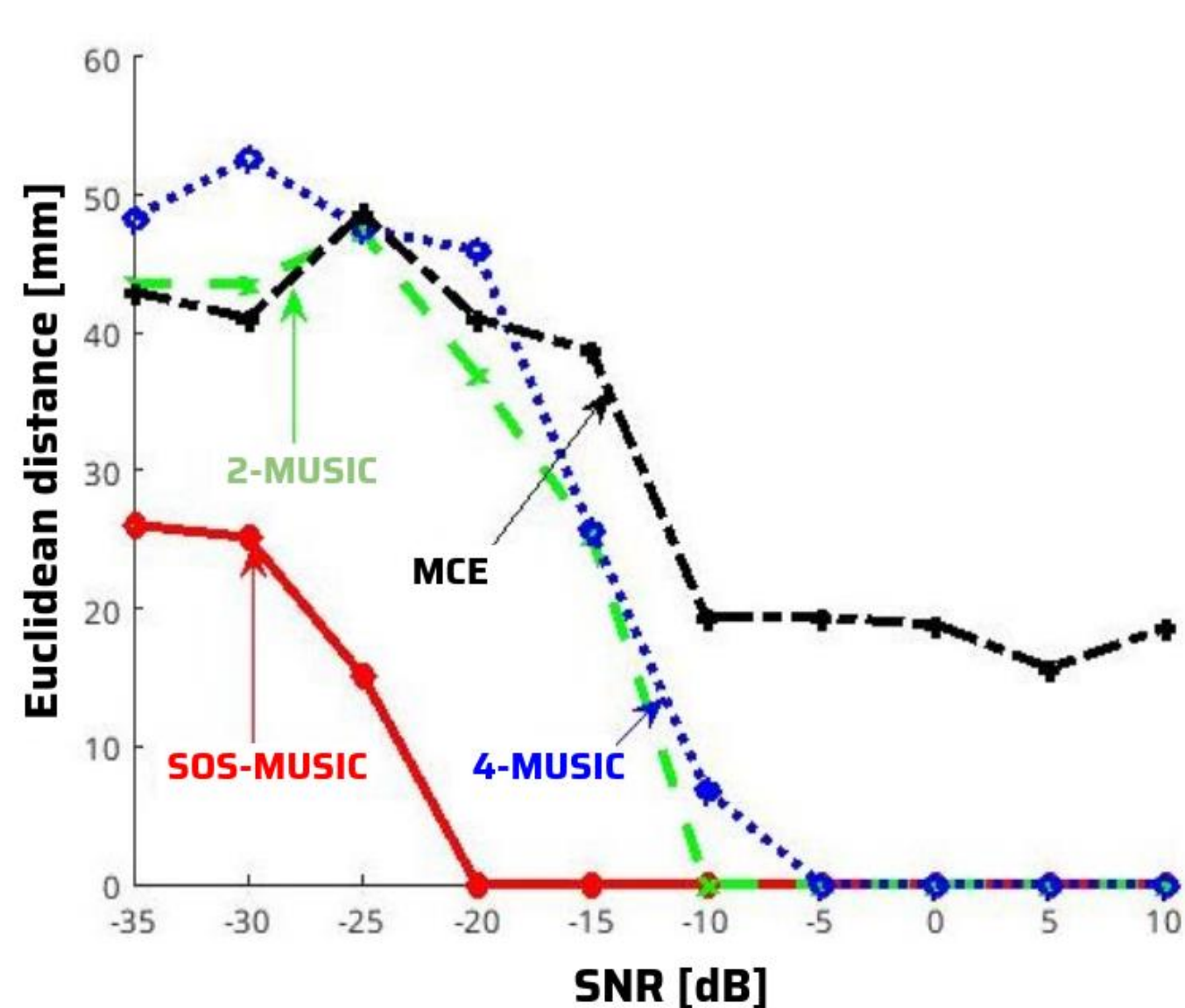


Fig 3. Localization error in mm for one deep epileptic source

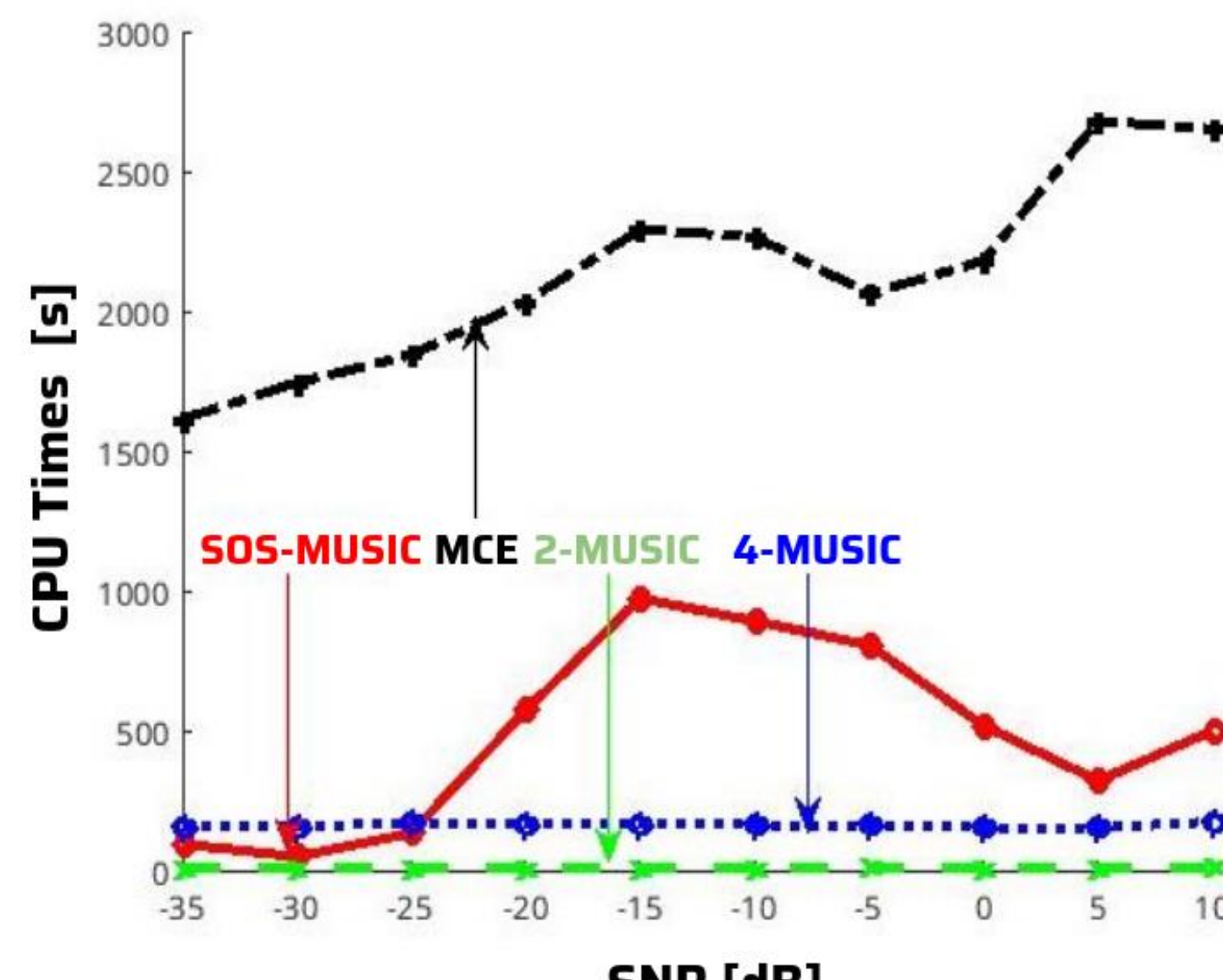


Fig 4. CPU time in seconds for one deep epileptic source

Scenario 2

Methods	Euclidean distance [mm]	CPU Times [s]
2-MUSIC	80.68	1.8
4-MUSIC	71.2	231.7
MCE	72.7	2540
SOS-MUSIC	0	710.7

TABLE 1. Localization error and CPU time in the presence of two synchronous epileptic sources

CONCLUSION

- An extension of the 2-MUSIC approach by regularizing the classical **2-MUSIC metric** and proposing an **automatic** minimization scheme.
- Promising results** for dealing with **synchronous** brain current sources and **low SNR** ratios as demonstrated through realistic computer simulations.

Discussion

- A higher SOS-MUSIC CPU times but a more accurate localization.

Future works

- Validating on real clinical EEG data and on **distributed** sources.
- An extension of the SOS-MUSIC method to **fourth-order** data statistics.

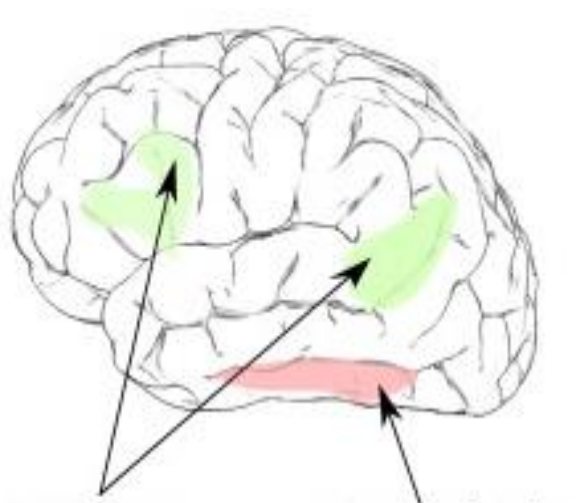


Fig 6. Distributed sources

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