Distinguishability as a noise performance metric for EIT algorithms

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Problem

We are motivated by the need to **compare EIT algorithms** and approaches in order to choose optimal algorithms and measurement configurations. Such comparisons are needed to answer questions such as:

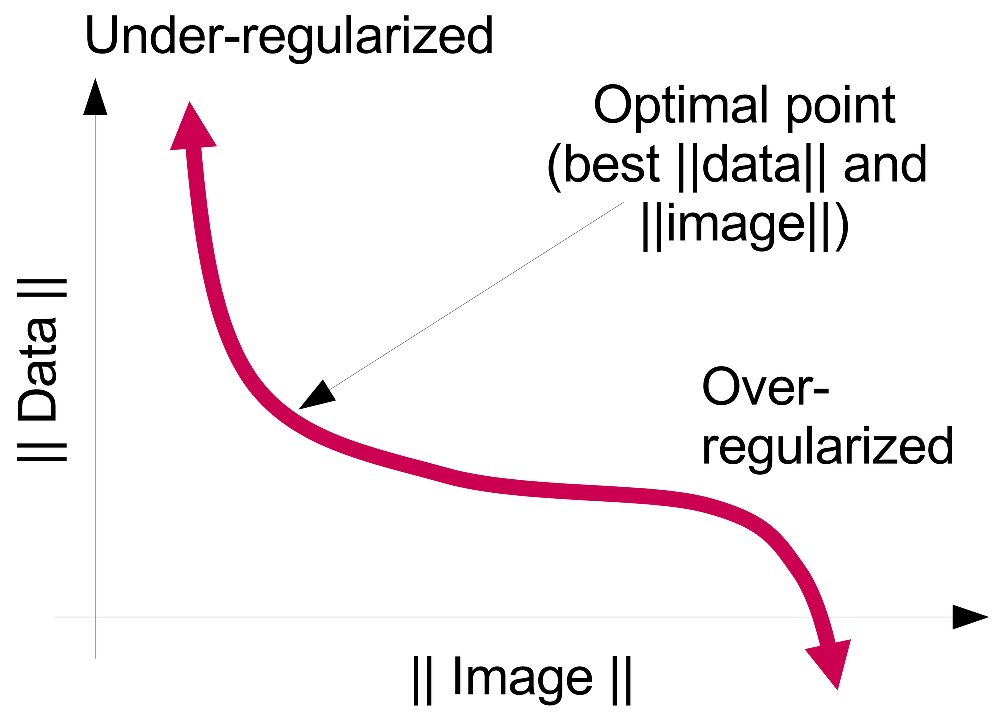
- What skip (spacing) between stimulation patterns is best to measure the lungs?
- Would it be useful to put a few extra electrodes near the heart?
- Has algorithm *A* a lower position error than *B*?

Such comparisons are not straightforward because most EIT algorithms have at least one **tunable parameter** (a “hyperparameter”, λ) which controls the **trade-off** between the ability to **reject noise** (noise performance) and the **resolution** and other accuracies.

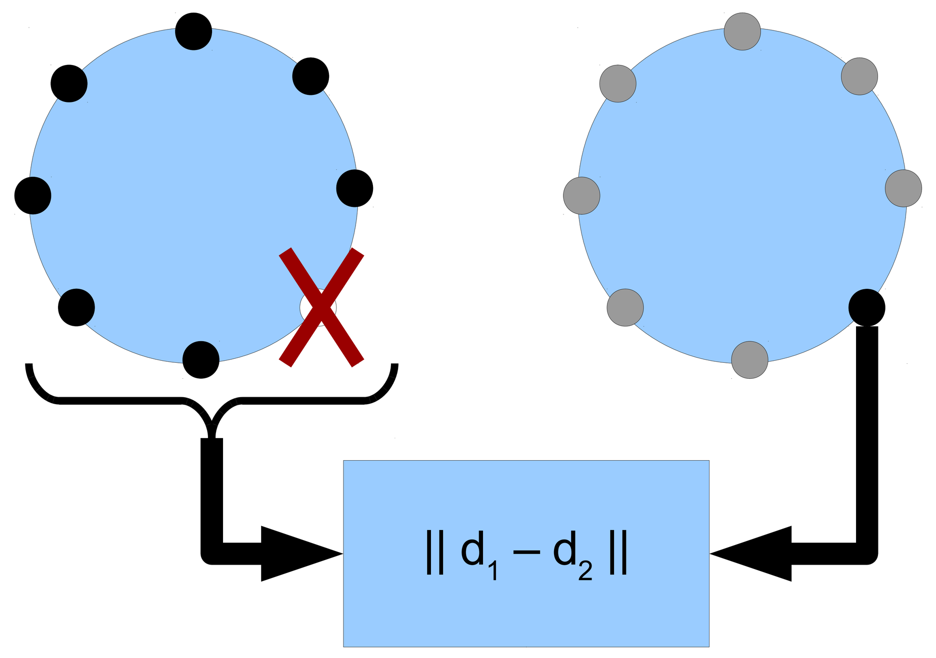
The values of λ are chosen based on either heuristic criteria, or using techniques such as the L-curve[1], cross validation[1] or the noise figure[2] as further discussed below. Such approaches require data for each tested algorithm to be identical. They are thus not suitable to compare across electrode positions or stimulation strategies. To address this requirement, we propose an approach based on a distinguishability metric[3].

[1] P. C. Hansen. Rank-Deficient and Discrete Ill-Posed Problems 1st edn, SIAM Philadelphia, 1997.
[2] B. M. Graham, et al. Physiol Meas, 27:S65, 2006.
[3] A. Adler, et al. Physiol Meas, 32:731, 2011.

L-curve



Cross Validation



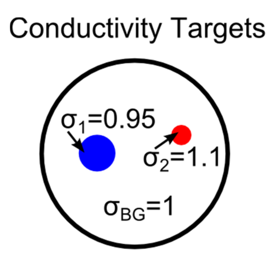
Noise Figure

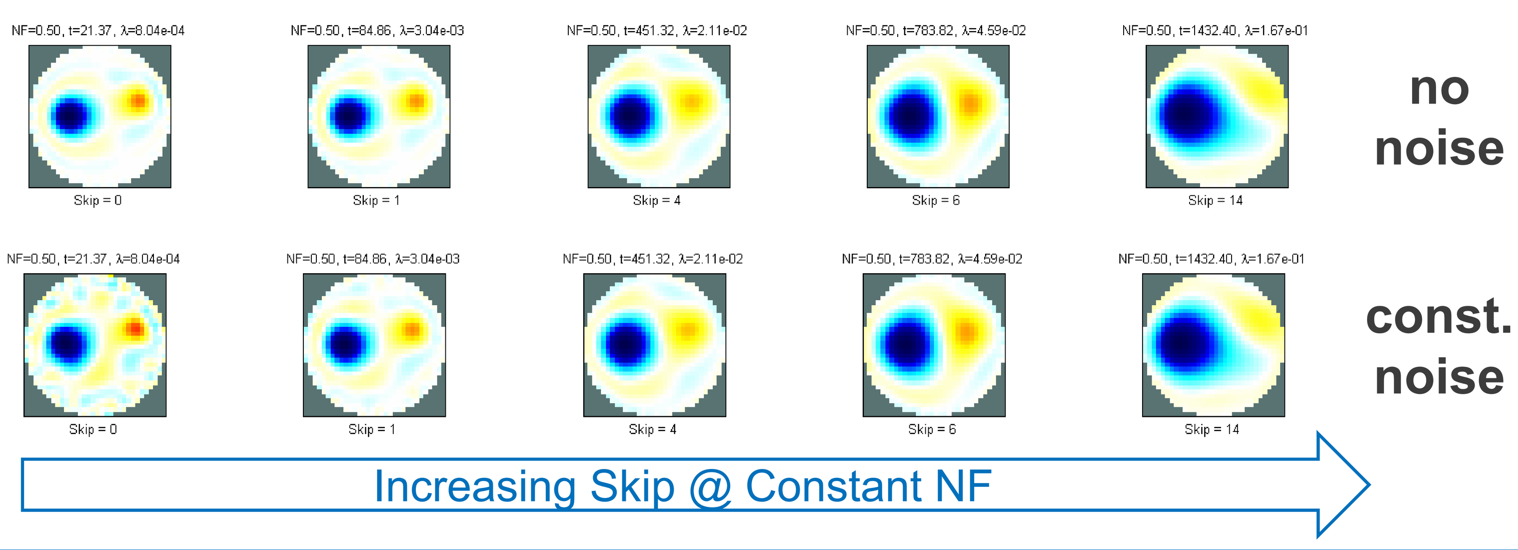
A common choice to select λ so that a measure of noise performance is equal: a common choice is the noise figure (NF). However, this is only applicable when comparing algorithms with identical data. It is thus not suitable to compare across electrode positions or stimulation strategies (as illustrated in the example below).

$$\mathrm{NF} = \frac{\mathrm{SNR}_{\mathrm{Data}}}{\mathrm{SNR}_{\mathrm{Image}}}$$

Test Setup

- Cylindrical tank
- 32 electrodes
- Gauss-Newton recon. (Laplace prior)

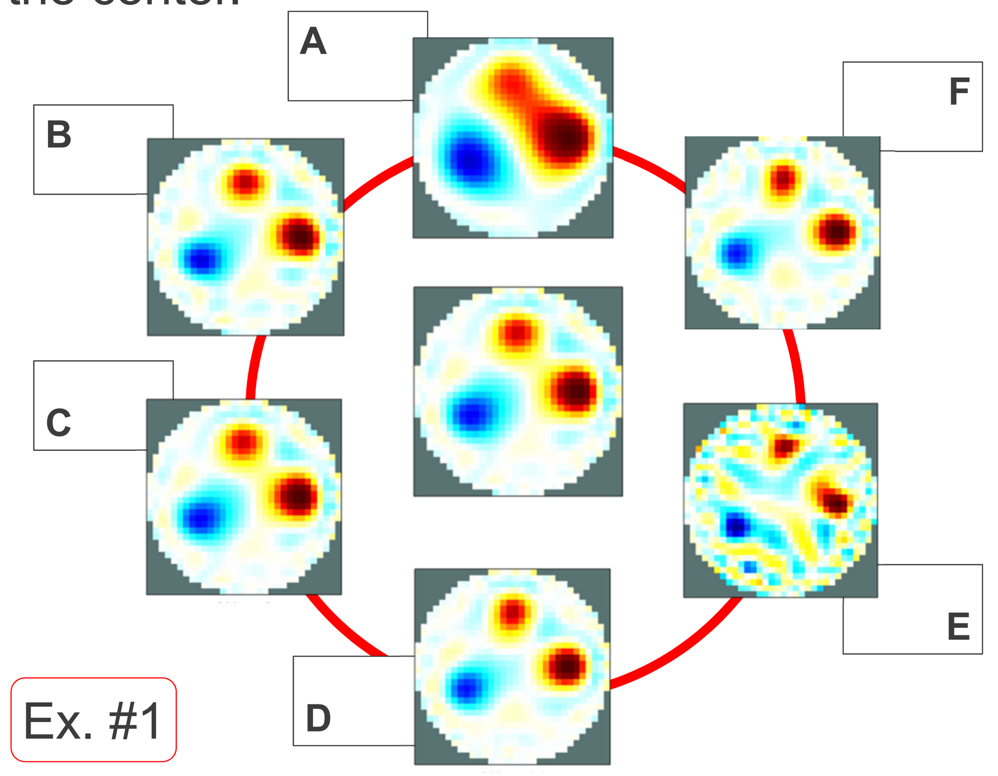


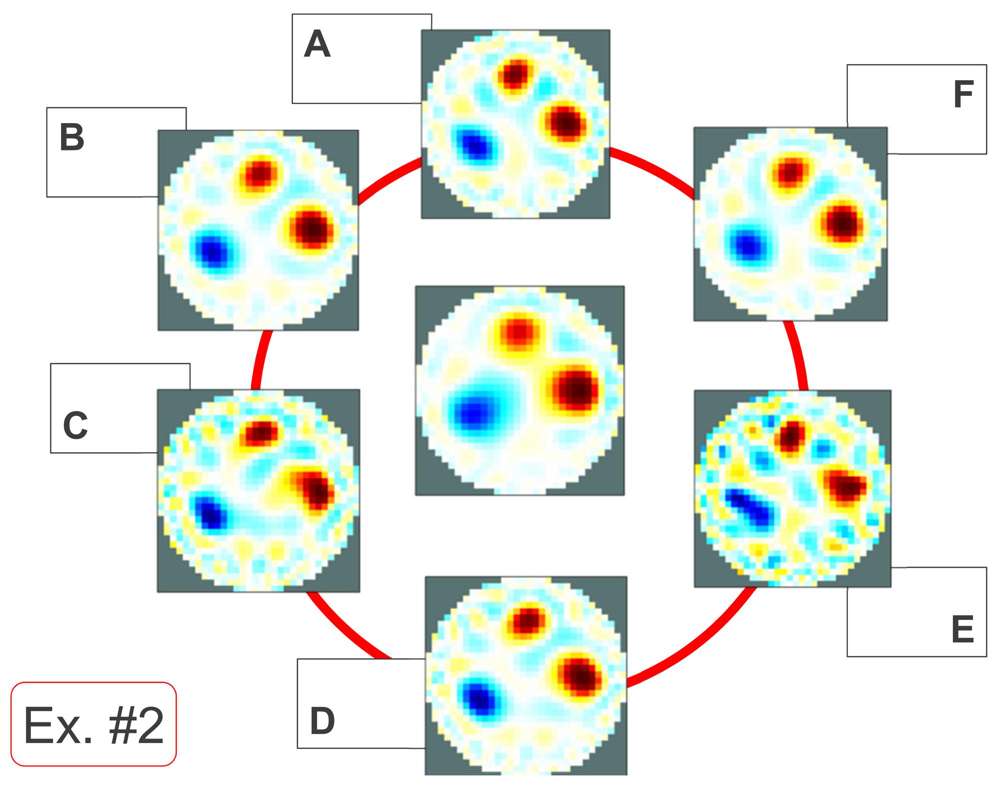


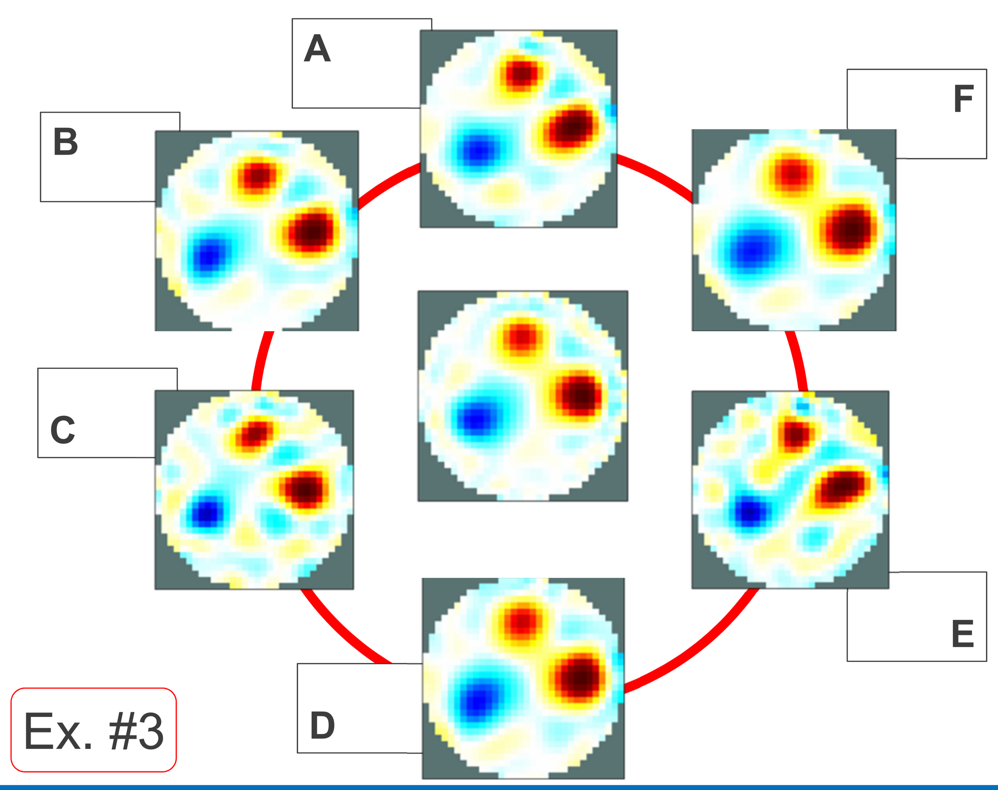
Survey

The authors decline all liability for damage caused by this brain racking survey!

Instructions: For each example #1 to #3, choose two images from A-E showing the closest noise performance with the image in the center.



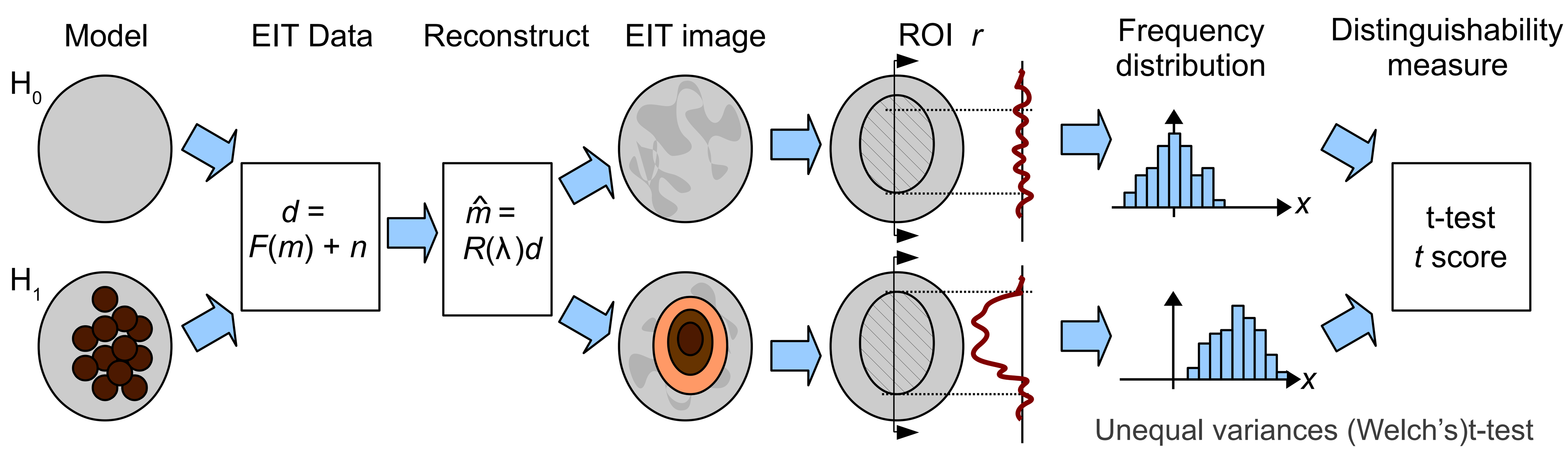


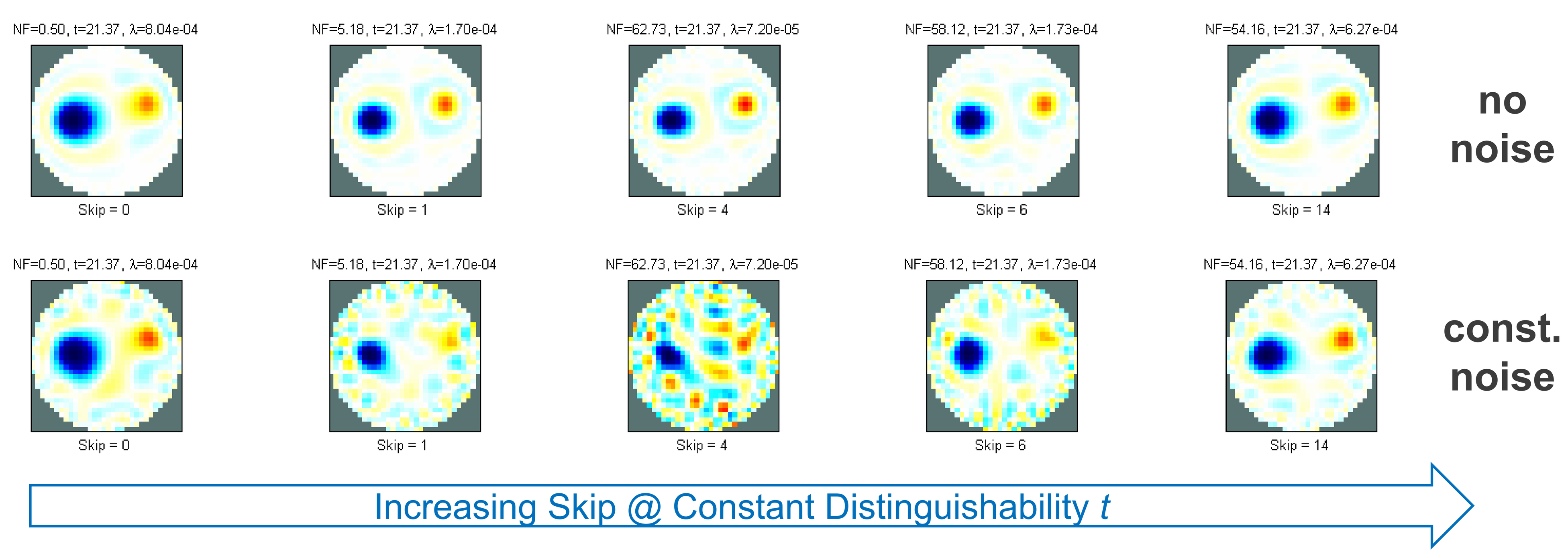


Distinguishability

The proposed framework estimates the noise performance of an algorithm in terms of the distinguishability of contrasts. Distinguishability measures the probability of detection of likely targets, H_1, from the background, H_0 . Algorithms with equal *p*(detection) are defined to have equal noise performance.

- Noise model n characterized by covariance Π_n
  - Independent uniform Gaussian zero-mean
- Likely targets m (mean $\bar{m}$ and covariance Π_m)





Example: unusual electrode placement