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Fighting Gravity Gradients with Gradient-Based Optimization

At the Einstein Telescope, gravity gradient noise is expected to be the dominant noise for low frequencies. Its impact is proposed to be reduced with the help of an array of seismometers that will be placed around the interferometer endpoints.

We reformulate and implement the problem of finding the optimal seismometer positions in a differentiable way. We then explore the use of first-order gradient-based optimization for the design of the seismometer array for 1 Hz and 10 Hz and compare its performance and computational cost to two metaheuristic algorithms. For 1 Hz, we introduce a constraint term to prevent unphysical optimization results in the gradient-based method.

In general, we find that it is an efficient strategy to initialize the gradient-based optimizer with a fast metaheuristic algorithm. For a small number of seismometers, this strategy results in approximately the same noise reduction as with the metaheuristics. For larger numbers of seismometers, gradient-based optimization outperforms the two metaheuristics by a factor of 2.25 for the faster of the two and a factor of 1.4 for the other one, which is significantly outperformed by gradient-based optimization in terms of computational efficiency.

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