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Parameter estimation using Cluster array magnetic field data: perfomance and limits of Capon's method

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Finding a set of model parameters using the in-situ spacecraft data (such as in the Earth or planetary magnetospheres and in the solar wind) is one of the common exercises in the field of space physics. Above all, parameter estimation using Capon's minimum variance projection, originally developed in the field of array seismology, has successfully been applied to recognizing various structures or spatial patterns in space. Examples of the Capon method can be found in the analysis of the wave structures (plane waves, spherical waves, and phase-shifted waves) and the static, large scale structures (planetary dipolar field and higher-order fields). In order to extend the scientific potential of array magnetic field data such as the Cluster, THEMIS, and MMS missions, the performance and the limits of Capon's method are studied in detail using both analytical and numerical approaches. Our findings are: 1) Capon's method is a simple yet robust implementation of the maximum likelihood method, and 2) its accuracy or error can be evaluated analytically. It is suggested that other inversion techniques such as the least square fitting, the singular value decomposition, the Tikhonov regularization, and the eigenvector-based method may be as competitive as Capon's method when the statistical method is limited in the data analysis. Data analysts have thus a wider range of choices for the structure recognition using array data.