Improved DOA Estimation with Small Sample Size and Its Subspace Leakage Analysis

Abstract

Classical methods of DOA estimation such as the MUSIC algorithm are based on estimating the signal and noise subspaces from the sample covariance matrix. For a small number of samples, such methods are exposed to performance breakdown, as the sample covariance matrix can largely deviate from the true covariance matrix. We invistigate DOA estimation performance breakdown. Specifically, we consider the structure of the sample covariance matrix and the dynamics of the root-MUSIC algorithm. The performance breakdown in the threshold region is associated with the subspace leakage where some portion of the true signal subspace resides in the estimated noise subspace. The subspace leakage notion is formally defined, and its theoretical derivation is given. We also propose a two-step method which improves the performance by modifying the sample covariance matrix such that the amount of the subspace leakage is reduced. Furthermore, we introduce a phenomenon named as root-swap which occurs in the root-MUSIC algorithm in the low sample size region and degrades the performance of the DOA estimation. A new method is then proposed to alleviate this problem. Numerical examples and simulation results are given for uncorrelated and correlated sources to illustrate the improvement achieved by the proposed methods. Moreover, the proposed algorithms are combined with the pseudo-noise resampling method to further improve the performance.