Subspace-Based Localization of Near-Field Signals in Unknown Nonuniform Noise

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Abstract

•We consider the problem of estimating the directions-of-arrival (DOAs) and ranges of multiple near-field narrowband signals impinging on a symmetric uniform linear array (ULA) in nonuniform noise in practical applications. By forming a Toeplitz-like correlation matrix from the anti-diagonal elements of the array covariance matrix to convert the nonuniform noise to a uniform one, a new subspace-based localization method is proposed, where the null space is obtained through eigendecomposition of the resultant Toeplitz-like matrix, and the MUSIC method is used to estimate the location parameters, while a new pairing scheme is presented as well. Additionally, an oblique projector based alternating iteration is presented to improve the estimation accuracy of the location parameters, where the "saturation behavior" encountered in most of localization methods is solved effectively. Furthermore, the Cramer–Rao lower bound (CRB) for the near-field signals in unknown nonuniform noise is also derived explicitly. Finally, the effectiveness of the proposed method is verified through numerical examples.

Covariance $\boldsymbol{R} = E\{\boldsymbol{x}(n)\boldsymbol{x}^H(n)\} = \boldsymbol{A}\boldsymbol{R}_s\boldsymbol{A}^H + \boldsymbol{Q}$ nonuniform noise

$$\boldsymbol{Q} = \mathrm{diag}\{\sigma_1^2, \sigma_2^2, \cdots, \sigma_{2M+1}^2\}$$

Toeplitz-like correlation Matrix

$$\boldsymbol{R}_0 = \begin{bmatrix} R_0(0) & R_0(-1) & \cdots & R_0(-M) \\ R_0(1) & R_0(0) & \cdots & R_0(-M+1) \\ \vdots & \vdots & \ddots & \vdots \\ R_0(M) & R_0(M-1) & \cdots & R_0(0) \end{bmatrix}$$

Uniform noise

$$\boldsymbol{R}_0 = \boldsymbol{A}_0\boldsymbol{R}_s\boldsymbol{A}_0^H + \boxed{\sigma_{M+1}^2\boldsymbol{I}_{M+1}}$$

Range space is nonoverlapping

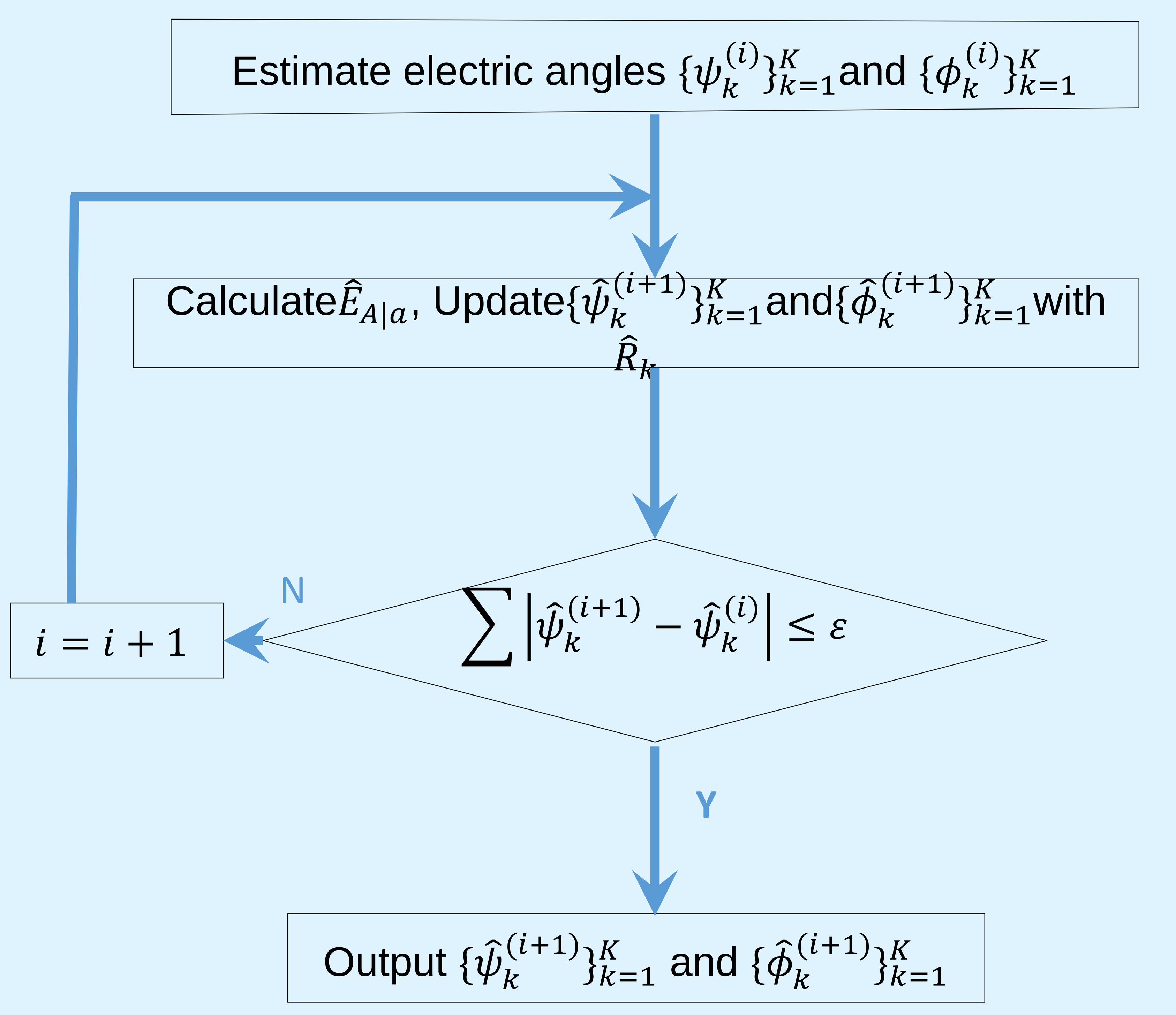
$$\Re(\boldsymbol{A}) = \Re(\boldsymbol{a}_k) \oplus \Re(\boldsymbol{A}_k)$$

Oblique projection operator

$$\boldsymbol{E}_{A_k|a_k} = \boldsymbol{A}_k(\boldsymbol{A}_k^H \textstyle\prod_{a_k}^{\perp} \boldsymbol{A}_k)^{-1}\boldsymbol{A}_k^H \textstyle\prod_{a_k}^{\perp}$$

One incident signal remained

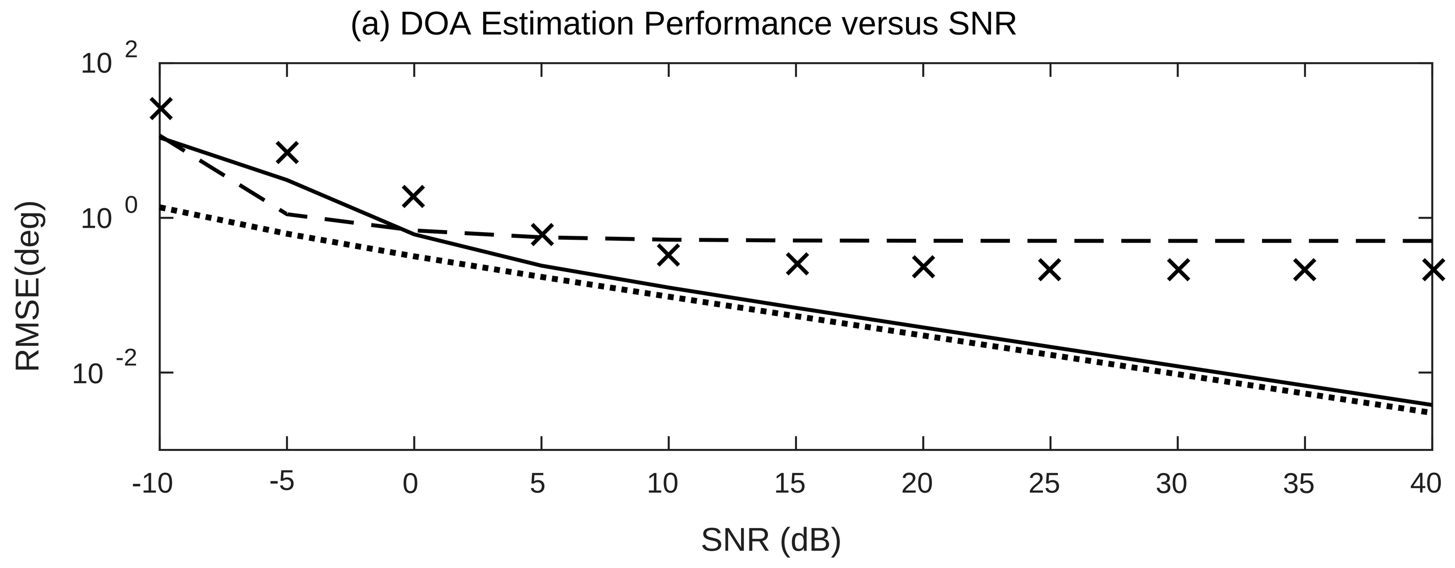
$$\boldsymbol{R}_k = (\boldsymbol{I} - \boldsymbol{E}_{\boldsymbol{A}_k|\boldsymbol{a}_k})\boldsymbol{R}(\boldsymbol{I} - \boldsymbol{E}_{\boldsymbol{A}_k|\boldsymbol{a}_k})^H \approx r_{sk}\boldsymbol{a}_k\boldsymbol{a}_k^H$$



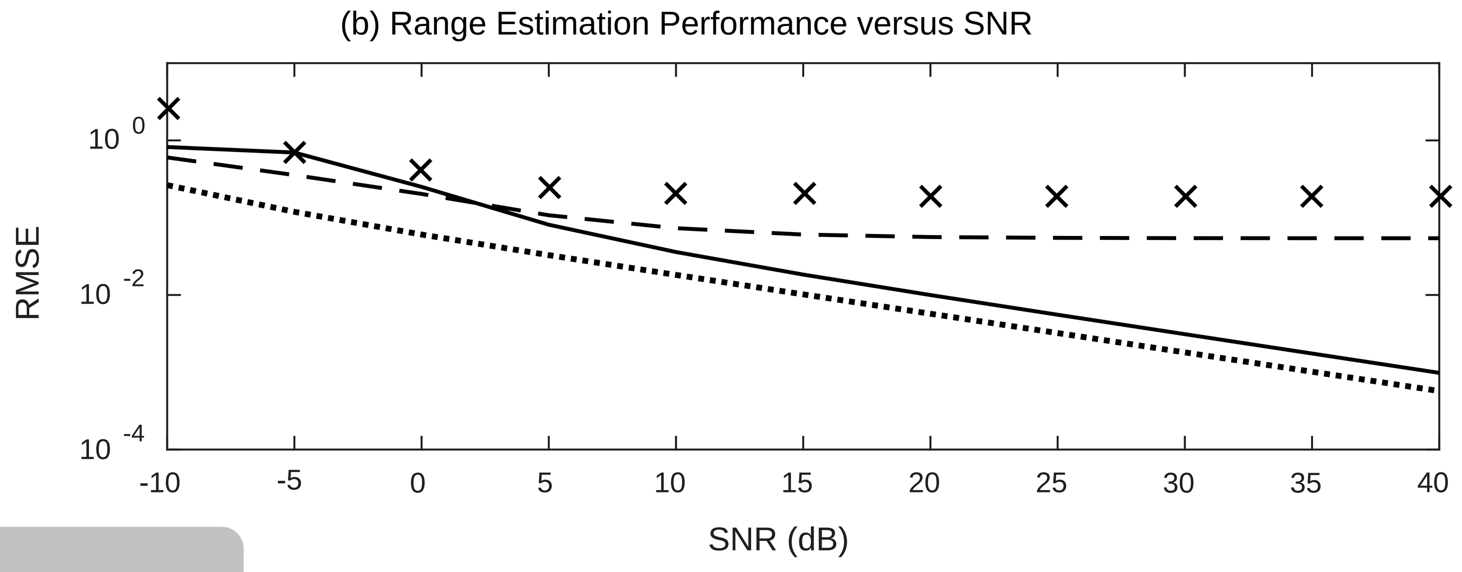
Simulation Results

- Simulation conditions: ULA consisting of 11 sensors with spacing $\lambda/4$, two equal power signal from $(-6°, 2.9\lambda)$ and $(21°, 3.3\lambda)$.
- Experiment 1: The RMSEs of the DOAs and ranges estimates vs SNR, snapshot = 200, max iteration number is 50.
- Experiment 2: The RMSEs of the DOAs and ranges estimates vs the number of snapshots, SNR = 10dB, threshold is 10^{-6}.

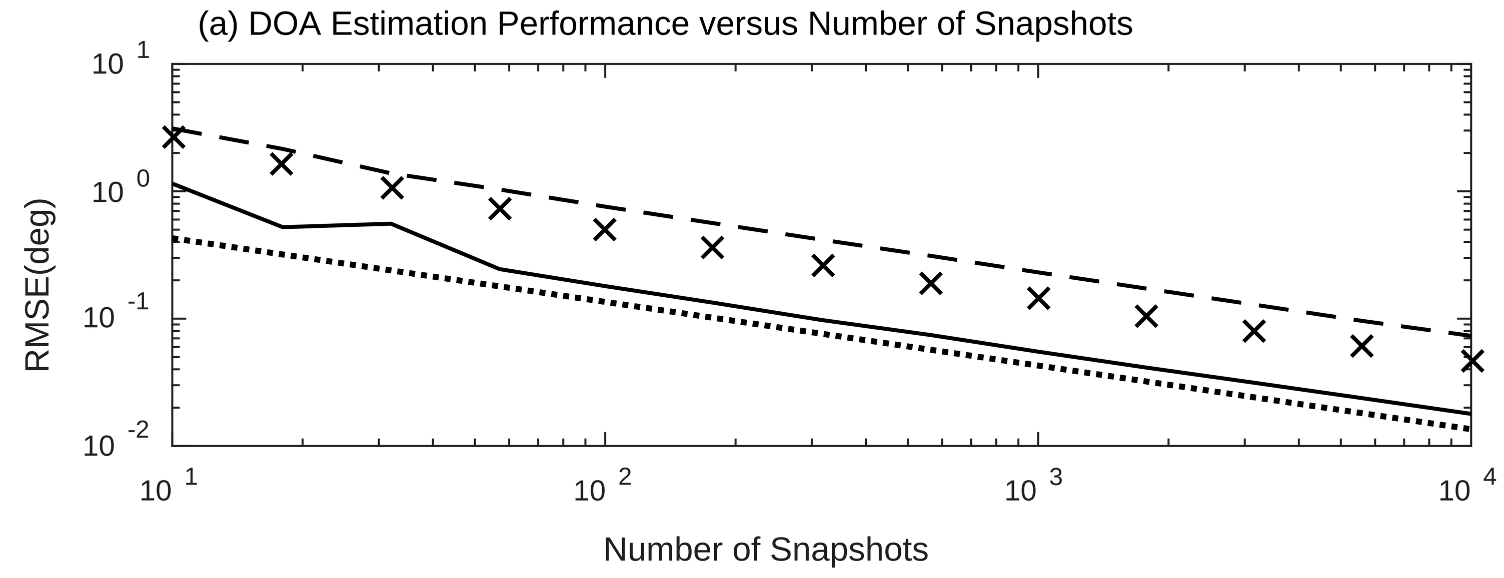
(a) DOA Estimation Performance versus SNR



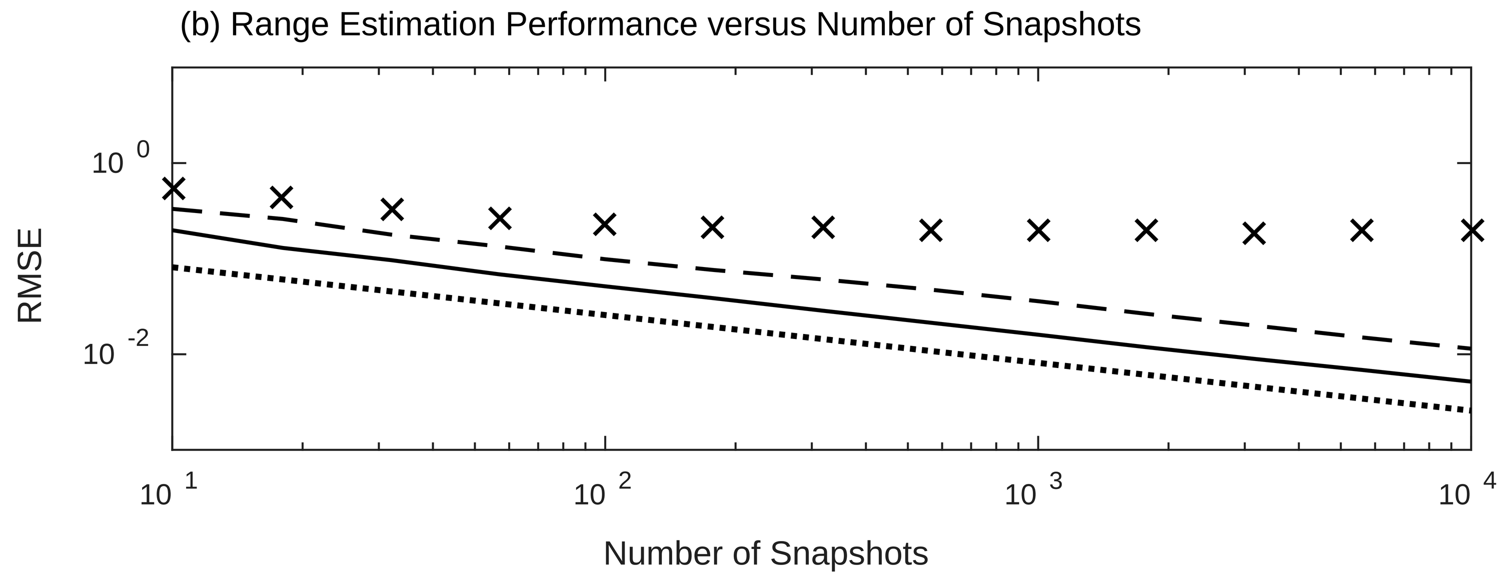
(b) Range Estimation Performance versus SNR



(a) DOA Estimation Performance versus Number of Snapshots



(b) Range Estimation Performance versus Number of Snapshots



Reference

E. Grosicki, K. Meraim, and Y. Hua, "A weighted linear prediction method for near-field source localization," IEEE Trans. Signal Process., vol. 53, pp. 3651-3660, 2005.