Quan-dong WANG, Liang-hao GUO, Wei-yu ZHANG, Sui-ling REN, Chao YAN, 2019. Robust generalized sidelobe canceller based on eigenanalysis and a MaxSINR beamformer. *Frontiers of Information Technology & Electronic Engineering*, 20(7):975-987. https://doi.org/10.1631/FITEE.1700367

Robust generalized sidelobe canceller based on eigenanalysis and a MaxSINR beamformer

Key words: Eigenanalysis; Interference-plus-noise covariance matrix reconstruction; Maximum signal-to-interference-plus-noise ratio criterion; Blocking matrix; Generalized sidelobe canceller; Direction of arrival mismatch

Corresponding author: Liang-hao GUO
E-mail: glh2002@mail.ioa.ac.cn

Motivation

1. One type of robust beamforming widely used is the generalized sidelobe canceller (GSC); however, it is still sensitive to model mismatches, e.g., direction of arrival (DOA) mismatch.

2. Several techniques have been proposed to improve the robustness of the GSC. Recently, several covariance matrix reconstruction methods have been proposed for use in MVDR beamformers to get rid of the SOI component. These methods can make the beamformers less sensitive to DOA mismatch, but are highly dependent on spatial power spectrum density estimation.

Main idea

We redesign the blocking matrix structure using an eigenanalysis method to reconstruct the IPN covariance matrix from the samples. Additionally, a modified eigenanalysis reconstruction method based on the rank-one matrix assumption is proposed to achieve a higher reconstruction accuracy.
The blocking matrix is obtained by incorporating effective reconstruction into the maximum signal-to-interference-plus-noise ratio (MaxSINR) beamformer. It can minimize the influence of signal leakage and maximize IPN power for further noise and interference suppression.

Method

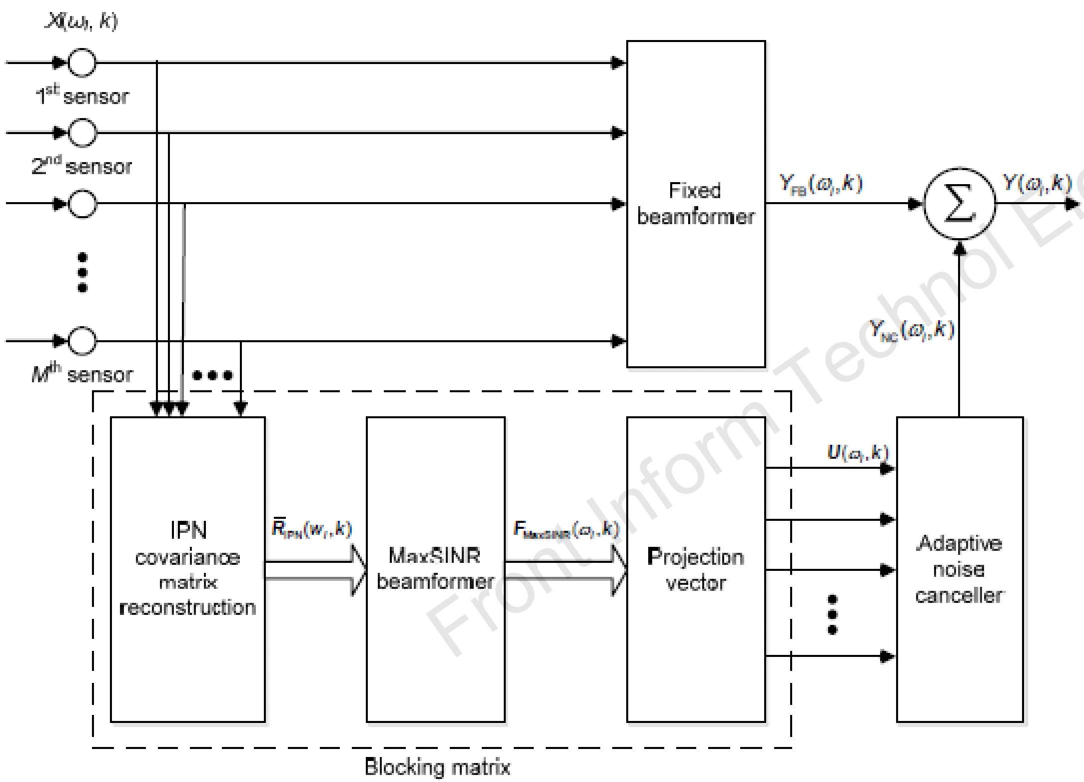


Fig. 1 The proposed generalized sidelobe canceller structure

Step 1: Obtain the fixed Beamformer $Y_{\mathrm{FB}}(\omega_l, k) = \boldsymbol{F}_{\mathrm{FB}}^{\mathrm{H}}(\omega_l, k)\boldsymbol{X}(\omega_l, k), l = 1, 2, \ldots, L.$

Step 2: Calculate PR_m with Eq. (7), and perform eigenanalysis

$$\begin{cases} \mathrm{PR}_m < \gamma \Rightarrow \boldsymbol{v}_m(\omega_l, k) \in \boldsymbol{U}_{\mathrm{IPN}}(\omega_l, k), \\ \mathrm{PR}_m \geq \gamma \Rightarrow \boldsymbol{v}_m(\omega_l, k) \in \boldsymbol{U}_{\mathrm{SOI}}(\omega_l, k), \end{cases}$$

m=1, 2, …, M, l=1, 2, …, L, to reconstruct $\bar{\boldsymbol{R}}_{\mathrm{IPN}}(\omega_l, k)$ with Eq. (9).

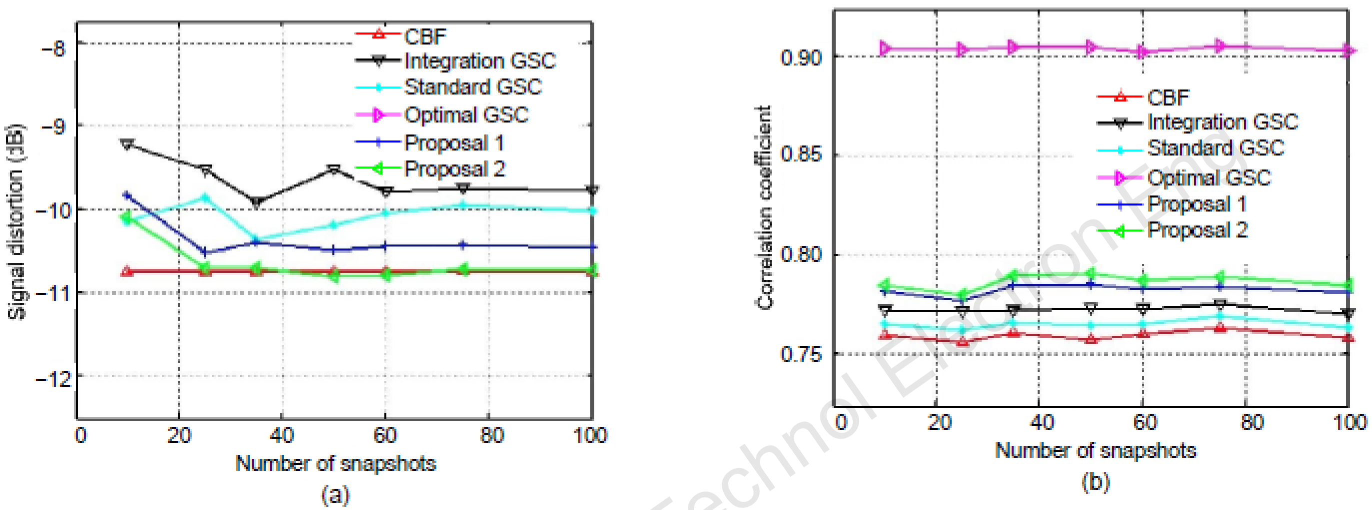
Step 3: Solve Eq. (14) with GEVD to obtain $\boldsymbol{F}_{\mathrm{MaxSINR}}(\omega_l, k)$.

Step 4: Calculate the blocking matrix $\boldsymbol{B}(\omega_l, k)$ with Eqs. (20) and (21), and then obtain the noise reference $\boldsymbol{U}(\omega_l, k)$.

Step 5: Update the multichannel Wiener filter in ANC $\boldsymbol{G}(\omega_l, k+1) = \boldsymbol{G}(\omega_l, k) + \mu \dfrac{\boldsymbol{U}(\omega_l, k)Y^*(\omega_l, k)}{P_U(\omega_l, k)}$, l=1, 2, …, L, and output the enhanced waveform $Y(\omega_l, k) = Y_{\mathrm{FB}}(\omega_l, k) - \boldsymbol{G}^{\mathrm{H}}(\omega_l, k)\boldsymbol{U}(\omega_l, k)$, l=1, 2, …, L.

Step 6: Repeat steps 1–5 until convergence.

Major results



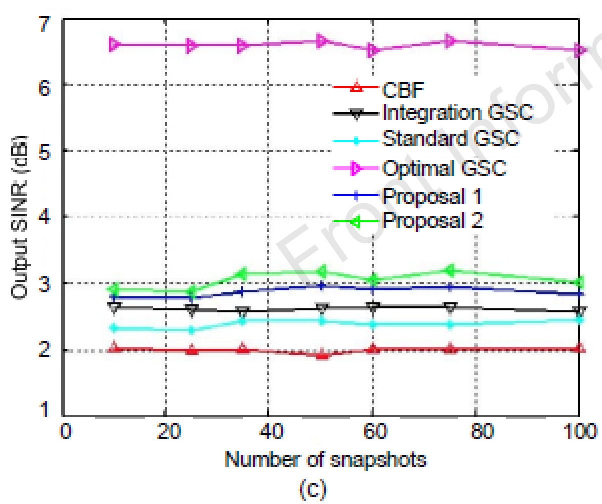


Fig. 2 Performance measurements in terms of the number of snapshots with SNR=−10 dB: (a) signal distortion; (b) correlation coefficients with the SOI; (c) output SINR

Here the assumed DOA of the SOI is in the center of Θ_{SOI} where a mismatch span Θ_Δ is set to include the actual DOA of the SOI while excluding the DOAs of the interference signals. Based on the array structure and the bandwidth of interest, the 3 dB main-lobe bandwidth of the CBF beam pattern is 2°. Thus, the mismatch span Θ_Δ=3° is reasonable. This means that Θ_{SOI} is set to be $(5°+\phi_\Delta-\Theta_\Delta,\ 5°+\phi_\Delta+\Theta_\Delta)$= $(2°+\phi_\Delta,\ 8°+\phi_\Delta)$, and Θ_{IPN} is $[-90°,\ 2°+\phi_\Delta]\cup[8°+\phi_\Delta,\ 90°]$.

Major results (Cont'd)

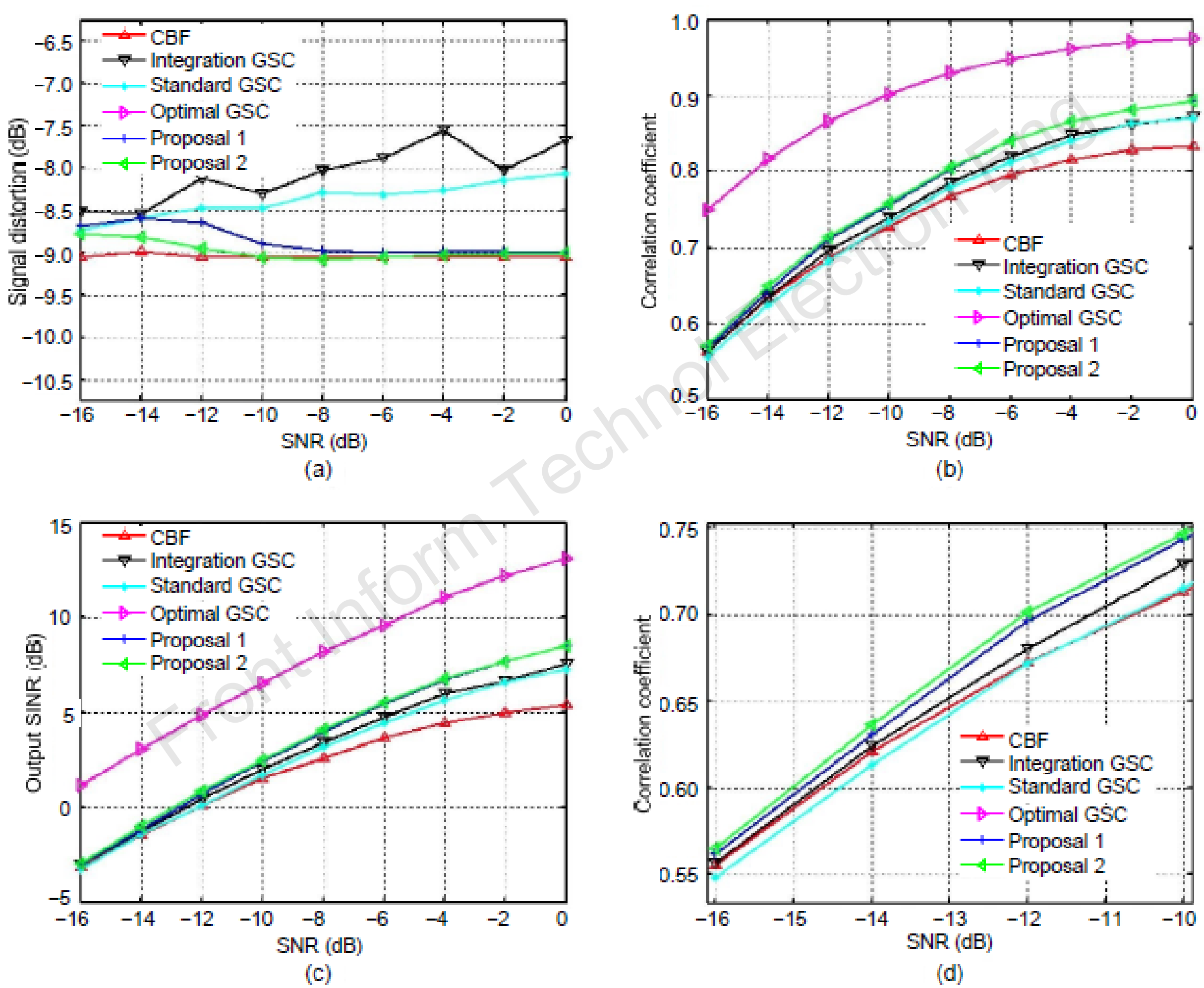


Fig. 3 Performance measurements in terms of the input SNR with K=25: (a) signal distortion; (b) correlation coefficients with the SOI; (c) output SINR; (d) part of (b) in the low SNRs

Major results (Cont'd)

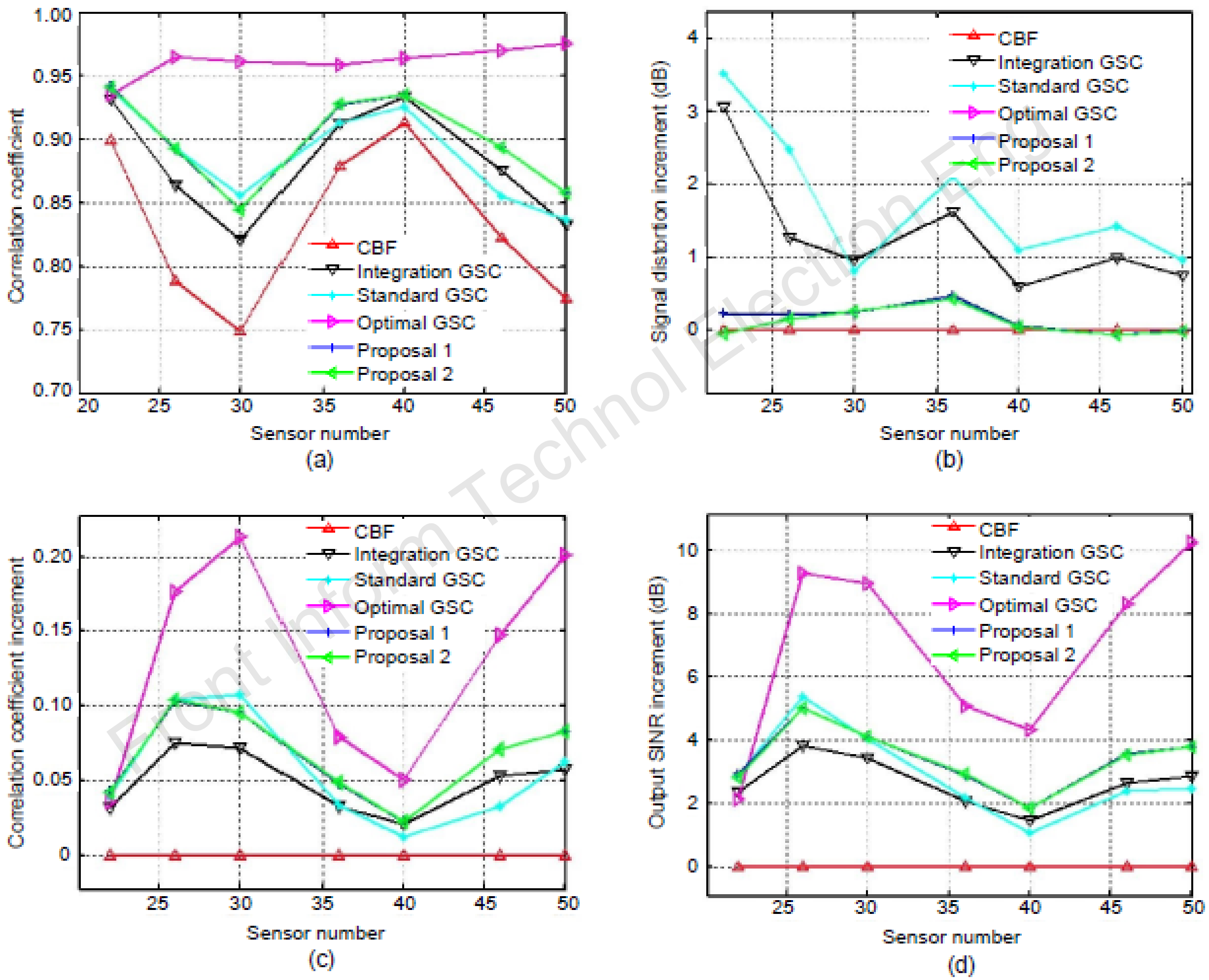


Fig. 4 Performance comparisons in terms of the number of sensors when SNR=0 dB and K=0.5M: (a) correlation coefficients with the SOI; (b) signal distortion increments referring to the CBF; (c) correlation coefficient increments referring to the CBF; (d) output SINR increments referring to the CBF

Conclusions

1. A GSC structure which is robust to DOA mismatch with an eigenanalysis-based blocking matrix is proposed.

2. The modified eigenanalysis method is based on the rank-one assumption to minimize the SOI leakage and maximize the noise and interference power in the noise reference.

3. When there is a DOA mismatch, the proposed GSCs not only remarkably decrease the amount of signal distortion, but also achieve considerable improvements in terms of the output SINR and correlation coefficients with the desired signal, especially with a large array, compared to other GSCs.

4. In addition, it can work even when the number of snapshots is smaller than that of sensors.