Adaptive Covariance Estimation Using Spectral Clustering

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Abstract

Adaptive beamformers rely on accurate estimation of the auto-covariance matrix for proper mitigation of interference and preservation of signals. Most practical beamformers use time averaging for covariance estimation, but it is difficult to acquire enough time snapshots in dynamic environments. Frequency averaging enables adaptation in rapidly changing scenarios, but the technique assumes homogeneity throughout the fixed averaging bandwidth. Cluttered environments with narrowband sources can break this assumption of consistency across frequency. This leads to many artifacts and causes the adaptive beamformer to under perform compared to a conventional filter. Separation of signal and noise frequency bins for covariance estimation mitigates the artifacts caused by fixed frequency averaging bands. Automatically segmenting data into signals and noise requires the use of an unsupervised clustering algorithm and creates a data-adaptive frequency averaging covariance estimator. This thesis proposes a data-adaptive covariance estimation approach for beamspace MVDR beamformers in one time snapshot environments.

Using fixed frequency averaging bands increases the noise floor and consequently compromises the detection of low SNR signals. The mismatch between the covariance estimate and the applied data causes the beam pattern of the adaptive beamformer to become ill-behaved. Clustering the data to provide separate covariance estimates for signal and noise

clusters mitigates these artifacts and preserves the detection of low SNR signals. This thesis also shows that the SNR of a signal is correlated to the increase in noise floor for fixed frequency averaging beamformers. The higher the SNR of a narrowband signal becomes, the higher the noise floor on all other frequency bins. The proposed data-adaptive covariance estimate beamformer mitigates these artifacts and preserves the noise floor. The main drawback to the proposed approach is the large computational burden. Applying an unsupervised clustering approach and creating additional weight solutions needed for every cluster is expensive. If the resources are available, the proposed approach shows that frequency averaging beamformers can operate in single time snapshot environments and retain the benefits of an adaptive beamformer without any artifacts in the beamformer output.