Multi-Antenna Receiver for Ambient Backscatter Communication Systems

Introduction

Consider an AmBC system consisting of an ambient wideband OFDM source, a narrowband AmBC device adopting BPSK modulation, and a simple multi-antenna receiver shown in Fig. 1.

- The limited bandwidth $B_1$ of the AmBC device affects only a certain subset of the OFDM carriers as shown in Fig. 2. A practical work in [1] has proved this design.
- The receiver makes the decision of the backscatter symbol over one OFDM symbol without knowledge of the CSI, the statistical channel covariance matrices, and the noise variance.

Proposed Solution

- Propose a simple sample covariance matrix (SCM) distance-based rule, with no need to invert the SCMs, for backscatter symbol detection because OFDM signals with a large number of subcarriers contain repetitive elements, such as control and synchronization information, inducing time correlation even if the sample rate is slow [2].
- Propose an interfaced and spread transmission scheme of pilots and data symbols for the AmBC device.

- The covariance matrix after de-spreading reads $\hat{R}[\mathcal{K}_p] = (1/L)\tilde{Y}[\mathcal{K}_p]C^-\tilde{Y}^T[\mathcal{K}_p]$, $p \in \{-1,1\}$
- The simple SCM distance metric based on the Frobenius norms is $\|\hat{R}[\mathcal{K}_1] - \hat{R}[\mathcal{K}_3]\|^2_F$ and $\|\hat{R}[\mathcal{K}_{-1}] - \hat{R}[\mathcal{K}_3]\|^2_F$
- The decision rule to decide the transmitted backscatter symbol is $\hat{x}_1 = \text{sign} \\text{tr}\{[\hat{R}[\mathcal{K}_1] - \hat{R}[\mathcal{K}_{-1}])\hat{R}[\mathcal{K}_3]\}$

Challenges

- Practically, the AmBC signal is much weaker compared to the direct path, i.e., $\gamma_1 \ll \gamma_0$.
- Extremely challenging to acquire accurate statistical covariance matrices for time-variant channels with large variances.
- A large number of samples spanning multiple OFDM symbol periods results in a low data rate to the AmBC.
- The receiver has no CSI, the statistical channel covariance matrices, and the noise variance.

Conclusion and Discussion

- A simple receiver can detect the backscatter BPSK symbols over one wideband ambient OFDM symbol period applying the time correlation induced by the contained repetitive elements.
- Limitations: 1) if the backscatter modulates the ambient OFDM signals at a very high rate, then the backscattered path frequency response will shift to another band in the frequency domain; 2) if the receiver has an analog bandpass filter, the AmBC signal may be filtered away; 3) if there is a wideband receiver, it will cause severe adjacent band interference.

References