WiFIUS: Collaborative Research: Ambient Re-Scatter Inspired Machine Type Communication for Heterogeneous IoT Systems

[1] Department of Communications and Networking, Aalto University, Finland
[2] Department of Electrical and Computer Engineering, University of Houston, USA

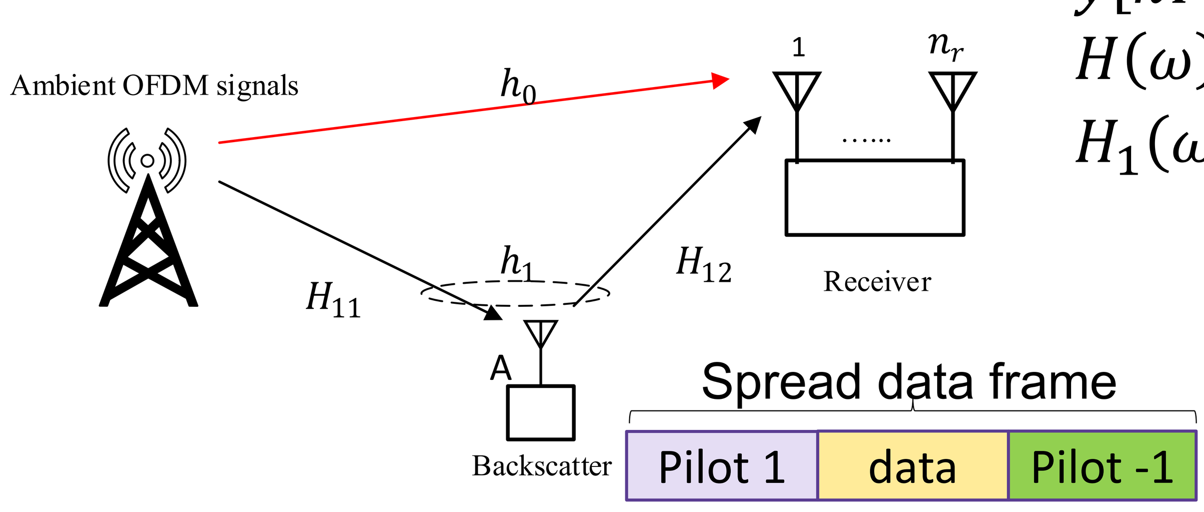
R. Duan[1], R. Jäntti[1], M. ElMossallamy[2], Z. Han[2], and M. Pan[2]

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.



$$y[kT] = \sqrt{\gamma_0}h_0[kT] + \sqrt{\gamma_1}h_1[kT]c_k x_1 + z[kT]$$
$$H(\omega) = \sqrt{\gamma_0}H_0(\omega) + \sqrt{\gamma_1}H_1(\omega)$$
$$H_1(\omega) = H_{12}(\omega)\big(A(\omega)H_{11}(\omega) * X(\omega)\big)$$

Fig. 1. An illustration of the considered system.

Challenges

- Practicaly, 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.

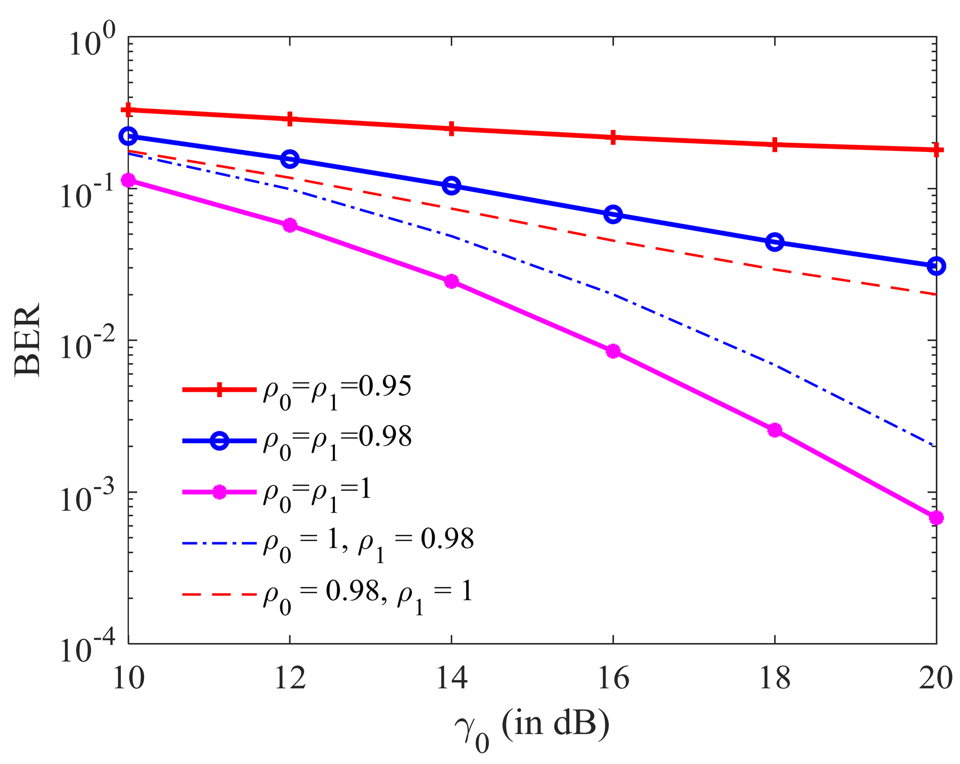


Fig. 3. BER vs γ_0 ($= \gamma_1 + 25dB$) for different time-correlation scenarios. ρ_0 and ρ_1 represent the direct and backscattering link, respectively

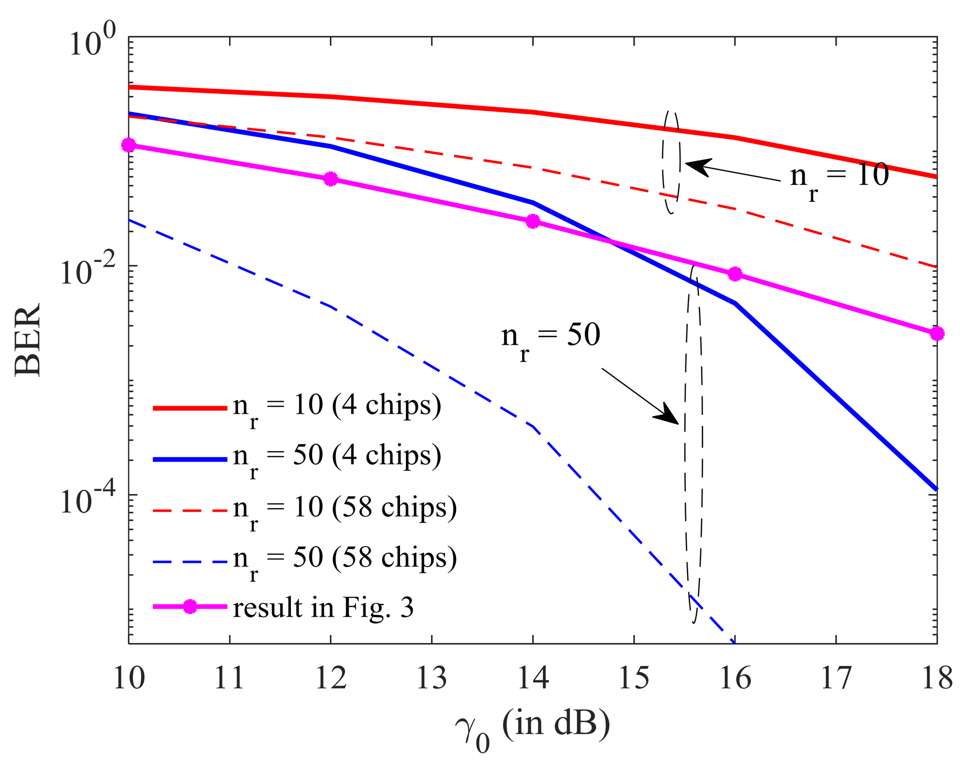


Fig. 4. BER as a function of γ_0 with $n_r = 10, 50$. $\rho_1 = \rho_0 = 1$.

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 interlaced and spread transmission scheme of pilots and data symbols for the AmBC device.

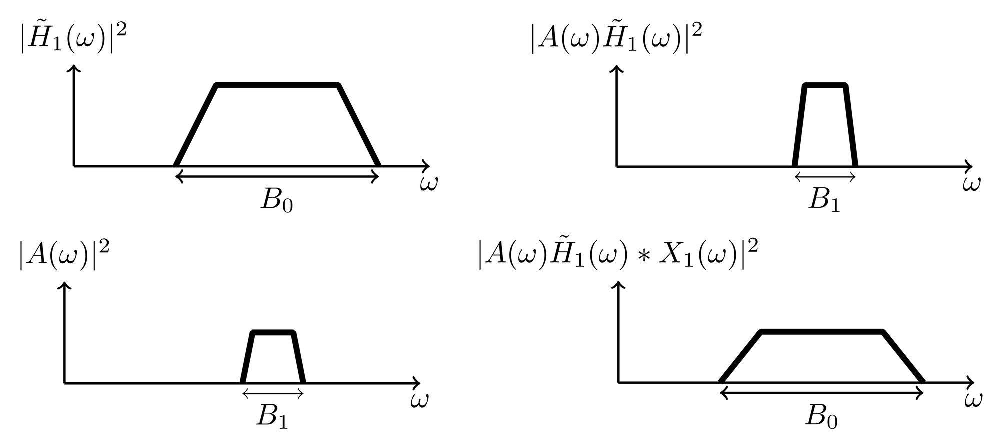


Fig. 2. An illustration of an AmBC modulated signal.

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

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

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[2] S. Wei, D. L. Goeckel, and P. A. Kelly, "Convergence of the complex envelope of bandlimited OFDM signals," *IEEE Trans. Inf. Theory*, vol. 56, no. 10, pp. 4893-4904, Oct. 2010.

Aalto University
School of Electrical Engineering

UNIVERSITY of HOUSTON
CULLEN COLLEGE of ENGINEERING
Department of Electrical & Computer Engineering