EE209AS: Special Topics in Circuits and Embedded Systems **Spring 2017**

Project — due Friday, June 16, 2017

Instructor: Prof. Danijela Cabric *Ghaith Hattab and Shailesh Chaudhari*

Instructions

- A group need to choose **one** project from the list below.
- Each group can have up to **two** students.
- E-mail the names of group members and the project selected to Prof. Cabric <danijela@ee.ucla.edu> and TA Shailesh Chaudhari <schaudhari@ucla.edu>. This is due by **Sunday, May 21st**.
- An archive file, i.e., a zip file, should be submitted by one of the group members on CCLE. Name of the zip file should be $lastname\_firstname$.zip with the name of the student submitting the file. It should contain a report showing the results and the project's findings as well as all the MATLAB/Simulink files.

OFDM Systems

P1: Impact of Phase Noise on OFDM

In this project, we analyze the impact of phase noise on OFDM systems. Phase noise is introduced by local oscillators, and it creates inter-carrier interference (ICI). The tasks of this project are as follows.

- Build an OFDM system: Consider an OFDM transmitter with BW= 20 MHz, 64 subcarriers, and CP length of 16. Assume an AWGN channel.
- Model phase noise: Introduce a phase noise in the OFDM receiver, which is modeled in [1]. Consider $\Delta f_{3dB} = \{50, 100, 150\}$.
- Phase compensation algorithm: Implement the phase noise correction algorithm used in [1].
- Results: Study the symbol error rate with variations of SNR over $[0, 30]$dB in the presence and absence of the compensation algorithm.

Relevant References

[1] D. Petrovic, W. Rave and G. Fettweis, "Intercarrier interference due to phase noise in OFDM - estimation and suppression," Vehicular Technology Conference, 2004. VTC2004-Fall. 2004 IEEE 60th, 2004, pp. 2191-2195. (IEEE Xplore link)
[2] (Optional reading) D. Petrovic, W. Rave and G. Fettweis, "Effects of Phase Noise on OFDM Systems With and Without PLL: Characterization and Compensation," in IEEE Transactions on Communications, vol. 55, no. 8, pp. 1607-1616, Aug. 2007. (IEEE Xplore link)

Spectrum Sensing in Cognitive Radio

P2: Impact of Non-linearity on Wideband Spectrum Sensing

Spectrum sensing is key to enable dynamic spectrum access. It is essential to have a spectrum sensor that provides high detection probability to avoid interfering with other systems and low false alarm to avoid missing spectral opportunities. In this project, we study the impact of RF non-linearities on the energy and cyclostationary detectors. The tasks of this project are as follows.

- Spectrum sensing: Use the cyclostationary and energy detectors given [3]. Consider the same non-linearity model used.
- Impact of non-linearity: Plot the probability of detection versus the probability of false alarm for both detectors in the presence and absence of non-linearities. Assume that the signal of interest and the blockers are 4-PAM with signal-to-blocker ratio $SBR = -67$dB and signal-to-noise ratio $SNR = 10$dB. Assume that the number of samples is 500 (refer to Fig. 4 in [3]).
- Compensation algorithm: Implement the compensation algorithm in [3] which is based on using the sensing time adaptation and threshold setting.
- Results: Show the probability of detection with variations of the SBR in the presence and absence of the compensation algorithm. Consider the number of samples to be 500, the false alarm probability to be 0.1, and the SNR to be 3dB (refer to Fig. 12 in [3]).

Relevant References

[3] E. Rebeiz, A. Shahed Hagh Ghadam, M. Valkama and D. Cabric, "Spectrum Sensing Under RF Non-Linearities: Performance Analysis and DSP-Enhanced Receivers," in *IEEE Transactions on Signal Processing*, vol. 63, no. 8, pp. 1950-1964, April 15, 2015 (IEEE Xplore link)

Impulse-based Radio Architecture for Ultra-wideband (UWB)

P3: Receiver architecture for UWB communication

The main challenge in UWB radio implementation is to reduce the complexity and power consumption. A low complexity receiver architecture based on hybrid matched filter correlator is proposed in [4]. The objective of this project is to study the performance of this architecture.

- Transmitter: Generate the transmit signal as in [4].
- Channel: Consider the IEEE channel CM-1.
- Receiver: Build the conventional and the hybrid receivers given in [4].
- Results: Plot the bit-error-rate (BER) versus the SNR for both receivers when the number of mono-cycles per symbol is $N_f = 10$. In addition, study the impact of the integration interval Q on the BER (refer to Fig. 5 in [4]).

Relevant References

[4] F. Tufvesson, S. Gezici and A. F. Molisch, "Ultra-Wideband Communications using Hybrid Matched Filter Correlation Receivers," in *IEEE Transactions on Wireless Communications*, vol. 5, no. 11, pp. 3119-3129, November 2006. (IEEE Xplore link)

Millimeter Wave Networks

P4: Hybrid beamforming in mmWave networks

Millimeter wave (mmWave) communication has spurred significant interest due to (i) the large swath of spectrum available at the mmWave spectrum and (ii) the small carrier wavelength at the GHz frequencies, which enables implementing large antenna arrays. Hybrid analog and digital beamforming is an emerging architecture for mmWave networks. The objective in this project is to design the hybrid beamforming algorithm in [6] in the presence of partial channel knowledge at the base station and the mobile user.

- Channel model: Use the system model in [5].
- Beamforming: Use and design the given hybrid beamforming in [5].
- Results: Using this beamforming technique, plot the spectral efficiency (given in eq. (9) of [5]) with variations of the SNR (refer to Fig. 3 in [5]). Assume the number of antennas at the BS to be 200 and the number of antennas at the user to be 100. Both the BS and the user are assumed to have 3 RF chains. In addition, plot the spectral efficiency versus SNR in the presence of phase quantization where the number of bits is $Q = \{1, 4, 8\}$.

Relevant References

[5]A. Alkhateeb, O. El Ayach, G. Leus and R. W. Heath, "Hybrid precoding for millimeter wave cellular systems with partial channel knowledge," 2013 Information Theory and Applications Workshop (ITA), San Diego, CA, 2013, pp. 1-5. (IEEE Xplore link)

[6] (Optional reading) O. E. Ayach, S. Rajagopal, S. Abu-Surra, Z. Pi and R. W. Heath, "Spatially Sparse Precoding in Millimeter Wave MIMO Systems," in IEEE Transactions on Wireless Communications, vol. 13, no. 3, pp. 1499-1513, March 2014. (IEEE Xplore link)