# Lab #8: OFDM

## Objective

The objective of this experiment is to understand the basic structure of OFDM, the effect of various impairments on its performance, and techniques that are used to overcome the associated problems. The students will be familiar with the following items:

- Ability to design OFDM transceiver.
- Comprehend inherent features of OFDM (such as its spectrum and PAPR)
- Out-of-band emission suppression techniques.
- Peak-to-average-power-ratio (PAPR) reduction techniques.
- Performance of OFDM in multipath channel:
    - Delay Spread
    - Doppler Spread
- Channel estimation, equalization, and effect of imperfect channel compensation.
- Performance in case of impairments:
    - Time offset
    - Frequency offset
    - PA nonlinearities
- Effect of OFDM parameters (such as CP size, FFT size, and subcarrier spacing) considering impairments.

**Procedures**

**Setup**

- Waveform: CP-OFDM
- Modulation: BPSK
- Subcarrier Spacing: 15 kHz.
- Number of Active Subcarriers: 48
- FFT Size: 64
- Number of OFDM symbols: 25
- Over sampling rate (OSR): 8
- Filter type: Rectangular
- **Channel setup:** Maximum excess delay: 3.2*10^-5 s.
- **Calculate:** i) Sampling rate (Fs) ii) Number of channel taps (N_taps) iii) Optimum CP size (N_cp).

**Steps**

1. Convert the text message given on the MATLAB script into bits.
2. Insert pilot bits into the vector of the message bits you created in step (1). The pilot bits should be inserted starting from 2nd data carrier and every 3rd carrier, i.e., Pilots bits goes as [1, 0, 1, 0…] on the indices [2, 5, 8…].
3. Modulate the output of step (2) into symbols using BPSK modulation.
4. Apply OFDM modulation on the obtained BPSK symbols based on the specified setup parameters (Use CP size equal to the optimum CP size you calculated earlier).

For the section I and II, complete the MATLAB script to complete the given tasks.

***I. OFDM CHARACTERISTICS***

a) Calculate PAPR of the OFDM signal you have generated.

b) Observe and comment on Spectrum and CCDF of the OFDM signal.

c) Repeat (a) and (b) by sweeping the following number of active subcarriers: 48, 32, and 16.

## *II. ENHANCING OFDM THROUGH BASEBAND OPERATIONS*

a) Implement an OOBE reduction technique (Transmitter windowing). Observe and comment on theplots.

b) Implement a PAPR reduction technique (Clipping). Observe and comment on the plots.

## *III. OFDM TRANSMISSION AND RECEIPTION*

**Transmission**

1. Generate and append preamble at the beginning of the OFDM signal you have generated. The preamble signal consists of two consecutive m-sequence symbols: *mseq(2,6)*.
2. Add guard intervals with 50 symbols at both end of the signal obtained in the step (1) above.
3. Apply rectangular filtering with the specified OSR
4. Plot the output signal (Tx Frame).

**Channel**

1. Using the *channeling()* function provided to you, pass the Tx Frame you have generated through the multipath channel. The channel function will add frequency offset, sampling offset, multipath channel and noise to the Tx frame to generate the Rx Frame.
2. From the output of the *channeling()* function, plot the channel impulse response (CIR) (use *waterfall* command here) and the RX Frame.

**Receiver**

1. Pass the Rx Frame through the *synchronization()* function provided to you.
2. Considering that the preamble portion of the signal is the single carrier, estimate its average channel and equalize the synchronized preamble symbols. Plot constellation. Provide your comment on what you have observed.

3. Perform OFDM demodulation on the synchronized OFDM signal. (FFT processing)
4. Leveraging the pilots symbols you inserted at the transmitter, estimate the channel frequency response of each OFDM symbol. Use *interp1()* MATLAB function to interpolate the channel of the data carrier
5. Plot the channel you have estimated.
6. Perform frequency domain equalization on all subcarriers in each OFDM symbol. Plot constellation of the equalized symbols. Compare it with the constellation of the preamble symbols you obtained in step (2).
7. Extract the message symbols and convert them into bits, and detect the transmitted text message.
8. Repeat the procedure by using CP size which is significantly low compared to the required optimum CP size you calculated.

## *IV. EFFECT OF IMPAIRMENTS ON OFDM PERFORMANCE*

In this sections use the data files provided. The frame structure is same as the frame structure implemented in the MATLAB script in the previous sections (only OSR = 1 in this case). Based on that developyour code to synchronize and observe effects of the related impairments on the OFDM signal.

a) **Effect of the delay spread**: Use the captured signals with CP-lengths: 2, 4, and 8. Observe and comment on the plots. If no change on the plots, what would you expect in severe conditions of delay spread?

b) **Effect of Doppler Spread**: Use the signals with subcarrier spacings: 1 kHz, 5 kHz, and 15 kHz. Observe and comment on the plots. If no change on the plots, what would you expect in severe conditions of Doppler spread?

c) **Effect of number of active subcarrier:** Connect an LNA between the transmitter and transmitter antenna. Sweep following number of active subcarriers: 16, 32, and 48. Take snapshot for each. Observe and comment on the plots.