**İSTANBUL MEDİPOL UNIVERSITY**



**EECD1212913: DIGITAL COMMUNICATION LABORATORY**

**Lab report No. 8: OFDM**

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**Introduction**

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
3. should be inserted starting from 2nd data carrier and every 3rd carrier, i.e., Pilots bits.
4. goes as [1, 0, 1, 0…] on the indices [2, 5, 8…].
5. Modulate the output of step (2) into symbols using BPSK modulation.
6. 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).
7. For sections I and II, complete the MATLAB script to complete the given tasks.

***I.OFDM CHARACTERISTICS***

a. The PAPR for the generated OFDM symbols is 19.3229.

b. The spectrum and CCDF of the OFDM Signal using 48 active subcarriers are as plotted below

|  |  |
| --- | --- |
|  |  |
|  |  |

c. For the subcarrier number 32 the PAPR obtained was 18.5049, and we have the following plots for CCDF and spectrum

|  |  |
| --- | --- |
|  |  |
|  |  |

For the subcarrier number 16 the PAPR obtained was 12.5580, and we have the following plots for CCDF and spectrum

|  |  |
| --- | --- |
|  | A graph of a function  Description automatically generated |
|  |  |

***II.ENHANCING OFDM THROUGH BASEBAND OPERATIONS***

a) Implement an OOBE reduction technique (Transmitter windowing).

Observe and comment on theplots.

The following plots show the effect of transmitter windowing on Out Of Band Emission

|  |  |
| --- | --- |
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|  |  |
|  |  |
|  |  |

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

plots.

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| --- | --- |
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|  |  |

***III. OFDM TRANSMISSION AND RECEPTION***

**Transmission**

1. We generate and append the preamble at the beginning of the OFDM signal you have

generated. The preamble signal consists of two consecutive m-sequence symbols: *mseq(2,6)*.

1. We add guard intervals with 50 symbols at both ends of the signal obtained in the step above.
2. We apply rectangular filtering with the specified OSR
3. We then plot the output signal (Tx Frame)

The time domain transmission signal for different numbers of subcarriers are as plotted in the figure below.

|  |  |
| --- | --- |
|  |  |
| 48 Subcarriers | 36 Subcarriers |
|  |  |
| 16 Subcarriers |  |

**Channel**

1. Using the *channeling ()* function provided, we pass the Tx Frame 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, we plot the channel impulse response (CIR) (useing *waterfall* command) and the RX Frame.

|  |  |
| --- | --- |
|  |  |
|  |  |

**Receiver**

1. We pass the Rx Frame through the *synchronization ()* function provided.
2. Considering that the preamble portion of the signal is the single carrier, we estimate its average channel and equalize the synchronized preamble symbols. We then plot constellation.

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| --- | --- |
|  |  |
|  |  |

The estimated channel is plotted below

|  |  |
| --- | --- |
|  |  |
|  |  |

The received message is as shown in the figure below

|  |
| --- |
|  |

Leaving everything intact, we tried with a CP size of 1 and the results are as plotted

|  |  |
| --- | --- |
|  |  |
|  |  |

|  |  |
| --- | --- |
|  |  |
|  |  |

The received message is as shown in the figure below

|  |
| --- |
|  |

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

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

1. **Effect of the delay spread**: Using the captured signals with CP-lengths:2,

4, and 8. We observe

To get the effect of delay spread, we will run the code to get constellation for different CP length as deployed in figure below.

|  |  |
| --- | --- |
|  |  |
|  | 0.4875 |
|  |  |
|  | 0.3825 |
|  |  |
|  | 0.4900 |

**Effect of Doppler Spread**: Using the signals with subcarrier spacings: 1

kHz, 5 kHz, and 15 kHz. We plotted the resulting figures as follows:

|  |  |
| --- | --- |
|  |  |
|  | 0.4875 |
|  |  |
|  | 0.3825 |
|  |  |
|  | 0.4900 |
|  |  |
|  |  |

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

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