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PAPR Reduction using DFT Spreading with FEC for OFDM Systems

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Abstract: ***Now a days, the demand for multimedia Division Multiplexing (OFDM) is used for all 4G wireless communication systems due its large capacity to allow the number of subcarriers, high data rate and good coverage with high mobility. But the major problem of OFDM is its high peak to average power ratio (PAPR). The high PAPR increases the complexity of analog to digital (A/D) and digital to analog (D/A) converters and also reduces efficiency of radio frequency of high power amplifier. Thus OFDM is significantly affected by PAPR. The DFT spreading is one of the scheme to reduce PAPR problem. This thesis present the DFT spreading technique to reduce PAPR problem. The DFT provides better PAPR compared with clipping, clipping and filtering, SML and PTS. The PAPR reduction capability of this technique id demonstrated by presenting simulation results of PAPR.***

I. INTRODUCTION

Nowadays, the demand for multimedia data services has grown up rapidly. One of the most promising multicarrier systems, Orthogonal Frequency Division Multiplexing (OFDM) is basis for all 4G wireless communication systems due to its large capacity to allow the number of subcarriers, high data rate and ubiquitous coverage with high mobility [1]. It effectively combats the multipath fading channel and improves the bandwidth efficiency. At the same time, it also increases system capacity so as to provide a reliable transmission. OFDM uses the principles of Frequency Division Multiplexing (FDM) [2]. The basic principle of OFDM is to split a high-rate data stream into a number of lower rate streams that are transmitted simultaneously over a number of subcarriers [3]. These subcarriers are overlapped with each other. Inter-symbol interference (ISI) is eliminated almost completely by introducing a guard time in every OFDM symbol [3]. An OFDM signal consists of a number of independently modulated subcarriers, which can give a large peak to average power ratio and these subcarriers are mutually orthogonal that's why its name occur as orthogonal frequency division multiplexing[4]. Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier modulation technique. OFDM provides high bandwidth efficiency because the carriers are orthogonal to each other and multiple carriers share the data among themselves. The main advantage of this transmission technique is their robustness to channel fading in wireless communication environment. In OFDM encoding of digital data is done on multiple carrier frequencies. OFDM has developed into a popular scheme for wideband digital Communication, whether wireless or over copper wires, used in applications such as digital television and audio broadcasting, DSL broadband internet access, wireless networks, and 4G mobile communications. OFDM is essentially identical to coded OFDM (COFDM) and discrete multi-tone modulation (DMT). OFDM a large number of closely spaced orthogonal sub-carrier signals are used to carry data in OFDM. The data is divided into several parallel data streams or channels, one for each sub-carrier. Each sub-carrier is modulated with a conventional modulation scheme (such as quadrature amplitude modulation or phase-shift keying or QPSK) at a low symbol rate, maintaining total data rates similar to conventional single-carrier modulation schemes in the same bandwidth. The primary advantage of OFDM over single-carrier schemes is its ability to cope with severe channel conditions (for example, attenuation of high frequencies in a long copper wire, narrowband interference and frequency-selective fading due to multipath) without complex equalization filters. Channel equalization is simplified because OFDM may be viewed as using many slowly modulated narrowband signals rather than one rapidly modulated wideband signal. The low symbol rate makes the use of a guard interval between symbols affordable, making it possible to eliminate inter-symbol interference (ISI) and utilize echoes and time-spreading (that shows up as ghosting on analogue TV) to achieve a diversity gain, i.e. a signal-to-noise ratio improvement. This mechanism also facilitates the design of single frequency networks (SFNs), where several adjacent transmitters send the same signal simultaneously at the same frequency, as the signals from multiple distant transmitters may be combined constructively, rather than interfering as would typically occur in a traditional single-carrier system.

II. DIGITAL GENERATION OF SUBCARRIERS

As we have seen that, more trucks are used to transport the load, the fewer packets are going to be carried by each one, the easier it is for each truck to complete the journey, and the less load is going to be lost in case of an accident.

Then, it can be said that in an OFDM transmission a large number of subcarriers is desirable so that the minimum possible quantity of data is lost in case of any non-ideality occurring in the transmission channel.

However, creating an OFDM signal with a large number of subcarriers following the analogue method presented before leads to an extremely complex architecture involving many oscillators and filters at both the transmit and receive ends.

In present-day OFDM transmissions, though, this complexity is reduced by transferring it from the analogue to the digital domain. To see this, take Equation (2.1), where just one OFDM symbol of the signal s(t) is sampled at an interval of $T_{s/}N$ sec . Then, the n_{th} sample of s(t) becomes:

$$s(nT_s/N) = \sum_{k=0}^{N-1} c_k e^{\frac{j2\pi f_k nT_s}{N}} = \sum_{k=0}^{N-1} c_k e^{\frac{j2\pi kn}{N}} = \mathcal{F}^{-1}\{c_k\}$$

(2.1)

Where Ƒ is the Fourier transform, and n € [1, N]. Thus, it can be said that the discrete value of the transmitted OFDM signal s(t) is merely a simple N-point inverse discrete Fourier transform (IDFT) of the information symbol . The same case can be applied at the receiver, where the received information symbol will be a simple N-point discrete Fourier transform (DFT) of the received sampled signal.

This superposition of independent modulated subcarriers is typically performed by the inverse fast Fourier transform (IFFT) where the input channels are spaced equivalently. In fact, IFFT/FFT blocks in an OFDM system are mathematically equivalent versions of an IDFT and a DFT of the transmitted and received OFDM signal, with the advantage of providing lower computational implementation.

Because of the orthogonality property, as long as the channel is linear, the OFDM receiver will calculate the spectrum values at those points corresponding to the maximum of individual subcarriers.

Then, the received subcarriers can be demodulated through an FFT operation without interference and without the need for analogue filtering to separate them, which makes OFDM not only efficient but also easy to implement in practical transmission systems.

Hence, it can be said that the modulated OFDM signal can be obtained by performing the IFFT operation to the symbols to transmit and then using a DAC to convert the digital signal into an analogue signal at a sampling rate A practical extension is a raised cosine characteristic fitted to the ideal low-pass filter, which is a commonly used pulse shape in OFDM. Its transfer function is given by expression 2.2:

$$For\ 0 \le |f| \le \frac{1-\alpha}{2T_s} \rightarrow G(f) = 1$$

$$For\ \frac{(1-\alpha)}{2T_s} \le |f| \le \frac{(1+\alpha)}{2T_s} \rightarrow G(f) = 0.5 \cdot \left(1 - sin\left[\left(\frac{\pi T_s}{\alpha}\right) \cdot \left(|f| - \frac{1}{2T_s}\right)\right]\right)$$

(2.2)

Here, Ts is the symbol period and α is the roll-off factor, defined as the ratio of excess bandwidth above. When α = 1 the bandwidth is doubled over the bandwidth when α = 0. The impulse response of the raised cosine filter used in VPI for α = 0 and α = 0.5 is shown in figure 2.1 Note that the length is reduced at the expense of increased bandwidth.

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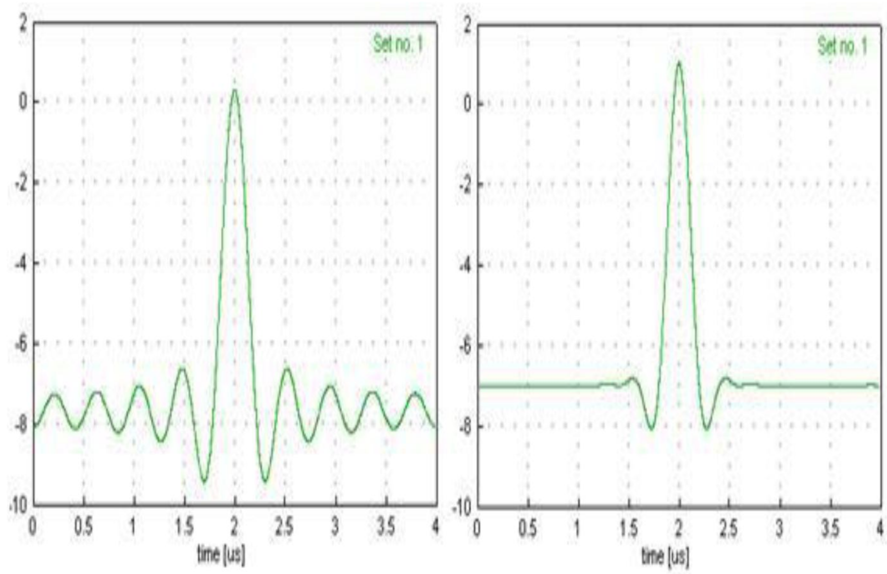

Fig. 2.1 Impulse response for the raised cosine for α = 0 and α = 0.5 [39]

III. PROPOSED SCHEME

This work proposed a scheme for PAPR reduction using Discrete Fourier Transformation. Before discussing the DFT-transformation technique, let us consider OFDMA (Orthogonal Frequency-Division Multiple Access) system. As depicted in Figure drawn below, suppose that DFT of the same size as IFFT is used as a (spreading) code. Then, the OFDMA system becomes equivalent to the Single Carrier FDMA (SC-FDMA) system because the DFT and IDFT operations virtually cancel each other [195]. In this case, the transmit signal will have the same PAPR as in a single-carrier system.

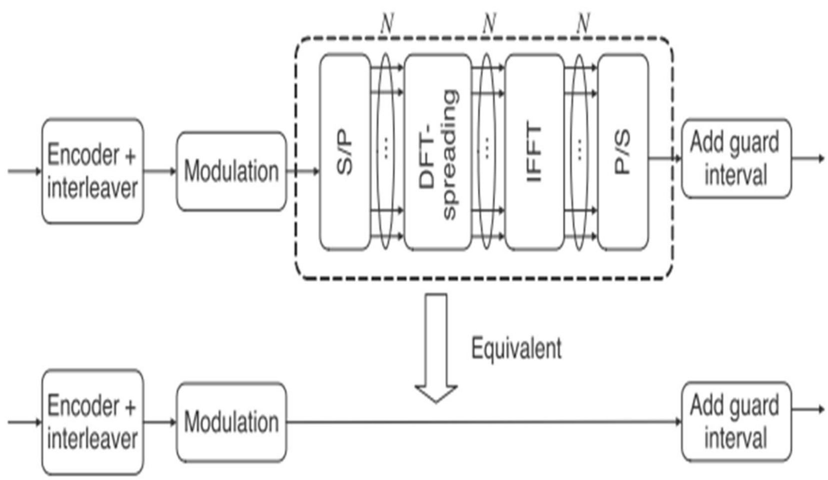

Fig.3.1 Orthogonal Frequency Division Multiple Access Technique

In OFDMA systems, subcarriers are partitioned and assigned to multiple mobile terminals (users). Unlike the downlink transmission, each terminal in uplink uses a subset of subcarriers to transmit its own data. The rest of the subcarriers, not used for its own data transmission, will be filled with zeros. Here, it will be assumed that the number of subcarriers allocated to each user is M. In the DFT-spreading technique, M -point DFT is used for spreading, and the output of DFT is assigned to the subcarriers of IFFT. The effect of PAPR reduction depends on the way of assigning the subcarriers to each terminal. As depicted in Figure drawn below, there are two different approaches of assigning subcarriers among users: DFDMA (Distributed FDMA) and LFDMA (Localized FDMA). Here, DFDMA distributes M DFT outputs over the entire band (of total N subcarriers) with zeros filled in N-M unused subcarriers, whereas LFDMA allocates DFT outputs to M consecutive subcarriers in N subcarriers. When DFDMA distributes DFT outputs with equi-distance N=M, it is referred to as IFDMA (Interleaved Frequency Division Multiplexing).

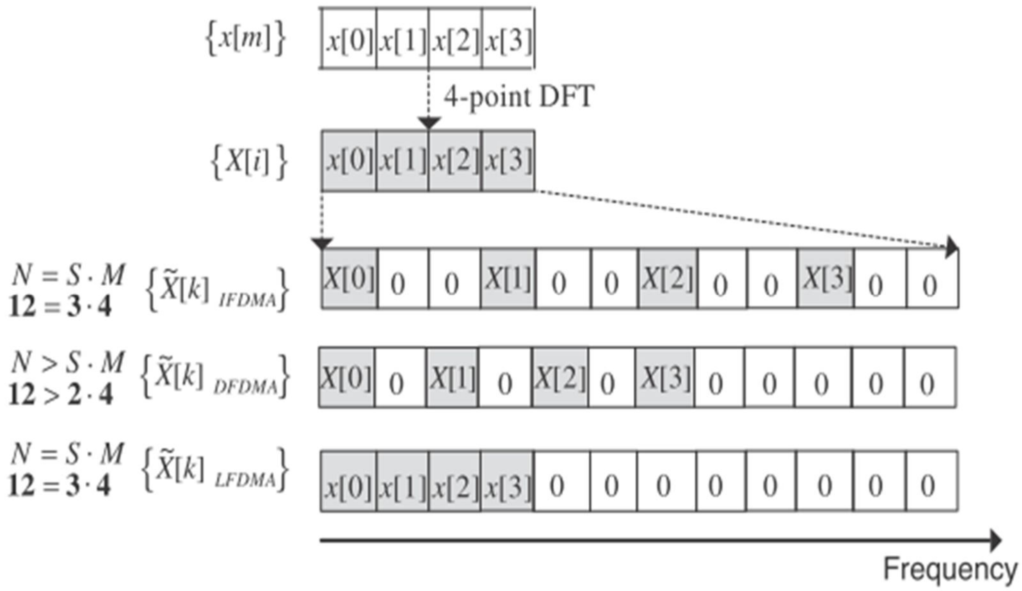

Fig.3.2. Examples of DFT for IFDMA, DFDMA and LFDMA: three users with N =12 ; M = 4, and S = 3.

Figure drawn below shows a block diagram of the uplink transmitter with the DFT-spreading technique that employs IFDMA. Here, the input data x[m] is DFT-spread to generate X[i] and then, allocated as

$$\tilde{X}[k] = \begin{cases} X[k/S], & k = S \cdot m_1, \quad m_1 = 0, 1, 2, \cdots, M-1 \\ 0, & \text{otherwise} \end{cases}$$

IV. IMPLEMENTATION AND ALGORITHM DEVELOPED

The basic block diagram of OFDM system which is incorporated in the carried out work is shown below in diagram:

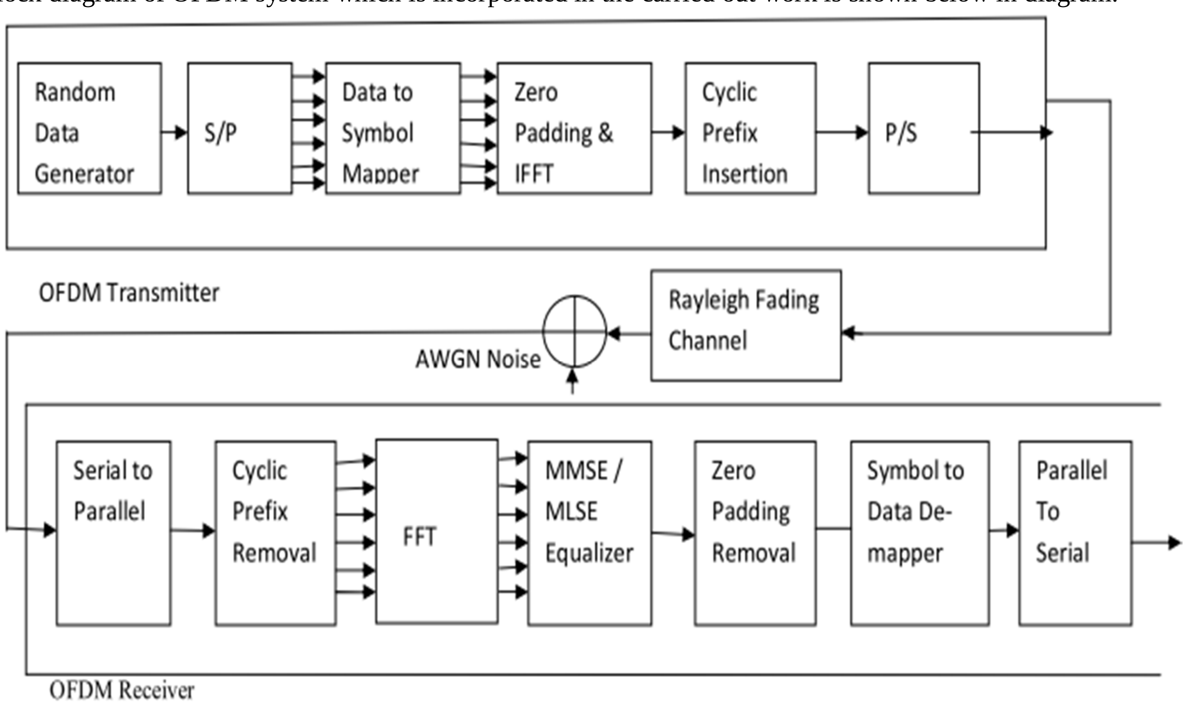

Fig 4.1 Block diagram of OFDM system

A. Random Data Generation and S/P:

To start the operation of OFDM system, we first need some data values that is to be used as a incoming signal to OFDM transmitter. Matlab helps us in this way by providing function randint to generate data. So the data can be generated in the following ways:

out = randint(m)

the above command generates an m-by-m binary matrix, each of whose entries independently takes the value 0 with probability 1/2.

```
Command Window
>> randint(5)

ans =

     1     1     1     1     1
     0     1     1     0     1
     0     0     1     1     1
     0     1     1     1     1
     1     0     0     0     1

>>
```

Fig 4.2 Randomly generated Data

B. Data to Symbol Mapper

Quadrature Amplitude Modulation is done to map the data into symbol, the syntax used in this way can be written as:

M=16 ;

y=modulate(modem.qammod(M),out);

```
>> y=modulate(modem.qammod(16),x);
>> y=modulate(modem.qammod(16),x)

y =

  Columns 1 through 4

  -3.0000 + 3.0000i  -3.0000 + 1.0000i  -3.0000 + 3.0000i  -3.0000 + 3.0000i
  -3.0000 + 1.0000i  -3.0000 + 3.0000i  -3.0000 + 3.0000i  -3.0000 + 3.0000i
  -3.0000 + 1.0000i  -3.0000 + 1.0000i  -3.0000 + 1.0000i  -3.0000 + 1.0000i
  -3.0000 + 3.0000i  -3.0000 + 3.0000i  -3.0000 + 3.0000i  -3.0000 + 3.0000i
  -3.0000 + 3.0000i  -3.0000 + 3.0000i  -3.0000 + 1.0000i  -3.0000 + 1.0000i

  Column 5

  -3.0000 + 1.0000i
  -3.0000 + 1.0000i
  -3.0000 + 3.0000i
  -3.0000 + 1.0000i
  -3.0000 + 3.0000i

>>
```

Fig 4.3 QAM using MATLAB at Command Window

1) The basic aim of our work is to reduce the Peak to Average Power approx. to 'Zero', and efficient channel estimation.
2) We are trying to improve the signal-to-noise ratio in the proposed algorithm, with much better channel estimation technique.
3) The OFDM technology we changed was designed by 16/ 32-QAM mapping for BER reduction and 32/ 128-points FFT/IFFT blocks.
4) Implementation of the above OFDM transceiver designed for BER reduction carried out over MATLAB 7.8.0.
   Implementation details are as follows:
5) We randomly generate the data using "randint" function provided in MATLAB for the random generation of data.
6) Encoding of data is carried out by "Trellis Encoding", we have done it also using space time trellis code.
7) Insert the Interleaving Bits by using "matintrlv" function
8) QAM modulation is done of 32 QAM.
9) After the cyclic prefix inserted data, we designed a channel for transmission, channel is prepared using "awgn" function.
10) At the receiver side for the decoding purpose *"Viterbi Detector* " is used
11) Bit Erro Rate is calculated using the formula: BER = Error Bits / Length of Data .

V. RESULTS

This Chapter deals with the results of work done in the dissertation. From signal generation to channel estimation result and comparison with previous one has presented in this chapter. Simulation parameter that has been used in this dissertation is shown below:

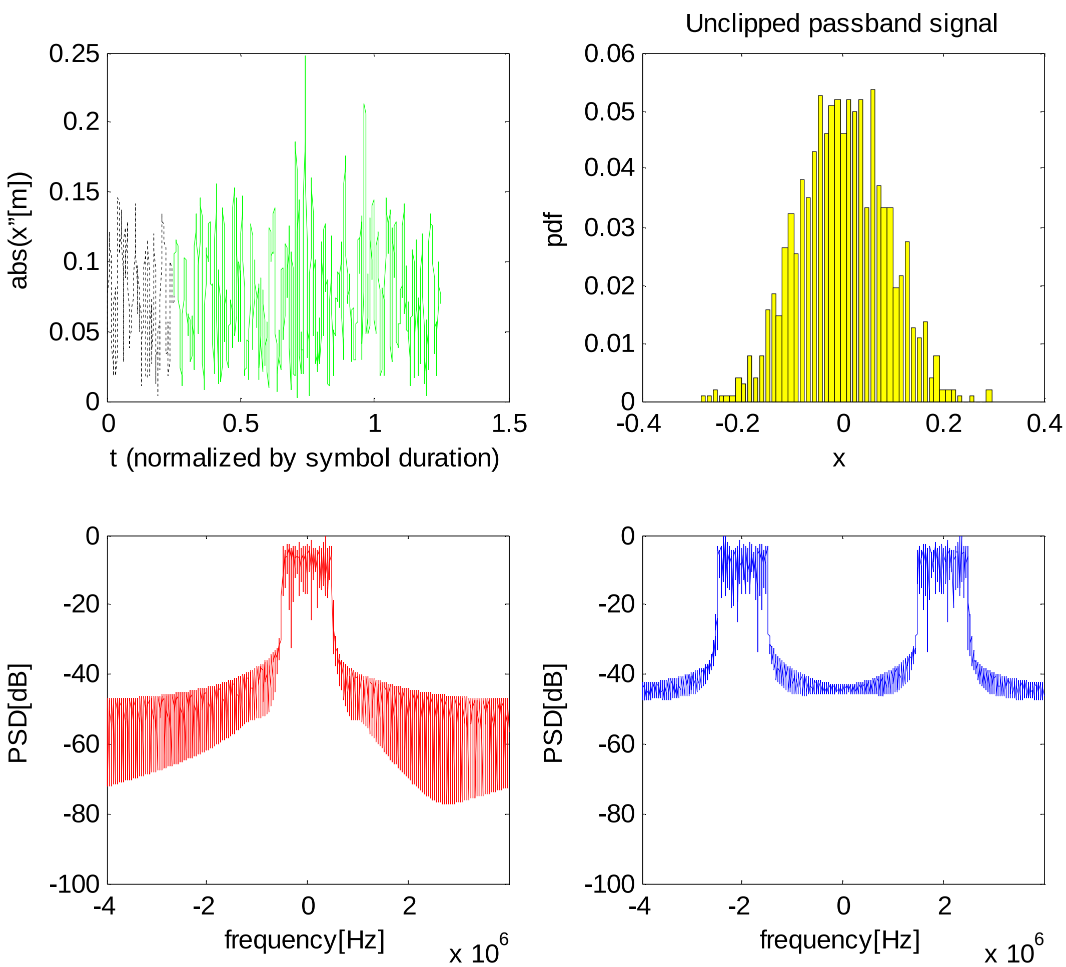

Fig 5.1 Output for Clipping and Filtering Technique

A. Tabular results

S.No.	Method	Name of Method	PAPR
1	First	Clipping-Filtering	0.6474

VI. CONCLUSION

A. We presented an architecture of OFDM with the help of 32-QAM and 128-IFFT/FFT which can easily reduce the PAPR and improves the performance of Signal-to-Noise Ratio.
B. Reduction in PAPR found to be satisfactory when compared with previous work
C. In our results it can be seen that as Signal-to-Noise Ratio increases the Bit Error Rate (BER) decreases.

VII. FUTURE SCOPE

A. In future the process can be followed by increasing the OFDM subcarriers.
B. One of the biggest demerit of OFDM PAPR can be Improved.
C. This work can be implemented in VHDL and burn into an FPGA.
D. Proposed for 802.16 standard Connection between subscriber's transceiver station and a base transceiver station.
E. For the future works, it is suggested to develop other modules such as interleaving, error correction, QAM or QPSK modulation, cyclic prefix module and RF part. These modules will make a complete set of OFDM system for transmitter and receiver.
F. Some extra functions could be added to the system like for example, configure a MIMO (multiple-input multiple-output) system, or adding other functions to make more robust the system, like for example adding a puncturer or an interleaver.
G. Possibility to add some functions to calculate some signal parameters like BER and PAPR.
H. Performance of MMSE equalizer with FFT can be done to judge the performance of OFDM under such a condition.

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