# PAPR Reduction using FFT Spreading with FEC for OFDM Systems

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***Abstract:*** **The next generation of mobile communication is based on OFDM technology. It is an efficient method of data transmission for high speed communication system. Orthogonal frequency division multiplexing (OFDM) systems have been proposed in the recent past years for providing high spectral efficiency, less vulnerability to echoes, low implementation complexity and resistance to non linear distortion .However the main drawback of OFDM system is high peak to average power ratio (PAPR) of transmitted signals due to inter-symbol interference between the subcarriers as a result the amplitude of such a signal can have high peak values. Thus a power amplifier must be carefully manufactured to have a linear input output characteristics or to have large input output back-off. Drawback of high PAPR is that dynamic range of power amplifier and Digital to Analog (D/A) converter during the transmission and reception of the signal is higher. As a result total cost of transceiver increases with reduced efficiency. Fast Fourier Transform (FFT) Spreading is one of the advantage over Discrete Fourier Transform (DFT) schemes, to boost the system performance for orthogonal frequency division multiplexing(OFDM) communication system which is faster than the DFT spread to reduce the PAPR problem in OFDM system by using different subcarrier mapping schemes. The system performances are usually measured by the unit of bit error rate. For 256 QAM the highest communication length will be achieved at the forward error control (FEC) limit.**

***Keywords:*** **OFDM, Peak to average power ratio (PAPR), Discrete Fourier Transform (DFT), FFT, IFDMA, DFDMA, LFDMA, FEC, Viterbi decoding.**

## I. INTRODUCTION

Nowadays, the demand for multimedia data services has grown up rapidly. One of the most promising multi-carrier 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]. OFDM is a combination of modulation and multiplexing. OFDM is a multicarrier system which uses Discrete Fourier Transform (DFT) or Fast Fourier Transform (FFT) [5].

However, one downside of OFDM is peak-to-average power magnitude relation (PAPR). PAPR causes directly nonlinear drawback in communication system. There are several researchers from several institutes are projected strategies to cut back such result [6]. One among the powerful strategies is discrete Fourier transform spread (DFT-spread). However, DFT-spread methodology raises further noise as a result of the DFT calculation conjointly spreads the noise through all the subcarrier so we are using FFT-spread to reduce the DFT calculation.

In order to reduce the PAPR in OFDM systems, there are several techniques developed such as Clipping and Filtering, Selected Mapping (SLM), Partial Transmit Sequence (PTS), Interleaving Technique, Tone Reservation (TR), Tone Injection (TI), Peak Windowing, DFT Spreading [7]. However, all of the above methods have some limitations. In this paper, we propose a PAPR reduction technique using modified DFT Spreading technique with FEC coding. This paper is organized as follows: In section II, Implementation of FFT spread, proposed method is explained in section III. Simulation results and discussions are given in section IV. Finally we will conclude in section V.

## II. IMPLEMENTATION OF FFT-SPREAD

The advantage of FFT spread is to reduce PAPR as well as it increases the computational speed compared to DFT spread.

### *A. PAPR Reduced by FFT-Spread*

The main thought of FFT-spread OFDM is that it transmits OFDM-like signal in single-carrier communication (SCC). Therefore, the PAPR is reduced to SCC. Fig. 1(a) and 1(b) show the main points of FFT-spread encoder and decoder. The From Fig. 1(a) and 1(b), those are equivalence to standard OFDM except that the additional IDFT and FFT operation wherever the FFT is found before Inverse fast Fourier

Transformation (IFFT) unit at the transmitter half and IFFT is found after the FFT unit at the receiver part. As you'll be able to see, the M-ary signal will be converted to frequency domain by using the FFT unit; and so once taking IFFT the signal will be during a virtual frequency domain. This is often known as single carrier OFDM (SC-OFDM) .In general, the PAPR is denoted by

$$PAPR = \frac{\max\left(|s(t)|^2\right)}{mean\left(|s(t)|^2\right)}$$

(s (t) is OFDM signal in time domain

As given in fig.4 the subcarriers can be assigned among the users in two different ways: DFDMA (Distributed FDMA) and LFDMA (Localized FDMA).

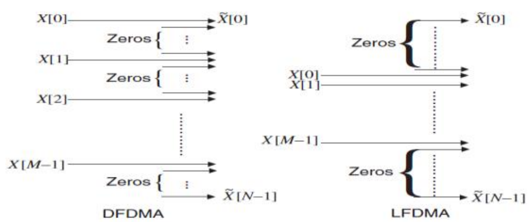



Fig.. Subcarrier mapping in OFDMA system: DFDMA and LFDMA

In fig.4. DFDMA distributes M DFT outputs over the entire band (of total N subcarriers) with zeros filled in (N-M) unused subcarriers. LFDMA allocates DFT outputs to M consecutive subcarriers in N subcarriers. When DFDMA distributes DFT outputs with equi-distance N/M=S, it is referred to as IFDMA (Interleaved FDMA) where S is called the bandwidth spreading factor.

Here, the input data x[m] is DFT-spread to generate X[i] and then allocated as:

$$\tilde{x}[k] = X\left[\frac{k}{S}\right], k = S.m1, m1 = 0,1,2, \ldots\ldots, M-1$$

$$0 \quad , \text{otherwise}$$

The IFFT output sequence $\tilde{x}[n]$with n=M. s+ m for s=0,1,2,......., S-1 and m =0,1,2, ......, M-1 can be expressed as

$$\tilde{x}[n] = \frac{1}{N}\sum_{k=0}^{N-1}\tilde{X}[k]e^{j2\pi\frac{n}{N}k}$$

$$= \frac{1}{S}\frac{1}{M}\sum_{m1=0}^{M-1}X\,[m1]e^{j2\pi\frac{n}{M}m1}$$

$$= \frac{1}{S}\cdot\frac{1}{M}\sum_{m1=0}^{M-1}X[m1]e^{j2\pi\frac{MS+m}{M}m1}$$

$$= \frac{1}{S}.x[m]$$

Here the repetition of the original input signal x[m] scaled by 1/S in the time domain occurs.

Similarly, if the subcarrier mapping starts with the rth subcarrier (r=0, 1, 2, 3, ........, S-1) in IFDMA, then the IFFT output-sequence, $\{\tilde{x}[n]\}$ is given by $\frac{1}{S}e^{j2\pi\frac{n}{N}r}.x[m]$ i.e. there is a phase rotation of $e^{j2\pi\frac{nr}{N}}$ in IFDMA.

However, the PAPR impact is usually measured by complementary cumulative distribution function (CCDF). Fig.2 two plots the simulation of CCDF for FFT-spread OFDM wherever the M-ary QAM is varied from 16-, 64-, and 256-QAM. The FFT size is 16,256, 1024 point.

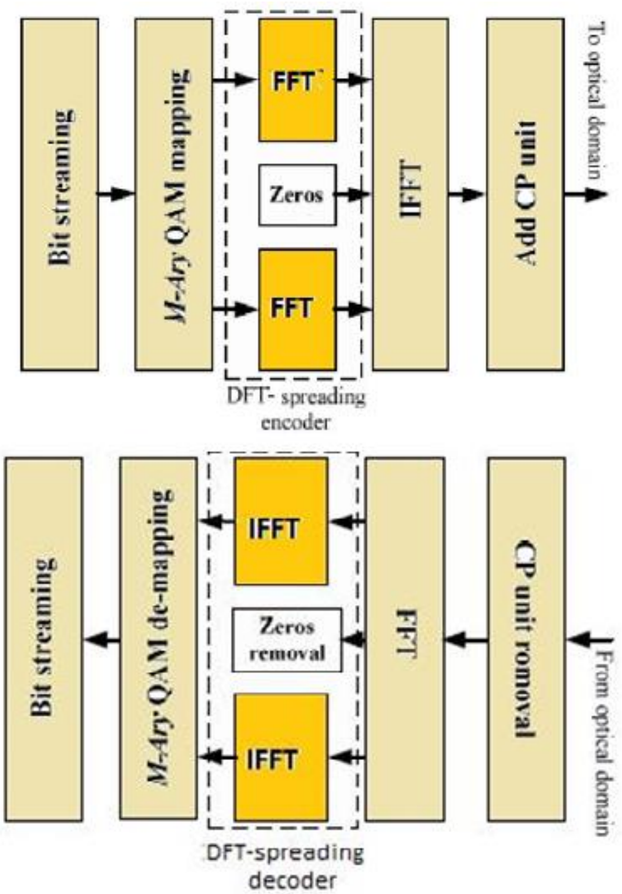



Fig.1. The concept of FFT-spread OFDM (a) transmitter (b) receiver.

*B. Brief overview of the OFDM*

In FFT- spread, also called single carrier (SC) FDMA, could be a multiple access technique that is based on the single carrier frequency-division multiplexing (SC-FDM) modulation technique. Its operation relies on the principle of OFDM. Therefore all the advantages in terms of multipath mitigation and low-complexity equalization are achieved. however FFT-spread differs from OFDM as FFT operation is performed before the IDFT operation leading to spreading of the information symbols over entire subcarriers and ends up in a virtual single- carrier structure as shown in Fig.3. The key advantage of FFT- spreading has a lower PAPR than OFDM system. The lower price of PAPR makes it a horny candidate for uplink transmissions, because it offers the benefit of transmitted power efficiency. It also permits the frequency selectivity of the channel as all symbols are gift altogether subcarriers. Info will still be recovered from alternative subcarriers experiencing higher channel conditions if a specific subcarrier is deeply faded. It suffers from the disadvantage of noise enhancement as noise is spread over all the subcarriers once FFT de-spreading is finished at the receiver.

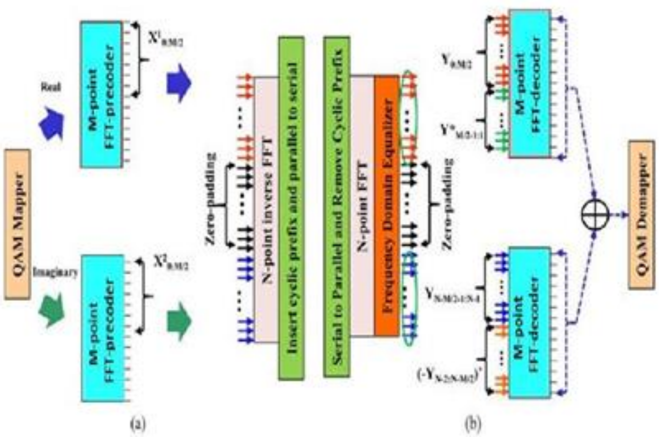



Fig.2. (a) Transmitter operation (b) Receiver operation.

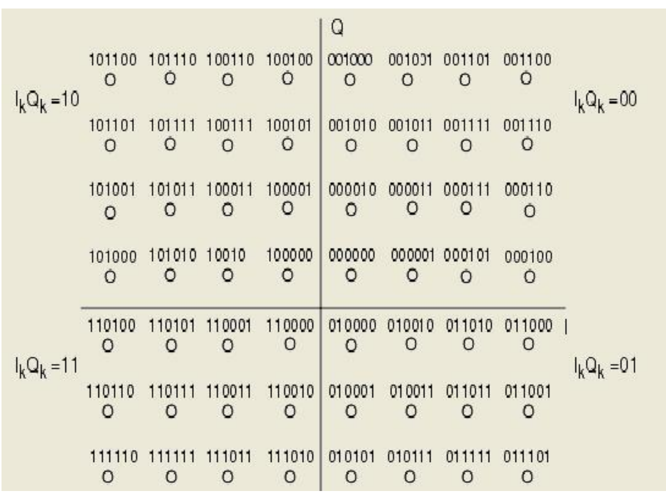



Fig.3. 64 QAM constellation diagram.

## III. PROPOSED METHOD

### *FORWARD ERROR CORRECTION (FEC)*

FEC technique allows automatic correction of errors. This method incorporates convolutional encoding with viterbi decoding. The performance of FEC technique is characterized for an AWGN channel. Convolutional encoding is one way of performing channel coding in the transmitter where as in the receiver; Viterbi decoding is a way of performing channel decoding. A convolutional encoder accepts a sequence of message symbols and produces a sequence of code symbols.

In Viterbi decoding, the Viterbi decoder examines an entire received sequence of a given length. The decoder computes a metric for each path and makes a decision based on this metric. When two paths coverage on one node, only one survivor path is chosen based on a decision. This decision can be achieved in two ways, resulting in the following two types of Viterbi decoding:

1. Hard decision Viterbi decoding
2. Soft decision Viterbi decoding

***Hard Decision Viterbi Decoding:** It is also referred to as the soft input Viterbi decoding technique; this uses a path metric called the Hamming Distance metric, to determine the survivor paths as we move through the trellis. Hard decision Viterbi decoding makes use of the maximum hamming distance in order to determine the output of the decoder.

The working of the Hard decision Viterbi decoder almost follows the same principle as that of the Soft decision Viterbi decoder. The only difference is that of the calculation of the path metrics. Here in this paper we have used Hard decision Viterbi decoding.

## IV. SIMULATION RESULTS

In the following simulation results, we compared LFDMA and IFDMA with OFDMA and their performance in PAPR reduction. Below figure shows the performance of PAPR with different no of subcarriers and different modulation techniques like 16 QAM, 64 QAM and 256 QAM.

| Figure number | No of subcarrier | No of symbol | PAPR of OFDMA in dB | | | PAPR of SC-FDMA in dB | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | LFDMA | | | IFDMA | | |
| | | | 16 QAM | 64 QAM | 256 QAM | 16 QAM | 64 QAM | 256 QAM | 16 QAM | 64 QAM | 256 QAM |
| 4(a) | 64 | 64 | 11.6 | 10.8 | 11.2 | 3.6 | 4.8 | 5.4 | 3.8 | 4.8 | 5.2 |
| 4(b) | 256 | 64 | 11 | 10.6 | 10.8 | 8.2 | 8.2 | 9.2 | 3.4 | 4.6 | 5.2 |
| 4(c) | 1024 | 64 | 12.4 | 12.2 | 12 | 9.2 | 9 | 8.8 | 3.6 | 5 | 5.2 |

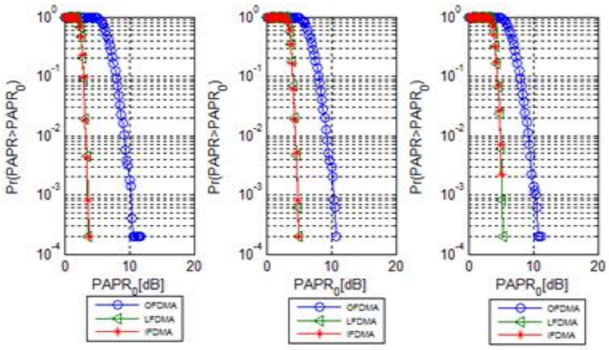



FIG 4(a)

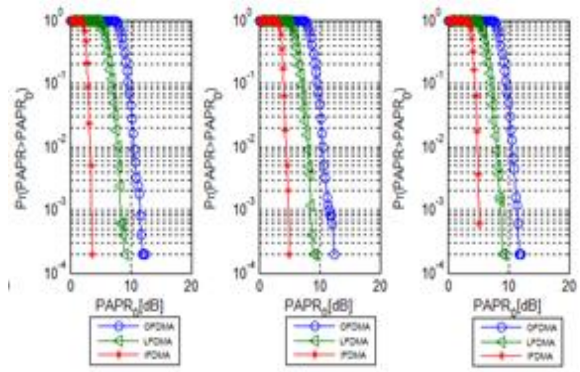



FIG 4(c)

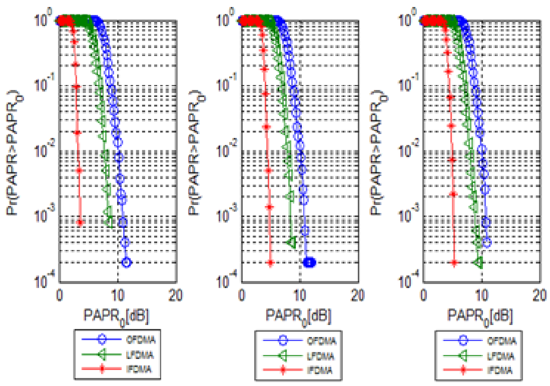
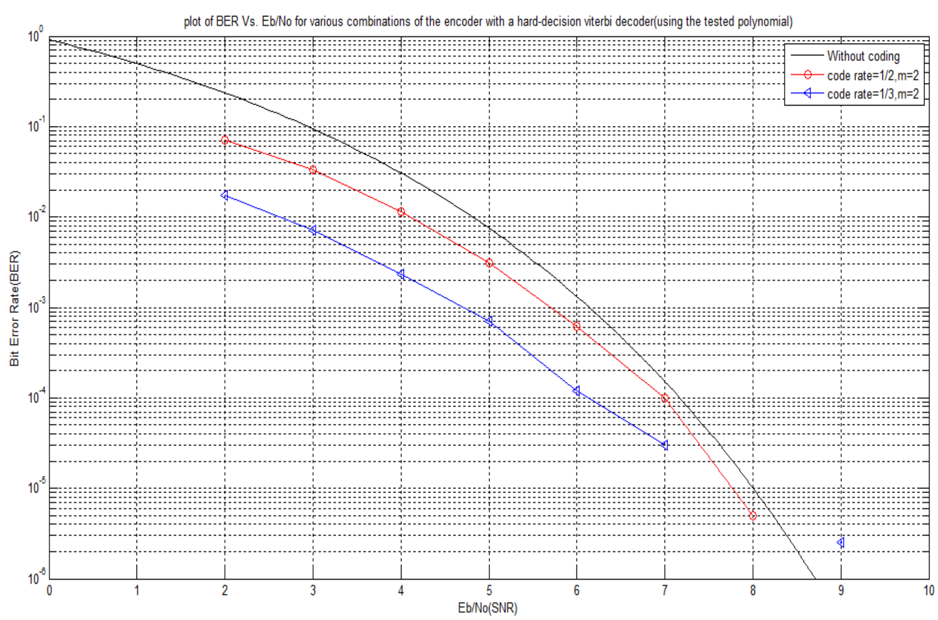



FIG 4(b)

The analysis of FFT spreading with FEC coding has been done using MATLAB. The simulation parameters considered for this analysis is summarized in table

Table- Simulation Parameters

| Sl.No | Parameters | Value |
|---|---|---|
| 1 | FFT size | 64 |
| 2 | Length of cyclic prefix | 16 |
| 3 | Modulation | QAM |
| 4 | SNR Range | 2-10 dB |
| 5 | FEC Code | Convolution codingwith viterbi decoding |
| 6 | FFT technique | Code rate ½ and 1/3 with m=2 |




BER performance is improving for higher values of SNR

The graphs indicate that performance is improving using DFT spreading with FEC coding. Almost 3db gain is achieved. With decrease in code rate the bit error rate (BER) performance is better.

## V. CONCLUSION

OFDM systems have generic problem of high PAPR. Drawback of high PAPR is dynamic range of power amplifier and D/A convertor which increases its cost. Hence we apply reduction techniques to reduce PAPR. This paper analyzed DFT spreading technique with FEC coding. For 64-QAM, The system performance includes a significant improvement once FEC is applied. We proved that FFT spread reduces PAPR as well as it increases the computational speed and reduces the multiplication and addition compared to DFT spread. Since DFT Spreading is distortion technique and degrades bit error rate performance of system. But by using FEC coding with FFT spreading, this approach not only reducing the PAPR of the OFDM system but also improving the BER performance.

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