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PAPR REDUCTION & BER PERFORMANCE OF OFDM USING CONVOLUTIONAL CODE SELECTION

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ABSTRACT

In this paper we have suggested the use of certain convolutional codes that not only provide error correction capability but also achieve PAPR reduction when used in an OFDM system. Choice of convolutional codes, however, produces delay due to the introduction of the registers for generation of polynomials. Three different tap configurations are checked for this purpose, that are, [171 133], [175 131] and [111 123]. Moreover, the BER performance of all the three tap configurations is analyzed in AWGN channel using BPSK modulation.

KEYWORDS: Orthogonal Frequency Division Multiplexing (OFDM);Peak to Average Power Ratio (PAPR);Convolutional Codes;Bit Error Rate (BER);Signal To Noise Ratio(SNR)

INTRODUCTION

Today's modern world is going to introduce high data rates technologies with reliable transmission system. The increasing demand on high data rates and reliable wireless system has led to many new emerging modulation techniques. Orthogonal Frequency Division Multiplexing (OFDM) is a form of multicarrier modulation that can be seen either as modulation technique or a multiplexing scheme. In OFDM, the digital data is sent by using a large number of narrow-band sub carriers, each of a different frequency and these sub carriers are regularly spaced in frequency, forming a block of spectrum. The frequency spacing and time synchronization of the sub carriers is chosen in such a way that the sub carriers are orthogonal, hence known as Orthogonal Frequency Division Multiplexing, meaning that they do not cause interference to one another. This is despite the sub carriers overlapping each other in the frequency domain.

Even though OFDM has a number of advantages, it has a potential drawback of high peak to average power ratio (PAPR). This high peak to average power ratio causes nonlinearities in the transmitted signal and also degrades the power efficiency of the system. In order to reduce PAPR problem many researcher have made efforts and a large variety of different PAPR reduction approaches are proposed. In this research work we try to reduce PAPR by using Error Correcting Code (ECC) technique. OFDM is considered as a very promising candidate for future mobile communication systems. At present, OFDM is a widely used communication technique in broadband access applications requiring high data rates. It is already used in different mobile technologies like (WiMAX, 3GPP LTE, 3GPP2 UMB), WLAN standards, ADSL and Digital Video Broadcasting (DVB).

BACKGROUND LITERATURE ON PAPR ISSUE OF OFDM

The success behind the implementation of OFDM system is that, it is more robust to multipath induced Inter Symbol Interferences (ISI) and has high spectral efficiency. Despite these advantages, OFDM has some disadvantages that need to be addressed for its successful implementation. A major disadvantage of OFDM is that it generates signals with large amplitude variation which is known as Peak to Average Power Ratio (PAPR). The Peak to Average power Ratio can be simply defined as the ratio between the average signal power and the maximum or minimum signal. As we know that basic cause of a high PAPR in the OFDM signal is the Gaussian signal distribution which arises due to the large number of sub channels and their linear combination due to the IFFT operation. Now we will look at the mathematical definition of PAPR. Mathematically, the PAPR for a given OFDM block can be written as

$$PAPR(x[n]) = \frac{\max\limits_{0 \le n \le N-1} \left| x[n] \right|^2}{E\left\{ x^2[n] \right\}} \tag{1}$$

Where $\max\limits_{0 \le n \le N-1} \left| x[n] \right|^2$ denotes the maximum instantaneous power and $E\left\{ x^2[n] \right\}$ denotes the average power of the signal.

The peak level before and after the addition of the cyclic prefix will be same because the cyclic prefix is just a copy of a part of the original signal block. The peak power of the symbol will be the same and the average power of the symbol will not change either. This PAPR definition is also denoted as block or symbol PAPR. In opposite to that we can also define the sample PAPR as:

$$PAPR(x[n_k]) = \frac{\left| x[n_k] \right|^2}{E\left\{ x^2[n] \right\}} \tag{2}$$

Where $\left| x[n_k] \right|^2$ represents the instantaneous power of the sample *k* and $E\left\{ x^2[n] \right\}$ denotes average power of the OFDM block.

High PAPR values result degradation of system performance by reducing the efficiency of the high power amplifier and also limits the dynamic range of Analog-to-Digital (A/D) and Digital-to-Analog (D/A) converters. These negative effects may outweigh all the potential benefits of OFDM transmission system in many low-cost applications.

METHODOLOGY

To transmit a signal that has high peaks require from the power amplifier in the transmitter to have a high signal span. Such amplifier consumes high power and is also costly. If we lower the average power of the signal then this will also lower the peaks that a power amplifier needs to handle. However reducing the average power of the signal will reduce the SNR at the receiver thus degrading performance. If we do not lower the average power of amplifier input signal but we do not allow large peaks to pass through the amplifier, this will introduce nonlinearities into the transmitted OFDM signal. So in order to overcome the problem of high Peak to Average Power Ratio we have two solutions, Amplifier Linearization and PAPR Reduction. The amplifier linearization method is very much costly and high power consuming method because to achieve the linearlized operation the use of High Power Amplifier is required which require high power to operate however several PAPR signal distortion and signal distortion less reduction techniques have been proposed during the last decades with different levels of success and complexity.

The main idea behind this research is the use of block coding technique especially convolutional codes which is signal distortion less technique, not only for achieving high data rates with excellent quality of services but also for reducing Peak-to-Average Power Ratio (PAPR). Convolutional codes were designed in such away so that decoding can be performed in some structured and simplified way. These codes belong to the class of linear codes, which accepts a fixed number of message symbols and produces a fixed number of code symbols its computations depend not only on the current set of input symbols but on some of the previous input symbols. We select those code words for encoding from series of convolutional codes whose Peak-to-Average Power is low. With usage of these low PAPR code words from convolutional codes, high peak values in OFDM which are result from the superposition of a large number of usually statistically independent subchannels/sub carriers that can constructively sum up to high peaks will reduce.

An OFDM system is simulated here for calculating the peak to average power ratio (PAPR) of OFDM signal with and without coding, and also made to analyze the effect of coding on OFDM system’s Bit Error Rate (BER) performance. We take the FFT size of 128 and the number of subcarriers to carry data equals to the size of FFT. However the number of OFDM symbols transmitted on each carrier is 1. Random data is generated with a length equal to the product of number of OFDM symbols and number of data subcarriers. Convolutional codes are employed for coding the random data with a constant constraint length of 7 with 3 different tap connections. The code rate of ½ is also constant in all the simulations where as modulation technique used in these simulations is BPSK. The modulated data is then mapped onto the subcarriers and IFFT is taken. Then we calculate the PAPR of OFDM signal. For analysis of the effect of coding with different tap connections BER is also calculated at the OFDM receiver. After passing OFDM signal through AWGN channel, the signal is received at receiver and reverse operations are performed on received signal.

SIMULATION RESULTS

PAPR with Different Tap Connections

The following simulation results illustrate the effect of implementing convolutional codes on PAPR. The convolutional codes used have the same constraint length but different tap connections. The following four cases discuss PAPR reduction and BER performance of coded OFDM system with different tap connections.

PAPR with Tap Connections [175 131]

In figure 1 CDF plot of PAPR with tap connections [175 131] is shown. This figure shows that the PAPR of uncoded OFDM signal will be at its minimum value 9 dB with least probability. With the highest probability i.e. 1, the maximum PAPR of the uncoded signal is 9.5424 dB. Now the PAPR values obtained by employing the convolutional coding with tap connections [175 131]. The PAPR of coded OFDM signal will be reduced due to coding to a minimum level of 5.0 dB with the least probability. With the highest probability i.e. 1, the maximum PAPR of the coded signal is 5.6349 dB. This graph clearly illustrates the reduction of the PAPR due to the implementation of the convolutional codes. The differences achieved in the power levels with tap connections [175 131] are up to 3.9075 dB which is a significant amount of reduction achieved.

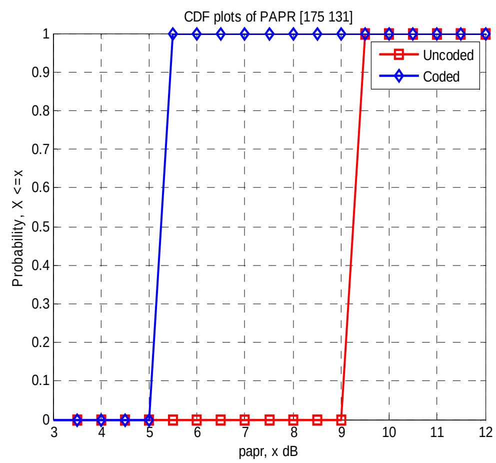

Figure 1: CDF Plot of PAPR with Tap Connections [175 131]

PAPR with Tap Connections [171 133]

In figure 2 CDF plot of PAPR with tap connections [171 133] is shown. This figure shows that the PAPR of uncoded OFDM signal will be at its minimum value i.e. 9 dB with least probability. With the highest probability i.e. 1, the maximum PAPR of the uncoded signal is 9.5424 dB. Now the PAPR values obtained by employing the convolutional codes with tap connections [171 133]. The PAPR of coded OFDM signal will be reduced due to coding to a minimum level of 4.5 dB with the least probability. With the highest probability i.e. 1, the maximum PAPR of the coded signal is 5.0815 dB. The differences achieved in the power levels with tap connections [171 133] are up to 4.4609 dB which is a significant amount of reduction achieved.

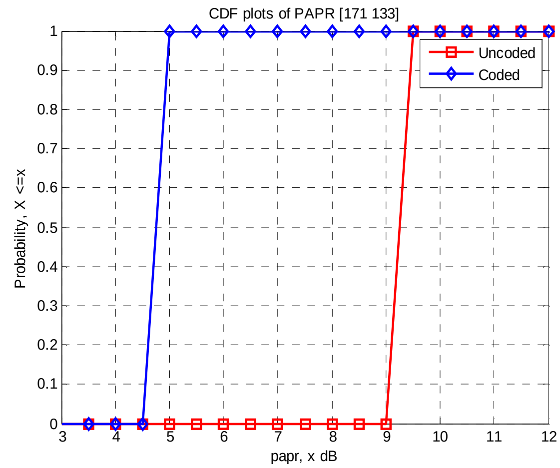

Figure 2: CDF Plot of PAPR with Tap Connections [171 133]

PAPR with Tap Connections [111 123]

In figure 3 CDF plot of PAPR with tap connections [111 131] is shown. The tap connections [111 123] are made by us to inspect the PAPR reduction through codes. This figure shows that the PAPR of uncoded OFDM signal will be at its minimum value i.e. 9 dB with least probability. With the highest probability i.e. 1, the largest PAPR of the uncoded signal is 9.5424 dB. Now the PAPR values obtained by employing the convolutional coding. The graph shown in figure 3, the PAPR of coded OFDM signal will be reduced due to coding to a minimum level of 4.5 dB with the least probability. With the highest probability i.e. 1, the largest PAPR of the coded signal is 4.9560 dB. The differences achieved in the power levels with tap connections [111 123] are up to 4.5864 dB which is a significant amount of reduction achieved.

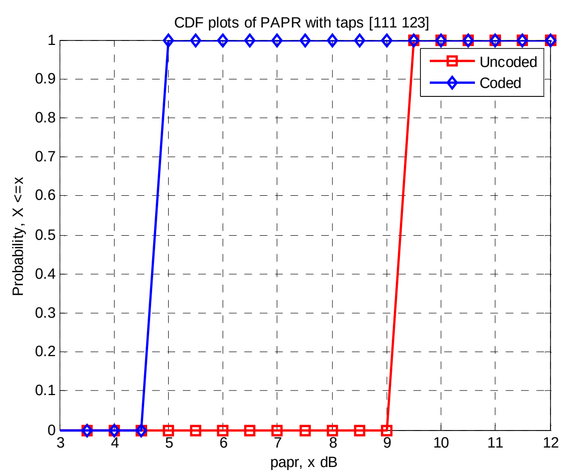

Figure 3: CDF Plot of PAPR with Tap Connections [111 123]

Table: 1 PAPR Reduction with Different Tap Connections and their Comparison

Tap Connections	PAPR (uncoded)	PAPR (coded)	Difference
[175 131]	9.5424 dB	5.6349 dB	3.9075 dB
[171 133]	9.5424 dB	5.0815 dB	4.4609 dB
[111 123]	9.5424 dB	4.9560 dB	4.5864 dB

BER Performance of Coded OFDM System with Different Tap Connections

In figure 4 BER versus SNR performance of OFDM system over AWGN channel is shown. This figure illustrates the effect of different tap connections used in convolutional coding on BER. From the figure 4 it is observed that by using tap connections [175 131] the BER performance is worst which is indicated by red line on graph. However by using standard tap connection of coding [171 133] and our suggested taps [111 123] the BER performance is approximately same which is indicated by blue and green line that is better than the taps [175 131].

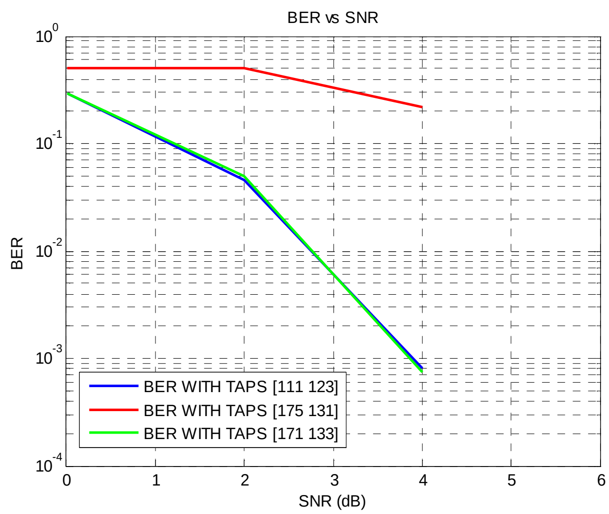

Figure 4: BER Versus SNR Performance of OFDM System

CONCLUSIONS

Initially a self-made tap configuration, [175 131], was put in use to reduce PAPR. This tap configuration reduced a considerable amount of power that is almost a difference of 3.9075 dB. To get a comparative view, a standard tap configuration [171 133] was implemented. This tap configuration reduced the power, producing a difference, between the maximum and minimum value, as much as 4.4609 dB. In order to further improve the PAPR reduction and increase the difference, another self-made tap configuration, [111 123] was designed. This tap configuration also reduced the PAPR to a significant level of 4.5864 dB, providing an improvement in reduction of 0.1255 dB in comparison to the standard tap configuration.

As the BER performance analysis is key to any coding technique, therefore this parameter is also verified. The BER analysis showed that two of the tap configurations, [171 133] and [111 123], have almost the same BER performance. However, the third tap configuration, [175 131], has very poor error correction capability.

The convolutional codes introduce redundancy along with information bits such that codewords with lowered peaks are generated and selected for transmission. Our proposed tap configuration [111 123] generated a codeword with minimum amount PAPR. The second lowest PAPR value is generated by the standard taps. On the basis of the above results discussed we conclude that PAPR reduction through convolutional coding is an effective method provided special care is taken about the selection of the codewords and [111 123] tap configuration may be used to perform this reduction with a standard BER performance.

FUTURE RECOMMENDATION

For the future work following recommendations are made:

1. The PAPR values produced by convolutional coding by different constraint lengths may be analyzed for effective reduction.
2. Further investigation for more powerful codes like Turbo coding and LDPC coding may be used to reduce PAPR effectively.
3. The delay introduced due to the selection procedure of codewords may be reduced by setting a threshold level for the maximum PAPR produced by a codeword and allowing only those codewords that produce peaks within the threshold level

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