CHAPTER – 4
PAPR REDUCTION USING ORDER BIT SELECTOR AND TRELLIS STRUCTURE

4.1 Introduction

A trellis based OFDM system for reducing the PAPR by making diplomatic choice of constellation subset is proposed here. The choice of subset is accomplished over a trellis structure with Viterbi algorithm by selecting a controlling sequence which keeps away from the mean power boosting on modulated messages. Higher order QAM is implemented in the scheme of high spectral efficiency, the excessive information is not dominant and hence the deterioration in noise margin becomes very less. In these cases, the recommend research work may be most desirable because of its advantages such as in band distortion is minimised and diversity is not deteriorated over a fading spectrum selective medium when compared with other conventional methods. In order to assess the performance of the proposed scheme BER is analysed This depends on the control bits that are selected at the transmitter side.

4.2 Transmitter Design

The proposed transmitter design block diagram is depicted in Figure 4.1. The transmitter block consists of conversion of data into binary bits followed by a channel coding i.e., convolution coding suitable for noisy channel. The order bit selector is used to select the QAM constellation such a way that the PAPR is scaled down. The output of modulation is given as input to the FCT block. Then IDCT and IWPT are applied in order to minimize PAPR in the OFDM system. The digital to analog convertor is used for conversion followed by RF up conversion then for transmission of data through channel.

![Figure 4.1 Proposed transmitter design](image_url)
4.2.1 Order Bit Selector

In communication systems, the simplest way of channel coding technique is Convolution coding. By virtue of its high coding gain and performance it is frequently used in wireless transmission network. The convolution coding is suitable for noisy channel such as AWGN. In order to control the error, the channel encoding is used. The basic building block of the order bit selector is a shift register. It requires less hardware and storage memory. The order bit selector is mainly defined by 3 variables namely: n, k, L where n is length of incoming bits, k is length of outgoing bits and L is number of shift registers used as memory elements which are also called as constraint length. The code rate r is given by \( r = \frac{k}{n} \). Figure 4.2 presents the functional diagram of order bit selector for \((n, k, L) = (2, 1, 2)\).

![Figure 4.2 Block diagram of Order bit selector](image)

Figure 4.3 shows the finite state diagram of order bit selector. Here 2 bits are used to represent each state. Each transition is represented by \(x/y_1y_2\). Where \(x\) is input bits and \(y_1y_2\) are output bits. If the current state is 00, and if the next input is 0, it will state in the same state by producing the 00 as output. If the next input is 1 then it will move to the next state 10 by producing an output 11. If the current state is 10 and if next input is 0 it will move to the next state 00 by producing output 11 and if the input bit is 1 it moves to 10 by producing 00 likewise it continuous for next two states. Table 4.1 shows the operation of this finite state diagram.
To produce output at the encoder the two previous input bits and one present input bit are used. The output $y_0$ and $y_1$ is generated by using modulo-2 addition which is denoted by

$$y_0 = x_0 \oplus x_1 \oplus x_2$$

$$y_1 = x_0 \oplus x_2$$  \hspace{1cm} (4.1)

After coding the order bit selector is used to select the QAM constellation such that the PAPR is reduced.
4.2.2 QAM Modulator

The combination of ASK and PSK gives to a new modulation scheme called Quadrature Amplitude Modulation technique which is used in communication systems. QAM signals has two carriers which are out of phase by 90 degrees and there is variation of both amplitude and phase in resulting output. This modulation is mainly used for high data rate applications.

The different forms of QAM are 8QAM, 16QAM, 64QAM, 128QAM, 256QAM and so on. Higher order QAM has more constellation points and hence it can transmit more bits per symbol with less bandwidth.

The general form of QAM signal is represented as

\[
S_i(t) = \sqrt{\frac{2E_{\text{min}}}{T_s}} a_i \cos(2\pi f_c t) + \sqrt{\frac{2E_{\text{min}}}{T_s}} b_i \sin(2\pi f_c t)
\]

\(0 \leq t \leq T, i = 1, 2, 3, \ldots, M\)

where \(E_{\text{min}}\) is signal energy

\(a_i\) and \(b_i\) are integers

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![Block diagram of QAM modulator](image-url)

Figure 4.4 Block diagram of QAM modulator
The general functional diagram of QAM modulator is depicted in Figure 4.4. The two-data input I and Q are obtained from base band possessing of the incoming signal. Once the in-phase and quadrature phase are obtained it is mixed with an oscillator frequency with 90 degrees apart. Then these signals are added and then transmitted over a channel.

Figure 4.5 depicts the constellation diagram of 16- QAM. Here there 16 points in QAM, where it has four I values and four Q values. Four bits per symbol can be transmitted, out of four bits two bits are denoted for I and rest two bits are denoted for Q.

\[ \begin{array}{c}
\text{Q} \\
\text{I} \\
\end{array} \]

16- QAM

Figure 4.5 Constellation diagram of 16- QAM

4.3 Receiver design

The proposed receiver design is depicted in Figure 4.6. The reverse working of the transmission will happen here. Receives the data from the channel, then converts into digital for processing WPT and DCT. The PTS decoder is used with the support of FFT and serial to parallel conversions. The decoded data is demodulated either with BPSK or QAM depending on modulation technique used. The channel decoding is done using viterbi decoder also called as trellis decoding or shaping. Conversion from binary to a required format either image or random data.
4.4 Trellis diagram with Viterbi decoder

At receiver for order bit selector viterbi decoder is used. Viterbi decoder uses two basic operation synchronization and quantization. The synchronization is used to know the range limits of code word and symbol. The quantization is used to quantize the analog signal and converter to digital using quantization square. There are two types of quantization techniques used in viterbi decoder. They are

- Hard decision
- Soft decision

**Hard decision**

The decoding process uses the trellis diagram and Hamming distance. It is quantized into one-bit precision either 0 or 1. The Hamming distance is used to measure the distance between the expected data at the decoder and the data sent from the encoder.

**Soft decision**

The information, when transmitted over a Gaussian channel is decoded using probability decoding. It uses multi bit quantization for received bits. If there are 3 or 4 bits of quantization the performance is better than the hard decision. The Euclidian distance is used to measure the distance between the bits. Figure 4.7 shows the internal block diagram of viterbi decoder. The functional blocks of decoder are Branch metric unit, add unit, compare and select unit, storage unit and back track unit.
The steps involved in the viterbi decoder are as follows:

- The two parallel bits are inputs to the viterbi decoder.
- The Hamming distance of the expected code and received code is calculated by using modulo 2 additions. Number of one’s is counted to measure the distance.
- The previous stage and present values are added and compared to select with the minimum path value to reach the next node.
- Each stage calculation is stored in the memory for further processing.
- The back-track unit is used to compare and track the optimal path value and the corresponding output is produced.

### 4.4.1 Trellis diagram

The general Trellis diagram is shown in Figure 4.8. It has four rows of horizontal dots where each row depicts one state of encoder. The solid line joining the dots illustrate the input transition bit as ‘one’ and the dotted line connecting the dots represent when the input transition bit is zero. To achieve better performance soft decision is used. The distance between the received codes and all possible codes are computed. Here the Hamming distance is used to compute the distance. The computation of Hamming distance is easy; it counts how many bits are different from received code to the all possible codes. The output of the Hamming distance can be 0, 1 or 2. At each unit of time the Hamming distance is computed and it is called as Branch Metric. These values are stored and accumulated to compute the optimal path.
4.5 Simulation Results

Figure 4.9 and 4.10 shows the plot between SNR and BER for 16 QAM of Rayleigh and AWGN channel. It can be noticed that the simulated technique has less BER when compared with other techniques. It has been observed that the efficiency of this technique will vary according to the channel. But still performance is better for both channel conditions.
Figure 4.10 BER versus SNR for 16 QAM AWGN channel

Here a higher constellation of QAM is used. Figure 4.11 and 4.12 shows the plot between SNR and BER for 256 QAM of Rayleigh and AWGN channel. It can be noticed that the
simulated work has less BER when compared with other techniques. The bit error rate is almost equal to the conventional PTS. It can be observed that the performance is better in different channels when compared with other techniques.

![Bit error probability curve for 256QAM of AWGN channel](image)

Figure 4.12 BER versus SNR for 256 QAM AWGN channel

Figure 4.13 shows the normalized BER versus SNR plots for AWGN channel for different PAPR reduction along with the implemented work. It can be contemplated that the BER is less when matched to other methods for the same value of SNR.

Figure 4.14 depicts the standardized BER vs SNR plots for Rayleigh channel for both conventional and proposed methods. It can be observed that the presented work has little high BER when compared with other methods for the same value of SNR.
We can observe from the Figure 4.15 the PAPR for the trellis based OFDM system is having the least value as compared to the other PAPR plots for conventional system without
PTS and without PTS. The value of PAPR of implemented technique is around 5.8 dB and the PAPR is reduced by 6 dB from the conventional OFDM system.

Figure 4.15 PAPR along with CCDF

Figure 4.16 Normalised Curve
Figure 4.16 and 4.17 shows the Normalised curve and time response of the conventional OFDM and implemented work. Here we can observe that the proposed work is almost matching to the conventional OFDM. Hence, we can conclude that the PAPR is reduced without
disturbing the performance of OFDM system. Figure 4.18 shows the signal constellation of 256-QAM modulation.

Table 4.2 presents the similarity of proposed work with the other methods. Here we can observe that there is a considerable reduction in PAPR when compared with other without affecting other parameters of the conventional OFDM.

Table 4.2 Comparison of PAPR reduction techniques with Proposed method

<table>
<thead>
<tr>
<th>Parameters Different technique</th>
<th>Complexity</th>
<th>Bandwidth Expansion</th>
<th>BER</th>
<th>SNR</th>
<th>PAPR</th>
</tr>
</thead>
<tbody>
<tr>
<td>OFDM</td>
<td>Less</td>
<td>No</td>
<td>High</td>
<td>High</td>
<td>Very High</td>
</tr>
<tr>
<td>OFDM with SLM</td>
<td>High</td>
<td>Yes</td>
<td>Moderate</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>OFDM with PTS</td>
<td>High</td>
<td>Yes</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Moderate</td>
</tr>
<tr>
<td>OFDM with DCT &amp; WPT</td>
<td>High</td>
<td>Yes</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Trellis structure</td>
<td>High</td>
<td>Yes</td>
<td>Low</td>
<td>Very Low</td>
<td>Very Low</td>
</tr>
</tbody>
</table>

4.6 Summary

A trellis structure based OFDM for reduction of PAPR is proposed. Here we have used an order bit selector for selecting a constellation points in QAM modulator and by selecting the points in QAM modulator the PAPR is reduced. The partial transmit sequence with DCT and WPT is included with this order bit selector to reduce PAPR without affecting bit error rate. At the side of receiver, the Viterbi decoder is used for decoding. Here the results of presented work are compared with the other methods and conventional OFDM. For Rayleigh channel and AWGN channel the BER vs SNR is also plotted. Here we have used 16 QAM and 256 QAM and could able to observe the BER is almost same for the proposed technique in both QAM techniques. As we use the higher order QAM the SNR will be more because of its higher bit error rate. Hence, we can observe the SNR in 16 QAM AWGN channel is 9dB and SNR in 256 QAM AWGN channel is 18dB, which is almost twice of the previous one. Hence it is better to use the lower order QAM modulator. For the proposed technique the PAPR is 5.8dB, and it is reduced by 6.0dB when compared with the conventional OFDM system.