CHAPTER 5

DESIGN OF LDPC ENCODER AND DECODER CIRCUIT OF OFDM

5.1 Importance of OFDM in Communication System

In recent years, a more sophisticated modulation technique known as orthogonal frequency division multiplexing (OFDM) has received much attention. This technique is considered suitable for achieving high bit-rates in wireless environments subject to multipath propagation and consequent channel fading. To encode digital data on multiple carrier frequencies, an efficient method called an orthogonal frequency-division multiplexing (OFDM) is used in communication system. OFDM has improved a scheme for wide band digital communication. Wireless or over copper wires, can be used in various applications such as digital television and audio broadcasting, wireless networks, DSL Internet access, 4G mobile communications and power line networks.

OFDM is basically equal to discrete multi-tone modulation (DMT) and coded OFDM (COFDM), and is a frequency-division multiplexing (FDM) method used as a digital multi-carrier modulation technique. The word “coded” is used in forward error correction (FEC). Huge numbers of closely spaced orthogonal sub-carrier signals are used to hold the data on several parallel data streams or channels. Each sub-carrier is modulated with a usual modulation scheme (such as quadrature amplitude modulation or phase-shift keying) at a low symbol rate, maintaining whole data rates similar to traditional single-carrier modulation schemes in the same bandwidth.

The advantages of OFDM are:

Efficient use of the available bandwidth since the sub channels are overlapping. This effectively randomizes the burst errors caused by the Rayleigh fading, so that instead of several adjacent symbols (in time on a single-carrier) being completely
destroyed, symbols in parallel are only slightly distorted. The symbol period is increased and thus the sensitivity of the system to delay spread is reduced.

The disadvantages of the OFDM modulation are:

OFDM signal is contaminated by non-linear distortion of transmitter power amplifier; because it is a combined amplitude-frequency modulation (it is necessary to maintain linearity). OFDM is very sensitive to carrier frequency offset caused by the jitter of carrier wave and Doppler effect caused by moving of the mobile terminal. The main disadvantages are large Peak to average power ratio (PAPR) and poor performance under non linear distortion.

The most important advantage of OFDM over single-carrier schemes is its ability to cope with crucial channel conditions without complex equalization filters. Channel equalization is easy because OFDM may be viewed as using a lot of slowly modulated narrowband signals rather than one quickly modulated wideband signal. The low symbol rate employ a guard interval between symbols affordable, making it achievable to eliminate Inter Symbol Interference (ISI) and employ echoes and time-spreading , on analogue TV these are observable as blurring and ghosting equally and to achieve a diversity gain, specifically a substantial improvement in signal-to-noise ratio. This method also facilitates the design of single frequency networks (SFNs), where more than a few adjacent transmitters send the same signal simultaneously at the same frequency, since the signals from multiple distant transmitters may be combined usually, to a certain extent than interfering as would typically occur in a conventional single-carrier system.

5.2 Error Detection and Correction (EDC) techniques

In forward error correction (FEC) method, extra bits or redundant bits are intentionally introduced to generate a codeword.
There are two error correction methods, one is block and another is convolution methods. The convolution methods are further divided into Viterbi codes and Turbo codes. Linear or block codes are divided into LDPC codes and Reed Solomon codes.
LDPC coders are further divided into Bit Flipping algorithm, Sum product algorithm and Min Sum algorithm. In this research work Convolution codes and LDPC codes are applied into OFDM and the results are compared and analyzed.

5.3 Linear Block coding technique

Linear Block coding involves programming a block of information bits into another block of bits with adding up a few redundant bits to conflict channel errors induced at some stage in wireless transmission. To carry out this, the encoder not only transmits information symbols but also one or more redundant symbols. The decoder uses the redundant symbols to sense and probably correct errors occurring in the duration of transmission as explained in the diagram below.

Fig.5.3 Circuit diagram of linear block coding.
5.4 Convolution Coding Technique for OFDM

A Convolution code is a kind of error-correcting code in which every $m$-bit information symbol (each $m$-bit string) to be encoded is transformed into an $n$-bit symbol, where $m/n$ is the code rate ($n \geq m$) and the transformation is a task of the last $k$ information symbols, $k$ represents the constraint length of the code. This code can be used in telecommunication system [75].

![Block diagram of convolution encoder.](image)

In convolution coding data encoding begin with $k$ memory registers, each one holding 1 input bit. Unless otherwise specified, all memory registers initiate with a value of ‘0’. The encoder has $n$ modulo-2 adders (a modulo-2 adder can be implemented through a single Boolean XOR gate, where the logic is: $0+0 = 0$, $0+1 = 1$, $1+0 = 1$, $1+1 = 0$), and $n$ generator polynomials - one for each adder. An input bit $m_i$ is fed into the left most register. By using the generator polynomials and the existing values in the remaining registers, the encoder output will be $n$ bits. Now bit shift all register values to the right ($m_i$ moves to $m_0$, $m_0$ moves to $m_{-1}$) and it waits for the next input bit. If there are no lingering input bits, the encoder continues output until every registers have reached to the zero state [74].
This convolution encoder and decoder are used to encode and decode the data in the OFDM transmitter and receiver circuits. Instead of normal encoder and decoder, convolution encoder is used in the conventional OFDM techniques.

5.5 LDPC Coding Technique for OFDM

Quadrature amplitude modulation (QAM) is both an analog and a digital modulation technique. QAM conveys two analog message signals, or two digital bit streams, by means of modulating the amplitudes of two carrier waves, using the amplitude-shift keying (ASK) digital modulation method or amplitude modulation (AM) analog modulation format. These two waves are out of phase with each other by 90° and are thus called quadrature carriers. The modulated waves are summed, and the resultant waveform is a combination of both PSK and amplitude-shift keying, or phase modulation (PM) and amplitude modulation (AM) [34]. In the digital QAM case, a finite number of at least two phases and at least two amplitudes are used. PSK modulators are frequently designed using the QAM principle, but it is not considered as QAM since the amplitude of the modulated carrier signal is constant [12].

A low-density parity-check (LDPC) code is a linear and nonlinear types of error correcting code, a process of transmitting a message in excess of a noisy transmission channel, and is designed via a sparse bipartite graph. LDPC codes are based on capacity-approaching codes, which means that realistic constructions survive that allow the noise threshold to be set very close to the theoretical utmost (the Shannon limit) for a symmetric memory less channel [18]. The resonance threshold defines an upper bound for the channel noise, up to which the probability of misplaced information can be made as small as preferred. Using iterative belief propagation scheme, LDPC codes can be decoded in time linear to their block length [32].

With the increasing demand on high data rate wireless applications, many recent communication systems employ ultra high throughput channel codes to match the data
rate requirements. For example 802.15.3c standard is targeted for the data rate in Giga bits per second thus LDPC codes are preferred over convolution codes.

Fig. 5.5 Structure of the LDPC coded clustered OFDM transmitter.

Fig. 5.6 Structure of the LDPC coded clustered OFDM receiver.

The structure of LDPC coded clustered OFDM transmitter and receiver are depicted in Fig. 5.6 and Fig. 5.7. The idea of wave pipelining is based on the fact that the clock speed can be increased, if idle time of the non-critical paths can be condensed. With wave pipelining, the clock period can be bridged as long as data from a particular clock cycle does not overwrite the data from the previous clock cycle [73]. The limiting factor of the clock period is the variation between the maximum and minimum data delays through the combinatorial block together with register timing. LDPC codes with
wave pipelined structure are applied to OFDM system. An analysis is performed between OFDM with Convolution codes and OFDM with LDPC codes [26].

The choice of an appropriate logic style is crucial in any wave-pipelined implementation, because mismatches in propagation delays at the level of basic building blocks may cause the architecture to fail. The wave-pipelined architecture has some attractive properties, namely the absence of pipeline latches which leads to decrease in area and power consumption, simpler clock distribution and higher throughput, but layout is critical for delay balancing [3].

![LDPC Coded OFDM system](image)

**Fig.5.7. LDPC Coded OFDM system**

OFDM modulation works on the principle of converting a serial symbol stream to a parallel symbol stream with each symbol from the parallel set modulating a separate carrier. The spacing between the carriers is $1/T$ where $T$ is the duration of the OFDM symbols (without cyclic prefix). This guarantees
orthogonality of the carriers i.e. there is no interference between carriers. The addition of orthogonal carriers modulated by parallel symbol streams is equivalent to taking the IFFT of the parallel symbol set. At the receiver the inverse operation of FFT is performed and the parallel symbol streams are converted to serial symbol streams.

Channels are the carriers that are used to transmit the original data to the receiver section. It acts as a communication bridge between the transmitter and receiver. Selection of the channel is the major constraint in designing a wireless channel. The factors that have to be taken into account are the Gaussian noise and the modeling of signals.

The objective is to design a physical layer of a WiMAX transceiver which includes the physical layer blocks in a Simulink tool. These models are designed to the specifications defined in the IEEE 802.16 standard. The design, their simulations and analysis were done using Simulink.

5.6 Results and Discussions

The conventional OFDM with convolution encoder and decoder and Proposed OFDM with LDPC encoder and wave pipelined based LDPC decoder are designed and synthesized using VHDL and Xilinx10.1. From the synthesized results, it is shown that LDPC encoder and decoder consumes less area, delay and high speed utilization than convolution encoder and decoder [72]. The simulation results are displayed below.
Fig. 5.8 Synthesized result of OFDM with LDPC Encoder for area utilization.
Fig. 5.9 Synthesized result of OFDM with LDPC Encoder for frequency utilization.
Fig.5.10 Synthesized result of OFDM with LDPC Decoder for area utilization.
Fig. 5.11 Synthesized result of OFDM with LDPC Decoder for frequency utilization.
Table 5.1 Comparison between OFDM with convolution encoder and OFDM with LDPC encoder.

<table>
<thead>
<tr>
<th>OFDM Techniques</th>
<th>Slices</th>
<th>LUT</th>
<th>Flip-flops</th>
<th>Frequency (MHz)</th>
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<tbody>
<tr>
<td>OFDM with convolution encoder</td>
<td>1307</td>
<td>795</td>
<td>1741</td>
<td>76.359</td>
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<tr>
<td>OFDM with LDPC encoder</td>
<td>1231</td>
<td>657</td>
<td>1721</td>
<td>166.499</td>
</tr>
</tbody>
</table>

Fig. 5.12 Comparison chart of OFDM with Convolution encoder and OFDM with LDPC encoder.
Table 5.2  Comparison between OFDM with convolution decoder and OFDM with LDPC decoder.

<table>
<thead>
<tr>
<th>Types of OFDM Techniques</th>
<th>Slices</th>
<th>LUT</th>
<th>Flip-flops</th>
<th>Frequency (MHz)</th>
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<tbody>
<tr>
<td>OFDM with convolution decoder</td>
<td>1011</td>
<td>611</td>
<td>1653</td>
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<tr>
<td>OFDM with LDPC decoder</td>
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<td>1627</td>
<td>268.014</td>
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</tbody>
</table>

Fig.5.13 Comparison chart of OFDM with Convolution Decoder and OFDM with LDPC Decoder.
5.7 Conclusion

This proposed research work of wave pipelined LDPC architecture is applied into OFDM technique. Conventional OFDM technique with Convolution encoder and decoder consumes more area, greater delay and high speed than LDPC encoder and decoder with wave pipelined technique. Simulation and Synthesis are done by using ModelSim6.3c and Xilinx10.1. The results shows that the proposed OFDM architecture is the best among the others and it can therefore be used in combination with wireless architectures like WiMax and 4G and hence the Spectral efficiency and bandwidth can be increased.