FPGA Implementation of Wavelet based SC-FDMA System

1Ramya.S, 2C.B. Vinutha, 3Mr. M. Z Kurian

14th sem, M.Tech (VLSI&ES), SSIT, Tumkur
2Lecturer, Dept. of E&C, SSIT, Tumkur, Karnataka
3Dean & HOD, Dept. of E&C, SSIT, Tumkur, Karnataka

ABSTRACT-Orthogonal Frequency Division Multiple Access (OFDMA) has recently been applied widely in wireless communication systems due to its high data rate transmission capability with high bandwidth efficiency and its robustness to multi-path fading. But it has several inherent disadvantages such as the large PAPR and the sensitivity to Carrier Frequency Offset (CFO). Hence much attention has been focused on Single Carrier systems with Frequency-Domain Equalization (SC-FDE) and SCFDMA systems. Recent research has shown that the SC-FDMA is an attractive technology for uplink broadband wireless communications, because it does not have the problems such as the large Peak-to-Average Power Ratio (PAPR) that is more significant OFDMA. In this paper, an efficient transceiver scheme for the SC-FDMA systems, using the discrete wavelet transform is proposed. Wavelet analysis at the transmitter and the receiver has the ability to reduce distortion in the reconstructed signals.

Keywords: SC-FDMA, OFDMA and Wavelet Transform.

I. INTRODUCTION

Single-carrier FDMA (SC-FDMA) is a frequency-division multiple access scheme (FDMA). Like other multiple access schemes (TDMA, FDMA, CDMA, OFDMA), it deals with the assignment of multiple users to a shared communication resource. The distinguishing feature of SC-FDMA is that it leads to a single-carrier transmit signal, in contrast to OFDMA which is a multi-carrier transmission scheme. Owing to its inherent single carrier structure, a prominent advantage of SC-FDMA is that it’s transmit signal has a lower PAPR resulting in relaxed design parameters in the transmit path of a subscriber unit. OFDMA has been applied widely in wireless communication systems due to its high data rate transmission capability with high bandwidth efficiency, and its robustness to multi-path fading. But it has several inherent disadvantages such as the large PAPR and the sensitivity to Carrier Frequency Offset (CFO). Hence much attention has been focused on Single Carrier systems with Frequency-Domain Equalization (SC-FDE) and SCFDMA systems. Recent research has shown that the SC-FDMA is an attractive technology for uplink broadband wireless communications, because it does not have the problems such as the large Peak-to-Average Power Ratio (PAPR) that is found in OFDMA [2].

II. SYSTEM DISCRIPTION

A. BLOCK DIAGRAM

Figure 1 shows a block diagram of SC-FDMA system using discrete wavelet transform (DWT). The input signal is modulated and for the real and imaginary outputs symbols are generated and they are padded with zeros on both the sides. The resulting signal is transformed by the wavelet transform via the DWT. The DWT outputs are mapped by localized sub-carrier mode. After that, add the cyclic prefix in order to reduce ISI (Inter Symbol Interference).
A. Quadrature amplitude modulation (QAM)

Quadrature amplitude modulation (QAM) is both an analog and a digital modulation scheme. It conveys two analog message signals, or two digital bit streams, by changing (modulating) the amplitudes of two carrier waves, using the amplitude-shift keying (ASK) digital modulation scheme or amplitude modulation (AM) analog modulation scheme. A 16-bit QAM is designed and it comprises of serial-to-parallel conversion and mapping. The two carrier waves, usually sinusoids, are out of phase with each other by 90° and are thus called quadrature carrier. QAM is a form of modulation which is widely used for modulating data signals onto a carrier. It is widely used because it offers advantages over other forms of data modulation. QAM is a signal in which two carriers shifted in phase by 90 degrees are modulated and the resultant output consists of both amplitude and phase variations. In view of the fact that both amplitude and phase variations are present they may also be considered as a mixture of amplitude and phase modulation.

A. Discrete Wavelet Transform (DWT)

Wavelet analysis is simply the process of decomposing a signal into shifted and scaled versions of a particular wavelet. Wavelet filters have finite length and due to this property, wavelet filter banks can perform local analysis. An important property of wavelet analysis is perfect reconstruction, which is the process of rebuilding a decomposed signal into its original transmitted form without deterioration. The DWT (Discrete Wavelet Transform) is computed by successive lowpass and highpass filtering of the discrete time-domain signal. The Haar wavelet is the simplest type of wavelet transform. In discrete form, Haar wavelets are related to a mathematical operation called the Haar transform. Like all wavelet transforms, the Haar transform decomposes a discrete signal into two levels of half its length. At each level, the highpass filter produces detail information denoted by $d(m)$, while the lowpass filter associated with a scaling function produces coarse approximations denoted by $a(m)$. The filtering and decimation process is continued until the desired level is reached. The maximum number of levels depends on the length of the signal. The DWT of the original signal is then obtained by concatenating all the coefficients, $a(m)$ and $d(m)$, starting from the last level of decomposition [2].

Figure 1: Block diagram of SC-FDMA System using DWT.

Figure 2: Single-level wavelet decomposition and reconstruction [2]

C. Subcarrier Mapping:

Figure 3: Subcarrier allocation method for multiple users (3 users, 12 subcarriers and 4 subcarriers allocated per user [1].
There are two methods to choose the subcarriers for transmission: distributed subcarrier mapping and localized subcarrier mapping as shown in Figure 3.

In the distributed subcarrier mapping mode, DFT outputs of the input data are allocated over the entire bandwidth with zeros occupying the unused subcarriers. Consecutive sub-carriers are occupied by the DFT outputs of the input data in the localized subcarrier mapping mode resulting in a continuous spectrum that occupies a fraction of the total available bandwidth. The localized subcarrier mapping mode of SC-FDMA is referred as localized FDMA (LFDMA) and distributed subcarrier mapping mode of SC-FDMA as distributed FDMA (DFDMA).

Figure 4 shows an example of SC-FDMA transmit symbols in frequency domain for \(N=4\) subcarriers per user, \(Q=3\) users and \(M=12\) subcarriers in the system. After subcarrier mapping, the frequency data is transformed back to the time domain by applying \(M\)-point inverse DFT (IDFT) [1].

### III SIMULATION RESULTS AND ANALYSIS.

#### A. TRANSMITTER

Figure 5 shows the simulation result of the transmitter. The input signal is modulated using the QAM modulation technique. For the modulated signal the symbols are generated by the symbol generator and then each symbol are padded with zeros on both the sides. Then DWT is performed and mapped using the sub-carrier mapping. Further IDWT is performed on the mapping output, lastly cyclic prefixed and transmitted. Figure 6 shows the RTL schematic of the transmitter.
B. RECEIVER

Figure 7 shows the simulation result of the receiver. The received input is inverse cyclic prefixed. Further DWT is performed. The resulting data is demapped then IDWT is performed. The original signal is obtained by demapping. Figure 8 shows the RTL schematic of the receiver.

![Figure 7: Result of the receiver.](image1)

![Figure 8: RTL schematic of the receiver.](image2)

IV HARDWARE RESOURCE UTILIZATION

Table I shows the RAM resource utilization both the transmitter and the receiver

<table>
<thead>
<tr>
<th>Mapping type</th>
<th>No. of Slices Used out of 547</th>
<th>No. of 4 input LUTs out of 109</th>
<th>No. of slice Flipflops out of 109</th>
<th>Maximum Frequency (MHz)</th>
<th>Maximum Power (mw)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmitter</td>
<td>95</td>
<td>82</td>
<td>120</td>
<td>188</td>
<td>198</td>
</tr>
<tr>
<td>Receiver</td>
<td>560</td>
<td>593</td>
<td>727</td>
<td>188</td>
<td>178</td>
</tr>
</tbody>
</table>

v CONCLUSION

The Single Carrier Frequency Division Multiple Access (SC-FDMA) is an attractive technology for uplink broadband wireless communications, because it does not have the problems such as the large Peak-to-Average Power Ratio (PAPR) that is more significant in Orthogonal Frequency Division Multiple Access (OFDMA). An effective transceiver scheme for the SC-FDMA system using Discrete Wavelet Transform has been presented. The modulation and DWT technique is analyzed. The simulated code is physically dumped on the FPGA and tested using the chip scope pro.

REFERENCES


