Abstract - In this paper, we present the progress of the wireless implementation of a SIMO/MISO OFDM testbed using Texas Instruments’ (TI) TMS320C6416 DSPs on Spectrum Digital development platforms. The channel model, channel coding, synchronization technique and implementation results of this system are presented. The SISO OFDM testbed will be modified for SIMO/MISO wireless OFDM transmission. The hardware interface required to convert the baseband signal from the DSP Kits to RF are presented. Future work regarding the conversion of the SISO OFDM testbed to support multiple transmit and receive antennas for performance measurements is discussed.

Index Terms—SISO, SIMO, MISO, MIMO, OFDM

I. INTRODUCTION

Wireless communication systems are required to deliver high data rates while maintaining a high QoS and low-complexity. Furthermore, these communication systems must overcome the challenge of operating in a multipath environment and combat interference and fading. A Single-Input Multiple-Output (SIMO) and Multiple-Input Single-Output (MISO) system uses either multiple receive or multiple transmit antennas. This increases the diversity gain, which increases the capacity and performance gain of a communication system. Orthogonal Frequency Division Multiplexing (OFDM) is a multicarrier transmission scheme which provides robustness against fading in multipath environments. A SIMO/MISO OFDM system has the combined advantage of providing high performance and reducing the influence of fading.

In this paper, we discuss the development of a SISO OFDM testbed, for an indoor channel, using two TMS320C6416 DSP kits. The testbed will be used to verify channel estimation algorithms developed in [1]. Similar implementations were developed in [2] [3]. The decision directed channel estimation (DDCE) approach used in [1] is preferred over channel estimation methods, using pilot symbols, implemented in [2] [3]. DDCE is faster, less complex and increases the spectral efficiency. The SISO OFDM communication system will provide the foundation on which the SIMO/MISO systems can be realised.

II. OFDM SYSTEM MODEL

For a discrete-baseband OFDM system model, the OFDM symbols at the transmitter can be represented by the vector

\[ x_m = (x_{0,m}, x_{1,m}, \ldots, x_{N_c-1,m})^T, \]

where \( N_c \) represents a block of data symbols. An inverse discrete Fourier Transform is performed on each symbol and a cyclic prefix of length \( N_{cp} \) is appended to the signal. From [4] the \( m^{th} \) OFDM symbol of the resulting complex-baseband discrete-time signal can be written as in Equation (1), where \( x_{k,m} \) is the data symbol modulating the \( k^{th} \) subcarrier in the \( m^{th} \) symbol interval, and \( n \) is the discrete-time index, \( n \in [0, N_c + N_{cp} - 1] \).

\[ s_m(n) = \begin{cases} \frac{1}{N_c} \sum_{k=0}^{N_c-1} x_{k,m} e^{j2\pi k(n-N_{cp})/N_c} & \text{if } n \geq N_{cp} \\ 0 & \text{otherwise} \end{cases} \]  

(1)

The complete time signal is given by the concatenation of all the transmitted OFDM symbols and is represented by \( s(n) \):

\[ s(n) = \sum_{m=0}^{\infty} s_m(n - m(N_c + N_{cp})) \]  

(2)

Figure 1 shows the complete block diagram for the SISO OFDM system implemented on two TMS320C6416 DSP kits via wired baseband communication.

III. SISO OFDM SYSTEM ARCHITECTURE

A. Channel Coding

To avoid the domination of errors, error correction coding is used to enable high data rates in the presence of fading and interference.

B. Synchronization

A simple OFDM synchronization method developed by Schmidl & Cox [5] was used for the system. It requires that the first OFDM symbol should consist of 2 repeated parts of length \( M = N_c/2 \). The method performs a correlation of the 2 parts and the peak of the correlation function indicates the optimal timing instant. Let \( d \) represent the timing index. The timing metric for synchronization is given by

\[ M(d) = \frac{|P(d)|^2}{R(d)} \]  

(3)

where

\[ P(d) = \sum_{m=0}^{M-1} r^*(d + m) r(d + m + M) \]  

(4)

and

\[ R(d) = \sum_{m=0}^{M-1} |r(d + m + M)|^2 \]  

(5)

The frequency offset is given by

\[ \Delta f = \frac{\theta}{\pi T} \]  

(6)

where

\[ \theta = \arg \max(P(d)). \]  

(7)

C. Channel Estimation

The channel estimation that will be implemented for the project is that developed in [1]. First the channel transfer
function is estimated from the known pilot symbols or the previously decoded symbols and the received signal. The channel impulse response is estimated using the Fast Data Projection Method and then the channel transfer function for the next symbol intervals is predicted using a Variable Step Size Normalized Least Mean Square algorithm.

IV. HARDWARE USED IN PROJECT

The project will be implemented using DSP kits from Spectrum Digital and the DSP processor is the Texas Instrument’s TMS320C6416. The C6416 DSP uses fixed point arithmetic and can run at 1 GHz which is adequate for implementing complex algorithms. The DSP kit includes an AIC23 codec that includes 2 ADCs and DACs.

The DSP kits will be used to process signals at baseband. RF stage modules have been designed for both the transmitter and receiver which will allow the signals to be transmitted wirelessly through the indoor channel. The transmitter RF stage includes TI’s TRF3702 modulator. The receiver RF stage includes TI’s TRF371125 demodulator which has filter and gain control capabilities.

V. CURRENT ACHIEVEMENTS

Currently a communication system that includes the discussed OFDM synchronization and a (2,1,6) convolutional code has been implemented using the DSP kits, one as a transmitter and the other as a receiver, at baseband. The system used 16 subcarriers, an FFT size of 1024 and a sampling frequency of 48 kHz. The maximum subcarrier frequency was 750Hz. The real and imaginary parts of the IFFT are used to modulate a carrier signal with a frequency of 6 kHz and this becomes the transmitted signal. At the receiver the carrier is removed to obtain the real and imaginary baseband components of the OFDM signal which is passed to an FFT to obtain the transmitted symbols. Once the symbols are obtained, Viterbi decoding is performed and the original information is recovered.

VI. FUTURE WORK

The SIMO/MISO OFDM testbeds will be developed based on the SISO OFDM testbed. The SIMO testbed will use three RF antennas in a 1x2 layout (see Figure 2a); one transmitter and two receivers. Similarly the MISO testbed will use three RF antennas in a 2x1 layout (see Figure 2b); two transmitters and one receiver. The channel estimation algorithms developed in [5] will be verified using the developed fully functional testbed, by comparing the estimated channel with a measured channel.

(a) SIMO

(b) MISO

VII. CONCLUSION

In this paper the implementation of a SISO OFDM system using two TMS320C6416 DSP kits has been discussed. The developed system includes channel coding and the implementation of a synchronization technique. The SIMO/MISO OFDM system will use similar principles and techniques to SISO OFDM whilst increasing the transmit and receive diversity gain.

REFERENCES


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