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Multiband OFDM Based UWB Receiver Design for Efficient BER for Large Delay Spread Channels

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ABSTRACT: Ultra-Wide Band communication is a technology for low range, low power sensor and mobile devices which employs very low transmission powers (below the level of unintentional emissions) and high bandwidth. It possesses a number of unique features that make it very attractive to many local applications. First, ranging with high accuracy is possible even indoors. Second, it is resistant to multipath fading which often pledges indoors communications. Third, it scales well in dense deployments. Fourth, cryptographic modulation is possible. In this talk, we describe the research done in the MICS Ultra-Wide Band network, showing ranging, dense deployment capabilities and medical applications. In this paper, we propose a method which adapts OLA length in UWB receiver depending on the current band of reception and the band wise estimated true FFT window start point. The proposed method is more beneficiary for high delay spread channel like channel model 4 (CM4). In CM4, the technique can achieve around 1 dB Eb/No gain at 10-2 of BER, while simulated over uncoded MB-OFDM based UWB system.

I. INTRODUCTION

OFDM based transmission system uses Cyclic Prefix (CP) in an OFDM symbol in order to maintain orthogonality of transmission. Present days' Ultra- Wideband (UWB) systems use Multi-Band OFDM (MBOFDM) techniques for transmission in application like Wireless Personal Area Network (WPAN). UWB based systems are power limited by the regulation of FCC. CP introduces correlation in the transmitted data sequence and hence introduces ripples in the power spectral density (PSD) of the transmitted data. This in turn reduces the range of data Transmission. However, use of zero-pad suffix (ZPS) will have a flat PSD and hence does not suffer from the range degradation problem. In the receiver, ZP removal requires use of a technique called as overlap and add (OLA) in order to capture the multipath energy of the channel and maintain the orthogonality in the received data. During transmission, the length of the ZP is fixed and equal to the channel length. During reception, in traditional OFDM receiver, the OLA is done using a ZP length of same as channel length as transmitted. In UWB receiver the FFT window gets smeared due to multipath fading and hence estimation of true FFT window start point does affect the OLA process and hence the overall system performance.

II. OVERVIEW OF OFDM SYSTEM

OFDM is currently being used in several new radio broadcast systems including the proposal for high definition digital television (HDTV) and digital audio broadcasting (DAB). However, little research has been done into the use of OFDM as a transmission method for mobile telecommunications systems. In CDMA, all users transmit in the same broad frequency band using specialized codes as a basis of channelization. Both the base station and the mobile station know these codes, which are used to modulate the data sent. OFDM/COFDM allows many users to transmit in an allocated band, by subdividing the available bandwidth into many narrow bandwidth carriers. Each user is allocated several carriers in which to transmit their data. The transmission is generated in such a way that the carriers used are orthogonal to one another, thus allowing them to be packed together much closer than standard frequency division multiplexing (FDM). This leads to OFDM/COFDM providing a high spectral efficiency.

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Orthogonal Frequency Division Multiplexing is a scheme used in the area of high-data-rate mobile wireless communications such as cellular phones, satellite communications and digital audio broadcasting. This technique is mainly utilized to combat inter-symbol interference.

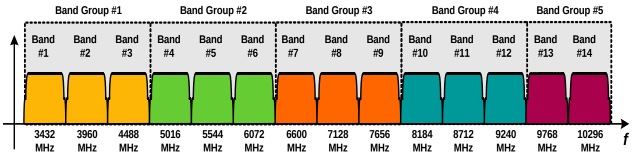
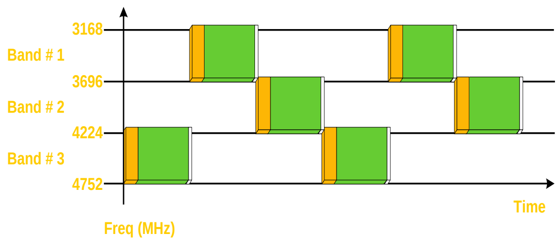


Fig. 1. Band planning for MB-OFDM system

Advantages:

- *Transmitter and receiver process smaller bandwidth signals.*
- *Instantaneous processing BW = 528 MHz*



Advantages

- *Exploits frequency diversity.*
- *Provide robustness against multi-path / interference.*
- *Same transmit power as if the entire band is used.*

III. OFDM PRINCIPLES

OFDM is a special form of Multi Carrier Modulation (MCM) with densely spaced sub carriers with overlapping spectra, thus allowing for multiple-access. MCM) is the principle of transmitting data by dividing the stream into several bit streams, each of which has a much lower bit rate, and by using these sub-streams to modulate several carriers. This technique is being investigated as the next generation transmission scheme for mobile wireless communications networks.

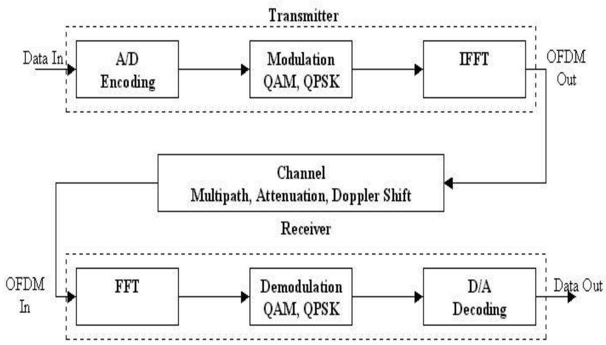


Fig. 2. OFDM Block Diagram

IV. CP VS ZP IN OFDM BASED SYSTEM

In traditional OFDM systems, a cyclic prefix is used before the OFDM symbol in order to maintain the orthogonality in the received signal after passing through the multipath channel. However as CP introduces a structure in the symbols transmitted, the system suffers from the ripple in the power spectral density (PSD) necessitating power back-off in the

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transmitter which can be as large as 1.5 dB for MB-OFDM based system [9]. In an alternative, it was pointed out in [7], that we can use zero-padding instead of cyclic-prefix in the transmitted OFDM symbols. The transmission using ZP does not suffer from the ripple in PSD and hence can transmit at maximum power and hence to a longer distance.

However to retain the circular convolution
property, which essentially provides robustness against multipath channel for OFDM system and facilitates the use of a single-tap frequency domain equalizer in receiver, we require to do a slight modification in signal processing in OFDM receiver. CP based system, can simply discard the CP portion of the received symbol, however for ZP based system we need to do overlap-add (OLA) operation in the receiver

V. PROPOSED OLA TECHNIQUE

In this section we propose a technique to reduce the ISI incursions from the subsequent OFDM symbol due to the use of fixed 'ZP_LEN' during overlap-add process. At the same time we try to make the method robust with respect to the estimation error of the true start point of the FFT window in the smeared received signal. In general the timing synchronizer block provides the estimated offsets over different bands as signed numbers because the estimation point can shift in left as well as right depending on the situation. If any of the estimated offsets becomes negative, we first make all of them positive using the following algorithm (Alg#1) and provide necessary delay in data path in order to make the receiver a causal system.

Alg#1:

Say, OB_i denotes the signed offset of band i, where $i \in 1, 2, or\ 3$. Let UOB_i denotes the unsigned offset of band i after making the system causal.

If $(OB_1 < 0\ or\ OB_2 < 0\ or\ OB_3 < 0)$ *Then*

{

  For $i = 1\ to\ 3$, %''i' *is the band number*

  $UOB_i = OB_i + \max(abs(all\ negative\ OB_j));$

  Where $j \in 1, 2, 3.$

}

Else,

  $UOB_i = OB_i;$

We notice that it is expected that $(OB_i \sim OB_j) \le 32$, i, j belonging to band number, as the channel length is 32 samples. This also guarantees that the range of UOB_i is 0 to 32.

The variation in *i UOB* is solely due to channel manifestation and the channel length remains same as 32 samples. So to avoid ISI incursion from the next OFDM symbol we use band-dependent variable ZP length ('ZP_LEN_Bi') during overlap-add operation over multiple
bands as per the following algorithm (Alg#2).

Alg#2:

For $i = 1\ to\ 3$, *% band number*

$ZP\_LEN\_B_i = 32 - \{UOB_i - Min(UOB_1, UOB_2, UOB_3)\};$

End for loop;

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Note that in Alg#2, apart from making the scheme robustto the estimation error of the true start point of the FFT window, we have also made sure that the chances of the equalizer of seeing non-causal multipath components minimal. The above algorithm (Alg#2) is valid for single band or dual band transmission as well. For single band transmission, the process ceased to be band dependent adaptive and becomes fixed 'ZP_LEN' as 32 samples. So, as per Alg#2, a band-dependent 'ZP_LEN' number of samples after the FFT window is picket up and added to the front portion.

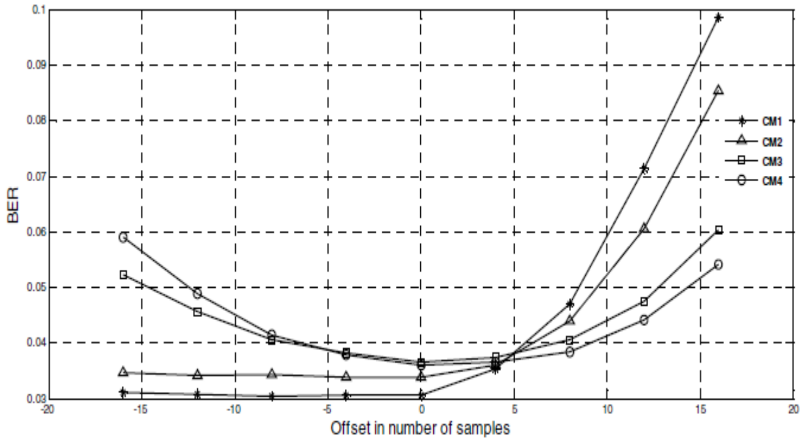

Fig.3 offset sensitivity of BER for all channel models at 10 dB Eb/No with fixed ZP_LEN

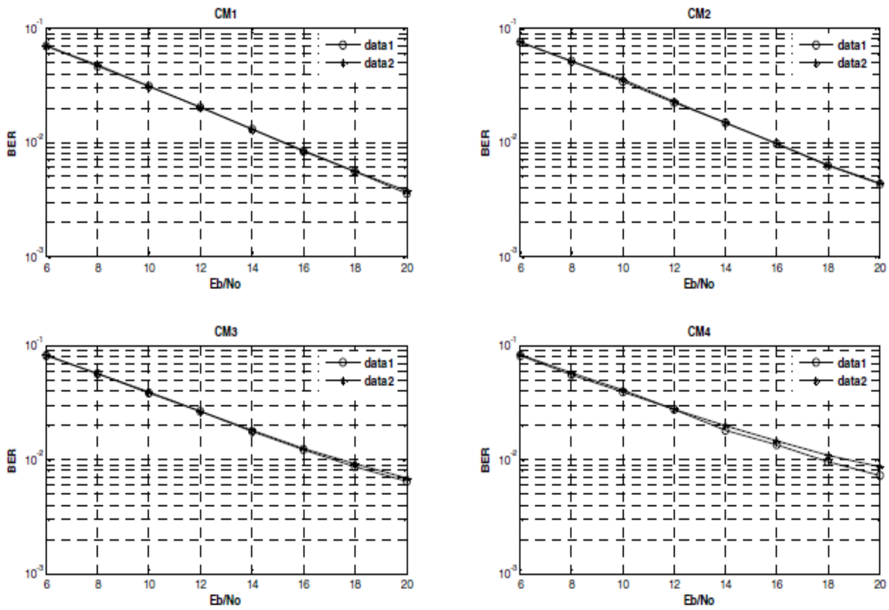

Fig.5. BER vs Eb/No simulation for all channel models in uncoded MB-OFDM system. Data1: using variable ZP length. Data2: using fixed ZP length of 32

VI. SIMULATION RESULTS

Figure 5 shows the BER curves for uncoded MB-OFDM based UWB system with and without band wise variable ZP length for overlap and add operation. For large delay-spread channels in UWB systems the mean excess delay is more compared to small delay-spread channels. This implies for large delay spread channel, the estimation of FFT window will be more away from the true FFT window resulting in more ISI incursions from next OFDM symbol. Hence the Proposed technique is more promising for large delay-spread channels. The curves show a significant amount of

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performance improvement (for CM4 around 1 dB of Eb/N0 savings at 10-2 BER for uncoded system) is achieved for large delay-spread channels.

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