MITIGATING MULTI-USER INTERFERENCE (MUI) IN ULTRA WIDEBAND (UWB) SYSTEM USING DS-CDMA BASED OFDM

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ABSTRACT

In this paper we propose two schemes to mitigate multi-user interference (MUI) in Multi user UWB system. Both these schemes are Direct Sequence Code Division Multiple Access (DS-CDMA) based Orthogonal Frequency Division Multiplexing (OFDM) systems. We investigate performance of both the proposed schemes under different users with additive white Gaussian noise (AWGN) and fading channel. Also, performance of proposed scheme is compared with DS-UWB proposed in [1].

1. INTRODUCTION

Ultra wideband (UWB) [2] is emerging as a promising technique to transmit high speed data. UWB’s applications to short-range wireless personal area networking (WPAN) is currently being explored [3]. Because of its wideband nature UWB system promises to deliver a very high data rate, which is 100 times faster than Bluetooth’s speed. In IEEE 802.15.3a and IEEE 802.15.4a, UWB is seen as a possible technique at physical layer [4].

Frequency range for UWB communication is 3.1GHz to 10.6GHz. Signal is considered as a UWB signal if it has a fractional bandwidth (\(B_f\)) of more than 20 % (at -10 dB emission points), where fractional bandwidth is defined as a ratio of signal bandwidth to its center frequency. Signal with bandwidth of more than 500MHz in assigned frequency range is also considered as UWB signal. Different literatures suggest two methods for multiple access with UWB. Old approach is time hopping based technique [3, 5, 6] in which UWB radio signal is comprised with sequence of pulses, which are sub-nano second duration pulses. Second approach is based on Multi-band OFDM [4, 7] in which available frequency band is divided into small sub bands with minimum bandwidth of 500MHz each. This approach is becoming popular as interference rejection due to coexisted system is easy by avoiding transmission in coexisted range.

In wireless data transfer, when reflected symbol reaches at receiver within symbol duration will create inter symbol interference (ISI). ISI causes poor performance of receiver in a fading channel. Adaptive equalization is required to eliminate multipath effect in which channel impulse response (CIR) is estimated. Implementation of adaptive equalizer at several megabits per second (like in UWB) has its own practical limitations. One possible way to overcome this problem in UWB is to use parallel transmission method [8, 9] like OFDM.

In a multiuser scenario, DS-CDMA provides high capacity and reduce multi user interference (MU). By combining DS-CDMA with OFDM for UWB transmission, we can overcome problems of MU and ISI.

DS-CDMA was used for UWB transmission in [1]. In [10, 11, 12] different issues for multi-user environment with OFDM for UWB communication are discussed. In this paper, we propose DS-CDMA based OFDM technique for multi-user UWB communication. The performance is evaluated using two schemes, under various users condition for AWGN and fading channel. The performance of our proposed schemes is compared with DS-UWB [1]. Section 2, discusses the system model for downlink with scheme-I and II. In Section 3, we describe the DS-UWB proposed in [1]. In Section 4, we show simulation results with AWGN and fading channel also comparison with DS-UWB is shown. Finally, in Section 5, we conclude our work.

2. DS-CDMA BASED OFDM SYSTEM MODEL

Here, multi user UWB system is considered for data transmission which is DS-CDMA based OFDM. For this method two schemes are proposed as shown in figure 1 and 2.

2.1 System Model for scheme-I

In proposed scheme-I, whose system model is shown in figure 1, raw user data is spreaded with unique code, as in DS-CDMA system. After this, data is fed to preprocessing block which consists of two sub blocks, serial to parallel conversion and data mapping block. Concatenated mapped symbols are fed to OFDM block which will take IFFT of data and insert guard interval.

Figure 1: System Model -I for DS-CDMA based OFDM for UWB.

Raw data for \(k^{th}\) user is \(b(k)(\cdot)\), where \(k = 1, \cdots, N\) and \(N\)
is the total number of users. After spreading, data for \( k^{th} \) user is \( d^{(k)}(m) = b^{(k)}(m) c^{(k)}(m) \), where \( m = 0, \cdots, \infty \) and \( c^{(k)}(.) \) is \( k^{th} \) user code.

In this scheme, each user data is fed to preprocessing block. This will first convert each user data into \( \ell \) parallel paths. Data rate on each link gets reduced by factor of \( \ell \). \( d^{(k)}_{\ell}(m) \) is \( m^{th} \) data of \( k^{th} \) user in \( \ell^{th} \) parallel path. Data on each parallel path is mapped to QPSK symbols which is \( d^{q}_{\ell}(m) \). This data is fed to IFFT block. Output of the IFFT block is

\[
S'(t) = \sum_{n=0}^{\infty} \sum_{i=0}^{M-1} D_i(n) \exp(j2\pi f_i(t-nT_s))g(t-nT_s)
\]

where vector \( D_i(.) \) is a complex number and it is obtained by concatenating \( d^{(k)}_{q\ell}(m) \) for all \( N \) users. So \( D_i(.) \) is written as

\[
D_i(.) = [d^{(1)}_{q\ell}(1), \cdots, d^{(1)}_{q\ell}(s), d^{(2)}_{q\ell}(1), \cdots, d^{(2)}_{q\ell}(s), \cdots, d^{(N)}_{q\ell}(1), \cdots, d^{(N)}_{q\ell}(s)]
\]

Now, \( f_i(i = 0, 1, \cdots, \infty) \) is the frequency of \( i^{th} \) sub carrier given by \( f_i = f_0 + \frac{i}{T_s} \), where \( T_s \) is the symbol duration of OFDM signal and

\[
g(t) = \begin{cases} 1 & 0 \leq t \leq T_s \\ 0 & \text{otherwise} \end{cases}
\]

In multipath environment, in order to reduce the effect of ISI, guard interval is inserted. Each OFDM symbol is preceded by cyclic extension of the signal itself. After inserting guard interval, OFDM signal is

\[
S(t) = \sum_{n=0}^{\infty} \sum_{i=0}^{M-1} D_i(n) \exp(j2\pi f_i(t-nT_{ttotal}))g'(t-nT_{ttotal})
\]

Where \( T_{ttotal} = T_g + T_s \), \( T_g \) is guard interval and \( T_s \) is symbol duration. If guard interval is more than channel impulse response, then ISI is removed.

\[
g'(t) = \begin{cases} 1 & -T_s \leq t \leq T_s \\ 0 & t < -T_s, t > T_s \end{cases}
\]

### 2.2 System Model for scheme-II

Block diagram of system model for scheme-II is shown in figure 2. This model considers the effect of Multi-user interference (MUI) by combining data from every user after DS-CDMA. This is given by

\[
d'(m) = \sum_{k=0}^{N-1} d^{(k)}(m)
\]

where \( d^{(k)}(m) = b^{(k)}(m) c^{(k)}(m) \) and \( m = 0, 1, \cdots, \infty \) are \( k^{th} \) user data and code respectively. All users combined data \( d'(.) \) is fed to a preprocessing block. This will first convert data in to \( \ell \) parallel links. \( d'_{\ell}(m) \) is \( m^{th} \) data in \( \ell^{th} \) link. Each link data \( d'_{\ell}(.) \) is mapped to QPSK symbols

![Figure 2: System Model -II for DS-CDMA based OFDM for UWB.](image)

which is denoted as \( d_q_{\ell}(.) \). After QPSK data is fed to IFFT block, output of IFFT block is

\[
S'(t) = \sum_{n=0}^{\infty} \sum_{i=0}^{M-1} d_q_{i}(n) \exp(j2\pi f_i(t-nT_s))g(t-nT_s)
\]

\( d_q_i(.) \) is a complex number. And \( f_i(i = 0, 1, \cdots, \infty) \) is the frequency of \( i^{th} \) sub carrier given by \( f_i = f_0 + \frac{i}{T_s} \), where \( T_s \) is the symbol duration of OFDM signal and

\[
g(t) = \begin{cases} 1 & 0 \leq t \leq T_s \\ 0 & \text{otherwise} \end{cases}
\]

After inserting guard interval OFDM signal is

\[
S(t) = \sum_{n=0}^{\infty} \sum_{i=0}^{M-1} d_q_{i}(n) \exp(j2\pi f_i(t-nT_{ttotal}))g'(t-nT_{ttotal})
\]

Where \( T_{ttotal} = T_g + T_s \), \( T_g \) is guard interval and \( T_s \) is symbol duration. \( S(t) \) is transmitted over multipath channel

\[
g'(t) = \begin{cases} 1 & -T_g \leq t \leq T_g \\ 0 & t < -T_g, t > T_g \end{cases}
\]

In this scheme only M data is transmitted while in scheme-I M.N data (N is total number of users and M is length of each user data) is transmitted. Because of this effective data rate is high in scheme-II.

### 2.3 Receiver Configuration for scheme-I and II

The received signal is contaminated by multipath fading and AWGN which is given as

\[
r(t) = \int_{0}^{T} h(t, \tau)s(t - \tau) d\tau + n(t)
\]

Where \( h(t, \tau) \) is channel response and \( n(t) \) is AWGN. In both the schemes, receiver first removes guard interval and subsequently signal is demodulated. After this, data is given to FFT block which will obtain output in observation range \([T_{gtotal}+iT_{ttotal} + T_g]\). Output after FFT of the \( i^{th} \) OFDM sub carrier is given by

\[
d_i(k) = \int_{T_g}^{T_{ttotal}+T_g} r(t) \exp(-j2\pi f_i(t-kT_{ttotal})) dt
\]

Next, all user data is demodulated with same code \( c^{(i)}(.) \) as in DS-CDMA system.
3. DS-UWB SYSTEM

3.1 System Model DS-UWB

In literature [1] DS-UWB system is proposed for Ultra-wideband communication. In this one bit duration is divided into \( N_f \) frames each with equal duration \( T_f \). During each frame UWB pulse is transmitted which is Gaussian monocycle or Scholtz Monocycle. In DS-UWB system transmitted signal is represented as

\[
S^{(k)}(t) = \sum_{j=-\infty}^{\infty} \sum_{i=0}^{N_f-1} d^{(k)}_i w(t - jT_f)
\]

Where \( S^{(k)}(.) \) is \( k^{th} \) user signal, \( d^{(k)}_i \) is \( k^{th} \) user bipolar spreaded data, \( N_f \) is number of frames per bit, \( w(.) \) is UWB pulse.

3.2 Receiver Configuration for DS-UWB

Received signal is contaminated by multipath fading and AWGN which is given as

\[
r(t) = \int_{0}^{\infty} h(t, \tau) s(t-\tau) d\tau + n(t)
\]

Where \( h(t, \tau) \) is channel response, \( n(t) \) is AWGN and \( s(t) \) is

\[
s(t) = \sum_{k=1}^{N} \sum_{j=-\infty}^{\infty} d^{(k)}_j w(t - jT_f)
\]

\( N \) is total number of users in the system. Here receiver is correlation based receiver as described in [1]. In which locally template is generated and data is recovered by correlation receiver.

4. SIMULATION RESULTS

We have carried out extensive Monte Carlo simulations under AWGN and fading channel for both the proposed schemes. We have used bit error rate (BER) as a performance comparison criterion and evaluated the performance of both schemes under various user conditions. In addition, performance of both proposed schemes is compared with DS-UWB proposed in [1]. For both the schemes, parameters for simulation are shown in Table 1. For scheme-I results are shown in figures 3 and 4 for AWGN channel with three and seven users respectively. It can be seen that for achieving same BER with seven users almost 4dB more power is required in scheme-I. Figure 7 shows the comparison between performance of DS-UWB proposed in [1] with our proposed scheme-I. From figures 7 and 8 it can be seen that in proposed scheme-I 4dB improvement is achieved with three users and 2dB improvement is achieved with seven users with compared to DS-UWB.

BER performance for scheme-II is shown in figures 5 and 6 with three and seven users respectively for AWGN channel. In this case, as compared to three users almost 6dB more power is required when numbers of users are seven. Also, the performance of scheme-II is compared with DS-UWB [1] (figures 7 and 8). From figure 7 it can be seen that our proposed scheme-II performs better than DS-UWB [1] and this improvement factor is 2dB.

For both proposed schemes performance is also evaluated with fading channel. We have considered different number of reflected rays for considering ISl effect. Figure 9 shows performance of scheme-I over multipath channel with two and six multipath components for three and seven users. It can be seen that with scheme-I when number of reflected rays are two almost 2dB improvement is achieved with three users as compared to seven users. When the reflected components are six, scheme-I with three users almost perform equally as compared to seven users with two multipath components. More degradation is present when six multipath components are considered in seven users case. Figure 10 depicts the performance of scheme-I under different user condition with two and six multipath components under fix \( [E_b/N_0] \) of 12dB. Figure 11 shows performance of scheme-II under fading channel. With less number of multipath com-

Table 1: Simulation Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spreading Code</td>
<td>Walsh code</td>
</tr>
<tr>
<td>Spreading Factor</td>
<td>8</td>
</tr>
<tr>
<td>Data Rate</td>
<td>25 Mbps</td>
</tr>
<tr>
<td>No. of parallel channels</td>
<td>64</td>
</tr>
<tr>
<td>Data Modulation</td>
<td>QPSK</td>
</tr>
<tr>
<td>FFT Length</td>
<td>64</td>
</tr>
<tr>
<td>Guard Interval</td>
<td>1/4 of symbol duration</td>
</tr>
</tbody>
</table>

![Figure 3: BER Performance for scheme-I with 3 users.](image3.png)

![Figure 4: BER Performance for scheme-I with 7 users.](image4.png)
ponents in scheme-II performance under three user condition is better compared to seven user case. With more multipath components almost same performance can be seen with three and seven user condition. For fix value of $\frac{E_b}{N_0}$ performance of scheme-II with different user condition is shown in figure 12.
5. CONCLUSION

In this paper, performance of UWB systems for multi-user environment using, DS-CDMA based OFDM system was evaluated with two schemes. Performance is evaluated with AWGN and fading channel. In multi-user environment, scheme-I gives better performance as compared to scheme II. For lower value of users both schemes give comparable results for AWGN channel. The performance of scheme-II is poor due to stronger influence of MUI. Almost 3dB degradation exists in scheme-II with three users and 6dB degradation exists for seven users in AGWN channel. Under fading channel, scheme-I performs better as compared to scheme-II. When reflected rays are six in scheme-II, performance is almost the same with three and seven user case.

6. FUTURE WORK

Here, system performance is evaluated with AWGN and fading channel. We will consider multi-path realistic UWB channel model which is Saleh and Valenzuela model (S-V model) [13] for both proposed schemes and ensure the performance under Multi-user environment.

REFERENCES