BOUNDING PERFORMANCE AND ANALYZING INTERCARRIER INTERFERENCE IN WIRELESS MOBILE CDMA

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Abstract
While rapid variations of the fading channel cause intercarrier interference (ICI) in code division multiplexing access (CDMA), thereby degrading its performance considerably, they also introduce temporal diversity, which can be exploited to improve the performance. In this paper, we first evaluate the Inter channel Interference which include the Signal to Interference Ratio (SIR) and Inter Carrier Interference (ICI) in a MC DS CDMA wireless system. However, existing ICI cancellation methods do not cancel ICI entirely and the BER performance after ICI cancellation is still much worse than the BER performance of original system without ICI. Moreover, popular ICI cancellation methods like ICI self-cancellation reduce ICI at the price of lowering the transmission rate and reducing the bandwidth efficiency. Other frequency-domain coding methods do not reduce the data rate, but produce less reduction in ICI as well.

Keywords: ICI, CDMA, MC DS CDMA, BER, OFDM

I. INTRODUCTION
Wireless communication is the transfer of information over a distance without the use of electrical conductors or "wires". The distances involved may be short (a few meters as in television remote control) or long (thousands or millions of kilometers for radio communications. Multiple access schemes based on a combination of code division and OFDM techniques have already proven to be strong candidates for future 4G systems[11]. Several techniques have been proposed. The three most popular proposals are multicarrier (MC-) CDMA, multicarrier modulation with direct sequence (DS-) CDMA, and multitone(MT-) CDMA . In this thesis, I concentrate on MC-CDMA, a novel digital modulation and multi access scheme and a very promising technique for 4th generation cellular mobile radio systems. MC-CDMA allows high-capacity networks and robustness in frequency selective channels. MC-CDMA is a combination of OFDM and code division techniques. Hence, we will study the current state-of-the art trends for implementation of OFDM and CDMA using Field Programmable Gate Array (FPGA) devices. The implementation of OFDM and CDMA have been categorized according to modulation/demodulation, detection, channel estimation, synchronization, interference suppression, frequency offset estimation, timing recovery, and equalization.

II. RELATED TECHNIQUES

A. Code Division Multiple Access (CDMA)

Code division multiple access (CDMA) is a channel access method utilized by various radio communication technologies. It should not be confused with the mobile phone standards called CDMA One and CDMA2000 (which are often referred to as simply "CDMA"), which use CDMA as an underlying channel access method.

One of the basic concepts in data communication is the idea of allowing several transmitters to send information simultaneously over a single communication channel. CDMA is a form of
spectrum “signaling, since the modulated coded signal has a much higher data bandwidth than the data being communicated.

An analogy to the problem of multiple access is a room (channel) in which people wish to communicate with each other. To avoid confusion, people could take turns speaking (time division), speak at different pitches (frequency division), or speak in different languages (code division). CDMA is analogous to the last example where people speaking the same language can understand each other, but not other people. Similarly, in radio CDMA, each group of users is given a shared code. Many codes occupy the same channel, but only users associated with a particular code can understand each other.

**B. Direct Sequence Code Division Multiple Access (DS-CDMA)**

In Direct Sequence spread spectrum transmission, the user data signal is multiplied by a code sequence. Mostly, binary sequences are used. The duration of an element in the code is called the “chip time”. The ratio between the user symbol time and the chip time is called the spread factor. The transmit signal occupies a bandwidth that equals the spread factor times the bandwidth of the user data.
Fig 3. A DS-CDMA signal is generated by multiplication of a user data signal by a code sequence

C. Multi Carrier Direct Sequence Code Division Multiple Access (MC DS CDMA)

The multicarrier DS-CDMA transmitter spreads the S/P converter data streams using a given spreading code in the time domain so that the resulting spectrum of each sub carrier can satisfy the orthogonality condition with the minimum frequency separation. This scheme is orthogonally proposed for a uplink communication channel, because the introduction of OFDM signaling into DS-CDMA scheme is effective for the establishment of a quasi-synchronous channel.

Fig 4. MC DS-CDMA scheme transmitter

Fig 5 MC DS-CDMA power spectrum of transmitted signal
The block diagram of a MC-DS CDMA transmitter is shown in Figure 4. The incoming data stream is first converted to a parallel stream and then spread in time using spreading codes. This ensures that the resulting spectrum has orthogonal subcarriers. The spreading code is represented as $C(t)$ and the processing gain is $N$. The receiver block is shown in Figure 6. The despreading is done in time after the FFT followed by a low pass filter and demodulation. In the figure show the MC DS-CDMA transmitted signal, respectively, where $G_{MC}$ denotes the processing gain, $N$ the number of sub carriers, and $C_j(t)$. The spreading code of the $j$-th user. In a MC DS-CDMA scheme with a larger sub carrier separation is proposed in order to yield both frequency diversity improvement and narrow band interference suppression. In addition, a MC DS-CDMA scheme, which transmits the same data using several sub carriers, is proposed.

III. Evaluation of Interchannel Interference

A. Gaussian Approximation

This method used to evaluate the effect of interchannel interference on the receiver performance is the Gaussian Approximation. To use the Gaussian Approximation the first and second derivatives of the MGF have to be calculated in order to obtain the mean and standard deviation.

Thus, we have:
As the mean is given by $M_{ON}^\alpha(0)$ we have

$$\mu_{ON} = \bar{\lambda}_1 + \bar{\lambda}_2$$

The variance which is given by (4) is

$$\sigma_{ON}^2 = -n_1\bar{\lambda}_1^2 - n_2\bar{\lambda}_2^2$$

By replacing $n_1, n_2, \bar{\lambda}_1, \bar{\lambda}_2$ with their definitions the following equations for the mean and standard deviation are obtained for the ON-case:

$$\mu_{ON} = 4mk^2 \left( \frac{2}{x} + 1 \right) + 4m(1-k)^2 \left( \frac{1}{x} + 1 \right)$$

and

$$\sigma_{ON} = \sqrt{8mk^3 \left( \frac{2}{x} + 1 \right)^2 + 8m(1-k)^2 \left( \frac{1}{x} + 1 \right)^2}$$

By taking a similar approach in the OFF-case, the mean and standard deviation are obtained as

$$\mu_{OFF} = 4mk^2 \left( \frac{1}{x} + 1 \right) + 4m(1-k)^2$$

And

$$\sigma_{OFF} = \sqrt{8mk^3 \left( \frac{1}{x} + 1 \right)^2 + 8m(1-k)^2 \left( \frac{1}{x} + 1 \right)^2}$$
With the use of the parameters calculated above, the BER can be calculated. To analyze the receiver performance the BER was fixed at $10^{-6}$ and $10^{-9}$. The optimum values of $m$ and the receiver sensitivity $pN$ were calculated for different values of the channel overlap $k$.

For the double-sided interference case the procedure is the same. However, equations (5) to (8) have to be changed to include the effects of two interfering signals and not just one. The equivalent equations are given by

$$\sigma_{OFF} = \sqrt{8mk^3 \left( \frac{1}{x} + 1 \right)^2 + 8m(1-k)^3}$$

(8)

$$\mu_{ON} = 4mk^2 \left( \frac{3}{x} + 1 \right) + 4m(1-k)^2 \left( \frac{1}{x} + 1 \right)$$

(9)

$$\sigma_{ON} = \sqrt{8mk^3 \left( \frac{3}{x} + 1 \right)^2 + 8m(1-k)^3 \left( \frac{1}{x} + 1 \right)^2}$$

(10)

$$\mu_{OFF} = 4mk^2 \left( \frac{2}{x} + 1 \right) + 4m(1-k)^2$$

(11)

$$\sigma_{OFF} = \sqrt{8mk^3 \left( \frac{2}{x} + 1 \right)^2 + 8m(1-k)^3}$$

B. Chi-Square Approximation

The second method used to evaluate the effect of the interchannel interference on the receiver performance is the chi-square approximation. The mean and variances, which were
obtained in the previous section for the Gaussian Approximation, were fitted into the MGF of a random variable with chi-square distribution.

For the ON-case, the MGF is of the following form

\[ M_{ON}(s) = \left[ 1 - 2\sigma_{ON}^2 s \right]^{2m_1} \]  
(12)

Where

\[ m_1 = \frac{\mu_{ON}^2}{2\sigma_{ON}^4} \]

\( \mu_{ON} \) and \( \sigma_{ON} \) are given by (5) and (6) respectively.

For the OFF-case, the MGF is of the form

\[ M_{OFF}(s) = \left[ 1 - 2\sigma_{OFF}^2 s \right]^{2m_n} \]  
(13)

Where

\[ m_n = \frac{\mu_{OFF}^2}{2\sigma_{OFF}^4} \]

and \( \mu_{OFF} \) and \( \sigma_{OFF} \) are given be equations (10) and (11) respectively.

The procedure described above is valid for both the single and double-sided interference cases. The only difference is the use of the different values of \( \mu_{ON} \), \( \sigma_{ON} \), \( \mu_{OFF} \), \( \sigma_{OFF} \) for each case.

IV. Simulation Results

A. Numbers of user (j) with the signal to interference ratio (SIR)
Here we can see the plot between the numbers of user \( (j) \) vs. the signal to interference ratio (SIR). If we increase the numbers of user \( (j) \), the signal to interference ratio will decrease. The signal to interference ratio depends on signal power \( (Ps) \). Here \( Ps=1\text{mw} \) and the curve is for the number of sub-carrier \( (Nc) = 4 \).

**B. Number of user with signal to interference ratio \( (Nc = 4, 10, 18, 30) \)**

This figure is modified version of previous one. Here we can see that the plot is in between the number of user vs. signal to interference ratio. Here the signal power is 1mw and we
vary the number of sub-carrier (Nc) such as Nc = 4, 10, 18, 30. If we increase the number of user (j) then the signal to interference ratio will be decrease.

C. The number of user (j) with Inter Carrier Interference (ICI)

Here we can see that the plot is about the number of user (j) vs. Inter Carrier Interference (ICI). If we increase the number of user (j) then the inter carrier interference (ICI) will be increase. Here the number of user is 14 times, signal power is 1mw and the we have used the ICI equation and the curve is for the value of alpha = 0.2

D. The numbers of user (j) with inter-carrier interference (ICI) (with value alpha)

Fig 9. ICI vs. j

Fig 10. ICI vs. j (with value alpha)
Here we can see the modified version of the plot between the numbers of user (j) vs. inter-carrier interference (ICI). We have plotted these curves for different values of alpha such as alpha = 0.2, 0.5, 0.7, 0.9. The signal power is also Ps = 1mw and the number of user is 14.

VI. Conclusion

1. On comparing Numbers of user (j) with the signal to interference ratio (SIR): If we increase the numbers of user (j), the signal to interference ratio will decrease. The signal to interference ratio depends on signal power (Ps).

2. On comparing Numbers of user (j) with the signal to interference ratio (SIR) with different value of Nc = 4, 10, 18, 30: If we increase the number of user (j) then the signal to interference ratio will be decrease.

3. On comparing the numbers of user (j) with inter-carrier interference (ICI) as we increase the number of user (j) then the inter carrier interference (ICI) will be increase.

4. On comparing the numbers of user (j) with inter-carrier interference (ICI) (with value alpha): If we increase the number of user (j) then the inter carrier interference (ICI) will be increase. We have plotted these curves for different values of alpha such as alpha = 0.2, 0.5, 0.7, 0.9.

References