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Analysis of BER Performance with MMSE Detection Scheme for DS-CDMA and MC-CDMA Systems and Compare them

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Abstract

In direct Sequence spread spectrum transmission, the user data is multiplied by a binary code sequence. And the receiver side, the coded signal is again multiplied by same code sequence to get original signal back. Multi-Carrier Code Division Multiple Access (MC-CDMA) is a multiple access scheme used in OFDM-based telecommunication systems, allowing the system to support multiple users at the same time. MC-CDMA system is orthogonal communication scheme. DS-CDMA system is on type of simple CDMA system. MC-CDMA is combination of OFDM and DS-CDMA. The performance measure is based on Rayleigh Fading Channel. The bit error rate performance of MC-CDMA and DS-CDMA systems with Minimum Mean Square Error (MMSE) detection are carried out by MATLAB simulation. This paper represents BER performance for DS-CDMA and MC-CDMA systems and find out which CDMA system is good for communication among DS-CDMA and MC-CDMA. This paper also presents that what effect on BER, if no of bits per user is increased, if no of data sub-carriers increased and if no of users increased.

1. Introduction

In a multi-user communication system, multiple access capability is required to transmit multiple signals simultaneously. The problem with simple non overlapping Frequency division multiplexing (FDM) system is that at least twice the bandwidth of the original data signal is required to transmit the multi-carrier modulated signal. A more efficient and improved version of FDM is orthogonal frequency division multiplexing (OFDM). OFDM is multi-carrier modulation scheme in which serial data stream is divided into several parallel bit stream, which are transmitted using large number of orthogonal carriers. OFDM is bandwidth efficient by allowing its sub-channels to overlap.

Code Division Multiple Access (CDMA) : Multiple users want to communicate in common geographical area. Now the problem is, how should we share our recourses so that as many users as possible can communicate simultaneously. We can solve this problem by CDMA system. In CDMA system each user is allocated with different codes. Also, there is no problem of interference because the codes are orthogonal to each other.

CDMA issues:

- Tight synchronization is required to use orthogonal codes, which then break in a multi-path channel anyway.
- Quasi-orthogonal codes cause self-interference, which dominates the performance in most CDMA systems.
- Near-far problem is a serious hindrance, requiring fast and accurate power control (that uses up bits we could otherwise send information with).
- And for all this, the required bandwidth is now *J* times larger than it was before, so there doesn't appear to be a capacity gain.

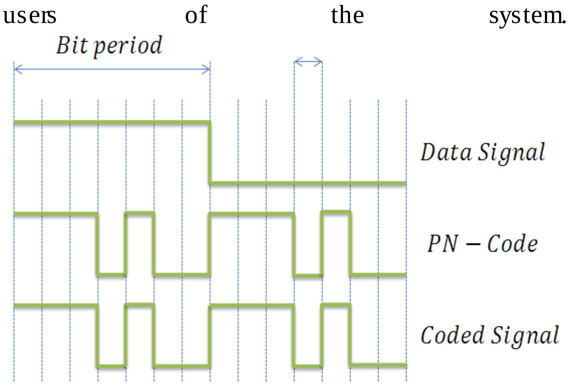
There are three types of CDMA system.

- Direct sequence-CDMA (DS-CDMA)
- Multi carrier (MC-CDMA)
- Multi carrier- direct sequence (MC-DS-CDMA).

We are interested only in analysis of MC-CDMA and generate BER performance based on MMSE detection scheme for single user and multi user system and observe the waveform generated by MATLAB code.

2. Direct Sequence Code Division multiple Access (DS-CDMA)

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. At the receiver, the received signal is again multiplied by the same (synchronized) code. This operation removes the code, so we recover the original user data. A major difficulty in Direct Sequence transmission is the Near-Far effect. That can be solved by power control system. There is also another problem of inherent diversity in case of DS-CDMA system. In a multi-path fading channel, direct signal may interfere with the delayed reflection signal. Hence, DS-CDMA signal is suffering from the multi-path dispersion, which can be detected by the rack receiver. These receivers' only combines the signals received over multiple paths. Multiple access capability in DS-CDMA is achieved by allocating distinct codes to different users of the system.



"Figure 1.DS-CDMA Signal"

From this waveform we can generate the BER performance MATLAB code for the DS_CDMA system. All signals are overlap and interfere with each other. Receiver can recover individual signal by correlating the combined signal with codes of desired users. If the cods are mutually orthogonal, then the original signal can be regenerated without any interference. This can be achieved by using orthogonal PN sequenced codes, and then it is the combination of DS-CDMA and OFDM. This combined system is called MC-CDMA system

3. Multi-carrier Code Division Multiple Access (MC-CDMA)

The future wireless mobile communication systems will be required to support high speed transmission rate. The high data rate requires broad frequency bands. Unfortunately in broadband wireless channel, due to the more number of resolvable multiple paths fading degrade the BER performance. MC-CDMA is multiple access scheme that allowing system to support multiple users at the same time with good BER using standard receiver techniques. MC CDMA spreads each user symbol in the frequency domain. That is, each user symbol is carried over multiple parallel sub-carriers, but it is phase shifted (typically 0 or 180 degrees) according to a code value. The code values differ per sub-carriers and per user. The receiver combines all sub-carriers signals, by weighing these to compensate varying signal strengths and undo the code shift. The receiver can separate signals of different users, because these have different (e.g. orthogonal) code values. Since each data symbol occupies a much wider bandwidth (in hertz) than the data rate (in bit/s), a signal-to-noise-plus interference ratio (if defined as signal power divided by total noise plus interference power in the entire transmission band) of less than 0 dB is feasible.

Unlike DS-CDMA, MC_CDMA applies spreading sequences in frequency domain. The original information becomes spreaded in frequency domain directly. After this spreading, the highly successful OFDM transmitter structure is borrowed and we hope that it will show all the benefits of DS-CDMA and OFDM.

Features:

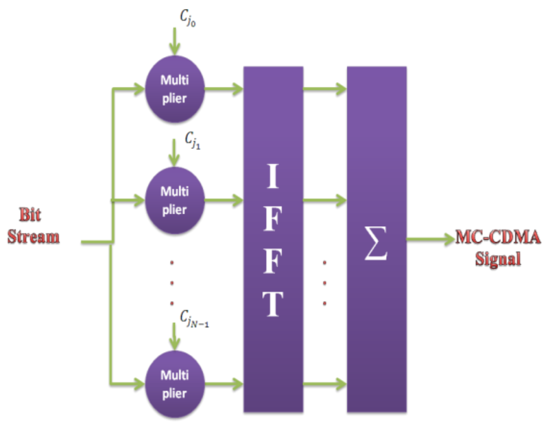
- Frequency domain spreading.
- The resulting spectrum of each subcarrier can satisfy the orthogonality condition with the minimum frequency separation. So, spectrum can be utilized more efficiently.
- In MC-CDMA, the code sequence is the Fourier transform of Walsh Hadamard sequence.
- It can be implemented via OFDM technique.
- In MC-CDMA, after spreading FFT is performed.

Advantages of MC-CDMA:

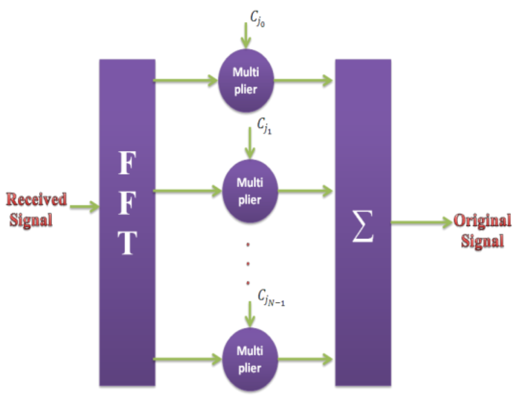
- *As compared to DS-CDMA:*
  DS-CDMA is a method to share spectrum among multiple simultaneous users. Moreover, it can exploit frequency diversity, using a RAKE receiver. However, in a dispersive multipath channel, DS-CDMA with a spread factor N can accommodate N simultaneous users only if highly complex interference cancellation techniques are used. In practice this is difficult to implement. MC-CDMA can handle N simultaneous users with good BER using standard receiver techniques.
- *As compared to simple OFDM:*
  To avoid excessive bit errors on subcarriers that are in a deep fade, OFDM typically applies coding. Hence, the number of subcarriers needed is larger than the number of bits or symbols transmitted simultaneously. MC-CDMA replaces this encoder by an N×N matrix operation. Our initial results reveal an improved BER.

Therefore, theoretically it is proved that MC-CDMA is more robust and identical to communication system than DS-CDMA. Now, to prove it practically, we have to generate MATLAB code for DS-CDMA and MC-CDMA with MMSE detection scheme.

4. Mc-CDMA Transmitter and Receiver Block Diagram



“Figure 2. MC-CDMA Transmitter”



“Figure 3. MC-CDMA Transmitter”

At the receiver side inverse process is done as shown in figure 3. According to these two block diagram generate MATLAB code for MC-CDMA system.

Here, we use Walsh-Hadamard code, which are orthogonal for a specific delay. They are not orthogonal in general. So, spreading is necessary. For a efficient communication BPSK modulation required. It converts 0 level into -1 level. At receiver side, received signal is filtered and noise corrupted version of transmitted signal.

As signal to noise ratio is higher, the system performance is better. Now, we have to implement BER versus E_b/N_0 graph. The transmitter block diagram for MC-CDMA is shown in figure 2.

5. Detection Techniques

Various detection methods have been investigated for MC-CDMA. Since each sub-carrier conveys a narrowband waveform, coherent detection schemes are the most common. For the downlink systems, single user based detection approaches such as MRC and MMSE are considered. In these schemes, the spreading code and channel coefficients of the user of interest are only utilized for the detection process.

5.1. Maximal Ratio Combiner (MRC):

In maximal ratio combining, (MRC) the amplitudes of the received signal are actually squared, so that it enhances the detection decision. The stronger amplitudes usually have less noise component in them. MRC is optimum for the single user case, but in the presence of multiple users, the distraction of orthogonality of the WH codes is increased which results in an increase in the effective multiple access interference (MAI). The gain expression is given by:

$W_l^* = h_l$. $l = 1, 2\ldots$ L. (1)

Where L = no of users.

5.2. Minimum Mean Square Error (MMSE):

In MMSE detection technique, the mean square error between transmitted signal S_l and the equalizer output X_l is given by

$E = \{|S_l - X_l|^2\}$. (2)

$W_l = h_l^*/(|h_l|^2 + (LN_0/(2KE_s)))$. (3)

Where Es denotes the average energy of the received data bit, K is the number of total users and No/2 is a two-sided noise spectral density. And h_l is Received signal bit. Thus, MMSEC detection requires finding the MMSE gains at each carrier using above eq. and then correlating the equalizer outputs signal with spreading code of the desired user.

6. Simulation and Results

Now, by using MATLAB software, we can generate our code of both CDMA systems for BER performance. For that there are some theoretical and practical BER expressions which are used in code, those are as below.

6.1. Theoretical expression

$snrlnr = 10^{snr/10}$ (4)

Theoretical BER for AWGN channel:

$TBer = 0.5 * erfc(sqrt(snrlnr))$ (5)

Theoretical BER for Rayleigh fading channel:

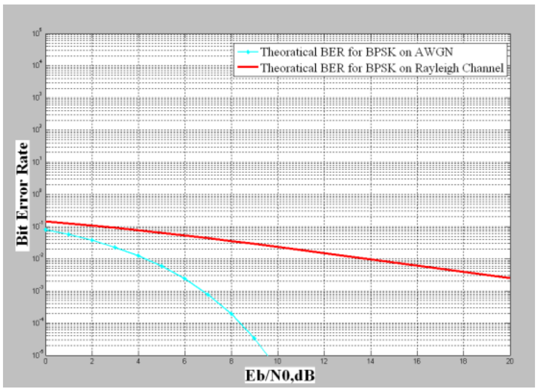
$TBerf = 0.5 * (1 - sqrt(snrlnr/(1 + snrlnr)))$ (6)

6.2. Practical expression

$BER = Error\ for\ user/No\ of\ bots\ per\ user$ (7)

$Total\ BER = BER\ of\ user1 + BER\ of user2 + \cdots$ (8)

6.3. Simulation Results for DS-CDMA



“Figure 4. Theoretical BER for AWGN and Rayleigh channel.”

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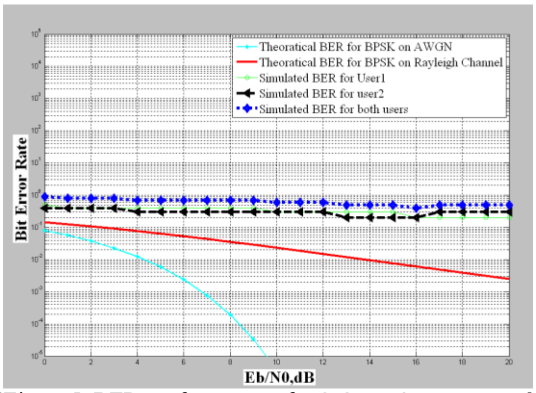
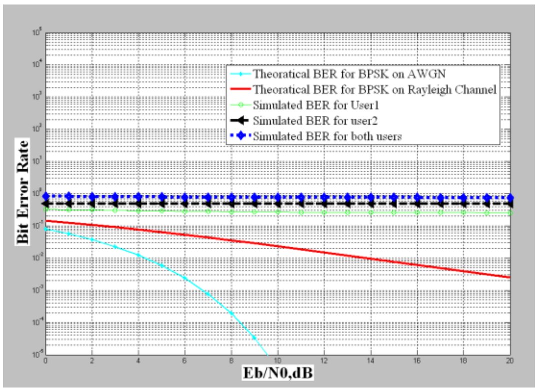


"Figure 5. BER performance of DS-CDMA sysyem with MMSE detection scheme with no of bits per user is 10, no of data subcarriers is 4 for the no of users is 2 "

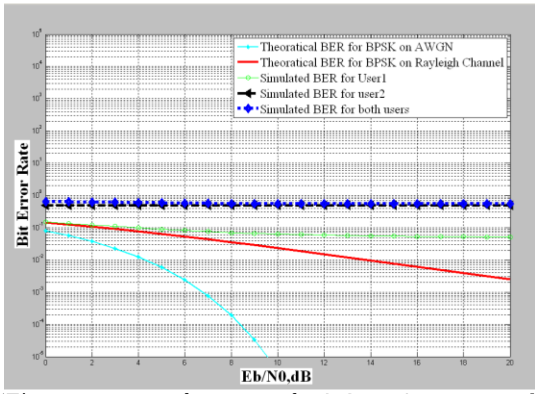


"Figure 6. BER performance of DS-CDMA sysyem with MMSE detection scheme with no of bits per user is 10^4, no of data subcarriers is 4 for the no of users is 2 "

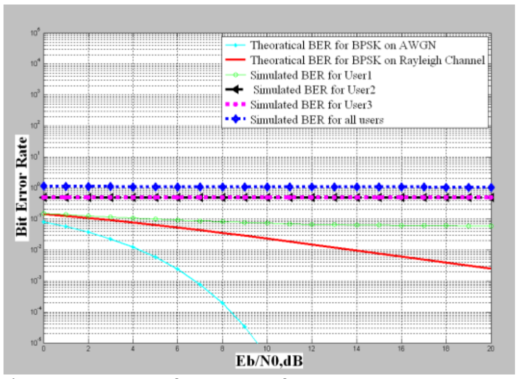
Figure 4 shows the theoretical BER performance for AWGN and Rayleigh fading channel. Figure 5 shows the BER performance of MC-CDMA for MMSE detection techniques with no of bits per user is 10 and no of data sub-carriers is 4. If we increase the no of bits per user from 10 to 10^4, we get better performance than in Figure 5.

The increased bits per user result is shown in figure 6. The increased no of data sub-carriers and increased no of users results for DS-CDMA are shown in figure 6 and figure 7 respectively.

The results of figure 5, 6, 7 and 8 are compare with Theoretical result in Figure 4. One can note that the results are not good for DS-CDMA system. Therefore we are going for MC-CDMA system and doing same process.



"Figure 7. BER performance of DS-CDMA sysyem with MMSE detection scheme with no of bits per user is 10^4, no of data subcarriers is 8 for the no of users is 2 "

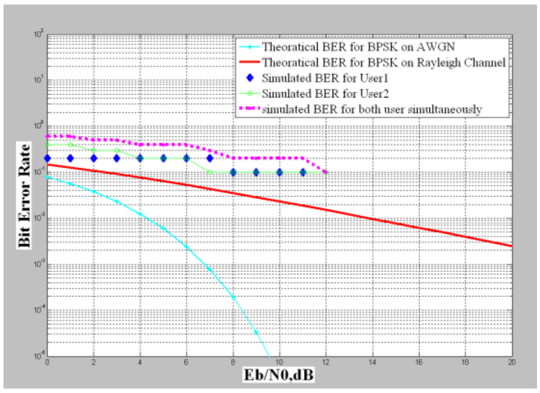


"Figure 8. BER performance of DS-CDMA sysyem with MMSE detection scheme with no of bits per user is 10^4, no of data subcarriers is 8 for the no of users is 3 "

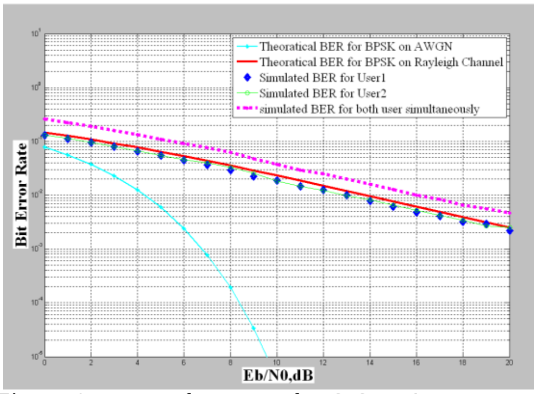
6.3. Simulation Results for DM-CDMA

The Figure 9 shows the BER performance for MC-CDMA system for MMSE detection technique. As we increased the no of bits per user from 10 to 10^4, we get better performance of MC-CDMA system as shown in figure 10.

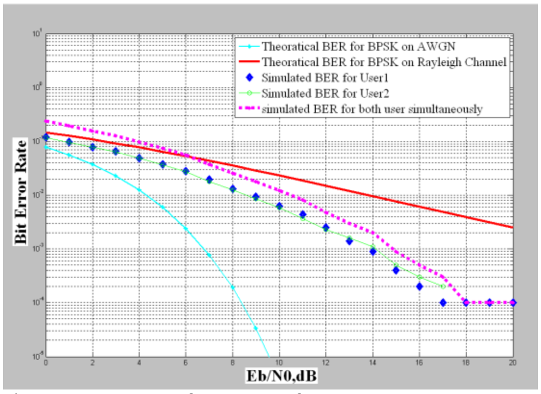
Now, if we increased the no of data-sub-carriers, we get much better result as shown in figure 11 than in figure 10. And if we increased no of users then the result is like figure 12. Now, compare MC-CDMA result with theoretical result in figure 4 and see the difference between the results of DS-CDMA and MC-CDMA. Also compare result of figure 8 and figure 12.



"Figure 9. BER performance of MC-CDMA sysyem with MMSE detection scheme with no of bits per user is 10, no of data subcarriers is 4 for the no of users is 2 "

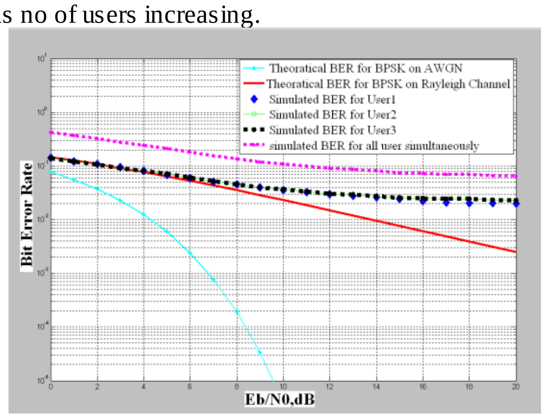


"Figure 10. BER performance of MC-CDMA sysyem with MMSE detection scheme with no of bits per user is 10^4, no of data subcarriers is 4 for the no of users is 2 "



"Figure 11. BER performance of MC-CDMA sysyem with MMSE detection scheme with no of bits per user is 10^4, no of data subcarriers is 8 for the no of users is 2."

By comparing the results of DS-CDMA and MC-CDMA in figure 8 and 12, one can say that, the MC-CDMA shows better performance than DS-CDMA, as no of users increasing.



"Figure 12. BER performance of MC-CDMA sysyem with MMSE detection scheme with no of bits per user is 10^4, no of data subcarriers is 8 for the no of users is 3."

MC-CDMA has good BER performance than DS-CDMA. So we can say that MC-CDMA is more robust and better performing for communication system than DS-CDMA.

7. Conclusion

MC-CDMA system is more robust and well performed in communication system than DS-CDMA and OFDM system, because of its unique advantages. The BER performances for MC-CDMA are better for increasing no users. The waveform for the multi user shows that as the no of bits per user increasing, the overall BER performance is increasing for MC-CDMA. So this system with MMSE detection technique provides a good system. Also as no of data subcarriers is increase, the BER performance is better for MC-CDMA system.

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