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A Review of Innovative Techniques in MC-CDMA for Future 4G.

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***Abstract*- The demand for high speed Mobile Communication is rapidly growing. 4G systems are expected to provide higher data rates, in the 100's of Mbps and greater flexibility for voice, data, video, and internet services to the customers.Multi-Carrier Code Division Multiple Access (MC-CDMA) is being considered for 4th generation wireless cellular systems (4G). MC-CDMA technology promises to be a key technique for achieving the high data capacity and spectral efficiency requirement for communication system for near future. This paper discuss the review of the innovative techniques in MC-CDMA for**

***Index terms*—MC-CDMA, OFDM, CDMA, Rayleigh fading.**

I. INTRODUCTION

The demand for wireless communications services has grown tremendously. Although the deployment of 3rd generation cellular systems has been slower than was first anticipated, researchers are already investigating 4th generation (4G) systems. These systems will transmit at much higher rates than the actual 2G systems, and even 3G systems, in an ever crowded frequency spectrum. The primary goal of next-generation wireless systems (4G) will not only be the introduction of new technologies to cover the need for higher data rates and new services, but also the ***integration*** of existing technologies in a common platform. The technique of ***multi-carrier transmission*** has recently been receiving wide interest, especially for high data-rate broadcast applications. The main advantages of multi-carrier transmission are its forcefulness in frequency selective fading channels and in particular, the reduced signal processing complexity by equalization in the frequency domain. Signals in wireless communication environments are impaired by fading and multipath delay spread. This leads to a degradation of the overall performance of the system. Hence, several avenues are available to mitigate these impairments and fulfill the increasing demands[1, 2] Fig-1 shows an example of *time variant multipath propagation.*

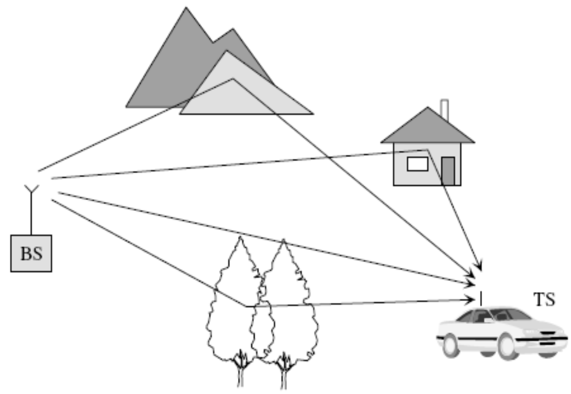

Fig1: Time variant multipath propagation

A lot of interest has been placed in modulation techniques like Orthogonal Frequency Division Multiplexing (OFDM) and Code Division Multiple Access (CDMA). Multiple access schemes based on a combination of code division and OFDM techniques have already proven to be strong candidates for future 4G systems. A major outfall of the higher generation wireless systems is spectral efficiency. Several techniques have been proposed. The three most popular proposals are multi-carrier (MC) CDMA, multi-carrier modulation with direct sequence (DS)CDMA, and multi-tone (MT-) CDMA .In this report, we 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 forcefulness in frequency selective channels. MC-CDMA is a combination of OFDM and code division techniques.[1]

II. NEED FOR MC-CDMA

Narrowband communications is immune to Intersymbol Interference but susceptible to attenuation caused by fading. CDMA is characterized by resistance to fading by spreading the signal over the entire bandwidth. However, this is affected by delay spreads and thus inter-chip interference is seen as a major drawback. OFDM is extremely popular in mobile communications over hostile radio environments. They use a large number of orthogonal parallel subcarriers for transmission. The biggest advantage of OFDM is the performance against inter-symbol interference at the receiver and frequency selective fading. A large peak to average ratio and sensitivity to frequency offsets are seen as major drawbacks to OFDM.MC-CDMA takes the advantages of both OFDM and CDMA and makes an efficient transmission system by spreading the input data symbols with spreading codes in the frequency domain. It uses a number of narrowband orthogonal subcarriers with symbol duration longer than the delay spread. This makes it unlikely for all the subcarriers to be affected by the same deep fades of the channel at the same time thereby improving performance. Synchronization during transmission becomes easier with longer symbol durations. The main advantages of MC-CDMA Compared to

(i).Direct Sequence (DS)-CDMA is a method to share spectrum among multiple simultaneous users. Moreover, it can exploit frequency multiplicity, 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.

(ii).Compared to OFDM: to avoid excessive bit errors on subcarriers that are in deep fade 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 NxN matrix operation[1,2]

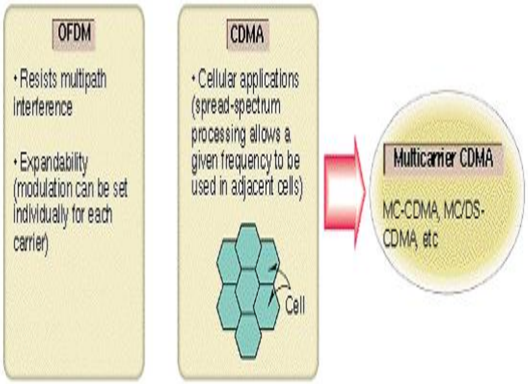

Fig2: OFDM + CDMA

Figure 2: shows MC CDMA, the communication technology for fourth generation cellular phones which combines OFDM & CDMA.

III. Basic OFDM System

Before we discuss about the MC-CDMA technique, the understanding of OFDM and CDMA techniques is necessary because MC-CDMA is a combination of these two methods. Orthogonal frequency division multiple access (OFDM) is seen as a useful multi tone modulation or multiplexing scheme with multiple access capability, higher resistance to inter-symbol interference (ISI) and improved performance over multipath fading channels. In multi-carrier modulation, the data stream is divided into N subcarriers or sub channels of lower data rate. This can be seen as parallel transmission in the frequency domain. This scheme does not affect the total bandwidth W. Each subcarrier is spaced W/N apart, while the symbol duration T is increased by a factor of N .This leads to the key idea in understanding OFDM which is the orthogonality of the subcarriers that allows simultaneous transmission on N subcarriers without interfering with each other.

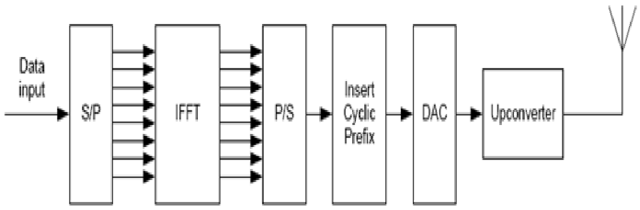

Fig3: Basic OFDM transmitter

Figure 3 illustrates the basic blocks of an OFDM transmitter.
In OFDM, the input data is sent to a serial-to-parallel converter (the S/P block). A high bit rate data stream is divided into N parallel low bit data streams each at a rate of 1/N. Then, the N parallel outputs of the S/P block feed the inputs of the Inverse Fast Fourier Transform (IFFT) block in order to create an OFDM symbol, sometimes called the OFDM modulator. Since the subcarriers are orthogonal to each other, the OFDM symbol has overlapping sinc spectra centered at the subcarrier frequencies as shown in figure 3.

For signals to be orthogonal, they have to satisfy:

$$\int_a^b \psi_p(t)\psi_q^*(t)dt = \begin{cases} k & \text{for } p = q \\ 0 & \text{for } p \neq q \end{cases}$$

where * denotes the complex conjugate and the interval [a, b] is the symbol period. By having these parallel data streams, the bandwidth of the modulation symbol is decreased by N or equivalently the time duration of the modulation symbol is increased by a factor of N. This can reduce ISI significantly. To ensure orthogonality, if the symbol period is T, the frequency spacing should be 1/T.The individual subcarriers are separated and they do not mutually interfere.

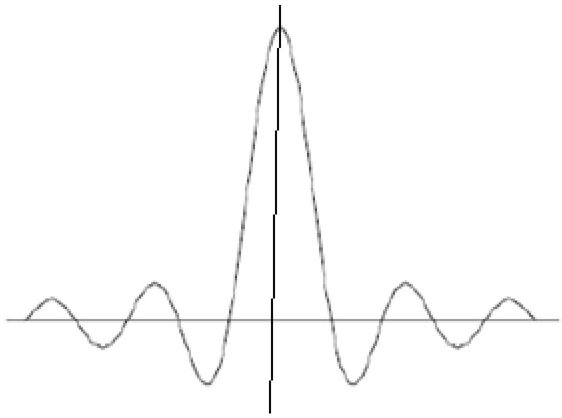

Fig4: Single carrier of OFDM

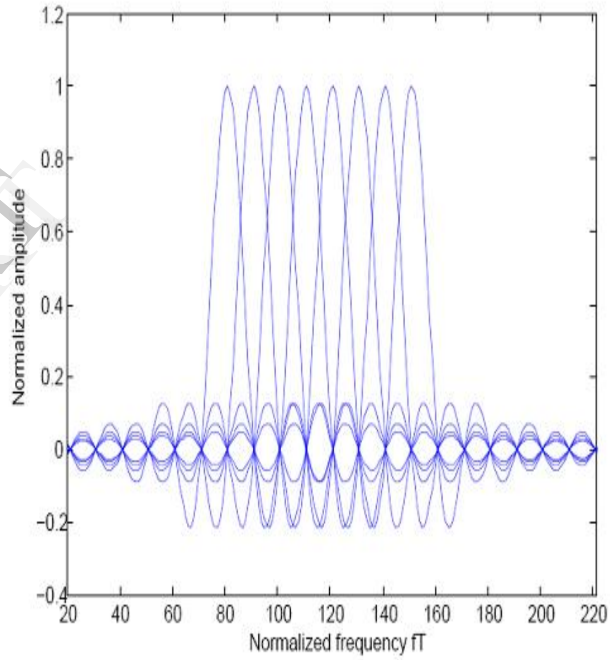

Fig5: Multiple carriers of OFDM

After the IFFT has been computed, the N complex numbers at the output of the IFFT block are parallel-to-serial converted (P/S block). Then, the cyclic prefix is inserted in order to combat the inter-symbol interference (ISI) and inter-carrier interference (ICI) caused by the multipath channel. Cyclic prefix is chosen to be longer than the maximum delay spread of the channel. This cyclic prefix is sometimes called the guard interval. In order to create the cyclic prefix, the complex vector of length Δ at the end of the symbol duration T is copied and appended to the front of the signal block. The OFDM symbol duration then becomes TS = T + Δ as shown in Figure 6 . In practice, the cyclic prefix is chosen to be longer than the maximum delay spread of the channel

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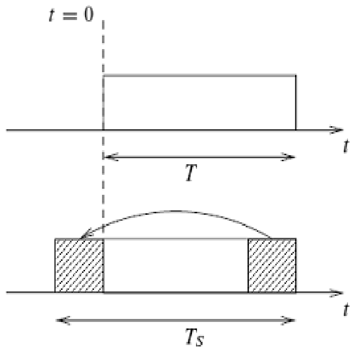

Fig6: Cyclic prefix of OFDM symbol

Finally, the output of the cyclic prefix block is fed to the digital to analog converter (DAC) and low pass filtered for each real and imaginary stream. The output of the DAC is up converted, sent through a band pass filter, and then sent to the antenna for transmission. At the receiver side, the received signal is the convolution of the transmitted sequence and the channel impulse response.
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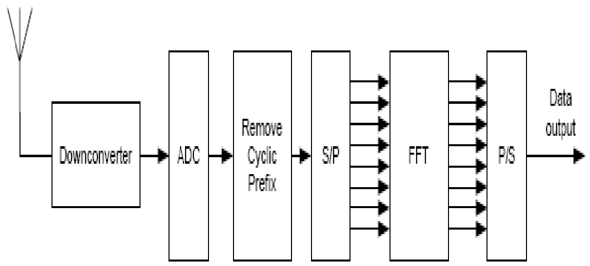


Fig7: Basic blocks of an OFDM receiver

Figure7 illustrates the basic blocks of an OFDM Receiver.
In the first step, the received signals are down converted and fed to an analog to digital converter (ADC). Then, the removal of the cyclic prefix is performed by circular convolution and the remaining samples are serial-to-parallel converted. The FFT block performs demodulation in order to obtain the transmitted symbols with the amplitude and phase corrupted by the channel response and the additive noise. The output bit stream is obtained by converting the output of the FFT block into serial bit stream.[3,4]
At the receiver end, the demodulation techniques available are:

- Coherent Demodulation of Non differential Modulation – The frequencies of each subcarrier should be synchronized or the phase offset is known to the system. Pilot carriers are used for synchronization purposes. In case of amplitude modulation techniques, attenuation of the subcarriers must also be known. For this type of demodulation, channel esfitimation is done at the receiver end. Some of the subcarriers are allocated to carry pilot symbols that contain transfer parameters for channel estimation. This means extra overhead for the system.

- Noncoherent Demodulation of Differential Modulation – This technique requires just the changes in the input to be known and recorded for demodulation. No pilot symbols are required which means lesser redundancy for the system.Channel Coding techniques are used at the transmitter level of the OFDM system to improve SNR levels. They can be coherent or noncoherent depending on the modulation technique used. Simple systems use convolution coding and bit interleaving at the transmitter level and use the Viterbi algorithm for decoding at the receiver end. The Block diagram of a simple Coded OFDM system is given in Figure 8. Other complex techniques include Trellis Coded Modulation and Multilevel Coding.

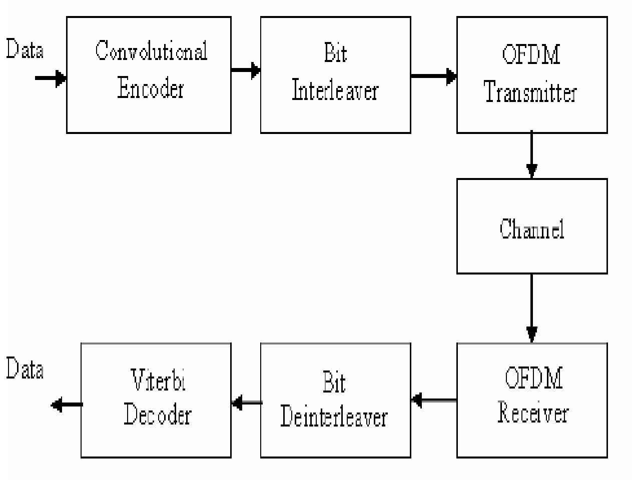


Fig8:coded OFDM system

Advantages and Disadvantage of OFDM

This section summarizes the strengths and weaknesses of multi-carrier modulation based on OFDM.[5]

Advantages:

- High spectral efficiency due to nearly rectangular frequency spectrum for high numbers of sub-carriers.
- Simple digital realization by using the FFT operation.
- Low complex receivers due to the avoidance of ISI and ICI with a sufficiently long guard interval
- Flexible spectrum adaptation can be realized
- Different modulation schemes can be used on individual sub-carriers which are adapted to the transmission conditions on each sub-carrier.

Disadvantages:

- Multi-carrier signals with high peak-to-average power ratio (PAPR) require high linear amplifiers. Otherwise, performance degradations occur and the out-of- band power will be enhanced.
- Loss in spectral efficiency due to the guard interval
- More sensitive to Doppler spreads then single-carrier modulated systems.
- Phase noise caused by the imperfections of the transmitter and receiver oscillators influence the system performance
- Accurate frequency and time synchronization is required[6]

IV. CODE DIVISION MULTIPLE ACCESS (CDMA)

Code division multiple access is a technique where multiple users share the same frequency band at the same time. Figure 9 illustrates an example of a simple CDMA transmission scheme[7]

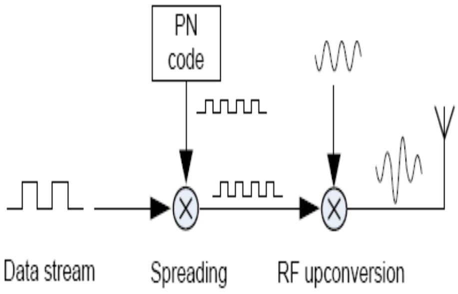


Fig9: example of simple CDMA transmitter

The heart of CDMA is the spread spectrum technique, which uses a higher data rate signature pulse to enhance the signal bandwidth far beyond what is necessary for a given data rate . Spreading is obtained via a multiplication of the baseband data information by a spreading sequence of pseudorandom signs, sometimes called pseudo noise (PN) or code signal, before transmission. An example of spreading is illustrated in Figure 12.[8,9]

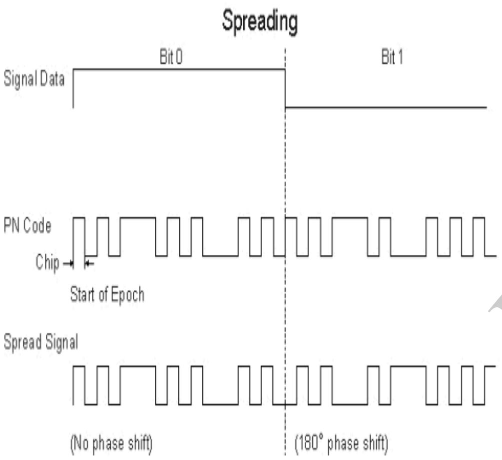


Fig10:example of spreading in CDMA

The spreading factor (SF) is defined as the ratio of the information bit duration over the chip duration

$$G_{MC} = SF = \frac{T_b}{T_c}$$

where Tb and Tc are the bit duration and the chip duration, respectively. This leads to an increase of the bandwidth by the spreading factor, as shown in Figure 11

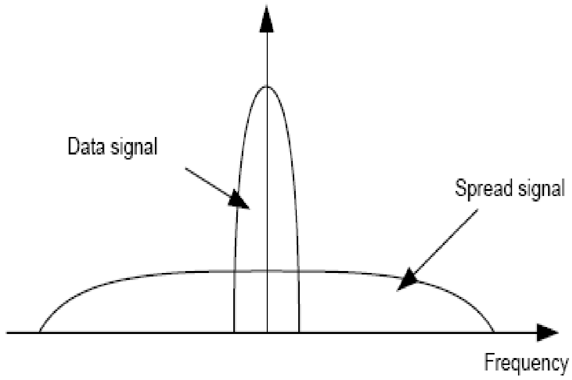


Fig11: power spectrum of spread signal vs data signal

spreading code is mainly characterized by its autocorrelation and cross-correlation functions. The rate of the spreading code is called the chip rate. CDMA provides good capacity for voice and data transmissions. As the number of simultaneous users increases, system performance decreases due to interference from users within the system. Thus, capacity and quality of service are limited. .[10,11]

Advantages of CDMA:

Following are the main advantages of CDMA:

(1).Low probability of interception
(2).Fading rejection
(3).Secure Transmission
(4).interference rejection

V. *Features of CDMA*

Power Control

The power seen by the handset is directly proportional to the distance between the transmitter and receiver. Thus, when a receiver is closer to the base station, the power with which it transmits is much higher than the power of a receiver at the edge of the cell. This is seen as interference to the receiver farther from the transmitter and is called the near-far effect. In order to avoid or reduce interference caused by this effect, the receiver design includes power control measures that reduce the power with which it transmits to the base station depending on the distance.[12.13]

VI. *Channel Model*

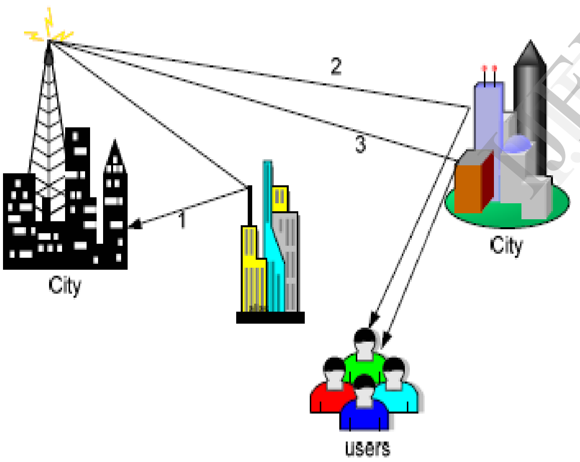
In order to evaluate the performance of the developed communication system, an accurate description of the wireless channel is required to address its propagation environment. The radio architecture of a communication system plays very significant role in the modeling of a channel. The mobile channel places fundamental limitations on the performance of wireless communication systems. The radio link between the transmitter and the receiver varies from simple line-of-sight to one that is severely obstructed by buildings, mountains, and hence suffers from severe multipath fading Multi-path is a condition where the transmitted radio signal is reflected by physical features/structures, creating multiple signal paths between the base station and the user terminal. These multipath signals can interfere with the desired signal and make it harder for receiver to detect the original signal that was transmitted .When the waves of multi-path signals are out of phase, reduction in signal strength can occur. One such type of reduction is called a fade; the phenomenon is known as "Rayleigh fading" or "fast fading." A fade is a constantly changing, three dimensional phenomenon. Fade zones tend to be small, multiple areas of space within a multi-path environment that cause periodic attenuation of a received signal for users passing through them.[16]

Fading channel models

Multipath fading is due to the constructive and destructive combination of randomly delayed, reflected, scattered and diffracted signal components. This type of fading is relatively fast and is therefore responsible for the short-term signal variations. Depending on the nature of the radio propagation environment, there are different models describing the statistical behavior of the multipath-fading envelope. The Rayleigh, Ricean and Nakagami are the most commonly used statistical models to represent small-scale fading phenomenon. In our simulation work we have taken Rayleigh fading channel and AWGN.[17]

VII. *Rayleigh Fading Channel*

The Rayleigh distribution is the most widely used distribution to describe the received envelope value. The Rayleigh flat fading channel model assumes that all the components that make up the resultant received signal are reflected or scattered and there is no direct path from the transmitter to the receiver, which is shown in fig 21. The Rayleigh distribution is commonly used to describe the statistical time varying nature of the received envelope of a flat fading signal, or the envelope of an individual multipath component. In the Rayleigh flat fading channel model, it is assumed that the channel induces amplitude, which varies in time according to the Rayleigh distribution.[17,18]



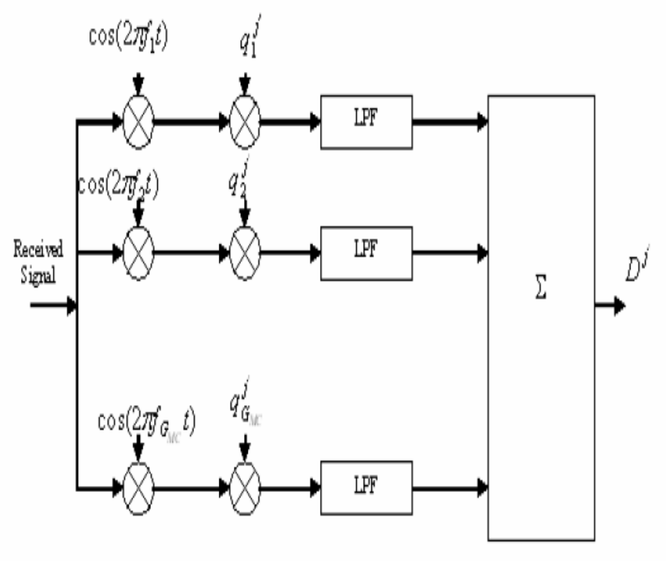


Fig21: Rayleigh fading

When the channel impulse response is modeled as a zero-mean complex-valued Gaussian process, the envelope at any instant is Rayleigh-distributed. The Rayleigh distribution of a received complex envelope of a signal z(t) = |x(t)| at any time t is given as

$$p_z(x) = \frac{x}{\sigma^2} e^{\left(\frac{-x^2}{2\sigma^2}\right)} \qquad (x \geq 0)$$

$$E\{x^2\} = 2\sigma^2 \quad \text{and } x \geq 0$$

where σ is the root mean square value of the received voltage signal before envelope detection , and is the σ^2 is the time-average power of the received signal before envelope detection. It is well known that the envelope of the sum of two quadrature guassian noise signals obeys a rayleigh distribution. This fading distribution could be described as follows:

•This represents the worst fading case because we do not consider having Line of Sight (LOS).
• It is caused by Doppler-shifted echoes with a Gaussian distribution,
• The power is exponentially distributed.
• The phase is uniformly distributed and independent from the amplitude.
• This is the most used signal model in wireless communication

Receiver Implementation

For an ideal channel environment, the receiver does a reverse of the transmitter implementation. The initial blocks are a reverse of the OFDM transmitter section followed by the de-spreading and demodulation of the output from there. After serial to parallel conversion, the received signal is multiplied by again q^j_m

The decision variable D^j is calculated as

$$D^j = \sum_{m=1}^{G_{MC}} q_m y_m$$

where $y_m = \sum_{j=1}^{P} z^j_m d^j c^j_m$ these gains vary for different detection techniques.

Within the family of linear combining techniques, different schemes based on channel state information (CSI) are known in the literature[2] where signals coming from different subcarriers are weighted by suitable coefficients to improve the system performance. Among these techniques, maximal ratio combining (MRC), equal gain combining (EGC) and orthogonality restoring combining are only some of the most known and frequently adopted when the CSI is available only at the transmitter or the receiver.we have applied equal gain combining method .this is single user detection method.

The gains for the equal gain combining and the maximum ratio combining are given by $q_m^{j'} = c_m^{j'} z_m^{j'*}/|z_m^{j'}|$ (EGC) and by $q_m^{j'} = c_m^{j'} z_m^{j'*}$ (MRC), respectively. In the case of one user , the maximum ratio combining method can minimize the BER. There are some other multi user methods also like ML-MUD(maximum likelihood multi user detection) ,etc.

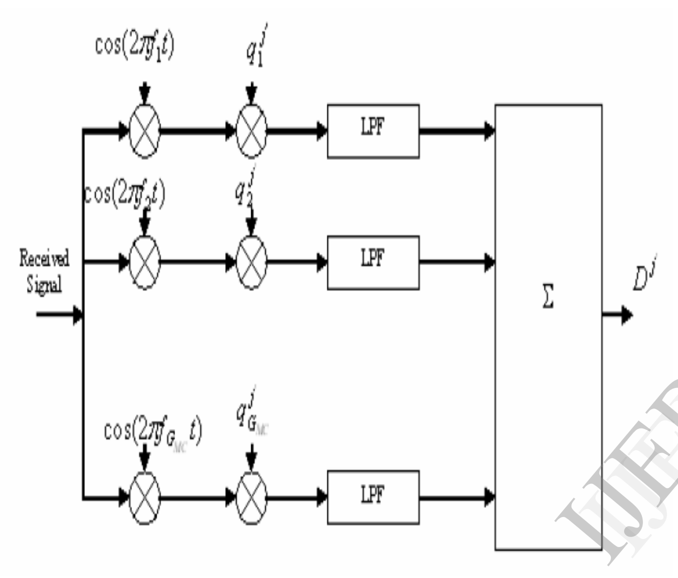
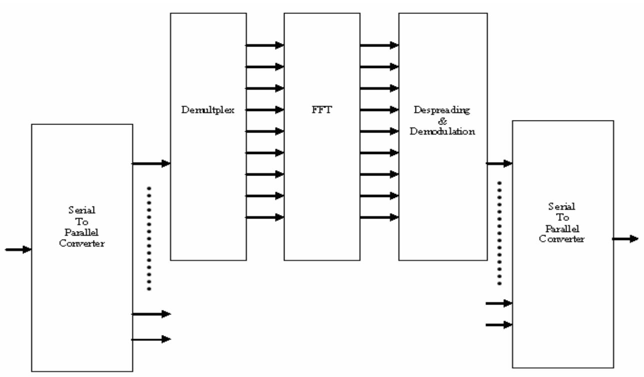


Fig22: Multicarrier CDMA Receiver



Since the Walsh code of the user is not known at the receiver section, a search operation is done where the received symbols are correlated to the Walsh codes and the codes with maximum correlation with the received symbols are chosen. Demodulation of the data is done according to the modulation method used at the transmitter side. In order to improve the performance of the system, an appropriate approach for channel estimation is to use dedicated pilot symbols that are periodically inserted in the transmission frame (in the time domain). This is known as block-type pilot channel estimation. The pilot tones can also be inserted into each symbol (in the frequency domain) with a given frequency spacing; this is known as comb-type pilot channel estimation. Block-type pilot channel estimation has been developed under the assumption of a slow fading channel (i.e. the channel transfer function does not change very rapidly). Comb-type pilot channel estimation has been developed under the assumption that the channel changes from one OFDM block to the other. Comb-type channel estimation estimates the channel at pilot frequencies. Furthermore, pilot tones may be inserted in both time and frequency domains .we have applied the pilot tones according to the standard wimax 802.16e.[15,16]

Advantages and Disadvantage

Advantages
i) Simple implementation with FFT
ii) Low Complex receiver
iii) High spectral efficiency
iv) High frequency diversity gain due to spreading in frequency direction

Disadvantage

i) High PAPR especially in the uplink
ii) Synchronous transmission

Thus, the high spectral efficiency and the low receiver complexity of MC-CDMA make it a good candidate for the downlink of a cellular system.

VIII. CONCLUSION

This paper discusses the different innovative techniques of MC-CDMA for future 4G perspective. The MC-CDMA is a basic combination of OFDM and CDMA.The aim of this paper is to understand the working of MC-CDMA and the factors which affect the receiving signals in cellular system. The BER occurs should be remove by channel coding and simulation technique, which is to be discussing in further research and should be present in the next paper.

IX. REFERENCE

[1]. "*Fundamentals of 4th Generation Multi- Carrier Code Division Multiple Access (MCCDMA)*". Author(s)**:** Nguyen, M-Q.; Fortier, P.; Roy, S. Corporate author(s)**:** Defence R&D Canada - Ottawa, Ottawa ONT (CAN);Laval Univ, Quebec QUE (CAN) Department de Genie Electrique et de Genie Informatique.

[2]. Xue Li, Ruolin Zhou, Steven Hong, and Zhiqiang Wu , "*Total Inter-Carrier Interference Cancellation for MCCDMA System in Mobile Environment*" , IEEE Communications Society subject matter experts forpublication in the IEEE Globecom 2010 proceedings.

[3] N. R. Van, and R. Prasad, *OFDM for WirelessMultimedia Communications,* Norwood,MA:USA, Artech House, 2000.

[4] T. Cui, and C. Tellambura, Semiblind ChannelEstimation and Data Detection for OFDMSystems With Optimal Pilot Design, *IEEETransactions on Communications,* vol. 55, no.5, May 2007, pp. 1053-1062.

[5] N. Yuan, An Equalization Techniques for HighRate OFDM System, *M.Sc. Thesis, Departmentof Electrical Engineering, University ofSaskatchewan, Saskatoon,* December 2003.

[6] K. E. Baamrani, A. A. Ouahman, and S. Allaki,Rate adaptive resource allocation for OFDM*Communication*, vol. 61, 2007, pp.30–34.

[7] E. Kim, Performance of Multicarrier DS CDMASystems, *EEL6503 Spread Spectrum andCDMA, Final Report*, December 2002, availableat heeke@ufl.edu.

[8] R. Venkatasubramanian, Beamforming for MCCDMA,*Thesis submitted to the faculty ofVirginia Polytechnic Institute and State*

[11] S. Kaiser, Multi-Carrier CDMA MobileRadio Systems Analysis and Optimization ofDetection, Decoding and Channel Estimation**,***Ph.D. dissertation, VDI-Verlag,Fortschrittberichte VDI*, Dusseldorf, 1998.

[12] S. Hara, and R. Prasad, Overview ofMulticarrier CDMA, *4th. IEEE InternationalSymposium on Spread Spectrum Techniques and Applications (ISSSTA'96),* Mainz, Germany,Vol. 35,No.12, December 1997,pp 126-133.

[13] S. Hara and R. Prasad, *Multi-CarrierTechniques for 4G Mobile Communications,* 1stEdition, Artech House, Boston, TK5103.4883.H37 2003.modulators, I*EEE Trans. on Circuit Theory*,Vol. 17, No. 3, August 1970, pp. 409-414

[14] A. Chooly, A. Brajal, and S. Jourdan,Orthogonal Multicarrier TechniquesApplied to Discrete Sequence Spread SpectrumCDMA Systems, *In Proceedings of IEEEGlobal Telecommunications Conference1993 (Houston, TX, USA),* 29 November- 2December (1993), pp. 1723-1728.

[15] G. Fettweis, A. Bahai, and Anvari, OnMulti-Carrier Code DivisionMultipleAccess (MC-CDMA) Modem Design, *InProceedings of IEEE VTC 94, (Stockholm,Sweden)*, IEEE, 8-10june (1994) , pp. 1670-1674.

[16] L. Hanzo, M. Munster, B. J. Chol, and T.Keller, *OFDM and MC- CDMA forBroadband Multi-user Communications,WLANs and Broadcasting*, John Wiley &Sons, (2003): CS-Books@wiley.co.ukWSEAS TRANSACTIONS on COMMUNICATIONS Haitham J. Taha, M. F. M. SallehISSN: 1109-2742 467 Issue 5, Volume 8, May 2009

[17] D. Lee, and L. Milstein, Comparison ofMulticarrier DS-CDMA Broadcast System in aMultipath Fading Channel, *IEEE Transactionon Communications,* Vol. 47, No. 12, December 1999,pp. 1897-1904.

[18] S. Chatterjee, W.A.C. Fernando, and M.K.Wasantha, Adaptive Modulation based MCCDMASystems for 4G Wireless Consumer Applications, *IEEE Transactions on ConsumerElectronics*, Vol. 49, No. 4, November 2003,pp. 995-1003.

[19] G. J. Andrews, and H. Y. M. Teresa,Performance of Multicarrier CDMA withSuccessive Interference Cancellation in Multipath Fading Channel, *IEEE Transactionson Communications,* Vol. 52, No. 5, May2004,pp. 811-822 .