A SURVEY OF LOW COMPLEXITY ESTIMATOR FOR DOWNLINK MC-CDMA SYSTEMS

Nitin Kumar Suyan, Mrs. Garima Saini

***Abstract* — This paper provides a survey among different types of channel estimation schemes for MC-CDMA. This paper reviews all possible channel estimation schemes for MC-CDMA and compares all schemes on the basis of performance and requirements. It is observed that each of the estimation technique has its own advantages and disadvantages. Some of the techniques have advantage of low complexity but on the other hand the performance degraded. Some techniques show better performance but complexities increases. Some of the estimation techniques have disadvantage of degraded performance for heavy load.**

***Index Terms*—Code division multiple access, Inverse Fast Fourier Transform, Orthogonal Frequency Division multiplexing, Multicarrier Code Division Multiple Access**

I. INTRODUCTION

MC-CDMA is effective transmission scheme for frequency selective fading channel because of easy equalization. Multicarrier Code Division Multiple Access (MC-CDMA) is a multiple access technology that combines CDMA with OFDM modulation. It is one of the candidate technologies considered for 4G wireless communication systems [1].

In an MC-CDMA Systems, the total transmission bandwidth is divided into many narrow sub channels and each data symbol is spread in the frequency domain by transmitting all the chips simultaneously. Thus frequency diversity can be achieved. Furthermore, by inserting a cyclic prefix between adjacent OFDM symbols, inter symbol interference can be prevented. Since different users share the same bandwidth at the same time with separate data. With these silent features, the MC-CDMA systems become an attracting technique to support both high data rate transmission and multiple accesses in a wireless communication environment [2]. The main features of MC-CDMA is its simple adaptability to variable bit rate transmissions making it suitable for users with different quality of service requirements.

In MC-CDMA System a synchronous downlink transmission is employed where the multiple access interference can be suppressed by using orthogonal spreading sequences over the AWGN channel.

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II LITERATURE SURVEY

1. **Yoshitaka Hara et al. in [3]** had suggested a new frequency averaged MMSE estimator. The proposed estimator provides an accurate estimation using few pilot OFDM symbols without a priori knowledge of multipath channel statistics. Authors concluded that this estimator can effectively reduce estimation error and have better performance than the conventional robust estimator under any channel conditions. The proposed estimator can achieve low complexity, selecting a suitable number of averaged subcarriers. But the proposed estimator also worse as delay spread increases.

2. **P. Marques et al. in [4]** have discussed Q-Robust MMSE low complexity channel estimator and Generic low-rank channel estimator with fixed SNR to simplify robust MMSE algorithm. In Q-Robust MMSE low complexity channel estimator the pilot tones are partitioned into reasonable size blocks and performs estimation in the blocks. In Generic low-rank channel estimator the computational complexity of pilot signal estimation based on MMSE criterion can be reduced by using a simplified MMSE estimator obtained with singular value decomposition and low rank approximation. Authors concluded that Generic low-rank channel estimation algorithm is less complex than Q-MMSE algorithm but originates an error flow for high values of SNR. Also it does not need matrix inversion operation however; it required some memory space to save unitary matrix and diagonal matrix for computation.

3. **Khairy El Barbary et al. in** had discussed about bit error rate performance of MC-CDMA systems with both maximal ratio combining (MRC) detection and minimum mean square error

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(MMSE) detection. Authors concluded that MRC shows an optimum performance for the single user case while it fails to satisfy reasonable bit error rate in case of heavy loads while MC-CDMA with MMSE shows robust performance in case of heavy load. Also, MC-CDMA with MMSE detection outperforms the DS-CDMA in the practical case of Rayleigh fading environment.

4. **J. Akhtman et al. in [5]** had suggested a reduced complexity minimum mean square sample spaced channel impulse response (RC-MMSE-SS-CIR) estimator which is suitable for DDCE-aided OFDM and MC-CDMA systems. Authors concluded that the performance of the proposed low complexity MMSE method is at least good as that of its high complexity counterpart, while its complexity does not exceed the complexity of the conventional LS-based estimator. Also in case of MC-CDMA the BER of proposed scheme become zero at high value of SNR as compared to conventional MMSE.

5. **Keli Zhang et al. in [6]** had discussed a new method to calculate equalizer coefficients for minimum mean square error (MMSE) combining scheme based on reduced size matrices. The complexity reduction is achieved by reducing matrix inversion size. Authors concluded that this method is used for even users but if there are an odd number of users the matrix inversion size cannot be reduce. However, this problem can be solved by transmitting signal of dummy user but system performance is affected because of interfere of dummy user. Also, more bit energy per noise power spectral density is required to add one more user to the system while maintaining system performance at reasonable BER.

6. **Luca Rugini in [7]** had proposed constrained minimum frobenius norm (CMFN) equalizer for channel estimation. This equalizer outperforms the minimum mean-squared error (MMSE) per carrier equalize, without requiring the spreading codes of the interfering users. Author concluded that the complexity of this equalizer is similar to that of the MMSE per equalizer, which however needs the spreading codes of the interfering users. But this equalizer is suitable when there are few interfering users.

III. MC-CDMA SYSTEMS BLOCK-DIAGRAM

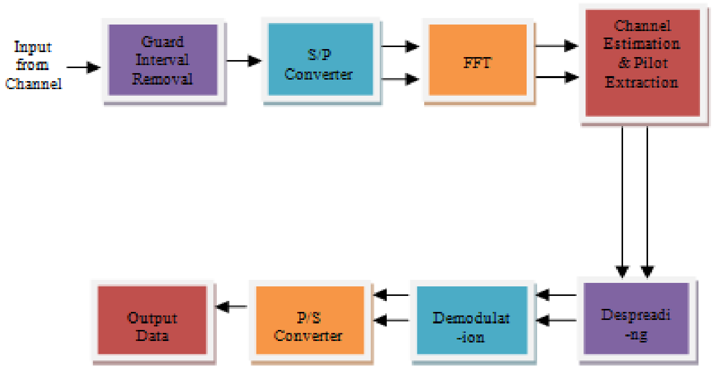

Fig 1 (a) Transmitter

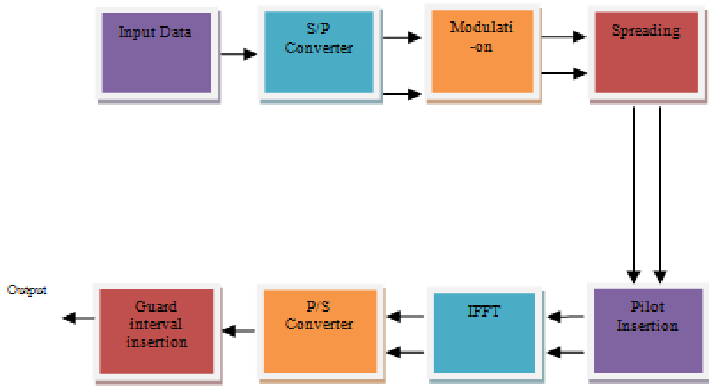

Fig 1 (b) Receiver

Fig. 1 shows the transmitter and receiver block-diagram of MC-CDMA systems in downlink [1]. Due to high spectral efficiency, simple implementation and low receiver complexity make it suitable for downlink.

TRANSMITTER

I. Input Data:-Data is usually image/wave/text which is converted into binary data bits. These bits are then padded with zeros to form group of bits to create symbols based on modulation scheme.

II. Serial to parallel converter:-The input serial data stream is applied to a serial to parallel converter and converted into parallel form. This is then applied to digital modulator.

III. Modulator:-The symbols to be transmitted on each subcarrier are first modulated. By modulation the signal wave is transformed in order to transmit it over the communication channel and to minimize the effect of noise. Usually QPSK or BPSK type digital modulation is used.

IV. Spreading:-The modulated signal is spread over a wide frequency band much wider than minimum bandwidth required to transmit the information being sent. Band spreading is done by means of a code which is independent of data. Usually Walsh-Hadamard Codes, PN Sequence Codes, and

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Gold Codes is used as spreading codes. Below figure shows the signal bandwidth after spreading.

V. Pilot insertion:-Pilots are like data symbols have IFFT operation on it, their values are known at the Transmitter & Receiver. They are used mainly in channel estimation at the receiver. Types of pilot arrangements are of two types.

(a) Comb type
(b) Block type

(a) **Comb type: -** Some sub-carriers are reserved for pilots for each symbol as shown in fig. (2).

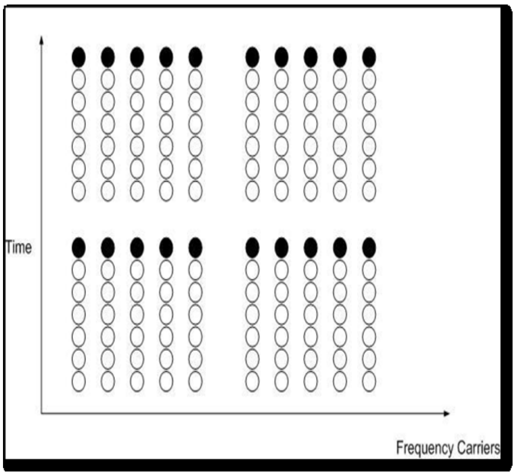

Fig. 2 Comb type pilot arrangement

(b) **Block type:-**All-subcarrier is used as pilot in a specific period as shown in fig. (3).

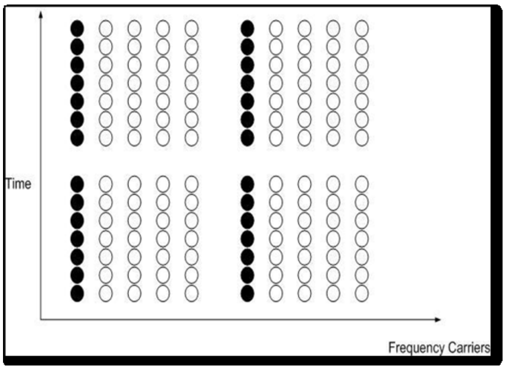

Fig. 3 Block type pilot arrangement

VI. IFFT:-Inverse Fast Fourier Transform (IFFT) is used to modulate the data on to orthogonal subcarriers. It converts the frequency domain signal into time domain signal.

VII. Parallel to serial converter:-Serializes data for transmission.

VIII. Guard interval insertion (Cyclic Prefix):-The transmitted signal suffers from the channel effects like fading, attenuation, dispersion. So to provide the immunity of signal to propagation delays, echoes, and reflections a guard period is added to the start of each OFDM symbol. To create guard band an end portion of the symbol is repeated at the beginning. Since cyclic prefix increases the symbol time (the length of the guard interval more than multipath delay spread of the fading channel), thus reducing ISI.

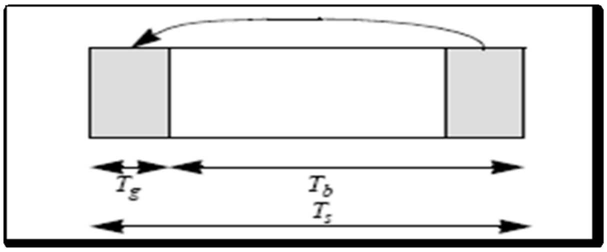

Fig 4 Guard interval insertion

$$T_s=T_g+T_b \quad (1)$$

Ts=total symbol time
Tg =guard interval
T_b=useful symbol time

IX. Channel Model: - A channel model is then applied to noise (AWGN) corrupted transmitted signal. Usually Rayleigh fading channel model and Rician channel model are used.

RECEIVER

The receiver basically does the reverse operation to the transmitter. The serially received data is converted to parallel form and then guard period is removed. The FFT of each symbol is then taken to find out the original transmitted spectrum. After that pilot symbols are extracted, they are used in channel estimation because channel response at pilots can be easily known. Channel estimators estimates the channel properties and correct the received signal. Various types of estimator like LS, MRC, and MMSE are used for estimation. The receiver code is used to de-spread and recover the data. Now the recovered OFDM symbols subjected to demodulator. After that parallel data is converted to serial data.

IV. SPREADING CODES

MC-CDMA systems spread the original information using spreading codes [3]. Different types of spreading

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codes are used for MC-CDMA systems. The selection of the spreading code depends on the given the given scenario. For example in the synchronous downlink, the orthogonal spreading codes are preferred, because they reduce multiple access interference compared to non orthogonal sequences. The characteristics of the spreading sequences play an important role in terms of the achievable system performance. The spreading codes used in MC-CDMA systems are summarized below.

(a) **Walsh-Hadamard Codes:-** Orthogonal Walsh Hadamard codes are generated by using following Hadamard matrix generation.

$$H_0 = [0] \quad (2)$$

$$H_n = \begin{bmatrix} H_{n-1} & H_{n-1} \\ H_{n-1} & -H_{n-1} \end{bmatrix} \quad (3)$$

Here n is the dimension of the matrix. The length of a Walsh code is an even number of chips and the number of codes is equal to the number of chips. A Walsh code of length n can be divided into two codes of length n/2.All n/2 length codes generated from length n codes are orthogonal to each other.

(b) **Fourier Codes:-**The column of an FFT matrix can be considered as spreading codes, which are orthogonal to each other. If Fourier spreading is applied in MC-CDMA systems, the FFT for spreading and IFFT for the OFDM operation cancel out if the FFT and IFFT have the same size; spreading is performed over all sub carriers. Fourier Codes are used for reduction of peak to average power ratio.

(c) **Gold-Codes:-**The Gold codes are generated by modulo-2 operation of two m-sequences clocked by the same chips clock as shown in below fig. (5). Since both m-sequences have equal length L and use the same clock, the created Gold-Sequences of length L as well as it is no longer maximal.

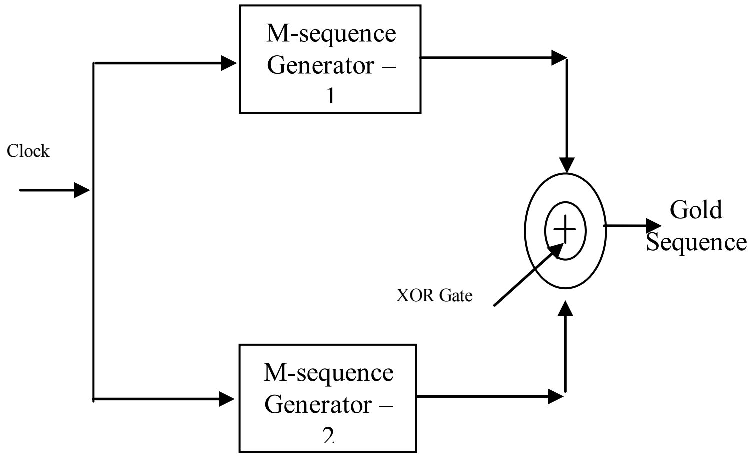

Fig. 5 Gold-Sequence Generator

Let N be the number of Flip-Flops in each m-sequence generator. The gold sequence length will be

$$L=2^N-1 \quad (4)$$

(d) **Pseudo Noise(PN) Spreading codes:-**The property of a PN sequence code is that the sequence appears to be noise like if the construction is not known at the receiver. They are generated by using shift registers of length m with linear feedback. The sequence has the period length of n and each period contains 2^{m-1} ones and 2^{m-1}-1 zeros.

Length of sequence is given as

$$N=2^m-1 \quad (5)$$

V. CHANNEL ESTIMATION

As we know that most of mobile systems operates in wireless indoor and urban environment. Where there is no line of sight (LOS) propagation. Signal comes at the receiver through different paths in degraded form. Therefore channel estimation is necessary to estimate the channel properties and correct the received signal. Different types of channel estimator are used for signal detection [10].

(a) **Maximum ratio combining (MRC):-** The amplitude of received signal is squared so it enhances the detection decision, because stronger amplitude has less noise. The drawback of MRC techniques in MC-CDMA systems in the downlink is that it destroys the orthogonality between the spreading codes and enhances the multiple access interference. This is suitable for single user detection.

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(b) **Least square (LS) estimator: -** This is simplest channel estimator. In LS estimator the received signal is divided by the input signals, which should be known pilot symbols. The estimated value is given as

$$HLS=y/x \quad (6)$$

It works best when no noise is present in the channel.LS estimator has low Complexity. The main disadvantage is that it has high mean square error.

(c) **Zero forcing estimator :-** It eliminates the multiple access interference by restoring the orthogonality between the spread data by using equalization coefficient. The main disadvantage of this estimator is that the equalizer enhances noise of small amplitudes.

(d) **Equal gain combining: -** EGC compensates only for phase rotation caused by the channel. This is a simple detection technique because it only requires information about the phase of the channel.

(e) **MMSE Detector: -** In the MMSE the mean square error between transmitted signal and equalizer output for each carrier is minimized. In this demodulated output is multiplied by equalizer gain and then subtracted from transmitted signal to calculate error.

$$\text{Error (E)} = S1 - G*R \quad (7)$$

S1=input signal
G=gain of equalizer
R=demodulated signal
Mean square error (J1) =M $\{|E|\}^2$

Mean square error can be minimized if J1 is minimized. MMSE detector is good when processing gain is small.

VI. Conclusions

From literature review inferences drawn are as discussed. Several channel estimation schemes have been proposed for MC-CDMA Systems. Generic low rank channel estimator, frequency averaged MMSE estimator, MMSE combining estimator has low complexity but have degraded performance. Blind channel estimator, FDFS estimator, S-PIC techniques, has high complexity but have better performance. Optimal MMSE estimator has high efficiency and shows robust performance in case of heavy load. It has large complexity and requires prior knowledge of multipath channel. PRE-EGC technique has low complexity and outperforms the PRE-MRC techniques but its performance degraded in case of heavy load. Two consecutive subcarriers channel estimation (CE-TCS) based on pilot channel estimation outperforms conventional pilot tone added channel estimation (PTCE) but its performance degraded in case of heavy load. Im-RLS based has better performance in terms of BER and less sensitive to multiple access interference but it has high complexity. CMFN equalizer outperforms MMSE equalizer but it is suitable where there are low interfering users.

Thus it is observed that each of the estimation technique has its own advantages and disadvantages. Some of the techniques have advantage of low complexity but on the other hand the performance degraded. Some techniques shows better performance but complexities increases. Some of the estimation techniques have disadvantage of degraded performance for heavy load.

References

[1] Khairy EL_Barbary and Hamed M. Alneyadi, "Comparison of the behavior of MMSE Detection Scheme For DS-CDMA and MC-CDMA," International Conference on Wireless, Optical Communication Networks, pp. 490-495, 2005.
[2] S.J. Yi, C.C. Tsimenidis and B.S. Sharif, "Transmitter precoding in downlink MC- CDMA systems over frequency-selective Rayleigh fading channels," IEEE Proc.- Communications, Vol. 152, No. 6, pp. 952-958, 2005.
[3] Yoshita Hara, Akinori Taira, Loic Brunel,Thomas Saizar, " Frequency-Averaged MMSE channel Estimator for Multicarrier Transmission Schemes," Vehicular Technology Conference Vol. 1, pp. 378-384, 2004.
[4] P. Marques, A Gameiro, "Low-complexity Channel estimation for Beyond 3G Systems," Vehicular Technology Conference Vol. 3, pp. 2148-2152, 2004.
[5] J. Akhtman and L.Hanzo, "Generic reduced-complexity MMSE channel estimation for OFDM and MC-CDMA," Vehicular Technology Conference, pp. 528-532, 2005.
[6] Keli Zhang, Yong Liang Guan and Qinghua Shi, "Complexity Reduction for MC-CDMA with MMSEC," IEEE Transactions on Vehicular Technology, Vol. 57, No. 3, pp. 1989-1993, 2008.
[7] Luca Rugini "Linear Equalization for Multicode MC-CDMA Downlink channels," IEEE Communications letters, Vol. 16, No. 9, pp. 1353-1356, 2012.
[8] S. Hara, R. Prasad, "Overview of multicarrier CDMA", IEEE Communications Magazine , Vol. 35, No. 12, pp. 126-133, 1997.
[9] L. Hanzo, Munster, B. Choi, and T. Keller, OFDM and MC-CDMA for Broadband Multiuser Communications, WLANs and Broadcasting. John Wiley-IEEE Press, 2003, 992 pages.
[10] Simen Coleri, Mustafa Ergen, Anuj puri, and Ahmed Bahai, "Channel estimation techniques based on pilot arrangement in OFDM systems," IEEE Transactions on broadcasting, Vol. 48, No. 3, pp. 223-229, 2002.

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