MC-CDMA for high speed Mobile Communication

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Abstract-- **This paper focuses on the performance of MC-CDMA (Multi Carrier-Code Division Multiple Access) for varying mobile speeds in a rayleigh channel. Multicarrier-CDMA is a modulation/multiple access scheme proposed for 4th generation mobile communication. Simulation results utilizing BPSK, QPSK & 16-ary PSK in Rayleigh multipath reception channel model at carrier frequency of 1GHz is considered. Performance is characterized by bit error rate (BER) of the system.The input data was convolutional encoded and frequency based pilot estimation was used. Performance results show that even at high mobile speeds BPSK and QPSK provide low error probability for input Signal to Noise Ratio (SNR) greater than 15db.**

***Index Terms*-- 4G, BER, MC-CDMA, Pilot estimation, Rayleigh channel.**

I. Introduction

MULTIPATH effects are a major drawback in wireless systems. Frequency selective fading [1] by B.Sklar, 1997 in a wideband channel has been shown to result in a number of important and potentially catastrophic effects on unsuitable modulation methods. Excess delay spread leads to the spreading of symbol energy into subsequent data symbols leading to the undesirable effects of Inter-Symbol Interference (ISI). For high data rate 4G systems OFDM is one of the possible transmission schemes as it is robustness against multipath propagation. The assignment of one or several sub-carriers to each user in an OFDM system leads to the multiple access scheme OFDMA. Contrary to OFDMA, the multi-carrier code division multiple access (MC-CDMA) scheme transmits in parallel chips of a spread data symbol on different sub-carriers. MC-CDMA, a 4G mobile technique as described in [2]-[3] is shown to limit the undesirable effects through the exploitation of the frequency selective nature of channel. An

MC-CDMA transmission scheme spreads the user data symbol energy over all channel resources and therefore offers diversity. However, MC-CDMA suffers from multiple access interference (MAI) due to the de-orthogonalization of the spreading codes. This paper is organized as follows: The MC-CDMA transmitter and receiver model is outlined. Then the results of BER performance for varying mobile speeds at carrier frequency of 1GHz and conclusion are presented.

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II. MC-CDMA Transmission and Reception

MC-CDMA is a modulation / multiple access technique that is a combination of Orthogonal Frequency Division Multiplex (OFDM) and Code Division Multiple Access (CDMA). In OFDM systems data is transmitted over multiple sub-carriers instead of a single carrier. CDMA is a multiple access scheme where different users in a system are identified by a unique spreading code.

Multi-carrier CDMA [4]-[5] involves the parallel transmission of identical data on multiple sub-carriers within an OFDM symbol. Each OFDM symbol consists of a summation of sub-carriers each of which is modulated to give a transmitted signal S where the elements of $S \in [1\ -1]$ (for the case of BPSK modulation). Orthogonal of each sub-carrier is achieved by making the carrier frequency spacing equal to the inverse of the active symbol period. The transmitted signal corresponding to the j^{th} data bit of the i^{th} user is

$$x_i(t) = \sum_{j=0}^{N-1} C_i(j) d_i(k) \cos(2\Pi f_c t + 2\Pi jt/Tb) p_{Tb}(t - T_b) \ldots\ldots\ldots\ldots(1)$$

where $C_i(j)$=[1 -1], Spreading code for the i^{th} user, fc =centre Carrier frequency, T_b = Bit duration, $d_i(j)$ = input data for the i^{th} user.

A. MC-CDMA Transmission

In a MC-CDMA transmitter with N sub-carriers the data symbol from user i is replicated N times and multiplied by a chip from a user specific spreading code, C(j ,i)where n = 0..N-1.The j^{th} spread symbol from each user is combined and then modulated onto one of the N sub-carriers. In effect spreading is performed in the frequency domain. Then the spread symbols in the transmitter are modulated onto N sub-carriers using an N-point inverse fast Fourier transform (IFFT). This creates an N–sample OFDM symbol at the output of the IFFT.

½ rate Convolution encoder of constraint length K = 7, {133,171} octal, is used in the transmitter and soft decision Viterbi decoding at receiver. Baseband modulation used was BPSK or QPSK or 16-ary PSK. Spreading is achieved using 32-bit Walsh - Hadamard codes. Pilot symbols are inserted in the frequency domain at regular spacing. Orthogonal Modulation was achieved using a 512-Point Inverse Fast Fourier Transform (IFFT) with a carrier spacing of 8 khz.

Subsequent cyclic prefix of duration N/4 (or guard interval) to prevent ISI was added.

B. MC-CDMA Reception

The signal at the input of the receiver is a mutipath signal consisting of a six ray rayleigh faded signal with AWGN. Let $h[m]$ be the sampling version of the channel, then the output of the channel is:

$$\tilde{y}_i[m] = \sum_{l=0}^{N+L-1} \tilde{x}_i[l]h[m-l] \qquad (2)$$

for m = 0,1,…, N+l -1.

The signal is converted from serial to parallel format and then the cyclic prefix is stripped. OFDM demodulation is performed by taking N- point IFFT of the received signal. The demodulated output is given by

$$\tilde{Y}_i[k] = \left(\sum_{k=0}^{N-1} \tilde{x}_i[m]\exp\left(-2\pi jk\frac{m}{N}\right)\right)\Im(h[k]) \qquad (3)$$

By simple division of above demodulated signal by the channel frequency response we get back the transmitted signal.

$$\tilde{Y}_i[k] = \Im(x_n[k])\Im(h[k]) \qquad (4)$$

The signal at each sub-carrier is multiplied by a channel equalizing co-efficient, h*(k)*and then de-spread using the user specific spreading code. The de-spread symbols are combined to form an estimate of the original data symbol for for user i.

Channel frequency response estimation [6] is evaluated at the pilot locations. Channel estimates from different pilot locations can then be interpolated to obtain channel estimates at all values. This is followed by baseband demodulation and Viterbi decoding to extract the original data sequence.

III. RESULTS

The BER Vs SNR performance for BPSK, QPSK and 16-ary PSK are simulated for Rayleigh multipath reception channel. Perfect synchronization is assumed between transmitter and receiver. The speed of the mobile is calculated using the relation

$$f_d = (v/\lambda) \qquad (5)$$

where v=mobile speed,

f_d = Doppler frequency,

λ = wavelength .

For Doppler frequency varied between 5Hz to 100Hz at a carrier frequency of 1GHz, the speed of the vehicle varies between 5.4Km/hr to 108Km/hr. The simulation parameters used are listed below.

TABLE I
SIMULATION PARAMETERS

PARAMETER	VALUE
Carrier frequency	1GHz
No of Sub Carriers	512
Bandwidth	4MHz
Useful symbol duration	125µs
Guard interval	31.25µs
Total symbol duration	156.25µs

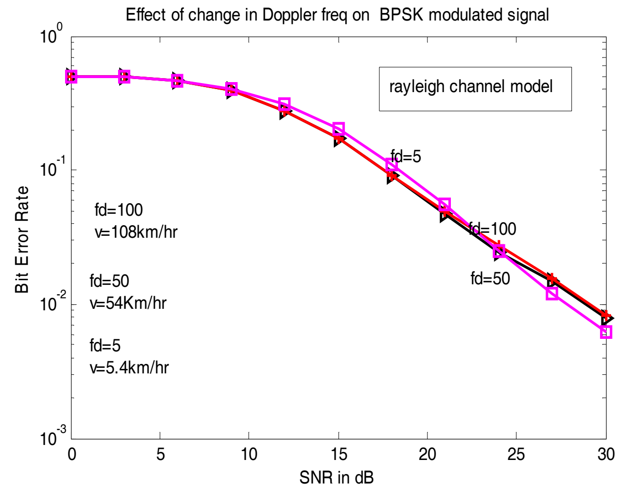

Fig.1 BER Vs SNR comparison for BPSK for varying mobile speed

IV. CONCLUSION

In MC-CDMA, at SNR's above 15db, the baseband modulation techniques of BPSK and QPSK has low bit rate for varying mobile speeds. For SNR less than 15db, 16-PSK outperforms BPSK and QPSK. BPSK and QPSK exhibit almost identical response of BER w.r.t SNR for change in mobile speed from 5 Km/Hr to 108 Km/Hr.

MC-CDMA is proposed as a possible candidate for physical layer in mobile communication. It is also being considered in wireless LAN, DVB and DAB technologies.

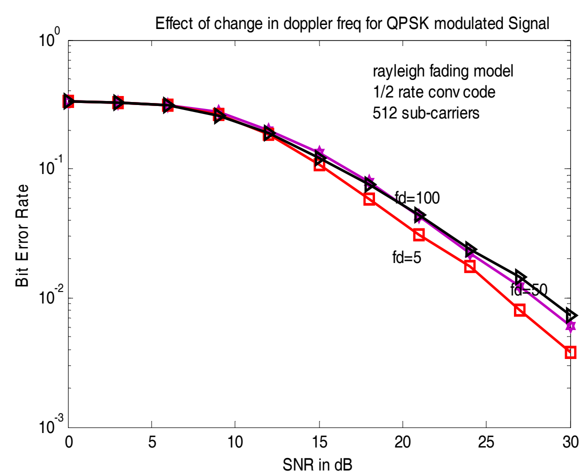

Fig.2 BER Vs SNR comparison for QPSK for varying mobile speed

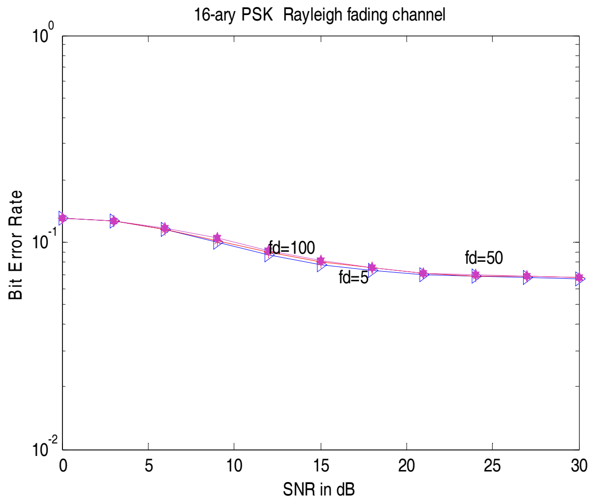

Fig3 BER Vs SNR comparison for 16-ary PSK for varying mobile speed

V. References

Periodicals:

[1] B. Sklar, "*Rayleigh Fading Channels in Mobile Digital Communication Systems Part II: Mitigation*", *IEEE Communications Magazine, July 1997, pp. 102-109.*

[2] S.Hara, R.Prasad,*"Overview of MultiCarrier CDMA,"IEEE Communications Magazine, December 1997, pp. 126-133.*

[3] J.A.C. Bingham,*" Multicarrier Modulation for Data Transmission: An Idea Whose Time Has Come,," IEEE Communications Magazine, pages 5-14, 1990.*

Papers from Conference Proceedings (Published):

[4] N.Yee, J.P.Linnartz, *"Multi-Carrier CDMA in Indoor Wireless Radio Networks", PIMRC 1993, pp. 109-113.*

[5] M.A.Cooper, S.M.D.Armour, J.P.McGeehan,*"Downlink Performance and Complexity Evaluation of Equalisation Strategies for an MC-CDMA '4G' Physical Layer* Candidate," *Proceedings Symposium IEEE Benelux Chapter on Communications and Vehicular Technology, 2003, Eindhoven.*

[6] M.A.McKeown, D.G.M.Cruickshank, I.A.B.Lindsay, S.A.Farson and Y. Hu. *"Pilot-assisted channel estimation in MC-CDMA for future mobile cellular systems," London Communications Symposium,University College London ,9th - 10th September 2002.*

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