MC-CDMA PERFORMANCE OVER FADING CHANNEL WITH DIFFERENT PARAMETERS

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ABSTRACT: *Limited data rate and performance of orthogonal frequency division multiplexing (OFDM) is due to loss of orthogonality between the sub carriers in time varying fading channel. Multi carrier Spread Spectrum provide solution for frequency-selective fading and it also handle multiple data rates for wireless multimedia communications. Multi-carrier Code division Multiple Access (MC-CDMA) and Multi-carrier Direct Sequence Code division Multiple Access (MC-DS-CDMA) offers its attractiveness in performance, flexibility in rate matching and complexity. But its self-interference (SI) and Multi User Interference (MUI) are noted as severe problems. This paper gives the overview of MC-CDMA and MC-DS-CDMA. For fading Additive White Gaussian Noise (AWGN) channel and for various values of Signal to Noise Ratio (SNR) with different number of sub carriers its performance is evaluated. Effect of frequency offset on its performance, carrier spacing and bandwidth have also been studied.*

KEY WORDS: *Multi carrier CDMA (MC-CDMA), Orthogonal frequency division Multiplexing (OFDM), Additive White Gaussian Noise (AWGN), Cyclic Prefix (CP), Gold codes (GC), Walsh-Hadamard (W-H) codes*

1. INTRODUCTION

Need for a bandwidth efficient modulation technique which can efficiently and reliably transmit data at high rates in wireless technology, W-LAN's, Wi-Max, Wi-Fi etc. arose since many years. Use of Multicarrier (MC) techniques in many research combine good bandwidth efficiency along with prevention of channel dispersion. In Orthogonal Frequency Division Multiplexing (OFDM), from 1970s, many users' symbols are transmitted in parallel with different sub carriers. Its long time duration symbols and narrow bandwidth compared to other modulation techniques are unique one. These systems are designed considering that the bandwidth is enough small to experience frequency-flat fading when signals received over a frequency selective channel [1]. It is seen from Fig.1 that sub carriers are overlapped in side lobes. Inverse Fast Fourier transform (IFFT) of the user bits are taken in practice before transmission. Different attenuation and phase shift due to dispersive wireless channel are noticed for each sub carriers [2].

Orthogonality of sub carriers is assured in the time invariant channel. Due to symbol attenuation in channel, errors occurs at sub- carrier's level, but it can be repaired by error correction codes. Redundancy in the error correction code is applied over many different sub carriers. OFDM found its uses in Digital Audio Broadcasting (DAB), Digital Video Broadcasting standard (DVB) and in many other technologies. Orthogonality of the OFDM sub carrier waveforms lost due to channels with a Doppler spread and the time variations. Hence, Multicarrier system finds its uses in high speed data and multimedia communication with its good performance and flexibility. Orthogonality among users in the frequency domain is achieved by Walsh-Hadamard sequences. Multicarrier transmission technique can be combined with a Code Division Multiple Access (CDMA) scheme to have multiple users. Multicarrier technique and CDMA are combined in many ways for high-rate communication over dispersive channels. Two techniques found for good orthogonality and minimum frequency separation, one as Multicarrier CDMA (MC-CDMA) and other as Multicarrier Direct Sequence CDMA (MC-DS-CDMA).

For MC-CDMA, first base band digital data stream is multiplied with the spreading sequence and then it is modulated by orthogonal carriers, as shown in Fig.2.[3].

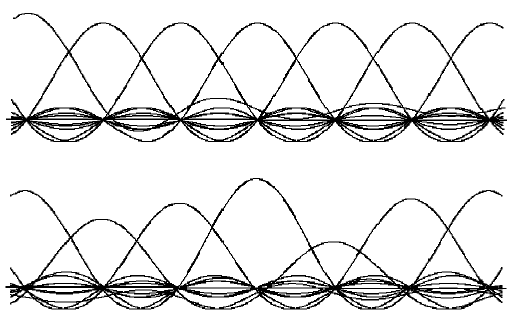

Fig.1 Spectrum of an OFDM signal

Here chips of the symbol are modulated on different carriers to achieve spreading in the frequency domain. But in MC-DS-CDMA scheme, data stream is multiplied with the spreading sequence after its serial to parallel (S/P) conversion and then after the chips of the same symbol modulate the same carrier, as shown in Fig.3.[4].

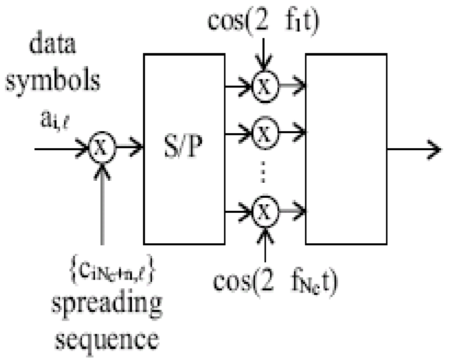

Fig.2 Transmitter for MC-CDMA

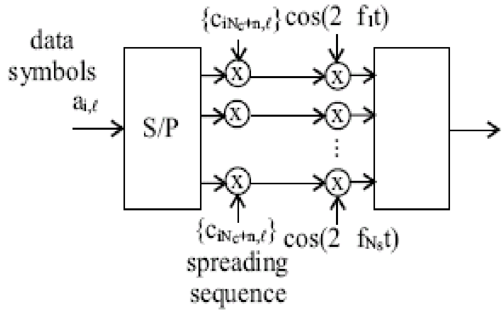

Fig.3 Transmitter for MC-DS-CDMA

Transmitter side, carrier oscillator up converts the base band signal for transmission and receiver side signal is down converted using a local oscillator. The receiver has to make good estimation of the transmitted carrier frequency and phase when it receives the signal. But interference, noise and other disturbances makes estimations not accurate and this lead to carrier phase errors. Literature shows that Multicarrier systems are very sensitive to phase errors of carrier with more carriers if used. The system performance rapidly degrades in the presence of carrier frequency offset when the number of carriers increases. In this paper, we have considered effect of carrier frequency offset on MC-CDMA and MC-DS-CDMA in downlink transmission and determined an analytical expression of both systems for the performance degradation in terms of the various system parameters.

2. SYSTEM DESCRIPTION

The MC-CDMA System

From the functional block diagram of a downlink MC-CDMA system as shown in Fig.4 [6], it can be seen that each data symbol is multiplied with a spreading sequence with a spreading factor N_c. Here N_c samples of the data symbol are transmitted in parallel on the different orthogonal multicarrier. Hence spreading is done in the frequency domain. Modulation on the orthogonal carriers, are achieved by an N_F-point Inverse Fast Fourier Transform (IFFT). Interference between nearer modulated carrier is avoided just like in OFDM, by addition of cyclic prefix of N_p samples at IFFT output. Samples rate of 1/T kept to apply it to a square-foot raised-cosine transmit filter *P(f)*. Only N_c carriers are actually used out of the total N_F available carriers.

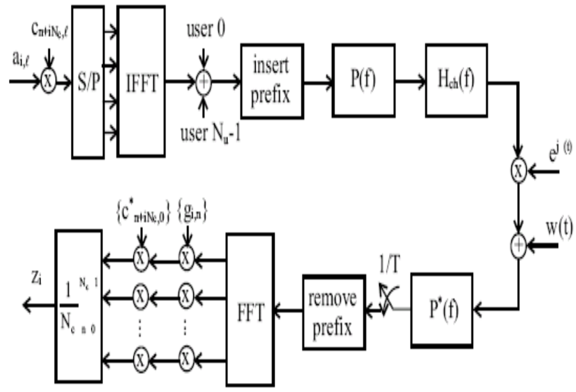

Fig. 4 Block diagram for MC-CDMA

Here,

$a_{i,l}$ = i^{th} symbol of user *l*

R_s = Symbol rate

N_c = Spreading Factor or No. of sub- Carrier

$C_{iNc+n,l}$ = n^{th} chip during the i^{th} symbol interval for the sequence of user *l*.

N_F = No. of IFFT/FFT point

N_P = No. of cyclic prefix

N_S = No. of symbols

N_u = No. of active users

1/T= ($N_F + N_P$) R_s =Rate of sample after Cyclic prefix

H_{ch} (f) = Channel Transfer function

P (f) = Transfer function of filter

W(t)=Additive White Gaussian Noise(AWGN)

$g_{i,n}$=Gain of Equalizer

Z_i=Output Sample

Carrier spacing =1/(N_FT) and bandwidth B are given with assumption $N_P << N_F$ by

$$\frac{1}{N_F T} = R_S \frac{N_F T + N_P}{N_F} \cong R_S$$

$$B = \frac{N_C}{N_F T} = N_C R_S \frac{N_F + N_P}{N_F} \cong N_C R_S \text{ ....(1)}$$

The base station broadcasts signals to all N_u active users in multi user scenario. Receiver uses a unique own spreading sequence to receive signal of a particular user among many active users. Here orthogonal user-dependent sequences Walsh-Hadamard (WH) sequences is considered one for a case. The maximum number of users N_c equals number of WH sequences of length N_c. It shows that number of used carriers, spreading factor and maximum number of users are equal. All users signal reaches to the receiver of a particular user via a channel having transfer function $H_{ch}(f)$. The signal is affected by the channel results in carrier phase error $\Phi(t)=2\pi\Delta Ft+\Phi(0)$, here ΔF is taken as ($|\Delta FT| << 1$), a small carrier frequency offset. The received signal is also affected by Additive White Gaussian Noise (AWGN) $w(t)$, whose power spectral density is $N_0/2$.Receiver's matched filter which samples signal at a rate of 1/T come in to pictures then. In every FFT block, receiver will removes the N_p samples of cyclic prefix and will keep the N_F samples. The receiver with N_F-point FFT and equalizers having gain $g_{i,n}$ for scaling and rotating FFT output during the i^{th} symbol interval. The spreading sequence chip of the user will be multiplied with equalizer's outputs and added to obtain samples Z_i, this is used for making a decision regarding data symbol.

The ratio of the power of the average useful component to the sum of the powers of the interference and the noise is the measure of signal-to-noise ratio (SNR) at the input of the decision device. Which decides the performance of the MC-CDMA system and it is

$$SNR(\Delta FT) = \frac{P_U}{P_N + P_I} \text{ .... (2)}$$

Where,

P_U =Useful power component

P_N =Noise power component

P_I = Interference power component

The degradation (in dB), due to the carrier frequency offset, is given by

$$Deg = 10\log(SNR_0)/\left(SNR\ (\Delta FT)\right) \text{..... (3)}$$

Highest degradation is obtained by

$$Deg \le -10\log|D(\Delta FT)|^2$$
$$+10\log\left(1 + SNR_0 \frac{N_u}{N_C}\left(1 - |D(\Delta FT)|^2\right)\right)$$

.... (4)

Here highest degradation by summing all N_F available carriers is taken.

The Highest degradation is achieved when N_c=N_F i.e. all carriers are modulated. From this approximate actual degradation found when less number of unmodulated carriers is taken, i.e. $N_c \cong N_F$.

3. PERFORMANCE COMPARISON

For performance evaluation of system, system parameter considered are number of the bits, filtering and length of the cyclic prefix, AWGN channel [8][9][10] etc... And graph of SNR versus average BER plotted for sub carriers and different PN codes types. Fig.5 shows BER and number of bits in errors for OFDM decrease for high value of SNR. It is evident from Fig.5 that QAM is having better performance than PSK for the same system configuration.

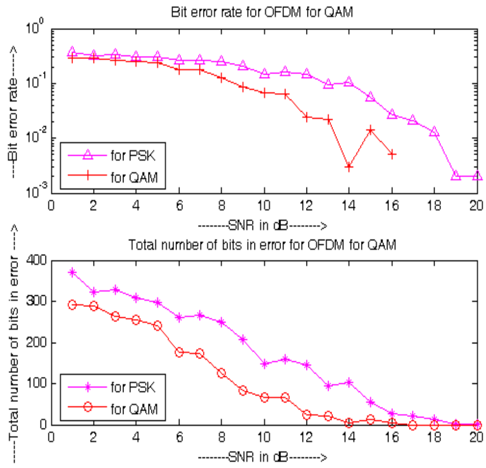

Fig.5 Plot of BER Vs SNR and No. of bits in Errors SNR OFDM for 16-QAM and 16-PSK, No. of Bits is 1000, SNR=1:20

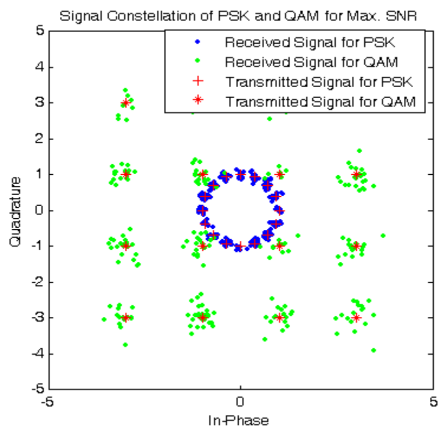

Fig.6 Constellation plot of OFDM for 16-QAM and 16-PSK, No. of Bits is 1000, SNR=20

As per Fig.6, received symbols are more accurately focused near transmitted one in 16-PSK than in 16-QAM.In Fig.7 variation of carrier spacing and bandwidth for MC-CDMA for various value of FFT point is shown. Fig.8 revels effect of signal degradation by frequency offset [14].Fig.9 gives comparison of BER for Gold and W-H code in MC-CDMA. Here shown that W-H code gives comparatively better performance. [5]Fig.10 shows comparison of BER for various values of subcarrier in MC-CDMA [6][7].

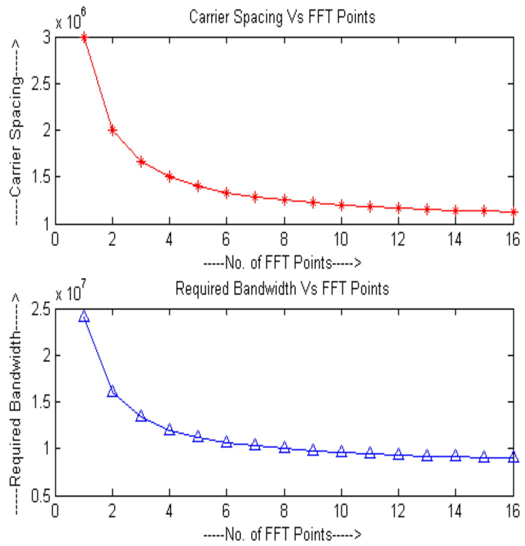

Fig.7 Required Bandwidth and Carrier Spacing for Different numbers of IFFT/FFT point. For (Nc=8, Rs=1000000, Np=2)

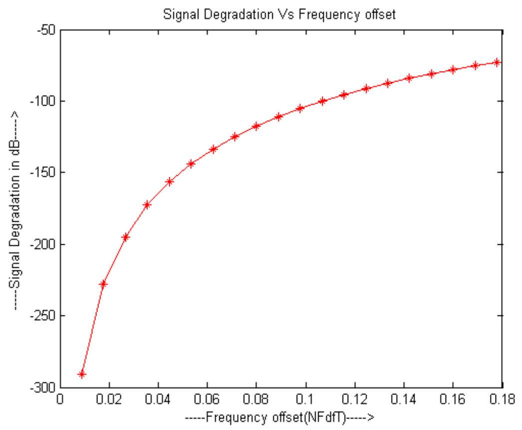

Fig.8 Signal Degradation for different value of NFΔFT (Nc=4, snr0=20dB, Rs=100, Nf=16, Np=2, Nu=Nc)

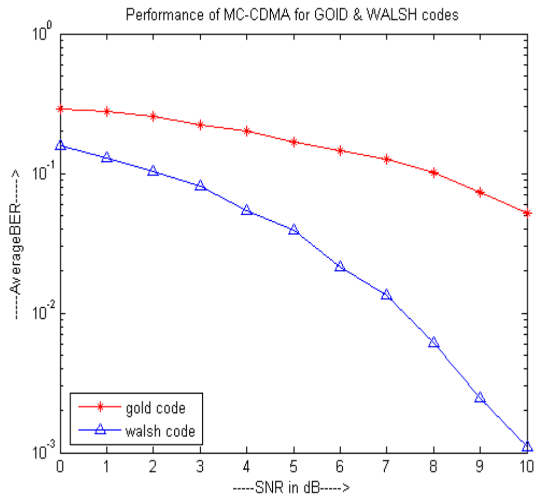

Fig.9 Performance of MC-CDMA for GOLD & WALSH codes (No. of bits per user=1024, No. of sub carrier=No. of IFFT=8)

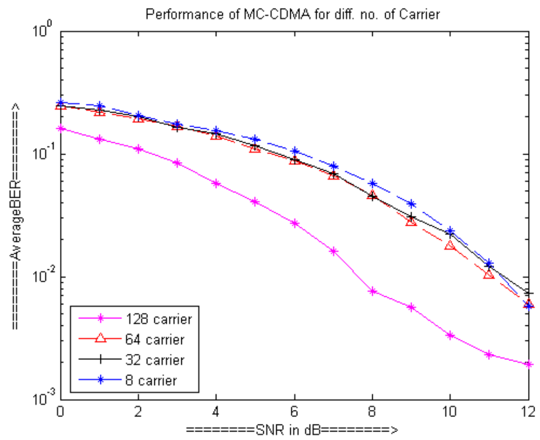

Fig.10 Performance of MC-CDMA for diff. no. of Sub Carrier (No. of bits per user=1000, No. of sub carrier=No. of IFFT)

4. CONCLUSION

In this paper a MC-CDMA system has been simulated using MATLAB. We can conclude from the results that the BER performance of MC-CDMA over AWGN is increasing for higher numbers of sub carriers. It also shows good performance for W-H codes. Also QAM is good for modulation than PSK. Increase in frequency offset reduce performance.

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