MODELLING AND SIMULATION OF ADAPTIVE MULTICARRIER (OFDM)-IDMA SYSTEM IN MULTIPATH FADING CHANNELS

Abhishek Tripathi[1], R. K. Singh[2] and S. K. Sriwas[3]
[1]AKTU, Luchnow, India
[2]KNIT, Sultanpur, India
[3]Bundelkhand Institute of Engineering & Technology, Jhansi, India
E-Mail: abhishektripathi04jpecoo6@gmail.com

ABSTRACT

This paper proposes the scope of adaptive Multicarrier (OFDM)-IDMA System in multipath fading channels. MC-IDMA is one of the multiple access techniques operating in multipath fading channels with adaptive sub channel allocation. In this paper we investigate the basic principle of MC-IDMA system, analyzed every model function, and also build a platform for its simulation. It also deals with the transmission of chips over sub channels which are having largest fading amplitudes. Zigzag codes are used as FEC codes. The simulation results shows that the adaptive sub channel allocation scheme used in conventional MC-IDMA system improves the BER performance of the system by large extent.

Keywords: MC-IDMA, multipath channels, CBC detection.

1. INTRODUCTION

MC-IDMA is a multi-user communication technique, based on combination of Orthogonal Frequency Division Multiplexing (OFDM) and Interleave Division Multiple Access (IDMA). The combination is made to combine the benefits from both OFDM and IDMA [1]. The key advantage of OFDM-IDMA is that MUD can be realized efficiently with complexity per user independent of the channel length and the number of users, which is significantly lower than that of other alternatives. The OFDM-IDMA scheme possesses several attractive properties, including: Very high spectral efficiency, Flexibility in multi-user as well as single-user mode transmission and Multi-user gain in fading channels [7]. In OFDM-IDMA there are some outstanding issues also like: pilot signal design, channels estimation, close loop power control, adaptive transmission and resource allocation but the possibility of low cost MUD creates quite different dimensions to these issues compared to the situation in the traditional systems as many functions can be conducted jointly and iteratively. The multicarrier [8] scheme inherits all the properties of the previous systems with some additional benefits. As the number of user increases, the performance of MC-IDMA goes on improving and approaches that of single user. An MC-IDMA system transmits N chips simultaneously by assigning each chip to a separate subcarrier so that each input symbol is transmitted on so many sub-carriers. Signal spreading in this scheme is performed in the frequency domain. In this paper we propose and MC-IDMA system with simple adaptive sub channel allocation scheme for the uplink transmission and the coding scheme used is Zigzag concatenated codes [2] as a FEC code [11]. The base station is used for estimation of amplitudes of all the sub-channels based on pilot symbols transmitted with the data symbols and feeds back the index of sub channel which has largest fading amplitude to transmitters (mobile stations). With the index information, the mobile stations allocate each user's chips into best sub channel for each user. After that we analyzed the chip-by-chip interleaving scheme with multicarrier communication in multipath fading channels. It shows that MC-IDMA system with adaptive sub channel allocation outperforms the conventional MC [8]-IDMA system. MC-IDMA system with adaptive sub channel allocation results in elimination of bad conditioned sub channels and allocated all the signal energy to the good conditioned sub channels.

OFDM-IDMA is proposed as an alternative to plain IDMA over multi-path channels. It inherits most of the merits of OFDM and IDMA. The key advantage of OFDM-IDMA is that MUD can be realized efficiently with complexity per user independent of channel length and the number of users, which is significantly lower than that of other alternatives.

2. MODEL DESCRIPTION

For M active users and each user transmitting QPSK symbols. The basic (adaptive MC-IDMA transmitter model) is as shown in below Figure-1. The ENC block consists of a Forward Error Correcting code (FEC) and an optional spreader. A user specific interleaver [1] interleaves the coded sequence of each user. Interleaver dispenses the coded sequence so that adjacent chips are uncorrelated. The interleaved data is converted from serial to parallel form. The chips are then ordered according to indices of the favourite sub channels fed back from the base station. The base station feeds back the indices to the mobile stations periodically by estimating the fading amplitudes with the pilot signals. Pilot symbols are transmitted with the data symbols. All the pilot symbols are assumed to be 1. The pilot symbols are transmitted over all the subcarriers so that the base station can estimate all the sub channels. Inverse Fast Fourier Transform (IFFT) operation modulates each chip on a different subcarrier and the modulated data is converted from parallel to serial form and cyclic prefixes are added to each symbol. Cyclic Prefixes (CP) make the MC-IDMA symbols to appear periodic so that convolution of the signal and the channel become circular. The signal is then transmitted over a multipath multiple access channel.

ARPN Journal of Engineering and Applied Sciences

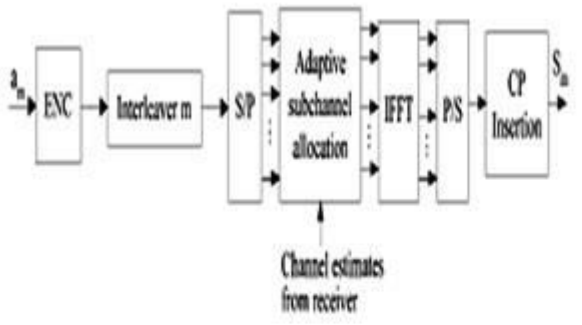

Figure-1. Showing the Proposed adaptive multi carrier (OFDM) - IDMA transmitter structure.

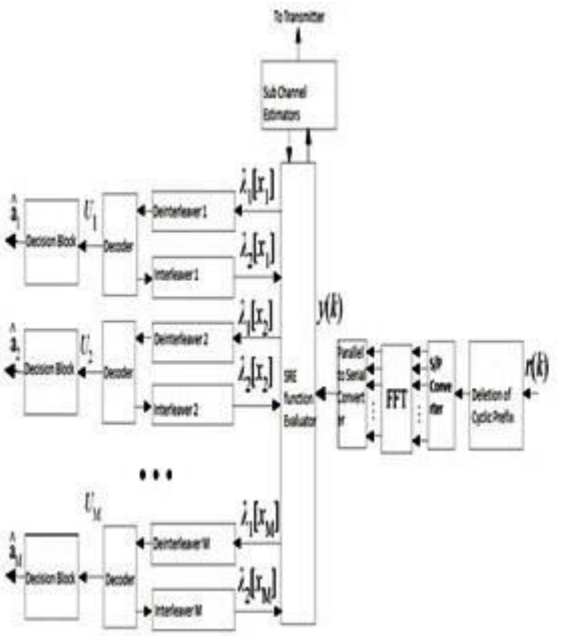

Figure-2. Showing the proposed adaptive multicarrier (OFDM)-IDMA receiver structure.

Let c_m be the resulting sequence of mth after FEC encoding and/or repetition coding (spreading) and interleaving. The output of mth user depends on FFT/IFFT size, the length of cyclic prefix, the processing gain and symbol duration etc.
The m^{th} user output is given by the equation;

$$S_m(t) = \sum_{i=-\infty}^{\infty}\sum_{q=0}^{Q-1}\sum_{l=0}^{L-1} c_{m.q}^{i}(l)p(t-iT_s')e^{j(2\Pi(Ql+q)t)/(T_s'-\Delta)} \quad (1)$$

$$\Delta+T_s'=QT_s \quad (2)$$

Where the product of Q and L defines the size of FFT/IFFT, Δ is the length of the cyclic prefix, L is the processing gain, T_s = 1/ (symbol rate), T_s' is the symbol duration at subcarrier, Q is an integer greater than or equal to one. If the value of Q>1, one multicarrier-IDMA symbol consists of more than one input symbols, and in this case frequency diversity is not achieved in an optimal way.

In the equation (1) p(t) is a pulse which satisfies the following relation:
p(t) = 1 when t is greater than or equals to $-\Delta$ and lesser than or is equals to (T_s' - T_s). and for any else values of t; p(t) will be 0.

The frequency selective Rayleigh fading is the assumed channel with the impulse response given by:

$$h(\tau,t)=\sum_{j=1}^{J} g_j\delta(\tau-\tau_j) \quad (3)$$

where t and τ represents the time and delays respectively. J is used for expressing the number of multipaths, τ_j is the delay in the path j, g_j is the gain of path j which is strictly independent of Gaussian random variable and δ is used for representing the Dirac delta function.

At the reception end, the received signal from all the users is computed as:

$$r(t)=\sum_{m=1}^{M}\int_{-\infty}^{\infty} S_m(t-\tau)\otimes h_m(\tau;t)d\tau+n(t) \quad (4)$$

this received signal can be expressed in terms of fading amplitude of the sub channel as:

$$=\sum_{i=-\infty}^{\infty}\sum_{q=0}^{Q-1}\sum_{l=0}^{L-1}\sum_{m=1}^{M} z_{q,l}^{m}(t)c_{m,q}^{i}(l)p(t-iT_s')e^{j(2\Pi(Ql+q)t)/(T_s'-\Delta)}+n(t) \quad (5)$$

Where $z_{q,l}^{m}$ is the fading amplitude of (Ql+q) th sub channel of the mth user and n(t) is the additive Gaussian noise. At the reception end, the received signal is sampled, cyclic prefixes are removed and the Fast Fourier Transform is used for coherent demodulation of the received modulated signal. In order to estimate the fading amplitudes of all the sub channels, sub channel estimators are used which uses the pilot symbols and decides the favourite sub channels indices. The received signal is given by:

$$r(k)=\sum_{m=1}^{M} z_m(k)x_m(k)+n(k) \quad (6)$$

where z_m and x_m are complex valued signals.The value of r(k) can also be written as:

$$r(k)= \sum_{m'=1}^{M} z_{m'}(k)\, x_{m'}(k) + n(k) \text{ for all those values of } m' \text{ not equals to } m = z_m(k)x_m(k)+\zeta_m(k) \quad (7)$$

Where $\zeta_m(k)$ is the aggregated signal content from all the other users except the mth user and noise? If the users are large in number and data from each users is strictly independent with each other; then by central limit theorem $\zeta_m(k)$ can be approximated as Gaussian Noise. This approximation is less valid for small number of users but the benefit of loss [9] of interference overcomes this problem. For combining the energy scattered in frequency domain the received signal in equation (vii) is multiplied by the complex gain G_m. For simplifying the calculations

ARPN Journal of Engineering and Applied Sciences

G_m is chosen as the complex conjugate of the fading amplitudes z_m for compensating the phase shifts only.

$$y(k)=\overline{z_m(k)}r(k)=|z_m(k)|^2x_m(k)+\overline{z_m(k)}\zeta_m(k) \quad (8)$$

This signal y(k) is now passed through Signal Reliability Estimator (SRE).The SRE is used for calculating the extrinsic information of each user by estimating the Log Likelihood Ratio (LLR) on the basis of received signal.

For ease of simplification the real or in phase component is considered only.
The LLR is found to be as;

$$\lambda_1(x_m^{Re}(k))=2|z_m(k)|^2\frac{y^{Re}(k)-E(Re(\overline{z_m(k)}\zeta_m(k)))}{Var(Re(\overline{z_m(k)}\zeta_m(k)))} \quad (9)$$

where $x_m^{Re}(k)$ is the in-phase or the real component of $x_m(k)$.The expected value (Mean) of $Re(\overline{z_m(k)}\zeta_m(k)$ can be computed as;

$$E(Re(\overline{z_m(k)}\zeta_m(k))=z_m^{Re}(k)E(r^{Re}(k))+z_m^{Im}(k)E(r^{Im}(k))-|z_m(k)|^2E(r^{Re}(k)) \quad (10)$$

And the variance of $Re(\overline{z_m(k)}\zeta_m(k)$ can be computed as;

$$Var(Re(\overline{z_m(k)}\zeta_m(k))=(z_m^{Re}(k))^2Var(r^{Re}(k))+(z_m^{Im}(k))^2Var(r^{Im}(k))+z_m^{Re}(k)\, z_m^{Im}(k)\, \psi(k) - |z_m(k)|^4Var(r^{Re}(k)) \quad (11)$$

Where

$\psi(k)$ can be calculated as;

$$\sum_m z_m^{Re}(k)z_m^{Im}(k)(Var(r^{Re}(k)) - Var(r^{Im}(k))) \quad (12)$$

The values of $Var(r^{Re}(k)$, $Var(r^{Im}(k)$, $E(r^{Re}(k)$ and $E(r^{Im}(k)$ can be easily calculated by using the equation (vii) in the following ways:

The value of $E(r^{Re}(k)$ can be computed as

$$=\sum_m(z_m^{Re}(k)E(x_m^{Re}(k)) - (z_m^{Im}(k)E(x_m^{Im}(k))) \quad (13)$$

The value of $E(r^{Im}(k)$ can be computed as

$$=\sum_m(z_m^{Re}(k)E(x_m^{Im}(k)) - (z_m^{Im}(k)E(x_m^{Re}(k))) \quad (14)$$

$$Var(r^{Re}(k))=\sum_k((z_m^{Re}(k))^2\ Var(x_m^{Re}(k)) + (z_m^{Im}(k))^2\ Var(x_m^{Im}(k))+\sigma^2) \quad (15)$$

$$Var(r^{Im}(k))=\sum_k((z_m^{Im}(k))^2\ Var(x_m^{Re}(k)) + (z_m^{Re}(k))^2\ Var(x_m^{Im}(k))+\sigma^2) \quad (16)$$

$$\&E(x_m^{Re}(k)) = (+1)\Pr(x_m^{Re}(k)=1) + (-1)\Pr(x_m^{Re}(k)=-1)=\tanh(\lambda_2(x_m^{Re}(k)/2)) \quad (17)$$

$$Var(x_m^{Re}(k))=1-(E(x_m^{Re}(k)))^2 \quad (18)$$

After each iteration these calculated means and variances are used to update the Global Mean $E(\zeta(k))$ and Global variance $Var(\zeta(k))$ and hence resulting in the reduction of multiple access interference (MAI).

The DEC blocks are used for approximating the extrinsic value, $\lambda_2(x_m^{Re}(k))$ using de-interleaved outputs of SRE blocks $\lambda_1(x_m^{Re}(k))$ as an a priori information. Let the decoded version of $\lambda_1(x_m^{Re}(k))$ be U_m, which is also the soft decision and the output of the detector after the last iteration. This soft decision is applied as the input to the user specific interleaver and then the extrinsic values $\lambda_2(x_m^{Re}(k))$ are evaluated in the following way:

$$\lambda_2(x_m^{Re}(k))=U_m(k)-\lambda_1(x_m^{Re}(k)) \quad (19)$$

The calculated $\lambda_2(x_m^{Re}(k))$ is applied as a feedback to the SRE block, where the means and variances are evaluated.The complexity of IDMA system is a function of the number of multipath (J) while the complexity of MC-IDMA system is strictly independent of the number of multipath (J) so it is justified that the MC-IDMA receiver system is less complex than the IDMA system by a factor of number of multipath (J).The received signal undergoes through processing in an iterative fashion. The probability of error [5] for the first user is calculated. Absolute value of LLR [5] is used for calculating the bit error rate in an iterative algorithm.

$$p_e=(1/K)\sum_{k=0}^{k=K-1}1/(1+e^{|U_1(k)|}) \quad (20)$$

And this above expression is evaluated after the last step performed.

3. RESULT OF SIMULATION

This section contains the simulation results for illustrating the performance of adaptive MC (OFDM) - IDMA system in multipath fading channels. A convention MC-IDMA system is considered as a base reference for comparison with the adaptive system. In the Figure-3, the performance of both systems without FEC encoding and with CBC detection is compared. It is assumed that all users at the same power level. The block length is 256 and the spread length is 32. The interleaver length is obtained as the product of block length and the spread length and it is equal to 8192. The input symbols are spread, by a balanced sequence of alternating +1 and -1 of length 32.Channel conditions is assumed to be known at the receiver. Figure-4 shows the performance comparison of the two systems with FEC encoding. Zigzag codes with coding rate ½ and 4 encoders with interleaving length 65536 are used in both cases. After FEC encoding the resultant sequence is spread by a sequence of alternating +1 and -1 of length 16 so overall code rate will become 1/32. We can see that the proposed adaptive system outperforms the convention MC (OFDM) [8] system. The reason behind it is because the bad conditions sub channels are eliminated and allocated all the signal energy to the good conditioned sub channels.

ARPN Journal of Engineering and Applied Sciences

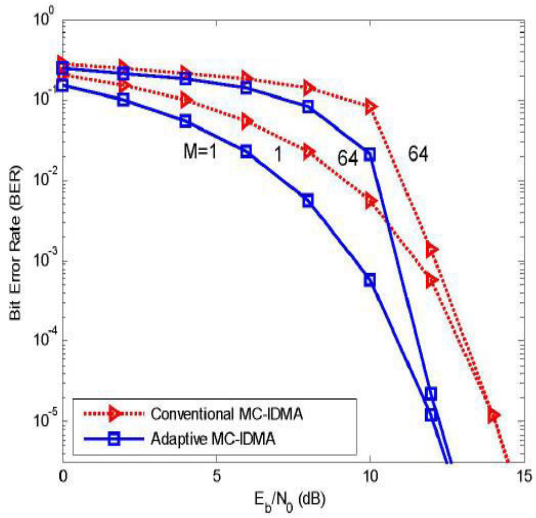

Figure-3. BER versus Eb/No curve for comparing the performance of Conventional MC-IDMA and Adaptive MC- IDMA systems without any FEC coding for various number of users in the channel (frequency selective-multipath).

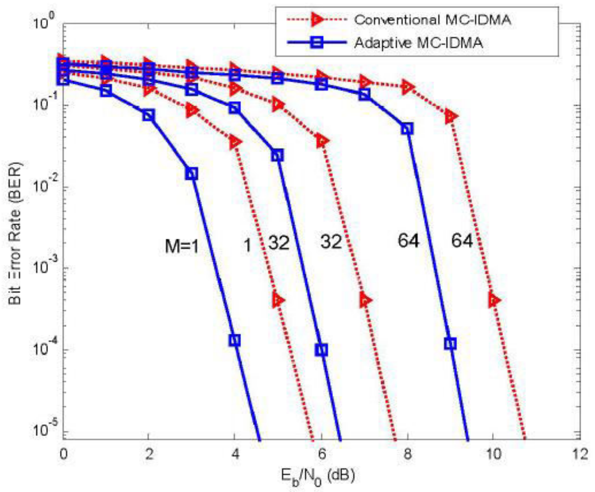

Figure-4. BER versus Eb/No curve for comparing the performance of Conventional MC-IDMA and Adaptive MC-IDMA systems with concatenated zigzag coding for various number of users in the channel (frequency selective-multipath).

4. CONCLUSIONS

This paper proposes an improved multicarrier (OFDM)-IDMA system with adaptive sub channel allocation for reverse links. In this scenario, the base stations are used for estimating the amplitudes of all the sub channels and it also feeds back the base indices of the best conditioned sub channels to the mobiles which in turn results in transmission over best conditioned sub channels rather than transmission over all the sub channels uniformly. The simulation result shows that the proposed system outperforms the conventional multicarrier (OFDM)-IDMA system.

REFERENCES

[1] Li Ping, L. Liu, K.Y. Wu and W. K. Leung, April, 2006. Interleave-division multiple-access. IEEE Trans. On wireless comm. 5(4): 938-947.

[2] Li Ping, X Huang and N. Phamdo. Feb. 2001. Zigzag codes and Concatenated Zigzag codes. IEEE Trans. Info. Theory. 47(2): 800-807.

[3] Li Ping, L. Liu, K.Y. Wu and W. K. Leung. Oct. 2002 A unified approach to multiuser detection and space-time coding with low complexity and nearly optimal performance. In: proc. 40th Allerton Conference, Allerton House, USA. pp. 170-179.

[4] Verdu. 1998. Multi-user Detection, Cambridge University Press.

[5] P. Hoeher, U. Sorger and I. L 2000. Loglikelihood values and montecarlo simulation. Some fundamental results. In: proc. 2nd international symposium on Turbo codes and related topics, Brest, France.

[6] N. Yee, J.P. Linnartz, and G. Fettweis. sep. 1999. Multicarrier CDMA for indoor wireless radio networks. Proc. PIMRC '93, Yokohama. pp. 109-113.

[7] S. Hara and R. Prasad. Sep. 1999. Design and performance of multicarrier CDMA system in frequenc-selective Rayleigh fading channels. IEEE Trans. On Vehicle. Tech. 48(5): 1584-1595.

[8] H. Rehman, M. Naeem, I. Zaka and S.I. Shah. Multicarrier interleave-division multiple access communication in multipath channels. Proceedings of the 5th WSEAS International conference.

[9] Sriwas S.K., Shukla M., Asthana R. and Saini J.P. 2016. Fix the nonlinear effect and dispersion in optical interleave division multiple access system for long distance. Indian Journal of science and technology. 9(35): 1-8.

[10] Sriwas S.K., Shukla M., Asthana R. and Saini J.P. 2016. High-speed Detection with Avalanche Photodiode in Optical Interleave Division Multiple Access Scheme. Indian Journal of science and technology. 9(38): 1-7.

[11] Sriwas S.K., Shukla M., Asthana R. and Saini J.P. 2016.Analysis of low rate convolutional codes on optical interleave-division multiple-access scheme. ARPN Journal of Engineering and Applied Sciences. 11(23): 13634-13660.