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The channel shortening comparison between OFDM and MC-CDMA System over an ADSL channel using a water-filling

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ABSTRACT

In this paper our objective focuses on the development of digital transmission techniques in order to solve the problem of Inter-Symbol Interference (ISI) due to multiple paths and the improvement of Multi-Carrier Code Division Multiple Access (MC-CDMA) system performance. The both algorithm: MERRY algorithm (Multicarrier Equalization by Restoration of Redundancy) called TEQ (Time domain EQualizer) and the power allocation method to allocate appropriate power to each user (Water-Filling technique (WF)) [1] is used. Finally, the numerical results show that combining Water Filling with TEQ technique allows to reduce the ISI for MC-CDMA systems.

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1. INTRODUCTION

Wireless communication is considered to be the fastest growing segment of the communications industry. Cellular systems have grown faster in the last decade and currently have two billion users worldwide. Because of the benefits of wireless communications, various major telephone service providers around the world have launched the radiotelephone. The growing number of subscribers and the need to provide new high-quality services have led to the emergence of successive cell systems that can be classified into different generations. Recently, broadband CDMA systems have been developed as a 3G competitor to increase data rates for the user. However, the large bandwidth of these high-speed links makes them vulnerable to Inter-Symbol Interference (ISI). CDMA and OFDM are not, independently, able to meet this requirement.

The MC-CDMA scheme (multiple access divisible by multi-carrier code) makes it possible to simultaneously exploit the advantages of CDMA and OFDM, a multi-carrier modulation scheme. The MC-CDMA system is considered one of the potential candidates considered to be capable of meeting the requirements of next-generation (4G) [1-6] high-speed wireless multimedia communication systems and Long Trem Evolution (LTE).

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The latter will increase the amplitude of the signal each time it is attenuated. This document is organized as follows. Section II discusses the system model and the description of the MERRY algorithm (redundancy restoration multi-carrier equalization) [7, 8]. Section III presents the optimization of water filling (WF). Section IV assesses a comparison between the proposed solution applied to MC-CDMA (WF .MC-CDMA) with TEQ equalizer and conventional MC-CDMA using TEQ by means of numerical simulations. Finally, section V presents some conclusions.

2. SYSTEM MODEL AND DESCRIPTION OF MERRY ALGORITHM

This section derives the basic MERRY. What come later will discuss various generalizations and performance-enhancing extensions. At the beginning, consider a MC-CDMA system in Figure 1. After the CP insertion, the last ν samples are identical to first ν samples in the kth symbol [8-10], i.e.:

$$x\,(Mn+i) = x\,(Mn+i+N) \qquad i \in \{1,2,\ldots,v\} \qquad \text{and } n=0,1,\ldots \tag{1}$$

The symbol period is M = N + v, and n is the symbol index. To simplify the notation, henceforth we assume n=0 (without loss of generality). The received data r is obtained from x by

$$r_k(i) = \sum_{l=0}^{L_h-1} h(l)\,.\,x_k(i-l) + n(i) \tag{2}$$

and the equalizer data y is similarly obtained from r by

$$y_k(i) = \sum_{l=0}^{T-1} w(j)\,.\,r_k(i-j) \tag{3}$$

Where T is the length of the equalizer w. The combined channel is denoted by:c= h*w. Figure 2 shows an example with N = 8, v= 2, and M = N + v = 10 [11]. Consider this example. The broadcasted samples 2 and 10 are the same. But, at the receiver, the interfering samples earlier than sample 2 are not the whole identical to their correspondences before sample 10. If h(2), h(3) and h(4) were zero, then r(2) = r(10). If we try to force r(2) = r(10), we may force h(2)= h(3)= h(4)= 0, forcing the channel selected the same like the CP. The location of the window of v non-zero taps can be varied by comparing r(3) to r(11), or r(4) to r(12), etc. In general, if the channel length L_h+1 ≤v, in that case the previous sample inside the CP must look like the previous sample inside the symbol. Unit cost function that reproduce:

$$J_{MERRY}(\delta)=E[|y(v+\delta)-y(v+N+\delta)|^2] \qquad \delta\in\{0,\ldots,M-1\} \tag{4}$$

Where δ is the symbol synchronization parameter, which represents the desired delay of the channel–TEQ combination.

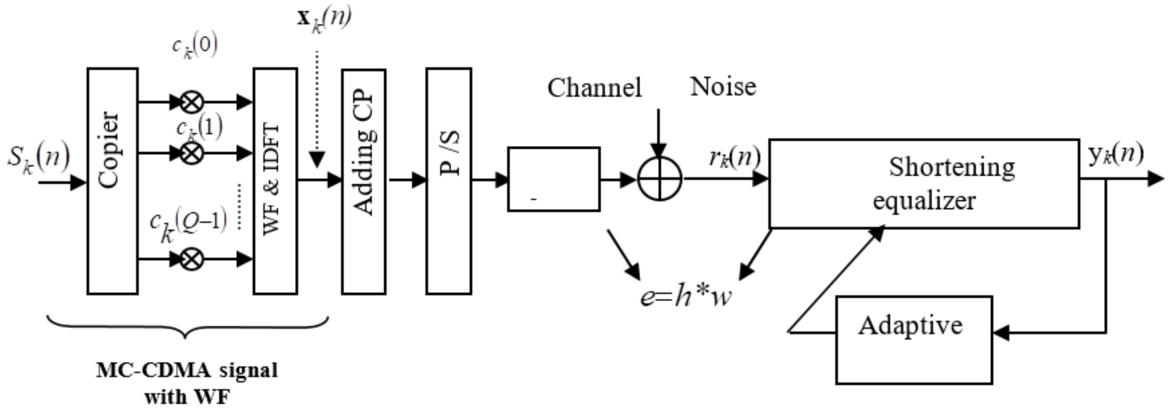

Figure 1. Channel shortening with a blind equalization for MC-CDMA-WF system

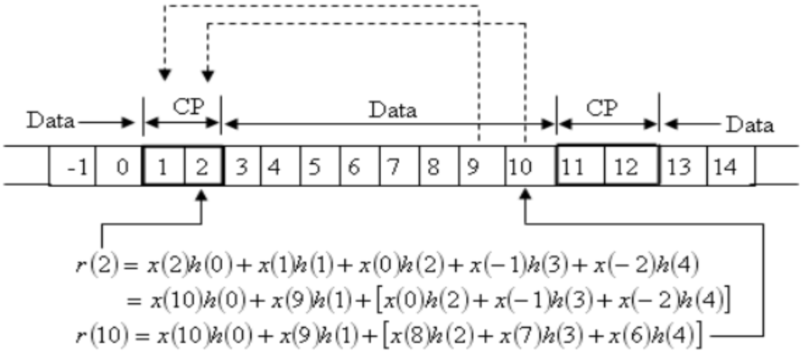

Figure 2. Illustration of the change in the ISI at the end of the received symbol and at the received CP

The MERRY algorithm [12-17], performs a stochastic gradient descent of (4), with a constraint to avoid the trivial solution w = 0. The MERRY algorithm is:

$$\begin{aligned}
&\tilde{\mathbf{r}}(n)=\mathbf{r}(n+\nu+\delta)-\mathbf{r}(n+\nu+N+\delta)\\
&y(n)=\mathbf{w}^{T}(n)\,\tilde{\mathbf{r}}(n)\\
&\hat{\mathbf{w}}(n+1)=\mathbf{w}(n)-\mu y(n)\,\tilde{\mathbf{r}}^{*}(n)\\
&\mathbf{w}(n+1)=\frac{\hat{\mathbf{w}}(n+1)}{\|\mathbf{w}(n+1)\|}
\end{aligned} \tag{5}$$

where r(n) = [r(n), r(n-1), …, r(n-L_w)]^T, (*) denotes complex conjugation, and µis the TEQ adaptation step size, it's taken at 0,75.

3. WATER-FILLING OPTIMIZATION

Water-Filling algorithm examines per-tone SNR and result in per-tone number of bits and energy levels that should be optimally used as shown in Figure 3.

To maximize the data rate, R = b/T, for a set of parallel subchannels when the symbol rate 1/T is fixed, requires maximization of the achievable $\mathrm{b} = \sum_{\mathrm{n}} \mathrm{b}_{\mathrm{n}}$ over b under a given total input energy and a target probability of error. Specifically, the number of bits allocated to the nth subchannel is [1-2]:

$$b_n = log_2(1 + \frac{\varepsilon_n g_n}{\Gamma}) \tag{6}$$

where $g_n = {|H_n|^2}/{2\sigma_n^2}$ represents the subchannel signal-to-noise ratio when the transmitter applies a unit energy to that subchannel. The ratio g_n is a fixed function of the channel, but ε_n, which denotes the 2-D subsymbol energy allotted to the n^{th} subchannel, can be optimized to maximized b, subject to a total transmit energy constraint of:

$$\sum_{n=1}^{N} \varepsilon_n \le \varepsilon_x \tag{7}$$

Since $log(1+x)$ is a strictly increasing function of x, the total energy constraint of (7) will be binding, i.e., equality is met. Using Lagrange multipliers, the cost function becomes

$$\frac{1}{\ln 2}\sum_n \ln\left(1+\frac{\varepsilon_n g_n}{\Gamma}\right)+\lambda\left(\varepsilon_x-\sum_{n=1}^{N}\varepsilon_n\right) \tag{8}$$

Differentiating with respect to ε_n produces

$$\frac{1}{\ln 2\left(\varepsilon_n + \frac{\Gamma}{g_n}\right)} = \frac{\lambda\Gamma}{g_n} \tag{9}$$

Thus, the aggregate bit rate in b is maximized when the optimum subchannel transmit energies satisfy

$$\varepsilon_n + \frac{\Gamma}{g_n} = K = \text{constant} \tag{10}$$

and K is chosen such that the total energy constraint given by (7) is met [1-2]

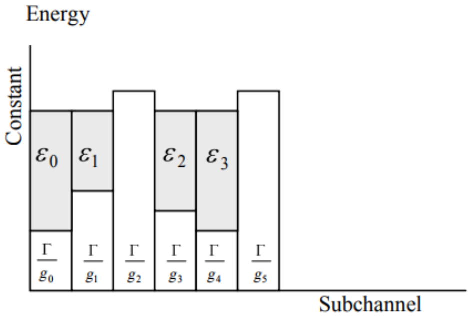

Figure 3. Water-Filling algorithm

4. SIMULATION RESULTS

We perform numerical simulations of Inter Symbol Interference (ISI). The evolution of the ISI as a function of the number of iterations allows us to know how to evaluate and compare the performances of the systems in terms of their speed of convergence. The ISI is obtained by varying the number of iterations (the number of symbols) that is equal to 1000. Figure 4 shows a plot of the ISI vs. Number of iterations. It shows simulation results using Water-Filling a standard ADSL test channel. The FFT size was 512, the CP length was 32, the TEQ had 16 taps, and signal to noise rapport was 40 dB.

Figure 5 shows that Water-Filling can converge rapidly provide a perfect result for MC-CDMA systems which combines multi-carrier modulation (OFDM) and Multiple Code Division Multiple Access (CDMA). In this figure, we notice that the system MC-CDMA.TEQ reaches the value ’ISI de (-4.75dB) and stay fixed in this value. In parallel, the MC-CDMA.TEQ &WF achieve a good performance which leads to a value of ’ISI N entre (-8 et -9dB).

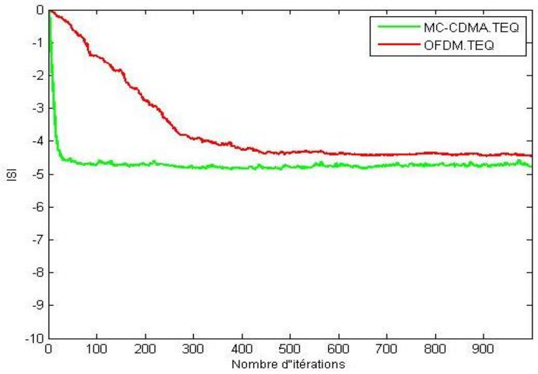

Figure 4. Performance of OFDM-TEQ Vs MC-CDMA-TEQ system in term of ISI

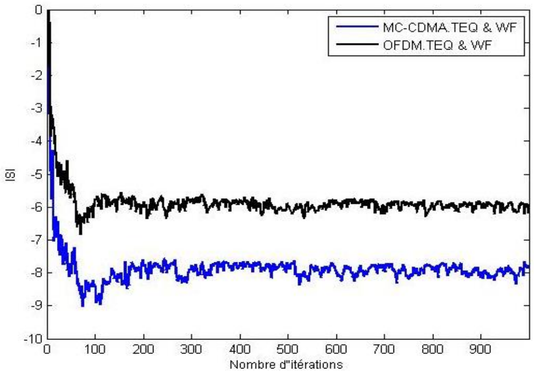

Figure 5. Performance of OFDM-TEQ Vs MC-CDMA-TEQ system in term of ISI, using the Water-Filling

Here, we compare both systems of transmission OFDM and MC-CDMA achieved for the equalization technic TEQ. We see that that the second system give better result than the other system, this is due to the advantages of using MC-CDMA where there is a remarkable difference because the OFDM begins to converge from an iteration count of 300, but the other system has already converged for a number of iterations of 50.

Note that the two curves are well improved thanks to the use of the technique of Water-Filling. We also note that the MC-CDMA approaches the optimum in termsof ISI and converges towards a realization of a system more efficient than that of the OFDM.

The representative curves of the four methods in terms of ISI are compared respectively in Figures 6. We have noticed that the curves of the MC-CDMA system are much better than that of the OFDM, and the use of the Water-Filling algorithm improves the results significantly. But the MC-CDMA system is still the most efficient.

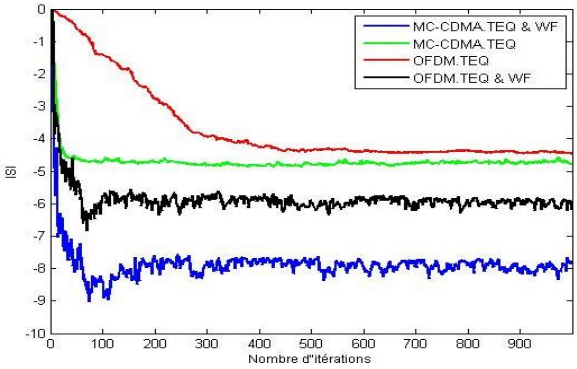

Figure 6. Performance of multicarrier transmission for different scenario

5. CONCLUSION

In this work, we displayed a Water Filling arrangement strategy for MC-CDMA framework. We have appeared that the proposed strategy connected to MC-CDMA frameworks accomplishes the required ideal vitality conveyance due to the execution of this transmission framework and the arrangement utilized. Recreation comes about and comparison with and without Water Filling calculations affirm the viability of the MC-CDMA channel strategy. The Water Filling arrangement is one of a kind since the maximized flow function is concave. Subsequently, there's a single ideal vitality conveyance and a comparing stream distribution. After all these comparisons, it has these were pointed at optimizing MC-CDMA frameworks to move forward their execution. An ideal TEQ must decrease the estimate of the channel to that of the prefix and dispose of inter symbol obstructions. So, the problem of power allocation can be solved by the optimization technique Water Filling.

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