ISBN: 978-88-900984-8-2
THIRD WORKSHOP ON POWER LINE COMMUNICATIONS, OCTOBER 1-2, 2009, UDINE, ITALY

Coded OFDM vs. Wavelet-OFDM and Circular Wavelet-OFDM for Power Line Communications

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Abstract

The paper presents results from simulations of three uncoded and coded multicarrier systems: OFDM, Wavelet-OFDM and Circular Wavelet-OFDM working in the in-door power line communications (PLC). Circular Wavelet-OFDM is a multicarrier scheme, in which frames are additionally processed in a circular fashion and the equalization is realized very simple thanks to the use of a cyclic prefix. The reported research is focused on investigation of coded BER performance for two different time-frequency tilling in the environment with statistical model of power line channels, asynchronous impulsive disturbances and colored background noise.

Index Terms

OFDM, Wavelet-OFDM, Circular Wavelet-OFDM, Reed-Solomon, convolutional codes

I. INTRODUCTION

OFDM modulation is a very well known transmission technique proposed for use in many future communication systems. However, recent developments show that application of the Wavelet-OFDM can be also beneficial in power line communications (PLC) [1, 2]. Additionally, proposed Circular Wavelet-OFDM [3] has all advantages of Wavelet-OFDM, but the problem of equalization was solved by the use of a circular post-processing and a cyclic prefix.

Main attention of this paper is focused on investigation of efficiency of three different multicarrier schemes with the industry standard concatenated codes in in-door power line communications. We present results from simulations of two different time-frequency tilling scenarios for a statistical power line channel model, impulsive disturbances and two levels of colored background noise.

II. MODULATION SCHEMES

In this paper we investigate standard OFDM, Wavelet-OFDM [1, 2] and Circular Wavelet-OFDM [3, 4] modulators. The OFDM makes use of (I)FFT, long frames and a cyclic prefix, and is easily equalized. The Wavelet-OFDM is based on extended lapped transform, exploits short frames, does not utilize the cyclic prefix and is more difficult to equalize [2]. In turn, the third modulator makes use of: extended lapped transform in circular fashion, long frames and the cyclic prefix, and, due to the prefix, it is simply equalized by means of FFT similarly to the OFDM. The Circular Wavelet-OFDM represents a circular version of the Wavelet-OFDM and it is a special form of a real circular (periodic) Gabor expansion [4] in which signal synthesis and analysis is done by means of cosine basis only.

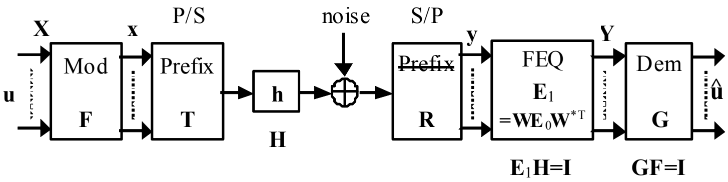

Fig. 1, Circular Wavelet-OFDM modulator block diagram.

General block diagram of the Circular Wavelet-OFDM signaling scheme is presented in fig. 1. All operations are performed in the same way as in OFDM, but the Fourier matrix **W** is replaced by the matrix **F** representing modified discrete cosine transform (MDCT). Additionally, after synthesis and before analysis, input data are processed circularly for each time slots like in the circular periodic Gabor time-frequency signal representation [5]. Our implementation allows using four types of configurations: 2x1024, 4x512, 8x256 and 16x128 (number of time slots x number of frequency slots). Perfect reconstruction filters are used in two first cases and near-perfect filter in two remaining ones. More information about Wavelet-OFDM and Circular Wavelet-OFDM can be found in [1, 2] and [3, 4] respectively. We limited our simulations to the two time-frequency configurations: 2x1024 and 16x128 only. Our previous research [3] showed that in case of uncoded systems they present extremely different sensibility to the level of colored noise.

III. SIMULATION RESULTS AND DISCUSSION

In our simulations we have used a statistical PLC channel model taken from the OPERA project [6]. 2PAM/4QAM, 4PAM/16QAM and 8PAM/64QAM constellation sizes have been exploited during transmission. The OFDM modulation had 2048 QAM data symbols in one frame (the size of FFT). In the baseband simulations we used only 768 complex symbols. Wavelet-OFDM and Circular Wavelet-OFDM were using 2*768 real PAM symbols. The sampling frequency was equal 62.5 MHz. Transmitters scaled energy of sent frames to the level of -70 dB [V^2/Hz].

Impulsive disturbances are the main reason of frames retransmission in PL communications [7]. In the reported research these impulses were modeled as exponentially attenuated sinusoids with randomly changed parameters. They were generated in the bandwidth from 1 MHz to 15 MHz with amplitudes in the range -250 to 250 mV and they were appearing in random places according to the Gaussian statistics. During simulations we have taken into account the colored background noise. The parameters of used in the simulations concatenated Reed-Solomon and convolutional codes are presented in Table 1.

Tab. 1, Parameters of concatenated codes for different constellation size

Encoding mode	Constellation size	Outer code (Reed-Solomon)	Inner code (Convolutional code)	Overall code rate
Enc1	2PAM/4QAM	(32,24,4)	(3,2)	1/2
Enc2		(40,36,2)	(6,5)	3/4
Enc3	4PAM/16QAM	(64,48,4)	(3,2)	1/2
Enc4		(80,72,4)	(6,5)	3/4
Enc5	8PAM/64QAM	(108,96,6)	(4,3)	2/3
Enc6		(120,108,6)	(6,5)	3/4

A. *Results of simulations with random PLC channels and white Gaussian noise*

These results were obtained for 50 realizations of randomly generated PLC channels from the class "good" according to the procedure presented in [4]. On the separate figures we presented mean bite error ratio for uncoded and coded system with three M-PAM/M-QAM constellations and six encoding configurations according to the Table 1.

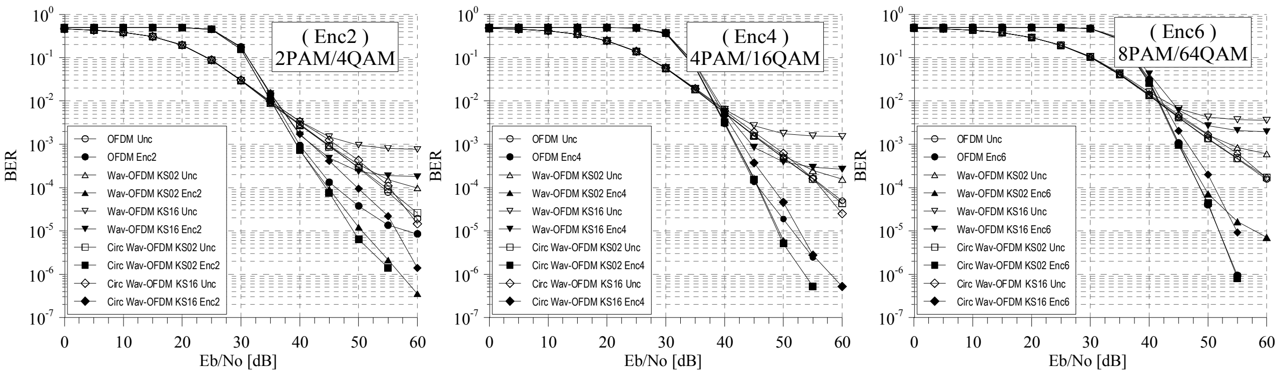

Fig. 2-4, BER comparison of three encoding configurations Enc2, Enc4 and Enc6 in power line channel and white Gaussian noise.

In case of uncoded systems Wavelet-OFDM lose its BER performance in the high bit SNR ratio, what is cause by the insufficient equalization of power line channel. When the coding is used and overall code rate is R= 1/2 (Enc1 and Enc3) all modulators presents similar performance. However, for coding rate 2/3 and 3/4 the difference is more noticeable what can be seen in the fig. 2-4. Better performance is observed when 2x1024 scheme is used then with 16x128 for both Wavelet-OFDM and Circular Wavelet-OFDM. Additionally, Circular Wavelet-OFDM with 16 time slots still performs moderately well in comparison to OFDM.

B. Results of simulation with presence of impulsive disturbances

Different situation is observed when frames are affected by heavy impulsive disturbances. The lowest BER is observed in case of Wavelet-OFDM and Circular Wavelet-OFDM with 16 time slots, especially when impulses are short. Wavelet-OFDM with 2 time slots still offers good performance in case of longer impulses. For codes with lower error correction capabilities (Enc2, Enc4 and Enc6), Wavelet-OFDM with 2 time slots offers an improvement over the other modulators.

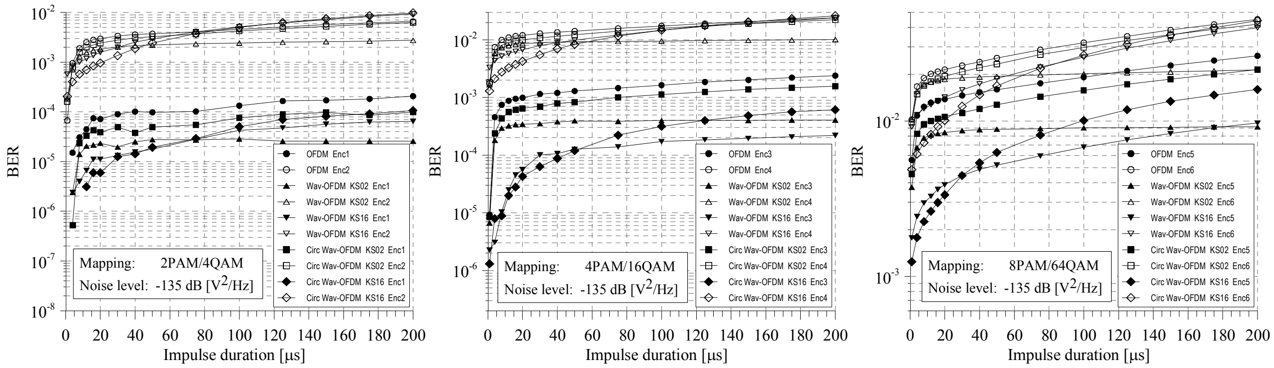

Fig. 5-7, BER comparison of coded systems with impulsive disturbances and -135 dB [V^2/Hz] background colored noise.

In case of lower level of background colored noise situation is very similar. This is different than in case of uncoded systems what has been showed in studies presented in [3]. OFDM is far behind other modulators regardless the noise level and sensibility to it in the remaining modulators is greatly reduced. Although it is better observed in case of codes with higher error correction capabilities (Enc1, Enc3, and Enc5).

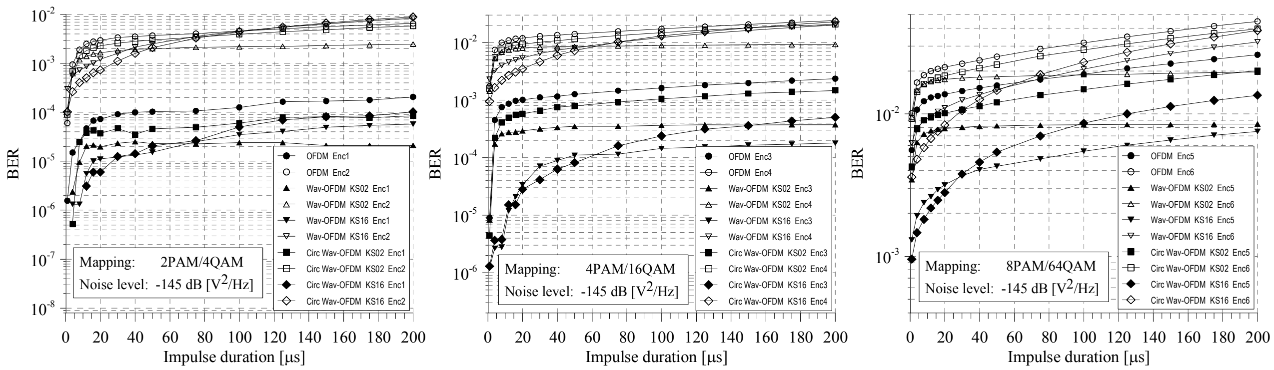

Fig. 8-10, BER comparison of coded systems with impulsive disturbances and -145 dB [V^2/Hz] background colored noise.

IV. CONCLUSIONS

In this paper were compared three different modulators: OFDM, Wavelet-OFDM and Circular Wavelet-OFDM working with two different time-frequency scenarios in the impulsive PLC environment. The comparison made for codes systems shows that, especially in case of impulsive disturbances, Wavelet-OFDM and Circular Wavelet-OFDM present very good performance. Error correction coding reduces also influence of the colored background noise level. Further results, including more sophisticated error correction schemes will be presented during presentation.

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