INVESTIGATION OF DISTORTION LESS PAPR REDUCTION APPROACHES IN O-OFDM

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Abstract

The signal has a non-constant envelope, i.e. it exhibits peaks whose power strongly exceeds the mean power: the signal is said to have a high *Peak-to-Average power Ratio* (PAPR). This prevents from the use of high-efficiency amplification devices (*High Power Amplifiers*, HPA), which exhibit deep non-linearities that give rise to intermodulation products; the latter cause in-band distortion and increase *Out-Of-Band Radiation* (OOBR), which results in a disturbing *Adjacent Channel Interference* (ACI) and a *Bit-Error-Rate* (BER) increase. However OFDM signals have a problem with high Peak-to-Average power ratio (PAPR) and thus, a power amplifier must be carefully manufactured to have a linear input-output characteristic or to have a large input power back-off. Here in this paper, author compares the two methods PTS & SLM approach used for reduction of PAPR.

Key words: Orthogonal Frequency Division Multiplexing (OFDM), Peak-to-Average Power Ratio (PAPR), High Power Amplifier (HPA), Partial Transmit Sequence (PTS), Selective Mapping (SLM).

I. INTRODUCTION

This paper discusses methods to reduce large envelope variations of OFDM signals. The envelope variations are one of the most frequently cited drawbacks of OFDM, because in practice any transmission system reveals some nonlinear characteristics and, moreover, is peak-power limited. Nonlinearities cause spectral widening of the transmit signal resulting in unwanted out-of-band (OOB) noise, a major concern especially in radio applications where possibly large differences in signal strength from mobile transmitters impose stringent requirements on adjacent channel interference (ACI) suppression. The transmit signal itself is degraded by nonlinearities, which results in increased bit error rates in the receiver. High peak values in OFDM result from the superposition of a large number of usually statistically independent sub channels that can constructively sum up to high peaks. Because of this well-known mechanism the appearance of high peak values had been considered unavoidable for some time. However, the recent interest in the application of OFDM to wireless networks has resulted in the development of methods to combat these problems. There are several different classes of approaches. For example, some researchers accept a high PAPR for the transmit signal and propose new amplifier concepts [1] for increasing the transmitter power efficiency. The optimization of existing amplifiers is under consideration [2]. Others attempt to find intelligent methods for modulation, in order to generate transmit signals with reduced PAPR. Consequently, existing amplifier technology can be used. Finally, comparing theory with the state of the art shows that there is still research required in this new field in order to approach the theoretical limits with low complexity technology.

II. SELECTIVE MAPPING APPROACH

The basic principle of PAPR reduction becomes most obvious with selective mapping (SLM). The method has been developed independently by several authors [4]. In selective mapping, M_a statistically independent signals x^l (b^i,t), with l = 1,. . . ,M_a are generated from the same information bi and that signal with the lowest peak power is selected for transmission. Figure 1 shows an SLM OFDM system. The information word bi is mapped onto a vector of OFDM coefficients di conventionally. From this vector, M_a statistically independent coefficient sequences are derived by elementwise multiplication with M_a fixed, but statistically independent vectors r^l, . . , r^{Ma}. Each coefficient sequence is transformed in time-domain by conventional modulation. Then, for each resulting time domain waveform x^l (d^i,t), the peak power is measured and that signal x^{lopt} $(d^l,$ t) with lowest corresponding peak power is selected for transmission. Since the peak powers are assumed to be statistically independent, selecting the best signal will reduce PAPR

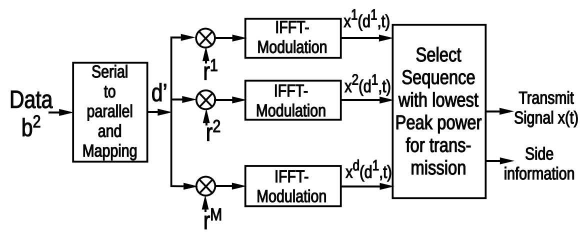

Fig. 1. Selective mapping approach [5]

For detection, the receiver needs to know which vector r^{opt} has been used in the transmitter in order to divide the demodulator output elementwise by r^{opt}. This knowledge could be transmitted as side information without significantly reducing the data rate, since only $\log_2(Ma)$ bits are needed. Of course, it is of greatest interest to know how many sequences are necessary to achieve a significant CF reduction and how much reduction is possible. Since for obtaining a CF, $C(r^{Ma})$ larger than a certain desired value Cd is a necessary requirement that the CF of all signals $x^l(d^i, t)$ is larger than Cd. C^{Ma} is determined by the following relationship

$$Pr(C^{Ma} > C_d) = Pr((C(R^1) > C_d), \ldots, (C(r^{Ma}) > C_d))$$

$$= \prod_{t=1}^{Ma} Pr(C(r^t) > C_d)$$

$$= (Pr(C > C_d))^{Ma} \qquad \ldots (1)$$

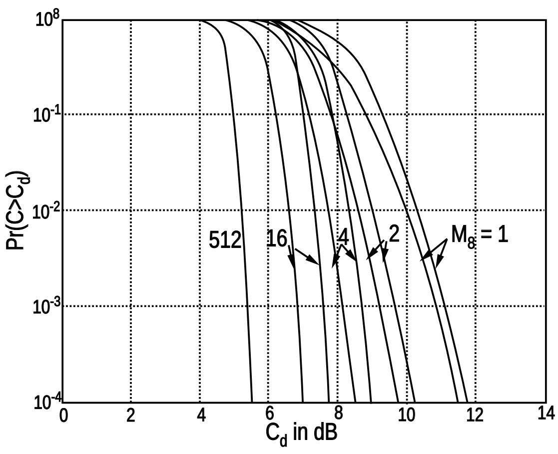

Fig. 2. CCDF of the CF for $N = 128$ and 8PSK OFDM with SLM.

The second line of above equation is derived assuming that the probabilities are independent. Figure 2 plots simulation results for $N = 128$ subchannels and $Ma = 1, 2, 4$ and 16. With an increasing number Ma of associated sequences, the PAPR reduces significantly.

III. PTS APPROACH

PTS is mainly motivated by the idea that an individual scaling and phase rotation of appropriately defined 'partial transmit signals' should be a powerful means to avoid the constructive addition of the components to high peak values. Figure 3 shows a possible implementation of this approach in the transmitter. The OFDM signal is partitioned into M_{PTS} disjoint sets of subchannels

$$s(t) = \sum_{g=1}^{M_{PTS}} \Theta_g \alpha_g(t) \qquad \ldots (2)$$

With

$$\alpha_g(t) = \sum_{n \in I_g} S_n \cdot E^{j 2 \pi n \Delta f t} \qquad \ldots (3)$$

The components $x_g(t)$ are called the 'partial transmit sequences' (PTS) or 'group signals'. The latter implies that the sets Ig consist of adjacent subchannels but this is not necessarily the case.

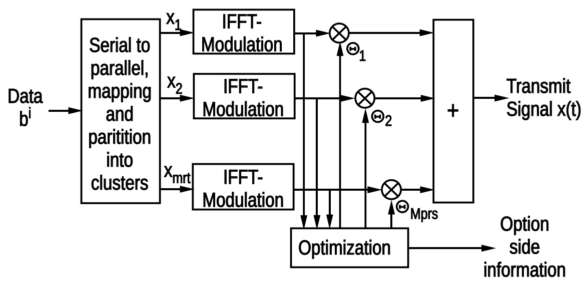

Fig. 3. Partial transmit sequence approach[5].

Each group signal is transformed in time-domain by conventional modulation. In time-domain, all group signals are weighted with an individual factor èg, and added to result in the transmit signal s(t). The complex factors è that usually have unit modulus allow for a phase rotation of each group signal. They are chosen so that the peak power of s(t) is minimal.

As with SLM, the receiver must have knowledge about the generation process of the OFDM signal, i.e. the chosen factors $(\theta_1, \theta_2, \ldots \theta_{MPTS})$. These factors could be transmitted as side information. Alternatively within each group signal differential encoding can be applied. In any case (neglecting the possibly required side information), the relative redundancy of this scheme is r = M_{PTS}/N, since we spend M_{PTS} complex factors for optimization. In principle, the group signals may consist of different numbers of subcarriers, but the best PAPR reduction capability is expected, when they are the same for all groups, i.e.|Ig|= N/M_{PTS}. where N is assumed to be an integer multiple of M_{PTS}. Also the particular selection of subchannels has an impact on the achievable amount of CF reduction. For brevity, we will consider only the simple case of adjacent subchannels with $I_t = \{ (g-1) \cdot N_g, \ldots g \cdot N_g - 1 \}$. Figure 4 shows the achieved PAPR reduction for various numbers of groups MpTS and two to eight phases, i.e. $\theta \,\varepsilon \{ 0, \Pi/2, \Pi, 3\,\Pi/2 \}$

and $\theta_g \,\varepsilon \{ 0, \Pi/8, 2\,\Pi/8 \ldots 7\,\Pi/8 \}$

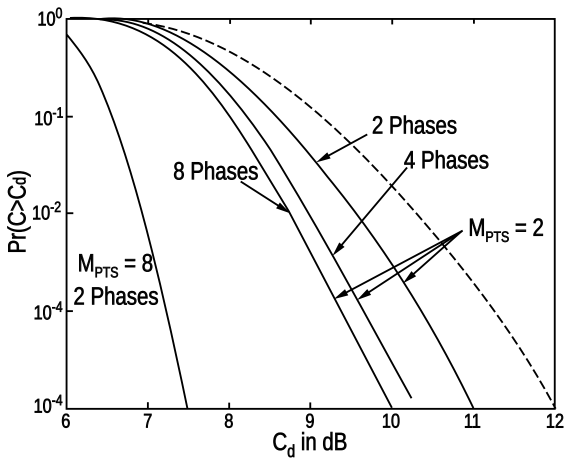

Fig. 4. PAPR reduction with PTS for 128 subchannels. Dashed line denotes conventional OFDM.

The results have been obtained by simulations with 8-PSK subchannel modulation and a full search over all parameter tuples. With an increasing number of groups M_{PTS} as well as with increasing number of possible phase values, the achievable PAPR reduction increases. With 8 phase values however, most of the possible PAPR reduction for a certain value of M_{PTS} is achieved. A finer granularity has little effect only. Also, in addition to the fact that the effective CF is reduced, also the true maximum peaks can be significantly reduced.

A disadvantage of the method is that the number of possible time-domain signals s(t) rapidly increases with the number of group signals M_{PTS} and phase values. Therefore, applying a full search procedure for finding the best time-domain waveform will often be impossible. There are several ways to combat this problem. In [3] it is proposed not to perform the full search optimization, but to try a certain number of sets of optimization parameters $(\theta_1, \theta_2, , \theta_{MPTS})$. We may note however that this approach is similar to SLM. In particular, because of the linearity of the Fourier transform, the factors Ng can be considered also in frequency domain. Hence, the rotation vectors r of SLM can be expressed in terms of the PTS optimization variables according to

$$r = \begin{pmatrix} \theta_1, \theta_1, \ldots, \ldots, \theta_{MPTS}, \theta_{MPTS}, \cdots \\ N_g \text{ variable} \qquad N_g \text{ variable} \end{pmatrix} \quad \ldots (4)$$

Consequently, the limits of the SLM approach are also valid for this variation of the PTS approach.

IV. CONCLUSION

Partial Transmit Sequence Approach	Selective Mapping Approach
1. Here some of the parameters are determined by the information to be transmitted, whereas the remaining are free for optimization.	1. Here statically independent signals are generated by the information only.
2. The optimization is performed so that peak values in the time domain waveform are as small as possible.	2. No any optimization technique is used.

Partial Transmit Sequence Approach	Selective Mapping Approach
3. Here some parameters are not available for transferring information anymore, the bandwidth efficiency is reduced.	3. Here all the parameters are used to transfer the information. So the bandwidth efficiency is not reduced.
4. Here the selection typically requires multiple transformations in time-domain, i.e. modulation processes.	4. Here for each bi we must generate associated signals $x^l(b^i,t)$, $l = 1, . . . , M_a$ so that a selection can reduce the peak power of the resulting multicarrier signal.
5. Here the side information is optional. In non coherent detection it is not required.	5. For detection, the receiver needs to know which vector r_{opt} has been used in the transmitter in order to divide the demodulator output element wise by r_{opt}. This knowledge could be transmitted as side information.
6. Here datarate is more in the case of noncoherent detection.	6. Here data rate is reduced because of side information.

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