# PAPR Reduction Using Hybrid Schemes for Satellite Communication System

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ABSTRACT

In the future, satellite communication systems, such as ISDB in Japan and DVB in Europe, are required to support higher transmission date rate for providing multimedia services including HDTV, high rate data communication etc. Considering the effectiveness of OFDM technique in efficient usage of frequency bandwidth and its robustness to the multi-path fading, several OFDM based standards have been proposed for satellite communication. However, the problem of high Peak to Average Power Ratio is one of the main obstacles for the implementation of OFDM based system. Many PAPR reduction schemes have been proposed for OFDM systems. Among these, the partial transmit sequences (PTS) is attractive as they obtain better PAPR property by modifying OFDM signals without distortion. In this paper, considering the complexity issue, we present a simplified minimum maximum (minimax) criterion and Sub-Optimal PTS algorithm to optimize the phase factor. This algorithm can be dynamically made tradeoff`f between performance and complexity on demand. In addition, we integrate guided scrambling (GS) with this method. Simulation in multiple antenna based OFDM system proves that the proposed Hybrid schemes can get much more PAPR reduction and do not require transmission of side information (SI). Thus it is helpful when implementing OFDM technique in satellite communication system.

**Key Words** : PAPR, OFDM, PTS, GS, SI, MIMO-OFDM, Satellite Communication

## I. Introduction

As the higher transmission data rate is required for future satellite communication system, advanced technique such as OFDM should be considered as the transmission technique. However, one of the problems introduced in any OFDM based system is the large PAPR. It brings disadvantages like an increased complexity of the analog-to-digital and digital-to-analog converters and a reduced efficiency of the PF power amplifier [1]. OFDM has become a promising candidate for high performance 4G broadband wireless communications. However, as an OFDM based technique, one main drawback is that the signals transmitted on different antennas might exhibit a prohibitively large PAPR.

To reduce the PAPR, several techniques have been proposed, amount which PTS is one of the best methods that is able to achieve good PAPR properties without distorting the signals [2]. A straightforward way for PAPR reduction seems to apply existing PTS for OFDM systems on each branch, respectively. And through the PTS part to get the minimum PAPR, then calculate the average value of theses minimum PAPR from each branch (mini-aver criterion). However, it will be very complex. In order to simplify the PTS scheme, we use a minimax criterion instead of minimum average (mini-aver) [3]. In addition, we propose a Sub-Optimal PTS algorithm to optimize the phase factor. It has low computation complexity than ordinary PTS, and can be assigned dynamically on demand.

GS is a multimode coding technique based on the same premise as PTS [4]. A scrambled binary sequence of length 2N with a Hamming weight close to N will often generate low PAPR [5]. GS is capable of guiding the scrambling process to produce a balanced encode bit stream. Since the correlated pattern among sub-carriers influences

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the PAPR, which highly depends on the patterns of the orthogonal sub-carriers used. This implies that the PAPR of the OFDM signal will be reduced if we can introduce a disturbance into the correlation among the sub-carriers. We can achieve a further PAPR reduction by using the fixed scrambling patterns and holding the scramble patterns. Thus, we expect that combining the GS with Sub-Optimal PTS is able to reduce the PAPR significantly.

The GS method is introduced in the second section, in which, both encoder and decoder are described. Then the proposed sub-optimum PTS is explained in the first part of section 3. The transmitter structure of the proposed hybrid scheme is also demonstrated in this section. Some simulation results and discussions are shown in section 4. Finally, we conclude our paper in section 5.

## 2. Guided Scrambling

A straightforward implementation of GS is depicted in Fig.1 and Fig.2. In this implementation, the encoder views the source stream as a series of words m bits in length. Each word is augmented with r augmenting bits, resulting in an augmented word of length n where

$$n = m + r \tag{1}$$

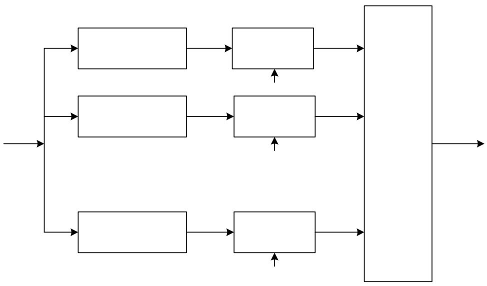

Fig. 1 Encoder

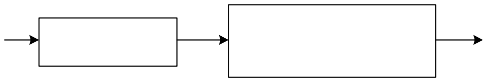

Fig. 2 Decoder

By augmenting the source word in the most significant positions with different augmenting bit values, 2r augmented bit streams are created. These augmented streams are simultaneously divided by the scrambling polynomial d(x) to form 2r quotients. We call this collection of quotients the quotient selection set. The quotient with best line code characteristics is selected for transmission and the division registers are updated. Decoding is performed without delay through multiplication by d(x) and removal of bits from the augmenting bit positions.

## 3. The Proposed Method

### 3.1. Sub-Optimal PTS

The proposed Sub-Optimal PTS algorithm introduced the Hamming distance theoretic to increase the number of weighting factor explored and used the Multi-level structure to keep the optimal weighting factor that determined in every level [6][7]. The Sub-optimal PTS is depicted in Fig. 3, where v stands for the number of sub-blocks, i is the index of number of levels, and j indicates the fixed optimum weighting factor bits in every processing level. Neighborhood of radius R is defined as the set of vectors with Hamming distance equal to or less than R from its origin and R denotes the radius of the neighborhood which is centered at b.

For the first level process, assume that $b = b_v = 1$ for all v where $b_v$, v = 1, 2 … M are the weighting factor bits and compute the PAP0 of the combined signal. Then, from the second weighting factor, invert the R bits weighting factor to –1 re-compute the resulting PAP1R1, and store it. If PAP1R1 for b11’ is small than PAP0, update b with b11’ and retain b11’ as part of the final weighting sequence and stop the optimization. If not, invert the other R bits weighting factor to -1 re-compute the resulting PAP1R2, and store it. If it is less than PAP0, retain b12’ as part of the final weighting sequence and stop the optimization. The first level processing then continues in this fashion until the last weighting factor. Then the smallest PAP value among the first level processes, $PAP_i$=1 is represented as

$$PAP_1 = PAP_{1j} = PAP_{1R} = \min\left(PAP_{1R1}, PAP_{1R2}, \ldots, PAP_{1R(M/R)}\right) \quad (2)$$

Next, invert the weighting factors $b_j$ = -1. If PAP1 is below PAP0, change PAP0 to PAP1 and proceed to the second level, otherwise, stop the optimization. For the second level process, assume that $b_v$ = -1 for all m, except for the weighting factors ($b_j$ = -1) obtained in the first level processes, and invert the weighting factors (b21' = -1) from the second bit $b_2$ to the last bit $b_M$ in the sequence, as the first level processes. After the last process is finished, the optimum weighting factors for the OFDM frame are given by

$$\{b_1', b_2', \ldots, b_M'\} = \min\left(PAP_1, PAP_2, \ldots, PAP_M\right) \quad (3)$$

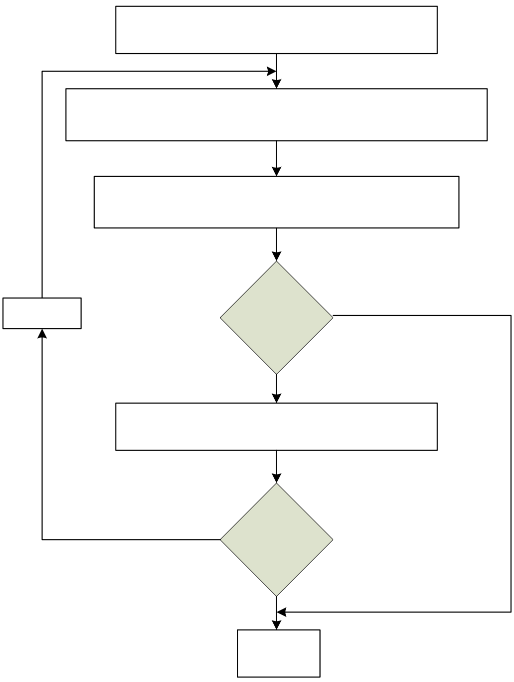

Fig. 3. The Proposed Weighting Factor Optimization Method

### 3.2. Combined with GS Coding

In this section, we introduce the proposed Hybrid algorithm, which exhibits very good PAPR performance. The structure of the Hybrid approach is shown in Fig. 4. The input data block, represented by a vector X=[X1, X2,…XM], is first partitioned into M disjoint subblocks {XM, M=1,2,…M}. Each subblock XM becomes the input to a signal selection set generation (SSSG) component shown in Fig.4. Then, the outputs of the SSSG components are through the Sub-optimal PTS part to minimize the PAPR. Only one output sequence is selected from each component. The final OFDM signal is obtained by combing the selected output sequences. In the Hybrid scheme, we propose simply selecting the signal fi(x) with the smallest value of PAPR in each coding interval. However, to effectively reduce the PAPR of OFDM signals by Hybrid, there must be at least one signal in the set {fi(t), i=0,1,…2r-1} which has a relatively small PAPR for each source word XM. This requires a good mapping between source words and the signals in the selection set, which in turn implies appropriate selection of the Signal scrambling polynomial d(x). In [4], we can know that, for r augmented bits, the polynomial d(x) = xr+1 can generate the good line code characteristics sequences. It is also shown that error extension in GS decoding is uniquely determined by the weight of the scrambling polynomial, and is less than or equal to this weight.

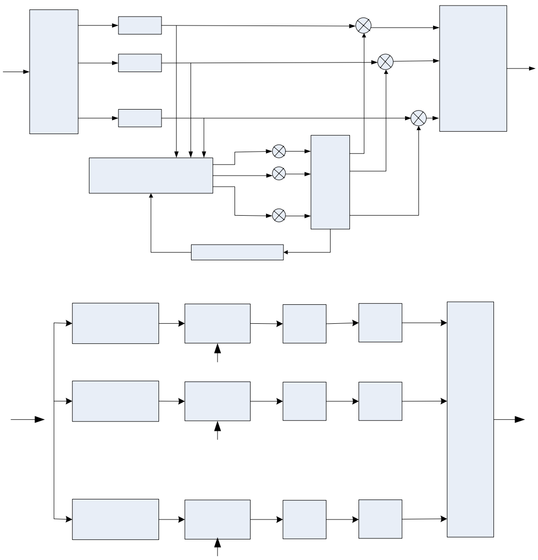

Fig. 4 Structure of the Proposed Hybrid Scheme

However, the scrambling polynomial of weight two results in relationship patterns with large PAPR. Considering of this rules, we propose searching for good scrambling polynomials from among those with low weight (≥3).

## 4. Results and Discussions

To evaluate and compare the performance of the new algorithm, computer simulation has been demonstrated. The parameters of simulation have been listed in Table 1. Fig.5. shows the comparison of minimax criterion and the mini-aver criterion. We can see that the minimax criterion's performance just a little decrease compared to the mini-aver, but the system's complexity has been reduced much more if we use minimax criterion.

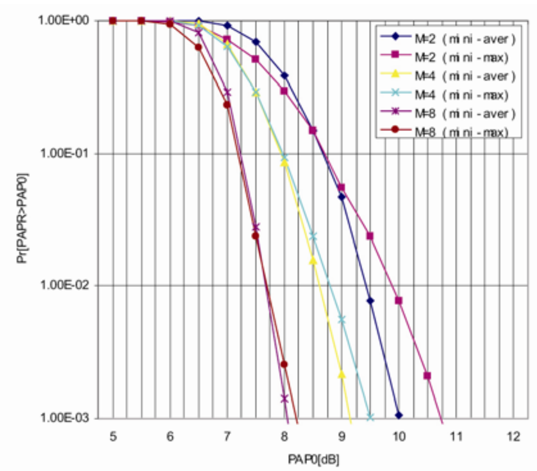


Fig. 5. Comparison of Mini-aver and Mini-max Criterions

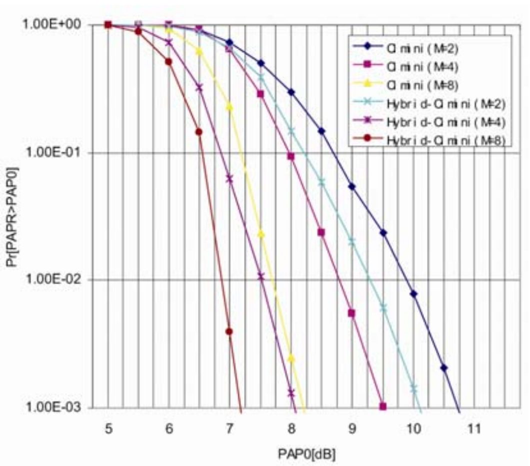


Fig. 6. Comparison of Cimini Method and Hybrid-Cimini Scheme

In addition, we can observe that the gap between these two criterions will be less when the number of sub-blocks is increase. So, we prefer to use minimax criterion in our Hybrid scheme.

From the Fig.6, in the case of M=2, we can see that the 0.1% PAP of the Cimini method is 10.7dB [2]. While the proposed Hybrid-Cimini algorithm just need 10dB. When the number of sub-blocks increased to 4 and 8, the Cimini method will need 9.5dB and 8.2dB. However, the Hybrid-Cimini can achieve 1.5dB and 1dB performance gain respectively.

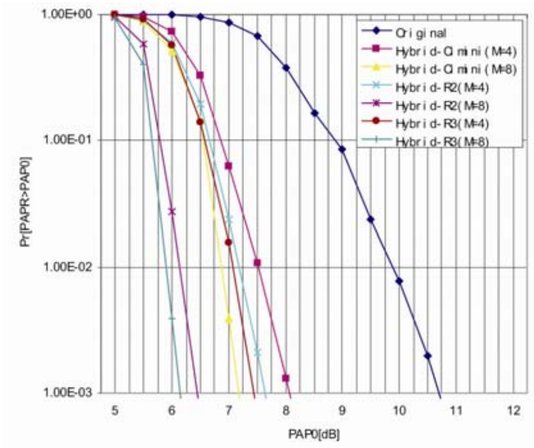


Fig. 7. Comparison of Hybrid-Cimini Method and Hybrid-Sub-Optimal Scheme

Table 1: The System Parameters

| Parameter | Value |
|---|---|
| Number of random blocks | 100,000 |
| Number of transmit antennas | 2 |
| Number of receive antennas | 2 |
| Number of sub-carriers | 256 |
| Number of sub-blocks (M) | 2, 4 and 8 |
| Sub-block Partitioning Scheme | Interleaving |
| Modulation Scheme | QPSK |
| Phase Factor | -1, 1 |
| Scrambling Polynomial | d(x)= x4+x+1 |
| Augmented bits (r) | 4 |

In Fig.7, we can found that the PAPR of the original MIMO-OFDM symbol is 10.7dB (used mini-aver criterion). The 0.1% PAP the Hybrid-Cimini method is 8 and 7.2dB in the case of M=4 and 8 respectively. In addition, in the case of M=4, our proposed Hybrid-sub-optimal methods with R=2 and R=3 can improved it by 0.5dB and 0.7dB, respectively. Moreover, when we increase M to 8, the proposed Hybrid-sub-optimal with R=2 and R=3 can get 0.7dB and 1.0dB gain compared with the Hybrid-Cimini. So, from the simulation results, we can know that our proposed Hybrid-sub-optimal schemes can achieve very good PAPR property.

## 5. Conclusions

In this paper a combined scheme for reducing the PAPR in MIMO-OFDM is proposed. At first, we propose a Sub-Optimal PTS scheme to optimize the phase factor, which can get better performance than Cimini method. Then, we integrate the Sub-Optimal PTS with guided scrambling, which is the proposed Hybrid method. From the simulation results, we can see that this scheme can get much gain in PAPR reduction. Moreover, Hybrid schemes don't need to transmit side information. In addition, in order to reduce the complexity, we prefer to use minimax criterion instead of mini-aver criterion. Though there is a little performance decrease compared to mini-aver, this gap will be smaller while the number of sub-blocks is increase.

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## Reference

[1] Richard Van Nee, Ramjee Prasad, OFDM for Wireless Multimedia Communications, Boston: Artech House Publishers, 2000

[2] L. J. Cimini, Jr. and N. R. Sollenberger, "Peak-to-average power ratio reduction of an OFDM signal using partial transmit sequence," IEEE Commun. Lett, vol. 4, no. 3, pp. 86-88, Mar. 2000.

[3] Myung-Sun Baek, Mi-Jeong KIM, Young-Hwan You, and Hyoung-Kyu Song, "Seme-Blind Channel Estimation and PAP Reduction for MIMO-OFDM System With Multiple Antennas," IEEE TRANSACTIONS ON BROADCASTING, vol. 50, no. 4, pp. 414-424, December. 2004.

[ 4 ] Ivan J.Fair, Wayne D. Grover, "Guided Scrambling: A new line coding technique for high bit rate fiber optic transmission systems," IEEE Transactions on communications, vol. 39. no. 2, Feb. 1991.

[5] P. Van Eetvelt, G. Wade and M. Tomlinson, "Peak to average power reduction for OFDM schemes by selective scrambling," ELECTRONICS Lett, vol. 32, no. 21, pp. 1963-1964, Oct. 1996.

[6] S. H. Han, J. H. Lee, "Reduction of PAPR of an OFDM signal by partial transmits sequence technique with reduced complexity," IEEE Globecom, pp. 1326-1329, 2003.

[7] Oh-Ju Kwon and Yeong-Ho Ha, "Multi-carrier PAP reduction method using sub-optimal PTS with threshold," IEEE Transactions on broadcasting, vol. 49, no. 2, pp 232-236, June 2003.

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