A Study on Huffman Coding to Improve Performance of OFDM

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Abstract

In this paper, we analyze one of the coding techniques on OFDM, named Huffman coded OFDM (HC-OFDM) that contributes not only to high data rate but also prevents peak the signals when they sum up after IFFT process, while decreasing the BER. HC-OFDM simulations reached valuable results on a big data stream transmission and lower peak to average power ratio (PAPR) probability over Rayleigh fading channel and phase offset comparison at the detection which their BER and PAPR values are smaller at $10^{-1}$ and 3-4 db respectively than an uncoded OFDM.

요 약

본 논문에서는, BER이 감소하는 동안 높은 데이터 전송속도뿐만 아니라 IFFT 과정 후 합계 신호 peak 방지에 기여한 Huffman coded OFDM의 코딩 기술 중 하나를 분석하고 제안하였다. Huffman에 대한 시뮬레이션 과정을 통해, Rayleigh 페이딩 채널에서 고속 데이터 스트림 변환과 낮은 PAPR 확률과 신호를 검출했을 때 phase offset을 비교하여 BER과 PAPR값이 $10^{-1}, 3 ~ 4$dB 정도 감소하는 결과 값을 얻었다.

Key words
guard period, Huffman coding, PAPR, phase offset.

I. Introduction

Nowadays, a big size of data transformation over a wireless fading channel throughout multimedia devices among users, is in challenge topic area. One of transceiver design, OFDM offers satisfactory QoS (Quality of Service) in 4G wireless technologies[1], however, modern researches have been discovering that it is certainly possible to increase, extend more and more. The robustness for mitigating ISI and ICI of this transceiver is pretty enough elevated because of guard period of symbols. Besides, in a cellular OFDM system, pilot density discrepancy solved interference problem accurately in[2]. Adding the guard period brings another problem at the time that all subcarriers arrive at receiver with different amplitude. In fact, some of them absolutely lost because of deep fading. To avoid of such problem in communication, we will use FEC (Forward Error Correction) means by using across the subcarriers, error of weak of them can be corrected up to certain limit that depends on channel and coding techniques. FEC categorized two types of coding are block and convolutional coding by their coding methods[3]. Huffman coding is a like block coding procedure which mainly used lossless data compression, meaning allows the exact original data to be reconstructed from the compressed data.

Accordingly, in our research, we have analyzed Huffman coding on 16-QAM/OFDM Scheme in frequency domain only, shows smaller BER than
without coding when a big size data transmitted. From now on first we will describe its encoding as well as decoding algorithm, to next parts of paper cover implementation on OFDM and simulation results of its performance.

II. Huffman Encoding and Decoding

Huffman encoding idea is to map an alphabet to a representation for that alphabet, composed of strings of data size, so that symbols that have a higher probability of occurring have a smaller representation than those that occur less often. The key to Huffman coding is Huffman’s algorithm, which constructs an extended binary tree of minimum weighted path length from a list of weights. For this problem, our list of weights consists of the probabilities of symbol occurrence. From this tree, the mapping to our variable-sized representations can be defined.

In our 16-QAM/OFDM Modulation System, encoding and decoding data using the Huffman algorithm is executed in Encoder and Decoder respectively as we describe coding algorithm in programming realization step by step.

2.1 Encoding.

Input values: Alphabet \( A = \{a_1, a_2, \ldots, a_n\} \), which is the symbol alphabet of size \( n \). Set \( W = \{w_1, w_2, \ldots, w_n\} \) the set of the symbol weights, or probability \( w_i = \text{weight}(a_i), 1 \leq i \leq n \).

Output data: Code \( C(A, W) = \{c_1, c_2, \ldots, c_n\} \), which is the set of (binary) code words, where \( c_i \) is the codeword for \( a_i \), \( 1 \leq i \leq n \).

Goal of coding: Let \( L(c) = \sum_{i=1}^{n} w_i \cdot \text{length}(c_i) \) be the weighted path length of code \( C \), where, \( L(C) \leq L(T) \) for any code \( T(A, W) \)[4].

Figure 1 illustrates the Huffman tree encoding algorithm execution on “UCON-LAB” input data that shows height of 3, where UONLCBA is an ASCII value representation the probability (probably ordered sequence) of the finding character.

![Huffman Coding Tree - "UCON-LAB"](image)

2.2 Decoding

Input values: Code \( C \) and codeword \( c_j \).
Output values: Real string data.

III. Huffman Coding Implementation on 16-QAM/OFDM

16-QAM/OFDM system is main common used structure view among the modulation schemes like QPSK, BPSK and others. 16-QAM is based on two QPSK modulation schemes that is well known to maintain high data rate means two times more than QPSK based. To enhance data rate, we considered to choose Huffman whereas, an issue which we have to take in a count, PAPR values are made up higher values than other systems such as, comparing to QPSK/OFDM, proved in[5].

Complex baseband signal for OFDM will be given something like this formula

\[ x(t) = \frac{1}{N} \sum_{n=1}^{N} a_n e^{j2\pi n f_s t} \]

where \( N, a_n \) denote subcarriers number and modulated
symbols respectively. In our 16-QAM modulation case, for instance, $a_n$ could be $\{ \pm 1, \pm \sqrt{3}, \pm j \}$. Finally, we could reach the equation for PAPR distribution function can be written as $P(PAPR \leq \varepsilon) = (1 - e^{-\varepsilon^N})$. In[6].

By simulating chosen coding technique on 16-QAM/OFDM, in Figure 2, PAPR probability estimation illustrates at an enough satisfactory result (red) that smaller than without coding simulated line (blue) where a decrease 4 db for $P(PAPR) = 10^{-1}$. In fact, in[7], shown 6 dB for $P(PAPR) = 10^{-2}$ point also observed low PAPR value.

Implementation of Huffman coding on 16-QAM/OFDM transceiver system is depicted in Figure 3 and its simulation graph describes in next section.

IV. Simulation Results

After getting the information the coherent detection estimates the phase offset and reference amplitudes to determine the best possible decision boundaries for constellation of each sub carriers. This graph (Figure 4) below illustrated phase offset comparison among the theoretical, Huffman Coded and without coding signals and at the taking a quick look, the semi analytic line visibly identifies at low BER.
It is obvious that in high data rate transmission BER also increases and other factors are related with environment fading, noise, Doppler shift etc... In our case, bit rate made up at 10,000 bit/s over Rayleigh Fading Channel is in superimposed in Figure 5 that identifies smaller $10^{-2}$ BER in high data rate transmission.

V. Conclusion

In conclusion, we can notice that as we have highlighted the Huffman coding for data lossless compression which accurately helps to transmit the data in high rate. Besides, it can be combined to reduce the PAPR of OFDM signals as well. The advantage of proposed scheme is that, the Huffman Encoder is used for two proposes, getting high data rate and PAPR reduction. This reduces hardware of complexity.

References

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