Comparison and Investigations of PAPR Reduction using 16-QAM & 64-QAM OFDM Codes

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ABSTRACT

Orthogonal Frequency Division Multiplexing is widely used along with QAM and therefore information data can be represented as sequences of complex numbers, called OFDM QAM sequences. A major drawback of OFDM is the high PAPR incurred in the uncoded OFDM signals that causes expensive system elements, higher power consumption and lower efficiency. So, to mitigate the influence of transmit signals with high PAPR on the performance of the transmission system PAPR reduction using 16-QAM & 64-QAM OFDM Codes has been proposed in this paper.

Keywords

Orthogonal Frequency Division Multiplexing (OFDM), Quadrature Amplitude Modulation (QAM), Peak to Average Power Ratio.

1. INTRODUCTION

In OFDM, carrier signals are orthogonal thus in the OFDM time-domain waveforms the mutual orthogonality is ensured even though subcarrier spectra may overlap. The condition for maintaining the orthogonality is that the frequency spacing between the carrier signals must be an integer multiple of the lowest carrier frequency [1]. It means each subcarrier has an integer number of cycles in time period T. The numbers of cycles in adjacent subcarriers differ by exactly one. This technique provides high data rate even if relatively small frequency bandwidth is available[1]. The OFDM system faces several challenges. One of the major concern is ISI due to multipath-use guard interval, peak to average ratio due to non linearity‟s of amplifier phase noise problems of oscillator which need frequency offset correction in the receiver[5]. High peak-to-average power ratio which distorts the signal if the transmitter contains nonlinear components such as power amplifiers. Nonlinear effects on the transmitted OFDM symbols are spectral spreading, inter modulation and changing the signal constellation. Moreover, the nonlinear distortion causes both in-band and out-of-band interference to signals. As a result the PAs requires a back off which is roughly equal to the PAPR for reduced distortion transmission. But this decreases the efficiency for amplifiers[7]. Hence, reducing the PAPR is of practical interest. In OFDM a high rate data stream is divided into many low data streams. These binary data streams are then mapped to form digital symbols utilizing modulation techniques such as BPSK, , QAM and QPSK etc [2]. These mapped symbols are then superimposed onto the orthogonal carriers in IFFT block. A composite signal so formed by multiplexing these modulated signals is known as the OFDM signal. Corresponding scheme has several advantages like easier frequency-domain equalization, low sensitivity to good modularity, impulse noise etc. Additionally, it is possible to choose the constellation size and energy for each subcarrier, thus approaching the theoretical capacity of the channel [3]. In general, Peak to Average Power Ratio (PAPR) of the OFDM signal is defined as the ratio between the maximum instantaneous powers of the signal to its average power [5]. Mathematically it can be expressed as

$$\mathrm{PAPR}[X(t)] = \frac{P_{\mathrm{PEAK}}}{P_{\mathrm{AVERAGE}}} = 10\log_{10}\frac{\max[|X(n)|^2]}{E[|X(n)|^2]} \quad (1.1)$$

Where,

P_{PEAK}	Represents the peak output power
P_{AVERAGE}	Represents the mean average output power P_{AVERAGE}
E[.]	Represents the expected value
X(n)	Represents the transmitted OFDM signals obtained after IFFT operation on modulated input symbols.

2. BASICS OF OFDM

The transmitted OFDM signal is the real part of the complex signal[2]

$$S(t) = \sum_{i=0}^{n-1} c_i(t) e^{2j\pi f_i t} \quad (1.2)$$

Where f_i is the frequency of the *i*th carrier, $c_i(t)$ is constant over a symbol period of duration T

To maintain orthogonality, the carrier frequencies are related by

$$f_i = f_0 + i\Delta f$$

f_i =frequency of the *i*th carrier.

f_0 = smallest carrier frequency.

Δf = integer multiple of the OFDM symbol rate.

Let $c_i(t)$ takes the value c_i over a given symbol period,

then the corresponding OFDM signal is denoted by $S_c(t)$

and can be expressed as

$$S_c(t) = \sum_{i=0}^{n-1} c_i e^{2j\pi f_i t} \quad (1.3)$$

Instantaneous Envelope Power

Instantaneous envelop power associated with the sequence $S_c(t)$ is give by $P_c(t)$[3][4]

$$P_c(t) = \left|S_c(t)\right|^2 = S_c(t).S_c^*(t) \tag{1.4}$$

$$= \left(\sum_{i=0}^{n-1} c_i e^{2j\pi f_i t}\right)\left(\sum_{k=0}^{n-1} c_k^* e^{-2j\pi f_k t}\right)$$

Letting $k = i + u$

$$P_c(t) = \sum_{u=0}^{n-1}\sum_{i=0}^{n-1} c_i c_{i+u}^* e^{2j\pi u\Delta ft}$$

$$P_c(t) = \sum_{i=0}^{n-1}\left|c_i\right|^2 + \sum_{u\neq 0}\sum_{i} c_i c_{i+u}^* e^{2j\pi u\Delta ft} \tag{1.5}$$

Average Power

The average power of c during a symbol period T [4] can be expressed as

$$\frac{1}{T}\int_0^T P_c(t)\,dt = \left\|c\right\|^2 = \sum_{k=0}^{n-1}\left|c_k\right|^2 \tag{1.6}$$

Aperiodic Autocorrelation

Also the aperiodic autocorrelation function (AACF) of sequence ‘c’ of length ‘n’ is given by[5]

$$A_c(u) = \sum_{i=0}^{n-u-1} c_i.c_{i+u} = c_u \otimes c^*_{-u} \tag{1.7}$$

Peak To Average Power Ratio (Papr)

The PAPR of the transmitted codeword c can be defined as

$$\mathrm{PAPR}(c) = \frac{\max_{0\le t\le T} P_c(t)}{P_{av}} \tag{1.8}$$

Let C be the collection of all the codewords that are to be transmitted [6] .Then the average power of the transmitted signals of C is

$$P_{av} = \sum_{c\in \mathrm{C}} \left\|c\right\|^2 p(c) \tag{1.9}$$

$p(c)$ is the probability of the transmission of the codeword c.

$$\mathrm{PAPR(C)} = \max_{c\in \mathrm{C}}(c) \tag{1.10}$$

3. RESULTS AND DISCUSSIONS

A 16-QAM constellation symbols can be written as the sum of two QPSK symbols. That 16-QAM sequence and can be associated with two QPSK sequences. Similarly construction of QAM sequences requires three QPSK symbols where each symbol can have four phase values as coefficients that are fourth roots of unity; so as to get a total of 64 constellation points. So, three QPSK complementary sequences are required to have 64 constellation points. Therefore 64-QAM constellation symbols and can be written as the sum of three QPSK symbols.

We initiated with the analysis of construction of 16-QAM OFDM codes which are then extended to 64-QAM OFDM codes. After meticulous investigations on PAPR, subsequent values for different codes Z_1 and Z_2, in 16-QAM comes out to be 3.6 and 3.6 respectively. Similarly for 64-QAM subsequent PAPR values for different codes Z_1, and Z_2, turn out to be 4.67 and 4.67, respectively. Among these codes that have been analyzed in detail the minimum PAPR values are revealed as 3.67, 4.67 OFDM codes respectively.

Table: 1 Comparison of 16-QAM OFDM & 64-QAM OFDM code

	16-QAM OFDM Code		**64-QAM OFDM Code**	
	Z_1	Z_2	Z_1	Z_2
B_1	$RM(1,m)$	$RM(0,m)$	$RM(1,m)$	$RM(0,m)$
B_2	$Q_\Pi + RM(1,m)$	$Q + RM(1,m)$	$Q_\Pi + RM(1,m)$	$Q + RM(1,m)$
B_3	$RM(1,m)$	$RM(1,m)$	$RM(1,m)$	$RM(1,m)$
B_4	$Q_\Pi + RM(1,m)$	$Q_\Pi + RM(1,m)$	$Q_\Pi + RM(1,m)$	$Q_\Pi + RM(1,m)$

size	$\left(\frac{m!}{2}\right)^2\left(4^{m+1}\right)^2$	$\left(\frac{m!}{2}\right)\left(4^{m+1}\right)\left(2^{m+2}\right)$	$\left(\frac{m!}{2}\right)^3$ $\cdot\left(4^{m+1}\right)^3$	$\left(\frac{m!}{2}\right)^2\cdot\left(4^{m+1}\right)^2$ $\cdot\left(2^{m+2}\right)$
PAPR	≤ 3.6	≤ 3.6	≤ 4.67	≤ 4.67

4. CONCLUSION

In this thesis different codes Z_1, Z_2, Z_3, Z_4 and Z_5 have been analyzed for 16-QAM, 64-QAM and more new codes for 256-QAM with reduced PAPR has been developed using BPSK sequences. Among these codes that have been analyzed in detail for 16-QAM and 64-QAM, minimum PAPR level comes out to be 3.6 and 4.67 respectively. Further on the work may be completed using different modulation techniques to enhance the system.

5. REFRENCES

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