On the Performance of COFDM System

Nasir A. Al-Awad, Muaayed F.Al-Rawi

Abstract— **This paper studies the performance of coded orthogonal frequency division multiplexing system using two modulation techniques, quadrature phase shift keying (QPSK) and M-ary quadrature amplitude modulation(M-QAM) with M=8, 16, 32, and 64. The convolutional code is used as error-correcting-code. The communication channel used is vehicular channel with Additive White Gaussian Noise (AWGN). Simulation results show that the performance of coded orthogonal frequency division multiplexing system is better than that with un-coded one for QPSK and M-QAM. Also, the performance of the system with QPSK is better than that with M-QAM. Furthermore, the performance degrades as M increases.**

***Keywords*— COFDM; performance analysis.**

I. INTRODUCTION

The standard of Orthogonal Frequency Division Multiplexing (OFDM) is to isolate a solitary high-information rate stream into various lower rate streams that are transmitted at the same time finished some smaller sub-channels. The orthogonality in OFDM can be accomplished via painstakingly choosing subcarrier separating, for example, letting the subcarrier dividing be equivalent to the corresponding of the valuable image time frame. As the subcarriers are orthogonal, the range of each subcarrier has an invalid at the middle recurrence of each of alternate subcarriers in the framework.

OFDM has turned out to be more well-known amid the most recent decades, since it gives a significant diminished in leveling many-sided quality contrasted with established adjustment procedures. Different points of interest incorporate battling inter-symbol interference (ISI) and between inter-carrier interference (ICI) which prompts decrease the multifaceted nature of the receiver. Also, OFDM gives high phantom effectiveness. Moreover, OFDM is more impervious to recurrence specific fading. Due to its extraordinary advantages and its wide applications, numerous current written works have examined the OFDM system [1-7].

OFDM has a few impediments. The primary drawback is that OFDM framework with substantial number of sub-carriers has a very large peak-to-average power ratio(PAPR) when the subcarriers include intelligibly. What's more, OFDM is more touchy to Doppler spreads than single-carriers modulated systems. Moreover, there is a stage commotion caused by the flaws of the transmitter and receiver oscillators which impacts the framework execution.

So as to exploit the decent variety gave by the multi-path fading, proper frequency interleaving and coding is vital. In this manner, coding turns into an indivisible part in most OFDM applications and a lot of research has concentrated on ideal encoder, decoder, and between leaver plan for data transmission by means of OFDM over fading environments, e.g. [8], and [9].

In spite of the fact that a lot of research has tended to the outline and usage of coded OFDM frameworks for frequency particular fading channels, relatively few of them give agreeable performance analysis of such frameworks due to the muddled idea of this issue. Here, a frequency-selective quasi-static fading channel is considered, which is a sensible presumption for an indoor wireless environment, that has multi-path fading however displays moderate changes after some time, modeled as semi static. Not at all like coding in Additive White Gaussian Noise(AWGN) channels, where there is one dominant pair-wise error probability, related to the minimum distance of a block code or the free distance of a convolutional code,, that decides the framework performance, all pair-wise error probabilities in a fading coded OFDM framework diminish as converse polynomial of the signal-to-noise ratio (SNR).Thus the powerful union-Cherno bound will be too free at any scope of SNR when the block length is large. Motivated by the performance analysis comes about on block fading channels in [10], the random coding upper limits [11] and the solid converse bring down limits [12] and in addition the idea of momentary channel capacity are actualized for the performance analysis of coded OFDM framework.

II. COFDM SYSTEM MODEL

The model of COFDM framework is appeared in Figure 1. It is mostly comprising of transmitter, receiver, and channel as a transmission way. These three sections are clarified in points of interest in ensuing segments [2].

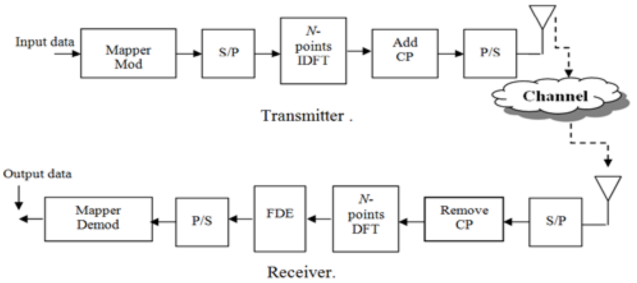

Figure 1 Model of COFDM system.

A- COFDM transmitter

The multi-carrier transmitter comprises of an arrangement of modulators, each with various carrier frequencies. The transmitter at that point consolidates the modulator yields and creates the transmitted flag. Assume that the N information to be transmitted are $\{x_k\}$, k = 0, 1, . . . , N-1, where $\{x_k\}$ is an unpredictable number in a given quadrature amplitude modulation(QAM) constellation . In this way, the yield of modulation mapper takes any estimation of sixteen distinct estimations of QAM constellation appeared in Figure 2 [3], and [4].

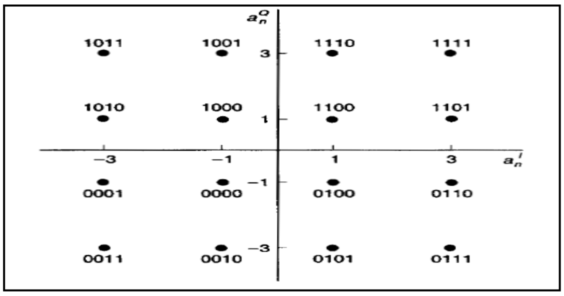

Fig. 2. 16-ary QAM constellation.

The yield from modulation mapper is connected to serial to parallel (S/P) conversion. The S/P changes over serial data into N parallel streams. Because of the S/P change, the length of transmission time for N symbols is reached out to NTs. Letting $t = nT_s$, where $T_s$is the sample interval, the advanced multi-carrier transmitter yield is

$$X(nT_s)=\sum_{k=0}^{N-1} x_k\, e^{j2\pi f_k nT_s} \qquad (1)$$

Furthermore, if the carrier frequencies are uniformly spaced in the frequency domain by a frequency spacing of f_s,$f_k = k f_s$,k = 0, 1, . . ., N-1,then

$$X(nT_s)= \sum_{k=0}^{N-1} x_k\, e^{j2\pi k f_s nT_s} \qquad (2)$$

Equation (1) represents the output of S/P conversion. Then, the parallel data samples are fed to the inverse discrete Fourier transform (IDFT) block to obtain the time domain OFDM symbols.

Let $f_s = 1/(NT_s)$ which is the minimum separation to keep orthogonality among signals on different modulators, then the OFDM signal is given by:

$$X(n)=\sum_{k=0}^{N-1} x_k\, e^{j2\pi k (1/N)n} \qquad (3)$$

The above recipe is the equation of a N-point IDFT. There are two duplicates of the got waveform, one on time and the other deferred by some time. ISI is prompted in light of the fact that the tail some portion of symbol-1 will meddle with the handling of symbol-2. To wipe out ISI, a monitor intervalT_G of tests is generally embedded toward the start of each OFDM symbol [5], [6], and [7].

The cyclic prefix (CP) is a void ISI since it goes about as watch space between progressive symbols, it likewise change over the straight convolution with channel drive reaction into a cyclic convolution. As a cyclic convolution in the time space converts into a scalar increase in the recurrence area, the subcarriers remain orthogonal. The CP is a precise of the last specimens of the OFDM symbol into its front. GiveT_G a chance to indicate the length of CP as far as samples, then the expanded OFDM symbols now have the span of $T_{sym} = T_{sub} + T_G$.   .

Figure 3shows two continuous OFDM symbols. The monitor interim longer than the greatest deferral of the multipath channel ($T_G/2$) takes into consideration keeping up the orthogonality among the subcarriers. As the coherence of each deferred subcarrier has been justified by the CP, its orthogonality with all different subcarriers is kept up finished T_{sub}. At the point when the length of the protect interim (CP) is set shorter than the most extreme postponement of a multipath channel, the tail some portion of an OFDM symbol influences the head some portion of the following symbol, bringing about the ISI.

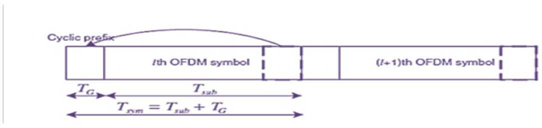

Fig. 3. OFDM symbols with CP.

The output equation of the CP block is $\overline{x(n)}=x((n-L))_N$, where n = 0, ……, N+L-1. Then the output from the CP block is applied to parallel to serial (P/S) conversion. The P/S converts parallel data into N serial streams [8], and [9].

- Convolutional code

A convolutional code is a sort of error-correcting code that produces parity symbols by means of the sliding use of a boolean polynomial capacity to an data stream. The sliding application represents the 'convolution' of the encoder over the data, which offers ascend to the term 'convolutional coding.' The sliding idea of the convolutional codes encourages trellis decoding utilizing a period invariant trellis. Time invariant trellis decoding permits convolutional codes to be most extreme probability delicate choice decoded with sensible intricacy. The capacity to perform conservative most extreme maximum likelihood choice decoding is one of the significant advantages of convolutional codes. This is as opposed to classic block codes, which are for the most part spoken to by a time-variant trellis and in this way are normally hard-choice decoded. Convolutional codes are regularly described by the base code rate and the depth (or memory) of the encoder [n,k,K]. The base code rate is ordinarily given as n/k, where n is the input data rate and k is the output symbol rate. The depth is frequently called the "constraint length" 'K', where the yield is a component of the present input and also the past K-1 inputs. The depth may likewise be given as the quantity of memory components 'v' in the polynomial or the greatest conceivable number of conditions of the encoder (commonly 2^v) [9]. Convolutional codes are frequently depicted as nonstop. In any case, it might likewise be said that convolutional codes have arbitrary block length, instead of being consistent, since most genuine convolutional encoding is performed on blocks of data. Convolutionally encoded block codes regularly utilize end. The arbitrary block length of convolutional codes can likewise be differentiated to great block codes, which for the most part have fixed block lengths that are dictated by logarithmic properties. The code rate of a convolutional code is generally adjusted by means of symbol puncturing. For instance, a convolutional code with a 'mother' code rate n/k=1/2 might be punctured to a higher rate of, for instance, 7/8 basically by not transmitting a part of code symbols. The performance of a punctured convolutional code by and large scales well with the measure of parity transmitted. The capacity to perform sparing delicate choice decoding on convolutional codes, and in addition the block length and code rate adaptability of convolutional codes, makes them extremely well known for digital communications [10].

B. Communication channel

To simplify the mathematical analysis, a time-invariant channel is assumed which has the following response with R taps

$$h^T = [h_0\, h_1 \ldots . h_{R-1}] \tag{4}$$

The channel impulse response is circularly convolved with the transmitted signals owing to the CP in OFDM signals, so the output of the channel will be as follows

$$y(n)=h(n)*\overline{x(n)}+N(n)$$
$$y(n)=h(n)*x\left((n-L)\right)_N+N(n) \tag{5}$$
$$y(n)=h(n)\circledast x(n)+N(n)$$

The output of the channel (i.e. the received signal) can be written in matrix form as follows [10]:

$$Y=X+\mathrm{N}\qquad \begin{bmatrix} \overbrace{0 \;\cdots\; 0}^{N_g-R+1} & h_{R-1} & h_{R-2} & \cdots & h_0 & \overbrace{0 \;\quad\quad\quad \cdots \quad 0}^{N-1} \\ 0 \;\cdots\; & 0 & h_{R-1} & h_{R-2} & \cdots h_0 & \cdots \quad 0 \\ & & & \cdots & & \\ 0 & & & \cdots & 0 \;\; h_{R-1} \;\; h_{R-2} & \cdots \quad h_0 \end{bmatrix} \tag{6}$$

C. COFDM receiver

At the receiver end, firstly, the received signal is applied to S/P conversion. The S/P converts serial data into parallel streams. Then the received signals $Y=[\,y_0\; y_1 \ldots . y_{N-1}\;]^T$ after removal of the CP can be expressed as:

$$\mathrm{y}=\begin{bmatrix} h_0 & 0 & \cdots & & & 0 & h_{R-1} & h_{R-2} & \cdots & h_1 \\ h_1 & h_0 & 0 & & & \cdots & 0 & h_{R-1} & \cdots & h_2 \\ & & & & & \cdots & & & & \\ h_{R-1} & h_{R-2} & \cdots & h_0 & 0 & & & & \cdots & 0 \\ 0 & h_{R-1} & \cdots & h_1 & h_0 & & & & \cdots & 0 \\ & & & & & \cdots & & & & \\ 0 & \cdots & & & 0 & h_{R-1} & & & \cdots & h_0 \end{bmatrix} \begin{bmatrix} x_0 \\ x_1 \\ . \\ . \\ . \\ . \\ x_{N-1} \end{bmatrix} +\mathrm{N}$$

$$Y = QX + N \tag{7}$$

where x consists of the last N elements in X and N is the Gaussian noise. Note that the circulant matrix Q can be diagonalized by the DFT and IDFT matrices, yielding

$$Q = F^{-1}\mathrm{H}F \tag{8}$$

where F and F^{-1} are the DFT and IDFT matrices, respectively. The matrix H is a diagonal matrix:

$$\mathbf{H}=\begin{bmatrix} H_0 & 0 & \cdots & 0 \\ 0 & H_1 & \cdots & 0 \\ & \vdots & & \\ 0 & \cdots & 0 & H_{N-1} \end{bmatrix} \tag{9}$$

where each diagonal element corresponds to the frequency-domain channel response at the corresponding subcarrier. Note that OFDM changes over the convolution in time area into augmentation in frequency domain and consequently basic one-tap frequency domain equalizers can be utilized to recuperate the transmitted symbols. After DFT, symbols are demodulated and decoded to acquire the transmitted data bits by demodulation mapper [11], and [12].

II. SIMULATION RESULT

The COFDM system is simulated by using Maltlab 2017 with modulation systems including QPSK, 8-QAM, 16-QAM, 32-QAM, and 64-QAM. Keeping in mind the end goal to enhance the framework execution, convolutional code is engaged with the model, so the OFDM is called coded OFDM (COFDM). A convolutional code with length 7 and octal generator polynomial (133,171) is picked. The channel display utilized is vehicular channel with 11 ways. The parameters utilized as a part of reproduction are recorded in Table.1

Table. 1 COFDM Simulation Parameters.

Parameter	**Value**
FFT Size	512
Cyclic Prefix Length	20 Samples
Time between Samples	24.41 ns
Channel Coding	Convolution Code with Rate =1/2
Modulation Types	QPSK, 8-QAM, 16-QAM, 32-QAM, and 64-QAM
Channel Model	Vehicular Channel with 11 Paths

The execution of the entire framework is measured regarding bit-error-rate (BER) versus signal-to-noise-ratio (SNR). Figure 4 and Figure 5 demonstrate the execution of the framework for un-coded system and coded system respectively. It seems that the performance of coded system is superior to that of un-coded system. Also, the performance with QPSK is superior to that with M-QAM, and as M increases, the performance degrades.

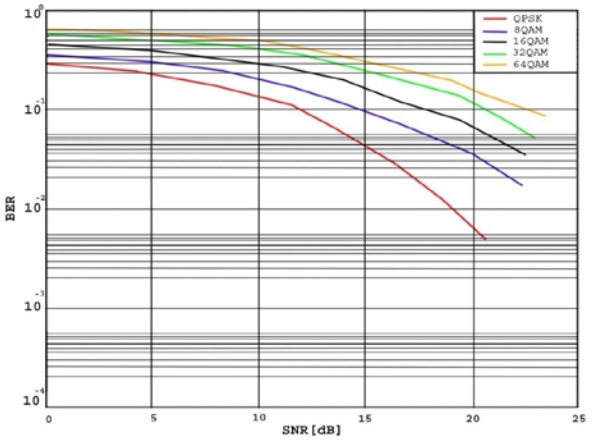

Fig..4 BER performance of un-coded OFDM over multipath fading channel.

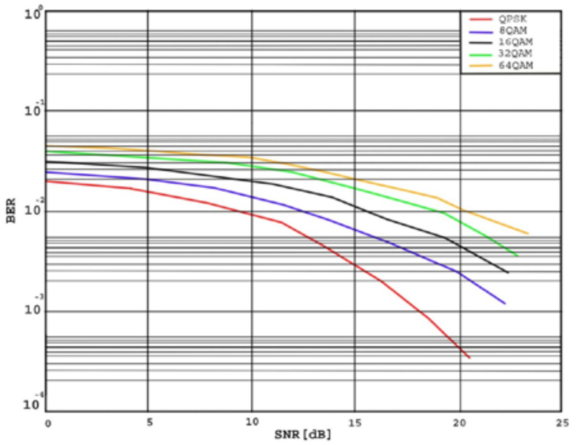

Fig. 5 BER performance of COFDM over multipath fading channel.

Model of COFDM system was developed to study its performance over vehicular channel with AWGN using QPSK, 8-QAM, 16-QAM, 32-QAM, and 64-QAM. The convolutional code was used as error-correcting-code. The results show that the performance of COFDM is better than that of un-coded one. Also, the performance with QPSK is better than that with M-QAM. Moreover, the performance degrades with increasing M.

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