Comparison Of BER Performances For Conventional And Non-Conventional Mapping Schemes Used In OFDM

Riddhi Parmar, Shilpi Gupta, Upena Dalal

***Abstract*—**Orthogonal Frequency Division Multiplexing (OFDM) is one of the techniques for high speed data rate communication with main consideration for 4G and 5G systems. In OFDM, there are several mapping schemes which provide a way of parallel transmission. In this paper, comparisons of mapping schemes used by some standards have been made and also has been discussed about the performance of the non-conventional modulation technique. The Comparisons of Bit Error Rate (BER) performances for conventional and non-conventional modulation schemes have been done using MATLAB software. Mentioned schemes used in OFDM system can be selected on the basis of the requirement of power or spectrum efficiency and BER analysis.

***Keywords*—**BER, π/4 Differential Quadrature Phase Shift Keying (Pi/4 DQPSK), OFDM, Phase Shift Keying, Quadrature Phase Shift Keying.

I. Introduction

ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING (OFDM) is being widely used in wireless communications standards, such as IEEE 802.11a, the multimedia mobile access communication (MMAC), HIPERLAN/2, and the 802.16 [1]. Long Term Evolution (LTE) and cognitive Radio (CR) is the latest application which uses OFDM due to its resilience to multipath delays and spread. Moreover, future wireless systems are expected to support a wide range of services which includes video, data and voice. In OFDM first of all high speed serial data is converted to low speed parallel data. Output of each parallel line is modulated by using any mapping scheme (conventional or Non-conventional).Parallel streams are again converted to an instantaneous serial stream prior to transmission. This phenomenon resembles Inverse Fast Fourier Transform (IFFT).The reverse process occurs at the receiver side [2].

During the early days of deep space program, Phase Shift Keying (PSK) was developed. Today, PSK is widely used in both military and commercial communications. PSK is considered to be efficient for these applications due to the fact that it offers the lowest probability of error. As a result this type of modulation schemes could possibly serve the aims of baseband processing modem [3].

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Today's high rate wireless OFDM system (like DVB-T or IEEE802.11a/HiperLAN2) are based on coherent demodulation and precise radio channel estimation which is required to perform the necessary channel equalization. Therefore some signaling overhead must be spent by inserting preamble or pilot signals into transmitted signal stream. Differential modulation schemes can be used to avoid any channel estimation procedure, equalization and even tracking scheme completely [4]. So, it can be a strong candidate to be used in OFDM system by allowing the low cost receiver design without channel estimation [5].

II. Review On Symbol Mapping

Today major challenge in telecommunication is to convey as much information as possible through limited spectral width. OFDM introduces the allocating more traffic channels within limited bandwidth of physical channel [2].

OFDM has been widely used in broadcast systems. It is being used for Digital Audio broadcasting (DAB) [6] and for Digital Video broadcasting (DVB) in Europe and Australia. Along with it is also used in many other applications like WiMAX, Long Term Evolution and Cognitive Radio. It was selected for these systems because of its high spectral efficiency and multipath tolerance.

Most OFDM systems use a fixed modulation scheme over all carriers for simplicity. However each carrier in a multiuser OFDM system can potentially have a different modulation scheme depending on the channel conditions. Any coherent or differential, phase or amplitude modulation scheme can be used including BPSK, QPSK, 8PSK, 16 QAM, 64QAM. Each modulation scheme provides a tradeoff between spectral efficiency and the bit error rate [7]. The spectral efficiency can be maximized by choosing the highest modulation scheme that will give an acceptable Bit Error Rate. A review for the mapping schemes which have been used in above mentioned systems or standards while using OFDM as a modulation technique has been presented in TABLE I. Mentioned standards are normally used for short distance communication and so the multipath scenario occurs there. In this environment the carrier frequency offset Doppler spread are very critical issue.

π/4-DQPSK OFDM system having small carrier frequency offsets and small Doppler spreads do not have much influence on the BER performance. However, keeping other conditions the same carrier frequency offset leads to worse system BER performance degradation than the same amount of Doppler shift [5].

π/4 DQPSK is one of the differential modulation scheme which has been firstly proposed by Baker [8] and was extensively examined by Feher [9], [10]. The π/4- shifted differentially encoded quadrature phase shift keying is receiving prominent attention in recent years because it is used by TDMA- based digital cellular mobile telephone systems such as North American IS-54 system [11], for high efficiency of its power spectral density. It has also been adopted in Digital Audio Broadcasting (DAB) standard.

TABLE I
COMPARISION OF PARAMETERS OF DIFFERENT STANDARDS USING OFDM

Standards	FFT size	Mapping schemes	Bandwidth
WiMAX (IEEE 802.16 (d/e)	128, 256, 512,1024, 2048	BPSK, QPSK, 16 QAM, 64QAM	1.75MHz-20 MHZ
LTE (3GPP)	1024, 2048,4096	QPSK, 16QAM, 64 QAM	6 MHz- 8MHz
DVB-H (EN 203 204)	2048, 8192	QPSK, 16QAM, 64 QAM	6 MHz- 8MHz
Cognitive Radio (802.22- WRAN)	Variable	Variable	Variable

The performance of π/4-QPSK modem with differential detection has been analyzed theoretically by computer simulations [12], [13] and experimentally [14], [15]. The BER performances of several differential modulation schemes, including MDPSK and π/4-DQPSK were examined in [16]-[19] by using Gaussian approximation methods.

The advantages associated with π/4-shifted QPSK are cited in [20] and are briefly discussed here. This modulation can be detected using a coherent detector, a differential detector, or a discriminator followed by an integrate-and-dump filter. The choice of using both differential detection and discriminator detection provides an advantage since both can be performed by low-complexity receiver structures. While coherent detection requires a more complex receiver than either differential or discriminator detection due to the carrier recovery process. Moreover in fast fading conditions, coherent results in a higher irreducible BER than either differential detection or discriminator detection [20], [21].Another advantage of π/4-shifted QPSK is that unlike QPSK, the transitions in the signal constellation do not pass through origin. As a result, the envelope of π/4-shifted QPSK exhibits less variation than that of QPSK and, therefore, has better output spectral characteristics. However, with a reasonably linear amplifier operated with a small amount of back-off, the advantage over QPSK is negligible [15].

Fig. 1 is the OFDM simulation block diagram. Brief about the blocks used has been described in the introductory part of the paper. Main focus of this paper is on mapping schemes.

The low data rate parallel bit stream is modulated in Signal mapper. A large number of mapping schemes are available allowing the number of bits transmitted per carrier per symbol to be varied. Digital data is transferred in an OFDM link by using a mapping scheme on each subcarrier. It is a mapping of data words to a real (In phase) and imaginary (Quadrature) constellation, also known as an IQ constellation. Mapping can be BPSK, QPSK, 8PSK, OQPSK, QAM, Pi/4DQPSK. Non-differential schemes like M-ary PSK and QAM are conventionally used mapping scheme with OFDM while Differential schemes like pi/4 DQPSK is non-conventionally used technique.

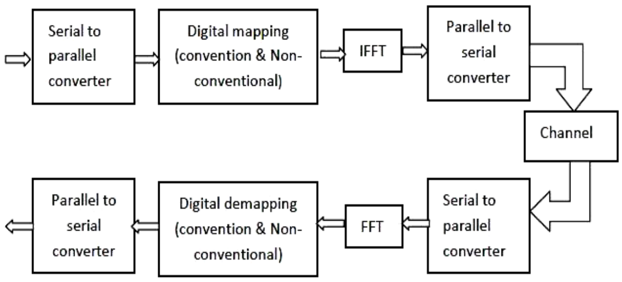


Fig. 1 Simulation diagram for OFDM system

III. Π/4 DQPSK SIGNAL GENERATION

The π/4-shifted QPSK signal constellation can be viewed as the superposition of two QPSK signal constellations offset by 45 degree relative to each other, resulting in eight phases. Symbol phases are alternately selected from one of the QPSK constellations and then the other and, as a result, successive symbols have a relative phase difference that is one of four angles, ± π/4 and ± 3π/4 [11]. Fig. 2 is the π/4-DQPSK modulator. (I(t), Q(t)) and (u(t), v(t)) are the uncoded and coded I-channel and Q-channel bits. The differential encoder of π/4-DQPSK modulator encodes I(t) and Q(t) into signals u(t) and v(t) according to the following rules [22].

$$u_k = \frac{1}{\sqrt{2}}(u_{k-1}I_k - v_{k-1}Q_k) \quad (1)$$

$$v_k = \frac{1}{\sqrt{2}}(u_{k-1}Q_k + v_{k-1}I_k) \quad (2)$$

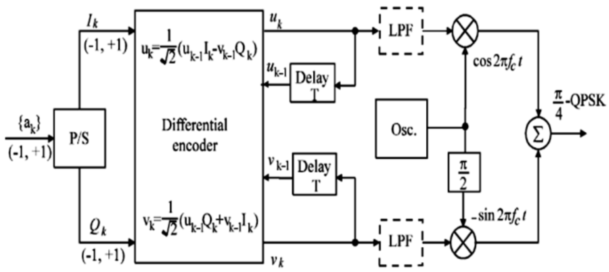


Fig. 2 π /4-DQPSK modulator [22]

Where u_k is the amplitude of u(t) in the k^{th} symbol duration and so on. We assume that I_kQ_k takes values of (−1, 1). If we initially specify that u_0 = 1 and v_0 =0, then u_k and v_k can take the amplitudes of ±1, 0 and ±1/√2.The output signal of the modulator is

$$s(t) = u_k \cos 2\pi f_c t - v_k \sin 2\pi f_c t \quad (3)$$

$$s(t) = A\cos(2\pi f_c t + \varphi_k), \quad kT \le t \le (k+1)T \quad (4)$$

Where $\varphi_k = \tan^{-1}\frac{v_k}{u_k}$

Which depends on encoded data and

$$A = \sqrt{u_k^2 + v_k^2} \quad (5)$$

is independent of time index k, that is, the signal has a constant envelope. A = 1 for initial values $u_0 = 1$ and $v_0 = 0$. It can be proved that the phase relationship between two consecutive symbols is

$$\varphi_k = \varphi_{k-1} + \Delta\theta_k \quad (6)$$

$$\Delta\theta_k = tan^{-1}\frac{Q_k}{I_k} \quad (7)$$

Where Δθk is the phase difference determined by input data.
There are four ways to demodulate a π/4-QPSK signal

1. Baseband differential detection;
2. IF band differential detection;
3. FM-discriminator detection;
4. Coherent detection.

The first three demodulators are reported to be equivalent in error performance. The coherent demodulator is 2 to 3 dB better [2]. Baseband differential demodulator diagram is shown in Fig. 3. In the absence of noise, the output of the BPF in the k thsymbol duration is

$$r(t) = A_k\,cos(2\pi f_c t + \varphi_k + \theta)\,, \quad kT \le t \le (k+1)T \quad (8)$$

Where θ is the random phase introduced by the channel.

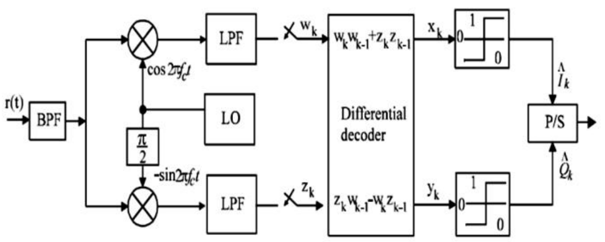


Fig. 3 Baseband differential demodulator for π/4-QPSK [22]

In the k th symbol duration, the I-channel multiplier output is

$$A_k\,cos(2\pi f_c t)\,cos(2\pi f_c t + \varphi_k + \theta) = \frac{1}{2}A_k[cos(4\pi f_c t + \varphi_k + \theta) + cos(\varphi_k + \theta) \quad (9)$$

The low-pass filter (LPF) output for the I-channel is therefore (ignoring the factor 1/2 and the LPF loss)

$$w_k = A_k\,cos(\varphi_k + \theta) \quad (10)$$

Similarly the Q-channel LPF output is

$$z_k = A_k\,sin(\varphi_k + \theta) \quad (11)$$

Since θ has not been changed from the previous symbol duration, then

$$w_{k-1} = A_{k-1}cos\,(\varphi_{k-1} + \theta) \quad (12)$$

$$z_{k-1} = A_{k-1}\,sin(\varphi_{k-1} + \theta) \quad (13)$$

Which is

$$\begin{aligned} x_k &= A_k A_{k-1}[cos(\varphi_k + \theta)\,cos(\varphi_{k-1} + \theta) \\ &\quad + sin\,(\varphi_k + \theta) sin\,(\varphi_{k-1} + \theta)] \\ &= A_k A_{k-1}\,cos(\varphi_k - \varphi_{k-1}) \\ &= A_k A_{k-1}\,cos\,\Delta\theta_k \quad (14) \end{aligned}$$

$$\begin{aligned} y_k &= A_k A_{k-1}[\sin(\varphi_k + \theta)\,cos(\varphi_{k-1} + \theta) \\ &\quad - cos\,(\varphi_k + \theta) sin\,(\varphi_{k-1} + \theta)] \\ &= A_k A_{k-1}\,sin(\varphi_k - \varphi_{k-1}) \\ &= A_k A_{k-1}\,sin\,\Delta\theta_k \quad (15) \end{aligned}$$

From Table II, the decision devices decide

$$\overline{I_k} = 1\,, if\ x_k > 0\ or\ \overline{I_k} = -1\,, if\ x_k < 0 \quad (16)$$

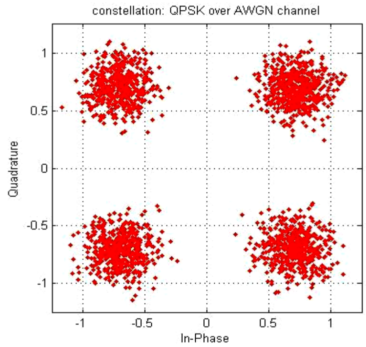
$$\overline{Q_k} = 1\,, if\ y_k > 0\ or\ \overline{Q_k} = -1\,, if\ y_k < 0 \quad (17)$$

TABLE II
π/4-QPSK SIGNAL PHASE ASSIGNMENT [22]

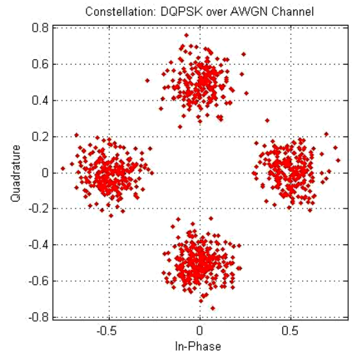
$I_k Q_k$	$\Delta\theta_k$	$cos\Delta\theta_k$	$sin\Delta\theta_k$
1 1	$\pi/4$	1/√2	1/√2
-1 1	$3\pi/4$	-1/√2	1/√2
-1 -1	$-3\pi/4$	-1/√2	-1/√2
1 -1	$-\pi/4$	1/√2	-1/√2

IV. SIMULATION RESULTS

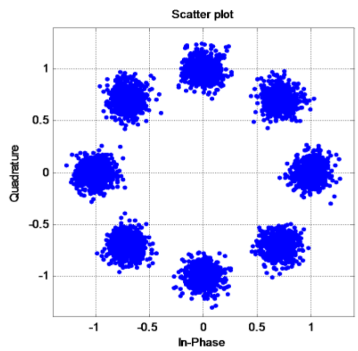
The constellation diagrams for QPSK, DQPSK and π/4 DQPSK have been shown in Fig. 4. It is observed that the spectral efficiency of π/4 DQPSK is better in comparison to the other mentioned mapping schemes.



(a)



(b)



(c)

Fig. 4 Constellation Diagram: (a) QPSK (b) DQPSK and (c) Pi/4 DQPSK over AWGN Channel

Fig. 5 illustrates the simulation results of BER vs. SNR for different mapping schemes (conventional and non-conventional). The system parameters used in Simulation are SNR= 1dB-12dB, Data Sub-carrieres=210, Symbol per carrier=50, IFFT bin size=1024, multipath=0.5 and clip compress=5. Channel used for simulation is AWGN.

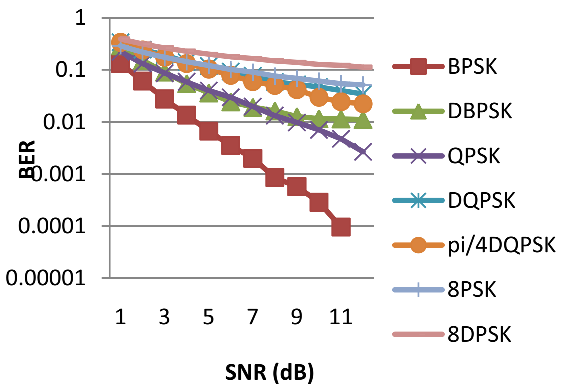


Fig. 5 Comparison of BER performances of conventional and non-conventional mapping schemes in OFDM over AWGN channel

V. Conclusion

In this paper a comparison regarding the mapping schemes used in various standards (which use OFDM as a modulation technique) has been shown. From the simulation result it can be concluded that BER performance over AWGN channel of $\pi/4$ DQPSK is better than 8-psk and M-ary DPSK($M \geq 4$) but poorer than BPSK,DBPSK and QPSK.

In spite of some of the poor results, this technique can be used in OFDM because of the following reasons: Firstly, It is a differential technique so hardware implementation of receiver section is less complex and hence cost effective. Secondly, It has better spectral efficiency. Third one, it is fast compared to BPSK. Some of the other reasons of using $\pi/4$ DQPSK have been discussed in the prior sections of this paper.

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