

OFDM/QPSK SYSTEM PERFORMANCE WITH DOUBLE DIFFERENTIAL DETECTION IN THE PRESENCE OF FREQUENCY OFFSET

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Abstract

In this paper we present the basic characteristics of Orthogonal Frequency Division Multiplex (OFDM) systems with differential quadrature phase shift keying (DQPSK) modulation and OFDM systems with double differential quadrature phase shift keying (DDQPSK) modulation. In the simulation environment designed for this purpose, we analyze the effects of frequency offset on the performance of OFDM digital communications and present the difference between these two systems. We analyze the influence of OFDM system parameters on system's performance for various values of frequency offset and the number of subcarriers. Comparing OFDM systems with DQPSK and DDQPSK modulation we can conclude that the OFDM system with DDQPSK modulation is the less sensitive to frequency offset but if we want to derive satisfying transfer quality, we need to increase the signal power.

Keywords: orthogonal frequency-division multiplexing, differential quadrature phase-shift keying, double differential quadrature phase-shift keying, frequency offset, frequency synchronization.

INTRODUCTION

The popularity of OFDM systems is rising due to its ability to support high-data-rate transmission over time-variant multipath fading channels. OFDM transmission techniques have found applications in the two digital terrestrial broadcasting services - digital audio broadcasting (DAB) and digital terrestrial video broadcasting (DTVB) [1], [2]. OFDM is used in the standards for wireless 5-GHz local area networks (IEEE 802.11a and HIPERLAN) [3], [4]. Asymmetric digital subscriber lines (ADSL) based on OFDM technology are used to deliver high-rate digital data over existing plain old telephone lines (POTS) [5]. More recent developments such as IEEE802.16 wireless metropolitan area network (WMAN) [6] standard address broadband fixed wireless access (BFWA) uses OFDM. OFDM is also being considered in the IEEE802.11n standard that considers Multiple-Input Multiple-Output (MIMO) systems.

OFDM waveforms are resilient to timing errors, yet highly sensitive to frequency offsets and phase noise in the transmitter and receiver

RF and sampling clock oscillators. Numerous methods for estimation and correction of frequency offset are proposed. Some of them use redundancy inherently built in every OFDM symbol, because of cyclic prefix usage, [7], [8]. Second group of estimation methods is based on the use of special pilot sequences for frequency offset estimation [9], [10].

In this paper, we present the performance of two OFDM systems, with DQPSK and DDQPSK modulation [11] in an AWGN (Adaptive white Gaussian noise) channel. DDQPSK is the less sensitive to frequency offset than DQPSK, as shown in [12]. Therefore, it is expected that the OFDM system with DDQPSK modulation is the less sensitive on frequency offset than OFDM system with DQPSK modulation. For this purpose we designed a special simulation platform and analyzed the influence of OFDM system parameters on system performance for various values of number of OFDM subchannels (N). The performance of these two different systems in the presence of frequency offset is also showed.

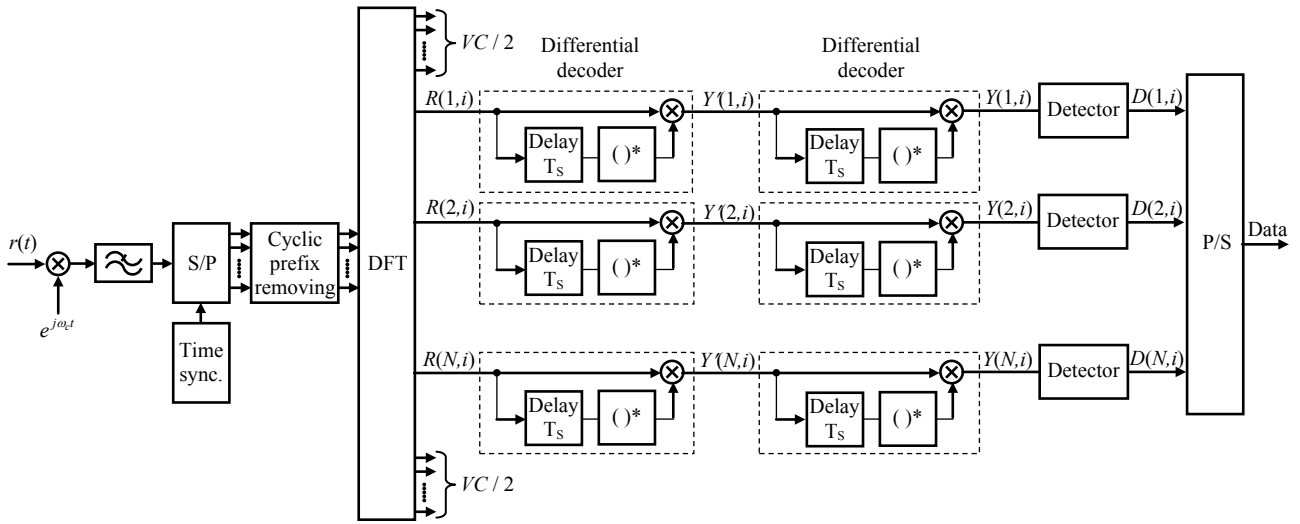


Fig 1. Proposed model of OFDM receiver with DDQPSK modulation

SYSTEM MODEL

The OFDM signal, at the output of the transmitter may be written as:

$$s(t) = \frac{1}{N} \operatorname{Re} \left\{ \sum_{i=-\infty}^{\infty} \sum_{n=0}^N d_{n,i} g(t - iT_s) e^{j2\pi(f_c + f_n)t} \right\} \quad (1)$$

where $d_{n,i}$ is the complex data symbol, $g(t)$ is the impulse response of the transmitter filters, f_c is the carrier frequency, $f_n = n/T_s$, $n = 0, \dots, N$ is the n -th subcarrier frequency, and $1/T_s$ is the symbol rate associated with each subcarrier.

Block diagram of the proposed OFDM receiver with DDQPSK is shown in Fig. 1. Received signal is down converted, low-pass filtered, and sampled with the period

$$T = \frac{T_s}{N + CP + GI} \quad (2)$$

where GI is the guard interval duration, and CP is the cyclic prefix duration, both expressed in the number of sampling periods, i.e. $T_{GI} = GI \cdot T$, $T_{CP} = CP \cdot T$. VC is the virtual channels duration.

S/P represents serial to parallel converter and it requires timing synchronization. After removing the cyclic prefix, a discrete Fourier transform (DFT) of length N is performed. DFT received and reconstructed OFDM data frame at the input, and transmitted modulated symbols influenced by frequency channel response are at the output. In this case we use OFDM demodulator with N subcarriers and discrete Fourier transform. Input is in time, and output in the frequency domain. Within

one OFDM symbol duration, each subcarrier data symbol is passed through a DDQPSK demodulator.

After DFT, block for double differential decoding is described with the following equations:

$$Y'(k,i) = R(k,i)R^*(k,i-1) \quad (3)$$

$$Y(k,i) = Y'(k,i)Y'^*(k,i-1) \quad (4)$$

where $R(k,i)$ is k th output of DFT block at i th time instant, $Y'(k,i)$ is output of first differential decoder and $Y(k,i)$ is output of second differential decoder. $R(k,i)$, $Y'(k,i)$, $Y(k,i)$ represents complex baseband signals at the outputs of corresponding blocks.

From (3) and (4) we have:

$$Y'(k,i-1) = R(k,i-1)R^*(k,i-2) \quad (5)$$

$$Y(k,i) = R(k,i)(R^*(k,i-1))^2 R(k,i-2) \quad (6)$$

Signal $Y(k,i)$ is then detected, and the detected signal is $D(k,i)$.

P/S represents parallel to serial converter and at the output, we have a received datastream.

NUMERICAL RESULTS

The performance of the described two systems is analyzed using Monte-Carlo simulation. The carrier frequency is 2.4 GHz, and the duration of each channel is $T_s = 10^{-2} \mu s$. For each channel we used DQPSK and DDQPSK modulation, respectively, and tested OFDM system performances as a function of parameter N , without frequency offset estimation and correction. Three different

cases were simulated. In the first case, the number of subcarriers is $N = 16$, the number of virtual channels is $VC = 2$, cyclic prefix duration is $CP = 2$, and guard interval duration is $GI = 2$, expressed in the number of T_s . In the second case, the following parameters are used: $N = 32$, $VC = 4$, $CP = 4$, and $GI = 4$. Finally, in the third case, parameters are: $N = 64$, $VC = 8$, $CP = 8$, and $GI = 8$.

Fig. 2. shows OFDM system bit error rate (BER) as a function of the energy per bit to noise power spectral density ratio (E_b/N_0), for different values of number of channels N , in the presence of frequency offset, $\Delta f = 150$ kHz (dashed lines) and without frequency offset (solid lines). If the system is ideally synchronized ($\Delta f = 0$ kHz) the curves for all three cases are very similar. It can be seen that system performances do not depend much on parameter N . Also, bit error rate difference in the presence of the frequency offset compared to the bit error rate without frequency offset is very small when the parameter N is small ($N = 16$).

In the presence of frequency offset, maximum deviation is in the case when the number of channels is the maximum ($N = 64$). Large number of channels leads to decline in the performance or failure of the system, which can be expected. Also, we can see that OFDM/DQPSK system performances are better than performance of OFDM system with DDQPSK modulation for smaller values of signal to noise ratio.

Fig. 3 shows bit error rate versus frequency offset Δf , with number of channels as a parameter, and $E_b/N_0 = 8$ dB for OFDM systems with DQPSK (solid lines) and DDQPSK (dashed lines) modulation. For smaller values of parameter N , frequency offset has less influence on the system performance. It means that, the band within it is possible to achieve satisfying transmission quality is the widest. With the increase of parameter N , the influence of frequency offset on transmission quality also increases. Frequency offsets range where is a satisfying transmission quality becomes narrower. Frequency offset range is wider for OFDM/DQPSK system but in this band BER is the bigger. OFDM/DDQPSK system is the less sensitive to frequency offset but

OFDM/DDQPSK system have the better BER in the range in which the system works.

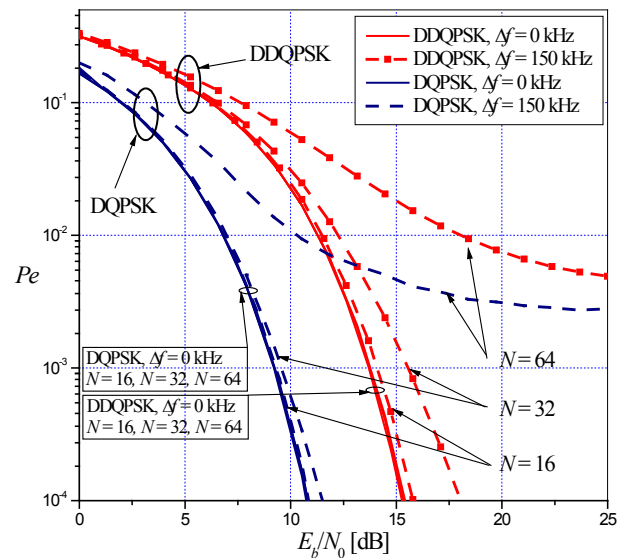


Fig. 2. Bit error rate versus E_b/N_0 for OFDM/DQPSK and OFDM/DDQPSK systems

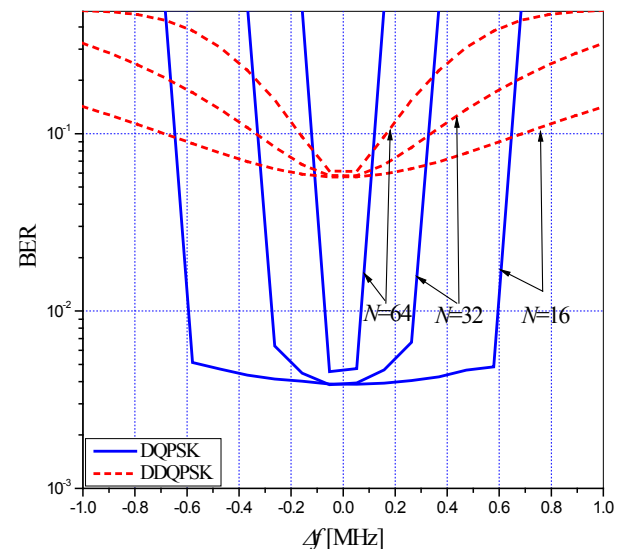


Fig. 3. Bit error rate versus frequency offset Δf for OFDM/DQPSK and OFDM/DDQPSK systems

CONCLUSION

Comparing OFDM systems with DQPSK and DDQPSK modulation we can conclude that the OFDM system with DQPSK modulation has better error probability as a function of the energy per bit to noise power spectral density ratio. Curves showing BER versus frequency offset, for both systems, have the same characteristics, but the range where there is a satisfying transmission quality is wider for OFDM/DDQPSK system. In

addition, the BER function versus frequency offset for OFDM/DDQPSK has the bigger values. It means that OFDM system with DDQPSK modulation is the less sensitive to frequency offset but if we want to derive satisfying transfer quality, we need to increase the signal power.

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