Parameters Optimization of a Newly Proposed DQPSK Receiver

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***Abstract* — Parameters optimization of a DQPSK signal receiver based on the principles of ξ–structure is considered in this paper. It was shown that the performances of the newly proposed receiver, with optimally chosen parameters, are always better than the ones of the conventional DQPSK receiver, regardless of the presence or absence of carrier frequency offset. The proposed receiver has good performances within a wide range of carrier frequency offsets (Δ*f* = ± 10kHz), and, in this case, the performances of the conventional receiver are drastically deteriorated.**

***Keywords* — adaptive transversal filter, differential phase shift keying, Doppler frequency shift, Rician fading.**

I. Introduction

Modern mobile links are characterized by frequency selectivity due to multipath propagation, as well as time selectivity arising from relative transmitter-receiver motion, oscillator drifts, or phase noise. When channel state information is not available at the receiver, differential schemes can obviate channel estimation and may collect diversity at the price of signal-to-noise ratio loss as well as decoding delay. One of the widely used differential schemes is differential quadrature phase-shift keying (DQPSK). Differential detection uses the phase and frequency of the carrier corresponding to the previous transmitted data symbol as a demodulation reference. In conventional differential detection (two-symbol observation) the phase of the current symbol is compared with the phase of the previous one (reference) and a decision is made based on the phase difference [1]. If the phase reference is not stable, due to fading, Doppler effect or poor frequency alignment between oscillators, the detector performance degrades leading to irreducible error floors [2]. To deal with this problem the phase reference can be averaged from more than one symbol interval [3] or multiple-symbol differential detection can be performed using maximum likelihood sequence estimation [4, 5]. However, both methods require, in general, processing of a large number of symbols to approach the performance of coherent detection, thus implying a large architectural complexity [6].

In this paper we address the detection of DQPSK signals in fast fading Rice channels affected by significant carrier frequency offsets caused by relative transmitter/receiver motion (Doppler effect), or poor frequency alignment between oscillators.

II. System Model

Block diagram of the proposed DQPSK signal receiver is shown in Fig. 1.

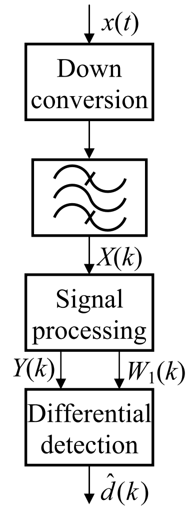

Fig. 1. Block diagram of the proposed DQPSK signal receiver

Signal at the input of the receiver is:

$$x(t) = s(t) + n(t) \tag{1}$$

where $s(t)$ is the useful DQPSK signal:

$$s(t) = \cos(\hat{\omega}_c t + \theta(t - T_s) + d(t) \cdot \pi / 2) \tag{2}$$

and symbol $d(t)$ has one of the following four values:

$$d(t) \in \{0,1,2,3\}, \quad pT_s \le t < (p+1)T_s, \, p = \pm 1, \pm 2... \tag{3}$$

T_s is the symbol interval.

$\hat{\omega}_c = \omega_c + \Delta\omega$ is the carrier frequency, ω_c is the locally generated fixed reference carrier frequency, $\Delta\omega$ is the frequency offset, and $n(t)$ is white Gaussian noise with variance σ^2.

Within the block *Down conversion* the input signal is multiplied by the fixed frequency reference carrier and passed through the integrate and dump circuit. The

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complex baseband signal at the input of the adaptive filter, can be expressed as

$$X(k)=\int_{kT_s}^{(k+1)T_s} x(t)\cos(\omega_c t)dt + j\int_{kT_s}^{(k+1)T_s} x(t)\sin(\omega_c t)dt \quad (4)$$

where k is discrete time at which there is output of the integrate and dump circuit.

Signal at the output of *Signal processing* block is given by the equation

$$Y(k)=\frac{1}{2L+1}\sum_{l=-L}^{L} R_l(k)\cdot X(k-l)\cdot W_l(k) \qquad (5)$$

Where $2L$ is the length of the proposed structure, and $R_l(k)$ are weights determined as:

$$R_l(k)=\arg\min_{r\in S}\left\{ |X(k)-r\cdot X(k-l)\cdot W_l(k)|^2\right\} \qquad (6)$$
$$R_l(k)\in S$$

where $S=\left\{e^{j\frac{\pi}{2}p}, p\in(0,1,2,3)\right\}$.

This structure has $W_l(k)$ transversal filter weights, which are being adjusted by LMS algorithm [9]:

$$W_l(k+1)=W_l(k)+\frac{E(k)[X(k-l)R_l(k)]^*}{\left(|X(k)|^2\right)} \qquad (7)$$

and $E(k)$ is the LMS algorithm error signal, given by

$$E(k)=\frac{\mu}{2\cdot L}\left(X(k)-Y(k)\right) \qquad (8)$$

where μ is the convergence factor.

Detection of kth symbol is performed as

$$\hat{d}(k)=\arg\min_{u\in\{0,1,2,3\}}\left\{\left|Y(k)-Y(k-1)W_1(k)\exp\left(j\frac{u\cdot\pi}{2}\right)\right|^2\right\} \qquad (9)$$

III. Numerical Results

Performance evaluation of the considered receiver is performed using Monte-Carlo simulation. System parameters are $f_c=\omega_c/2\pi = 900$ MHz, and $1/T_s = 100$ kHz.

Fig. 2 shows the symbol error probability as a function of the carrier frequency offset. The parameter is the convergence factor. The signal to noise ratio is 16 dB.

Constant error probability in a wide range of frequency offsets (± 10kHz), the system has for $\mu = 0.1$. If there is no frequency offset, the best performance is achieved for $\mu = 0.01$. It can also be noticed that within the frequency offsets range ± 10kHz, performance of the system for $\mu = 0.01$ is better than the performance for $\mu = 0.1$. If the value of parameter μ is lower than 0.01, the error probability is higher in case of zero frequency offset ($\Delta f = 0$), and, at the same time, the frequency offsets range with acceptable performance level is more narrow ($\Delta f = \pm$ 2kHz). Based on this analysis, the optimal value of parameter μ is chosen to be $\mu = 0.01$.

Symbol error probability, as a function of filter length L, is shown in Fig. 3 for SNR = 16 dB. The parameters are the convergence factor and the frequency offset. In case of zero frequency offset, the increase in filter length above $L = 5$ do not cause any significant decrease in error probability. Also, if $\mu \le 0.01$, the filter length has no

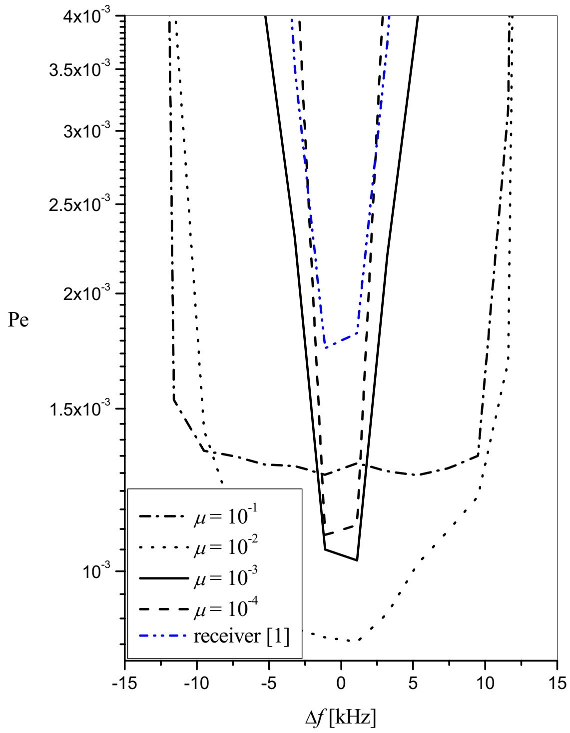

Fig. 2. Error probability as a function of frequency offset with convergence factor μ as a parameter

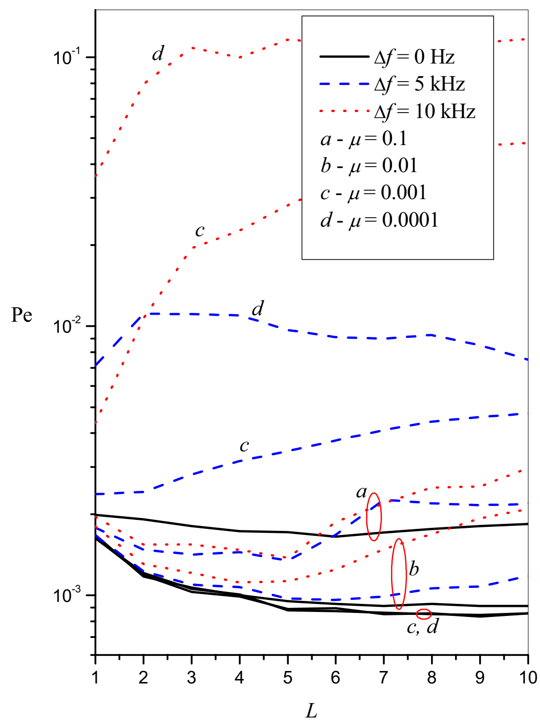

Fig. 3. Error probability as a function of filter length L

influence on error probability (curves for different values of parameter μ are overlapping).

If there is a frequency offset (high or low values) one can notice a unique optimal value of parameter μ equal to 0.01 (curves labelled with b). This is the same conclusion as in the analysis of Fig. 2.

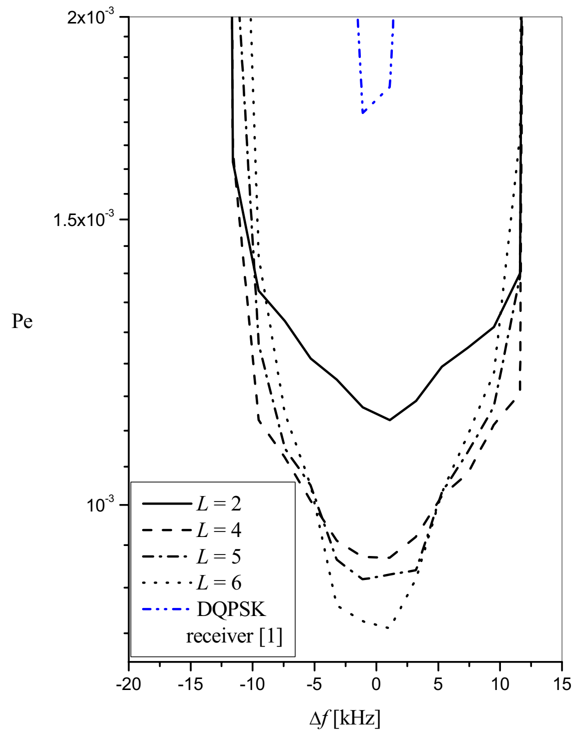

Fig. 4. Error probability as a function of frequency offset with filter length L as a parameter

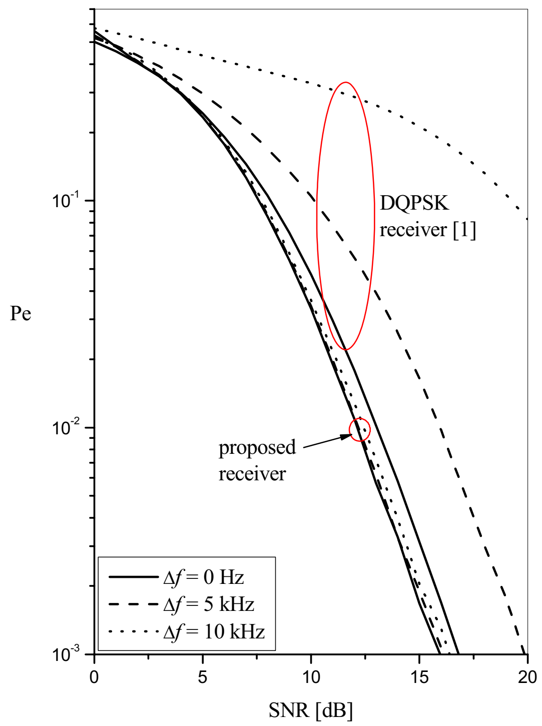

Fig. 5. Error probability as a function of signal to noise ratio

Fig. 4 shows the symbol error probability as a function of frequency offset for signal to noise ratio equal to 16 dB. The parameter is the filter length. In case of frequency offset absence, the error probability decreases with the increase of filter length. On the other hand, for filter lengths $L \leq 4$ the width of frequency offsets range with acceptable performances is $\Delta f = \pm$ 10kHz. With further increase of parameter L the width of frequency offsets range with acceptable performances is more narrow than for $L = 4$. Therefore, the optimal value of filter length is chosen to be $L = 4$.

The symbol error probability as a function of signal to noise ratio is shown in Fig. 5. There are two groups of curves, the curves for the conventional receiver [1], and the ones for the proposed receiver. The parameters of the proposed receiver are optimal and equal to $L = 4$ and $\mu = 0.01$.

It can be seen that the proposed receiver has better performances for the considered SNR range, regardless of the frequency offset value. In case of frequency offset $\Delta f = 10$ kHz, for SNR of practical importance (SNR > 10 dB), the proposed receiver has the error probability for more than order of magnitude lower than the conventional receiver.

IV. Conclusion

This paper proposes a DQPSK signal receiver, based on the principles of ξ–structure. It was shown that, in case of zero frequency offset, its performances are better in considered SNR range, compared to the conventional DQPSK receiver. The proposed receiver has equally good performances for a wide range of carrier frequency offsets ($\Delta f = \pm$ 10kHz), and the performances of the conventional receiver are highly deteriorated even for small values of the frequency offset.

The proposed receiver is especially important for the application at mobile communications, where the frequency offset may be caused by mobile unit moving (Doppler effect), as well as at fixed communications where the frequency offset at the receiver is caused by the instability of the local oscillator.

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