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BPSK Receiver Based on Adaptive Structure with Remodulation

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Introduction

BPSK modulation is often used at mobile satellite communications [1], as well as at diversity mobile systems [2–5]. In most of the papers, during the analysis of BPSK signal reception performance, an ideal reference carrier synchronization is assumed. If the reference carrier synchronization is not ideal, there is a performance drop, as it was considered in [3], and [6].

In this paper we propose a new BPSK signal receiver where the frequency offset between the input signal and the fixed frequency reference carrier in the receiver does not degrade the performance compared to the ideal coherent BPSK signal reception. The receiver is based on a complex adaptive transversal filter with the introduction of signal remodulation at each filter branch, with the LMS algorithm for weights adaptation. The performance of the proposed receiver are close to the performance of the receiver with an ideal extraction of the reference carrier for a wide range of frequency offsets of practical importance between the input signal, and the locally generated carrier in the receiver.

System model

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

Signal at the input of the receiver is

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

where $s(t)$ is the useful BPSK signal

$$s(t) = m(t)\cos\hat{\omega}_c t\,, \tag{2}$$

where $m(t)$ is independent information stream with bit interval T_b, $\hat{\omega}_c = \omega_c + \Delta\omega$ 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 power spectrum density N_0.

The input signal is multiplied by the fixed frequency reference carrier and passed through the integrate and dump circuit. Signals at in-phase and quadrature branches are:

$$\begin{cases} X_I(k) = \displaystyle\int_{kT_b}^{(k+1)T_b} r(t)\cos(\omega_c t)dt, \\ X_Q(k) = \displaystyle\int_{kT_b}^{(k+1)T_b} r(t)\sin(\omega_c t)dt, \end{cases} \tag{3}$$

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

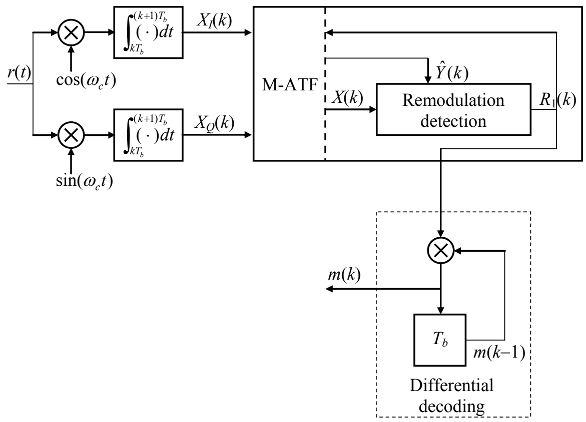

Fig. 1. Block diagram of the proposed BPSK signal receiver

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

$$X(k) = X_I(k) + jX_Q(k)\,. \tag{4}$$

Signal $X(k)$ is processed by the first part of the proposed structure, denoted as M-ATF. The block diagram of M-ATF structure is shown in Fig. 2.

It is a one-sided complex transversal filter of length L, having remodulation weights $R_l \in \{+1,-1\}$, $l = 1,...,L$. M-ATF operates with the algorithm consisting of the following steps:

1. It is supposed the the remodulation weight $R_1(k)$ is

equal to 1;

2. Preliminary estimate of the input signal is performed:

$$\hat{Y}(k)=\frac{1}{L}\left(1\cdot X(k-1)\cdot W_1(k)+\sum_{l=2}^{L}R_l(k)\cdot X(k-l)\cdot W_l(k)\right); \quad (5)$$

3. Within the block *Remodulation detection*, we estimate $R_1(k)$

$$R_1(k)=\begin{cases}1, & \left|X(k)-\hat{Y}(k)\right|^2\le\left|X(k)+\hat{Y}(k)\right|^2,\\ -1, & \left|X(k)-\hat{Y}(k)\right|^2>\left|X(k)+\hat{Y}(k)\right|^2;\end{cases} \quad (6)$$

4. Using $R_1(k)$ we estimate the input signal

$$Y(k)=\hat{Y}(k)\cdot R_1(k). \quad (7)$$

In this way, we correct a possible mistake made in step 1;

5. LMS algorithm error signal is calculated as

$$E(k)=X(k)-Y(k); \quad (8)$$

6. Besides the remodulation weights, M-ATF also has $W_l(k), l=1...L$ weights which are being adjusted by LMS algorithm [7]

$$W_l(k+1)=W_l(k)+\frac{\mu E(k)[X(k-l)R_l(k)]^*}{\frac{1}{L}\sum_{l=1}^{L}\left(X(k-l)\right)^2}, \quad (9)$$

where μ is the adaptation factor;

7. Remodulation weights for the next sampling interval are calculated with the following recursive relation

$$R_l(k+1)=R_{l-1}(k)\cdot R_1(k),\quad l=2,...,L, \quad (10)$$

which represents shifting and sign correction.

Weight $R_1(k)$ represents the estimated difference between kth and $(k-1)$th information bit. Therefore, we need to perform the differential decoding

$$m(k)=m(k-1)\cdot R_1(k). \quad (11)$$

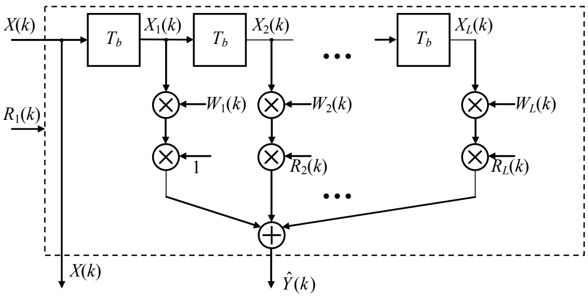

Fig. 2. M-ATF block diagram

Numerical results

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

The performance of the proposed receiver is compared to the performance of the BPSK signal receiver using second order remodulation PLL (R-PLL) [8] for the reference carrier extraction. The operation of the receiver with R-PLL is modelled as:

$$\begin{cases}d(k)=\begin{cases}1, & X_I(k)\ge 0,\\ -1, & X_I(k)<0,\end{cases}\\ e_1(k)=d(k)\cdot X_Q(k),\\ e_2(k)=(1-A)e_2(k-1)+A\cdot e_1(k-1),\end{cases} \quad (12)$$

where $X_I(k)$, $X_Q(k)$ are defined in (3); $d(k)$ is the detected signal, $e_1(k)$ is the signal at the input, and $e_2(k)$ is the signal at the output of R-PLL low pass filter, defined by parameter A. Frequency correction is calculated as

$$\delta\omega=\frac{K}{T_b}e_2(k), \quad (13)$$

where K is the loop gain.

Finally, R-PLL frequency is

$$f_{PLL}=f_c+\frac{\delta\omega}{2\pi}. \quad (14)$$

Error probability as a function of transversal filter length, with LMS algorithm adaptation factor μ as a parameter, is shown in Fig. 3.

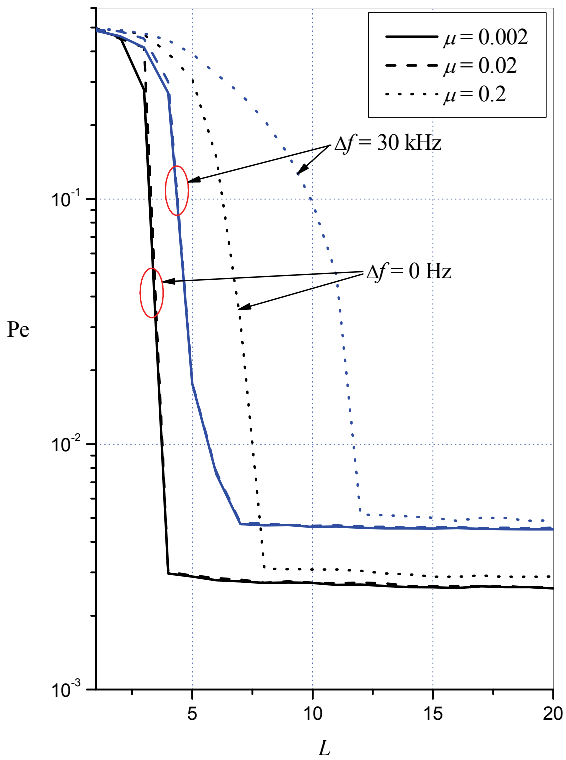

Fig. 3. Error probability as a function of carrier frequency offset

The figure shows that the error probability improves with the filter length L, and that there is some threshold value of L, after which the error probability does not improve anymore. Also, the lower μ the lower error probability is. The same conclusion stands in both cases of presence or absence of frequency offset, with the difference that the threshold value for L is higher in case of higher frequency offset.

Fig. 4 shows the error probability as a function of the energy per bit to noise power spectral density ratio (E_b / N_0). M-ATF filter parameters are $\mu = 0.02$, $L = 100$. This figure also shows previously described advantages of R-ATF over R-PLL. This figure also illustrates additional problems regarding R-PLL parameters (K and A) choice trade-off. In fact, in case of of non-zero carrier frequency offset, all R-PLL performance curves (*g, e, i*, and *k*) show that there is a range of E_b / N_0 where performance of such a system significantly drop, and that is not the case with the proposed receiver (curves *a*,*b*, and *c*).

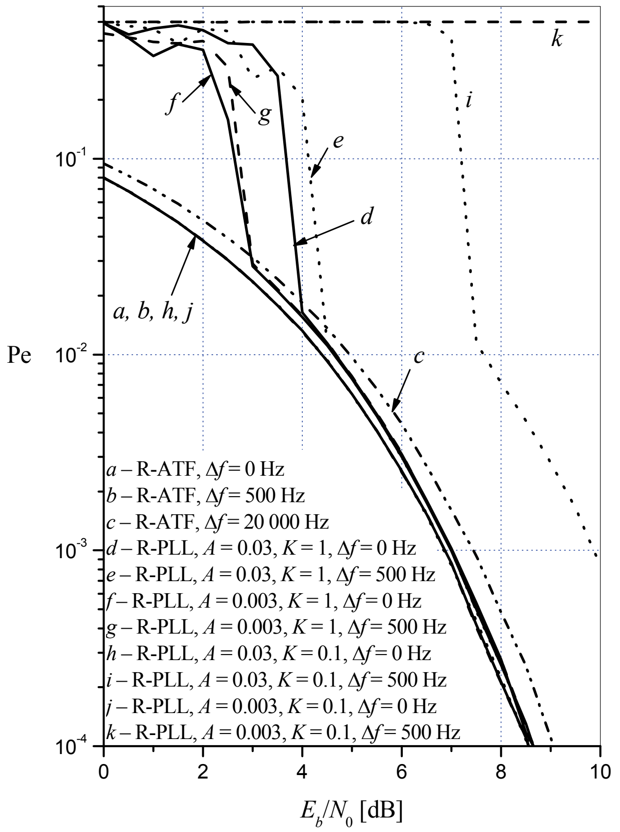

Fig. 4. Error probability as a function of signal to noise ratio

Error probability as a function of local carrier frequency offset Δf is shown in Fig. 5 for different values of LMS algorithm adaptation factor μ and filter length L, as well as for different R-PLL parameters A and K; E_b / N_0 is equal to 6 dB.

The proposed receiver with R-ATF ensures operation of the system with much higher carrier frequency offsets compared to the system using R-PLL (curves *e*, and *f* have the narrowest working range).

Carrier frequency offset range at x-axis of Fig. 5 is equal to the half of the considered system bandwidth ($\pm B / 2 = 50$ kHz). Of particular interest are offsets that do not cause a significant performance degradation. For the considered case it is a range $\Delta f = \pm 20$ kHz. Within this offset range the perfromance of the proposed receiver with R-ATF just slightly vary for a wide range of filter length L and adaptation factor μ.

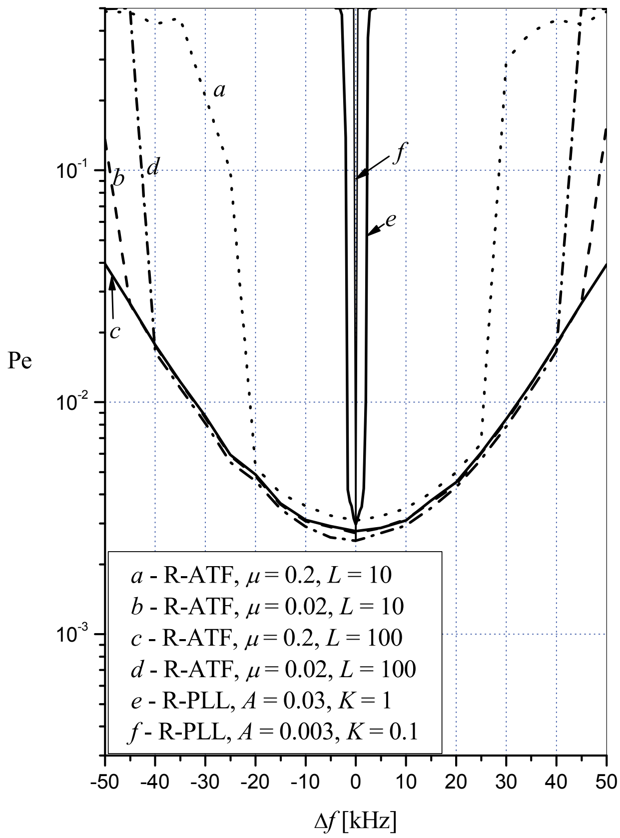

Fig. 5. Error probability as a function of carrier frequency offset

Fig. 5 also shows that in case of zero offset, for certain values of parameters L and μ, performance of the system with the prorposed structure is slightly better than that of R-PLL (curves *d* and *e*). System with R-PLL may achieve the same performance as R-ATF system in case of $\Delta f = 0$ Hz, for a combination of parameters K and A, but such a system can operate with a very narrow frequency offsets range (curve *f*). In case of all other frequency offsets ($\Delta f > 0$ Hz) there is a significant advantage of the proposed R-ATF structure.

Conclusions

This paper proposes a BPSK signal receiver where the reception is performed using a new complex adaptive structure with remodulation. The performance of the proposed receiver are close to the performance of the BPSK receiver with an ideal extraction of the reference carrier ($\Delta f = 0$ Hz) for a wide range of frequency offsets of practical importance between the input signal and the fixed frequency reference carrier in the receiver.

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References

1. **Rice M., Perrins E.** A simple figure of merit for evaluating interleaver depth for the land–mobile satellite channel // IEEE Transactions on Communications. – IEEE, 2001. – No. 49(8). – P. 1343–1353.
2. **Smadi M. A., Prabhu V. K., Al–Jazzar S. O.** Analytical study on the effect of cochannel interference on partially coherent diversity systems // IEEE Transactions on Communications. – IEEE, 2009. – No. 57(1). – P. 117– 124.
3. **Smadi M. A., Prabhu V. K.** Performance Analysis of Generalized–Faded Coherent PSK Channels with Equal–Gain Combining and Carrier Phase Error // IEEE Transactions on Wireless Communications. – IEEE, 2006. – No. 5(3). – P. 509–513 .
4. **Milošević B., Spalević P., Petrović M., Vučković D., Milosavljević S.** Statistics of Macro SC Diversity System with Two Micro EGC Diversity Systems and Fast Fading // Electronics and Electrical Engineering. – Kaunas: Technologija, 2009. – No. 8(96). – P. 55–58.
5. **Petrovic I., Stefanovic M., Anastasov J., Panic S., Djordjevic G., Milic D.** Outage Probability of SSC Receivers in Correlated Rayleigh Fading Channel with Multiple Cochannel Interferers // Electronics and Electrical Engineering. – Kaunas: Technologija, 2010. – No. 10(106). – P. 67–70.
6. **Kam P. Y., Teo S. K., Some Y. K., Tjhung T. T.** Approximate Results for the Bit Error Probability of Binary Phase Shift Keying with Noisy Phase Reference // IEEE Transactions on Communications. – IEEE, 1993. – No. 41(7). – P. 1020–1022.
7. **Glisic S., Nikolic Z., Dimitrijevic B.** Adaptive Self Reconfigurable Interference Suppression Schemes for CDMA Wireless Networks // IEEE Transactions on Communication. – IEEE, 1999. – No. 47(4). – P. 598–607.
8. **Gardner F. M.** Phase Lock Techniques. – Wiley: New York, 1979. – 304 p.

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B. Dimitrijevic, N. Milosevic, Z. Nikolic. BPSK Receiver Based on Adaptive Structure with Remodulation // Electronics and Electrical Engineering. – Kaunas: Technologija, 2011. – No. 7(113). – P. 93–96.

In this paper we propose a binary phase shift keying (BPSK) signal receiver, where the reception is performed by a new complex adaptive structure with remodulation (R-ATF) which does not require the exact knowledge of the carrier frequency. Therefore, this receiver does not have a phase-locked loop (PLL), and it has a fixed frequency oscilator with frequency equal to the expected input signal frequency. The proposed structure is created by modifying a complex adaptive transversal filter with the introduction of signal remodulation, and it uses least mean squares (LMS) algorithm for its weights adaptation. The main feature of this receiver is that it has performances that are close to the performances of the BPSK receiver with an ideal extraction of the reference carrier for a wide range of frequency offsets of practical importance between the input signal and the fixed frequency reference carrier in the receiver. Ill. 5, bibl. 8 (in English; abstracts in English and Lithuanian).

B. Dimitrijevic, N. Milosevic, Z. Nikolic. Adaptyviosios struktūros BPSK imtuvo su pasikartojančia moduliacija tyrimas // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2011. – Nr. 7(113). – P. 93–96.

Analizuojamas BPSK signalų imtuvas, pasižymintis nauja kompleksine adaptyviąja signalų priėmimo struktūra su pasikartojančia moduliacija. Tokiu atveju nebūtina žinoti nešlio signalo dažnį. Be to šis imtuvas neturi fazinės kilpos. Siūlomos struktūros našumas yra artimas BPSK imtuvui, kai pakankamai tiksliai nustatytas signalo nešlio dažnis. Il. 5, bibl. 8 (anglų kalba; santraukos anglų ir lietuvių k.).