MQAM Interference Rejection Using LMS Algorithm in UWB Radio System

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Abstract – **Performances of UWB system using PPM in the presence of MQAM interference are considered in this paper. Interference rejection is performed using a adaptive transversal filter (ATF). A ATF parameter (filter length) optimization is performed in this paper.**

Keywords – **UWB, adaptive filtering, interference rejection**

I. INTRODUCTION

Ultra-wideband (UWB) technology has been recently proposed as a viable solution for high-speed indoor short range wireless communication system, because of its robustness to severe multipath conditions and low cost and low power implementation.

Time Hopping combined with pulse position modulation (TH-PPM) has been the original proposal for UWB systems [1]. An analysis of this modulation and multiaccess scheme performance in terms of bit error rate has been proposed in [1] for AWGN channel. In [1] a method to evaluate the bit error rate performance of time hopping TH-PPM in the presence of multiuser interference and AWGN channel is proposed. Gaussian quadrature rules are used in this approach.

In this paper TH-PPM UWB radio system performance in the presence of MQAM interference will be determined. The receiver uses a ATF for the interference rejection. Filter weights are adapted using the LMS algorithm.

II. SYSTEM MODEL

The signal transmitted by the desired user is modeled as:

$$s(t)=\sum_i b(t-iNT_f-(1-a_i)\Delta)\cos\omega_c t \tag{1}$$

where

$$b(t)=\sum_{n=0}^{N-1} g(t-nT_f-h(n)T_c) \tag{2}$$

ω_c is channel carrier frequency. $g(t)$ represents basic pulse shape (rectangular pulse) and T_f represents frame duration during which there is only one pulse T_c seconds wide. The sequence $h(n)$ is the user's time-hopping code and its elements are integers taking values in the range $0 \le h(n) \le N-1$. The parameter T_c is the duration of an addressable time bin. In other words, the right hand side of (2) consists of a *block* of N time-hopped monocycles. a_i represents information bits (0,1). Equation (1) says that, if a_i were all zero, the signal would be a repetition of $b(t)$-shaped blocks with period NT_f. Δ may be viewed as the time shift impressed by a unit data symbol on the monocycles of a block. It is clear that the choice of Δ affects the detection process and can be exploited to optimize system performance. To summarize, the transmitted signal consists of a sequence of $b(t)$-shaped position-modulated blocks. The code sequence restarts at every data symbol.

The receiver block diagram is shown in Fig. 1. When several time-hopping signals are simultaneously transmitted over a channel with L_c paths, the composite waveform at the output of the receiver antenna may be written as:

$$r(t)=\sum_{l=1}^{L_c}\left(\gamma_l^{(I)}s(t-\tau_l)\cos\omega_c t+\gamma_l^{(Q)}s(t-\tau_l)\sin\omega_c t\right) + n(t)+j(t) \tag{3}$$

$$r^{(I)}(t)=r(t)\cos\omega_c t,\quad r^{(Q)}(t)=r(t)\sin\omega_c t \tag{4}$$

where $n(t)$ is noise, and $j(t)$ is the total interference, $\gamma_l=\gamma_l^{(I)}+j\gamma_l^{(Q)}$ is the complex attenuation and τ_l is the delay in l-th path.

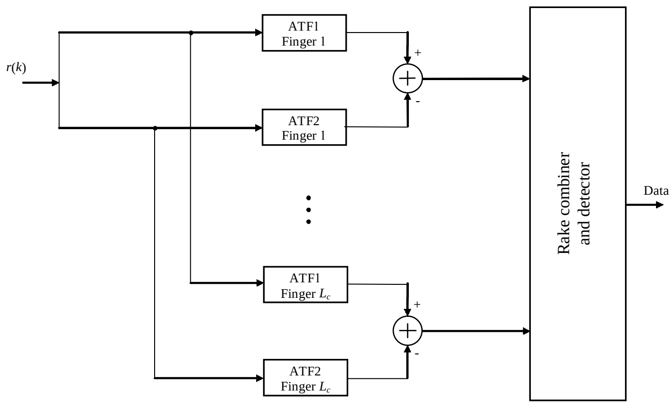

Fig. 1. Receiver block diagram

If we consider signal sampled at chip interval T_c we have:

$$r(k)=r^{(I)}(k)+jr^{(Q)}(k),\quad k=\frac{t}{T_c} \tag{5}$$

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The interference is rejected using two two-sided adaptive transversal filters of length 2M, denoted as ATF1 and ATF2. In order to predict the interference signal, sampling is performed at frame rate, and the adaptation of filter weights using LMS algorithm is performed at bit rate.

The filter weights are adapted using the LMS algorithm and for ATF1 and ATF2 we have, respectively:

$$W_m(i+1) = W_m(i) + \frac{\mu e_1^l(i)\left(S1_m^l(i)\right)^*}{\sum_{j=-M}^{-1}\left(S1_j^l(i)\right)^2}, \quad -M \le m \le M, \; m \neq 0 \qquad (6)$$

$$W_m(i+1) = W_m(i) + \frac{\mu e_2^l(i)\left(S2_m^l(i)\right)^*}{\sum_{j=1}^{M}\left(S2_j^l(i)\right)^2}, \quad -M \le m \le M, \; m \neq 0 \qquad (7)$$

where μ denotes the adaptation factor, and :

$$S1_m^l(i) = \sum_{n=iN}^{(i+1)N} A_m^l(n), \quad S2_m^l(i) = \sum_{n=iN}^{(i+1)N} B_m^l(n), \quad -M \le m \le M \qquad (8)$$

$e_1^l(i)$, $e_2^l(i)$ may be calculated as:

$$e_1^l(i) = S1_0^l(i) - \sum_{\substack{m=-M \\ m\neq 0}}^{M} S1_m^l(i) W_m(i)),$$
$$e_2^l(i) = S2_0^l(i) - \sum_{\substack{m=-M \\ m\neq 0}}^{M} S2_m^l(i) W_m(i)) \qquad (9)$$

i represents the sequence number of the considered bit.

Therefore, variables $A_m^l(n)$ and $B_m^l(n)$ from Eq. (9), belonging to filter 1 and filter 2, respectively, may be calculated as

$$A_m^l(n) = \sum_{k=n\frac{T_f}{T_c}-\frac{\tau_l}{T_c}}^{(n+1)\frac{T_f}{T_c}-\frac{\tau_l}{T_c}} r^{(I)}(k) g\left(k - n\frac{T_f}{T_c} - \frac{\tau_l}{T_c} - h(n) - m\right) + j \sum_{k=n\frac{T_f}{T_c}-\frac{\tau_l}{T_c}}^{(n+1)\frac{T_f}{T_c}-\frac{\tau_l}{T_c}} r^{(Q)}(k) g\left(k - n\frac{T_f}{T_c} - \frac{\tau_l}{T_c} - h(n) - m\right) \qquad (10)$$

$$B_m^l(n) = \sum_{k=n\frac{T_f}{T_c}-\frac{\tau_l}{T_c}}^{(n+1)\frac{T_f}{T_c}-\frac{\tau_l}{T_c}} r^{(I)}(k) g\left(k - n\frac{T_f}{T_c} - \frac{\tau_l}{T_c} - h(n) - m - \frac{\Delta}{T_c}\right) + j \sum_{k=n\frac{T_f}{T_c}-\frac{\tau_l}{T_c}}^{(n+1)\frac{T_f}{T_c}-\frac{\tau_l}{T_c}} r^{(Q)}(k) g\left(k - n\frac{T_f}{T_c} - \frac{\tau_l}{T_c} - h(n) - m - \frac{\Delta}{T_c}\right) \qquad (11)$$

n designates the considered frame index (n = 0, N-1), and m is ATF weight index.

The detection variable in the first Rake receiver finger is:

$$d(i) = \sum_{l=1}^{L_c} \left(\mathrm{Re}\{D^l(i)\} * \mathrm{Re}\{T^l(i)\} + \mathrm{Im}\{D^l(i)\} * \mathrm{Im}\{T^l(i)\}\right) \qquad (12)$$

where

$$\mathrm{Re}\{D^l(i)\} = \mathrm{Re}\{e_1^l(i) - e_2^l(i)\}, \quad \mathrm{Im}\{D^l(i)\} = \mathrm{Im}\{e_1^l(i) - e_2^l(i)\} \qquad (13)$$

$$\mathrm{Re}\{T^l(i)\} = \overline{\mathrm{Re}\{e_1^l(i)\} + \mathrm{Re}\{e_2^l(i)\}}, \quad \mathrm{Im}\{T^l(i)\} = \overline{\mathrm{Im}\{e_1^l(i)\} + \mathrm{Im}\{e_2^l(i)\}} \qquad (14)$$

and i is again the sequence number of the considered bit.

The error probability is computed using Monte-Carlo simulation.

III. Numerical Results

Fig. 2. shows error probability as a function of filter length. Interference bit duration is chosen to be $T_j = 1000T_c$. Signal to noise ratio is SNR = 10 dB, and interference to signal ratio is J/S = 20 dB.

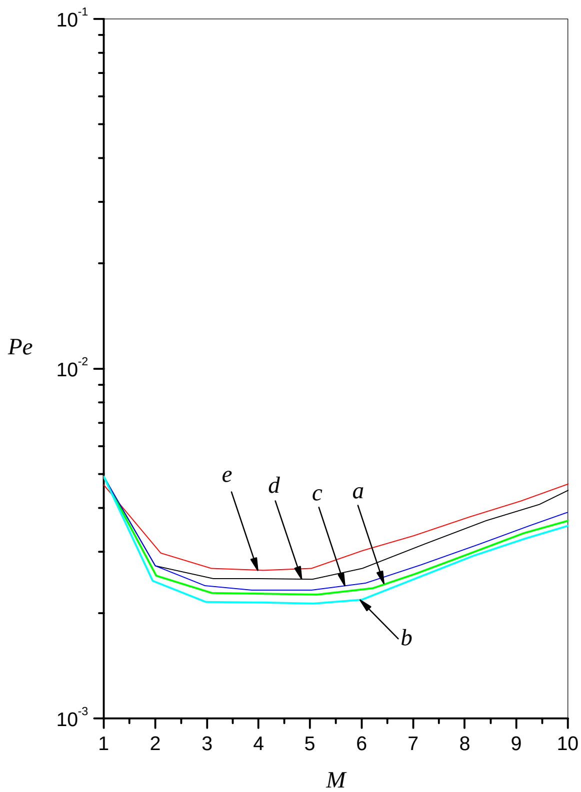

Fig. 2. Error probability as a function of filter length
a – PSK interference; b – 4QAM interference
c – 16QAM interference; d – 64QAM interference
e – 256QAM interference

It can be noted that there is a range of ATF lengths for which the error probability is minimal, regardless of interference constellation (PSK, 4QAM, 16QAM, 64QAM, 256QAM). The smallest filter length that meets the requirements for the minimal error probability is M = 4, and it was chosen to be optimal.

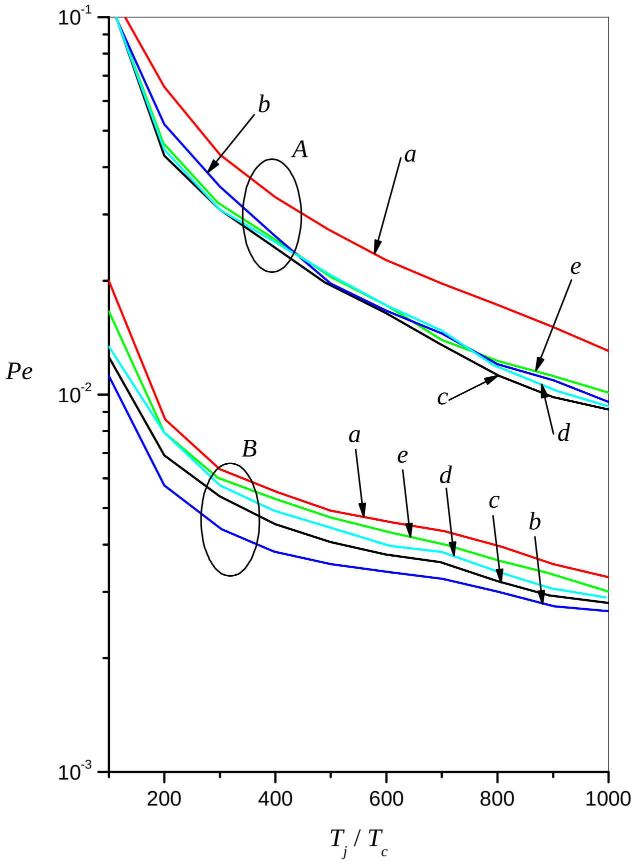

Fig. 3. Error probability as a function of interference bit duration
A – without interference rejection
B – with interference rejection with ATF
a – PSK interference; *b* – 4QAM interference
c – 16QAM interference; *d* – 64QAM interference
e – 256QAM interference

Fig. 3. shows error probability as a function of interference bit duration. Filter length is chosen to be M = 4. Signal to noise ratio is SNR = 10 dB, and interference to signal ratio is J/S = 20 dB.Curves labeled with *A* stand for the case is there is no interference rejection with ATF, and curves *B* represent the performance of the system if there is ATF. The figure shows that interference suppression with ATF at TH-PPM UWB radio brings the decrease of error probability for almost one order of magnitude compared to the case if there is no interference rejection.

IV. Conclusion

In this paper we consider TH-PPM UWB radio system error probability. Interference rejection is performed using adaptive transversal filter. The ATF length optimization is also done in this paper. A significant performance drop may be noticed with the interference rate increase. The interference suppression with ATF at TH-PPM UWB radio system brings the decrease of error probability for almost one order of magnitude, regardless of the interference bit rate.

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