DDPSK 시스템을 위한 결정궤환복조에 근거한 적응등화기

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Decision Feedback Demodulation-based Adaptive Equalizers for DDPSK Systems

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ABSTRACT

This study extends the modified linear feedback equalizer (MLFE), normally used for differentially coherent DPSK systems, to the equalization of double differentially coherent PSK (DDPSK) signals. By feeding back into the feedback part after modifying the equalizer output usingdecision feedback-based demodulation, the proposed equalizer can operate like an equalizer with a decision feedback structure. Simulation results showthat performances of the decision feedback demodulation-based feedback equalizer (DFD-FE) approach those of the DFE/coherent.

I. Introduction

In an attempt to alleviate the need for frequency tracking loops in DPSK receivers, the development of the double differentially coherent DDPSK systems has been pursued since the 1970's. Recently, to reduce the performance gap between conventional double differentially coherent demodulators and coherent ones, advanced demodulation schemes have been investigated for the case of additive white Gaussian noise (AWGN) channels [3]-[5], yet without the presence of channel distortion due to intersymbol interferences (ISI). In contrast decision feedback-type equalizers have been employed in coherent communication systems and differently coherent DPSK systems [1][2]. However, these equalization schemes are not compatible with double differentially coherent DDPSK systems.

Accordingly, this paper considers the equalization of distorted signals in non-coherent DDPSK systems, which has received little attention until now. The proposed equalizer is considered as an extension of the equalizer in [1], originally proposed for double differentially coherent DPSK systems, and is a hybrid of a decision feedback-baseddemodulator [5] and a linear feedback equalizer. That is, by modifying the equalizer output based on the decision feedback demodulation before feeding back into the feedback part of the linear equalizer, the proposed equalizer can perform like a decision feedback equalizer with coherent detection. This is demonstrated through computer simulation.

II. Decision feedback demodulation-based adaptive equalizers

Consider the transmission of doubly differential PSK (DDPSK) signals over multipath fading channels. At the transmitter, the information symbols, a_k are differentially encoded into

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$$b_k = a_k b_{k-1} = b_0 \prod_{i=1}^{k} a_i \tag{1}$$

Thereafter, the transmitted symbols, d_k can be obtained through another differential encoding:

$$d_k = b_k d_{k-1} = d_0 \prod_{i=1}^{k} b_i \tag{2}$$

in which $d_k = \exp(j\varphi_k)$; φ_k is represented by $2\pi i/M$, $i = 1, \ldots, M-1$ for M-ary communication systems. For a multipath fading channel, the received signal, r_k is represented as

$$r_k = \sum_{i=-\infty}^{\infty} h_i d_{k-i} e^{j(w_d k + \theta)} + n_k \tag{3}$$

where $\{h_i\}_{i=-\infty}^{\infty}$ depicts the overall channel impulse response which includes the transmitting filter, the channel, and the receiving filter, w_d and θ represent the carrier frequency and phase uncertainties of the carrier, respectively, n_k stands for an AWGN channel with a zero mean and variance $\sigma_n^2 (= N_o/E_b)$, where N_o is the single-sided noise power spectrum density, and E_b is the signal energy per bit taking unity magnitude.

It is shown in [4] that under an AWGN channel (i.e., $h_i = 1$ for $i = 0$, and $h_i = 0$ otherwise), a decision feedback-based demodulator of DDPSK signals can be given by

$$\tilde{a}_k = dec\{v_k B_{k-1}^*\} \tag{4.a}$$

$$\widetilde{d}_k = r_k + \beta_1 B_k \tilde{d}_{k-1} \tag{4.b}$$

$$\widetilde{b}_k = v_k + \beta_2 \widetilde{a}_k \tilde{b}_{k-1} \tag{4.c}$$

$$v_k = r_k D_{k-1}^* \tag{4.d}$$

where $B_k = \widetilde{b}_k / \{\widetilde{b}_k\}$, $D_k = \widetilde{d}_k / \{\widetilde{d}_k\}$, $dec\{\circ\}$ means a decision device, and β_1 and β_2 are the forgetting factors which limit the effects of previous signals and have values within a range of $0 \le \beta_1, \beta_2 < 1$. In (4.d) D_k is employed since $\tilde{d}_{k-1}$ is an estimator of $d_{k-1} e^{j(w_d(k-1)+\theta)}$, which has a unity magnitude in DDPSK systems. Its implementation is illustrated in Fig. 1.

In order to combat an unknown channel distortion and frequency uncertainties simultaneously, this demodulator is then combined with a linear feedback equalizer to produce a *decision feedback demodulator-based feedback equalizer* (DFD-FE), shown in Fig. 2.

The equalizer output is double differentially demodulated and then quantized to produce the decision $\widetilde{a}_k$, the error signal e_k is obtained for equalizer tap adaptation, and the estimated reference signal D_k is fed into the feedback

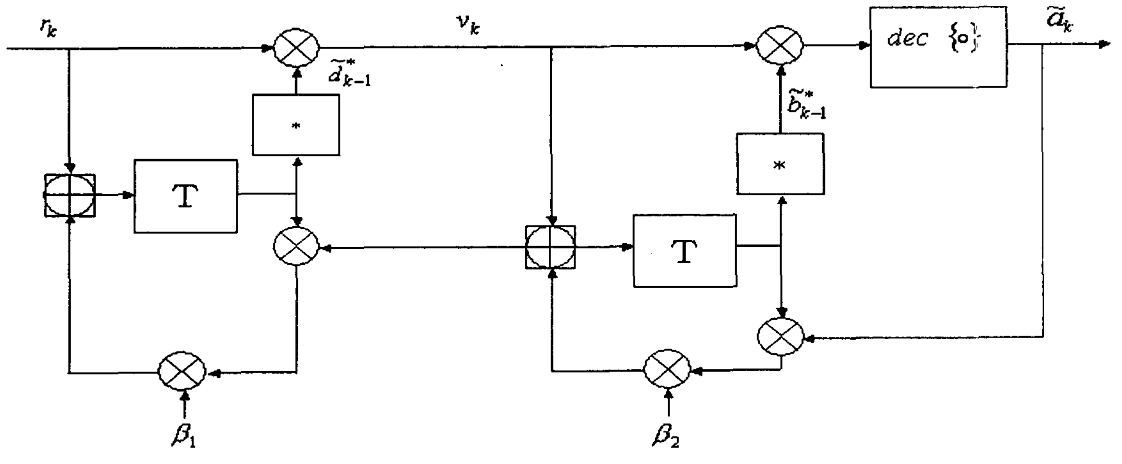

Fig. 1 Decision feedback-based demodulator for double differentially coherent DDPSK systems (depicts a function which normalizes after summation, * means a complex conjugate)

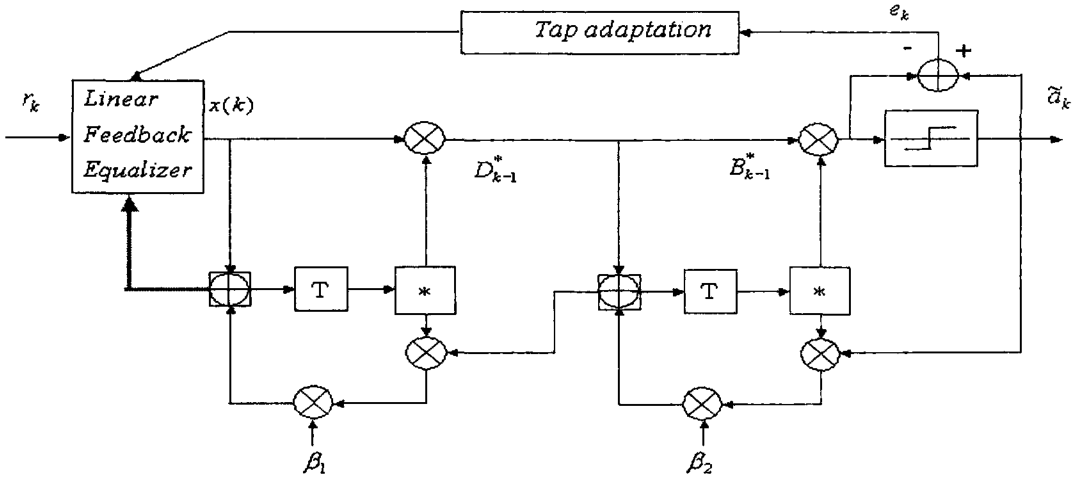

Fig. 2 DFD-FE for double differentially coherent DDPSK systems

part. If a least mean square (LMS) algorithm is used for the tap adaptation with the assumption of a constant $B_{k-1}D_{k-1}$, the system can be specified by the following equations:

$$x_k = W_k^t Q_k \tag{5.a}$$

$$e_k = \widetilde{a}_k - x_k D^*_{k-1} B^*_{k-1} \tag{5.b}$$

$$W_{k+1} = W_k + \mu e_k Q^*_k D_{k-1} B_{k-1} \tag{5.c}$$

where t means the transpose, $Q_k^t = \{ r_{k+N_f}, \ldots, r_k D_{k-1}, \ldots, D_{k-N_b} \}$ with N_f and N_b the number of feedforward and feedback taps, respectively. W_k is the $N_f + N_b + 1$ dimensional tap coefficient vector at k. This system reduces to a *linear equalizer* for non-coherent DDPSK systems if $D_{k-1}B_{k-1}$and Q_k^t are replaced with $x_{k-1}x_{k-1}x^*_{k-2}$ and $R_k^t = \{ r_{k+N_f}, \ldots\ldots, r_k, \ldots\ldots r_{k-N_b} \}$, respectively. If only Q_k is replaced with R_k, then the system becomes a *decision feedback demodulation-based non-feedback equalizer* (DFD-NFE) for DDPSK systems.

Ⅲ. Simulation Result

The performance of the proposed equalizer was examined through computer simulation with DDBPSK, and compared with that of a DFE with coherent demodulation. In the simulation, two linear phases, finite impulse response (FIR) channels were considered, as in [1], that is, channels A and B, specified by $\{h_0, h_1, h_2\} = \{0.304, 0.903, 0.304\}$ and $\{0.407, 0.815, 0.407\}$, respectively. Channel B had a spectral null in its frequency response and causedmore severe ISI. Each equalizer had 15 taps with $N_f = 9$ and $N_b = 5$, and $w_d = 0.5\pi$ and $\theta = 1.5\pi$. The step size for the tap adaptations was set at $\mu = 0.002$, plus the parameters for the decision feedback demodulator were: (a) $\beta_1 = 0.5, \beta_2 = 0.9$ for DFD-NFE and (b) $\beta_1 = 0.0, \beta_2 = 0.9$; $\beta_1 = 0.5, \beta_2 = 0.9$ for DFD-FE. The tap coefficients were initially obtained using 10^5 training BPSK signals. The BER values were empirically estimated by processing 10^7 binary input data. Figs. 3 and 4 show the BER values for channels A and B, respectively. For both channels, the performances of DFD-FE compatible with double differentially coherent detection outperformed DFE-NFE and were even comparable to those of the DFE with coherent detection (DFE/coherent).

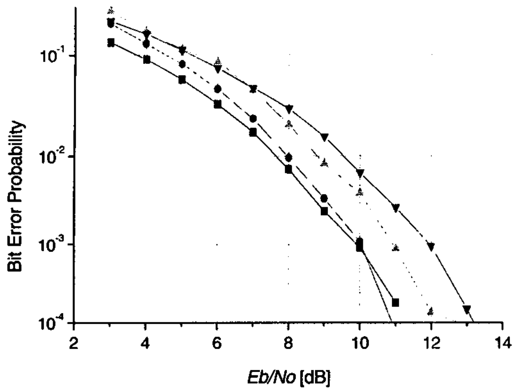

Fig. 3 Bit error probability relative to E_bN_o for channel A. (DFD-NFE: ▼$\beta_1=0.5, \beta_2=0.9$ DFD-FE: ▲$\beta_1=0.0, \beta_2=0.9$; ●$\beta_1=0.5, \beta_2=0.9$, ■ DFE/coherent)

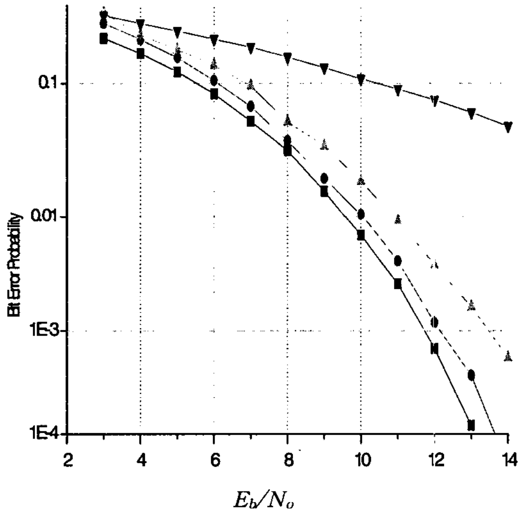

Fig. 4 Bit error probability relative to E_bN_o for channel B. (DFD-NFE: ▼$\beta_1=0.5, \beta_2=0.9$ DFD-FE: ▲$\beta_1=0.0, \beta_2=0.9$; ●$\beta_1=0.5, \beta_2=0.9$, ■ DFE/coherent)

Ⅳ. Conclusions

Decision feedback demodulator-based adaptive equalizers for the detection of DDPSK signals were proposed under the multipath fading channel with relatively large frequency uncertainties. The equalizers are based on extending the equalization techniques of DPSK to cases of DDPSK. Through computer simulations, it was confirmed that the performances of the decision feedback demodulation-based feedback equalizer (DFD-FE) werecomparable to those of the DFE,coherent.

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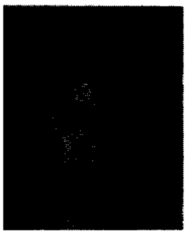

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