New algorithms for telecommunication channels adaptive equalization based on statistical characteristics of signals

Abstract

This thesis proposes a new solution of telecommunication channel adaptive equalizer with decision feedback structure (DFE) and so called *blind* algorithms which are initially driven by partially known statistical characteristics of transmitted signal. These blind algorithms are specially derived for the nonlinear part of the "*self-optimized*" DFE scheme (SO-DFE) [LABA1], i.e., its feedback filter (FBF), with the aim to improve the *post-cursor* intersymbol interference (ISI) cancellation which is the key equalization problem of signals with deep spectral nulls. Although the original SO-DFE works reasonably well, its overall convergence achievements are not very impressive in severe fading environments because its FBF filter, which is based on a "hard decision" device and *least mean-square* (LMS) algorithm, cannot meet learning ability to compensate for deep spectral nulls in the transmission passband.

The new blind adjustment method of the soft FBF (SFBF) filter coefficients is based on the learning principles of Bell-Sejnowski neuron model maximizing Shannon's entropy. Following this information theoretic approach, the set of propositions is defined how to select/design a complex-valued function for nonlinear mapping of a signal at the input of the SFBF filter. Generally, this mapping function is assumed to be continuously-differentiable, and also bounded in a way to guarantee a stable input-output transformation of a signal in every iteration of filter coefficients adjustment. Then, for the special complex-valued function $g(z) = z(1+\beta|z|^2)$, where β is a positive real constant, the basic stochastic gradient algorithm $b_{j,n+1} = b_{j,n} + \mu z(1-\beta|z_n|^2)r_n^*$ (CJEM) is derived for the SFBF filter coefficients $\{b_j\}$. In the next step, the CJEM is modified in accordance with the tasks of SFBF in the SO-DFE scheme. When the SFBF acts as the all-pole whitening filter of received signal (blind acquisition mode), the CJEM works as the corresponding decorrelation algorithm, and then, when the SO-DFE is transformed back into the classical DFE structure with the SFBF in its nonlinear part (soft transition mode), the CJEM uses the previously detected symbols, i.e., it works in decision-directed mode (DD-LMS). In this way, the improved SO-DFE (Soft-DFE) is obtained whose complete adaptation passes through three operation modes: blind acquisition, soft transition and classical DD-LMS tracking.

The parameter β, which changes the shape of the mapping function $g(z)$, is used as a suitable tool for CJEM algorithm optimization. In accordance with a simple procedure, the optimal value of β is selected for a given signal constellation by means of software simulations. Numerous simulations, which are carried out for a class of multipath channels in the presence of additive noise, have shown that the optimal value of β is practically independent of channel characteristics, but it depends only on the applied signal constellation. The purpose of this parameter selection method is to evade the β adaptive adjustment algorithm, and, in this way, to preserve a simple implementation of the CJEM algorithm.

Finally, the evaluation efficiency of the SFBF filter is considered by means of the comparison test between SO-DFE and Soft-DFE equalizers. The results of Monte Carlo simulations for 16-QAM and 32-QAM signals and severe multipath channels are provided. These tests, which have measured the mean square-error (MSE) convergence and convergence success with respect to the given MSE index corresponding to an enough open eye diagram, have confirmed the superiority of Soft-DFE with respect to SO-DFE. Also, this superiority comes from the new SFBF filter, i.e., its CJEM algorithms.

Index Terms: adaptive equalization, blind deconvolution, blind decision feedback equalization, joint entropy maximization criterion, Bell-Sejnowski neuron, Bell-Sejnowski learning rule.