利用軟體無線電實作遞迴最小化平方差分數取樣等化器

Implementation of RLS-FSE algorithm by Using Software-Defined Radios

指導教授：袁正泰 教授 指導學長：張維傑、許柏森 學生：鍾家燁

輔仁大學 電機工程學系 大學部專題生

Abstracts

•A Recursive Least-Squares algorithm based on fractionally-spaced equalizer (RLS-FSE) algorithm has been proposed, which is then applied in single-input-multiple-output (SIMO) measurement systems.

•Computer simulations were conducted based on baud-spaced equalizer (BSE) and FSE with four-path channel using MATLAB so that the proposed RLS-FSE algorithm can be compared with its Least-Mean-Square (LMS) algorithm and Normalized LMS (NLMS) algorithm counterparts [1].

•Experiments that demonstrate the mean-squared error (MSE) and the symbol error rate (SER) were also conducted to compare these algorithms on the software defined radio (SDR) platforms.

Introduction

•Adaptive channel equalization is an effective tool for eliminating intersymbol interference (ISI) caused by multipath channel distortion [2]. We describe the structure of the FSE algorithm by using a two-path channel as depicted in Fig. 1, in which $c_k^{(0)}$ and $c_k^{(1)}$ are the impulse responses of two the sub-channels, and $w_n^{(0)}$ and $w_n^{(1)}$ are the corresponding additive white Gaussian noise (AWGN). Notably, $r_n^{(0)}$ and $r_n^{(1)}$ are the received signal, and $f_{n,k}^{(0)}$ and $f_{n,k}^{(1)}$ are the time-varying tap weights of the adaptive sub-equalizers with s_n and y_n being the source signal and output signal, respectively. The proposed RLS-FSE algorithm is summarized in Table 1.

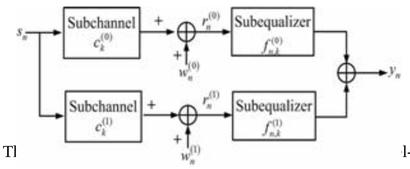


Fig. 1. Tl … l-path.

Table 1 Summary of the RLS-FSE algorithm

Initialize the algorithm by setting:

M: the sub-equalizer length

$$\mathbf{\Phi}_0^{-1} = \begin{bmatrix} \delta^{-1} & & 0 \\ & \ddots & \\ 0 & & \delta^{-1} \end{bmatrix}_{2M \times 2M}$$

where δ : positive constant has negative correlation with signal-noise ratio (SNR).

For each instant of time, $n = 1, 2, \ldots,$

Step 1: $\mathbf{k}_n = (\lambda^{-1} \cdot \mathbf{\Phi}_{n-1}^{-1} \mathbf{r}_n) / (1 + \lambda^{-1} \cdot \mathbf{r}_n^H \mathbf{\Phi}_{n-1}^{-1} \mathbf{r}_n)$

Step 2: $\mathbf{f}_n = \mathbf{f}_{n-1} + \mathbf{k}_n \cdot (\mathbf{s}_n^* - \mathbf{r}_n^H \cdot \mathbf{f}_{n-1})$

Step 3: $\mathbf{\Phi}_n^{-1} = \lambda^{-1} \cdot \mathbf{\Phi}_{n-1}^{-1} - \lambda^{-1} \cdot \mathbf{k}_n \mathbf{r}_n^H \mathbf{\Phi}_{n-1}^{-1}$

where $\mathbf{r}_n = [r_{n,0}^{(0)}, \cdots, r_{n,M-1}^{(0)} \mid r_{n,0}^{(1)}, \cdots, r_{n,M-1}^{(1)}]^T$ and $\mathbf{f}_n = [f_{n,0}^{(0)}, \cdots, f_{n,M-1}^{(0)} \mid f_{n,0}^{(1)}, \cdots, f_{n,M-1}^{(1)}]^T$.

•Laboratory Virtual Instrumentation Engineering Workbench (LabVIEW) developed by National Instrument™ (NI) has been used to control the SDR platform [3]. The LabVIEW is a visual-based programming language, and it uses a set of block diagrams rather than a set of sequential commands to implement the algorithms. The NI Universal Software Radio Peripheral (NI USRP), which is commonly used by researchers as a wireless prototyping platform, was chosen to be the SDR platform in our experiments.

Computer Simulations and Experiments

•Part I: Computer Simulations. In our computer simulations, we compare the FSE with the BSE by adopting a channel proposed by Z-Ding [4] and Proakis-A [5] when the normalized 16-quadrature amplitude modulation (16-QAM) was used with SNR = 30 dB.

•Simulation results demonstrate that FSE outperformed the BSE in terms of their rate of convergence and the steady-state MSE as shown in Figs. 5 and 6.

•Part II: Experiments. The outdoor experiments were conducted in the campus area of Fu Jen Catholic University, and the area consists of several buildings which are connected by roads and sidewalks. In contrast to the simulation systems, there are several uncontrollable factors, such as the traffic and the weather that make the conditions of wireless channel much more severe than those in simulations. These experiments were carried out by using two NI USRP-2920 platforms as the SDR transmitter (TX) and SDR receiver (RX) as shown in Figs.2 and 3.

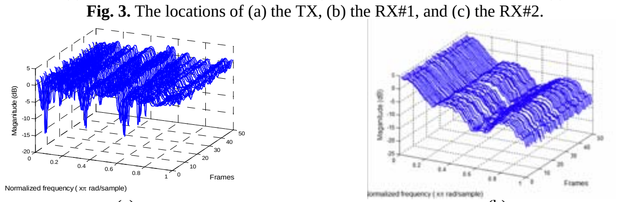
•Data frames were transmitted from the TX to both the RX #1 and the RX #2, and each frame contains 10000 symbols modulated by the normalized 16-QAM. Figure 4 shows the frequency impulse response of the estimated time-varying channel over 50 independent measurements in the outdoor environment.

•The ensemble averaged MSE and SER performances over 100 independent trials from our experiments in Fig. 7 demonstrates that the FSE system significantly outperformed the two BSE systems. Furthermore, the proposed RLS-FSE algorithm always displayed the best performance among the six algorithms.

Fig. 2. The location of the transmitter (TX) and the receivers (RX#1 and RX#2). The horizontal distance between the TX and the RX #1 (RX #2) is 110 meters (100 meters). The TX and the both RXs (RX #1 and RX #2), respectively, with a height of 24 meters and 1 meter above the ground level.

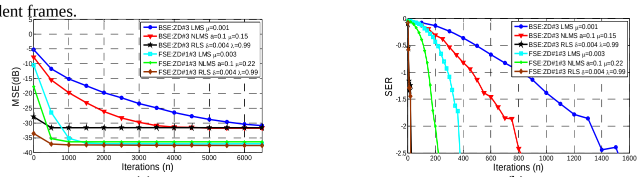
(a) (b) (c)

Fig. 3. The locations of (a) the TX, (b) the RX#1, and (c) the RX#2.



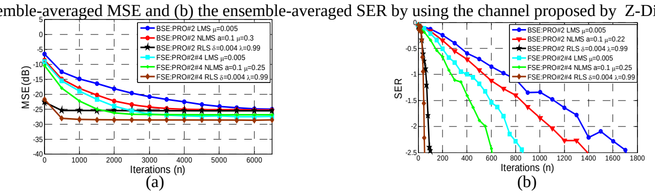
(a) (b)

Fig. 4. The frequency response of the estimated time-varying channel at (a) RX#1 and (b) RX#2 from 50 independent frames.



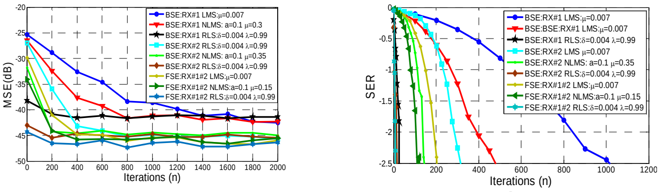
(a) (b)

Fig. 5. Comparison among LMS, NLMS, RLS algorithms based on FSE (N=35) and BSE (N=35) in terms of (a) the ensemble-averaged MSE and (b) the ensemble-averaged SER by using the channel proposed by Z-Ding [4].



(a) (b)

Fig. 6. Comparison among LMS, NLMS, RLS algorithms based on FSE (N=35) and BSE (N=35) in terms of (a) the ensemble-averaged MSE and (b) the ensemble-averaged SER by using the channel proposed by Proakis-A[5].



(a) (b)

Fig. 7. Comparison among LMS, NLMS, RLS algorithms based on FSE (N=11) and BSE (N=21) in terms of (a) the ensemble-averaged MSE and (b) the ensemble-averaged SER in the outdoor environments.

Conclusion

This work aims to implement a measurement system on software defined radios platforms. By evaluating the performances of the LMS, NLMS and RLS algorithms based on the BSE and the FSE in our simulations and experiments, results show that the FSE yielded a better performance in terms of MSE and SER than that of the BSE. The RLS-FSE algorithm outperformed other algorithms in terms of their steady-state MSE and rate of convergence.

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