國 立 交 通 大 學

電信工程研究所

博 士 論 文

數位無線通訊系統之通道估計與等化技術的研究

A Study on Channel Estimation and Equalization Techniques for Digital Wireless Communication Systems

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摘 要

在一個多路徑衰變通道的環境中，符際干擾(Intersymbol interference)會明顯地降低無線通訊系統的效能，通常大家所採用的補救方法是用等化器來緩和符際干擾效應，而等化器則須輔助以良好的通道估計才能精確的發揮其功能。此外，也可進一步去加強等化器的功能。在本論文中，我們提出兩個改善傳統通道估計方法的技術，另外也提出一個能增進傳統檢測器(或等化器)效能的後檢測器技術。

首先，著眼於將每筆傳輸區塊中的已知資料做最大限度的使用，我們提出一種以最小平方(Least squares)為基礎的兩級式通道估計法。此架構將通道估計分成兩級，第一級先用傳統的通道估計法針對正常訓練序列(Normal training sequence)粗估出通道脈衝響應。然後估算出此通道的最大通道記憶長度，並運用它去找出在訓練序列的守護區間中沒受到前方隨機資料透過通道記憶而影響到的無污染資料。第二級則是將此無污染資料與正常訓練序列一起利用最小平方法來細估通道脈衝響應。根據理論分析與電腦模擬的結果顯示，我們所提出之通道估計法之效能優於傳統單級通道估計法之效能。

接著，為了降低前法在第二級使用最小平方法所需的計算量，我們提出一個以多路徑干擾消去為基礎的兩級式通道估計法。第一級先用傳統的通道估計法針對正常訓練序列求出通道脈衝響應。 然後估算出此通道的最大通道記憶長度及有效路徑，並運用此資訊去找出不受前方資料透過通道記憶而影響到的訓練序列區間，同時也在此區間進行有效路徑的資料重建。接著計算個別路徑的干擾並從接收訊號中萃取出個別路徑訊號。第二級則是運用個別路徑訊號與其所對應到的訓練序列資料進行相關運算來估算出細調的通道脈衝

響應。根據理論分析與電腦模擬的結果顯示，此通道估計法之效能和前法相當且均優於傳統單級通道估計法之效能，但此法所需的計算複雜度則明顯地低於前述以最小平方為基礎的兩級式通道估計法。

最後，我們提出一個可用來增進接收機效能的後檢測器技術。此架構將接收機分成前檢測器與後檢測器。在經過前檢測器與通道估計器後，可取得初步決斷的資料與通道脈衝響應。接著後檢測器則是聯合運用這兩個資訊去計算每一單獨路徑所受的多路徑干擾，進而萃取出每一條單獨路徑的信號，再利用最大比例結合(Maximal-ratio combining)的方法去結合所有單獨路徑的信號以提升系統的訊噪比，使得系統的信號更正確。再進一步則可利用軟決定並回授到後檢測器的輸入重複去做，使系統的效能逐次地增進。根據電腦模擬的結果顯示，如預期的此系統的效能依重複執行次數的增加而逐漸增進。

A Study on Channel Estimation and Equalization Techniques for Digital Wireless Communication Systems

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Abstract

The performance of typical wireless communication systems is significantly degraded by intersymbol interference (ISI) in multipath fading channels. As a remedy, equalizers have been employed to alleviate the ISI effects. However, an accurate estimation of channel impulse response (CIR) is usually required in order to ensure successful equalization. In addition, an equalizer can be enhanced to improve the system performance. In this dissertation, two channel estimation methods and a posterior detector are proposed to improve the performances of conventional channel estimation techniques and a conventional data detector (or equalizer).

First, a least-squares based two-stage channel estimation (LS-2SCE) method is proposed. In contrast to conventional channel estimation methods, this method makes the maximum use of the information contributed by the known data in every transmission burst. In the first stage, the least-squares (LS) algorithm was used to estimate the CIR based on the normal training sequence. Then the maximum channel memory was estimated and used to locate the uncorrupted data in the guard interval. In the second stage, the uncorrupted data together with the normal training sequence were sent to the LS algorithm again to obtain the fine-tuned CIR. Both theoretical analysis and computer simulations were done to verify the efficiency of the proposed method. Computer simulation results confirm the analysis results and demonstrate that the proposed LS-2SCE method outperforms a conventional single-stage channel estimation method.

Secondly, a multipath interference cancellation based two-stage channel estimation (MIC-2SCE) method is proposed to avoid the needed computation complexity of the LS-2SCE method in processing the LS algorithm in the second stage. In the first stage, a conventional channel estimation method based on the normal training sequence was used to estimate a coarse CIR. After the maximum channel memory and the effective paths were estimated, they were used to locate the uncorrupted data in the received training sequence and reconstruct the individual path data of each effective path in the second stage. In this stage, the individual path interference could be calculated and the individual path signal could be extracted from the received signal. Then, the individual path signal was used to correlate with the corresponding data in the training sequence to obtain the fine-tuned CIR. Theoretical analysis and computer simulations were done to verify the efficiency of the proposed method. Computer simulation results confirm the analytical results and demonstrate that the proposed MIC-2SCE method outperforms a conventional single-stage channel estimation method. Furthermore, from our simulation results and the discussion on computation complexity, it is clear that the MIC-2SCE method has approximately equal MSE performance as that of the LS-2SCE method but it has a lower computation complexity.

Finally, a posterior detector for wireless communication systems is proposed. The whole detector is divided into a preliminary detector and a posterior detector. After the preliminary detector and channel estimator, the preliminarily decided data and estimated CIR could be acquired. Jointly using these corresponding results, the individual path interference could be calculated and the individual path signals could be extracted. Then, maximal-ratio combining (MRC) technique was used to combine these signals to get more reliable data. Furthermore, a soft decision was executed and its output was sent back to the posterior detector to improve the system performance successively. Computer simulation results demonstrate that the proposed posterior detector achieves diversity gains in inherent multipath environments and BER performance becomes better as the iteration time increases.

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