行政院國家科學委員會專題研究計畫　期中進度報告

多輸入多輸出有限脈衝系統的盲判別與對等化(1/3)

計畫類別：個別型計畫
計畫編號：NSC92-2213-E-009-085-
執行期間：92 年 08 月 01 日至 93 年 07 月 31 日
執行單位：國立交通大學電機與控制工程學系

計畫主持人：林清安

報告類型：精簡報告
報告附件：出席國際會議研究心得報告及發表論文
處理方式：本計畫可公開查詢

中　華　民　國 93 年 5 月 28 日

Blind Identification and Equalization of MIMO FIR Systems
A Progress Report

NSC-93-2213-E-009-041

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We describe briefly the research work in progress, the preliminary results obtained so far, and the expected final results at the end of the first year's research. We will give more specific and more detailed account of the first year's research effort in the **Final Report**. Topics of research we have undertaken includes

- Blind OFDM channel identification taking advantage of finite alphabet source property
- Equalization of FIR periodic channel
- Subspace method: robustness channel order over-estimation

1 Blind OFDM channel identification taking advantage of finite alphabet source property

Suppose the wireless channel is frequency selective and is described by the FIR transfer function

$$H(z) = h_0 + h_1 z^{-1} + \cdots + h_L z^{-L}.$$

The orthogonal frequency division multiplexing (OFDM) technique converts the channel into a flat fading channel described by the multi-carrier gains $H(e^{j2\pi k/M})$, $k = 0, 1, \cdots, M-1$, where M is the number of tones or carriers.

This is achieved by preprocessing the source signal before it is sent through the channel and postprocessing the received signal before equalization. The preprocessing consists of serial-to-parallel conversion, IFFT, and cyclic prefixing (CP); the postprocessing consists of CP removal, FFT, and parallel-to-serial conversion. The advantage gained by these pre- and post- processing is that the relation between source and (FFT) output is freed from inter-symbol-interference (ISI) and that the equalization and signal detection is much simplified.

Let s be the source sequence and y be the sequence obtained at the output of the parallel-to-serial converter. The input-output relation the OFDM channel becomes

$$y(n) = H(e^{j2\pi k/M})s(n) + v(n)$$

where $k = n \bmod M$ and v is the additive channel noise. The channel is thus periodic with period M and can be considered constant (and diagonal) if block inputs and outputs (of size M) are used.

The usual assumptions for the OFDM channel are

- The source s is stationary with zero-mean and is drawn from a finite alphabet set with equal probability
- The channel noise v is white zero-mean circular Gaussian
- The channel noise and the source are uncorrelated spatially and temporally

We note that the output signal y is cyclostationary, the auto-covariance function is periodic with period M. Under the assumptions, it follows that

$$Ey^l = H(e^{j2\pi k/M})^l Es^l$$

for any positive integer l. Since the source is drawn from a finite set of alphabets, there is a minimal integer J so that

$$Es^J \neq 0 \text{ and } Es^l = 0, \; \forall 0 \leq l \leq J-1$$

For QAM constellations, $J = 4$; for PSK constellations, $J =$ the number of alphabet in the set, *e.g.*, $J = 2$, for BPSK, $J = 4$, for QPSK.

This property can be used for estimation and hence equalization of the channel. First we have

$$H(e^{j2\pi k/M})^J = \frac{Ey(k)^J}{Es(k)^J}, \; 0 \leq k \leq M-1$$

Since $Es(k)^J$ is constant and known and $Ey(k)^J$ can be approximately computed by time average, the quantities

$$H(e^{j2\pi k/M})^J, \;\; 0 \leq k \leq M-1.$$

can be approximately computed. Of interest, from equalization point of view however, is

$$H(e^{j2\pi k/M}), \;\; 0 \leq k \leq M-1.$$

There is phase uncertainty when we try to determine $H(e^{j2\pi k/M})$ from $H(e^{j2\pi k/M})^J$, specified by the Mth roots of unity. A key problem in blind identification of the channel is to remove this phase uncertainty reliably and with reasonable amount of computation. Methods proposed in the literature include the minimum distance (MD) method, the modified minimum distance (MMD) method, modified minimum distance method with phase directed (MMD-PD) algorithm [1], and the clustered subcarrier (CSC) algorithm [2]. The first 3 methods rely on exhaust search and thus are computationally unrealistic when J and L, the channel order, is large. The CSC method is in comparison much less computation intensive but is less accurate.

Our research is mainly on the removal of phase uncertainty, *i.e.*, to determine $H(e^{j2\pi k/M})$ from $H(e^{j2\pi k/M})^J$ reliably. We propose a method based on the observation that the phase change is small over the adjacent tones where the magnitude is large. Hence if we compute the ratio

$$(\Delta H_k)^J = \frac{H(e^{j2\pi k/M})^J}{H(e^{j2\pi (k+1)/M})^J}$$

we can confidently determine

$$\Delta H_k = \frac{H(e^{j2\pi k/M})}{H(e^{j2\pi (k+1)/M})}$$

by choosing the phase of ΔH_k to be the one with the smallest absolute value (among the possible J values). We could then compute the channel gain at a number of tones (where magnitude is large), the rest of the gain can be computed by solving least squares problems. The method drastically reduces the amount of computation required. We are in a stage of writing up the paper. Further research in this area includes robustness with respect to channel order overestimation.

2 Equalization of FIR periodic channel

We study the problem of equalization of periodic FIR channel. The periodic channel may arise from periodic modulation at the transmitter. The periodic channel is described by

$$z_n = \sum_{k=0}^{M} g_{n,k} u_{n-k}, \ n \geq 0.$$

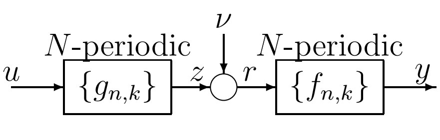
where

- the coefficients satisfy $g_{n+N,k} = g_{n,k}$, for $k, n \geq 0$.
- the filter is of order M, if $g_{n,M} \neq 0$ for some n.
- the filter is completely described by $N(M+1)$ coefficients

$$g_{n,k}, \quad 0 \leq n \leq N-1, \quad 0 \leq k \leq M$$

The equalization problem can be formulated as one of finding an approximate inverse.

Consider the following diagram



$$z_n = \sum_{k=0}^{M} g_{n,k} u_{n-k}, \quad r_n = z_n + \nu_n, \quad y_n = \sum_{k=0}^{M_1} f_{n,k} r_{n-k}$$

where

- input u : white zero-mean, $E|u_k|^2 = 1, \forall k$.
- noise ν : white zero-mean, $E|\nu_k|^2 = \delta_\nu^2, \forall k$.
- u and ν are uncorrelated.
- M_1 : order of the approximate inverse

The problem: Find FIR N-periodic filter so that $y \simeq$ a delay version of u.

The difference between y and the d-step delayed u (at time n) is

$$e_n = y_n - u_{n-d}$$

Proposition:

(a) $Ee_n = 0, \ \forall n \geq 0$.

(b) $E|e_n|^2 = E|e_{n+N}|^2, \ \ \forall n \geq M + M_1$.

(c) $J := \sum_{n=K}^{K+N-1} E|e_n|^2$ is constant for all $K \geq M + M_1$.

Optimal inverse problem Choose

$$f_{n,k} \ \ 0 \leq k \leq M_1, \ 0 \leq n \leq N-1$$

so that J is minimized.

Assumption: $M_1 \geq \max(d - M, 0)$ (hence $M + M_1 \geq d$.)

We solve this problem for SISO periodic channel. The optimal or minimum mean square equalizer is also periodic and its impulse response can be found by solving a set of least squares problems. The result is presented at ICASSP2004 [**?**]. We are currently extending this result to MIMO periodic channels.

3 Subspace method: robustness channel order over-estimation

The subspace method for blind channel identification has been proposed for both SISO channels and SIMO channels [4, 5]. One major weakness of the method is its sensitivity to channel order overestimation. If the channel is overestimated the computed channel coefficients are not confined in a one dimensional null space of a certain matrix, but instead the null space has dimension great than 1. We propose a algorithm which can be used to find the best linear combination of the independent vectors in the null space to give the best estimate of channel impulse response. We are in the process of verifying the result by numerical examples. The preliminary result we obtained so far look promising.

4 Discussions

In addition to the problem discussed in the previous three sections, we are also studying problems relating to MIMO channels. These problems include blind identifiability condition for MIMO FIR channel, extension of periodic modulation and the corresponding blind identification problem to MIMO channel, and power control problem in multiuser wireless systems. We will present some of these results at the 2005 ISCAS.

References

[1] S. Zhou and G. B. Giannakis, "Finite-Alphabet Based Estimation for OFDM and Related Multicarrier Systems," *IEEE Trans. Communications*, Vol. 49, No. 8, pp. 1402-1414, 2001.

[2] T. Petermann, S. Vogeler, K. Kammeyer, and D. Boss " Blind TurboChannel Estimation in OFDM Receivers," *Proceedings 35th Asilomar Conference on Signals, Systems, and computers* , pp. 1489-1493, 2001.

[3] J. Y. Wu and C. A. Lin,"Optimal FIR Approximate Inverse of Linear Periodic Filters," Proceeding ICASSP 2004, Montreal Canada, May 17 – May 21, 2004.

[4] E. Moulines, P. Duhamel, J. Cardoso and S. Mayargue, "Subspace methods for blind identification of multichannel FIR filters," *IEEE Trans. Signal Processing*, Vol. 43, No. 2, pp. 516-525, 1995.

[5] K. Abed-Meraim,et. al., "On subspace methods for blind identification of single-input multple output FIR systems," *IEEE Trans. Circuits and Systems-I*, Vol. 44, No. 9, pp. 813-820, 1997.