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Direct Method for Converting FIR Filter with Low Nonzero Tap into IIR Filter

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Abstract—In this paper, we proposed the direct method for converting Finite-Impulse Response (FIR) filter with low nonzero tap into Infinite-Impulse Response (IIR) filter using the pre-determined table. The prony method is used by ghost cancellator which is IIR approximation to FIR filter which is better performance than IIR and have much larger calculation difference. The direct method for many ghost combination with low nonzero tap of NTSC(National Television System Committee) TV signal in Korea is described. The proposed method is illustrated with an example.

Keywords—NTSC, Ghost cancellation, FIR, IIR, Prony method.

I. Introduction

RECEPTION of NTSC TV signals and other signal in urban or hilly area are often derogated from the presence of electrically large reflecting objects such as the obstacle. The multipathing effect generator multi-path reception , refered to as ghosting , is widespread problems. Using a lot of ideas and algorithms many paper have addressed the ghost cancellation problem [1]– [13].

The characteristic of NTSC TV signal is line-by-line processing which overcomes limitations of standard equalizers to allow suppression of ghosts even with nulls and ghosts are completely eliminated as long as the total ghost with delays. This paper describes a new simple ghost cancellation system built-in NTSC television which method for calculating the filter coefficients simply. FIR filter (or equalizer) provides a good solution to the ghost problem, even though it requires more taps than an IIR filter (or equalizer). Therefore many technique about the IIR approximation of FIR filter [7]– [13].

That is performed in the state space by applying model reduction techniques are the most promising in [10] and [11]. A stable IIR ghost filter that represents a good approximation using the Hankel norm was obtained by truncating and balancing the state-space model of the FIR filter [5] and [12]. But, the prony method provides more better performance than hankel method. The proposed direct method using the characterizations to NTSC TV signal with low nonzero tap and prony method, this paper provides simple conditions for the given IIR filter approximations to converge as numerator order increases to the desired FIR filter.

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The paper is organized as follows. Chapter 2 will provide the basic method FIR filter by IIR filter. Chapter 3 presents an the direct method for converting FIR filter with low nonzero tap into IIR filter using the pre-determined table. Chapter 4 illustrates the performance of the proposed method . Finally, concluding remarks are presented in Chapter 5.

II. FIR filter by IIR filter

A. Prony Method

Let us consider the following channel model:

$$H(z) = \frac{B(z)}{A(z)} = \frac{b_0 + b_1 z^{-1} + \cdots + b_M z^{-M}}{1 + a_1 z^{-1} + \cdots + a_N z^{-N}} \quad (1)$$

$$= \sum_{n=0}^{\infty} h[n] z^{-N} \quad (2)$$

$$B(z) = H(z)A(z) \quad (3)$$

$$\begin{bmatrix} b_0 \\ b_1 \\ \vdots \\ \vdots \\ b_M \\ 0 \\ \vdots \\ \vdots \\ 0 \end{bmatrix} = \begin{bmatrix} h_0 & 0 & 0 & \cdots & 0 \\ h_1 & h_0 & 0 & \cdots & 0 \\ \vdots & h_1 & h_0 & 0 & 0 \\ \vdots & & & & \vdots \\ \vdots & & & & \vdots \\ h_M & & & & \vdots \\ \vdots & & & & \vdots \\ \vdots & & & & \vdots \\ h_K & \cdots & \cdots & \cdots & h_{K-N} \end{bmatrix} \begin{bmatrix} 1 \\ a_1 \\ a_2 \\ \vdots \\ \vdots \\ \vdots \\ a_N \end{bmatrix} \quad (4)$$

$$\left[\begin{array}{c} \mathbf{b} \\ \hline 0 \end{array}\right] = \left[\begin{array}{c|c} \multicolumn{2}{c}{H_1} \\ \hline h_1 & H_2 \end{array}\right] \left[\begin{array}{c} 1 \\ \hline \mathbf{a} \end{array}\right] \quad (5)$$

$$\mathbf{a} = (H_2^T H_2)^{-1} H_2^T h_1 \quad (6)$$

$$\mathbf{b} = H_1 * \begin{bmatrix} 1 \\ \mathbf{a} \end{bmatrix} \quad (7)$$

where **b** is column vector of the N denominator coefficients of (1), **a** is column vector of the $M+1$ numerator coefficients of (1), h_1 is column vector of the last $K-M$ terms of the impulse response, H_1 is $(M+1)$ by $(N+1)$ partition of the matrix in (5) and H_2 is $(K-M)$ by N partition of the matrix in (5).

III. Proposed Prony Method Direct Table with Low Nonzero Tap

Assume that the condition is following holds:

$$O_1 < O_2 < O_3 < \cdots < O_n \quad (8)$$

where O_n is a order of n-th nonzero tap. (9)

TABLE I
THE DIRECT TABLE WITH 3 NONZERO TAP

Position of O_2 and O_3	Position of K and M	a	b
$O_2 = M+1$ $O_3 \geq K+1-M$	$K < 2M$	$\begin{bmatrix} 0 \\ \vdots \\ 0 \\ \frac{\beta}{\alpha} \\ 0 \\ \vdots \end{bmatrix}$	$\begin{bmatrix} 1 \\ 0 \\ \vdots \\ 0 \\ \frac{\beta}{\alpha} \\ 0 \\ \vdots \\ \beta \end{bmatrix}$
$O_2 = M+1$ $O_3 \geq K+1-M$	$K = 2M$	$\begin{bmatrix} 0 \\ \vdots \\ 0 \\ \frac{\beta}{\alpha} \end{bmatrix}$	$\begin{bmatrix} 1 \\ 0 \\ \vdots \\ 0 \\ \alpha+\frac{\beta}{\alpha} \end{bmatrix}$
$O_2 < M+1$ $O_3 \geq K+1-M$	$K < 2M$ $K = O_2+M-1$	$\begin{bmatrix} 0 \\ \vdots \\ 0 \\ \frac{\beta}{\alpha} \end{bmatrix}$	$\begin{bmatrix} 1 \\ 0 \\ \vdots \\ 0 \\ \frac{\beta}{\alpha} \\ 0 \\ \vdots \\ \beta \end{bmatrix}$
$O_2 < M+1$ $O_3 \geq K+1-M$	$K < 2M$ $K < O_2+M-1$	$\begin{bmatrix} 0 \\ \vdots \\ 0 \\ \frac{\beta}{\alpha} \\ 0 \\ \vdots \\ 0 \end{bmatrix}$	$\begin{bmatrix} 1 \\ 0 \\ \vdots \\ 0 \\ \frac{\beta}{\alpha} \\ 0 \\ \vdots \\ \beta \\ 0 \\ \vdots \\ 0 \\ \beta \end{bmatrix}$
other case	other case	no solution	no solution

Using the characteristics of NTSC TV signal with low nonzero tap, this paper provides theoretical conditions for the given IIR filter approximations to converge as numerator order increases to the desired FIR filter.

A. 3 Nonzero Tap Weight

The case is the direct method with 3 nonzero tap. Prony Method Direct Table is written by Table I.

B. N Nonzero Tap Weight

The case is the direct method with N nonzero tap. The filter is following holds:

$$h = \begin{bmatrix} 1 & \cdots & \alpha\cdots\beta\cdots\gamma\cdots(N-2)\cdots(N-1)\cdots N \end{bmatrix}. \quad (10)$$

The following condition is necessary condition which have solutions with coefficients of **a** and **b**.

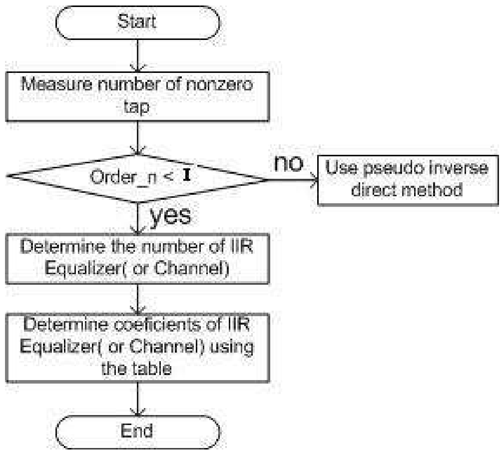


Fig. 1 Flowchart of the algorithm

Note that

$$\begin{aligned} O_{h2} &\leq M+1 && (11)\\ O_{h3}+1 &\leq O_{h2}+M && (12)\\ O_{h4}+1 &\leq O_{h3}+M && (13)\\ &\vdots && (14)\\ K+1 &\leq O_{h(N+1)}+M && (15) \end{aligned}$$

where O_{hn} is the order of n-th tap , K is a order in last tap of h and M is the order of 2-th tap.

Algorithm: Direct Method for converting FIR filter into IIR filter

(1) Measure number of nonzero tap in FIR filter.
(2) If it is larger than I. Else, go step 3 .
(3) Determine the number if IIR Equalizer.
(4) Solve the IIR ghost problem using the direct table

The objective is to make an algorithm and direct table to use and gain good performance.

IV. SIMULATION RESULTS

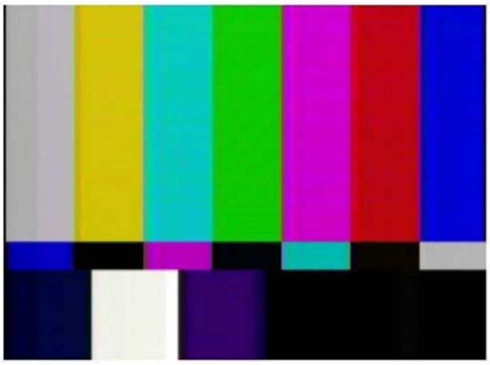
Example 1: To demonstrate the performance of the proposed method, let us consider the ghost combination 2 in [1] which is Korean ghost cancellation reference signal :

$$\begin{aligned} Path\ delay &= \begin{bmatrix} 0 & 0.45 & 2.3 \end{bmatrix} \mu s && (16)\\ Path\ gain &= \begin{bmatrix} 0 & -19 & -24 \end{bmatrix} dB && (17) \end{aligned}$$

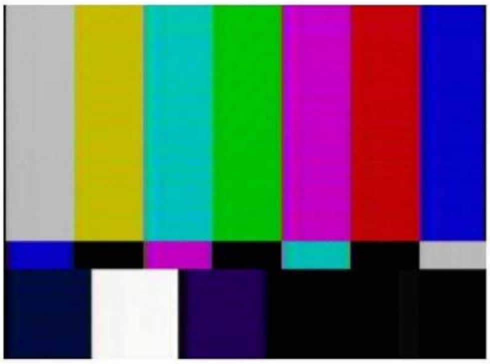
In this case, assume that $M = N$ FIR ghost filter have 139 taps and 5 nonzero taps. But, the proposed ghost filter have only 71 taps with This filter coefficeints are simply solved by Table and Algorithm 1.

Example 2: To demonstrate the performance of the proposed method, we consider the ghost combination 4 in [1] which is Korean ghost cancellation reference signal. The ghost combination 4 is following as:

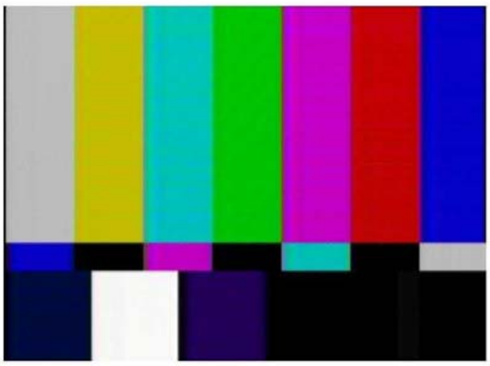
$$\begin{aligned} Path\ delay &= \begin{bmatrix} 0 & -1.8 & 2.2 & 39.0 \end{bmatrix} \mu s && (18)\\ Path\ gain &= \begin{bmatrix} 0 & -23 & -14 & -20 \end{bmatrix} dB && (19) \end{aligned}$$



(a)

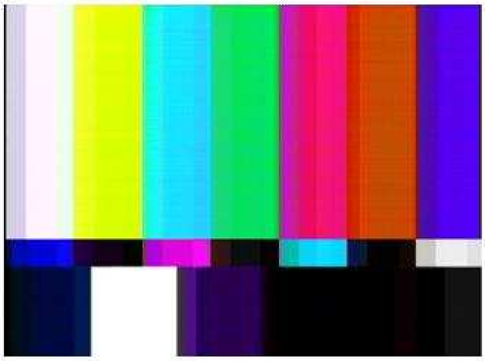


(b)

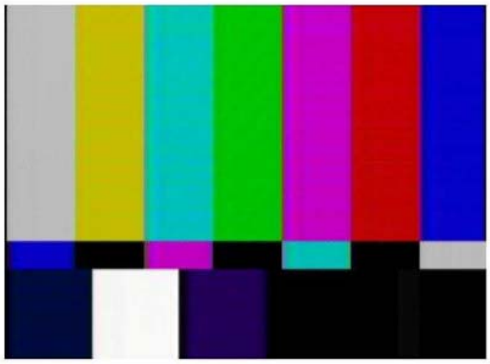


(c)

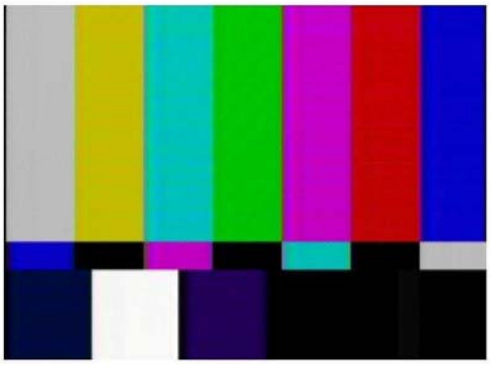
Fig. 2. (a) The original image with ghost, (b) The deghosting image using FIR Ghost equalizer, (c) The deghosting image using IIR Ghost equalizer



(a)



(b)



(c)

Fig. 3. (a) The original image with ghost, (b) The deghosting image using FIR Ghost equalizer, (c) The deghosting image using IIR Ghost equalizer

As shown in Fig. 2 and Fig. 3, we can easily find the coefficients. So we find the big difference by comparing Fig. 2(a)and Fig. 3(a) and Fig. 2(c) and Fig.3(c), But,by comparing Fig. 2(b) and Fig. 3(b) and Fig. 2(c) and Fig.3(c), we can't find the difference of image.

V. Conclusion

We proposed the direct method for converting FIR filter with low nonzero tap into IIR filter using the pre-determined table. But, proposed Direct Tables Method, which we use, have big profit in computation because it need only little calculation of $0.5 * M^2$, when we gain the filter coefficient in **a** and **b**. We experimented on FIR ghost equalizer that we proposed as ghost model [1] which had about 100 $\sim$ 600taps. Tap of true nonzero tap weight is below 10 numbers, and little tap of multi-step method have only nonzero tap weight at a time, therefore, if we do approximation FIR ghost equalizer which we proposed for IIR ghost equalizer, we will get shorter computation.

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