IMPROVEMENT OF CONVERGENCE SPEED FOR SUBBAND ADAPTIVE DIGITAL FILTERS USING THE MULTIRATE REPEATING METHOD

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ABSTRACT

We propose a method for achieving both a fast convergence speed and the low orders of adaptive digital filters(ADFs) for subband ADFs. The proposed method is based on the multirate repeating method which uses wasted signals by downsampling. First we show how to apply the multirate repeating method to the standard structure of subband ADFs. Next we consider a new structure of subband ADFs for extending the multirate repeating method. Finally, we show the validity of the proposed method by computer simulations.

1. INTRODUCTION

Adaptive digital filters(ADFs) have been used in echo cancellation for the ease of adaptations and the simplicity of the structure. The echo path to be equalized is ordinarily in the order of thousands in order to achieve practical echo cancellation. Equalizing such long systems restricts constraints on the real-time capabilities of the system while using standard architectures. To overcome this problem the subband ADFs have been proposed[?]-[?].

The subband ADFs can achieve a lower order of ADFs and generate both advantages of reducing computational complexity and improving the effect of colored signals. Decreasing the orders of ADFs is related closely to the number of channels and the decimation ratio. It is well known that the choice of the large number of channels and large decimation ratios provides better efficiency for reducing the orders of ADFs. However, the large decimation ratio causes the problem of a late convergence speed in real-time system identifications, since the number of updates of the weights of ADFs per time decreases. Therefore the subband ADF provides a poor convergence speed when the decimation ration is large, although the orders of ADFs are reduced.

In this paper we consider applying the multirate repeating method[?]-[?] to subband ADFs for improving the problem. Generally, most of the signals are wasted by downsampling for subband ADFs. On the other hand the multirate repeating method utilizes the wasted signals for improving the convergence speed. The use of the multirate repeating method enables us to increase the number of updates per time so that we can achieve a fast convergence speed without increasing the orders of ADFs.

Moreover we consider a new structure of subband ADFs for extending the multirate repeating method. When the number of channels is small in the standard structure, we cannot select the large number of updates. The small number of updates restricts the improvement of the convergence speed on using the multirate repeating method. The new structure of subband ADFs has a large degree of freedom for selecting the number of updates, even if the number of channels is small. As a result we can realize a faster convergence speed than the standard structure.

2. APPLYING THE MULTIRATE REPEATING METHOD TO SUBBAND ADFS

In this section we consider applying the multirate repeating method to the M channel subband ADF as shown in Fig.1.

2.1. The multirate repeating method

The multirate repeating method utilizes the wasted signals by decimation for updating the weights of ADFs. The principle figure of the method is shown in Fig.2. To briefly discuss, Fig.2 shows an arbitrary pth channel in Fig.1, where the number of repeats N is chosen as $N \leq D$, namely N is less than or equal to the decimation ratio D.

In Fig.2, the output signal $g(n)$ of an unknown system and the input signal $x(n)$ are filtered by the analysis filter $H_p(z)$ and then decimated to $1/D$ at different timings. Here D data sequences $x_{p,0}(m), x_{p,1}(m), \cdots,$

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$x_{p,D-1}(m)$ are generated from $g(n)$ and similarly D desired sequences are generated from $d(n)$. From these data we can choose N data for updating the ADFs. Using the multirate repeating method[5]-[7], the weights of ADFs $h_p(m)$ are updated N times per unit time before downsampling. For example, when using the normalized LMS(NMLS) algorithm, $h_p(m)$ is updated as follows.

For $l = 0$ to $N-1$

$$h_p(m+l+1) = h_p(m+l) + \alpha e_{p,l}(m) x^*_{p,l}(m) \quad (1)$$

$$\alpha = \beta / |x_{p,l}(m)|^2 \quad 0 < \beta < 2 \quad (2)$$

End

where h_p and $x_{p,l}$ indicate the tap-weight vector and the tap input vector respectively. $e_{p,l}(m)$ denotes the error signal between $x_{p,l}(m)$ and $d_{p,l}(m)$. The error is expressed as

$$e_{p,l}(m) = d_{p,l}(m) - h_p(m)^T x_{p,l}(m) \quad (3)$$
$$l = 0, 1, \cdots, N-1$$
$$p = 0, 1, \cdots, N-1$$

Note that the number of repeats N has no influence on the length of ADFs so that the orders of ADFs are not increased even if we choose $N < D$.

2.2. A degree of freedom for selecting data

Applying the multirate repeating method, the number of repeats N is chosen as $N \leq D$. If we choose $N < D$, the multirate repeating method has some degrees of freedom for selecting data. In Fig.2, N data sequences for updating ADFs are selected at continuous timings as $x_{p,0}(m), x_{p,1}(m), \cdots, x_{p,N-1}(m)$. However the multirate repeating method enables us to pick out not only data sequences at continuous timings but also at different timings.

For example we consider the case for $M = 4$ and $N = 2$. Fig.3 shows two examples for selecting data in this case. Here it is possible to choose N data sequences as either (a) or (b) in Fig.3. Note that both (a) and (b) achieve the improvement of the convergence speed and the way of (b) is easier to realize than (a) since the method (b) has a constant time interval for updating the weights of ADFs.

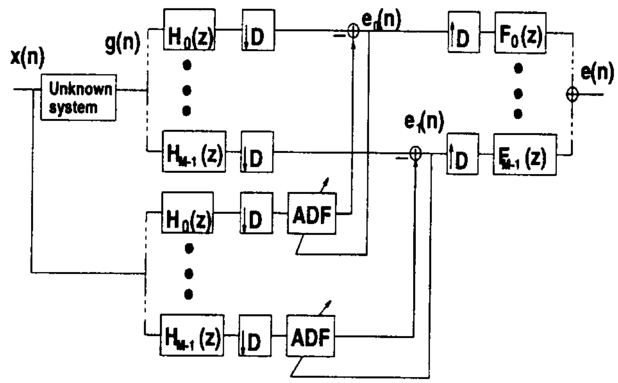

Fig.1 The standard M-channel subband ADF.

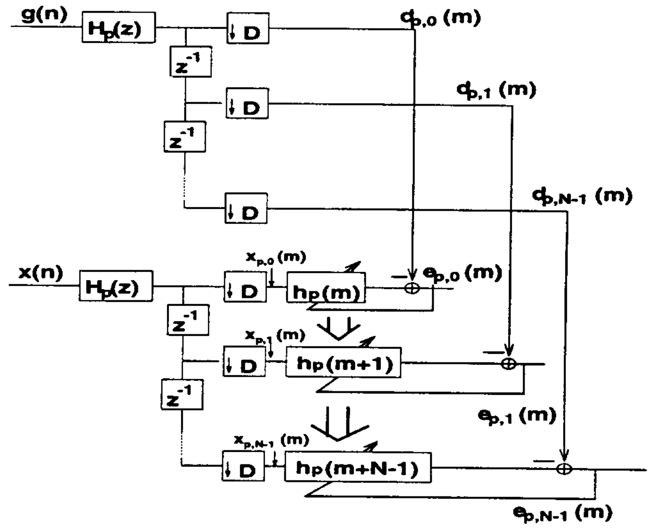

Fig.2 The multirate repeating method for pth channel.

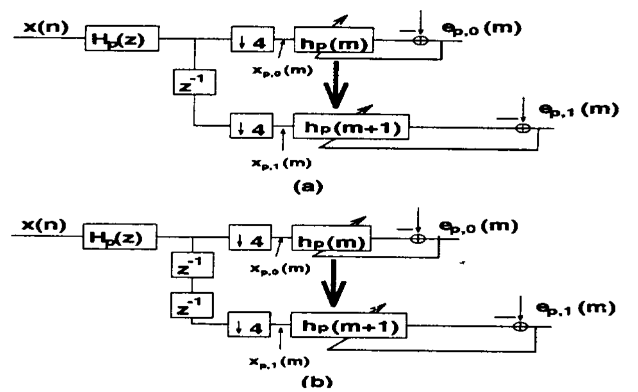

Fig.3 Examples of data choice at different timing for the multirate repeating method.

3. EXTENSION OF THE MULTIRATE REPEATING METHOD

Since the decimation ratio D has to be chosen as $D \leq M$, when the number of channels M is small we cannot choose a large D, accordingly also a large N as the number of repeats from the relation $N \leq D$. The small number of repeats restricts the improvement of the convergence speed. To solve the problem we introduce a new structure of the subband ADFs.

3.1. A filter bank with rational decimation ratio

A filter bank with rational decimation ratio is shown in Fig.4, where U, M and D are positive integers. The filter bank has been proposed for avoiding the effect of the aliasing with maximally decimation($M = D$)[4]. In this paper, we show that the structure is also effective for applying the multirate repeating method.

The filter bank consists of complex filters and the procedure of the filter bank is explained as follows. The input signal to the filter bank is interpolated with ratio U, then split into M frequency bands by the analysis filters $H_p(z)(p = 0, 1, \cdots, M-1)$, and each subband signal is downsampled to $1/D$. The downsampled signals are upsampled, then added up after filtering with the synthesis filters $F_p(z)$. Finally only real part of the composed complex signal is picked out by "2Real" procedure in Fig.4, then downsampled to $1/U$ and filtered by equalizer $E(z)$ which corrects all-pass characteristics. After these procedures the input signal is reconstructed. In Fig.4 $E(z)$ is not always necessary, if the other filters are designed so that the filter bank is satisfied with the conditions of perfect reconstruction.

3.2. Overcoming the restricts of the repeat number

In Fig.4, the decimation ratio R of the filter bank is defined as

$$R = D/2U, \qquad 2U \leq D < 2MU \tag{4}$$

where D and U are positive integers. We can see from Eq.4 that when $D = 2U$ the decimation ratio R is 1, when $D = 2MU$ the decimation ratio R equals to M and it corresponds to the usual critical sampling.

Note from Eq.4 that it is possible to select D larger than M so that the number of repeats N is chosen as $N < 2MU$. As a result the subband ADF using the filter bank enables us to choose a large N and overcome the restrictes of the number of repeats on using the multirate repeating method, even if the number of channels M is small.

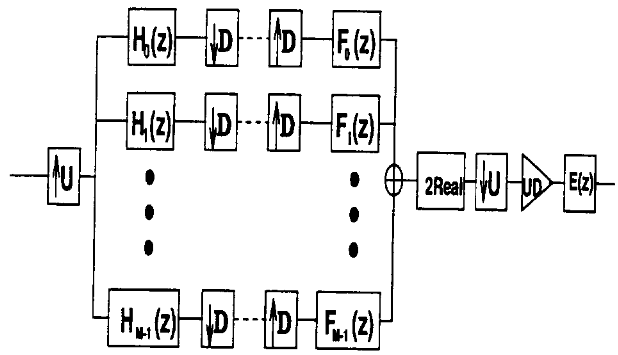

Fig.4 A filter bank with rational decimation ratio.

4. SIMULATION RESULTS

To verify the validity of the proposed method, we show the computer simulations for the structures shown in Fig.1 and Fig.5. The conditions of the simulations are as follows.

1. The number of channels M = 4, the decimation ratio D = 3 or R = 3.
2. The input signal $x(n)$ is a white Gaussian with variance 1.0.
3. We use two unknown systems which are real FIR systems with the length 100. The unknown systems are exchanged in the middle of the implementation.
4. The NLMS algorithm and the multirate repeating method are used for updating the weights of ADFs.
5. ADFs have enough orders which are not influence on the convergence characteristics.
6. As the reference of comparison we use mean squared error(MSE) defined as $10 \log_{10} \frac{E[e^2(n)]}{E[g^2(n)]}$

First, to confirm the effect of the multirate repeating method, we implemented the simulation based on Fig.1, where $D = 3$ is selected as the decimation ratio to avoid the influence of aliasing. Fig.6(a),(b) show the convergence characteristics, where (a) is for using the NLMS and (b) is for using the multirate repeating method with $N = 3$. We can see that the convergence speed is improved by utilizing the multirate repeating method.

Fig.6(c) is the result for using the multirate repeating method with $N = 10$ for Fig.4 where $R = 3, U = 2$ and $D = 12$. In this simulation $N = 10$ data sequences are chosen at continuous timings in accordance with Fig.3(a). The standard structure shown in Fig.1 is impossible to choose a larger N than M so that the improvement of the convergence speed is restricted. On the other hand, by applying the structure of Fig.4 we can select the larger N than M. We can see that the multirate repeating method is used effectively and (c) shows the faster convergence speed than the others.

Finally, Fig.7 indicates the effect of N. We used $N = 1, 6$ and 10 as the number of repeats. From this figure (c) shows the faster convergence speed than the others, since the number of repeats $N = 10$ is the largest number.

5. CONCLUSION

First we proposed applying the multirate repeating method to the standard structure of subband ADFs. Using the multirate repeating method we can achieve a fast convergence speed without increasing the orders of ADFs.

Moreover we considered a new structure of the subband ADFs for extending the multirate repeating method. The proposed method enables us to improve the convergence speed even if the number of channels is small. As a result we could achieve a faster convergence speed than the standard structure.

6. REFERENCES

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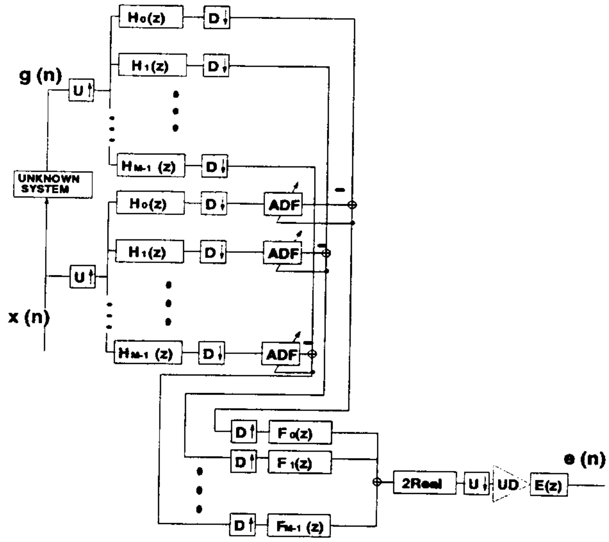

Fig.5 An M channel subband adaptive system with rational decimation ratio.

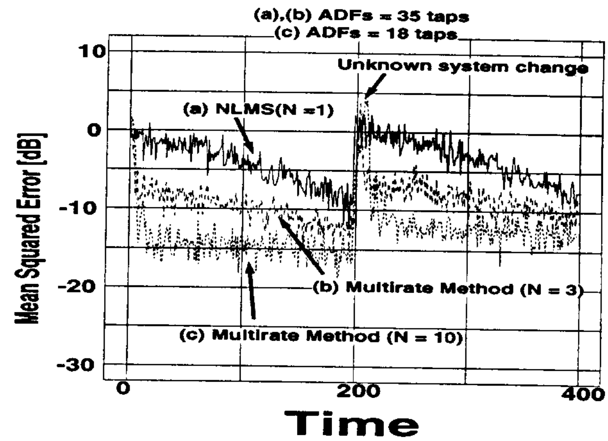

Fig.6 The MSE characteristics of the 4 channel subband ADF.
(a) and (b) ADFs : 35 taps
(c) ADF : 18 taps

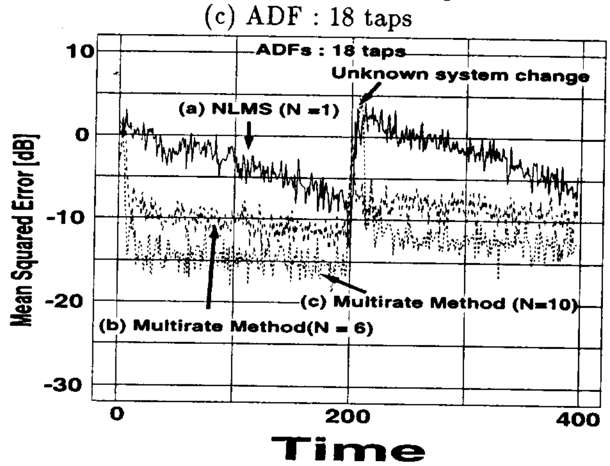

Fig.7 The effect of the number of repeats N.
All ADFs have 18 taps