The New Variable Step-size Algorithm Adaptive Lattice Structure for Echo Cancellation

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Abstract: Adaptive algorithms are widely used for various applications. One challenging application is an echo canceller in the long distance telephony network. This paper proposes the new variable step-size algorithm for adaptive lattice structure for echo cancellation. The new algorithm is using power of the output signal and the error signal to controlled the step of adaptation process. By this technique, the proposed algorithm is an excellent and effective in good stability. Performance comparison of the proposed algorithm and the other algorithm is made through simulation results.

Keywords: Echo canceller, Adaptive algorithm, Lattice structure

1. INTRODUCTION

Network echoes is a major source of impairment to speech quality in telecommunication. The echo in telephone network as depicted in Figure 1.

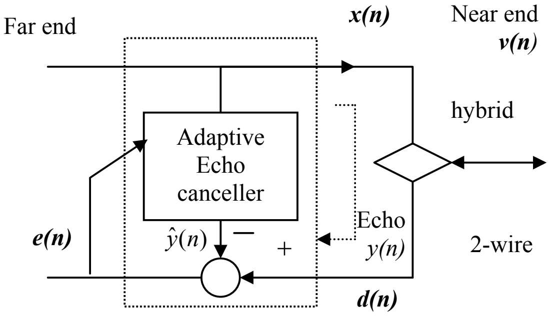

Fig. 1. An echo canceller in telephone network

The adaptive lattice filter structure [1] allows fast convergence and high performance. The variable step-size algorithm has exits a trade-off between the filter convergence rate and steady state error. In [2] proposed lattice structure which used variable step-size algorithm to improve the performance of adaptive echo canceller in noisy environment.

In this paper, a new variable step-size algorithm adaptive lattice filter presented high performance in both low and high signal to noise ratio (SNR) situations. The proposed algorithm has compare its performance with the previous algorithm [2] and we have observed that the proposed algorithm perform high performance with the manageable of misadjustment of adaptation in noise disturbance.

2. THE ECHO CANCELLER STRUCTURE

Consider the adaptive echo canceller described in Figure 1; where $x(n)$ and $v(n)$ represent the far-end signal and near-end speech signal, respectively. Also $d(n)$, $c(n)$ and $\hat{y}(n)$ denote the received input signal to the echo canceller, background noise, and the estimated echo signal [3]. That can be described as

$$\hat{y}(n) = W^T(n)X(n) \tag{1}$$

$$E(n) = d(n) - \hat{y}(n) \tag{2}$$

$$d(n) = v(n) + y(n) + c(n) \tag{3}$$

3. NOISE-ROBUST STEP-SIZE LATTICE STRUCTURE

It is known that the convergence of adaptive filter can be improved when the lattice filter structure is used [2]. The modular Lattice structure is very useful to vary filter and easily to consider its stabilization. The variable step-size algorithm is useful when the filter coefficient which closes to the optimum solution a small step-size is used, otherwise a large step-size is applied instead. We assume the linearity of a finite duration (*n)* of the echo impulse response path with length of *n* samples containing the noise $c(n)$ are input $x(n)$ and the estimate echo are $\hat{y}(n)$ all can be expressed as[6]:

$$Echo \quad path = \sum_{i=0}^{n} R_i \exp[-\frac{(i+1)}{880}]\delta(n-i) \tag{4}$$

where *n* is the numbers of samples and R_i is a random number with in –2, +2 and $\delta(n)$ is the Dirac function, and the transfer function of adaptive echo canceller output in lattice structure is given as follow:

$$\begin{aligned} \hat{y}(n) &= u(n) + 2\hat{k}_0(n)u(n-1) + u(n-2) \\ u(n) &= x(n) - \hat{k}_0(n)(1+\rho)u(n-1) - \rho u(n-2) \end{aligned} \tag{5}$$

where $\hat{k}_0(n)$ is filter coefficient vector of adaptive lattice filter structure at time *n*.

The adaptive algorithm used for update filter coefficient described as follow:

$$\hat{k}_0(n+1) = \hat{k}_0(n) - \mu(n)\,\mathrm{sgn}\left\{\mathrm{sgn}[\hat{y}(n)]\frac{\partial \hat{y}(n)}{\partial \hat{k}_0(n)}\right\} \tag{6}$$

The robust step-size algorithm that used to control adaptation process in order to reduce a misadjustment in noisy environment is described as

$$\mu(n+1) = \alpha\mu(n) + \gamma p^2(n)\cdot g^2(n) \tag{7}$$

$$p(n) = \sigma p(n-1) + (1-\sigma)\hat{y}^2(n) \tag{8}$$

$$g(n) = \lambda g(n-1) + (1-\lambda)\hat{y}(n)\cdot\hat{y}(n-1) \tag{9}$$

where σ, α, γ, λ are constants in the range between 0 and 1. The parameter σ is an exponential weight parameter of forgetting factor. These parameter is to define the filter coefficient to estimating the replica echo path.

4. THE NEW VARIABLE STEP-SIZE ALGORITHM ADAPTIVE LATTICE STRUCTURE

The transfer function of the output signal of adaptive echo canceller has refer in (5) and the gradient signal [4] of the second-order adaptive IIR notch filter can be expressed as:

$$g(n) = \frac{\partial \hat{y}(n)}{\partial \hat{k}_0(n)} \tag{10}$$

In the update recursion of the filter coefficient, if we can control the process in the initial update recursion to gives the algorithm has a fast convergence speed and after approach the optimum the amount of the update recursion is more accuracy, we ensure that the algorithm gives highly performance. To approach this result, the adaptation process used the new variable step-size algorithm to be an objective. The step-size algorithm using the energy of the instantaneous output signal and the error of the output correlation to control step value. The new algorithm of notch filter parameter update recursion for adaptive lattice structure IIR notch filter is given by

$$k_0(n+1) = k_0(n) - \mu(n)\cdot y(n)\cdot \mathrm{sgn}\left(\frac{g(n)}{1+|g(n)|}\right) \tag{11}$$

where $\mu(n)$ is variable step-size parameter. The new variable step-size update equation used to control notch filter coefficient is expressed as

$$\mu(n+1) = \alpha(n)\mu(n) + \gamma p^2(n) \tag{12}$$

where $\alpha(n)$ is the estimated of the error control signal and $p(n)$ is the estimated of the output control signal.

There are two objectives of used the new variable step-size algorithm. First, the fast convergence speed, the step function $\mu(n)$ that we used the energy of the output signal to control the adaptation expressed as:

$$p(n) = \sigma p(n-1) + (1-\sigma)y^2(n) \tag{13}$$

At the beginning $p^2(n)$ has highest value that made $\mu(n)$ has highest value and fast convergence. After convergence $p^2(n)$ has lowest value made $\mu(n)$ has lowest value too. Second, to rejects the effect of uncorrelated noise sequence on the step-size update to ensuring low misadjustment. We uses the output error correlation to accommodated an effective adjusting of $\mu(n)$ when the solution is far from the optimum and step update $\mu(n)$ decreasing as we approach the optimum even in the presence noise. The estimate in the time-varying of the error correlation $e(n)\cdot e(n-1)$ that described as

$$\alpha(n) = \varepsilon\alpha(n-1) + (1-\varepsilon)\hat{e}(n)\cdot\hat{e}(n-1) \tag{14}$$

$$\hat{e}(n) = x(n) - \hat{y}(n) \tag{15}$$

where ε is positive constant. The $\alpha(n)$ gives the step-size update $\mu(n)$ has the accurate step value in early adaptation process stage when it has contain large value of noise and not effect by independent disturbance noise for overall adaptation process.

5. PERFORMANCE EVALUATION

The goal of an echo canceller is to completely remove any emanating signal from impedance mismatching. Real systems are incapable of perfect cancellation for a variety of reasons. It is important, therefore to be able to quantify actual adaptive echo canceller performance and to understand system and physical limitations that effect cancellation so that an adaptive echo canceller can be optimized for its environment. The most common measurement of adaptive echo canceller performance is Echo Return Loss Enhancement (ERLE) [7]

$$ERLE(dB) = 10\log_{10}\frac{E[y^2(n)]}{E[e^2(n)]} \tag{16}$$

The ERLE is simply to the ratio of signal to the ‘noise’ that could not be cancelled from the signal. On the other hand, ERLE is the logarithm which defined as the power ratio of original echo to echo residue. In this paper we evaluate the performance of echo canceller by ERLE simulation.

6. SIMULATION RESULTS

In this section, the performance of the proposed filter structure is compared with the previous algorithm in [2] that applied to an echo cancellation. For fair comparison, convergence parameters are selected to equalize the steady state performance. The assumed parameters of the proposed algorithm and the previous algorithm in [2] are given as $\hat{k}_0(0) = 0$, $\mu(0) = 0.07$, $\alpha(0) = 0.95$, $\rho = 0.99996$, $\sigma = 0.99$, $\varepsilon = 0.0001$, $\lambda = 0.95$, $\gamma = 0.000001$ and data range N = 1000, iteration in 10 times. For the echo to background noise ratio is set to 70 *dB*. The simulation results of two structures performance comparison is shown in Figure 2. The proposed algorithm has same convergence rate as the previous algorithm in [2].

The focus in this paper is noise robustness adaptive step-size which in low signal to noise ratio*(SNR)* of system input. From Figure 3 is residual echo power comparison with the proposed algorithm and the previous algorithm [2] in varieties *SNR* within -10 *dB to 70 dB*. From the figure improve that the proposed algorithm gives low error.

In order to get the good performance of the echo canceller structure, one way to improve the estimated echo path in the noisy environment that is the means of ERLE in the changed of *SNR*. We assumed *SNR* in the ranges of -10 *dB* to 70 *dB*. Figure 4 shows that for low *SNR* the proposed structure is an excellent to improve high performance.

7. CONCLUSIONS

In this paper the new variable step-size adaptive lattice structure for echo canceller had proposed. The proposed algorithm achieved high performance, high accuracy and provided good stability of ERLE in low *SNR* .

REFERENCES

[1] N.I.Cho, "On the adaptive lattice notch filter for the detection of sinusoidal," *IEEE Trans.Circuits Syst.,*vol. 40, no.7, pp. 405-416, July 1993.

[2] C.Benjangkaprasert, S. Teerasakworakun, S.Jorpo chaudom, S. Puntheeranurak, " An implementation of superior noise-robust step-size lattice structure for echo cancellation," Proceeding of NOLTA2002, Oct. 2002.

[3] Jae Ha Yoo, Sung Ho Cho, and Dae Hee Youn, "A Lattice/Transversal Joint (LTJ) structure for an acoustic echo canceller," 1995 Proceeding of IEEE International Symposium on Circuits and Systems, Volume: 2, pp. 1090 – 1093, 1995.

[4] J.F. Chicharo and T.S. Ng, " Gradient-based adaptive IIR notch filtering for frequency estimation," *IEEE Trans. Acoust., Speech, Signal Processing*, vol. ASSP-38, pp. 769-777, May 1990.

[5] ITU-T Recommendation G.168: Digital Network Echo Canceller, 1997.

[6] K. C. Ho, Q. G. Liu, R. Rabipour, P. Yatrou. "A new sampling of echo paths in north America networks," Proceeding of ICASSP, pp.809-812, vol.2, 2000.

[7] B. Farhang - Boroujeny, Adaptive filters : theory and applications, Chic hester : John Wiley, 1998.

[8] P.Chumchu, R.Punchalard, and C.Benjangkaprasert, "Simplify adaptive IIR notch filter based on least mean *p*-power error criterion," IEEE APCCAS., pp. 335-338, Nov.24 – 27, 1998.

[9] S.C. Pei and C.C. Tseng , "Adaptive IIR notch filter based on least mean *p*-power error criterion," IEEE *Trans. Circuit Syst. -II, vol.*40, pp. 525-529, Aug. 1993.

[10] L.J.Griffiths, "An adaptive lattice structure for noise cancelling application," *Proc. of ICASSP,* pp. 69-70, 1978.

[11] T. Aboulnasr and K. Mayyas, "A robust variable step-size LMS- type algorithm analysis and simulation," *IEEE Trans. Signal Processing, vol.*45, no.3, pp. 631-639, March 1997.

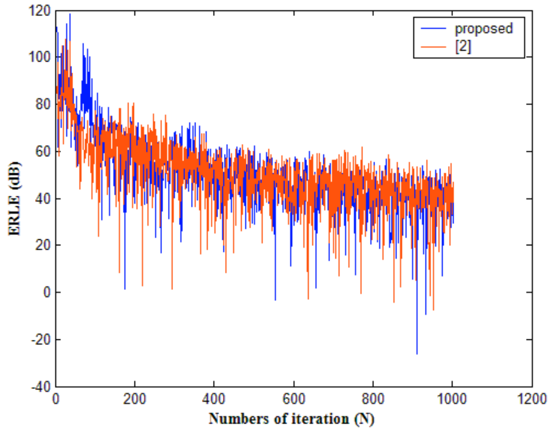

Fig. 2. ERLE (*SNR* = 70 *dB*)

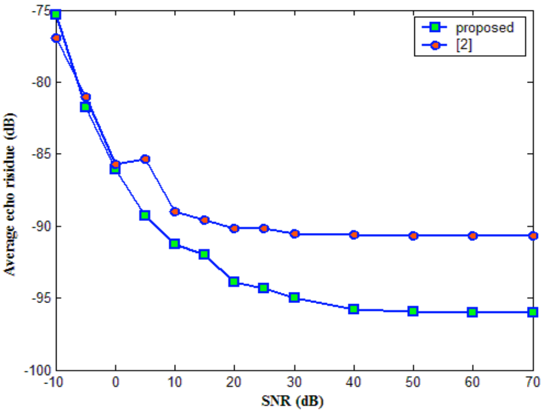

Fig. 3. Average echo residue (*SNR* = -10 to 70 *dB)*

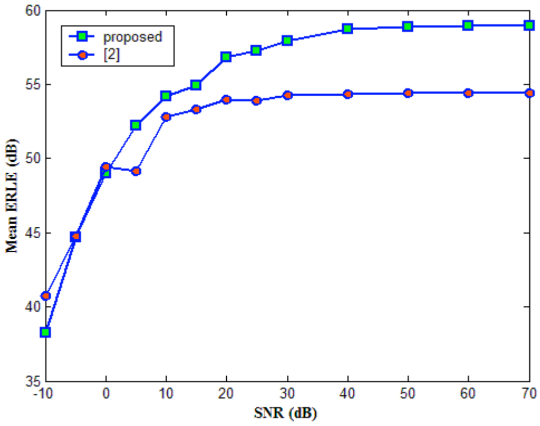

Fig. 4. Mean ERLE (*SNR* = -10 to 70 *dB)*