

## Application of Adaptive Spectral-line Enhancer in Bioradar

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**Abstract.** When bioradar detects the survivals under the ruins, it is hard to find the ideal signal as reference in signal-processing. A variable step-size LMS adaptive spectral-line enhancement algorithm based on error rate is introduced and applied to the signal-processing of bioradar by studying a number of conventional adaptive algorithms. This algorithm doesn't need an ideal signal as reference with good convergence, small steady-state error and good robustness. MATLAB simulation has proved that it is effective in signal-processing of bioradar.

**Keywords:** bioradar; error rate; adaptive spectral-line enhancement; variable step-size LMS;

### 1. Introduction

Bioradar is a special equipment for earthquake and disaster relief. It can detect the life parameters from the radar signals which carry the weak life characteristics (breathing, body move, etc.), and penetrate through certain media (brick wall or ruins) and distance to detect vital signals, find alive or trapped personnel who can be rescued timely [1-3]. However, the bioradar accepts life signal while it inevitably collects such as background noise, land miscellaneous echo even defending signal, which overlap with life signal. The processing effect of acquisition signals directly determines the properties of bioradar. Various signal processing methods were put forward to solve this problem. Reference [4] proposed an adaptive directional technology. Through adaptive changing gain value instead of part samples delay value, this method made the system zero adaptive mobile. When the signal and noise existed at the same time, it could guarantee the zero always towards noise direction. Reference [5] used double antennas modules to signal processing. The master antenna gathered the mixed signals as desired which included the useful and interfering signal, and the assist antenna collected the jamming signal as reference. Through analysis of the specific characteristics of rescue signal, [6] put forward application solutions which combined the single channel linear filter and LMS algorithm. It made two given signals as two orthogonal reference signals. Reference [7] employed the variable step-size LMS adaptive side-lobe cancellation system based on modified S-type function. It could rapidly approach the jamming signal of the master antenna and have smaller error. Above algorithms need to be given reference signal, but it is hard to find an ideal signal as reference in the complex rescue environment and alive human individual difference under rubble. In order to solve the problem, a variable step-size LMS adaptive spectral-line enhancement algorithm based on error rate is introduced applied to the signal-processing of bioradar. This algorithm does not need the ideal signal as reference but with the delay of the input signal.

### 2. Principle of Adaptive Spectral-Line Enhancer

The adaptive spectral-line enhancer was first proposed by Widrow and so on in 1975. At present, the adaptive spectral-line enhancer based on adaptive linear combination editor has been widely applied in spectrum estimation, spectral lines estimator, narrowband testing and other fields. In narrowband signal plus

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broadband signals circumstances, the adaptive spectral-line enhancer without independent reference signal can deliver signals isolated, thereby it improves the detection capacity of life detection system for weak signal, and its principle is shown in Fig. 1.

If  $x(n)$  is the superposition of narrowband signal  $s_N(n)$  and broadband signal  $s_B(n)$ , because the autocorrelation function's time related radius of narrowband signal is shorter than broadband signal, the time delay  $\Delta$  chosen for less than broadband noise time related radius and greater than narrowband signal time related radius will make broadband noise  $s_B(n)$  and  $s_B(n-\Delta)$  become not related, but narrowband signal  $s_N(n)$  and  $s_N(n-\Delta)$  still related. So the output of filter will be the best estimate of narrowband signal  $s_N(n)$ , and the subtraction of  $s_N(n) + s_B(n)$  and  $s_N(n)$  is the best estimate of broadband noise  $s_B(n)$ . Now we separate  $s_B(n)$  and  $s_N(n)$ . The output of filter is the useful signal we need.

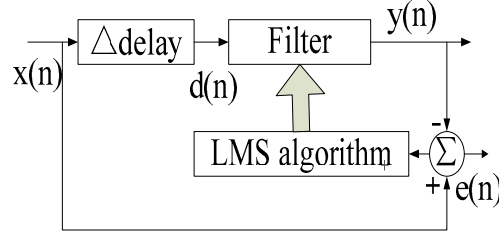


Fig.1 Principle of adaptive spectral-line enhancer

$$\begin{cases} d(n) = x(n-\Delta) \\ e(n) = x(n) - d(n)W(n) \\ W(n+1) = W(n) + 2\mu(n)e(n)x(n) \end{cases} \quad (1)$$

Where  $x(n)$  represents the input signal,  $d(n)$  represents the delay of  $x(n)$  as the reference signal.  $e(n)$  designates error signal,  $W(n)$  designates the weight coefficient, and  $\mu(n)$  represents the step-size.

### 3. Adaptive Spectral-Line Enhancement Algorithm Based on Error Rate

Initial convergence speed and time-varying system tracking abilities and steady disorder is three most important technical indexes measured adaptive filter algorithm. In LMS algorithm, the most simple learning rate parameter selection is off for constant, i.e.:

$$\mu(n) = \mu \quad 0 < \mu < 1/\lambda_{\max} \quad (2)$$

Where  $\lambda_{\max}$  represents maximum eigenvalue of the input signal correlation matrix. However, this approach could lead to contradiction between convergence and stability properties. Big learning rate can improve filter convergence rate but reduce steady performance. Conversely, small learning rate can improve the steady performance but reduce the tracking speed and convergence. So the chosen of learning rate must give consideration to both steady performance and convergence speed. The simple and effective method is using different learning rate parameters in different iterative practice, i.e. time-varying learning rate. Several variable step-size adaptive algorithms were introduced by [8-11] which basically solved the contradiction of fixed step-size. But all of the above algorithms require ideal signal as reference signal to get error signal which tends to zero to control the change. But the ideal error of adaptive spectral-line enhancement system is not to zero but approximate to broadband noise, therefore even system has been completely tracking, step-size factor  $\mu(n)$  still has value, i.e. algorithm will continue to iteration. A variable step-size LMS adaptive spectral-line enhancement algorithm based on error rate is introduced. It controls the step-size factor  $\mu(n)$  by error rate to guarantee stop iteration when the system achieves steady-state. The update formula is shown as:

$$\begin{cases} b(n) = |U(n)| \\ \mu(n) = b(n)^k [1 - \exp(-\alpha * b(n)^m)] \\ U(n) = |e(n)| - |e(n-1)| \\ W(n+1) = W(n) + \mu(n)e(n)X(n)U(n) \end{cases} \quad (3)$$

Where  $k$  represents the step-size control factor,  $U(n)$  represents the step-size vector,  $W(n) = [\omega_1(n)\omega_2(n)\cdots\omega_M(n)]$ ,  $M$  represents the order of filter,  $\alpha$  is a constant to control function shape,  $m$  is adjustable factor.

#### 4. Algorithm Convergence Analysis

The relation curve between step-size  $\mu(n)$  and error rate is given by Fig. 2-4. From Fig. 2, we can see that if  $m$  chooses too small, the curve is too sharp,  $b(n)$  is close to zero, and the change of  $\mu(n)$  is too big, so the system does not have slowly changing characteristics, which will cause bigger steady-state noise. If  $m$  chooses too big, the curve is gentle, but  $\mu(n)$  is zero when  $b(n)$  hasn't close to zero, which will lead to bigger steady-state noise.  $k$  influences the algorithm convergence speed form overall can be seen by Fig. 3. Big  $k$  will lead  $\mu(n)$  to zero too earlier. Small  $k$  will lead to big steady-state error.  $\alpha$  controls the function shape can be seen by Fig. 4. Therefore the chosen of  $m$ ,  $k$  and  $\alpha$  is based on the specific system environment and requirements.

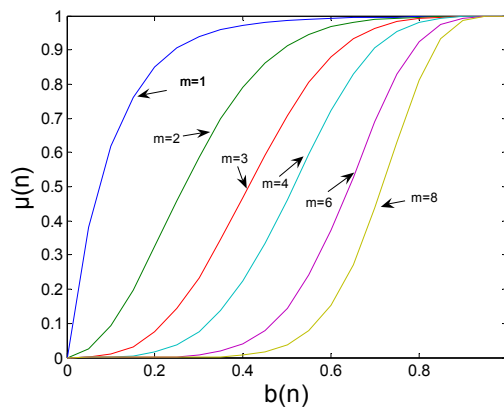


Fig..2 Relation curves when  $m$  is different,  $k = 0.1$ ,  $\alpha = 10$

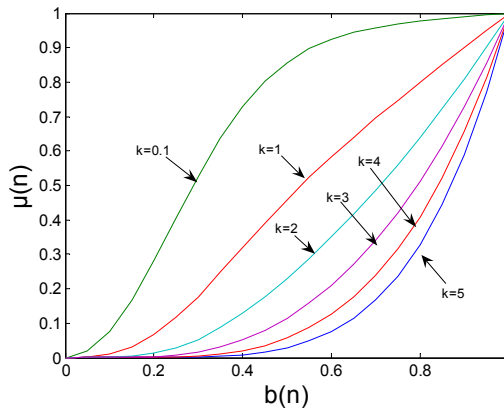


Fig..3 Relation curves when  $k$  is different,  $m = 2$ ,  $\alpha = 10$

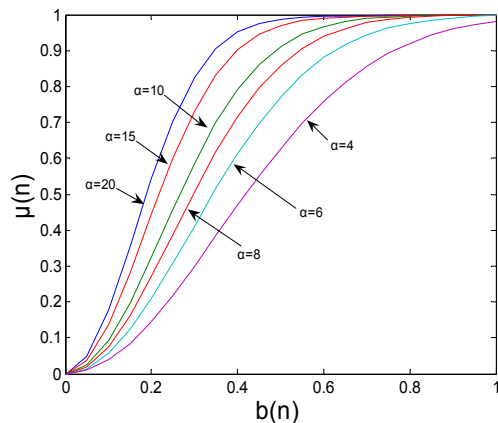


Fig..4 Relation curves when  $\alpha$  is different,  $k = 0.1$ ,  $m = 2$

## 5. Application of Algorithm in Bioradar Signal Processing

Someone breathing signal of bioradar detection is regularly and nearly sinusoidal [12], so we adopt sine signals to simulate the breathing signal of detected person. Clutter can approximate represent by Gaussian clutter based on the analysis of collected data. According to the normal breathing frequency interval, we set the breathing signal is signal-to-noise ratio 5dB, frequency 0.4Hz sinusoidal signal which is interfered by Gaussian noise. For the smaller steady-state disorders quantity and shorter convergence time, we set  $\alpha = 600$ ,  $k = 2$ ,  $m = 4$ ,  $\Delta = 20$ , and the order of filter is 100.

The results of experiment are shown by Fig. 5-7. Fig. 5 is the breathing signal of bioradar collected. Fig. 6 is the extracting close-spaced comparing between this paper and [11]. Fig. 7 is the compare of convergence curve. We can see that the algorithm of this paper has good tracking performance, small steady-state error and good convergence.

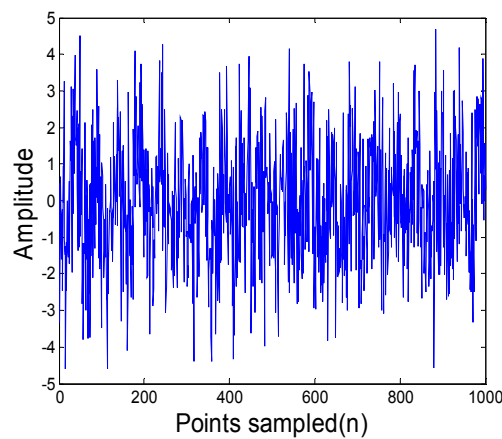


Fig..5 Collected breathing signal

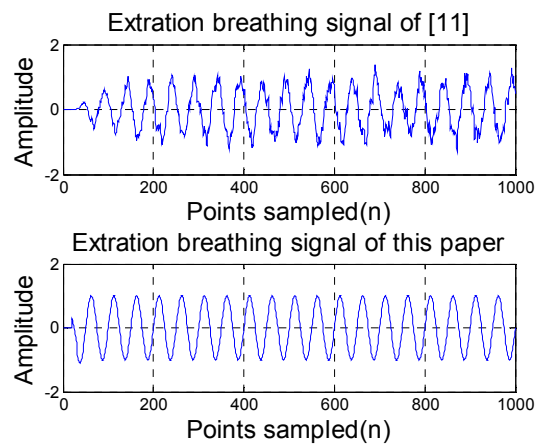


Fig..6 Sine signals compared

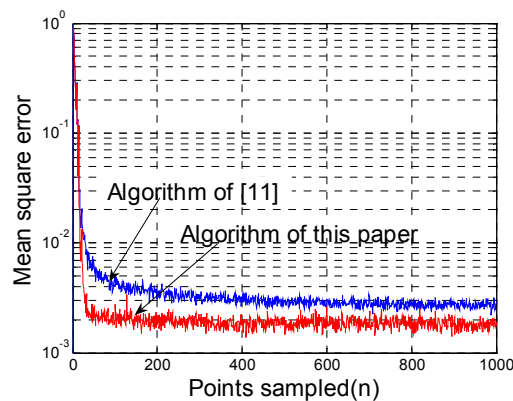


Fig..7 Convergence curve compared

## 6. Conclusion

Through analysis the insufficiency of traditional LMS algorithm, a new variable step-size adaptive spectral-line algorithm is introduced and applied to the signal-processing of bioradar. When the system is catastrophic, this algorithm can have fast convergence, good robustness and achieve good results. It also has very good tracking performance in low signal-noise ratio condition.

## 7. Acknowledgment

First, thank my family, their care and support makes me complete this article successfully. Then I want to thank my workmate LI Hongxia. She has finished the task on time.

## 8. Reference

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