# Normalized Adaptive Method for Hearing Protection in Industries

G.Suresh
*Principal, Gnanavikasa Polytechnic, Challakere road, Chitradurga-577501, Karnataka.*
sureshnov27@yahoo.co.in

**ABSTRACT:** Industrial noise induced hearing loss is an increasingly prevalent disorder that is the result of exposure to high intensity sounds, especially over a long period of time. Several investigations on industrial noise proved that industrial workers need at least 10-15 dB higher SNR (Signal to Noise Ratio) than the other places. The objective of this paper is to implement Normalized Least Means Square (NLMS) algorithm to reduce the effect of industrial noise and to improve overall sound quality of industrial workers. The computer simulations results show superior characteristics of the algorithm by improving the SNR of more than 15dB and noise reduction performance is better than single source adaptive algorithm. These results suggest that a headset with digital signal processing adaptive algorithm is useful for hearing protection in workplaces with high levels of wide band industrial noise.

***Keywords: Industrial noise, Hearing protection, Hearing loss, adaptive filter, SNR improvement, NLMS.***

## 1. Introduction

High-intensity noises are a health hazard for industrial workers, and hearing protection is necessary to prevent hearing loss. Hearing loss caused by occupational noise is one of our biggest industrial diseases. It is a disease that has been recognized since the Industrial Revolution. The conventional passive methods, such as ear muffs, are ineffective against low-frequency noise [3]. This problem can be effectively solved by using the adaptive algorithms for different frequencies [4]. The main intension of this paper is to highlight the filtering nature of NLMS technique to reduce the effects of industrial noise on workers and to improve overall sound quality for industrial workers.

Many researchers has stated that [7] noise can not only cause hearing impairment due to long-term exposures of over 85 dB, but it also acts as a causal factor for stress and raises systolic blood pressure. Additionally, it can be a causal factor in work accidents, both by masking hazards and warning signals, and by impeding concentration [12]. Noise also acts synergistically with other hazards to increase the risk of harm to workers [2]. [10] States that exposure to 85 dB of noise for more than eight hours per day can result in permanent hearing loss. Since decibels are based on a logarithmic scale, every 3 dB sound pressure level increase results in a doubling of intensity, meaning hearing loss can occur at a faster rate. Therefore, gradual developing industrial noise induced hearing loss occurs from the combination of sound intensity and duration of exposure.

Noise induced hearing problems are typically is centered at 4000 Hz. The louder the noise is, the shorter the safe amount of exposure is. Normally, the safe amount of exposure is reduced by a factor 2 for every additional 3 dB. For example, the safe daily exposure amount at 85 dB is 8 hours, while the safe exposure at 91 dB is only 2 hours [8], [9]. Sometimes, a factor 2 per 5 dB is used. Personal electronic audio devices, such as iPods, because iPods often reaching 115 decibels or higher. This can produce powerful enough sound to cause significant hearing loss in the workers, given that lesser intensities of even 70 dB can also cause hearing loss [11]. Different kinds of filtering methods are suggested in the literature for the minimization of noise in industries [5], [6]. However, through the proper use of ear protection, education, hearing conservation programs in the workplace, and audiological evaluations, industrial noise induced problems can be reduced [13]. Hence in this paper, suggests the NLMS noise cancellation algorithm for hearing protection of the industry workers.

## 2. NLMS Noise Canceller

Adaptive filters can adapt their filter coefficients to the environment according to preset rules. Adaptive system with directional microphones is the best way to improve SNR in industries to protect workers [1]. Hence, in this work the NLMS is implemented to reduce the effect of noise in industries. In the adaptive noise cancellation process, the desired speech signal $d(n)$ is to be calculated from a noise-corrupted speech signal $x(n) = d(n) + v_1(n)$. In this method, reference signal, $v_2(n)$ is correlated with $v_1(n)$. This reference signal may be used to estimate the noise $v_1(n)$, and the estimate can be then be subtracted from $x(n)$ to get the estimate of $d(n)$.

$$\hat{d}(n) = x(n) - \hat{v}_1(n) \qquad 1$$

If $d(n)$, and $v_1(n)$ are jointly wide-sense stationary processes, and if the autocorrelation $r_{v_2}(k)$ and the cross-correlation $r_{v_1v_2}(k)$ are known, then filter can be designed to find the minimum means square estimate of $v_1(n)$. If the reference signal $v_2(n)$ is uncorrelated with $d(n)$, then the minimization of mean square error $E\{|e(n)^2|\}$ is equivalent to minimizing $E\{|v_1(n) - \hat{v}_1(n)|^2\}$. 2

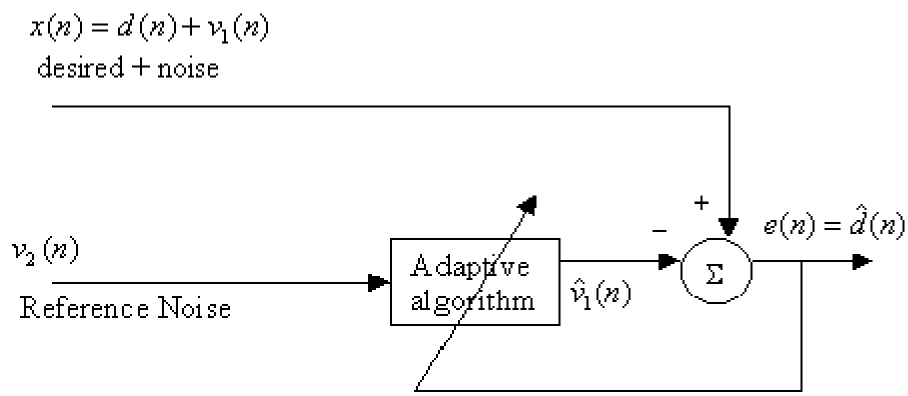


*Figure 1 Adaptive noise canceller*

The output of the adaptive filter is the minimum mean square estimate of the noise $v_1(n)$. Since the output of the adaptive filter is the minimum mean square estimate of $v_1(n)$, then it follows that $e(n)$ is the minimum mean square estimate of the desired speech signal $d(n)$. It is an efficient noise canceller and is implemented in ear cap (or any other similar device) for reducing noise effects.

## 3. Performance evaluation

Performance of the adaptive filters are measured, compared and analyzed with the help of following parameters.

***a.*** Convergence rate: The convergence rate determines the rate at which the filter converges to its resultant state. Usually faster convergence rate is the desired characteristic of an adaptive system. Convergence rate is not, however, independent of all other performance characteristics. If the convergence rate is increased, the stability characteristics will decrease, making the system more likely to diverge instead of converge to the proper solution. In this work, convergence rate is measured in terms of eigenvalue ratio.

***b.*** Minimum mean square error (MSE): The MSE is a metric indicating how well a system can adapt to a given solution. A small minimum MSE is an indication that the adaptive system has accurately modeled, predicted, adapted and/or converged to a solution for the system.

***c.*** Stability: Stability is probably the most important performance measure for the adaptive system. The algorithm convergence time and stability depends upon the ratio of the largest to the smallest eigenvalue associated with the correlation matrix of the input sequence. Therefore, stability of the algorithm is defined in terms of eigenvalue ratio.

***d.*** Eigenvalue ratio: Eigenvalue ratio or the eigenvalue spread is the ratio between the maximum eigenvalue and the minimum eigenvalue of the input autocorrelation matrix. The eigenvalue ratio $r$ can be calculated as

$$r = \frac{\lambda_{\max}}{\lambda_{\min}} \qquad 3$$

Where $\lambda_{\max}$ and $\lambda_{\min}$ are the maximum and minimum eigenvalues, which found on the main diagonal of the autocorrelation matrix. Then the rate of convergence can be calculated as

$$C.rate = \frac{(r-1)^2}{(r+1)^2} \qquad 4$$

From the above equation it is clear that, the convergence time decreases if the eigenvalue ratio increases and vice versa.

***e.*** SNR: Amount of noise filtering can be measured from adaptive system with the help of input SNR and output SNR. Input SNR is the ratio between the power of input signal and power of noise at input. Output SNR is the ratio between the power of filtered signal and power of noise at output. In general SNR is defined as

$$SNR = \frac{\sum_n x^2(n)}{\sum_n e^2(n)} \text{ and } SNR(dB) = 10\log_{10}\frac{\sum_n x^2(n)}{\sum_n e^2(n)} \qquad 5$$

Where, $x(n)$ is the input signal and $e(n)$ is the noise.

The algorithm is evaluated for different types of industrial noises with different SNR. In this work $x(n)$ is the speech signal and $e(n)$ is the industrial noise. Results show that, both parameters SNR and eigenvalue ratio are strongly depending on type of noise.

| Input SNR in dB | Output SNR in dB | Eigenvalue ratio |
|---|---|---|
| 0 | 19.1 | 1005 |
| 5 | 23.3 | 1012 |
| 10 | 25.2 | 1001 |

*Table.1 Performance of NLMS Noise canceller*

For different input SNR, the output SNR and eigenvalue ratios are calculated as shown in Table 1. The eigenvalue ratio is calculated to find out how well the algorithm converges to the optimum Wiener solution. The main disadvantage of this algorithm is its high eigenvalue ratio. Because, filters having high eigenvalue ratio requires longer time to converge and vice versa.

# 4 Conclusions

Noises of industry can cause partial deafness, interference with communication by speech and annoy. These undesirable effects are best avoided by reducing the noise to acceptable levels. NLMS method can be used for noise reduction in industries to protect workers. Off-line tests in different conditions show improvements in SNR up to 20 dB for zero dB input SNR and the overall performance is better than single source adaptive algorithm. In a more realistic environment, they may have the variations of ± 5 dB. But, the results show that the algorithms have high eigenvalue ratio. Hence, they need more time to converge into the optimal solution.

ISSN: 2278-0181
Vol. 1 Issue 6, August - 2012

## 5. REFERENCES


1. Bernard Widrow and Samuel D.Stearns. Adaptive Signal Processing, Pearson Education Asia, 2002.
2. Bauer.P., Korpert, K., Neuberger, M., Raber, A., & Schwetz, F. (1991). Risk factors for hearing loss at different frequencies in a population of 47 3888 noise-exposed workers. Journal of Acoustical Society of America, 90(6), 3086-3097.
3. Chen & Tsai. (2003). Hearing Loss among Workers at an Oil Refinery in Taiwan. Archives of environmental health, 58(1), 55-58.
4. Dolan, T. & Maurer, J. (1996). Noise exposure associated with hearing aid use in industry. Journal of Speech and Hearing Research, 48, 251-260.
5. Fausti. S., Wilmington, D., Helt, P., Helt, W., & Konrad-Martin, D. (2005). Hearing Health and Care: The Need for Improvised Hearing Loss Prevention and Hearing Conservation Practices. Journal of Rehabilitation Research & Development, 42(4), 45-62.
6. Hetu. R. & Getty, L. (1993). Overcoming difficulties experienced in the work place by employees with occupational hearing loss. The Volta Review, 95, 391-402.
7. Henderson, Donald; Bielefeld, Eric C.; Harris, Kelly Carney; Hu, Bo Hua, The Role of Oxidative Stress in Noise-Induced Hearing Loss, Ear & Hearing. 27(1):1-19, February 2006 .
8. National Board for Science and Technology, Dublin (Ireland). (1980). Noise and the environment. U.S. Department of Commerce Springfield, VA. (NTIS No. PB84-108638).
9. National Institute for Occupational Safety and Health. (1988). Self-reported hearing loss among workers potentially exposed to industrial noise- United States. Journal of America Medical Association, 259(15), 2213-2217.
10. Occupational Safety & Health Administration. (2002). Hearing Conservation. Retrieved March 3, 2007, from http://www.osha.gov/Publications/OSHA3074/osha3074.html
11. Rosenhall, Ulf; Pedersen, Kai; Svanborg, Alvar Presbycusis and Noise-Induced Hearing loss, Ear & Hearing, 11(4):257-263, August 1990.
12. Sataloff, R. T., & Sataloff, J. (1987). Occupational Hearing Loss. New York: Marcel Dekker, INC.
13. Simpson. T., Stewart, M., & Blakley. B. (1995). Audiometric referral criteria for industrial hearing conservation programs. Arch Otolaryngol Head Neck Surgery, 121, 407-411.