Feedback Active Noise Control using Linear Prediction Filter for Colored Wide-band Background Noise Environment

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***Abstract*—In this paper, we propose a new Feedback Active Noise Control (FB-ANC) system to improve the suppression performance for narrow-band noise buried in colored wide-band background noise. The proposed system adopts a linear prediction filter to the input signal in order to separate narrow-band noise and wide-band noise. The simulation result shows the proposed method can perform robust noise suppression.**

I. Introduction

Acoustic noise problems become more and more serious as increasing number of industrial equipment such as engines, blowers, fans, transformers, compressors, and so on. As the conventional approach to suppress the acoustic noise, we often use the passive techniques such as enclosures, barriers, and silencers. Such the passive silencers require extremely high spatially costs for the satisfactory attenuation over broad frequency range.

Active Noise Control (ANC) is an electroacoustic system that cancels the primary undesired noise by the antinoise sound emitted from the second source speaker. ANC system can be categorized into 2 types, which are the feedforward ANC and the feedback ANC. The feedback ANC system efficiently attenuates narrow-band noise but has a problem that the noise suppression effect is degraded when the narrow-band noise is disturbed by colored wide-band noise. This is because the whitening effect of the feedback ANC strongly affects the colored wide-band noise when the wide-band noise level is high. To solve this, this paper describes a method for separating narrow-band noise and colored wide-band noise using a linear predictor to efficiently attenuate narrow-band noise.

II. Active noise control using linear prediction

We describes the principle of the proposed method. Figure 1 shows the structure of the proposed method. Comparing with the original feedback ANC system, three linear predictors are added to the error signal $e(n)$, the filtered restoration noise $r(n)$, and presudo-output signal with secondary path model $y'(n)$. These linear predictors have common filter coefficients. The detail of the signals in Fig. 1 are shown as below.

$d(n)$:Noise
$y(n)$:Output signal
$e(n)$:Error signal

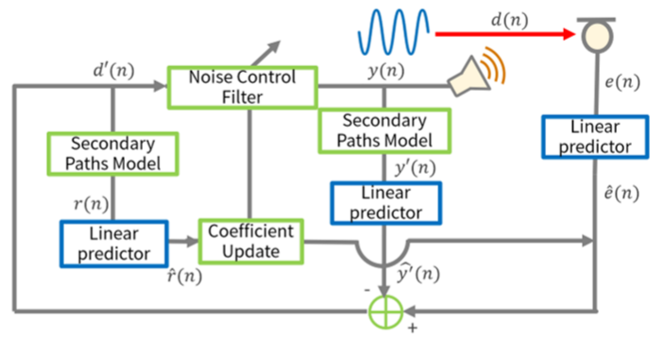

Fig. 1. The structure of linear prediction feedback ANC.

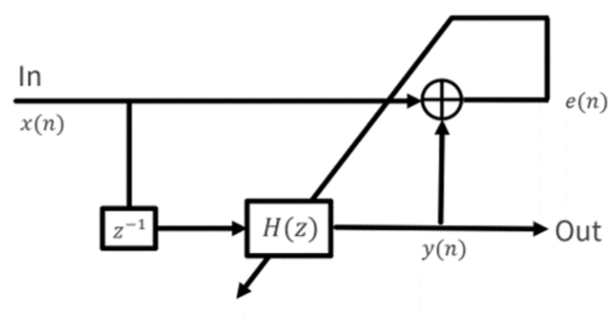

Fig. 2. The structure of linear prediction.

$\hat{e}(n)$:Predicted error signal
$r(n)$:Filtered-restoration noise
$\hat{r}(n)$:Predicted filtered-restoration noise
$d'(n)$:Restoration noise
$y'(n)$:Pseudo output signal with secondary path model
$\hat{y}'(n)$:Predicted pseudo output signal with secondary path model

To achieve the linear predictor reducing the wide-band noise, we utilize an adaptive filter. The structure of the linear predictor is shown in Figure 2. The output signal $p(n)$ is obtained by

$$p(n) = \sum_{i}^{M} h_i(n) x(n-i), \tag{1}$$

where $x(n)$ is the input, $h_i(n)$ is the i-th filter coefficient corresponding to $x(n-i)$, and M is the filter order. prediction error used for updating the filter coefficients is calculated by

$$p_e(n) = x(n) - p(n), \tag{2}$$

The filter coefficient $h_i(n)$ is updated using Normalized Least Mean-Square (NLMS) algorithm. The updation is defined by

$$h_i(n+1) = h_i(n) - \mu \frac{p_e(n) x(n-i)}{E[x^2(n-i)]},\ i = 1, \cdots, M, \tag{3}$$

where μ is the step-size parameter and $E[\cdot]$ is a mean operator.

The linear predictor can predict only the periodic components included in the input. After convergence, ideally the output of the linear predictor includes only a narrow-band noise signal since the background wide-band signal is weakly periodic.

III. Noise suppression experiment using harmonic noise

In order to verify the effectiveness of the proposed method, the noise suppression simulation was performed. As the narrow-band noise, the recorded sound of driving vacuum cleaner is used. In the proposed method, we set $M = 40$ and $\mu = 0.5$. For comparison, we used the normal feedback ANC which is the same system as shown in Fig. 1 without the linear predictors. In the feedback ANC, the order of the noise control filter is 150, the order of the secondary path model is 100. The secondary path model is appropriately estimated in advance. For updating the noise control filter, we used NLMS algorithm with $\mu = 0.01$.

Figure 3 shows the output waveforms for three methods, which are no ANC, the conventional ANC, and the proposed ANC. From this figure, ANC works well for suppressing the noise, but there is a little difference between the result of the conventional ANC and the one of the proposed ANC.

Figure 4 shows the power spectrum of the error signal after convergence. From this figure, we can see that the input narrow-band noise whose fundamental frequency is 500Hz is buried in the wide-band colored noise. The conventional ANC, which corresponds to the green line, provides the highly suppression noise performance for low frequency band, since the conventional ANC works so as to whiten the input signal, that is, to suppress the high level narrow-band noise such as 500Hz frequency component and 1000Hz one. On the other hand, the low level narrow-band noise such as 5000Hz frequency component or 6000Hz one tends to be ignored. The proposed method, which is blue line, can suppress not only the high level narrow-band noise but also the low level one. In Fig. 4, it is clear that the proposed method can effectively suppress the narrow-band noise and output only the wide-band noise. From the above results, we can verify the effectiveness of the proposed method.

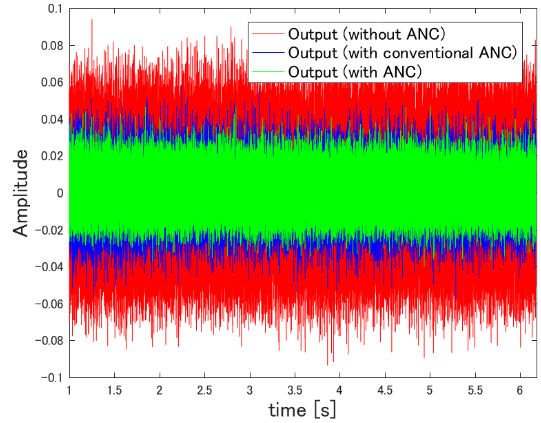

Fig. 3. Waveform obtained from error microphone of noise suppression experiment.

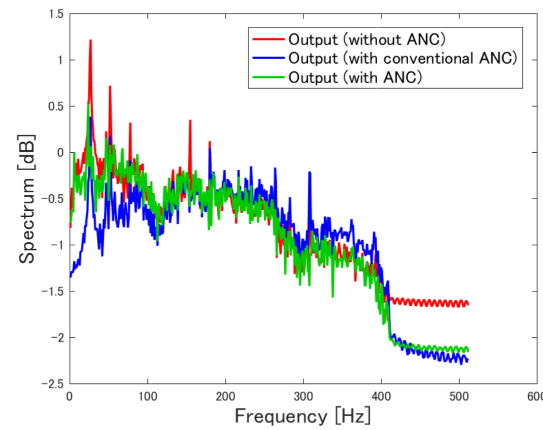

Fig. 4. Spectrum of the error signal after convergence (red: only noise, green : the conventional method, blue : the proposed method.

IV. Conclusion

In this paper, we proposed a new feedback ANC system using three linear predictors. Since the linear predictor allows only narrowband noise to pass, we can separate the narrow-band noise from the background wide-band noise which degrades the noise suppression effect. From the experiment, the effectiveness of the method was confirmed.

References

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