Adaptive Equalizer for Acoustic Feedback Control

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Acoustic feedback is a recurrent problem in audio applications involving amplified closed loop systems. The goal of the proposed acoustic feedback control algorithm is to adapt an equalizer, applied to the microphone signal, to prevent feedback before its effect is noticeable. This is achieved by automatically decreasing the gain of an equalizer at frequencies where feedback likely will occur. The equalization curve is determined using information contained in an adaptively estimated feedback path. A computationally efficient implementation of the proposed algorithm, using short-time Fourier transform, is described.

0 INTRODUCTION

0.1 Problem of Acoustic Feedback

Acoustic feedback arises when the sound captured by a microphone is emitted by a loudspeaker and, again, is picked up by the microphone [1]. Feedback causes problems in sound reinforcement, public address, hands-free communication, and hearing aid applications [2]. The common artifact resulting from acoustic feedback is an oscillation that is triggered by the sound captured by the microphone. The two main issues are, first, the limited amplification that can only be applied to keep the system stable, referred to as the maximum stable gain (MSG), and second, an impaired sound quality, including ringing and howling effects.

The typical feedback problem is illustrated in Fig. 1. The microphone signal is modeled as

$$y[n] = s[n] + h * x[n], \quad (1)$$

where s is the desired sound source signal and h is a linear filter modeling the acoustic feedback path. Note that the potential local noise is part of the source signal s. Moreover, the loudspeaker signal x can be expressed as

$$x[n] = g * y[n], \quad (2)$$

where g is a linear filter modeling the forward path. It is usually assumed that g has a minimum delay of one sample [3].

0.2 Review of Feedback Control Methods

State-of-the-art feedback control methods can be categorized into four classes [4]: phase modulation methods, gain reduction methods, spatial filtering methods, and room modeling methods.

- The best known implementation of a phase modulation method is based on frequency shifting [5]. The basic idea behind frequency shifting is that feedback gets generated at specific frequencies of the loudspeaker to microphone transfer function. Frequency shifting moves the generated feedback frequency along the transfer function until it reaches a section that effectively attenuates the feedback. However, the amount of frequency shifting that can be applied is limited by the resulting distortions. This also limits the achieved increase of MSG.
- The gain reduction methods reproduce, in an automatic way, what a sound engineer would do to reduce feedback [6]. Examples are automatic gain control (AGC), which adapts the full-band gain of signals such that feedback does not appear [7], automatic equalization, which attenuates frequency ranges where feedback is triggered [8,9], and adaptive notch filtering that suppresses frequencies where feedback appears [10,11]. The drawback of these approaches is that feedback gets only eliminated once it already appeared.
- Spatial filtering methods require the use of a beamformer to enhance the direct desired source signal at the microphone while attenuating the feedback signal arriving from out-of-beam directions [12]. Thus, in this approach, the relative placement of the microphone is constrained.
- The room modeling method estimates the acoustic feedback path, similarly as the well-known acoustic echo cancellation (AEC) [13,14]. The conventional approach, called adaptive feedback cancellation (AFC), uses the predicted feedback path to estimate the feedback signal that is then subtracted from the microphone signal. However, contrary to AEC, the fundamental problem remaining in the AFC approach is the correlation between the loudspeaker signal and the desired source signal. Thus, adaptive filtering theory, applied to the AFC, leads to