Chapter 5

ADAPTIVE ALGORITHMS FOR MIMO ACOUSTIC ECHO CANCELLATION

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Abstract  The first thing that comes in mind when we talk about acoustic echo cancellation is adaptive filtering. In this chapter, we discuss a large number of multichannel adaptive algorithms, both in time and frequency domains. This discussion will be developed in the context of multichannel acoustic echo cancellation where we have to identify a multiple-input multiple-output (MIMO) system (e.g., room acoustic impulse responses).

Keywords:  Acoustic Echo Cancellation, Multichannel, Adaptive Algorithms, LMS, APA, RLS, FRLS, Exponentiated, MIMO, Frequency-Domain
1. INTRODUCTION

All today’s teleconferencing systems are hands-free and single-channel (meaning that there is only one microphone and one loudspeaker). In the near future, we expect that multichannel systems (with at least two loudspeakers and at least one microphone) will be available to customers, therefore providing a realistic presence that single-channel systems cannot offer.

In hands-free systems, the coupling between loudspeakers and microphones can be very strong and this can generate important echoes that eventually make the system completely unstable (e.g., the system starts howling). Therefore, multichannel acoustic echo cancelers (MCAECs) are absolutely necessary for full-duplex communication [1]. Let $P$ and $Q$ be respectively the numbers of loudspeakers and microphones. For a teleconferencing system, the MCAECs consist of $PQ$ adaptive filters aiming at identifying $PQ$ echo paths from $P$ loudspeakers to $Q$ microphones. This scheme is, in fact, a multiple-input multiple-output (MIMO) system. We assume that the teleconferencing system is organized between two rooms: the “transmission” and “receiving” rooms. The transmission room is sometimes referred to as the far-end and the receiving room as the near-end. So each room needs an MCAEC for each microphone. Thus, multichannel acoustic echo cancellation consists of a direct identification of an unknown linear MIMO system.

Although conceptually very similar, multichannel acoustic echo cancellation (MCAEC) is fundamentally different from traditional mono echo cancellation in one respect: a straightforward generalization of the mono echo canceler would not only have to track changing echo paths in the receiving room, but also in the transmission room! For example, the canceler would have to reconverge if one talker stops talking and another starts talking at a different location in the transmission room. There is no adaptive algorithm that can track such a change sufficiently fast and this scheme therefore results in poor echo suppression. Thus, a generalization of the mono AEC in the multichannel case does not result in satisfactory performance.

The theory explaining the problem of MCAEC was described in [1] and [2]. The fundamental problem is that the multiple channels may carry linearly related signals which in turn may make the normal equations to be solved by the adaptive algorithm singular. This implies that there is no unique solution to the equations but an infinite number of solutions, and it can be shown that all but the true one depend on the impulse responses of the transmission room. As a result, intensive studies have been made of how to handle this properly. It was shown in [2] that the only solution to the nonuniqueness problem is to reduce the coherence between the different loudspeaker signals, and an efficient low complexity method for this purpose was also given.