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Robust Active Noise Control System for Fighter Aircraft Pilot Helmet Application

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Abstract

This paper proposes an Active Noise Control (ANC) scheme for fighter aircraft pilot helmet application. The proposed scheme addresses the noise environment inside the helmet to achieve perceivable noise attenuation. It also incorporates algorithms such as energy based detectors to control the operation of ANC system and variable step-size to increase the performance of ANC, to make the system robust. The paper highlights the real-time algorithm development on a DSP processor to meet the real-time resource constraints. The developed ANC system is evaluated in the laboratory for a typical fighter aircraft noise and the results when compared with the performance of existing system, found to be quite promising.

Keywords: Adaptive Noise Canceller; Fighter Aircraft Pilot Helmet; FXLMS; LMS; Robust Active Noise Control; Variable Step-size.

1. Introduction

The cockpit of a fighter aircraft will be very noisy and their mean levels range from 95 to 105 dB. This exceeds the damage risk criterion of 8 h/day exposure. Hence, may result in hearing impairment to the pilot, especially during prolonged exposures. Increased periodontal disease in aircrew members and cardiovascular risks demands the reduction of noise levels. Further, speech intelligibility and recognition of warning signals is adversely affected in a noisy environment as the primary effect of noise is masking of voice communication signals.

The prime purpose of a fighter aircraft pilot helmet is protection and it is made of high strength, lightweight para-armid reinforced with epoxy resin shell and the helmet earcups use open-cell foam rubber. In addition to protection, it filters out most of the noise signals of high frequency range, hence providing passive attenuation. Owing to broadband nature of the noise, considerable low frequency noise will be audible in the earcup. This can be addressed using ANC technology.

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Considerable developmental effort has been spent on Active Noise Reduction (ANR) headsets[1] and are being successfully used in aircraft cabin environments, where the ambient noise level is very low compared to fighter aircraft cockpits. Few of the ANR helmets availableare based on passive electronic components or feedback control principles[2]. The use of passive electronic components lacks the ability to adapt to changing noise environments and its performance is very poor for broadband noise. Alternatively, the use of feedback algorithm (FBANC), which cannot differentiate between noise and communication signals, may affect the speech quality. Hence, there is a necessity to clearly understand the requirements to develop a helmet ANC system.

The noise perceived inside the helmet earcup is due to two components[3]. First one is the noise component that enters directly through the helmet, referred as Cockpit Noise Direct (CND) and second one is the noise component that enters through the pilot microphone and Audio Management Unit (AMU), referred as Cockpit Noise AMU (CNA). The presently existing Helmet ANC systems only address CND. To have an effective perceived noise reduction, it is necessary to address both these noise components.

The proposed method addresses CND, which is realized using Feed Forward approach (FFANC) proposed by Sen and Morgan[4], this ensures that the communication signals are not affected by ANC operation. For catering CNA, an adaptive noise canceller is used, which uses Least Mean Square (LMS) algorithm[5].

The ANC system might diverge in case of absense or due to sudden variations of the cockpit noise. The paper tries to address this by incorporating energy-based conditions[6] to limit the ANC residual error to pre-defined bounds. A good ANC system is expected to have faster convergence rate and lower residual error. Therefore, it is proposed to incorporate Variable Step-Size (VSS) algorithm[7] in this paper.

Further, the above mentioned algorithms were developed on Texas Instruments' TMS320C6748 floating point DSP processor. As far as the real-time performance of ANC is concerned, increasing sampling rate of the system extends the frequency range of ANC operation and resulting in better attenuation. However the real-time coding using a high-level language is unable to achieve desirable performance. Hence, the development of ANC algorithms using processor specific assembly language is considered in this paper.

Nomenclature

ANC	Active Noise Control
AMU	Audio Management Unit
CND	Cockpit Noise that enters pilot helmet Directly
CNA	Cockpit Noise that enters pilot helmet through AMU
FXLMS	Filtered Least Mean Square
FFANC	Feedforward Active Noise Control
STE	Short-Term Energy
NSS	Normalized Step-Size
VSS	Variable Step-Size

2. Algorithms for Helmet ANC System

This section gives details of the algorithms used in realizing helmet ANC. These are categorized under algorithms for noise attenuation and algorithms for incorporating robustness into the system. Each of them is described in the sections below.

2.1 Algorithms for noise attenuation

Figure 1 shows the block schematic of the proposed helmet ANC system. As mentioned earlier, there are two components of noise CND and CNA, to be addressed to achieve good attenuation inside the helmet earcups. CND is addressed by FFANC and CNA by the adaptive noise canceller algorithms. Both of them use the same cockpit noise as reference. This noise reference $x(n)$ is obtained using a microphone, which is placed inside the cockpit.

Two separate channels of FFANC are used for each earcups. The generated anti-noise is fed to the loudspeakers present in the earcups. An error microphone placed inside each of the earcup gives the residual noise signals.