THE INTEGRATION OF ACTIVE NOISE REDUCTION AND BINAURAL TECHNOLOGIES IN THE DESIGN OF COMMUNICATION HEADSETS

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1.0 INTRODUCTION

This study reviewed the fundamental basis and the technical aspects involved in integrating two relatively new technologies in the design of communication headsets. The first technology, known as active noise reduction (ANR), can improve speech intelligibility by reducing the amount of interfering noise from the environment. The second technology, known as binaural technology, allows the simulation of 3D auditory displays, which can enhance speech intelligibility and situational awareness over monophonic listening. A typical use of such a device would be inside an aircraft cockpit environment [1,2].

2.0 ANR TECHNOLOGY

Communication headsets with sound attenuation capabilities are often used in situations where an individual must be in contact with others at a remote location while operating in a noisy environment. The most common design is based on a passive circumaural hearing protective device (HPD) fitted with earphones inside the earcups and a boom microphone in front of the mouth. The reduction in environmental noise depends on the attenuation characteristics of the earcups. Passive circumaural HPDs tend to be most effective above 1000 Hz [3], and often do not provide much more than 10-15 dB of attenuation at low frequencies, even in the best designs and under controlled laboratory conditions.

In situations of intense low-frequency environmental noise, the performance of passive communication headsets can be enhanced using ANR technology. A miniature microphone picks up the noise inside the earcup and produces a phase-inverted copy for sound wave cancellation. The active attenuation achieved in this way is currently limited to frequencies below 500-1000 Hz, where it adds to the passive attenuation provided by the earcup. Maximum active low-frequency attenuation in the order of 10-20 dB has been measured over the passive mode [1,4].

The additional low-frequency reduction in environmental noise achieved with ANR headsets points to improvements in auditory perception for signals transmitted through the communication channels. However, this has not been consistently demonstrated in practice [5]. Firstly, ANR devices often show a negative amount of active attenuation of about 3-6 dB in the region of 1000-3000 Hz [3], which can have adverse effects on auditory perception, particularly speech intelligibility. Secondly, the frequency response of the communication channels and the effect of the ANR circuitry on the speech transmission quality are also important determinants of intelligibility. Table I lists additional factors affecting auditory perception with communication headsets.

3.0 BINAURAL HEARING AND TECHNOLOGY

The detection, discrimination and recognition of a signal in the presence of other competing signals and/or interfering noise can sometimes be markedly improved when listening binaurally rather than monaurally. In particular, binaural speech intelligibility in noise has been investigated extensively over the past decades in headphone, sound field and simulated sound-field studies [1,2]. Comparison of binaural listening to monaural listening through the ear with the best S/N ratio showed a constant binaural advantage equivalent to a reduction in speech reception threshold of about 3 dB across a range of experimental conditions [6]. This relatively small decibel advantage could give rise to a substantial speech intelligibility improvement given the very steep slope of the intelligibility function near the 50% intelligibility level, typically 15% per dB for sentence material.

Communication headsets with 3D auditory display capabilities are needed to take full advantage of the binaural system [7]. In addition to improved speech intelligibility in noise, virtual auditory environments and 3D models of the listening space can be created, which can greatly facilitate the monitoring and interpretation of the various acoustic sources of information. The binaural technology procedures [8] necessary to create 3D auditory displays require knowledge of the head-related transfer functions of the listener, and proper equalization of the sound delivery system, typically a set of headphones.

4.0 HEADSET DESIGN

Table II lists the principal technical features to consider in the selection of a suitable ANR headset for binaural technology applications. In a prototype system, the binaural signal processing unit should likely be external to the ANR headset itself. This unit would store the head-related transfer functions of the listener and execute all the operations required to transform each acoustic source into left and right ear signals, given the direction of (virtual) sound incidence. These signals would be presented to the listener via the communication channels of the ANR headset. Depending on the application, the binaural unit would also store a more or less complex model of the 3D auditory environment to be created, and execute all angular adaptations related to the head motion of the listener.

ANR communication headsets based on analog electronics have been commercially available for the past 10-15 years. Table III lists the devices surveyed. All devices support stereophonic listening, a pre-condition for binaural technology applications. However, they differ in several other respects such as the amount of attenuation provided, and the method of processing and adjusting the level of the communication signals [1,2]. The most likely candidates are the Peltor, Sennheiser and

TechnoFirst devices. However, many important technical characteristics including the amount of cross-talk attenuation, the earphone linearity, the electronic noise floor and the degree of interaural earphone matching are unspecified by the manufacturers, and would require extensive testing.

Finally, prototype ANR devices based on digital technology have been tested in research laboratories in the past few years [9], and the first commercial digital ANR headsets have been recently introduced. Since binaural technology is also based on digital signal processing, digital ANR headsets could lead to more completely integrated and compact ANR-binaural systems than analog ANR headsets.

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Table I: General factors affecting auditory perception with communication headsets

Task:	Detection
	Discrimination
	Word Recognition
	(Virtual) Sound localization
Listener:	Age
	Fluency
	Hearing status
Background:	Quiet or Noisy
	Type, Spectrum and Level of noise
	S/N ratio
Device:	Attenuation characteristics
	Passive or Active
	Communication channel characteristics

Table II: Technical factors affecting the reproduction of virtual audio signals with communication headsets

Listening mode
Volume control
Cross-talk attenuation
Earphone linearity
Earphone frequency response
Electronic noise floor
Coupling to the ear
Interaural matching

Table III: Analog ANR communication headsets surveyed

Peltor ANR Aviation Headset
Sennheiser NoiseGard
Bose Aviation Headset
Bose Aviation Series II
David Clark DCNC Headset
David Clark H1013X
Telex ANR Headset System
Telex ANR 4000
TechnoFirst NoiseMaster