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EUROSPEECH '97
5th European Conference on Speech
Communication and Technology
Rhodes, Greece, September 22-25, 1997

AN ASSESSMENT OF THE BENEFITS ACTIVE NOISE REDUCTION SYSTEMS PROVIDE TO SPEECH INTELLIGIBILITY IN AIRCRAFT NOISE ENVIRONMENTS

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ABSTRACT

The high noise levels being experienced in some military fast jet aircraft and helicopters generally result in a reduction in the intelligibility of speech communications.

A study has been conducted to assess the effect of reducing noise levels at the ear, by the use of current Active Noise Reduction (ANR) systems, on speech intelligibility in aircraft noise environments. The results of this study indicate that ANR would improve speech intelligibility in both types of aircraft. The assessment has been conducted using Diagnostic Rhyme Test (DRT) and Articulation Index (AI) techniques. The study has also allowed the correlation between DRT and AI test results to be investigated.

A more detailed account of the work reported in this paper is provided at [1].

1. INTRODUCTION

The high noise levels being experienced in some military aircraft generally result in a reduction in the intelligibility of speech communications. In addition, these noise levels present a hearing damage risk and can also affect auditory monitoring tasks such as the detection of audio warnings presented to aircrew.

The most practicable and cost effective method of reducing noise levels at aircrew's ears is to incorporate hearing protector earshells inside the flight helmet. However, a technological limit is being reached in the passive attenuation performance of this type of earshell [2], and therefore active systems have been developed to reduce noise levels at the ear further. One such system is Active Noise Reduction (ANR), a technique which was proposed as early as 1953 [3]. The principle of ANR and its practical implementation in flight helmet earshells is described in detail at [4]. Figure 1 shows a block diagram of the system. Noise at the ear is monitored using a miniature microphone, the signal is then inverted and fed back in anti-phase to the telephone (tel) transducer in the earshell to produce destructive interference and hence noise cancellation within the earshell. The Defence Evaluation and Research Agency (DERA) have miniaturised the ANR electronics to fit into a standard flight helmet earshell, with 28V DC power being the only additional connection required. The most recent analogue system is DERA Mk2 ANR and an assessment of the attenuation performance of this system is given at [5]. The system provides active attenuation at frequencies up to 1kHz and thus compensates for the poor low frequency passive attenuation of standard flight helmet earshells.

This paper describes work to assess the effect of the DERA Mk2 ANR on speech intelligibility in fast jet aircraft and helicopter noise environments.

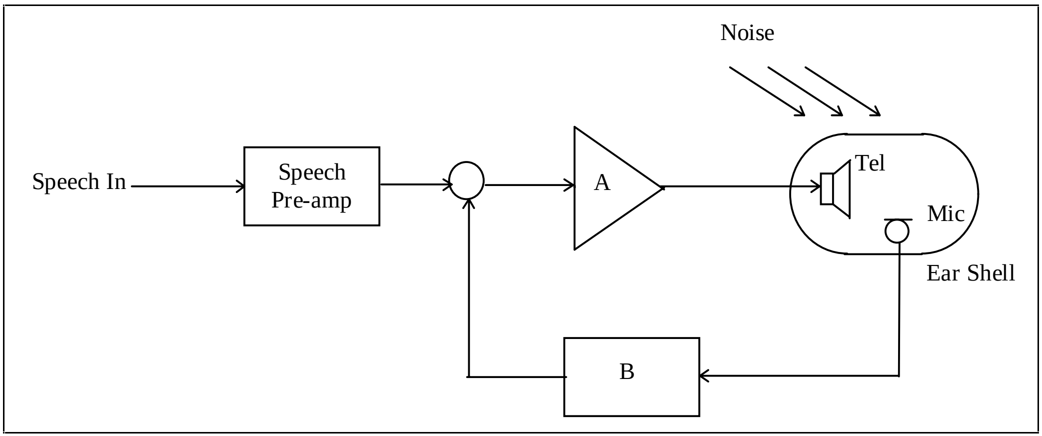

Figure 1 - ANR Block Diagram

2. ASSESSMENT METHODS

Intelligibility has been defined as "…. the percentage number of ideas correctly transmitted over a circuit" [6].

The methods available to measure intelligibility can be classified as either "subjective" or "objective". Subjective tests are those in which the ability of a listener to understand speech transmitted over a communications system is tested. Objective tests however attempt to predict intelligibility by measuring physical parameters of the actual communications system (frequency, amplitude, distortion, etc.). Descriptions of a range of subjective and objective tests are provided at [1].

In this study, one subjective test (the Diagnostic Rhyme Test, DRT) and one objective test (the Articulation Index, AI) have been used to assess the benefits of the ANR system to speech intelligibility.

2.1 Diagnostic Rhyme Test

The Diagnostic Rhyme Test (DRT) [7] is widely used to assess the intelligibility of military voice communications [8] and has been used extensively at the DRA for assessing the performance of aircraft communications systems. The DRT is based on the ability of a listener to distinguish between pairs of words which differ only in one acoustic attribute of their initial consonant. There are 192 words arranged in 96 rhyming pairs in the DRT vocabulary. For example, "veal" and "feel" are a rhyming pair which differ because the initial consonant is voiced in "veal", but unvoiced in "feel". The six attributes tested are voicing, nasality, sustention, sibilation, graveness and compactness.

The result of a DRT test is expressed as a percentage of correct responses, adjusted for guessing. This means that a listener who gets half of the words correct will score 0% as this result could have been achieved by guessing.

The validity of DRT results is highly dependent on the listening panel used. The panel must be audiologically screened to check their hearing. The listening panel must also be "trained" by completing a series of DRT training runs before the full tests are conducted. These are designed to identify the listeners who are not suited to the long periods of concentration necessary for the tests. They also allow checks to be made on the consistency and repeatability of the performance of individual listeners - an essential feature of the DRT.

2.2 Articulation Index

The Articulation Index (AI) was originally proposed by French and Steinberg [9] and an ANSI Standard has also been published to describe the method [10].

AI predicts speech intelligibility by taking the following factors into account:-

- The frequency spectrum of the interfering noise;
- The speech spectrum at the listener's ears;
- The relative importance of each frequency band to the intelligibility of the speech.

The speech-to-noise ratios in each of the frequency bands that are important to speech are calculated. These are each multiplied by a weighting factor based upon the importance of that band to the overall speech intelligibility, and summed to give the Articulation Index, which is a number between 0 and 1.

3. TESTS

As previously stated, tests were conducted to asses the benefits of ANR to speech intelligibility in two aircraft noise environments, a fast jet and a helicopter. The mean "noise-at-ear" spectra (the noise reaching the listener's ear under the helmet earshell) for these two conditions are shown in Figures 2 and 3, where "Std" denotes the noise-at-ear with the standard flight helmet earshell and "ANR" denotes the corresponding spectra with the ANR earshells. Table 1 shows the overall noise-at-ear levels for each condition. The figures have been A-weighted so that they relate to the subjective impression of "loudness". A reduction of 13.6dB(A) was achieved in helicopter noise, but only 4.6dB(A) in fast jet noise. This is because helicopter noise is predominantly low-frequency in nature, where ANR is more effective (Section 1).

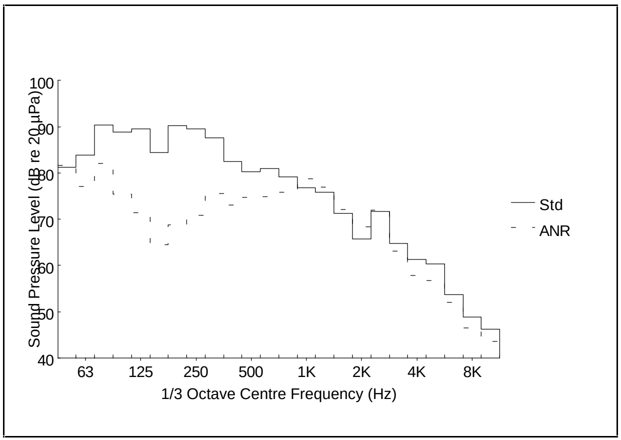

Figure 2 - Fast Jet Noise-at-Ear

	Std	ANR
Fast Jet	88.9	84.3
Helicopter	84.6	71.0

Table 1 - A-weighted Noise-At-Ear, dB(A) SPL

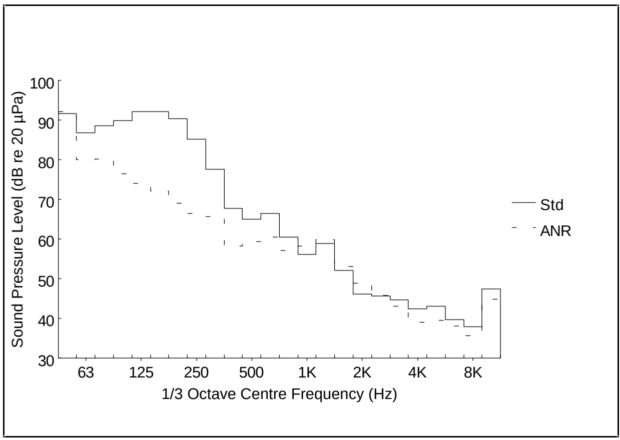

Figure 3 - Helicopter Noise-at-Ear

In all the intelligibility tests, the speech material used was recorded using the standard communications microphone for the aircraft tested, and at a relatively poor speech-to-noise ratio (SNR) of 10dB.

Five talkers and twelve listeners participated in the tests.

4. RESULTS

The mean results across all talkers and listeners are presented in Figures 4 and 5. Figure 4 shows that ANR increases DRT scores by over 5% in both fast jet and helicopter noise environments, and statistical analysis shows that this improvement is statistically significant [1]. The DRT scores achieved (both with and without ANR) are lower in fast jet noise than in helicopter noise. This is due to differences in the overall noise levels and in the spectral composition of the noise for each aircraft type (Table 1 and Figures 2 and 3).

The AI results (Figure 5) follow the same general trends as the DRT scores, with increased scores when ANR is used. However, the increases in AI scores are not statistically significant [1].

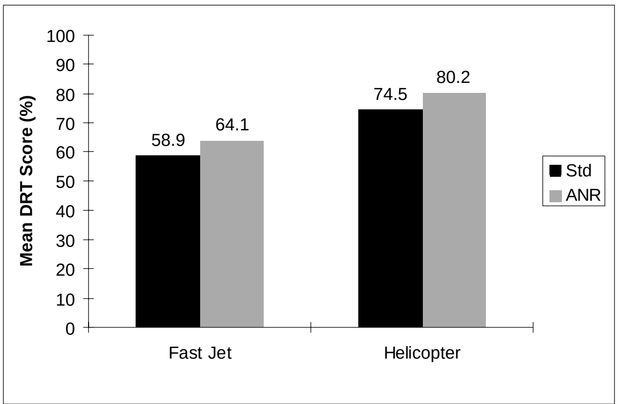

Figure 4 - DRT Results

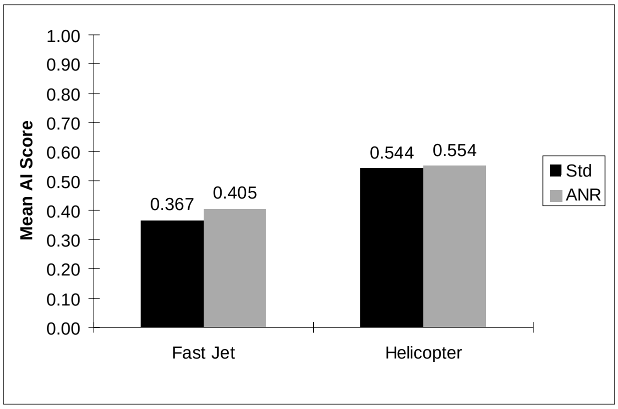

Figure 5 - AI Results

5. CORRELATION OF DRT AND AI RESULTS

Thirteen different conditions were tested as part of the trial, but for brevity only the results for two noise fields have been described and reported in this paper. The complete results are provided at [1].

Figure 6 shows the relationship between the AI and DRT scores measured in the thirteen conditions (the data points for the 13 conditions are each marked by an X). A regression line has been calculated for this set of data and is shown by the solid line on the graph, and the formula for the regression line is also displayed. Note that the R^2 value of 0.9627 indicates that the regression line generated is a good fit to the data ($R^2 = 0$ is a poor fit, $R^2 = 1$ is a perfect fit).

The dotted line in Figure 6 is the relationship between AI and DRT derived by Smith [11] and included in Def Stan 00-25 [8].

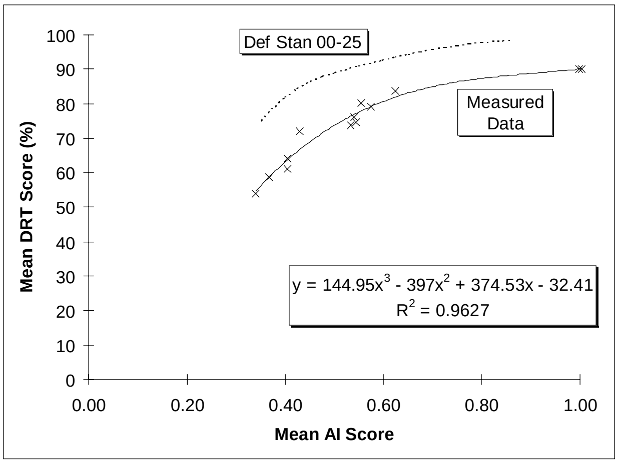

Figure 6 - DRT Score vs AI Score

Figure 6 shows that for a given AI score, the measured DRT score in the tests was significantly lower than that suggested by Smith. Possible explanations are outlined overleaf.

Smith conducted DRT tests on speech recorded through a high quality wideband microphone and electrically mixed with white noise at a range of talker SNRs. The tests were conducted with the listeners wearing headphones in a quiet listening environment. AI scores were then estimated at each of these SNRs.

The present study used aircrew microphones and helmets (which do not have flat frequency responses), and high levels of fast jet and helicopter noise at the talker and listener positions. The AI calculation may not take account of some of the characteristics of this more complicated scenario. If the AI score was over-estimated then this would lead to a higher predicted DRT score than that actually obtained in practice.

It is possible that the listeners made a significant number of errors in the DRT tests i.e. they thought they heard the correct word but selected the wrong word. This would explain why the mean DRT score was limited to 90% even under quiet conditions. However, the author has previously conducted DRT tests in the quiet with wideband microphones and high quality headphones and obtained DRT scores close to 100% and thus this is unlikely.

6. CONCLUSIONS

ANR improves the intelligibility of speech in the fast jet and helicopter noise fields used in this study, and the increase in DRT scores was statistically significant.

DERA are currently developing digital and ear insert ANR systems [12] which will provide even better noise attenuation performance than the analogue system used for the tests described in this paper. It is likely that these systems will produce even greater gains in speech intelligibility.

The DRT and AI scores measured in this study are well correlated. However, the regression line for the data is significantly different to that published in Def Stan 00-25.

It is hoped that further speech intelligibility tests such as Speech Transmission Index (STI) and Phonetically Balanced (PB) word tests [8] will be conducted on the ANR system during 1997. These tests will enable further correlations between speech intelligibility metrics to be investigated.

7. REFERENCES

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