AN ACTIVE NOISE REDUCTION SYSTEM FOR AIRCREW HELMETS

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INTRODUCTION

In a high noise environment conventional ear-defenders may be incapable of providing sufficient noise attenuation. An active noise reduction system (ANR) has been developed for use in aircrew flying helmets (ref. 1) in which the acoustic noise field inside the ear defender is detected using a miniature microphone and an antiphase signal is fed back to a communications telephone within the ear defender. The feed-back loop also affects the communications signal which has to be compensated outside the loop in order to retain the original transfer function from telephone amplifier to listeners ear.

The concept was not new at the outset of the work reported. In 1953 Olsen and May (ref. 2) investigated the possibility of creating a noiseless zone in free field conditions, but the technique had not apparently been successfully applied to headsets. However, the Procurement Executive, Ministry of Defence had outlined a method which proved the basis of this present work.

The major engineering development involved in integrating the technique into a conventional aircrew flying helmet was associated with the identification and characterisation of suitable microphones and telephones. At the time of previous publication (ref. 1) the feasibility of active reduction had been demonstrated though tests with random noise had not been undertaken. Some instability problems still existed and the performance with a communications signal had not been assessed.

During the last two years the remaining engineering problems have been overcome and an extensive program of laboratory subjective trials has been completed. In-flight trials of the system are currently underway. Throughout this programme of work there has been active participation by the Royal Aircraft Establishment, Farnborough, and the development has been carried out with the support of the Procurement Executive, Ministry of Defence, U.K.

PRINCIPLES

One channel of the complete system is shown schematically in Figure 1. The design is based upon the existing ear defender shell and seal, and incorporates a high-fidelity type moving-coil telephone and a miniature electret microphone.

A complete analysis of the system shows that the pressure at the ear (P_e) is comprised of two components due to the signal (S_v) and the external noise field without ANR (n_p).

$$P_e = \left(\frac{AT_1}{1 + ABKT_1T_2}\right) S_v + \left(\frac{1}{1 + ABKT_1T_2}\right) n_p \qquad (1)$$

where A, B, K, T_1 and T_2 are the transfer functions of the amplifier, feedback loop, acoustic cavity, telephone and microphone, respectively.

It is apparent that the amplification of the two components is different and that if the signal S_v is pre-emphasised, to compensate for its attenuation by the feedback loop, and returned to its original level then an improvement of a factor $(1 + ABKT_1T_2)$ can be achieved.

The product of the terms KT_1T_2 is of fundamental significance as it represents the overall electrical transfer function of the telephone - cavity - microphone system. To provide ANR, the product AB would ideally have a complementary variation with frequency. In practice the frequency response must be tailored to ensure that when the loop gain approaches unity the total loop phase shift does not approach 180^o.

The systems ability to match this transfer function KT_1T_2 will determine the degree of noise reduction which is obtained.

EVALUATION

The ANR system has been comprehensively tested in a series of laboratory trials, prior to flight trials by the Royal Aircraft Establishment.

Two basic methods of measuring ANR have been used throughout the project. These are:

a) An electronic computation method

b) An external broadband noise method

The computer method used a single frequency excitation which was analysed by means of an analogue computer circuit that calculated the value of $1 + ABKT_1T_2$ and continuously plotted its amplitude and phase as a function of frequency.

In the second method, preferred because of its close approximation to the real life situation, subjects wearing the ANR modified flying helmet were exposed to an external noise field similar to that experienced by pilots in a high performance strike aircraft. Comparisons of attenuation and speech intelligibility scores, with and without the ANR system in operation, were made, and the modified helmet's attenuation was also checked against a standard flying helmet.

Objective measurements of helmet attenuation were made using miniature microphones placed at the subject's pinnae, and outside the helmet.

These two methods of measurement were carefully compared in a structured series of eight experiments to check that the more convenient laboratory computational method gave the same results as the noise excited experiment.

The intelligibility testing was carried out using anglicised modified Rhyme Test material comprising four sets of fifty initial or final consonant words plus twenty five central vowel words. The subject was required to score his reception of a word by marking a score sheet showing all six rhyming alternatives for a given word and, at the end of the experiment, the sheets were marked by the experimenter. For each condition - ANR on or off - two of the four word lists available were presented and the number of subjects was chosen to give a fully balanced experiment with a satisfactory level of statistical significance. The speech signal presented to the ear was matched, for all the helmet configurations tested, to within ± 1 dB(A) overall and ± 1 dB in each 1/3 octave band.

Eighteen subjects were tested twice in each configuration and the mean improvement in attenuation was found to be 12 dB(A) for the noise field used (Figure 2).

Figure 3 shows the ANR performance as a function of frequency, together with a measure of the scatter of results. The comparison between mean helmet attenuation values is shown in Figure 4.

The mean improvement in speech intelligibility with the ANR system in operation was 21% relative to a baseline of 51% when the system was switched off. The individual performances of subjects are shown in Figure 5.

All those tested commented upon the increased comfort provided by the higher attenuation of the ANR system, particularly at lower audio frequencies, where the aircraft's noise energy is concentrated.

CONCLUSIONS

The use of active noise reduction in a laboratory trial simulating flight conditions has been shown to give encouraging objective and subjective results. The system is capable of application to a wide range of situations where high attenuation (with or without voice communications) against low frequency noise is required. The response of the ANR system may be engineered, to an extent, to optimise attenuation for particular noise fields, such as are experienced in rotary wing and fixed wing aircraft, and for certain applications, the system may be fitted into a small, battery operated, electronics package which may be easily worn on the person.

REFERENCES

1. Dorey, A.P., Pelc, S.F., and Watson, P.R. 1975, "An Active Noise Reduction System for use with Ear Defenders". 8th International Aerospace Symposium, Cranfield, 24-27.

2. Olsen, H.F., and May, E.G. 1953, J.A.S.A. 25 , No.6.

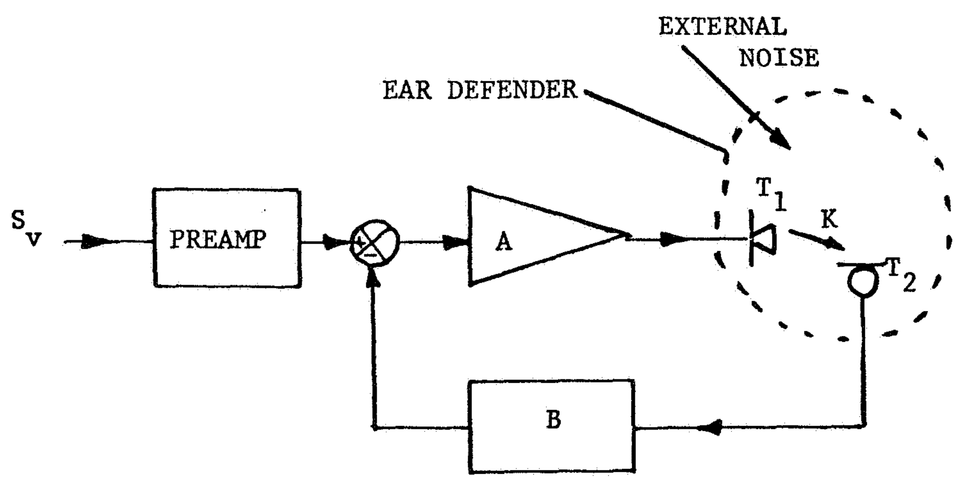

Figure 1.- A system block diagram.

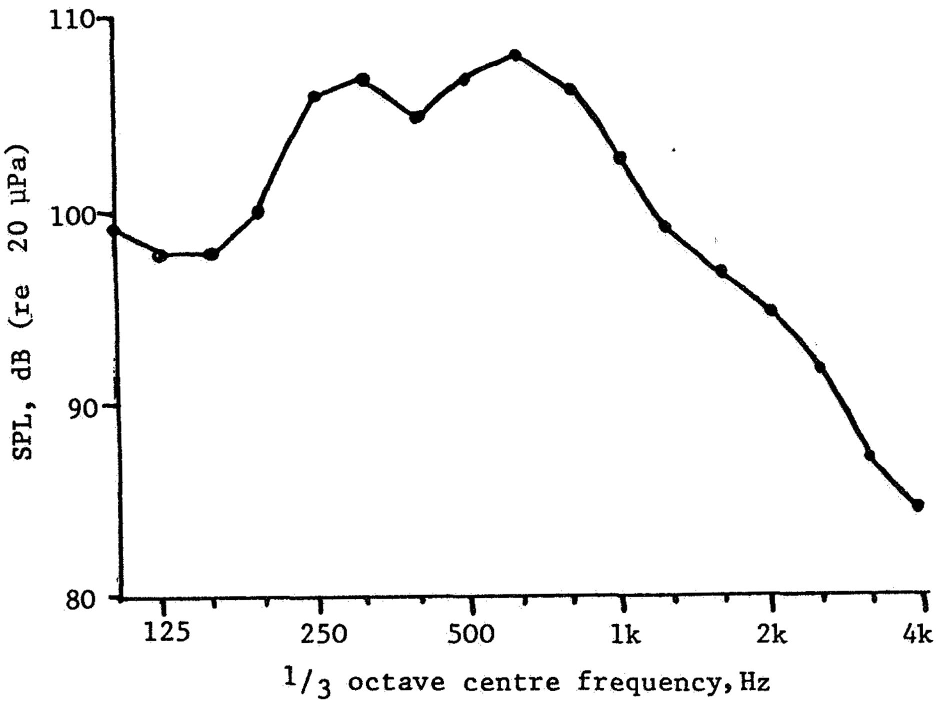

Figure 2.- Simulated aircraft cockpit noise.

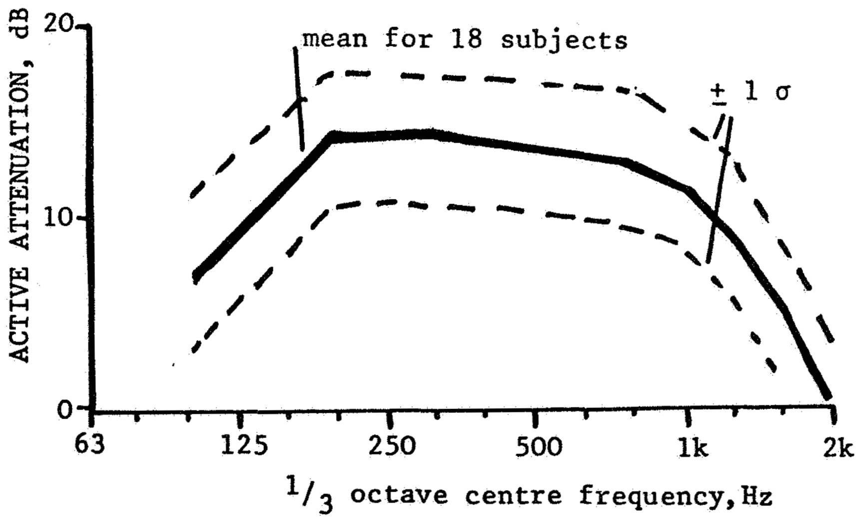

Figure 3.- ANR performance.

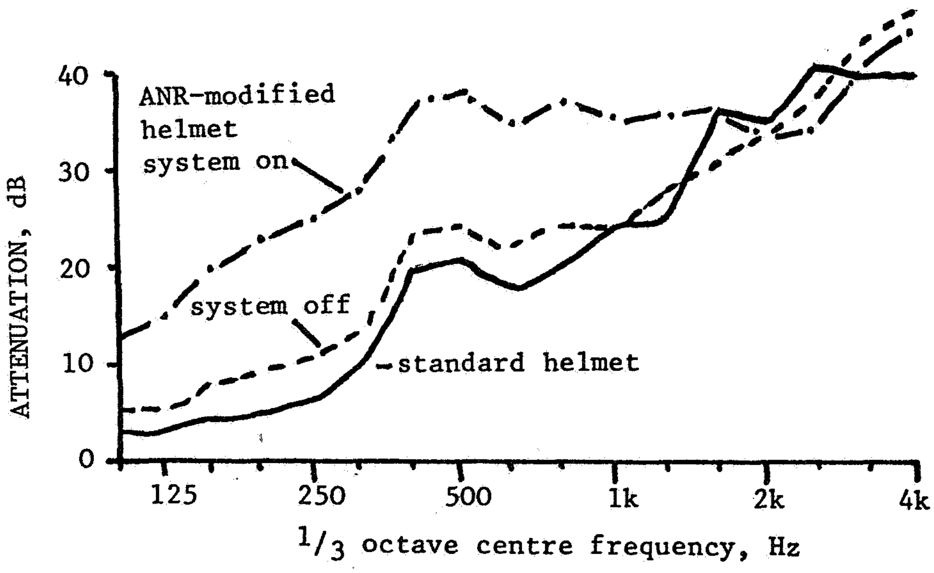

Figure 4.- Mean helmet attenuation.

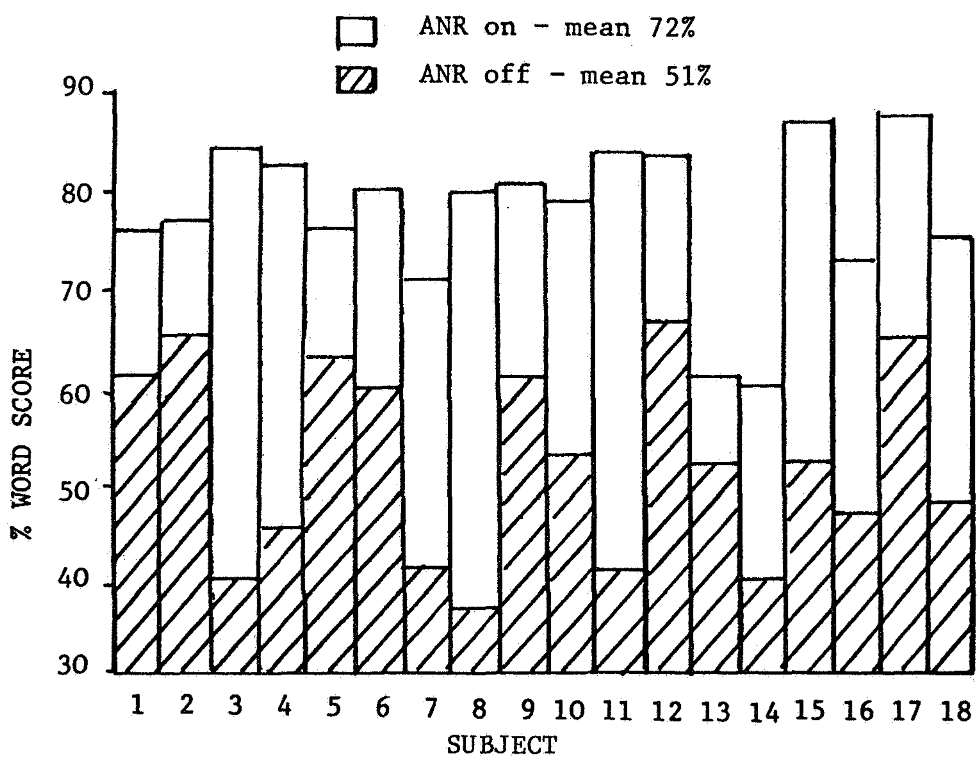

Figure 5.- Word scores for 18 subjects.