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SYNCHRONOUS ADAPTIVE CANCELLATION IN VEHICLE CABINS.

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INTRODUCTION

Although the Essex "repetitive" system, unlike other free-field anti-noise systems, enables the noise and anti-noise sources to be precisely phased, there are situations where the noise source is not physically accessible, and it is therefore impossible to site the anti-noise source adjacent to it.

This situation occurs in an enclosed space, such as the cab of a tractor, in which the internal noise is induced by a variety of mechanisms, including vibrating panels. It is sometimes possible to tackle these various mechanisms separately, as in the case of aircraft cabin noise, but this procedure can be complex, and is not regarded as suitable for a vehicle cab. In this latter case, a lower cost solution is to provide a zone of silence around the driver's head position.

Many repetitive noise sources are not small relative to the important acoustic wavelengths, and their geometrical complexity is often such that they cannot be divided into several separate sources which could then be cancelled individually.

There are two possible solutions to the large, complex source problem. One is to place the cancelling source close to, or within, the ear cavity using anti-noise ear defenders, and the other is to create a spatial zone of noise cancellation, as considered here.

THE CAB NOISE PROBLEM

Modern vehicle cabs incorporate a wide range of sophisticated passive noise control measures, to reduce the environment noise as well as the noise in the cab, including sound-absorbing panel enclosures, rubber-sealed doors and windows, engine inlet and exhaust silencers, and vibration isolation of the cab enclosure. Such measures are particularly necessary in a tractor because the driver is close to the engine, and is likely to use his machine for long periods, at full power.

In spite of this comprehensive, and quite expensive, passive treatment, some significant problems remain. For example, its effectiveness falls off at the lower frequencies, which are becoming increasingly recognised as a health hazard and the cause of operator discomfort and fatigue. In addition, the mounting of the cab on flexible vibration-isolating supports can add to the discomfort of the operator by inducing motion sickness. The passive seals on the doors and windows deteriorate through the (normal) rough usage of the equipment, resulting in a reduction of the acoustic isolation with usage.

A more fundamental problem is that the passive "quiet cab" isolates the driver from his environment, including warning sounds and, in the case of tractors, the noise of his towed machinery. Frequently, windows or hatches are opened to relieve these problems, but this effectively by-passes the passive treatment.

The Role of Active Cancellation

The conventional active method for producing a "zone of silence" is the close coupled microphone/loudspeaker negative feedback loop, but this has the disadvantage of requiring the loudspeaker to be sited at the driver's head position, and of being unable to discriminate between wanted and unwanted sounds.

The Essex Repetitive System (Ref.1) can produce a zone of silence around a residual microphone placed near the operator's head, even though the cancelling loudspeaker is located remotely. Furthermore, the system adapts automatically to changes in the acoustic environment, such as the opening of doors and windows, and inherently discriminates between wanted and unwanted sounds.

Experiments on a Tractor Cab

Two high-efficiency ported loudspeakers, of a compact design, were placed within a modern "Quiet" tractor cab (Ford, Mark SK82), one by each footrest, and the residual microphone was sited centrally, just above head height at the seat position. Loudspeakers were also placed outside the cab to produce a simulated exhaust noise, based on a filtered 15Hz square wave, which (measured inside) represented the tractor noise in the worst (open window) case. Figure 1 shows the spectra measured by the residual microphone before and after cancellation, using the Essex "transform" algorithm (Ref.2). At

50Hz a reduction of 26dB was achieved, a value typical in this region. Although the degree of cancellation deteriorated at positions progressively further away from the residual microphone, the effect was still substantial in all the normal operator head positions.

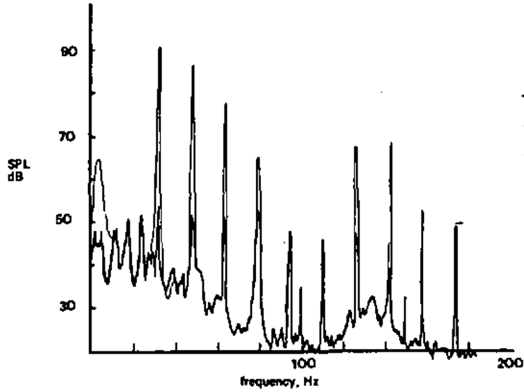

Figure 1

Noise spectra, at the driver's head position in the tractor cab, before and after cancellation.

APPLICATION TO AIRCRAFT PROPELLER NOISE

Consideration is being given to using propellers for the next generation of long-haul civil aircraft, in order to reduce fuel costs. If existing cruising speeds are to be maintained, the fuselage is likely to experience considerable acoustic pressures at the blade passage frequency, of around 100Hz, in line with the inboard propellers. Passive treatment to reduce the noise entering the fuselage interior to an acceptable level would incur a significant weight, and hence payload, penalty especially if constant propeller revolution rate cannot be guaranteed.

Early in 1981 the Essex Group were asked by British Aerospace to outline ways by which active methods might be used to cancel this noise, to enable a comparison to be made with passive methods, and some of the possibilities are indicated in Fig.2.

The cancellation mechanism chosen would depend on the magnitude, and source size, of the vibration and noise. The noise might be cancelled outside the fuselage, but this is probably beyond present technology. Inertial actuators, opposing the vibration induced on the outer skin, would be the next best solution, as this would also counter the metal fatigue problem. However, it is likely that at the high pressures expected, the force required from the actuators

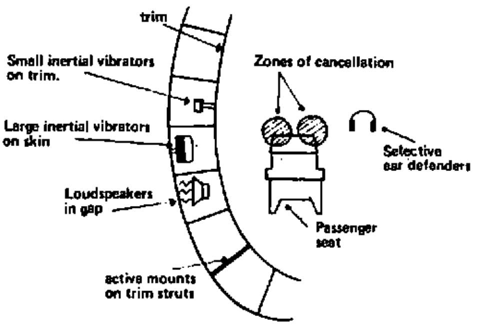

Figure 2

Possible methods for cancelling propeller-induced noise within an aircraft fuselage.

would require relatively large inertial masses, and a sufficient saving in weight would not be achieved. A more promising solution might be to introduce cancelling noise into the region between the outer skin and the inner trim, and/or to attach relatively small inertial actuators to the inner trim. Noise cancelling earphones, (Ref 3) might also be an acceptable solution in an aircraft, since they could double-up with in-flight entertainment. Alternatively, zones of cancellation could be produced in the regions around the passenger headrests, akin to that in the tractor cab.

However, in October 1982, British Aerospace decided to review the whole question of the next generation of aircraft, and so they deferred the proposed quantitive evaluation of active methods.

CONCLUSIONS

The experiments have demonstrated that a useful reduction of the low frequency components of a repetitive noise source can be effected in a zone around the driver's head position in a tractor cab. Only engine-related noise components are cancelled, allowing the driver to hear other noises freely.

REFERENCES

[1] G.B.B. Chaplin & R.A. Smith, 'Waveform Synthesis - The Essex Solution to Repetitive Noise and Vibration' Inter-Noise 83 Proceedings.

[2] R.A. Smith & G.B.B. Chaplin, 'Some Classes of Essex Algorithms for Major Industrial Applications' Inter-Noise 83 Proceedings.

[3] O. Jones & R.A. Smith, 'The Selective Anti-Noise Ear Defender' Inter-Noise 83 Proceedings.