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WAVEFORM SYNTHESIS - THE ESSEX SOLUTION TO REPETITIVE NOISE AND VIBRATION.

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WHY WAVEFORM SYNTHESIS?

Active control is poised to enter the market place in many major industries, such as shipping, automotive, aircraft, and manufacturing, for a wide range of periodic noise and vibration sources, including diesel engines, compressors, motors and propellers. This widespread penetration of a technology which, hitherto, was restricted mainly to ducts, follows a simple observation made in 1976 (Refs.1 & 2). It was pointed out that the traditional active principle had a fundamental limitation. The concept of sensing the offending source and then electronically filtering the signal before injecting the resulting anti-phase version, included an inherent delay. Thus source and anti-source could never be coincident in time, and applications were largely restricted to ducted systems, where this limitation could be accommodated.

Fortunately, a great number of our major noise and vibration problems are of a periodic nature, and it is a fundamental fact that this periodicity enables the delay to be eliminated. In fact, both sensing and filtering become unnecessary, and the anti-phase version can simply be synthesised, and made coincident with the source. This high precision timing is achieved by synchronising the synthesiser to the noise source, and this synchronisation results in the further property of selectivity - a unique feature which cannot be achieved by passive means, and significantly widens the scope of the control of noise and vibration in general.

Selectivity also results in a further property of the system - namely directionality - which is an important requirement for the active control of vibration, such as for active mounts for engines.

The Basic Periodic System

Fig.1 shows how the Essex system differs from the traditional concept.

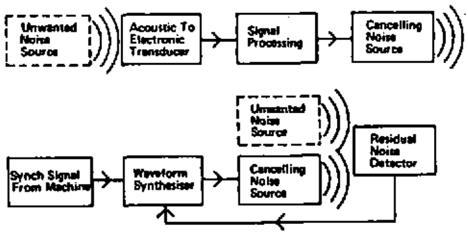

Fig.1 a) The traditional active system. Delay, inherent in all three functions, separates the unwanted and cancelling noise sources.

b) The Essex (periodic) system. The two sources are now coincident. The residual detector is an inherent part of the system and enables it to adapt to a changing acoustic environment.

The system makes use of the information from the previous repeat cycle, and so has the benefit of "negative time" in which to synthesise the cancelling noise pressure waveform, and propagate it at precisely the right instant.

The adaption time of the system depends on the strategy (algorithm) adopted, and can be a fraction of a second. In practice the system adapts continuously, and has only to cope with the variation from one repeat cycle to the next. The adaption time can thus become negligible and, in any case, it only affects the degree of cancellation. Typically, this is 20dB for noise such as the exhaust noise of a 3,000 HP diesel engine in the range 20-250Hz, and over 40dB for vibration - such as at the mounts of an engine in the range 1.0Hz (or less) to 250Hz.

The Synthesiser Module The synthesiser simply adjusts its output waveform to minimise the residual error signal at its input. The synthesiser module itself is therefore common to all applications and remains unchanged. However, the optimum strategy required to minimise the residual signal will vary with the type of application, and this is catered for by a plug-in read-only memory chip. A number of algorithms, each stored in its own ROM, have been developed, and it takes only a few seconds to plug in a different algorithm when required.

Implications and Applications

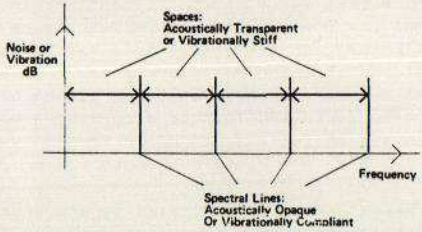

Fig. 2 Schematic frequency spectrum of engine-related noise or vibration.

Figure 2 shows a schematic spectrum of low frequency periodic noise or vibration. Note the narrow harmonically-related spectral lines, and the wide regions which separate them.

Cancellation only occurs at the frequencies of the lines; the frequency bands between remaining unaffected. This results in the unique selective properties shown and enables normal speech to be heard clearly in an otherwise impossibly noisy room, as with the headset of Fig. 3 or in a region of space, such as a tractor cab.

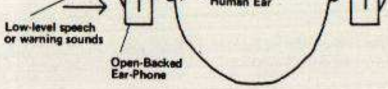

Fig.3 Selective Ear Defender. Standard open-backed headphones, with the Essex system fitted, cancel the unwanted engine-induced noise but allow through speech, and warning sounds.

Similarly, engine mounts appear rigid to motional forces, produced for example by vehicles or ships, but do not transmit engine-related vibration (Ref.3).

The benefits of the system are not restricted to the resulting environmental improvement. For example, the selective feature alone can have significant economic implications. An active "quiet cab" could cost less than its passive counterpart, continue to function when windows or hatches are opened, and enable extraneous warning sounds to be heard. In the case of vibration, a ship's engine manufacturer has predicted that the rigidity of the active mount to seaway forces could allow the cardan shaft to be dispensed with, enabling the engine to be installed further aft, with a consequent reduction in pipe runs and an increase in cargo space.

Actuators

The potential of the Essex System is indicated by its increasing adoption by other noise and vibration organisations, and the point has already been reached where progress is no longer determined by the system itself, but by the need for improved actuators. One such improvement is a novel loudspeaker enclosure developed for silencing the exhaust of the M.V. Saint Oran (Fig.4).

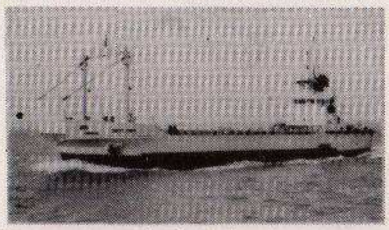

Fig.4 The MV 'Saint Oran' undergoing acceptance tests fitted with the Essex system.

The spectrum included noise pressure levels of 123dB at 1 metre in the 35 and 70Hz regions, but cancellation was achieved with an electrical input of less than 500 W. More fundamental work is needed to produce low-cost vibration actuators for mounting large engines, but feasibility studies have already indicated several promising solutions.

References

[1] Chaplin G.B.B., R.A. Smith & R.G. Bearcroft 'Active Cancellation of Recurring Sounds', UK Patent No. 19717/76 (1976)

[2] Chaplin G.B.B. 'The Cancellation of Repetitive Noise and Vibration', Inter-Noise 80 Proceedings, 699-702 (1980).

[3] Chaplin G.B.B. 'Anti-Noise - The Essex Breakthrough' - Chartered Mechanical Engineer, 30, 41-47 (1983).

Acknowledgements

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