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Acoustics

Unwanted and wanted sound

Thomas D. Rossing

More and more people are becoming concerned about the control of environmental noise. That was certainly true of those attending the joint meeting of the Acoustical Society of America and the Institute of Noise Control Engineering in June*. Although the meeting included more than 100 sessions covering all aspects of acoustics, noise control received particular attention — especially active control of noise and vibration.

In active noise control, a controlled source is used to cancel out an unwanted sound or vibration. It may employ either feedback or feedforward control (C. Hansen, Adelaide Univ.). In a duct, for example, a basic feedback system uses a microphone and a loudspeaker, along with an electronic controller. The loudspeaker vibrates to cancel out as much of the source sound as possible and to produce a minimum sound level at the error microphone (Fig. 1a). In a basic feedforward system, a reference microphone is added to sample the source noise before it reaches the error microphone (Fig. 1b). Because of their inherent stability, feedforward controllers are generally preferred over feedback controllers. Adaptive logic and other refinements can be added.

Effective noise control often requires the reduction of noise transmission through panels or partitions. In active structural acoustic control, actuators are attached to a panel to change its radiation characteristics. For example, 'smart' foam, with a piezoelectric actuator in between layers of sound-absorbing foam, can reduce sound radiation from vibrating plates (C. Guigou and C. R. Fuller, Virginia Polytechnic Inst.). And a new active interior trim panel can control aircraft noise at low frequency, up to 400 Hz (S. Sharp, G. Koopmann and W. Chen, Penn State Univ.). The actuator is a small, rigid panel that is driven in a piston-like motion by a moving-coil transducer similar to that of a loudspeaker.

In contrast to these papers on unwanted sound, a special session on loudspeakers dealt with improving the quality of wanted sound. Gabriel Weinreich (Univ. Michigan) has designed and built a loudspeaker with a direc-

tional radiation pattern that is a strong function of angle and frequency, like a violin's output at frequencies above 850 Hz. This produces the illusion that each note comes from a slightly different direction, confusing the common psychoacoustic cues and endowing the sound with a striking spatial sense like that of a violin, an instrument especially noted for its 'directional tone colour'. Weinreich demonstrated the ability of this loudspeaker to reproduce the sound of a violin and a pipe organ. Conversely, an ear-catching demonstration by Bruce Edgar, using his own voice, showed how a new horn design could be used to remove the sound colorations that plagued many vintage horn systems.

Sound can be 'wanted' for rather different purposes. By recording an incoming sound wave, reversing its time structure and re-emitting it, it can be focused back to its point of origin (this time-reversal technique has precedents in radar and optical technology). Practical time-reversal mirrors consist of large, ultrasonic transducer arrays. They have applications in medicine (to destroy kidney stones, for example) and in non-destructive testing of solids (M. Fink, Univ. Denis Diderot, Paris).

Time-reversal mirrors also have applications in the sea, but here the method is complicated by the fact that the medium is changing with time. Yet two experiments conducted in the Mediterranean Sea in April

1996 and May 1997 demonstrated that an acoustic time-reversal mirror can focus sound back to its origin even in an inhomogeneous ocean. William Kuperman (Scripps Instn, San Diego) and colleagues used 20 sources and 20 receivers in a vertical array 77 m across. A source that sent out a 50-ms ping every two minutes was towed through the focus of the array. The signal was received, reversed and retransmitted successfully to distances as great as 30 km. This experimental result is particularly remarkable when one considers that a spot 1/10th as deep as the waveguide is projected to a range more than 300 times the depth, with a horizontal extent of about one waveguide depth. These methods can be used to learn more about acoustic propagation in the ocean, perhaps for communications purposes, and to study fluctuations in currents, temperature and salinity using sound as a probe.

Returning to airborne sound of the desirable variety, Judith Brown (Wellesley College and MIT) discussed how to use computers to identify the sounds of musical instruments. The most successful schemes for identifying human speakers rely on the formant structure of speech sounds. (Formants are resonances of the vocal tract that determine speech sounds. Each vowel sound, for example, is characterized by three to five formant frequencies.) Identifying the formants of each speaker allows a computer to distinguish speakers through pattern recognition.

So Brown followed the same procedure for the oboe and saxophone. It turns out that a computer can do very well — in fact, it scored considerably better than humans in identifying oboe sounds, although in the case of saxophones there was little difference. So, as well as doing clever things with sound production, some automatic systems can appreciate the result for us. □

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Figure 1 Two schemes for active noise control. a, Simple feedback, in which the control signal is tweaked to cancel out the unwanted noise; b, 'feedforward', in which a second microphone samples the noise, giving a rough value for the control signal directly, and so avoiding the instabilities of simple feedback.

* 133rd Meeting of the Acoustical Society of America, held jointly with NOISE-CON 97 (National Conference on Noise Control Engineering), Pennsylvania State University, State College, Pennsylvania, USA, 14–20 June 1997.