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Cut Out That Racket

"Active" noise-cancellation systems battle noise rather than just muffle it. So far their use is mostly industrial, but soon they will silence refrigerators and dishwashers -- and maybe even your neighbors

by John Sedgwick

MODERN technology may not have improved the world all that much, but it certainly has made life noisier. Unmuffled motorcycles, blaring car alarms, and roving boom boxes come first, second, and third on my list of most obnoxious noise offenders, but everyone could come up with his own version of aural hell -- if he could just find a quiet spot to ponder the matter.

Yet what technology has done, other technology is now starting to undo, using computer power to zap those ear splitting noises into silence. Previously silence-seekers had little recourse except to stay inside, close the windows, and plug their ears. Remedies like these are quaintly termed "passive" systems, because they place physical barriers against the unwanted sound. Now computer technology is producing a far more effective "active" system, which doesn't just contain, deflect, or mask the noise but annihilates it electronically.

The system works by countering the offending noise with "anti-noise," a somewhat sinister-sounding term that calls to mind antimatter, black holes, and other *Popular Science* mind-benders but that actually refers to something quite simple. Just as a wave on a pond is flattened when it merges with a trough that is its exact opposite (or mirror image), so can a sound wave be negated by meeting its opposite.

This general theory of sound cancellation has been around since the 1930s. In the fifties and sixties it made for a kind of magic trick among laboratory acousticians playing around with the first clunky mainframe computers. The advent of low-cost, high-power microprocessors has made active noise cancellation systems a commercial possibility, and a handful of small electronics firms in the United States and abroad are bringing the first ones onto the silence market.

Silence buffs might be hoping that the noise-canceling apparatus will take the shape of the .44 Magnum wielded by Dirty Harry, but in fact active sound control is not quite that active. The system might more properly be described as reactive, in that it responds to sound waves already headed toward human ears. In the configuration that is usual for such systems microphones detect the noise signal and send it to the system's microprocessor, which almost instantly models it and creates its inverse for loudspeakers

to fire at the original. Because the two sounds occupy the same range of frequencies and tones, the inverse sounds exactly like the noise it is meant to eliminate: the anti-noise canceling Beethoven's Fifth Symphony is heard as Beethoven's Fifth. The only difference is that every positive pressure produced on the air by the orchestra is matched by a negative pressure produced by the computer, and every negative pressure is matched by a positive, thereby silencing the sound. The system is most effective as a kind of muffler, in which microphones, microprocessor, and loudspeaker are all in a unit encasing the device that produces the sound, stifling it at its source. But it can work as a headset, too, negating the sound at the last moment before it disturbs one's peace of mind.

Active systems are potentially capable of handling the full range of audible frequencies, but they are currently most effective on the lower ones. Passive systems handle low frequencies poorly, because of low notes' power and remarkably long wavelengths -- about fifteen feet for a C two octaves below middle C. (That's why the throbbing bass of a neighbor's rock music comes through the wall, but not the lilting melody.) With tight "coupling," by which noise and anti-noise are perfectly matched, the result is absolute silence, but usually some of the noise leaks through, or the anti-noise spills out. Still, active noise systems can cut up to 80 percent more noise than conventional mufflers. At that rate the roar of an industrial fan becomes a gentle whir -- not absolutely silent, but acceptably quiet.

The technology has made its first appearances in the marketplace in certain narrow segments where the money for it is most forthcoming. Noise Cancellation Technologies, one of the leaders in the new field, has developed a noise-canceling headset for patients undergoing magnetic resonance imaging, a cross-sectional scanning technique that is extremely loud. It has also quieted the vacuum-powered machines used to unload grain by a large railroad transportation company called CSX, based in Richmond, Virginia. The device had produced as much noise as a jet at takeoff. When the active system was installed, the noise was reduced to "the hum of an airconditioner," in the words of Roger Posey, the manager of operations at CSX.

In partnership with Walker Manufacturing, which makes automotive mufflers, NCT has begun producing electronic muffler prototypes for American and European automakers. The automakers are less interested in them for their silencing capabilities than for their ability to eliminate the "back pressure" placed on the engine by conventional mufflers as they force exhaust through many sound-absorbing chambers. Back pressure makes the engine work harder, cutting fuel efficiency. Tests performed by a laboratory certified by the Environmental Protection Agency have shown that active noise cancellation can improve fuel efficiency by one to two percent on the highway and five to six percent in the city. "In the automobile industry," says Michael Parrella, the president of NCT, "half a percent is considered significant fuel savings." Such an efficiency gain allows manufacturers to meet increasingly stringent congressional standards without cutting back on the number of profitable gas-guzzlers at the high end of the market. "The car manufacturers' interest is all the fuel savings," Parrella confides. "We're talking big business here. It has nothing to do with noise."

Some automobile manufacturers are more directly receptive to the sounds of silence, however. Lexus, hoping to enhance its reputation as one of the quietest cars on the road, has expressed interest in the products of a competing firm, called Active Noise and Vibration Technologies. After Porsche told ANVT's president, Tom Hesse, that its drivers *liked* to hear engine noise, ANVT developed a special Porsche version of the technology in which the sound cancellation quiets the engine only when the car's stereo system is playing.

Other systems are in development. At its Baltimore laboratory NCT has come up with a prototype of a product it calls the Silent Seat, an executive's chair equipped with anti-noise speakers to create a quiet zone for its occupant not very different from the one under the Cone of Silence in the old *Get Smart* TV show. To achieve the maximum quieting effect, however, one has to position one's head exactly at the midpoint between the two antinoise speakers. When I sat in it, I had the eerie sensation that my head was a radio being tuned to the one silent station on the dial. The Silent Seat is intended for the cabins of especially noisy vehicles like trucks and helicopters, but NCT recognizes that such a chair might find its way into offices someday. "We've had a lot of requests," Parrella says.

Bose has come up with another solution to the same problem: an anti-noise headset. It employs two rings of silicon to provide an unusually tight seal, and supplements that passive barrier with an analog form of active noise control. Dick Rutan and Jeana Yeager wore prototype Bose headsets to protect their hearing in the cockpit of the Voyager in their record-breaking around-the-world flight. (The electronics failed before the trip was over, but the tight seal on the ear cup did not, preventing any hearing loss.) NCT has entered into partnership with the Japanese manufacturer Foster Electric Company to produce Sony Walkman-style headsets for use in noisy industrial environments. In this version the computer technology is to be strapped around the user's waist; it will be battery-powered and lightweight.

DAZZLING as the technology is, it may be an answer looking for a question. Noise, defined as unwanted sound, has been around for so long that people may have gotten used to it by now. The Romans imposed some of the first noise ordinances on record, restricting the nighttime driving of chariots, whose wooden wheels on the stone roads must have made a frightful racket. New York City was the first municipality to consider the noise problem in any organized way; it took the first community noise survey in 1929. Like most such surveys conducted since then, this one was never acted upon, because something more important came along to distract everyone's attention. Indeed, the level of national preoccupation with noise might be a leading indicator of good times. When Americans are overwhelmingly worried about noise, things are pretty much okay.

By that standard, the all-time highwater mark for American life may well have been reached in the 1970s, when federal preoccupation with the problem of noise attained its historical peak. In 1970 Congress created the Occupational Safety and Health Administration, and an important part of its agenda was to limit noise in the workplace.

The Environmental Protection Agency, empowered by the 1972 Noise Control Act, which Congress passed overwhelmingly, established an Office of Noise Abatement and Control, with a staff of 130 and an annual budget of \$10 million.

But before the government could regulate noise in any sweeping way, someone had to figure out what noise was, and exactly what was so bad about it. Noise differs from other environmental pollutants in that it is both invisible and temporary: it leaves no bathtub ring. But noise resembles the others in that although noise is clearly terrible at an extreme, it is hard to say just where that extreme begins. Considerable research was done on the precise nature of the annoyance, much of which bordered on the self-evident. For example, one pair of psychologists demonstrated that someone was less likely to stop to help a stranger who had dropped books on the sidewalk if an earsplitting lawn mower was running nearby. Another group of psychologists discovered that business students evaluating resumes in a quiet room awarded higher salaries than other business students did in one where a lot of typewriters were clattering in the background. A third study examined a San Francisco neighborhood and discovered that people socialized with their neighbors more on quiet side streets than on noisy thoroughfares.

Other researchers busied themselves looking at the physiological consequences of noise, which proved little easier to measure. It has long been apparent that exposure to loud noise gradually causes deafness: the powerful vibrations damage the delicate hairs in the cochlea, which receive the sounds that are transmitted along the auditory nerve to the brain. But it has been more difficult to demonstrate other suspected connections, chiefly that of noise-related stress to heart disease. A team of researchers at the University of Miami found that protracted exposure to noise levels of 85 to 90 decibels, about lawn-mower level, raised the blood pressure of rhesus monkeys for at least four months after the period of exposure. Such tests have been difficult to conduct on human beings, however, since it is nearly impossible to isolate noise from other sources of stress. There is some evidence that loud noise might even be pleasurable, because it causes an adrenaline surge that can feel like a caffeine rush; this might explain why some people jack up the volume on their boom boxes. Another reason might be that they have gone deaf. An audiologist looking into why New York City sirens so frequently exceeded permissible noise levels determined that a number of the senior firefighters who were buying powerful sirens had lost much of their hearing.

Everyone is bothered by noise at earsplitting extremes, of course. But once the levels drop, or the screech becomes intermittent, the noise is open to interpretation. Any number of factors influence a person's reaction. One study showed that someone is less likely to be annoyed by highway noise if he believes that the highway is bringing an economic benefit -- more customers, for instance, or higher property values. People are more bothered by airplane noise if they fear that the plane might crash in their neighborhood. Such attitudes can be manipulated to take the edge off noise. In Sweden the neighbors of an air-force base who had been given a souvenir booklet detailing the proud history of the service and its importance to Sweden were less likely to be annoyed by the noise than the neighbors who hadn't received the booklet.

Another, possibly more important, issue is control: few are irritated by the terrible din of thunderstorms, whereas many are irritated by equivalent noises that are man-made and presumably could be stopped. So it may make sense to conclude, as some psychologists have, that noise irritation is best thought of as a form of interpersonal anger: the sufferer feels he has been not just bothered but wronged.

Such theorizing, however, ground pretty much to a halt in 1982, when the Reagan Administration closed the Office of Noise Abatement and Control as an example of useless Washington bureaucracy and struck noise from the list of pressing federal interests. There had been some unfortunate excesses. Alice Suter, a former employee of the office, admits that the EPA made "needless enemies" because of its "sometimes arrogant" style. Noise control was supposed to shift to the state and local levels, but those levels had their budgetary constraints as well. Without any federal agency to provide technical support, the entire field of noise control has dwindled away.

BUT noise remains, and it continues to increase. No nationwide statistics have ever been developed, but the acoustician William Galloway has argued persuasively that noise levels are simply a function of population density: people make noise, and so the more people, the more noise. It is possibly for this reason that in noise consciousness the United States still lags behind Europe, where population densities are significantly greater. The Occupational Safety and Health Administration set a national legal standard of 90 decibels as the maximum level that workers should be allowed to endure over an eight-hour work period. Noise restrictions in the European Community begin five decibels lower. Since the decibel scale is logarithmic, a five-decibel difference means about a 25 percent reduction in loudness.

In the United States noise awareness centers on airports, specifically in the unending NIMBY controversies over where new airports should be built. "Noise is *the* major issue in airport expansion," says Kenneth Feith, a senior scientist and noise specialist with the EPA. As it is, airports have to conform to thirty-seven categories of noise "procedures," including state and local noise ordinances, restrictions against specific aircraft types, weight limitations, thrust requirements, and nighttime curfews.

Highway traffic noise is probably the second most agonizing form, as evidenced by the increasing number of noise barriers being placed along the nation's highways. According to Robert Armstrong, a senior noise specialist at the Federal Highway Administration, it costs nearly \$1 million a mile to put up a typical barrier. More than half a billion dollars has been spent to build noise barriers along 720 miles of state roads. And industrial noise, especially in construction (those jackhammers) and in manufacturing (those punch presses), runs third.

All these areas are potential markets for active noise control. Headset versions of the technology are already available for use inside noisy factories, and mufflerlike versions can quiet the machinery. A company called Applied Acoustic Research, managed by Glenn Warnaka, one of the original patent holders in noise cancellation, is working on a

prototype highway anti-noise system that would replace concrete barriers with a series of noise-control systems spaced at regular intervals along the highway -- and open the views besides. Michael Parrella believes that his systems could someday cut the "tire whine" that is a major component of road noise, thus quieting the ride for drivers and passengers as well. He also believes that noise cancellation could muffle jets, but that would be more difficult, because jet roar shifts according to the Doppler effect (which causes pitch to drop as a noise source moves away), and complicated harmonics and fiendishly high temperatures are also involved.

None of the anti-noise companies has plans to enter the private-household market directly any time soon. NCT is working to quiet sloshing dishwashers, grinding refrigerator compressors, and rattly oven fans in the belief that, with "open plans" exposing more of the household to kitchen noise, consumers would prefer quiet products. The company has recently signed an agreement with the Sweden-based AB Electrolux, the parent company of Frigidaire (refrigerators) and Eureka (vacuum cleaners), as a step in this direction. Parrella claims that NCT products could someday insulate homes from street noise and loud neighbors as well. "All we need to do is find a good partner," he says. The system would dampen window panes, which are the major source of incoming sound. Windows act like stereo speakers, transmitting sound by vibration. Anti-vibration devices can negate the vibration exactly the way anti-noise devices cancel sound. NCT and other companies currently produce anti-vibration devices to still automobile engine mounts. By the same principle, an anti-vibration screen can be mounted on a wall, ceiling, door, or window to silence a loud neighbor.

Seductive as the technology may appear, one should not get carried away by it. The more one thinks about noise, the worse it gets. Michael Parrella himself has been in the noise field for six years, and the experience has drastically heightened his noise sensitivity. Now that the firm's mini-van is silenced electronically, he is bothered by the gentle whoosh of the air-conditioner. "I'll be honest with you," he says. "Noise didn't used to get to me. But now it drives me nuts."