YOU SAY YOU WANT A REVOLUTION

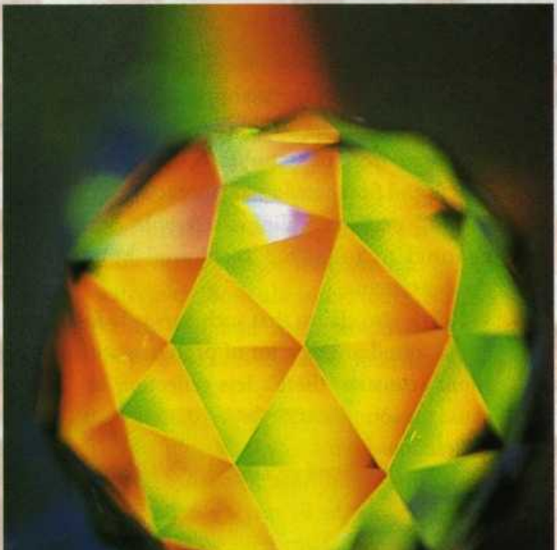

Photo: ©Yamamoto/Photonica

by **Ivan Berger**

SPEAKER DESIGNERS HAVE A FEW TO OFFER YOU

Speaker designers are increasingly shifting their focus from refinement to revolution. Refinement has taken us a long way, dramatically improving the performance of traditional speaker drivers—cones, domes (a cone variant), and electrostatics and other planar types—all of which work by moving surfaces back and forth, like the pistons of a gas or diesel engine. But the more refined a technology, the less further refinement can be wrung from it. As more and more of the big bugs get worked out, development shifts toward nibbling back the minor ones. That doesn't stop many speaker designers from advancing the art, but it does make others wonder whether it's better to polish technology that already gleams or to try fresh approaches.

It also makes marketers wonder how they can sell speakers that look just like the old models, operate in the same ways, and sound better but not greatly different—especially when the old ones sound as good as ever. (As one noted designer put it, "Thirty-five million pairs of speakers have been sold in the past 20 years—and most of them still work.") It gets harder each year to make traditional speakers that are New and Improved in ways plainly perceptible to the average buyer.

So, speaker makers lately have been looking hard at nontraditional driver technologies: new planar drivers like those from NXT ("Mondo Audio," February 1997 issue), Noise Cancellation Technologies (NCT), and American Power and Light; rotary subwoofer "motors" like ServoDrive's woofers and Phoenix Gold's Cyclone; older designs like the Walsh and the Heil Air Motion Transformer (AMT); and an application of ultrasonic technology that could totally revolutionize speaker design (if it gets out of the starting gate). Since that's the most revolutionary—and controversial—of them, let's start there.

HyperSonic Sound

You can't hear ultrasonic waves. But Elwood Norris of American Technology Corporation (ATC) in San Diego, California, plans to use them as the basis of a revolutionary new loudspeaker, which he calls HyperSonic Sound.

The basic idea goes back to the 18th century, when Italian composer and theoretician Giuseppe Tartini noticed that interference between two sound waves of different frequencies could generate a third sound whose frequency is the difference between the other two. (Such difference frequencies can also be generated when electrical signals mix; this causes intermodulation distortion in audio but is used deliberately in tuning superheterodyne radios.) What Norris realized was that the difference produced by interference between two ultrasonic frequencies can fall into the audible range—and that this has interesting implications for a speaker. Mix the output of a transducer delivering, say, 200 kHz with one whose output can be varied from 200 to 220 kHz, and you wind up with difference frequencies of 0 to 20 kHz—the audio band, and then some.

Paradoxically, such a system could cover a wider range of audio frequencies than any conventional speaker while operating over a mere fraction of an octave. The band from 20 Hz to 20 kHz is about 10 octaves, whereas the range from 200 to 220 kHz is only about a 10th of an octave—a 100-to-1 difference. It is much easier to make a driver linear over a 10th of an octave than over even two or three whole octaves. An ultrasonic difference-tone system could therefore do without the multiple drivers and crossovers that conventional speaker systems need in order to cover the full audio range.

Norris also claims that the HyperSonic system would make distortion less of a problem, since most, if not all, of it would be harmonics of the two ultrasonic frequencies—far above the human hearing range. And the close coupling of the small transducers required should ensure well-nigh perfect phase and time response.

A speaker's directivity at any given frequency depends mainly on the ratio between the sound's wavelength and the size of the driver reproducing it. So

Early HyperSonic prototype, with piezoelectric drivers and hand-glued whizzer cones

Elwood Norris of ATC, with recent HyperSonic transducer prototype

The recent HyperSonic prototype, with electrostatic transducers

with almost all conventional speakers, directivity varies with frequency—a problem that need not occur with a transducer reproducing less than an octave. As a result, a HyperSonic Sound speaker's coverage should be very even.

It would also be very narrow. For broad coverage, a driver must be less than half the size of the smallest wavelength it will reproduce. But at 200 kHz, the wavelength of sound is about 0.0678 inch, and it would be hard to get much output from a transducer half that size. In fact, ATC uses transducer arrays to increase power handling (which narrows the beam still further). The dispersion of the prototype arrays is about 6°, according to Jim Croft of Carver Corporation (ATC's first HyperSonic Sound licensee). There are ways around this, from curving the array to aiming its beam at a curved reflector (a billiard ball would do). On the other hand, such tight beams of sound can be aimed, and ATC sees potential use for that capability.

"For example," Norris says, "you could mount a bunch of transducers on a ball, controlled by a surround decoder." Instead of running wires to speakers at five points in the room, you'd just run wires to the ball, then mount passive reflectors in the desired "speaker" positions. Another ATC idea is to "build an array of transducers on a hemisphere and fire them in sequence to sweep a sound," perhaps adding a steerable extra channel to today's 5.1-channel home theater systems.

Norris also claims that such narrowly focused sound avoids a lot of problems with room acoustics; there's less reflection because the sound scatters less, reducing room interactions by as much as 50 dB. To accomplish this, you'd have to ensure that the sound reaches the listener's ears before hitting a wall so that any reflections the listener then does hear will reach him well after the original signal. Aiming the HyperSonic speakers directly at listeners would also enable very precise imaging control, says ATC.

There are applications where beamed sound is best anyway. In car stereo, for example, a HyperSonic system could deliver separate programs to each listener. HyperSonic sound systems for computers would focus sound to minimize annoyance to occupants of adjoining workstations. Narrow sound beams could deliver private messages across reasonably long distances. A focused beam of infrasonic sound, at 10 to 12 Hz, could be used for crowd control, to temporarily disable key agitators (one of Norris's more controversial claims). Norris says: "We can add a level of directionality to audio frequencies that are traditionally not directional, a kind of spotlight effect—not total directionality with low bass and subsonic, but a directional character. The audible sound has been created in a highly directional column (unless you disperse the ultrasonic wave). Therefore, once the ultrasonic component has been attenuated by distance or a screen, the audible component will maintain its directionality (to our surprise and delight). We've demonstrated that we can project sound across a field, almost 500 feet, and shine it like a flashlight beam. Even up close, outdoors, if you point the speaker straight up you hear no sound."

Norris says the sound can also be made to materialize in midair. As he explains, "Air absorbs ultrasonics—the higher the frequency, the quicker the absorption. At 200 kHz, an ultrasonic wave is 3 dB (50%) down at 3 meters and rolls off further as the distance increases. Audio dissipates in space from the point where the carrier rolls off, which means it would seem to originate along the line where this rolloff takes place." Norris cites that as a reason for the sound's directionality. A grille cloth would also attenuate the ultrasonic frequencies, so presumably, sound from a grille-covered HyperSonic speaker would seem to originate at the grille itself.

A grille cloth may prove necessary. ATC dismisses concerns about possible harm from the system's ultrasonic beams, pointing out that ultrasound is now used in medicine for sonograms (which ATC claims is based in part on technologies Norris helped develop) and to speed the healing of bone fractures and other injuries. (Cats and dogs shouldn't be bothered, either, because they hear only up to about 40 kHz.) In a demonstration at *Audio*'s office, no one mentioned any discomfort. But at least one speaker researcher, caught directly in the beam of ATC's prototype speaker from only a few inches away, reported severe aural pain at

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that instant followed by discomfort that persisted for several days.

This makes me dubious about another potential application cited by ATC: hearing aids. I'm not skeptical of ATC's claim that a HyperSonic hearing aid could eliminate feedback squeals, because the sound would be generated at the eardrum, not right behind the microphone. I also believe the claim that such a hearing aid could reproduce the entire audio spectrum yet still fit in the ear. But I do worry a bit about possible effects from the ultrasonic frequencies, even though the levels involved would be minuscule. (Norris also claims that HyperSonic speakers wouldn't cause feedback in concert or public-address sound systems, even if pointed directly at the microphone, adding that he suspects it might be because of "a slight, broadband phase shift.")

But enough about what the HyperSonic system does. How does it do it? Norris is hardly the first inventor to try producing sound from the difference between two ultrasonic frequencies. The problem has been getting the carrier signals to generate the required sum and difference frequencies, a process called intermodulation or heterodyning. The big mystery about HyperSonic Sound is how Norris gets the signals to heterodyne, which none of ATC's 19 patent filings on the HyperSonic system explains. Intermodulation occurs only when there's some nonlinearity involved (which is why nonlinear audio components produce intermodulation distortion). So where is the nonlinearity coming from? One authority I consulted told me, "The nonlinearity needed must come from the air or from the transducer; if it's from the transducer, then I'd expect distortion, too." Others believe the nonlinearity may be in the listener's ear.

Norris has added to the confusion. During his demonstration at *Audio*, he said, "I worried that I'd need to make air nonlinear. But Helmholtz showed that the nonlinearity is amplitude-related, like a rubber band that is linear for small stretches but not for large ones." Later on, however, Norris said, "Air is nonlinear at all amplitudes." Yet researchers I've consulted doubt that air is nonlinear enough, unless the carrier levels reach 140 or 150 dB SPL.

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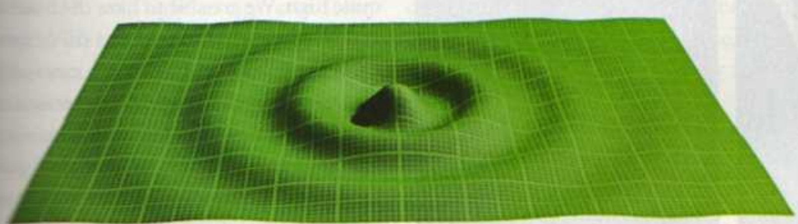
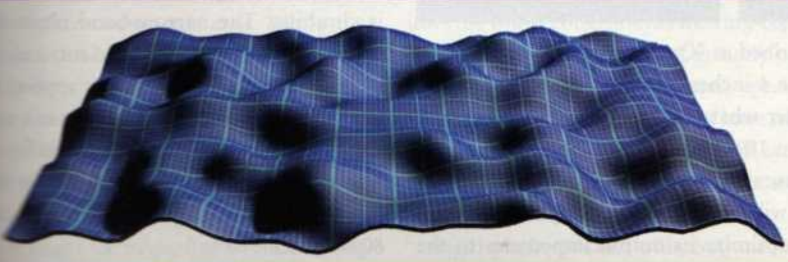
In any case, Norris no longer seems to be relying on air as his mixing medium. "If you rely on acoustical events in the air, it's so haphazard that the effect is observable but useless," he told *Business Week*. He's now using a single transducer to generate, effectively, both ultrasonic tones. Norris recently promised me he would disclose just how he gets his signals to intermodulate as soon as certain key additional patent applications are filed, adding: "What surprises me is how everyone's missed the secret of generating the difference tones—and a lot of big companies have tried. An acoustical engineer couldn't have invented this, but I came from an electronics background. Still, there is an acoustical effect, which I missed at first, too."

In HyperSonic speakers, the variable frequency must be amplitude-modulated so that simple rectification of the signal mix will yield sound. This creates sidebands above and below the carrier frequency. Norris says these sidebands "dance in and out like skirts, in opposite phase. Where the audio signals produced by these sidebands mix, as they do at bass frequencies, they cancel out." The prototype I heard exhibited rapid cancellation below 200 Hz and almost no output below 160 Hz, which Norris readily acknowledges. He says this problem can be solved by some carrier-to-sideband manipulation, but the analog filters he used in his demo weren't up to the job. He's working with Motorola on a custom DSP chip that will perform the modulation and then "kill the lower modulation sideband and fold its energy back into the upper sideband."

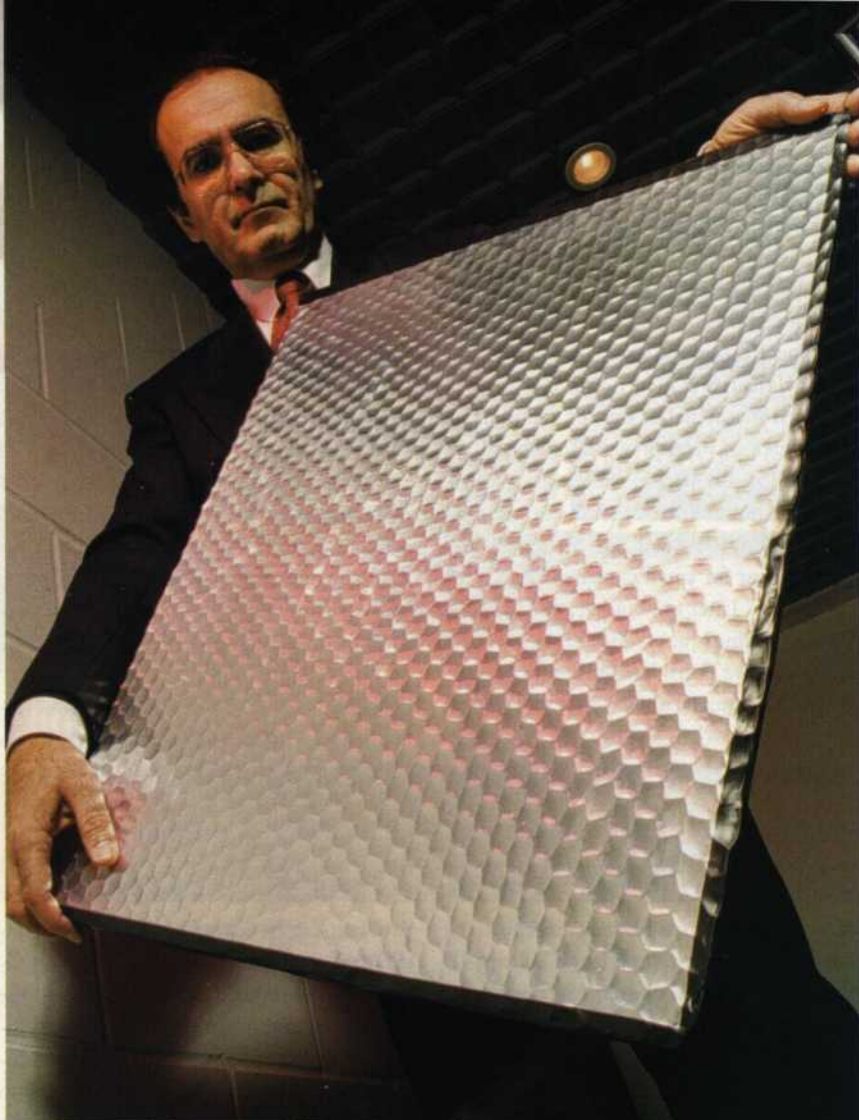
What I heard at Norris's demonstration, late in 1996, was a hand-built prototype. It was intended strictly as proof of principle—"Still Kitty Hawk," according to Norris. The transducers were piezoelectric microphones, which he used as drivers: "Transmitters are too sharply peaked," he said. Since microphones haven't much power-handling capacity, a cluster of 17 was used, with sequin-sized whizzer cones hand-glued to each to help them move enough air. Some of the hand-glued parts had come loose, causing distortion, and the sound rolled off not only below 200 Hz but also above 11 kHz. Overall, the prototype sounded like a small transistor radio—but it did work. About a month later, at the Consumer Electronics Show, ATC held another demo, using a slightly bigger transducer array, better whizzers, and improved electronics.



Applying signals to a stretched-membrane speaker produces coherent ripples.



Applying signals to an NXT panel produces complex bending waves.



Farad Azima, chairman of NXT, shows off the thinness and light weight of a prototype NXT panel.

NXT staff and executives hold two speaker panels, one disguised as a picture.

The actual drivers, Norris says, will have little in common with either of these prototypes. Their elements will be electrostatic, not piezoelectric, and, like electret microphones, will require no polarizing voltage sources. These elements will not be hand-glued but will be fabricated on multi-element wafers, like ICs, and then etched and wired in parallel. The wafer has been described as "Oreo-sized" by Norris and as "3 or 4 inches in diameter" by others. No matter what the size, each wafer will have about 10% more transducers than it needs, in case some don't come out right. The system will be sold with an amplifier that will self-optimize its output impedance to the number of transducers on the wafer that are actually active.

The power required of that amp will be modest, 50 watts or less per channel. And the current required will be even more modest, since the drivers will have very high impedance. ATC claims very high efficiency for the HyperSonic speaker design, about 10% versus 0.5% or less for conventional speakers, due to a closer acoustical impedance match to the air than conventional speakers can boast. A white paper posted on ATC's web site (www.atcsd.com) claims output up to 120 dB at all frequencies and a power requirement no greater than 50 watts. According to Norris, "You can get a difference signal with greater amplitude [presumably, displacement] than the two ultrasonic signals together because of the vast difference in the energy level of a high-frequency wave at a given amplitude." Further, he has said that "the difference tone has 63% (4 dB less) of the combined equivalent energy of the two carriers plus the sidebands" and that "for 110-dB audio, the carriers should probably be about 125 dB SPL." These are contradictory statements. But Norris has also said that the effect depends on distance and that "it drops off so much with distance that you can measure more audio than carrier at some distances." Says Carver's Jim Croft, "The HyperSonic Sound system's conversion efficiencies are

The flat-panel speakers are as

quite high. We are able to have the baseband audio demodulate to within a dB or two of the carrier level and, in some cases, equal the carrier level. The final conversion efficiency—from power amp output, to single-sideband carrier level, to baseband audio level—is still subject to further testing with our new transducers to determine how good it can get. But right now the total system efficiency appears to be above 50% and is climbing. The narrow-band ultrasonic transducer can be quite efficient, and the techniques for which ATC has applied for patents create the difference tones in a new, coherent manner that is also quite efficient. The mathematical analysis at this time suggests that total system efficiencies of over 80% are achievable."

Others are skeptical. Says one, "Suppose they could make a broadband, high-fre-

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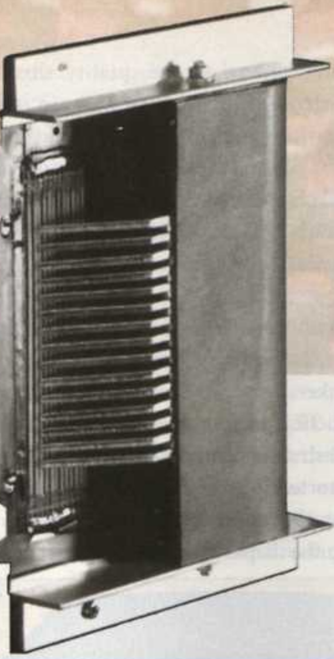


Heil driver used in Precide Kithara speaker

quency source at 200 kHz that were 25% efficient and could produce 167 dB SPL, a level high enough to make the air nonlinear, over an area of 10 square centimeters. This is a power density of 4 watts per square centimeter and an output of 40 acoustic watts, requiring 160 electrical watts to produce. (It is also a dangerous sound level: 165 dB SPL can acoustically levitate stone, and 170 dB will light a cigarette from acoustic friction.)

"The acoustic output of a constant-volume-velocity source [one whose excursion diminishes with increasing frequency] falls 6 dB per octave as frequency decreases. Even if 100% of the volume velocity were converted to audible sound, at 1.5 kHz, some seven octaves below the carrier, the level would be 42 dB down, or 127 dB over a 10-square-centimeter area. While that sounds like a lot of dB, it is 1/16,000th the power density of the carrier and, from a point source (which the dimensions dictate), is about 86 dB at 1 meter. An output of 86 dB is usually acceptable for a 1-watt input, but not at full power. This problem grows larger as frequency decreases, suggesting that, while the conversion mechanism works down to (and below) 20 Hz, the driver would have stopped being audible many octaves above. (The threshold of hearing at 20 Hz is about 80 dB.) Decreasing the carrier frequency would help the loss of efficiency and reduce acoustic streaming losses (not included in the example). A 50-kHz carrier has a +12-dB edge over a 200-kHz carrier, for instance."

All of the skepticism could, of course, be blown away when ATC reveals the full details of its system. So far, only Carver Corporation has licensed the HyperSonic Sound technology. But if it works as Elwood Norris says, Carver won't be the only licensee for long.

kers are as radical as HyperSonic Sound, but radically different from it.

Plane Speaking

Far removed from ATC's point-source technology, but nearly as radical, are the latest planar speaker designs. Where cones and domes generate sound by moving small diaphragms large distances, planar speakers move the same volumes of air by moving large diaphragms short distances. Traditional planars use thin, light, flexible diaphragms and distribute the needed driving force over the diaphragm's surface, either through electrostatic attraction and repulsion between a charged grid and a charged coating on the diaphragm or, as in Magneplanar speakers, through a flat voice coil printed on the diaphragm and a large, distributed set of magnets. These speakers are all dipoles, radiating signals from the front and back in opposite phase.

The most striking difference between the new planars (from NXT, NCT, and American Power and Light) and the old is their use of rigid diaphragms, which can be driven from a few discrete points rather than requiring distributed drive. This, in turn, allows the use of conventional moving-coil or piezoelectric actuators. (Not entirely conventional, however: Some planar speakers from American Power and Light have moving-magnet rather than moving-coil actuators because, with today's lightweight magnets, they have lower moving mass.)

Rigid-plane speakers offer both acoustical and practical benefits. On the practical side, they can be mounted in or on almost any flat surface, including wall-hung pictures, the sides of computer monitors (piezoelectric actuators are nonmagnetic—perfect for this), or projection screens (American Power and Light offers projection screens using its flat-driver technology). The first application I saw of such technology, NCT's Top Down Surround Sound, used panels in a car's headliner; it struck me as unsettling for music but a very good method for listening to traffic reports, phone calls, and other spoken material. The panels' light weight is obviously a benefit in cars and airplanes. And NXT and NCT, at least, have said that their transducer panels can be molded into special shapes for custom applications.

The main acoustical benefit of these speakers is that the sound falls off more slowly with increasing distance than the sound from conventional speakers does. This carries many advantages. In home theater, it makes it easier to balance front and surround levels for all seats, front to back. (As NCT puts it, "Not a sweet spot—a sweet space.") In a car, it lets the sound of the front speakers reach listeners in the back at levels that won't blast the driver's ears out. In public-address systems, it requires fewer drivers to produce fairly even sound volumes over large areas. According to Werner Eymann of Eymann/Marquiss, the European distributor for American Power and Light, "The energy radiation does not beam but sprays," which means that powerful reverberations won't mask subtle recorded information about the recording venue's acoustics. He says that this spray of music is less likely to be heard through walls by neighbors or other family members. Eymann points out that rigid-plane speakers do not have cabinet walls to introduce spurious resonances or edge diffraction and that the speaker's output is phase-correct.

It may be significant that the companies leading this wing of the speaker revolution all have had some involvement with active cancellation of acoustic noise. NCT was one of the first to introduce noise-cancelling headphones. Stanley Marquiss, of American Power and Light, has also worked in this field. And the development of the NXT speaker was a direct outgrowth of noise-cancellation research. Kenneth Heron, who was working for Britain's Defence Research Agency, tried using damping panels to cut background noise in fighter cockpits, only to discover that the panels were actually radiating sound instead of absorbing it. After he filed for patents on this discovery, his idea was licensed by the Verity Group, which owns Mission, Cyrus, Wharfedale, Quad, and Roksan; Verity has since set up a subsidiary, New Transducers Limited (NXT), to develop and license this panel-speaker technology.

The NCT and NXT approaches overlap, and the two firms have cross-licensed their patents. "Our breakthrough was finding a way to transfer energy linearly to a large, flat diaphragm," says NCT, "a unique patented method of coupling [actuators] to maximize energy transfer to the membrane, particularly at low frequencies." I'm told NCT's patents chiefly concern ways of mounting the actuator, or exciter, whereas NXT's patents are more concerned with optimal placement of actuators on the panels.

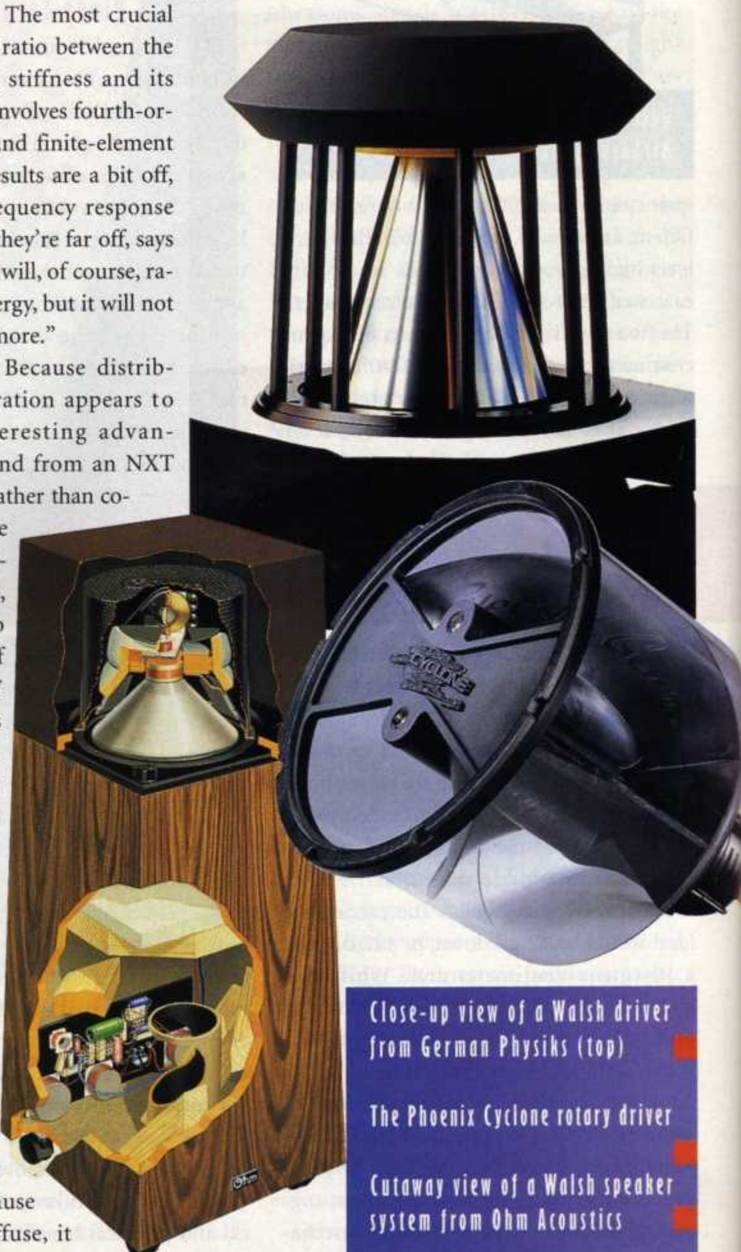
The NCT system uses piezoelectric exciters, which are flatter than the electromagnetic exciters used by NXT and have no magnetic fields; NCT's Flat Panel Transducers (FPTs) have clamped edges and usually more than one exciter per panel. Although the panels can be painted or covered with wallpaper or pictures, NCT says, "You wouldn't want to paint an original oil onto them; the vibration would flake that paint." The FPTs produce sound through a combination of bending and pistonic motion. As you'd expect, they are dipoles, whose front and back waves are in opposite phase, so some sort of baffle is required to keep the rear wave from cancelling the front wave at low frequencies or to make that rear wave reinforce the front wave. (The latter, of course, increases the speaker's efficiency and bass output.)

At first glance, the NXT approach seems only slightly different. Its prototype panels have used moving-coil exciters, as do cone and dome drivers, although piezoelectric or moving-magnet drivers could also be used; the panel edges are free. However, their "distributed-mode" operating principle is distinctly different and extremely unconventional. Cone and dome drivers attempt to push and pull the air as a perfect piston would, ideally moving as one surface without ripples or subsidiary vibrations. Stretched-panel speakers, such as electrostatics, have coherent ripples. An NXT panel, by contrast, carries complex bending waves over its entire surface. The panel is also a dipole, but only up to about 250 Hz; above that, it operates as a bipole, with its front and back waves essentially in phase rather than 180° out of phase.

Getting this right involves juggling myriad variables: panel dimensions and other physical characteristics, location of the drive point (usually just one), and type of panel mounting. The most crucial parameter is the ratio between the panel's bending stiffness and its mass. The math involves fourth-order integration and finite-element analysis. If the results are a bit off, the speaker's frequency response will be peaky; if they're far off, says NXT, "The panel will, of course, radiate acoustic energy, but it will not be a speaker anymore."

Why bother? Because distributed-mode operation appears to have some interesting advantages. The sound from an NXT panel is diffuse rather than coherent—like the output from a piano soundboard, according to Stan Curtis, of Wharfedale. NXT says this reduces the response irregularities often caused by destructive interference. The resulting radiation pattern, a fat figure-8, is said to vary far less with frequency than that of a typical cone loudspeaker—again, a broader sweet spot. Because the sound is diffuse, it seems to get around obstacles better, so sound quality shouldn't change much if someone walks in front of you while you're listening. That diffuse sound should be a natural for surround speakers, yet in a demonstration I heard, it did not seem to diminish the panels' ability to act as front speakers in a home theater setup.

Frequency response is claimed to be "of the same order of flatness as conventional speakers," even before taking the claimed reduction in room-response irregularities. And strange as it may seem considering the contorted look of distributed-mode vibrations, the resulting minute movements help keep the diaphragm and exciter well within



Close-up view of a Walsh driver from German Physiks (top)

The Phoenix Cyclone rotary driver

Cutaway view of a Walsh speaker system from Ohm Acoustics their linear ranges, which is said to keep distortion low. Further, the minute travel of the panel surface and the voice coil reduces the generation of back-EMF; according to NXT, that and the simple nature of the panel's mechanical impedance make this speaker an almost purely resistive load and thus very easy for an amplifier to drive. Light panel weight and restricted travel are also said to give the NXT speaker fast transient response.

In the demos I've heard, the NXT drivers sounded reasonably good and the NCT drivers slightly muffled. But these were far from being production units. When those come, they'll be from licensees: So far, NXT has signed NEC, Samsung, and Peerless as well as the Verity Group's Mission, Quad, and Wharfedale; NCT has signed a development pact with the Harman Professional Group; and Johnson Controls plans to build FPTs for use in cars. As to American Power and Light, its Planar Transducer (PT)—a flat, free-piston device—is in production.

The sound from an NXT panel is diffuse rather than coherent—like the output from a piano soundboard.

Golden Oldies

Another product of American Power and Light, the V-Driver subwoofer has drivers facing each other across a deep, V-shaped notch. (I've seen diagrams of this system with conventional cone woofers as well as with flat panels, hinged at the apex of the V and controlled by linear actuators.) One of the claims made for this arrangement is speed, since the air-mass acceleration within the V is the sum of the opposing drivers' accelerations.

A similar effect, differently produced, was at the heart of the old ESS Heil Air Motion Transformer invented by Oskar Heil, a technology that is now back, from Swiss manufacturer Precide. In this design, a rectangular diaphragm, with a voice coil of conductive strips bonded to it, is folded into deep vertical pleats within a magnetic field. As the signal voltage fluctuates, the voice coil is alternately attracted to and repelled by the magnets, opening and closing the pleats. Instead of pushing and pulling air like a piston, the Heil driver alternately squeezes the air out and sucks it back in. This yields increased air-mass acceleration and high air velocity, despite short diaphragm movements. The diaphragm has comparatively low mass and, because its driving force is distributed across its entire area, should be relatively free from breakup.

Precide manufactures Ergo headphones and two speaker models (the Aulos and Kithara) using Heil technology. Precide says that its Oskar Air Velocity Transformer (AVT) incorporates improvements made by Oskar Heil since the ESS version. These are said to include a more even magnetic field, a structure that gives the driver almost 360° dispersion, more rigid mountings, softer, less harsh-sounding diaphragms, and better phase coherence.

Another golden oldie back in a new form is the Walsh driver—which, unlike the AMT, never went away. Like some planar speakers, the Walsh (named after inventor Lincoln Walsh) uses bending waves, but in a very different manner. Although its transducer is a cone, the Walsh driver, unlike conventional cones, faces downward rather than at the listener. It has very steep, long sides and is excited in a different way from conventional cone speakers: Instead of being pushed and pulled, the Walsh stands still while acoustical waves ripple down its steeply raked sides, subtly bending the cone as they pass over it.

The horizontal components of these ripples push and pull the air, creating sound waves. If the cone's materials and slope are chosen properly, each ripple will reach the bottom of the cone just in time to generate a sound wave that's perfectly synchronized with the other waves it's generated on the way down. For example, if the ripple takes 0.2 millisecond to roll down the cone, it will generate a sound wave at the bottom of the cone 0.2 millisecond after generating one at the top. Since sound travels through air at a bit over 10 inches per millisecond, the sound wave generated at the top of the slope will have traveled 2 inches outward from the driver's center. But if the cone's radius is 2 inches greater at the bottom than the top, the wave it generates will start out 2 inches further from the center than the wave from the top. As a result, these bottom and top waves (and all those in between) will move in parallel, radiating a cylindrical sound field. (By changing the slope or material of the cone, the sound field can be made conical; Ohm Acoustics' shortest Walsh model, the Walsh 100, uses this technique to aim the sound slightly upward.) Whatever the radiating pattern, it should be the same at all frequencies, ensuring perfect time and phase coherence and uniform polar response. Other claimed advantages are excellent impulse response and a very wide listening area.

In practice, however, it's difficult to make a Walsh driver that performs well over the entire frequency range. Therefore, both Ohm Acoustics (which was first to produce Walsh speakers, back in the early 1970s) and German Physiks (which has been selling them for 3 years) offer two-way systems. Ohm uses Walsh drivers to reproduce the bass and midrange, while German Physiks (which calls its version the DDD Bending-Wave Converter) uses them for midrange and treble. This difference seems to be based on differing views of optimum directionality. German Physiks prefers 360° radiation, which is inherent in Walsh drivers throughout their passband and is easily achieved from low-frequency drivers of almost any type. Ohm, on the other hand, feels that restricting the speaker's radiation reduces room interactions, so it directs the highs to a conventional tweeter while blocking off part of the Walsh driver's rear output. This controlled pattern also enables you to angle the speakers for a time-intensity trade-off, a common way of stabilizing the stereo image for off-axis listeners.

The Incredible Exploding Football

Another way of making omnidirectional speakers has been available for several years from mbl-Akustigeräte, of Berlin. The mbl "isotropic" driver is a spheroid made of flexible strips that are interconnected by soft plastic. The strips are fixed at the top and are driven at the bottom by a magnet and voice coil. The voice coil's action alternately compresses and stretches the strips; the resultant increase and decrease in the spheroid's radius generates the sound waves. This is the closest approach I've seen to the often-voiced idea of a pulsating-sphere driver, which itself is the practical embodiment of the theoretically perfect point source. Three mbl models sold in this country use this technology. Models 101C and 101D use three isotropic drivers: a football-shaped woofer, a nearly spherical midrange, and a tweeter resembling a squashed sphere; Model 111 uses isotropic drivers for the upper midrange and treble and cone drivers for the lower midrange and bass.

Motor-Driven Bass

Two other companies' wildly unconventional woofer designs turn out to have come from one inventor, Thomas Danley, holder of 16 patents on loudspeakers and other acoustical and electromagnetic systems. What these designs have in common is motors that turn instead of moving back and forth like the motor (voice coil and magnet) of a conventional cone driver.

Rotary motors offer several potential advantages. Unlike voice-coil motors, which become nonlinear when pushed to their extremes, rotary motors are designed to turn indefinitely, with no nonlinear areas of operation. Moreover, since these motors need not be attached directly to the cones, they can be made large enough for good heat dissipation. This not only increases power-handling capacity but also keeps output from dropping off during sustained high-level signals; when voice coils heat, their resistance rises and the power delivered to the speaker drops.

But though none of these woofers has a voice coil, two of them—originally made by Intersonics, now by ServoDrive—do use cones. One, the BassTech 7, is a large horn designed to be used in clusters in commercial sound systems. The other, the ContraBass, is a conventional-looking box with a 15-inch active driver and an 18-inch passive radiator at each end. Inside, a single servo motor moves both drivers via a heavy-duty belt system that converts the motor's rotary motion into linear motion; rigid shafts transfer the motion to the cones. Because the ServoDrive speakers handle only bass frequencies (the ContraBass's rated bandwidth is 15 to 125 Hz between –3 dB points), the low-inertia motor does not turn at high speed, so it should have no problem reversing to follow signal oscillations. The cones move in opposite directions (excursion is rated at ¾ inch, peak to peak), which means both move in or out simultaneously. This poses less strain on the motor, as the woofers are mechanically out of phase so that the forces on the cones are opposed rather than additive. But acoustically, the two woofers are in phase at all times, yielding an omnidirectional radiation pattern. Originally designed to reproduce wild elephants' 14-Hz chest tones over vast distances, the ContraBass is now sold for use in commercial sound systems. It is rated to deliver 114 dB SPL at 1 meter continuously at 16 Hz, which might lead some home bass freaks to cheerfully ignore its 37-inch height, 120-pound weight, and black carpeted exterior.

Danley's other motor-driven woofer design, the Phoenix Gold Cyclone, was originally devised for car stereo systems, though a home version is now under development. The Cyclone is conceptually more complex than the ContraBass but mechanically simpler: It uses a rotary impeller that eliminates the need for the ContraBass system's rotary-to-linear converter. The impeller, which looks a bit like a washing machine's agitator, has the same area as a 12-inch cone, but its 38° rotation gives it the same air-moving capacity as a 12-inch cone with 3 inches of travel. The impeller turns within a 12-inch cylinder that separates the acoustical output from the radiator's front and rear surfaces, but the assembly still requires a 3-cubic-foot enclosure; the entire Cyclone driver assembly drops easily into the same size hole as a conventional 12-inch woofer. The home version will have its own enclosure and sophisticated electronics, including an unusual feedback scheme. The ServoDrive and Phoenix Gold woofers may not be the most radical of the designs discussed here—I think the ATC HyperSonic system takes that honor—but their rotary drive systems definitely make them revolutionary. A

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Carver Corp., P.O. Box 137, Woodinville, Wash. 98072; 425/482-3400 (fax: 425/778-9453); www.carver.com

Ergo, c/o May Audio Marketing, 10524 Lexington Dr., Suite 300, Knoxville, Tenn. 37932; 423/966-8844 (fax: -8833); mayaudio@aol.com

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mbl, 8730 East Via de la Luna, #13, Scottsdale, Ariz. 85258; 602/991-8001 (fax: -8797); www.mbl-hifi.com

New Transducers Ltd. (NXT), Stonehill, Huntingdon PE18 6ED, England; 44-0-1480-451777 (fax: 44-0-171-589-7771); info@next.co.uk; www.nxt.co.uk

Noise Cancellation Technologies (NCT), One Dock St, Suite 300, Stamford, Conn. 06902; 203/961-0500 (fax: 203/348-41060); www.nct-active.com

Ohm Acoustics, 241 Taaffe Place, Brooklyn, N.Y. 11205; 718/783-1111; www.ohmspeakers.com

Phoenix Gold, 9300 North Decatur, Portland, Ore. 97203; 503/288-2008 (fax: 503/978-3381)

Precide, c/o Jason Scott Distributing, 411-E Caredean Dr., Horsham, Pa. 19044; 215/773-9600 (fax: -0332); www.jason-scott.com

ServoDrive, 1940 Lehigh Ave., Suite C, Glenview, Ill. 60025; 847/724-5500 (fax: -4847)

Wharfedale, c/o M. Rothman & Co., 50 Williams Dr., Ramsey, N.J. 07446; 201/818-1600 (fax: -9267); mr50@ix.netcom.com