Setting a New Standard

High-definition television will bring movie-like picture quality and stereo sound to America's couch potatoes. Choosing a standard will involve economic as well as technical considerations.

IN 1950, THE NOW-FORGOTTEN color wheel system became the first attempt to bring color television to American homes. The color wheel, designed by CBS and approved for broadcast use by the Federal Communications Commission, seemed like a natural way to move from black and white displays to color. In a color wheel TV, red, green, and blue filters on a rotating wheel were precisely coordinated with the flickering black and white images of a cathode ray tube. The result was a series of alternating one-color images that merged in the eye to look like a single, full color picture.

The color wheel never worked out. Since each filter on the wheel had to be as big as the screen, the wheel itself had to be twice as large as the screen, and this resulted in bulky, awkward television sets with relatively small screens. A much worse problem was that the color wheel system was not compatible with the nation's 25 million black and white television sets—viewers with the earlier sets could not watch programs televised in the color wheel system.

In 1953, after a color system appeared that was compatible with black and white TVs, the FCC reversed itself and adopted the standard that American television still obeys—a system using red, green, and blue dots on the screen instead of a wheel. The color-dot TVs had poorer picture quality than the color wheel sets, but that was a small price to pay for compatibility.

The color wheel mistake is being remembered now as the television industry faces a change as profound as the switch from black and white to color: a move from the current 35-year-old standard to high-definition television (HDTV), which will have pictures as good as those in movie theaters and stereo sound like that of compact discs. The stakes are higher this time around, though. Some industry observers believe HDTV may represent the last good chance for the American consumer electronics industry to regain a share of the domestic electronics market.

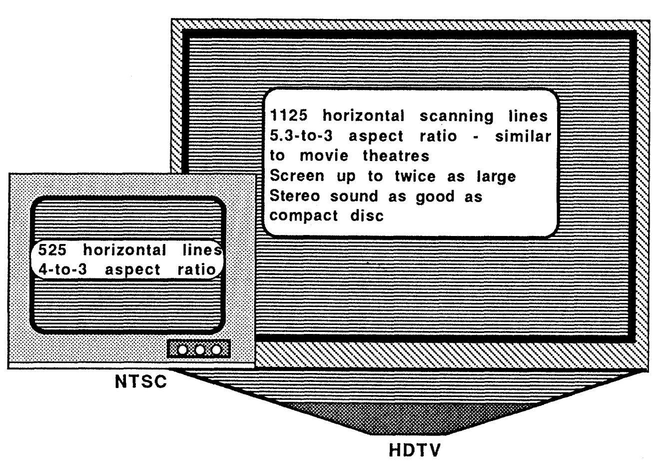
Two actions last month highlighted the coming move to HDTV. On 1 September, the FCC issued initial technical guidelines for high-definition television. Mindful of the lesson of the color wheel, the FCC said that all stations that begin broadcasting in a HDTV format must allow viewers with traditional sets to continue to receive all programming. (The current standard is called NTSC, for the National Television System Committee that instituted it.) The FCC report, however, left open the question of which HDTV standard the commission will favor among a dozen or so competing systems now under development. Among others, Zenith Electronics Corp., North American Philips Corp., the David Sarnoff Research Center, the New York Institute of Technology, the Del Rey Group, Faroudja Laboratories, and Japanese broadcasting giant NHK are working on HDTV systems for the American market.

On 7 September, the House Subcommittee on Telecommunications and Finance held a hearing on advanced television technologies, including HDTV. The subcommittee focused on the potential effect HDTV technologies could have on the American economy and foreign trade and on how the choice of a standard could affect American competitiveness in this market.

The FCC action was the first step toward fixing the rules under which high-definition broadcast television will operate. The commission found that "existing service to viewers utilizing NTSC receivers must be continued . . . , at least during a transition period." HDTV broadcasters could continue to provide this existing service, the FCC said, either by making the new signal compatible with the old or else by broadcasting both the new and old signals simultaneously. Since the nearly filled radio/television spectrum makes it unlikely that the FCC will allot two separate channels for the same signal in different formats, and since most HDTV formats under design are compatible with NTSC anyway, it seems likely that high-definition television in this country will be compatible with the existing standard. There will be no repeat of the color wheel.

Addressing the problem of the increasingly crowded electromagnetic spectrum, the commission provided a partial answer about where it plans to find space for HDTV broadcasts. Because HDTV signals will carry several times as much information as current television signals, they are likely to need more bandwidth in the spectrum than NTSC broadcasts. (Bandwidth measures the range of frequencies allocated to a television or radio broadcast and is analogous to the width of a lane on a highway. Larger bandwidths mean more information per channel but fewer channels.) Since in major markets, such as New York City, television stations already take up every channel allowed by the FCC, there seem to be no channels on which to broadcast the extra information needed for HDTV. Some HDTV proponents had urged the commission to set aside space for HDTV broadcasts outside the VHF (very high frequency) and UHF (ultrahigh frequency) bands now allocated to television.

The commission decided, however, that if advanced television signals do need extra



High-definition television *will offer bigger screens, sharper pictures, and better sound than traditional telvision.*

space in the spectrum, this space should be found somehow inside the VHF and UHF bands. Using channels outside these bands would have several disadvantages, the FCC said, including competing with other forms of communication and putting off the introduction of HDTV for several years while allocation hearings took place.

But trying to find space for HDTV signals in the VHF and UHF bands has its own problems. Under the existing assignment of channels, each VHF and UHF station is allotted 6 megahertz of bandwidth, and the NTSC television signal easily fits into this 6-megahertz slot. But high-definition television will probably need either 9 or 12 megahertz for a complete signal and so will not fit into a single channel.

Where does the FCC fit the overflow? Television stations that broadcast to the same area must be separated on the television dial or their signals interfere with each other, and in some densely populated markets the only open channels are these in-between frequencies that must be kept free.

The FCC is certain to keep the 6 megahertz per channel format, at least for the foreseeable future. This means HDTV signals will either have to be crammed somehow into 6 megahertz—which most observers believe to be unlikely, at least for true high-definition television—or else spread over more than a single channel. Most HDTV systems under development split the signal into two pieces, where one of the signals would be broadcast on a 6-megahertz channel and could be received by current NTSC television sets. This would automatically guarantee compatibility. The rest of the signal—which will take up 3 or 6 megahertz—would provide extra information that only an HDTV set would use. The question facing the FCC is where to put these extra signals without interfering with existing stations. Some of the proposed HDTV systems would get around the problem by digitizing this second signal, which would allow it to be transmitted at such low power that it would not interfere with signals from adjacent stations.

The choice of which HDTV standard will be used in American television is likely to hinge on economic as well as technical considerations. On 7 September, saying that hundreds of thousands of jobs are at stake, Representative Edward J. Markey (D–MA) convened the House Subcommittee on Telecommunications and Finance to begin to create a national policy on HDTV and other advanced television systems. "Economists predict that over the next several decades, advanced television technologies, including HDTV, will create $50 billion to $250 billion of economic activity," he said.

A Chance to Retake TV Market?

No matter which high-definition television (HDTV) systems are eventually chosen as broadcast standards for the United States and other countries, television manufacturers will want to offer consumers large-screen televisions that can take advantage of the improved resolution and extra width of the HDTV picture. These extra large screens will offer the U.S. electronics industry a once-in-a-lifetime chance to recapture a big share of the television market, says William Glenn, director of the Science and Technology Research Center at the New York Institute of Technology.

Although most of the attention toward HDTV has been focused on choosing a standard for the new television, much of the technology needed to make HDTV sets will be essentially independent of that standard. Glenn estimates that the electronics to process the HDTV signal would account for only about 10% of the total cost of a large-screen high-definition television, assuming the set was built with current display technology. Much of the rest of the cost would be devoted to the display, he says, including cathode ray tubes and optical components.

Observers say that using current display technology to build extra large screens would make the television sets too expensive for most consumers—estimates of the cost range up to $5000. On the other hand, one of the primary selling points of HDTV is its ability to produce a high-quality picture on screens 4 to 5 feet across. These two facts imply that the commercial success of HDTV may well hinge on finding a way to make less expensive large-screen displays. The company or country that develops the technology to make such displays, Glenn says, is likely to capture a large part of the HDTV consumer market, a market that is projected to be worth $20 billion a year by 1997.

For the U.S. electronics industry, this could offer a golden opportunity. The Japanese excel in taking technology created elsewhere and developing it for commercial production, as their domination of the videocassette recorder market indicates. ("They'll be the first to make HDTV sets for the U.S. market no matter what the standard is," Glenn says.) But American companies still have an advantage in technological innovation. The weakness of American industry in competing with the Japanese, most observers agree, is not due to a failure of research and development but rather to a weakness in taking products to market.

"We don't have a chance if we use traditional technology," Glenn says, because the Japanese already dominate the traditional television market. Indeed, Zenith is nearly the only American-owned company still making television sets. "The only way to compete is by using new technology," Glenn says. This would eliminate the advantage the Japanese enjoy with their large capital investment in plants making traditional televisions and could throw the market wide open.

Glenn and the New York Institute of Technology have a big stake themselves in the development of large television screens. The Institute is developing a solid-state projection system called a "light valve" that could be used in HDTV sets. According to Glenn, the light valve works much like a slide projector except that light is reflected off a solid-state chip instead of transmitted through a photographic slide. The chip that produces the image to be projected onto the screen has two parts: a light modulator, which consists of an elastic membrane coated with a metallic substance that reflects light, and a drive chip that produces varying electrostatic forces across the face of the light modulator, causing ripples in the modulator and affecting the way light is reflected off the modulator and into a projection lens. This "chip with a TV on it," as Glenn calls it, is about the size of a business card and has good enough resolution to match the quality of 35-millimeter movies in theaters.

"We have operating projectors and operating light modulators," Glenn says. The missing piece is the drive chip, technically called a thin-film transistor active-matrix driver, and Glenn says there is "no significant effort in the United States" to develop that chip. Other countries, particularly Japan and West Germany, are working on such drive chips for use in liquid-crystal displays.

Other technologies, such as liquid-crystal displays, may ultimately prove to be a better choice than the light valve for HDTV large displays, and the field now is wide open. One way or the other, though, if American companies wait until the technology to display HDTV signals is developed elsewhere, they are unlikely to catch up with the Japanese in this future market. ■ **R.P.**

"The question before the subcommittee is whether U.S. industry and U.S. employees will share in that bounty."

In the hearing, Markey asked for the relevant federal agencies and the American electronics industry, through its trade associations, to submit "action reports" to Congress by 4 January, outlining how best to ensure an American presence in the coming HDTV industry. Industry observers say the choice of HDTV standard could have a big effect on how well the American electronics industry can compete in this market. A standard that depends on American-developed technology could give American companies a head start, or at least an even start, in the race against Japanese and European countries to market HDTV in the United States. (Japanese companies have marketed HDTV equipment for several years for specialized uses, and the Japanese company NHK plans to begin broadcasting in HDTV by 1990. NHK's system, however, is not compatible with NTSC.)

Markey said that because it is not the FCC's job to preserve American jobs, Congress will probably want to take the lead in developing a HDTV policy and that will hurry Congress to start work on it soon after the action reports arrive. That policy, electronics industry observers say, might well include a cooperative effort among many American companies to develop an HDTV system. The fruits of a successful HDTV industry are likely to be plentiful enough for all to share. ■ ROBERT POOL

A Testable Theory of Superconductivity

New calculations from a theory based on magnetic interactions predict superconductors will never reach room temperature

IS THE DREAM of room-temperature superconductivity over? News reports around the country last week suggested that it is, after theoretical physicist William Goddard of the California Institute of Technology announced he has developed a theory describing high-temperature superconductivity. Speaking at the 196th American Chemical Society National Meeting in Los Angeles, Goddard said the highest critical temperature for any of the copper-oxide superconductors now under development is likely to be around 225 K, or −54°F.

The announcement received extensive press coverage, but superconductivity researchers seemed surprised by the attention. After all, much of Goddard's theory had appeared 7 months earlier, in two research reports in the 19 February issue of *Science*. Further, the result that interested the press—that room-temperature superconductivity may not be attainable in copper-oxide superconductors—was not surprising to scientists in the field. Many researchers had concluded from phenomenological considerations that the materials' maximum critical temperature would be 200 to 300 K.

Goddard himself downplayed any predictions about room-temperature superconductivity and instead emphasized his ability to make numerical predictions from first principles. "The magnon-pairing theory that we have developed at Caltech is unique in that it starts from fundamental quantum-mechanical principles and makes very specific predictions," he said. "This means that if there is something wrong with the theory, experiments will disprove it very quickly."

Using his model, Goddard has calculated explicitly several properties of various copper-oxide superconductors, including their critical temperatures, critical fields, coherence lengths, penetration depths, and specific heats. There are no undetermined parameters in his model, he says—no numbers that must be determined experimentally and put in by hand.

The search for a theory to describe high-temperature superconductors started with the discovery in early 1987 of materials that become superconducting at liquid-nitrogen temperatures (above 77 K). Since these materials lose electrical resistance at much higher temperatures than earlier superconductors, observers predicted many valuable commercial applications, from superpowerful magnets to ultrafast computers. If a room-temperature superconductor could be found—one that needed no expensive refrigeration—it could turn out to be one of the most valuable materials ever made by man.

But although researchers have learned to fabricate these materials and know their atomic structures, no one has perfected a theory to explain high-temperature superconductivity. Scientists now know about three classes of high-temperature superconductors, based on yttrium (or various other rare earths), bismuth, and thallium. All three have layers of copper and oxygen atoms that are essential to their superconductivity.

The mechanism leading to superconductivity in high-temperature materials apparently is fundamentally different from that of low-temperature superconductors. The Bardeen-Cooper-Schrieffer theory, or BCS, explains low-temperature superconductivity as a result of interactions between conduction electrons and phonons, or vibrations in the material's atomic lattice. According to BCS, interactions between the electrons and phonons cause the electrons—which normally repel each other—to travel in pairs, and this pairing coupled with a second mechanism allows the electrons to travel through the material without resistance.

Early experiments on high-temperature superconductors showed that their electrons also traveled in pairs but that the pairing was not caused by an electron-phonon interaction. One possible explanation was that high-temperature superconductivity was caused by a BCS-like mechanism using something besides electron-phonon interactions to pair the electrons.

Goddard's theory is such an explanation. He describes electron pairing as being caused by magnetic interactions between electrons and pairs of copper atoms—"magnon pairing." His papers in the 19 February issue of *Science* (pp. 896 and 899) laid out the theory, explaining how some of the oxygen atoms in the copper-oxygen planes lose electrons, which gives them a net magnetic moment, which in turn causes the copper atoms on either side to align their own magnetic moments. The resulting magnetic fields cause an attraction between electrons, creating electron pairs.

Since February, Goddard has applied the theory to make numerical predictions for various properties of superconductors, and his numbers agree relatively well with experiment. If the theory proves correct, he says, it may point out a way to maximize the critical temperature at around 225 K, or 100 K higher than it is now. It remains an open question whether other superconductors than copper-oxide might someday surpass room temperature. ■ ROBERT POOL