Chapter 1
Radio Broadcasting

INTRODUCTION

It is remarkable, given the pace of technological change in this century, that an AM radio receiver manufactured in 1930 will still pick up any standard broadcast station today. In part, this is because broadcasting in the United States and other countries has been protected by regulatory agencies intent on preventing technical obsolescence. In general, technical changes in AM service have been permitted only where they did not make the service incompatible with existing receivers. These changes included the substitution of semiconductor electronics for earlier vacuum tube devices and the use of automation technologies, magnetic recording, and other labor-saving tools in radio stations. Thus the history of "standard" broadcasting after World War II is a story of vitality and continued growth.

"Standard" Broadcasting, Wired Radio, and Short-wave

There was a considerable expansion of AM service in many countries after 1945. In Europe and Asia, this was due initially to the rebuilding of war-damaged stations: only in the United States had the broadcasting infrastructure been unaffected by World War II. For example, only four of the 42 pre-war French broadcasting stations were still operating when the war ended. Much reconstruction took place under the auspices of the Allied forces in order to expedite the implementation of propaganda and information services. The European network of AM (or "medium wave" as it is usually called) stations was soon rebuilt to its pre-war state.[1]

In the United States, AM broadcasting emerged from the War in robust physical and financial state and in general remained a profitable business in subsequent years. Contrary to the notion that

Vacuum tube production reached its peak shortly after World War II. The transistor, invented at Bell Telephone Laboratories and announced in 1948, began to replace vacuum tubes in most applications during the 1950s. Photo courtesy of the Smithsonian Institution

television "killed" the radio business, AM stations have remained profitable (on average) to the present day. Even the introduction of the new FM services failed to displace AM, and the number of AM stations on the air has increased dramatically. In the United States alone the number rose from 919 stations in 1945 to over 4,000 in 1983. National governments treat their existing AM infrastructure of thousands of stations and millions of receivers as a valuable resource rather than an outmoded relic. The United States in the 1950s, for example, made existing AM stations the backbone of its "civil defense" emergency information system. In most countries other than the U.S., AM broadcasting remains the standard for most radio listening, particularly for portable and automobile radios.[2]

In many countries, basic broadcast service was supplemented in the pre-war period by "wired radio," and although this service persisted after 1945 it was in decline by the 1980s. The Soviets had an enormous wired radio network by 1945, with a large proportion of the nation's "receivers" actually being wired radio sets rather than actual radio receivers. Soviet wired radio networks prospered through the 1970s, when they finally began to be replaced by broadcast receivers. Some governments saw wired radio as a way to achieve instantaneous mass communication of wireless radio while retaining political control. In the Soviet Union and many other countries, the public's wired radio sets received only one channel for many years. Only in the early 1960s did multi-channel, multiplexed wire transmission appear in Moscow and some other areas. Similarly, in China all radio broadcasts came to citizens via wire until the 1980s—only regional distribution centers operated by the government had radio receivers. Loudspeakers were placed in the centers of villages, in markets, and in workplaces, and constantly shouted messages to the citizenry.[3]

Wired radio also had an important economic justification. Countries with dispersed rural populations or rugged terrain, such as Sweden, used wired radio extensively as late as the 1980s, when satellite distribution became more widespread. It was less expensive to string wires to isolated farms than provide comprehensive radio coverage. For the poorer Eastern Bloc countries, inexpensive wired radio sets, because of the simplicity of their designs, did not put as much of a burden on scarce supplies of electronic components.

During World War II, wired sets had also proven resistant to enemy action, and after the war wired radio retained a certain appeal to the Cold War belligerents. The Soviets recalled how citizens of Leningrad kept their wired radios switched on 24 hours a day during that city's siege by the Germans during World War II. With the coming of the Cold War, the preservation of such a "survivable" system remained politically desirable. Several developing nations had wired radio networks dating from the 1930s, often built by foreign companies or colonial governments. Ghana, for example, had a network feeding single-channel speaker boxes that was built in 1935 and was still in operation in the late 1970s. The system actually grew between 1949 and 1978 from about 7,000 subscribers to over 60,000.[4]

Wired radio had a very different history in the United States. Commercial radio broadcasters repeatedly sought to prevent wired radio enterprises from delivering this service to American households Something technically similar emerged instead, but it was not a service delivered to the homes of individuals as in other countries. Instead, it was limited to "background music" for commercial establishments and public areas, such as restaurants and hotel lobbies. Several companies, notably Muzak Corporation, achieved notable success selling this type of service, which was so widespread by the 1960s that it became a symbol of the intrusiveness of modern technology.

Many factors have contributed to wired radio's worldwide decline in recent years. The emergence of redundant communications systems in most countries has lessened the need for a "survivable" wired radio network. Microwave and satellite distribution systems have made it possible to deliver telephone, television, and radio services over wide geographic areas relatively inexpensively. Finally, in Europe, Africa, and South America most wired radio networks were supported by government subsidy, and some governments simply decided to cease supporting the technology. In the United States, while Muzak-type services have proliferated, their methods of distribution have shifted to less expensive means, such as magnetic tape, FM radio, and satellite broadcasting.[5]

A third popular pre-war broadcast service that persisted in the postwar period was short-wave radio, used widely after the early 1930s for long distance and international broadcasting. Short-wave takes advantage of the skywave propagation possible at certain wavelengths to broadcast over the horizon, but it is susceptible to fading and static. Many colonial nations had relied on short-wave broadcasts from Europe or the U.S. before World War II, but as these nations began to achieve their independence in the 1950s and 1960s they established their own broadcast services. The creation of these national broadcasting services (often standard broadcasting or television rather than short-wave) was a long process that lasted until the 1970s, when even the smallest nations, such as the Cayman Islands, inaugurated their first broadcast services.[6] Short-wave has survived in many countries to provide

news and entertainment to nationals living abroad or to service the remnants of European populations in former colonial areas. The BBC's short-wave service is one of the best known examples of this. One of short-wave broadcasting's most influential uses has been for propaganda purposes, primarily between Communist and non-communist countries. The United States' Voice of America, for example, beamed ideological content to friends and foes alike beginning shortly after World War II.

The Introduction of FM Service

FM was in regular use in the early 1950s in many places in Europe, the United States, and other industrialized nations, but has not yet spread to some developing countries. Certain European countries extended FM service very rapidly, particularly West Germany, which had a network with over 100 FM stations operating by 1955. European countries saw FM not only as a technically improved service but as a way to ease overcrowding in the medium-wave AM band. Nations with rural populations saw little advantage in FM since long-distance skywave propagation was so limited, and AM remained the best way to reach a widely scattered audience by radio. One exception was South Africa, which instituted a remarkable FM network providing comprehensive coverage of its territories. British FM broadcasting was phased in after 2 May, 1955, when the first regular BBC broadcasts in FM took place.[7] Like some other countries, the BBC took advantage of what at first seemed a disadvantage—FM's relatively limited reception area—to rethink the nature of its broadcast programming. The BBC introduced FM as a way to implement radio programming that was intended to be local rather than national (as most AM programs had been). By contrast, since U.S. stations had always served local markets (though they carried much national network programming), FM

The IEEE Consumer Electronics Society

The IEEE Consumer Electronics Society has its roots in two older institutions. The first, the annual convention of radio receiver engineers in Rochester, New York, began in the 1930s and emerged after World War II as the IRE Professional Group on Broadcast and Television Receivers (PGBTR). Its first president was Virgil M. Graham. A second group, called the Committee on Television and Aural Broadcasting Systems, was created by members of the AIEE in about 1952. The two merged in 1962 with the merger of the IRE and the AIEE, with the new organization retaining the name and publications of the IRE group. The PGBTR began publishing its Transactions in 1952. The name of the organization changed several times over the years to reflect the shifting interests of engineers and changes in technology. It was briefly called the IEEE Consumer Electronics Group in 1974, but then it combined with two other Professional Groups and was renamed the Broadcast, Cable, and Consumer Electronics Society by 1976. This union did not last, and in 1983 it split into the Broadcast Technology Society and the Consumer Electronics Society. The Consumer Electronics Award established in 1964 honored many of the key individuals involved in the development of magnetic recording, television, standards, and entrepreneurship.

programs in most ways resembled those delivered by the AM service. In fact, from 1948 through the mid-1950s, owners of U.S. AM stations who also owned FM equipment could broadcast exactly the same programming on both stations simultaneously (in more recent years, as AM has declined somewhat, the reverse has been true since about 1986).[8]

FM in the United States

FM radio's current domination of the radio business in the United States did not appear instantly. Although regular broadcasts began in 1939, it was not until the late 1970s that FM as an industry could be considered a success, and even as late as 1980 there were far more AM stations than FM stations on the air. AM radio ownership is nearly universal. In 1945, only 1.4 million homes in the U.S. lacked a radio receiver, compared to over 46 million homes with receivers.[9]

After inventor Edwin H. Armstrong's dramatic demonstration of FM, the medium faced opposition in varying degrees from the Radio Corporation of America and the National Broadcasting Company through 1945. Aside from its success and widespread application as a military communications technology during World War II, FM broadcasting was reigned in by the FCC's wartime restrictions, then faced a serious setback when its frequency allocation was shifted from the 42-50 MHz band to the current 87-108 MHz band, effective in 1947. The new band gave FM more room to grow, but it came at the expense of making all existing receivers and some transmitting equipment obsolete.[10]

Edwin Howard Armstrong's accomplishments included the development and promotion of a new system of frequency modulated (FM) broadcasting. Armstrong's battle over FM with RCA would contribute to his suicide. Photo courtesy of the Smithsonian Institution

FM in the late 1940s in the United States was seen as a competitor to television service, particularly by the Radio Corporation of America, which led the campaign for commercial television. RCA refused to back FM broadcasting wholeheartedly and RCA leader David Sarnoff publicly dismissed the proposals of FM's inventor and champion, Edwin Armstrong. Armstrong was an audiophile who believed in FM's ability to bring "good music" to the people. It would in his view improve the public's taste, since people would for the first time have in their homes the technology to hear classical music as it sounded in the concert hall. After suffering for years the frustrations of a court battle with RCA over the issue of FM patents, virtually ruining his marriage and

draining his personal fortune, Armstrong apparently decided to commit suicide: his body was found below his 14th story apartment window in 1954.[11]

For the decade of the 1950s, FM broadcasting in the U.S. showed little commercial promise. Local broadcasting companies, which often held both AM and FM licenses, were permitted to save money by duplicating a large percentage of their AM program material over their FM channels. FM owners found an even better way to make money, by selling a service called "storecasting," in which an inaudible tone inserted into the programming before and after announcements activated a special receiver. The result was that the commercials and other talk were suppressed, and stores could use the broadcasts as a form of inexpensive background music. Stations made money on this service by charging a fee for the use of the receivers.

After 1955, the FCC allowed FM stations to apply for Supplementary Carrier Allocations (or SCAs) to exploit their unused sidebands. Stations could then transmit Muzak or other commercial services that could not be heard via ordinary consumer receivers.[12] But this profitable adjunct to FM broadcasting was soon challenged by proposals to use that same slice of extra bandwidth to introduce two-channel stereophonic transmissions. Stereo radio had been attracting considerable attention among the growing number of "audiophiles" in cities like New York and Chicago, where experimental stereo broadcasts were conducted through the simultaneous transmission of two signals on separate channels. Listeners apparently found the results impressive, even when one of the two channels came from an AM rather than an FM station. The ensuing debate over a stereo standard for FM resulted, in the U.S., in a system in which the left-plus-right signal modulated a 15-kHz baseband. This signal could be received on monaural receivers or used to derive a stereo signal. Eventually this type of stereo broadcasting also spread to other countries.

In this system, an FM channel requires about 53 kHz, the first 15 kHz being used for the combined left-plus-right signal, which can be used "as-is" by a monophonic receiver. The left-minus-right signal information is broadcast in the top part of the broadcast channel, between 23 and 53 kHz. Along with this "subchannel," a pilot signal at 19 kHz provides the receiver with enough additional information to derive electronically the original left and right signals. The system was only one of several that various companies proposed, and it succeeded partly because it achieved the political goal of compatibility with monaural FM. This standard also allowed stations to transmit SCAs, though at the expense of a degraded signal-to-noise ratio and increased susceptibility to multipath distortion (a type of distortion caused by reflections of the signal off the ground or nearby buildings).[13]

Eventually, rising levels of FM radio ownership, and the falling price of AM-FM radio phonograph combinations, helped make FM a profitable industry in the U.S. The automobile radio was one of the keys to FM's success in the 1970s. The number of U.S. automobiles with FM radios rose from only 14 percent in 1970 to 85 percent by 1985. The automotive FM radio, criticized in the 1960s for its poor performance, improved steadily, particularly after the adoption of integrated circuits, which allowed better tuning circuits to be packed in a smaller space. By 1976, the FCC could report that most American FM stations were showing a profit.[14]

Another important factor in FM's popularity in the United States, England, and some other countries was that many FM stations chose to broadcast rock and roll music. Rock fans, who tended to be teenagers and young adults, sought out FM broadcasting rock because the medium was so well suited to the sonic characteristics of the music, especially in the reproduction of heavy percussion and electronic instruments. Thus the initial technical appeal of FM for the high fidelity reproduction of classical music eventually became much less of a factor in the medium's success than its ability to handle loud, raucous popular music. In the late 1980s, only 44 of some 3800 commercial FM stations in the U.S. listed their primary programming as being classical music. Clearly, technology was not the main factor in determining musical taste.[15]

Stereo: FM Triumph and AM Frustration

Edwin Armstrong, the FM pioneer, began experimenting with multiplexed radio broadcasts as early as 1934, but these were not yet stereophonic transmissions.[16] It was only in the 1950s that radio stations in a few cities began experimenting with true stereo. At first, this required two separate channels; thus, several early stereo broadcasts took place using one FM and one AM channel. The Japanese broadcasting authority, NHK, broadcast experimentally this way as early as 1952.[17] Interest among radio station owners in the possibility of regular stereophonic broadcasts spurred the FCC in the U.S. to create a national Stereophonic Radio Committee, and similar organizations sprang up in Great Britain and elsewhere. By 1961, the FCC had a+pproved one of the several proposed standards, although it was not until the 1970s that the majority of FM stations broadcast in stereo.[18]

AM broadcasters, manufacturers, and even the IEEE made several attempts after 1945 to upgrade AM service to include stereo, though they met with little success. As stereo was incorporated into phonograph disks

and FM technologies, engineers sought ways to apply the same ideas to AM. However, they encountered problems of both the technical and regulatory sort. In the United States and Europe, where stereo was most popular, engineers proposed to broadcast a stereo AM channel that would be compatible with existing monophonic receivers. Yet the AM bands were already crowded, and the additional bandwidth required by the various compatible-AM proposals demanded considerable revision to spectrum allocations. It was 1975 before the FCC was ready to evaluate the AM stereo issue and decide on a standard, but in the end the agency did not settle the issue of AM stereo as effectively as it had FM stereo. At first the FCC chose the Magnavox AM-OM system in 1980. Ronald Reagan's deregulation initiative (plus the FCC's reluctance to repeat the error of earlier color television standards decisions, see p. 24) led to a reversal in 1982 and a decision to authorize the standards of all four top competitors; market forces would determine the final outcome. Of the four systems rated best by the FCC[19], only one (the third on the list) appeared to have gained serious marketplace acceptance by the late 1980s: Motorola Corporation's C-Quam, which began to spread in the U.S., South Africa, and Australia. This system was compatible with standard AM receivers, using the sum of the left-plus-right signals to amplitude-modulate the main carrier, while the difference, or left-minus-right signal, is transmitted on a separate, phase-modulated carrier. As of 1988, Motorola reported sales of over sixteen million of the C-Quam decoder circuits used in receivers. However, by this time there was much discussion of eliminating AM broadcasts altogether, and using the bandwidth for something else.[20]

Pirate Radio

One international phenomenon that blossomed in the postwar period was that of so-called pirate, or unauthorized, broadcasting. These were stations broadcasting in the band spread that could be received by ordinary radios, but operating without authorization from broadcasting authorities. They were distinct from the related phenomenon of official but clandestine stations broadcasting propaganda, such as those operated in several countries by the United States Central Intelligence Agency during the Cold War. Many of the more notorious pirate stations operated from ships moored in international waters, making their suppression more difficult. A few others used abandoned artificial islands once used by military forces and dating from World War II. The miniaturization of electronic equipment and cost reduction brought about by the advent of semiconductor electronics made the establishment of pirate operations much easier, and in fact there were more of them after the early 1960s. Nations with conservative broadcast program policies were particularly subject to pirate broadcasts. Several northern European countries, for example, reluctant to broadcast rock and roll music, found themselves dealing with unauthorized stations catering to rock and roll fans.

The nuisance these stations presented to authorized broadcasters led to condemnations by the Council of Europe (1965) and the British government (1967), but by then Britain, Holland, Sweden, Israel, New Zealand, and other nations had publicly announced relaxed policies on popular music, thereby undermining the appeal of the pirates.[21] Pirate television was a more limited phenomenon, but also combined elements of social protest and commercial enterprise. A striking example of this was Italy, where by 1970 there were hundreds of unauthorized private cable television systems operating commercially throughout the country. By 1974, the influence of these "pirates" was so great that the Italian court had proclaimed that the state monopoly on broadcasting was unconstitutional.[22]

Technical Change in Radio: The Impact of Television

Although television did not spell the end of radio, its coming had a profound impact on radio program production and studio operations in many countries. The best-known examples come from the United States, where television service has had a huge economic and social impact. Over the course of about a decade after 1945, the American networks moved quickly to expand or inaugurate television services. The result was a sudden scarcity of network resources for radio production, especially after a boom in television sales beginning in 1948. Radio advertising revenues in the U.S. remained strong through about 1952, while a "freeze" on new station building spurred by the Korean war kept the number of TV stations relatively small. But with the expiration of the freeze in 1952 there were already fifteen million TVs in American homes; subsequently the numbers grew even more. Expensive live musical programs on radio were some of the first to be dropped, and broadcasters were soon cutting out the popular quiz and call-in shows, some of which re-appeared on television. In their place, local stations instituted new formats like "Top 40" and "Urban Music." This new programming was innovative not only from a business standpoint but also technologically—it relied heavily on sound recording, a technology seldom used in pre-war network programming.[23]

The use of recordings had been suppressed by the two major American networks, NBC and CBS, virtually since radio's inception. Although special 16-inch long-playing phonograph recorders were available which might have been the basis of many radio programs, networks clung to a system of live distribution via cable to local stations. In their own studios, neither these special "transcription" disks nor ordinary phonograph records were allowed, with only rare exceptions (the recording of the Hindenburg disaster, for example, or "sound effects," drawn from special transcription disks created for that purpose). Although a few companies had gone into business as mini-networks by distributing programs on 16-inch disks—Amos and Andy from 1928-1929 was one—the most successful programs would invariably be bought by the major

networks and converted to live broadcasts. The use of live broadcasting was one strategy the networks used to keep competitors at bay, by making the capital requirements for establishing a new network very high.[24]

By contrast, European radio networks used recordings more freely. The tape recorder was developed for use in radio systems, particularly ones such as the BBC, where long programs could be recorded and re-broadcast at night over short-wave channels. During World War II, the use of recordings in radio began to change in U.S. broadcasting as well. The Armed Forces Radio Service, a military network serving American soldiers overseas, distributed all its programs on transcription disks, proving the value and convenience of recorded programs to its staff— the host of civilian volunteers recruited from local stations and the networks. The experience of using recordings during wartime would have an impact when these men returned home.

The AFRS and the Army Signal Corps also experimented with several radically new recording technologies. One was the Hart Recordograph, a machine that embossed a sound record on a cellophane strip. While the Army news services found the Recordograph useful, in the postwar period it failed to catch on. Somewhat more successful was the magnetic wire recorder designed by the Armour Research Foundation of Chicago. Armour, now the Research Institute of Illinois Institute of Technology, originally intended to sell the machine to consumers, but found a ready market in the military. The machine, which recorded sound on extremely fine steel wire, was redesigned at the end of the war, again with home consumers in mind. Tens of thousands of wire recorders were manufactured under license by companies such as Webster-Chicago, Wilcox & Gay, and RCA before the wire recorder succumbed to competition from a similar technology, the tape recorder.[25]

The Tape Recorder in Studio Production

A few radio stations purchased and used wire recorders for their news programs in the years immediately after World War II, but abandoned them after the appearance of high-quality tape recorders in 1947-48. The tape recorder was invented in the late 19th century, but was not widely used until the 1930s. German companies designed the first modern type of tape recorder following requests from the German Reich Rundfunk Gesselschaft [RRG] radio service, which as early as 1933 installed them in its stations in Germany and (as the war started) occupied countries. The most popular of these machines, called the magnetophon, was developed in 1936 by the German firm AEG. Instead of the heavy, expensive steel bands or wires used previously, the magnetophon utilized an inexpensive, lightweight plastic strip with a coating of iron oxide. Magnetophon tape was developed in cooperation with a second German firm, I.G. Farben. AEG continued producing magnetophon tape recorders after the

war, but the I.G. Farben conglomerate was broken up following revelations of collaboration with the Nazi regime (the firm manufactured the poison gas used in Nazi death camps). Today's BASF, still a major tape manufacturer, is the descendant of the original I.G. Farben tape manufacturing division.

There are many accounts of American and British servicemen "discovering" the AEG magnetophon in European radio stations during 1944 and 1945. A number of these men somehow obtained permission to bring back examples of these bulky machines. John T. Mullin, a former Signal Corps technician, demonstrated the magnetophon to radio engineers in 1945, hoping to arouse interest in making an American version of the device. A few tape recorders actually went into service, tentatively, in American radio stations as early as 1945, using a machine called the Brush Soundmirror, intended for consumer use. By 1948, the Ampex Corporation, a former military contractor, introduced its Model 200, a machine built to virtually the same standards as the pre-war magnetophon, though with significant improvements.[26]

Even though the tape recorder was used extensively in European radio in the 1930s and early 1940s, it had not been adopted in the U.S. A confluence of events led to the rapid and widespread acceptance of this new product. The large radio networks, particularly the newly created American Broadcasting Company, lured star Bing Crosby away from a competitor by agreeing to let him record his shows. Crosby at first experimented with disk recordings, but later used a magnetophon and compelled ABC to give Ampex its first major order for tape recorders. This isolated event was indicative of the more important shifts in the economics of radio production, due mostly to the coming of television. By about 1952, scores of local radio stations, hard put to find affordable material to replace dwindling network offerings, looked for ways to reduce the costs of staying on the air. With the networks offering fewer programs, stations had to purchase programs from other firms or produce them locally. The tape recorder was an excellent cost-cutting tool. It was easier and less expensive to use than the disk recorders that stations already had, and, unlike disks, tape recordings were relatively easy to make and the medium could be easily edited. Low-cost alternatives to the Ampex machines (which cost over $2500) were soon available from firms including the Magnecord Corporation of Chicago. The tape recorder rapidly became a major source of broadcast programming.

It is worth mentioning two other magnetic recording technologies used in radio broadcasting. One became popular as part of the more general movement toward station automation. Automation in radio studios relied heavily on magnetic recording technologies to provide program content. As radio studio staff dwindled to the bare minimum of an announcer, an engineer, and a board operator (and sometimes one person acted as all three), stations found it profitable to record long

programs on tape and replay them without human intervention. Convincingly spontaneous-sounding broadcasts could be made up ahead of time, with musical selections on one tape, separated by inaudible reference tones that would automatically switch to a second tape containing recordings of an announcer's voice. While the FCC continued to require that someone be present at the station at all times, with automated equipment only an unskilled attendant might be necessary.

A second important technology was the Fidelipac cartridge. This was an endless loop cartridge first developed in the early 1960s as a source of background music for public places. Radio stations began to use these cartridges by the late 1960s for commercial announcements and individual songs. Because it was so easy to pop the cartridge into the player, the job of the disk jockey was made easier. A series of players could be wired to operate in sequence, and as one tape ended it could signal the next tape to begin. Then, since the recordings were loops, each tape was poised to be replayed again—an important feature for frequently repeated commercials or hit music singles. The "cart," as it was called, was ubiquitous in radio stations well into the 1990s, when it began to be replaced by digital technologies.

The Radio Receiver

Radio receiver sales had been substantial even during the Great Depression, yet many smaller manufacturers had been forced out of business. The most successful firms of the 1930s survived by offering low-cost, tabletop radios with minimal features and cost-cutting designs. From the consumer's point of view, radio receivers changed little during this period, but real change had occurred in manufacturing, where high-speed automated tube manufacturing, circuits employing fewer and cheaper components, and low-cost cabinets made of plastic (or even paper) replaced the more costly designs of previous years.

Instead of disappearing when prosperity returned, most of these features survived into the postwar boom years and in fact paved the way for more complex, but still affordable, new types of home electronic equipment. One such survival was what radio enthusiasts in the U.S. have (rather chauvinistically) dubbed the "All American Five," a Depression-era five-tube AM receiver design that was eventually manufactured with only slight variations by virtually every American and European maker of radio sets. This circuit employed a standardized set of receiving tubes with filaments designed to be wired in series across the full household current (which is about 115 volts in the U.S. and some other countries). The total potential drop across the series of filaments was 115 volts, making it unnecessary to use a transformer in the power supply; thus manufacturers saved the cost of an expensive component. This gave the All American Five a decided price advantage over transformer-

equipped sets, although it came with some risk: there was a very real danger of fire or electric shock if, for example, a capacitor shorted in the high-voltage "b+" circuit and the consumer touched an exposed part of the chassis. Such failures were quite common, though rarely fatal. Some circuits minimized the risk by using a rectifier tube, in which the filament acted as a fuse, opening the circuit in the case of an overcurrent.

The Transistor

From the early 1920s to the middle 1950s, the vacuum tube reigned in the field of radio and phonograph amplifiers. Semiconductor devices appeared first in the form of rectifiers in power supplies, taking the place of the original vacuum tube devices. The earliest applications for the transistor, a semiconductor amplifier invented in 1947, were initially limited to telephone system applications and military technologies. Only in the early 1950s did the first consumer transistor products appear, and even then applications were limited by the transistor's high cost and minuscule amplifying capability. The hearing aid, a product that caused embarrassment to many of its wearers and thus was purposefully made as small as possible, was available in transistorized form as early as 1952. But the average price of a transistor as late as 1953 was $8, as compared to the average tube price of about $1, hampering commercialization.

The use of transistors for radios expanded rapidly after 1954, when Texas Instruments (through an affiliate, Regency Electronics of Indianapolis) and Raytheon both introduced miniature transistor radios. The prices were high: $50 for the Regency and $80 for the Raytheon versus as little as a few dollars for an inexpensive vacuum tube radio. Nonetheless these models sold surprisingly well as novelties. The next year, a similar miniature transistor radio, the Sony TR-55, was made in Japan. Originally just a brand name, the Sony trademark became the corporate name of its manufacturer by 1957.[27]

One of the most important early consumer markets for transistors was in automobile radios. Until the 1950s, these relied on vacuum tubes, even though they required high voltages not readily available in a car's 6- or 12-volt system. Although transistors were more expensive than vacuum tubes, they resulted in car radios that were smaller, lighter, simpler, and more reliable. Ironically, at about the same time, radio manufacturers devised low-voltage tubes for automobile radios that required no more than 12 volts. Along with tube-transistor hybrids, low-voltage vacuum tube radios survived for several years before succumbing to competition from the increasingly inexpensive transistor.

As prices for the "transistor" (a word that came to refer to the radio, not the component) fell, sales swelled to twelve million units by 1959.[28] Battery-operated transistor radios were very popular in the United

Miniaturization and Entertainment Electronics

Miniaturized electronic devices first appeared not in high-tech missiles and aircraft but in unexpected places like hearing aids and automatic telephone switchboards. Back in the 1930s, the Raytheon company had developed ultra-miniature vacuum tubes for use in hearing aids, and these became part of the first miniaturized electronic weapons systems in World War II. The transistor was intended to be a substitute for electromechanical switches used in the Bell Telephone system, but its small size and miniscule power requirements endeared it to engineers struggling to make radar sets, missile guidance systems, and (of course) portable radios much smaller.

Manufacturers (mainly those selling in both military and civilian markets) were devising other sorts of miniaturized electronic devices by the 1950s, including passive devices such as capacitors, resistors, and switches used extensively in radios and televisions.

The creative re-packaging of circuit components into a more compact form, and the military effort to produce some kind of "modular" circuit in the 1950s, contributed to the advent of printed circuit techniques. The printed circuit board was a non-conductive fiberglass or phenolic plastic card onto which was applied (or created by photolithographic etching) conducting paths. Electronic components could then be inserted into holes in the board and soldered to it, forming a circuit. Printed circuit boards could even be assembled by machines in some cases, a fact that appealed to those in government and industry who saw mass production as the key to success in both military and civilian contexts. Within a few years of its introduction, printed circuits began to replace older "point-to-point" wiring techniques in many inexpensive radios and most televisions. By the 1960s, virtually all consumer electronic devices were constructed this way. One notable exception was Curtis-Mathes television sets, which were hand-wired into the 1970s.

Printed circuit concepts, combined with advances in transistor design, led to integrated circuits. Following the introduction of printed circuit boards were efforts to "print" or apply not only the conductors but other electronic components directly to the board. Experiments at several military contractors in the late 1950s aimed at using layers of semiconducting metal and photolithographic printing technologies to produce conducting paths, diodes, resistors, and capacitors, as well as active elements such as junction transistors. This effort ultimately produced the modern form of integrated circuit.

Like printed circuit boards, integrated circuits proved to appeal initially to military markets, where small size and performance were paramount, or in consumer applications where high-volume production and low cost were important. By the middle 1960s, certain high-volume consumer products such as television sets incorporated integrated circuits, although most radios, tape recorders, and other consumer electronics products continued to use "discrete" components on printed circuit boards.

States and Europe with children and teenagers, who quite often used them to listen to the rock and roll music that their parents disapproved of. They were also purchased by many Americans and kept ready in case of power outages—it was widely assumed that nuclear war with the Soviet Union would knock out power systems. The transistor radio and spare batteries were standard items in the fallout shelters built by the thousands during the 1950s and 1960s. Additionally, the transistor radio had a great importance in rural areas not served by electricity, particularly in developing countries.

Chapter 2

Television Broadcasting

INTRODUCTION

Television broadcasting services began in 1936 in England and France, and in 1939 in the United States, but the onset of World War II and the destruction of many European transmitting stations greatly retarded television's diffusion. When service resumed after the war, growth was fastest in the United States, where thirty-five million of an estimated forty-six million households had sets by 1955.[29] Only five countries had television service as late as 1950, though the number rose to seventeen in 1955 and sixty-eight in 1960. By 1980, 138 countries had television service, and it was estimated that some 400 million receivers were in use around the world.[30]

The Great International TV Standards Wars

In some ways, there were many national differences in radio broadcasting. The pre-war period had seen long-lasting and bitter squabbling, particularly in Europe, about frequency allocations for AM radio and there were many complaints about interference between stations in neighboring countries. Internationally, radio service varied widely in terms of program content. In a technical sense, however, AM radio systems were remarkably similar across the world. This was certainly true from the listener's point of view, since a single type of radio receiver could be used almost anywhere in the world with good results. Not so for television. Basic technical specifications for television varied considerably from system to system and did not eventually merge into a single global standard.[31]

The public debate over television standards focused on one important aspect of transmission, namely the number of lines of

Most early postwar television receivers were, like their pre-war predecessors, bulky devices with rather small picture tubes. Within a few years, however, manufacturers had reduced the size and cost of receivers and increased the maximum picture size to 21 inches or more. Photo courtesy of General Electric

horizontal resolution drawn on the television screen, though there were many other issues at stake. The technical situation at war's end was confused even within countries, and pre-war television systems were nearly all incompatible. The British operated with a 405-line standard, the French had 455 lines, the Germans 441, the Danish 567, and the United States 525.

When television broadcasts resumed after the war, only the U.S. standard remained unchallenged, and several countries adopted it (or the 625-line version adapted for areas with 50 Hz electric power). The British kept their pre-war standard for 405-line black and white for many years but would add 625-line black and white broadcasting in 1964. The French, who

Why Is There No Channel One in the United States?

Frequency allocations for television broadcasts have been changed several times since 1927, when the first experimental broadcasts were made. In 1928, the Federal Radio Commission established enough spectrum space to allow five channels of television, each 100 kHz wide, between 2 and 3 MHz. The allocations changed again in 1929 and 1937. Following the end of World War II, when networks were eager to make television broadcasting a regular service, the FCC once again redivided the spectrum, this time providing 13 television channels between 44 and 216 MHz, with a large section in the middle of this range devoted to FM radio, facsimile, and other services. The low end of the spectrum was occupied by commercial FM broadcasting services that would be reassigned to different channels, and the entire original FM allocation was eventually to be assigned to TV Channel One. Existing FM stations were given a deadline of January 1, 1948 to cease broadcasting in the old band. However, in 1948 the FCC decided to delete Channel One entirely and reassign it to other services, which was accomplished by 1952. By this time, television sales were taking off, so manufacturers were not asked to redesign their sets. Channel Two remained the lowest channel number.

had been compelled to use the German standard during the wartime occupation, now seemed more interested in devising their own high-definition black and white standard than in adopting any existing technology. In November 1948, Francois Mitterand, then Minister of Information, announced with great fanfare a new 819-line black and white system. Ironically, the French until 1956 also broadcast the pre-war German 441-line television, but only in Paris. By contrast, the Soviet Union and several other countries including Denmark, Germany, Switzerland, and Italy adopted the 625-line black and white system promoted heavily by the Philips company and RCA (and later the compatible 625-line color system). The eastern European nations with the exception of East Germany and Yugoslavia used still another black and white standard called System D.[32]

Though the ensuing standards negotiations may strike the reader as arcane, at the time they involved heady issues of national sovereignty. The understated BBC historian, Asa Briggs, commented there was "an element of drama in the European line struggle." Disagreement over these technical standards engaged world leaders as no technical standard had done before, reaching even Pope Pius XII, who let it be known that he was leaning toward the 819-line standard for proposed Vatican broadcasts.

First Regular Television Broadcasts in Selected Countries

Black and White Broadcasts

Germany	1935	Philippines	1953	Iran	1958
Great Britain	1936	Italy	1954	India	1959
Soviet Union	1938	Denmark	1954	Kuwait	1959
United States	1939	Thailand	1955	Lebanon	1959
Mexico	1950	East Germany	1955	Syria	1960
Holland	1951	Iraq	1956	UAR	1960
West Germany	1952	Australia	1956	Indonesia	1962
Canada	1952	South Korea	1956	Malaysia	1963
Japan	1953	Hong Kong	1957	Taiwan	1962
Belgium	1953	Saudi Arabia	1957	Pakistan	1964
Switzerland	1953	China	1958	Cambodia	1965

Color Broadcasts

Netherlands	1952	India	1959	Soviet Union	1967
United States	1953/4	Japan	1960	Western Europe	1967
Poland	1953	Ireland	1961		
Australia	1956	Canada	1965		

Standards issues were not simply technical questions, nor were their outcomes of interest only to the corporations making television equipment. Instead they reflected the political imperative to resist all sorts of foreign, particularly American, incursions into weakened postwar economies. It was evident to all involved that the American firm RCA, through its ally the Philips corporation, was busy at work attempting to promote an American-designed 625-line system in Europe. The television standards debate in France was particularly heated, reflecting the swell of French nationalism in the postwar period, and this partly explained why the French developed their own system rather than adopting one of the other standards.

Following the 1947 meeting of the International Telecommunications Union in Atlantic City, New Jersey, the ITU established a Radio Consultative Committee (CCIR) in 1948 with one of its aims being the standardizing of the standards, but it was only successful in codifying the existence of multiple standards and not reducing their number. The situation had not improved much by the late 1950s and early 1960s when European nations began to consider color television. After considerable debate, the countries of Europe chose between four different and mutually incompatible color standards, including the two that dominate today, which are known by the acronyms SECAM (Sequentiel Couleur Avec Memoire) and PAL (Phase Alternation Line). Eastern Europe including the Soviet Union (but not Yugoslavia or Romania), adopted the French SECAM system of color transmission after it was introduced in 1958. SECAM, first proposed by Henri de France of the Compagnie de Television, differed from others in that it transmitted its hue and saturation information sequentially rather than simultaneously. This necessitated an analog memory device in the receiver to store one line of information and store it until the rest of the information arrived to display the line in color on the screen.

The rest of Europe including Great Britain adopted the PAL system developed under the leadership of Walter Bruch of Telefunken in West Germany. Based on the NTSC system, PAL alternates the phase of the color signal from line to line to avoid certain types of distortion. Like SECAM, this system also required a one-line memory or delay unit installed in the receiver and line-identifying switching circuits. Meanwhile, partly through the efforts of the International Telecommunications Union, various black and white standards faded away until only four were left, and in 1985 the CCIR declared obsolete its standards for systems employing any other than 525 or 625 lines. This last item represented a hollow victory for the American companies that originally sponsored these standards, since by 1985 no American company made black and white television receivers or studio equipment.[33]

The existence of multiple standards had a bright side, which was that incompatibility helped to establish a minor industry in the manufac-

ture of translating devices, so that programs could be exchanged internationally.[34] This type of exchange within Europe had been a serious problem until the CCIR helped establish a "Eurovision" network based on land transmission and converter stations, which simplified access to foreign broadcasts.[35]

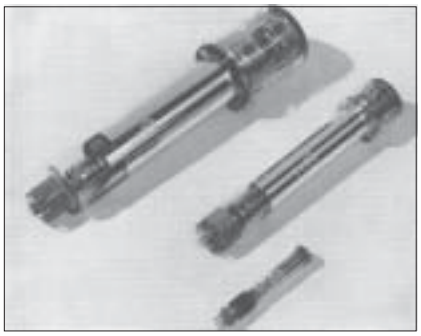
Television Standards in the U.S.: The Dispute over UHF

Television broadcasting and transmission standards in the United States were worked out before World War II by the NTSC, so that when postwar broadcasting resumed the situation had already stabilized to a certain degree. However, one standards-related issue decided after the war significantly affected the structure of American broadcasting for many years. This was the FCC's decision to continue to use frequencies in the VHF range for television in the postwar years, even though equipment to use the much wider UHF band was by then practical. It was not until 1953 that the UHF band was opened for regular broadcasting, but even after UHF stations were in operation, set manufacturers were not required to include a UHF tuner as part of television sets. UHF station owners complained loudly that their band had been given "second class" status in favor of the established VHF channels, and noted that many VHF stations were the ones affiliated with the major networks. It not until 1964 that set makers were required to include UHF tuners as part of new television receivers, but the new regulation still did not satisfy UHF interests. Station owners still complained that the odds of their success were threatened by FCC rules that allowed less-costly "variable" tuners (i.e. in the style of radio tuners rather than the more convenient pre-set tuners used for channels 2-13. The issue was never fully resolved, but became more or less irrelevant in the 1980s with the decline in the availability of mechanical tuners of any sort in favor of electronically tuned receivers and infrared remote controls.[36]

Changes in Broadcasting Technologies: The Legacy of World War II

Many circuits and devices developed for television in the 1930s found application in early radar systems, as when British radar researcher Eddie Bowen combined a CRT and a television receiver into a lightweight, experimental airborne radar system in 1937. A few years later, after World War II, the trend would be reversed as electronics manufacturers applied technology used for military applications to civilian television equipment.[37]

Philco, a major beneficiary of U.S. War Department contracts during World War II, used its new technological base to manufacture both consumer television receivers and equipment for microwave-based television transmission networks. The company demonstrated the system in April of 1945 by beaming program material from the Statler Hotel in



The Image Orthicon, a television camera tube, was widely used after World War II. Photo courtesy of General Electric

Washington, D.C. to a station in Philadelphia using a series of relay towers. Other radar manufacturers were working along the same lines. AT&T, RCA, Raytheon, and a joint venture between GE and IBM all announced similar microwave distribution networks shortly thereafter. In the end, AT&T's system would prevail.[38]

One of the key innovations in postwar television production was the Image Orthicon tube used in television cameras to substitute for an older pickup tube called the Iconoscope. Originating from a tube developed by Albert Rose and Harley Iams of RCA in 1939, the Orthicon was first used in experimental guided bombs code-named the Block Equipment. Like the Iconoscope, the Orthicon contained a photoemissive plate sensitive to light that retained a sort of electrostatic impression of a visible scene. Electrons from a beam scanning the plate would be absorbed or reflected according to the state of charge at a particular spot on the plate. Thus the reflected beam, which was detected as the signal, would be a "negative," version of the original image. Then it was relatively simple to create the "positive" signal electronically. After the war, Rose, Paul Weimer, and Harold Law developed a version that would be widely used for broadcasting, known as the Image Orthicon.[39]

Because the Image Orthicon was so much more sensitive than the Iconoscope, it was immediately picked up by postwar broadcasters for use in cameras. Its major flaw was the high inherent level of video "noise" that it generated. The Iconoscope, because of its high image quality, continued to be widely used for the conversion of films to broadcast. The Image Orthicon remained the standard for almost 20 years, and its nickname, the "immy," is the root of the "Emmy Award."[40] Marconi Communications Systems, an English company, was prominent in the field of television cameras from the 1950s on, using the Image Orthicon tube in cameras of its own design. While RCA was the major supplier in the U.S., Marconi soon came to dominate the European market.[41]

Transmitters and Transmission

The creation of new television networks worldwide created a market for new types of transmitting tubes, transmitter assemblies, and antennas. The Klystron tube, another product of wartime radar research, figured prominently in many postwar transmitter designs. Because of the

high power requirements of broadcast transmitters (both radio and television), solid state components were slow to find their way into the market, and many stations today rely on vacuum tubes for the final amplification of their signals.

Just as in the early days of radio, television production was predominantly live. Much effort went into the development of transmission technology to allow the distribution of television programs instantaneously from a central point. For example, most television programming in the United States originated in New York, Chicago, or Los Angeles, yet there was initially no link between east and west. AT&T, however, quickly established television links using coaxial cable and the new technology of microwave transmission. Coaxial cable had already been in use for some years to provide multiplexed voice circuits for telephony and wideband program circuits for radio networks. The first inter-city "L1" coaxial cable link was installed between New York and Washington, D.C., using 3/8 inch diameter cable and special electronic repeaters. The bandwidth was only 2.7 MHz, so that only black and white images could be transmitted this way. New technologies to transmit color TV remained several years away. Microwave transmission, an outgrowth of radar work during World War II, was possible as early as 1951, with the first microwave relay link between Omaha, Nebraska, and San Francisco, California.[42]

National Differences in Television Broadcasting Techniques

Aside from the many well-known differences between American and European programming, there were significant technical differences as well. For example, in the Soviet Union, videotape recorders were less commonly used than elsewhere, while live broadcasting persisted longer than in the U.S. or Europe. The U.S., for many years the leading supplier of videotape equipment, put restrictions on the overseas sale of VTRs in the 1950s, and persuaded Japan to do the same, leading to a shortage in the U.S.S.R. The rationale for this was that videotape technology could be turned to military purposes. The Soviets designed and built much of their own television production equipment, however, and built an experimental video tape recorder in 1961, years after the first commercial VTRs were available in the U.S.[43]

European transmitter tower design also took a distinctive path in the postwar era. Whereas most U.S. towers were rather utilitarian, slender, triangulated-frame designs held up with guy wires, European towers were often self-supporting structures intended to be public attractions. A 1,750-foot television tower at the major Soviet TV production facility in Ostankino was claimed to be the tallest self-supporting structure in the world. Many European cities built centralized, multi-purpose telecommunications towers which loomed over the other architecture and which often housed public observation platforms and restaurants.[44]

Before the advent of videotape recording, most television originated from motion picture film. The television film "chain" shown here included a 16-mm projector and a Vidicon television camera. Photo courtesy of General Electric

Video Recording in the Television Studio

While certain widely appealing live shows thrived, justifying the cost of network transmission, television industry managers sought ways to reduce costs and increase efficiency (particularly by making it cheaper to repeat performances) through the use of recordings. The established technology of image storage, motion picture film, was initially the only technology available for television transmission. Films not only allowed networks to repeat performances at a lower cost, but allowed independent producers to syndicate programs and distribute them by courier or mail. Film was so important in television production that by 1960 over 80 percent of network programs originated from it. But film was unsuitable for certain types of programs, such as news, since it required time-consuming processing before it could be televised. Film stock was also expensive, and the amount of it needed to keep a television network or station running was almost prohibitive. Thus as recorded programming became an established part of television, the industry began to look for ways to lower its cost.[45]

Storage of television images through the mid-1950s was accomplished using 16-millimeter film and special film-to-television converters. The standards adopted for television in various nations in large part determined the type of converter used. In the U.S., television was broadcast at the rate of 30 frames per second, corresponding to one-half of the frequency of the electric power to which television equipment is synchronized. However, the worldwide standard for 16-millimeter film equipment was 24 frames per second. In Europe, where power frequency is 50 Hz and television operates at 25 frames per second, it was easy enough to speed up the film a little to achieve synchronization. This allowed them to use Flying Spot film scanners to convert film to television at a one-to-one frame rate. In the U.S., film scanners had to achieve a "3:2 pull down," a technique to convert six film frames to five television frames each sixth of a second. The equipment used in this conversion projected the film onto a television image tube rather than scanning the film directly as in the European case. An analogy would be that of an individual going to a movie theater with a camera in hand to obtain a copy of a film on the screen; the final image was somewhat degraded. More serious were the problems encountered in recording television images for later transmis-

sion (as opposed to broadcasting directly from a film source such as a Hollywood movie). Here, the Kinescope method was used, which was simply the recording on film of the image from a television screen. Sound was provided by a magnetic tape recorder synchronized (either mechanically or electronically) to the film. On top of all its technical problems, the Kinescope method was expensive.[46]

Ampex employees demonstrate their new Videotape recorder about 1965. "Videotape," once an Ampex trademark, soon fell into common usage to describe all magnetic video tape recorders. Photo courtesy of Ampex Corporation

Today, the most common way that broadcasters record video signals is by videotape recording. Research in video recording began in the late 1920s, and certain kinds of video information, such as radar "scope" signals, were recorded on magnetic tape during World War II, but the wide bandwidth required to record television proved to be a daunting obstacle. Several organizations independently began work on video tape recorders in the early 1950s: RCA, GE, Marconi in Britain, the Armour Research Foundation, and Bing Crosby's firm Bing Crosby Enterprises.[47]

RCA entered the magnetic recording field shortly after World War II, designing a line of wire and tape recorders for audio. By 1951, however, RCA turned to research on video recording, putting Harry Olson in charge of its team of engineers. At about the same time, at Bing Crosby Enterprises, audio engineer Jack Mullin also began working on a videotape recorder. The Armour Research Foundation's Marvin Camras also designed an experimental video recorder with a special rotating head design. While his recorder was not a success, the rotating head would be picked up by Ampex.

The first demonstrations of video recording equipment were disappointing to say the least. Late in 1951, Jack Mullin of Bing Crosby Enterprises demonstrated a crude video recorder to the press; in late 1953, RCA did the same. Elsewhere, Dumont, General Electric, the BBC, and magnetic recording pioneer Edward Shuller in Germany all worked on the problems associated with recording standard television signals on a magnetic tape. However, it was an upstart firm, Ampex Corporation of California, that succeeded in producing the first recorder with features acceptable to broadcasters. Ampex was a prototype of the "Silicon Valley" high technology firm, capitalizing on the resources provided by local

colleges and the nearby motion picture industry. The Ampex Videotape recorder[48], demonstrated with great fanfare in 1956, recorded black and white signals onto two-inch-wide tape using the novel principle of helical scanning. In this method, four recording heads mounted 90 degrees apart in a rotating drum laid down the recorded track as a series of diagonal stripes across the width of the tape. This technique solved a vexing technical problem; engineers in the late 1940s believed that the bandwidth requirements of television would require impractical tape speeds of 4000 inches per second (versus audio tape's fifteen inches per second). Different inventors found ways to reduce the tape speed and RCA demonstrated a machine operating at only 120 inches per second, but tape consumption remained a critical problem. Not only was the wide, high-quality tape required for video expensive, but the mechanical devices needed to control a huge reel of tape were heavy, bulky, and unreliable. By reducing the speed to only thirty inches per second, the Ampex VTR made videotape recording much less expensive than film recording. Combined with the fact that the Videotape machine made instant records requiring no processing, and that tapes could be re-used if needed, magnetic recording was instantly attractive to a growing industry that consumed more feet of motion picture film per year than Hollywood studios. Ampex took orders for $5 million worth of these $50,000 machines at their first public demonstration, and grabbed a virtual monopoly of the market that lasted for several years.[49]

The Ampex tape recording system divided the incoming signal information into discrete intervals, each of which was short enough to be recorded across the width of a tape, perpendicular to its length. Such a system gave high-quality results, but the machines of the 1950s and 1960s were bulky and needed careful maintenance. Greater portability and ease of use came with the second generation of recorders, which used a "helical scan" process. Though the image quality of early helical scan recorders was not as good, gradually, helical scan VTRs were improved to the point where the image quality satisfied television broadcasters, and they became especially important in electronic news gathering.[50]

The Battle for Color TV in the U.S.

A new standards war, limited to the United States, developed as manufacturers forged ahead with plans for color television. Unlike the rhetoric surrounding the European battle, which concerned issues of national sovereignty, in this case the issue was that of modernity—specifically, RCA tried to convince the public that electronics was the essence of postwar modernity, as compared to mechanical technology, which was said to be a relic of the past. RCA and its competitor, CBS, were both major corporations with deeply entrenched commitments to their own particular technical standards. CBS in the past had been only a broadcasting company, but was moving into the realm of electronics

research and had entered the manufacturing field through the acquisition of the Hytron Radio and Electronics Corporation of New York.[51] RCA was the largest manufacturer of home television receivers, and also made a full line of television transmitters and studio production equipment.

The FCC in 1945 had deferred a decision about color standards, then chose the CBS standard in 1950 on the basis of successful demonstrations. The CBS system, developed by Austrian immigrant Peter Goldmark, used a rotating "color wheel" filter to generate separate red, green, and blue images, which were transmitted in sequence and recombined by the receiver, again using a mechanical color wheel, to form a full-color image. The only mechanical element of the system was the rotating wheel, and the rest employed ordinary electronic television technology, but RCA leaders attacked these mechanical features, proclaiming that they were a throwback rather than a leap forward.

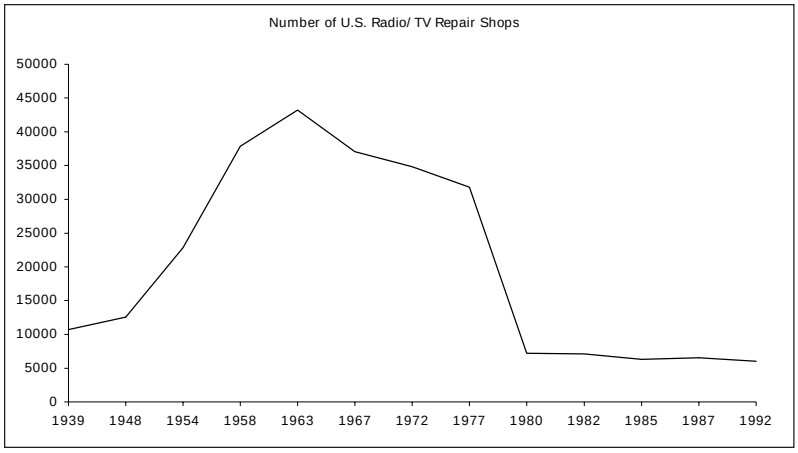
A ban on color TV receiver production during the Korean war gave RCA the time it needed to perfect its own system of all-electronic color television. In this system, the color information or "chrominance" signal was transmitted separately from the "luminance," or total brightness signal. An ordinary black and white receiver had only to receive and display the latter, thus making the RCA color transmissions compatible with existing black and white televisions. After an intense publicity campaign and much behind-the-scenes maneuvering, the FCC finally reversed its endorsement of the CBS system in 1953 and allowed RCA to move ahead with all-electronic color. But sales of color televisions did not approach those of black and white sets until the late 1960s, and it was not until 1972 that more than half of American households with televisions had a color set. By 1975, however, approximately 46-million households had a color receiver.[52]

New Receiver Technologies

The heart of the television receiver is its picture tube. Monochrome picture tubes were developed for use in oscilloscopes and were widely used as early as the 1930s. Postwar television production made numerous improvements to the picture tube, making it less prone to implosion, less expensive, larger, flatter, and more rectangular in shape (to fit the shape of the source material, which was often film). Tube sizes were generally seven inches or less in 1947, but by 1949 manufacturers such as Dumont began offering ten-inch or larger tubes.[53]

The color Kinescope was developed in a remarkably short time by engineers at the Radio Corporation of America. Color Kinescopes, then and now, use the shadow mask principle, in which the three streams of electrons (representing the red, green, and blue beams) are aimed at the phosphor-coated screen through a very fine mesh. The beams are aimed

Number of Television Repair Businesses in the U.S., 1939-1992



so that they strike the appropriate red-, green-, or blue-emissive phosphor dots, which are placed in groups of three; when viewed, these combine to form a picture element, or pixel. This principle was first proposed in 1938 by Werner Flechsig in a German patent, but was not applied commercially until RCA's first shadow mask tube in 1949. An important advance in color tubes was Sony's 1968 development of the Trinitron. This tube utilized a line-type mask and phosphor pattern and an improved, common focus electrode which allowed for a smaller beam spot size.[54]

While most television receivers still use cathode-ray screens, by the 1970s and 1980s vacuum tube-based cameras were beginning to be challenged by new solid state designs. The primary motivation in this was the desire to make electronic news gathering easier through the miniaturization of equipment. Again, RCA led the way, by developing a solid state CCD element to convert the visual image to an electrical signal, plus the increasing use of integrated circuits in place of vacuum tubes and transistors. However, RCA's success was only momentary, as competitors in Japan and Europe moved into the market. By the 1980s, solid state imaging devices found considerable commercial success in consumer "cam-corders" and surveillance cameras.[55]

Television Receiver Production

A television purchase was a big investment in the postwar years. Prices for receivers started at about $200 for the least expensive sets and were more like $400-500 for the larger, "living room" sets. In addition to the

purchase price, sets had to be installed at additional cost and an antenna set up, usually on the roof of one's home. Early televisions, like all vacuum tube electronics, also needed regular maintenance. With more than three times the number of tubes than a standard radio, the early sets represented a considerable maintenance expense. Television production methods and electronic components changed considerably beginning in the 1950s, however. Television makers made extensive use of printed circuit boards and automated assembly techniques, reducing the cost of TV sets by nearly 50 per cent by the early 1950s. Most manufacturers were slow to adopt the new transistor technology, however, and it was a Japanese company, Sony, that introduced the first transistorized television, the model TV8-301 in 1960.[56]

Broadcast receiver technology of the postwar period changed continually, as did the conditions under which it was made. In the United States, companies that made radio receivers saw their share of the market drop from about 99.9 percent in 1955 to about 16 percent in 1980. Exports of receivers actually rose, but almost all of these were specialized, high- priced units. The average value of imported receivers in the early 1980s was under $200, as compared to over $700 for U.S.-made exports. Certain other consumer electronics markets in the U.S. saw this takeover by imports, mostly Japanese firms, at an even earlier time. The date at which imports took 90 percent of the market for tape recorders was 1968; for radios, 1970. Half of all black and white television receivers, phonographs, and radio-phonograph combinations were imports by 1970. By the early 1970s, virtually the only remaining markets for U.S.-made consumer electronics products were automobile radios and color television sets. American manufacturers of color television sets managed to maintain about 80 percent of the market until the 1980s, though the number of firms dropped from eighteen in 1968 to six in 1980. It is also worth noting that the market for television receivers remained sizable during these years. Manufacturers sold more than $6.5 billion worth of color television sets in 1996, plus over $2 billion worth of black and white, projection, and combination TV/VCR units. [57]

A variety of television cameras employing the Image Orthicon tube, circa 1960. Photo courtesy of General Electric

Technological Alternatives to the Networks: Subscription and Cable Television

The idea of selling television service to consumers instead of financing it through advertising or government subsidies originated in the earliest days of broadcasting. Zenith Radio Corporation, an early television broadcaster, had introduced its Phonevision system in 1931, a technology using modified telephone lines to deliver electronically "scrambled" television signals to homes. A set-top box corrected the signal if an appropriate punched card were inserted into the box. After World War II ended, Zenith and RKO (a subsidiary of RCA) invested $10 million in a pay-TV system to serve the town of Hartford, Connecticut. The system provided ordinary broadcast channels by wire during the day, and special "pay per view" features in the evenings.[58] By the 1960s, a Canadian service was supplying pay television programming using equipment made by the International Telemeter Corporation.

Until 1977, the FCC tightly regulated cable television, resulting in slow growth. Much of its early growth was in the suburbs, areas not well served by broadcast stations but densely populated enough to justify the major expense of infrastructure building.[59] In 1952, the first year for which statistics are available, there were only 14,000 subscribers to cable systems in the U.S. The number had risen to over 26 million by 1983.[60]

Cable television broadcasters benefited enormously from the introduction of satellite transmission systems. Previously, these systems had exchanged programs with other broadcasters by exchanging video tapes or films via a "bicycle" network (so named because of a few instances of material actually traveling via bicycle). In 1975, Home Box Office became the first pay cable network to use direct transmission by satellite. A little later, WTBS, a small UHF station in Atlanta, Georgia, began distributing its regular programming (consisting of movies, re-runs of older television shows, and advertisements) to other cable systems via satellite. The station charged participating cable operators about five cents per subscriber per month to re-broadcast WTBS. Within two years of their inauguration, both Home Box Office and WTBS were financial successes and both drew a host of imitators.[61] Cable television has not been a worldwide success. Rather, it is a way that a few wealthy countries have provided premium television services in addition to standard broadcasts.[62]

Another Alternative: Direct Satellite Television

The preeminent use for artificial satellites has been for telecommunications, often civilian rather than military. The first Russian Sputniks, launched in 1957, were in fact telecommunications satellites. However, most satellites were used only for narrow-bandwidth voice transmissions through the 1960s, when integrated circuits and other innovations began to make satellite television less expensive.[63]

Postwar telecommunications in the Third World, particularly telephone service, was dominated by the role of satellites in the postwar period. The original purpose of satellites was to link continents, and organizations such as INTELSAT initially concentrated on this business. But soon, developing countries trying to "catch up" without the huge cost of coaxial or microwave distribution networks began to think of satellites in terms of domestic service. INTELSAT first experimented with this kind of service in 1972, when TV programs originating in Alaska were broad-

High Definition and Digital Television

Even in 1945, when television broadcasting had just begun, engineers argued the relative merits of improving the quality of TV images. The French, for example, chose a standard with 819 lines of horizontal resolution versus the U.S. standard of 525 lines. Several different proposals for high definition color television emerged between 1950 and the 1990s, but all were rejected on the grounds that they required too much bandwidth or would make receivers too expensive for consumers to afford.

Digital television experiments began in earnest in the early 1970s, when the BBC, Ampex Corporation, and others began to develop digital video tape recorders. Ampex was apparently the first to demonstrate a commercial system in 1979. By this time, however, video editing machines had already been partially converted to digital operation, and the basics of digital television imaging were in place. Although digital television promised interference-free reception, it required even more bandwidth than standard analog broadcasting.

The Japanese were innovators in HDTV, broadcasting it experimentally in 1981. However, the 30 megahertz bandwidth required for one channel of the Japanese HDTV system used all the available broadcast channels. Engineers developed a new data compression algorithm called MUSE (which stands for multiple sub-Nyquist encoding) in 1985, allowing digital signal compression, although transmission of the signal was still analog. In combination with Direct Satellite Broadcasting, HDTV became a popular service in Japan, even though an HDTV broadcast still required the equivalent bandwidth of two NTSC channels and was subject to interference and other distortion.

The possible export of Japanese HDTV to the United States became the focus of a hotly debated political issue in the U.S. in the late 1980s. The humiliating collapse of the U.S. consumer electronics industry in the 1960s and 1970s led Congress to sponsor a movement to create an American version of HDTV. By doing so, they believed that the U.S. could take the lead in establishing a new consumer television manufacturing industry. By 1987 the FCC had organized a committee to study HDTV standards, but the agency made little headway for several years. A particular concern was rapid change in digital electronics technology, which soon made all analog HDTV proposals seem obsolete. The FCC in 1990 made the decision to allow a new HDTV service that is not compatible with existing televisions, shattering a long tradition of insistence on "backward compatibility" for new services. At about the same time, most of the companies and research laboratories experimenting with HDTV were switching from analog to digital systems, in recognition of the rapid advances in digital signal processing and VLSI chips. Finally, in 1993, a consortium of U.S. manufacturers, laboratories, and others with a stake in HDTV (including AT&T, General Instruments, MIT, Philips, Sarnoff Laboratories, Thomson, and Zenith) formed a new "Grand Alliance." The first experimental HDTV broadcasts in the United States began in 1994, supplied by satellite to consumers who purchased special receiving antennas. By 1995, the FCC had approved a set of standards, and thus the technical component of commercial HDTV was in place. Broadcasters have been authorized to begin implementing HDTV over the next few years, but it remains to be seen whether this new service will succeed.

cast within that state via a satellite over the Pacific ocean. This service went commercial in 1975, with some nations using it mainly for telephone service and others setting up national TV networks almost instantly. The former USSR and Canada operate several of their own domestic satellites, or "domsats," providing telephone and television.[64]

Like many countries, Japan's mountainous terrain makes it difficult to reach all television viewers using conventional broadcasting methods. The Japanese were leaders in supplying consumers with cable television, but by the 1980s had shifted the focus to satellite transmission. Whereas American consumers in rural areas often purchased 1.5-meter satellite receiving dishes, these dishes were far too large for the cramped Japanese urban conditions. Japan's 1987 Direct Broadcast Satellite (DBS) was the first in the world, and attracted over one million customers within a year. The higher power DBS system allowed for much smaller 75-cm dishes, which made urban reception feasible.

Satellite TV and DBS in the U.S.

Cable television networks in the United States owed much of their success not to the land-based transmission technology of coaxial cable but to the national or international distribution of programs via geosynchronous satellites. The FCC in 1972 decreed that virtually any legitimate entity could own and operate a space satellite, creating an "open skies" policy in which AT&T was actually restrained from adding to its fleet of satellites for a period of years. Immediately RCA, Western Union, and several others took advantage of the opportunity. RCA, for example, had its first satellites in operation by 1975/76, finding customers in the Department of Defense and the Armed Forces Radio Service, the Alaskan telephone and television service, and two cable networks. Programs originating from a variety of sources were beamed to these satellites, shifted in frequency to avoid interference, then rebroadcast to earth, usually in a wide pattern. Despite the fact that the power of this "transponder" was only 5 or 10 watts compared to the hundreds of thousands of watts typical of many television stations, the placement of the satellite allowed the signal to reach a huge geographical area.

In North America and Japan, a portion of the spectrum in the K-band (12 and 14 GHz) was set aside for direct-to-home broadcasting. While the K-band did not interfere with terrestrial microwave telecommunications systems, as earlier satellite systems did, it was affected by atmospheric conditions such as rain. These K-band DBS systems used somewhat less bandwidth, more power, and required much smaller receiving antennas. They were intended to compete with cable systems or provide cable-like service in rural areas.

THE ECONOMIC AND SOCIAL ASPECTS OF TELEVISION

Hollywood and Television

One of the chief economic effects of television's success was to throw the motion picture industry into turmoil. The postwar period saw rapid changes in the technology of making motion pictures and the ways that people saw the movies. Television and rapid suburbanization contributed to declining attendance at urban movie palaces, as annual movie admissions in the U.S. dropped by a factor of six between 1948 and 1967. As these theaters began to close during the 1950s and 1960s they were replaced by drive-ins and less grandiose theaters in suburban shopping malls. Television viewing, which in the 1940s was expected to decline after the "novelty factor" wore off, continued to rise, from about six hours per day in the U.S. in the 1960s, to about seven hours in the 1970s, and finally to eight hours in the late 1980s.[65]

Motion picture exhibitors (i.e. theater owners), hoped to contain television in its early years by installing projection television equipment in theaters and arranging for special broadcasts. Excluded from direct ownership of television stations by postwar antitrust legislation, the motion picture industry turned to the promotion of television viewing in theaters. Of the many projection television systems demonstrated in the laboratory, only a few actually saw commercial use, including the RCA system for relatively small theaters. A competing system promoted by Paramount actually recorded television signals (received via a land line feed or over the air) onto a special 35-millimeter film, processing the film almost instantly and projecting it in the conventional way. While Paramount in particular hoped to revitalize interest in live theater through the use of live television, the motion picture producers found that only sports events could draw people into the movie houses to watch television. Television-equipped theaters were never common, numbering only 75 in the United States in 1950, and the cost of the necessary equipment was a daunting obstacle to their diffusion. By 1953, when motion picture producers began experimenting with three-dimensional movies and wide-screen formats, experiments with theater television declined, not to be seriously attempted again until the 1980s, when satellite television networks briefly revived the idea of showing live sports events in theaters.[66]

As theater attendance in the U.S. dropped by 50 percent between 1946 and 1952, Hollywood imposed austerity measures, including the reduction of stars on its payrolls and experimentation with new technologies. Some of this experimentation was intended to cut the cost of production, as in the use of magnetic sound recording for production purposes. Much of it, however, was intended to make films more appealing to the public.

Always striving for greater "realism" in film, Hollywood movies in color began to appear in greater number after the early 1950s, though the

color process had been available since the 1930s. Beginning in the early 1950s, Hollywood began to produce movies designed to use special types of projection. The first of these was the stereoscopic, or three-dimensional, film. By using two cameras, separated by the approximate distance between the eyes, projecting both of these images onto the theater screen, and then providing the viewer with special polarizing glasses, producers achieved a startling "3-D" effect. Two slightly different processes, both demonstrated as early as the 1920s, were used for color and black and white films. In the former, the projectors included special filters to polarize the light corresponding to each image in two different directions, the polarized lenses of the viewing glasses allowing the viewer's brain to separate the images. A 3-D movie fad ensued, but fizzled after the novelty wore off in the mid-1950s, only to be revived several times in later years, particularly for horror, science fiction, and pornographic genres. 3-D movies and television shows still occasionally appear, almost always using the color process. Film makers in the Soviet Union, France, Spain, and elsewhere used variations of the stereoscopic process to make films, devising about a dozen variations of the technology.[67]

Another exhibition technique of the era involved at least a half-dozen variations on the theme of wide-screen projection. The standard aspect ratio of theater screens since the 1920s had been approximately 1 to 1.5. Although wide-screen formats had appeared in the 1930s, another round of experimentation appeared after World War II. The most dramatic was inventor Hazard Reeves' Cinerama. Using three cameras, Cinerama covered approximately 146 degrees of panorama on a wide, curved screen. The system incorporated multichannel stereo, a higher-than-usual frame rate, and demanded special modifications to theaters. Cinerama was expensive both to shoot and to exhibit, and after a few notable films, such as *How the West Was Won* in 1962 and *The Wonderful World of the Brothers Grimm* in 1963, enthusiasm faded. Cinerama's sponsors and several others subsequently shot many films on the less expensive double-width 70-millimeter film, or used 35-millimeter film with special lenses to produce interesting but somewhat less spectacular wide-screen effects under the names CinemaScope, Superscope, Todd-AO, Super Panavision, and others.[68]

Motion picture production and exhibition since World War II has seen a great shift toward the use of electronics technologies. In exhibition, the use of control information on the film, sometimes in digital form, has been used in several different special sound systems, notably the Dolby Laboratories stereo system and Sensurround, another multichannel system. Motion picture producers have used digital electronics to enhance special effects on film. The popular appreciation of this technology came with the release of the Walt Disney film *Tron* in the early 1980s.

The Critique of the Mass Media

The rapid expansion of electronic communications after World War II prompted renewed efforts by scholars to assess their "impact" on society. Earlier in the century, scholars had seen mass media as either vehicles for social good or evil—or sometimes both.[69] Progressives sought media reform because they believed that the mass media had superseded personal communication in industrialized societies. Therefore, the media might rectify or aggravate social problems associated with industrialization, such as the loss of a sense of community, and the decline of political participation. Among this movement's early leaders was the pragmatist philosopher John Dewey, who in 1916 began publishing studies of the uses of media. He felt that internationalism and industrialism had replaced local autonomy and that communication was a potential tool for creating an environment in which local communities kept elites and scientists aware of their local problems. Democracy required this sort of "unshackled media" to keep citizens fully informed.[70]

Beginning in the 1930s, German immigrant Paul Lazarsfeld began the first of a highly influential series of studies on media effects that would influence the field for many decades. Lazarsfeld postulated that the media reaches "opinion leaders," who in turn pass on their opinions to the less interested.[71] A second line of inquiry that would become very important in the postwar period originated among a group of scholars who left Germany during the 1930s and who re-established themselves at the University of Chicago. This "Frankfurt School" rejected the quantitative methodologies of Lazarsfeld and attempted to explain the nature of mass media through an understanding of the commercial structure and ideological basis of the media "industries." Much of the work of the Frankfurt School became known only after 1945, and provided part of the intellectual basis for the countercultural movement of the 1950s and 1960s. One of the most famous of the Frankfurt School scholars, Herbert Marcuse, argued that industrialization and modern media encouraged a "one-dimensional" existence without real social discourse. The writings of Canadian scholars Harold Innes and Marshall McLuhan drew upon Frankfurt School ideas about the hierarchical structure of the media and its implications. McLuhan seemed less disturbed by this condition, and went so far as to say that the worldwide interconnection of communities through electrical communication would create a happy sort of "global village."[72]

Meanwhile, Lazarsfeld's concept of "limited effects" became nearly universally accepted by the 1960s.[73] Even media corporations themselves adopted this model. In 1960, J.T. Klapper, head of research for CBS, published *The Effects of Mass Communications*, which elaborated the "limited effects" theory. Television networks, under attack because of their heavy use of advertising, found comfort in the limited effects theory,

because it meant that they could not be directly blamed for society's evils. On the other hand, the notion that the messages in television advertising had only limited powers of persuasion obviously undermined the medium's commercial basis. Nonetheless, taking a middle ground seemed preferable to either extreme.

As television continued to make inroads into American life (Americans watched an average of 5.1 hours per day in 1960[74]), the limited effects consensus and the presumption that the media had mostly benign effects once again came under fire. By 1961, 89 percent of U.S. households had a television set (the figure was 97 percent by 1976). While the content of radio had been debated periodically since the 1920s, television seemed to elevate the public's concern over the supposed effects of certain types of programs on the public, and particularly on children.[75]

In 1952 and again in 1954, Senator Estes Kefauver organized hearings on the subject of juvenile delinquency, which paid careful attention to the content of television programs. At about the same time, a major project conducted in Great Britain by the Nuffield Foundation also studied the effects of television on children. The results, published in 1958, showed that children follow their parents' viewing habits and that more intelligent children watched less TV. Further, while researchers concluded that emotionally disturbed children may be driven to violence by viewing violence on TV, overall there was no discernible difference between viewers and non-viewers. This seemed to confirm the "limited effects" theory.[76] Other research seemed to indicate otherwise. The 1972 Surgeon General's Scientific Advisory Committee on Television and Social Behavior supported the idea that media violence increases likelihood of aggressive behavior.[77]

Research on sexual content in the media had similar results. In 1968, Lyndon Johnson appointed a Commission on Obscenity and Pornography, which published findings that did not show a strong correlation between obscenity and deviance. But the commission included Klapper of CBS, and some suggested that the media corporations were orchestrating the research.[78] This feeling seemed to be confirmed by Lazarsfeld who, late in his career, was said to have admitted that he felt a strong need to avoid losing the support of media companies, and that this may have affected his research.

The question of television's effects on viewers came to a head during the 1977 trial of fifteen-year-old Ronald Zamorra, accused of killing eighty-two year old Elinor Haggert. His defense was temporary insanity brought on by constant exposure to televised violence. Zamorra idolized the television detective Kojak, played by actor Telly Savales. That Zamorra was convicted seemed to indicate that the public (or at least the judge in the case) was not yet ready to accept the notion that television is a strong influence on behavior.[79]

Chapter 3

Hi-Fi and the Entertainment Electronics Revolution

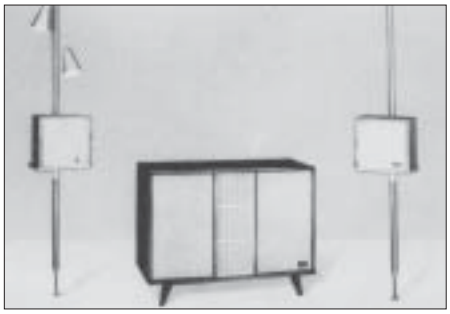
HIGH FIDELITY IN THE HOME

The preceding sections have focused on the changing role of technologies in the creation and distribution of electronic entertainment by broadcasters and record companies, but electronic entertainment would be useless without the consumer devices needed to experience it. In the years before World War II, the promoters of new forms of electrical or electronic entertainment technologies had successfully created inexpensive ways for ordinary people to experience motion pictures and radio. By 1945, radio listening and movie-going were at all-time highs, but promoters of new technologies were also trying to capture the public's attention. The adoption of new technologies has occurred unevenly in different parts of the world. In some places, radio listening in the evening is still the primary form of in-home electronic entertainment, while in many countries television has displaced radio for evening entertainment. In addition to basic radio and television, many varieties of electronic entertainment have appeared since 1945.

Setting the Stage for High Fidelity

One of the most important drivers of change in consumer electronics has been the fascination with the aesthetic quality of sound recording and reproduction. Although the phonograph industry had nearly disappeared during the Great Depression, the fashion for high fidelity that appeared after World War II revived record sales and paved the way for the introduction of many new technologies. FM stations broadcasting classical music began operations in larger cities by the early 1950s, and with the introduction of television came another source of high- quality sound, for the audio portion of TV is transmitted in wide-bandwidth FM.[80]

Although record companies had been experimenting with new high-fidelity phonograph records for many years, the real problem was the design of affordable equipment on which to play them. In 1938, Ted Hunt, a physicist at Harvard with an interest in sound recording, and a graduate student named Jack Pierce published an influential article in *Electronics* which suggested that a much lighter cartridge with a harder, jewel stylus for use with standard 78-rpm disks would result in much better sound quality. Where before phonograph manufacturers had aimed simply to keep the high-mass, rapidly moving phonograph stylus from jumping out of the groove, these two authors proposed a cartridge with a very low mass stylus and cantilever that could accurately trace the groove walls without heavy stylus pressure. This they combined with a jewel stylus that was carefully ground to shape at the factory to replace the steel styli commonly in use which were ground to shape by interaction with the groove (and which phono manufacturers recommended replacing after every play).



Home audio styling took on a distinctively modern, European look by the late 1950s, replacing the "streamlined" look that had been in fashion since the 1930s. Shown is a Zenith model D/FC stereo combination with remote loudspeakers. Photo courtesy of the IEEE History Center

Manufacturers incorporated Hunt and Pierce's ideas into the piezoelectric phonograph cartridges of the later 1930s and early 1940s. Piezoelectric cartridges exploited the ability of a Rochelle salt crystal to generate a small voltage if twisted or otherwise subjected to pressure, and while they were inefficient they sounded good. Their real popularity came later, when a more effective way of coupling the stylus to the crystal appeared, allowing phonograph designers to reduce the stylus pressure to less than 6 grams. This was a fraction of ordinary stylus pressures, gave entirely satisfactory performance, and greatly extended the life of records. World War II-era research on such seemingly unrelated technologies as underwater acoustics contributed to the further development of piezoelectric technology, especially by the Brush Development Company, a small Cleveland firm. While Brush made cartridges on some scale, it had greater success licensing the technologies to others, such as the famous Shure Brothers and Astatic companies.

Along with these new reproducers came improvements in home phonograph disks. Several manufacturers were considering low-noise plastic compounds and finer grooves, but the exact form of the new disks was an open issue. In the pre-war period, the market for phonograph

records was dominated by sales of singles. Not surprisingly, the first new product to appear, the 45-rpm record offered by RCA in 1948, was a seven-inch disk capable of holding only a few minutes of recorded sound per side. RCA's 45-rpm record was the product of a research project to produce a cheaper version of the 78-rpm disk that offered better sound quality.

By contrast, the 12-inch, long-playing record that CBS introduced in the spring of 1948 was not well-suited for singles. It was similar in format to the 16-inch diameter "transcription" records used since the 1930s in radio stations to record and broadcast programs of up to twenty minutes per side.[81] One of its leading spokesmen, engineer Peter Goldmark, believed that the new format would be best suited to the presentation of the long passages common in classical music. The press pitted these two products in a somewhat fictitious "battle of the speeds," but in fact they were not competing for the same markets. Further, because the two firms had been working along similar lines, specifications for the disks and playback equipment were virtually identical except for the diameters of the disks themselves, the size of the hole in the center, and the speed. After a brief period of promoting a special player that could only be used with the 45-rpm disk, RCA retreated somewhat and designed inexpensive, multi-speed record players and center-hole adapters so that both types of disks could be played on the same equipment. Other record manufacturers routinely manufactured players capable of three speeds (78-, 45-, and 33 1/3-rpm) after about 1950.[82]

Though both formats persisted until the 1980s, the LP appealed more to those involved in the growing high-fidelity fad, and its sales exceeded expectations. By early 1950, RCA was offering a large catalog of LPs, as were most other record companies. Still, overall record sales flattened in the 1950s. 1946 sales amounting to $198 million were about three times 1940 sales, but then leveled off. It was not until the advent of rock and roll that record sales again took off, rising to $400 million by 1957 and about $800 million by 1966. Phonograph players sold at a rate of less than two million per year until the mid-1950s, then grew to four million per year by 1960.[83]

The LP format, which was originally just a convenient way to present collections of hits, motion picture soundtracks, or lengthy classical selections, was embraced by popular bands. Soon entertainers were self-consciously releasing albums intended to be a collection with a particular theme. From these albums, the most popular songs would be released as singles on 45-rpm disks, so the two format complemented each other rather than competing. The real loser was the 78-rpm disk, which survived only until the mid-1960s. However, the LP's adoption took many years longer than the 45-rpm disk, and for some years the greatest competition was between the 45 and the 78. In 1956, almost 20 million

more 78-rpm disks were sold than LP records. Sales of LPs grew steadily, however, and exceeded those of 45-rpm disks for the first time in 1959, despite the fact that they cost more than three times as much. By 1961, LP sales represented over 51 percent of the number of records sold in the U.S., but 81 percent of the dollar value of those sales.[84]

The Introduction of Stereo Recordings

The first commercial stereophonic or "binaural" recordings appeared around 1953 on the new medium of magnetic tape. Tape recorder manufacturers and smaller "good music" record labels offered these to an eager (but small) hi-fi enthusiast market, hoping to find a niche for pre-recorded tapes. Many of the early binaural recordings were essentially novelty items, including such things as recordings of passing trains or ping-pong games. But other recordings explored the possibilities of two-channel sound for orchestral music.

The record companies that offered tapes in the early 1950s failed to settle on a standard stereophonic format, creating havoc for consumers and record dealers alike. In contrast to the accommodating attitude that equipment makers adopted to allow both 45-rpm and LP records, they did not find a simple way to modify tape players to allow the use of all the different formats. For several years, the existence of tape recorders with different playback standards made it necessary for record companies to offer selections in full-track monophonic, half-track mono and two-track stereo. RCA's introduction in 1958 of yet another format, the four-track stereo tape, initially seemed too much to bear, but soon this became the industry standard. Several companies announced that they would continue to offer two-track stereo tapes, but they did not do so for long.[85]

The transition to stereo disks went somewhat more smoothly. Among the early experimenters in two-channel stereo recording were researchers at Bell Telephone Laboratories in 1931 and 1932. Consumer phonograph equipment to reproduce stereo recordings was not really practical until after the introduction of the LP and 45-rpm disks in the late 1940s. By 1957, both Westrex (a subsidiary of Western Electric) and the Decca Record Company in London were ready to produce stereo disks. The standards for the two designs were differed somewhat, but when the standards committees of the Recording Industry Association of America voted in favor of the Westrex standard, Decca capitulated. RCA introduced its first stereophonic records in 1958, along with a new phonograph on which to play them. Although CBS records in 1958 developed a compatible monophonic disk, no record companies adopted it. Instead, some releases appeared in mono, others in stereo, and still more in both formats—creating an

inventory control disaster for record dealers. Nor did monophonic records did not fade away quickly. Only after 1967, when the record companies abruptly raised the price of monophonic disks to the level of stereo records, did consumers begin to turn away from mono.[86]

Home-Built Equipment

A significant number of early high-fidelity enthusiasts built their own electronic equipment to save money or to get something not available in the marketplace. Often they did so simply for the fun of building the equipment. Electrical engineers and radio technicians pioneered this hobby, and many of the subsequent generations of EEs got their start as teens building these projects. Engineering journals and hobbyist magazines of the day were filled with construction project ideas, and many manufacturers offered kits, particularly for radio receivers, loudspeakers, and amplifiers. Spending long evenings in the workshop alone with the smell of solder steam and sting of burnt fingers became a pastime for many adventurous souls. For the truly shriven, there was the awesome challenge of assembling a television kit, which contained hundreds of opportunities to make fire-starting, project-ruining mistakes. Chain stores such as Radio Shack (later purchased by Tandy Corporation, which operated a chain of leather-making hobby stores), Olson Electronics, Lafayette, and others sprang up to provide such kits, component parts, and construction plans. The Heath company was perhaps the best known kit marketer in the U.S., selling hi-fi gear, test equipment, televisions, electronic musical instruments, and other items in kit form. Many hobbyists found that their lovingly soldered Heathkits did not work when the moment of truth finally came, and turned to Heathkit for help. The company made a considerable percentage of its money finishing half-built kits and rewiring projects gone bad.

Many people built their own audio equipment to save money or simply for the fun of it. In the 1960s, Heathkit emphasized kit-building as a family activity, although men dominated the hobby. Detail from a Heathkit catalog, 1963. Photo courtesy of the IEEE History Center

One of the most popular pieces of home built equipment was the audio power amplifier, and by far the most influential design was that of British engineer D. T. N. Williamson. After publishing specifications for his amplifier in the journal *Wireless World*, many hobbyists built their own versions of his 15-20 watt unit with its "push-pull" output stage and plenty of negative feedback. Later, dozens of commercially produced amplifier

kits adopted the Williamson design. Even in 1954, one hobbyist newsletter in New York claimed that "we do not know of a single high-fidelity enthusiast who has not heard the name [Williamson]."[87] The Williamson amplifier, originally a vacuum-tube design, passed through the transition to transistors unscathed and continues to be popular today. The value of electronic kits (including not only hi-fi equipment but also games, ham radio equipment, and test instruments) sold in the U.S. rose from about $19 million in 1965 to $28 million by 1967 (or some 350,000 units), but sales were in decline by the 1970s.[88]

Tubes Versus Transistors

In computers and nearly every other form of electronic equipment, transistors rapidly replaced vacuum tubes in the late 1950s and early 1960s. The transistor's high reliability and steadily falling costs endeared them to manufacturers and consumers alike. By the early 1960s, engineers had developed transistors capable of handling several watts of power, and companies such as Transitronics offered the first transistorized hi-fi amplifiers. Power limitations still made vacuum tubes a better choice, and as late as 1965, most audio amplifiers still used vacuum tubes. Only in the early 1970s did transistorized amplifiers take most of the audio market.

One of the most important effects of the transistorization of home audio equipment in the 1960s was to help create a new market for all-in-one or "packaged" systems, which were a successor to the older radio-phonograph combinations. In 1962, the American company KLH offered a completely transistorized phonograph system in a portable case called the Model 11. Where many radio-phonograph combinations of the vacuum-tube era were intended to satisfy wealthier customers, the new generation of transistorized all-in-one products greatly expanded the market for less expensive systems.

In general, economy and reliability are not as important in some audio products as they are in other types of electronics. High-fidelity enthusiasts have remained influential enough to determine the success or failure of many new designs. Operating through a network of informal clubs and publications, including the seminal *The Phonograph*, published in England, *High Fidelity*, and *Stereo Review*, the elite of the recorded sound hobby have exercised considerable influence through the critical evaluation of

The application of transistor did not always radically transform consumer electronics products. Some items, such as this Westinghouse portable phonograph, remained outwardly unchanged. Photo courtesy of IEEE History Center

recordings and equipment. This was one reason the transition from vacuum-tube electronics to semiconductors has not been as straightforward as it was in the field of computers, military electronics, or television. Even when high-power bipolar transistors for audio amplifier applications became available in the later 1960s, audiophiles still frequently derided the "transistor sound" as inferior. These purists kept alive a small market for vacuum-tube amplifiers during the 1970s.[89]

Interestingly, audiophiles did not reject solid-state electronics in every application. Many have accepted transistors for low-power applications such as tape recorders and radio tuners (a tuner is a radio without an amplifier or loudspeaker) began to appear shortly after the their more famous counterpart, the miniaturized transistor radio. The 1957 Radio Shack catalog, for example, listed a Fisher Radio Corporation transistorized preamplifier module for microphones or magnetic phonograph cartridges. Soon, the low-power electronic circuits in tape recorders, preamplifiers, and other audio equipment were converted to transistors, which even audiophiles seemed to appreciate. Later, in the 1970s, transistorization was taken a step further through the use of integrated circuits. These tiny packages of transistors, capacitors, and resistors replaced hand wiring (making electronics components less expensive) and reduced the size and power consumption of circuits. While integrated circuits are often associated with digital computers and microprocessors, much innovative work in the audio field revolved around the use of analog ICs. The Fairchild Semiconductor MVA709 and other integrated circuit operational amplifiers, although originally designed for analog computers, became a building-block for low-power applications. One of the first such applications was a tone-control circuit used in 1969 by the Scott company.[90]

However, even though transistor and integrated-circuit designs improved rapidly, a significant faction of enthusiasts remained loyal to vacuum tubes. Today, the number of vacuum-tube amplifiers, pre-amplifiers, and other devices on the market is higher than at any time since the late 1950s, though prices start around $1000 and most manufacturing companies are very small. One indicator of the continued interest in vacuum-tube equipment is tube sales. In 1996, for example, Americans purchased over $3.6 million worth of vacuum tubes.[91]

HOME RECORDING, THE WALKMAN, AND THE DIGITAL REVOLUTION

Home Magnetic Tape Recording

Many of the first consumer magnetic recorders recorded on steel wire rather than tape. This technology was developed by the Armour Research Foundation of Chicago and manufactured by a diverse range of

radio-phonograph manufacturers in the U.S. and Europe. After a brief spurt of sales in 1946-47, these machines disappeared from the scene by the early 1950s.

Although magnetic recording was invented in the late 19th century, few people heard of it before the introduction of home tape recorders in the late 1940s. The Crestwood recorder shown here was one of over twenty brands of home recorders manufactured in the United States in the 1950s. Photo courtesy of Rutgers University Archives

Although many of the earliest tape recorders were large "studio" machines, inexpensive magnetic tape recorders were available almost immediately after the end of the war from the Brush Development Company and its licensee, the Amplifier Corporation of America. Soon, a host of firms entered the magnetic recording field, including Webster-Chicago, Wilcox-Gay, Revere Camera Corporation, and Pentron in the U.S., EMI and Ferrograph in England, and Telefunken in Germany. Despite the success of tape recorder promoters to make the public aware of this technology, sales remained disappointingly low through the mid-1960s. Early tape recorders were not universally accepted by either the hi-fi enthusiasts or the general public, partly because so few recorded

Quadraphonic Sound

Inventors experimented with multi-channel audio systems as early as 1881, when Alexander Bell demonstrated a stereophonic telephone concert in Paris. Early proposals for stereo tape systems in the late 1940s often included several three-channel types, but two-channel stereo was more easily implemented on long-playing disks and 45-rpm records, so manufacturers of tape recorders in the late 1950s also stuck with two-channel stereo. But multi-channel experiments continued with the aim of enhancing the "realism" of recorded music.

An abortive quad system appeared in the 1950s for use in conjunction with FM broadcasting, but the FCC declined to approve it for commercial use. Quadraphonic home systems began to look more economically feasible after transistors and integrated circuits began to be more widely used in consumer audio equipment in the 1960s, bringing costs down. In 1970, JVC pushed forward with a new four-channel technology, demonstrating its "CD-4" quadraphonic disk (not to be confused with the current Compact Disc). In this system, the audio information for the extra channels was superimposed onto the groove walls used for the left and right channels through the use of a high-frequency carrier. JVC also began to supply phonograph cartridges and electronics capable of handling these high frequencies, but these quadraphonic record changers could also play ordinary disks.

Between 1970 and 1972, several other four-channel systems appeared under various names and spellings, including Quadraphonic, Quadriphonic, Quadrophonic, Quadrisonic, Quadrasonic, and Tetrasonic. Just plain "Quad," though widely used to describe these devices, was actually trademarked in 1962 by a British company that was not a participant in the quadraphonic fad.

Besides the CD-4 system, the most popular quadraphonic formats were the Electro-Voice system (later called "RM" or Regular Matrix), the CBS "SQ" (Stereo-Quadraphonic) system, and the Sansui "QS" system (apparently nearly indistinguishable from RM). Record and electronics companies had to decide for themselves which system to adopt, with some, such as Sony, choosing SQ and others, such as RCA, choosing CD-4. By 1973, two more formats had been added, this time on tape. RCA in that year began to offer its first "Mark 8" quad 8-track systems with four discrete music tracks, and several record companies offered discrete four-channel recordings on reel-to-reel tape. Unlike the disks, which all used a frequency-shifted, multiplex approach to put four channels of information into two sides of a record groove, the tape systems had the advantage of four separate, parallel recordings. The Quad-8 was the most popular of the tape formats, especially for use in cars. Quad-8 players were offered by several American auto makers as optional equipment. There are quite a few quad recordings on reel-to-reel and Quad-8 which are, apparently, quite distinctive from the stereo versions, and record collectors often seek them out.

The matrixed systems, however, could be broadcast over existing FM stations and decoded electronically by consumer receivers. By late 1974, there were over 200 U.S. stations experimentally using the Sansui system. The FCC belatedly launched a study to compare quad broadcasting standards and recommend standards for broadcasters, although it didn't announce its findings until late 1977.

As more and more companies became interested in quad, the catalog of available recordings expanded and the prices of equipment came down. By 1974, there were approximately 400 titles available on quad disks or 8-track tapes, and 75 on open-reel tapes. Equipment prices began to drop significantly after Motorola Corporation introduced a single-chip decoder suitable for several of the matrixed disk formats. The only bottleneck to a mass market for quadraphonic sound was in retail distribution, but Quad record clubs began to spring up to cater to four-channel fans.

Soon, however, the electronics press began to claim that record manufacturers, record retailers, and electronics dealers were not fully supporting these products. Record companies and retailers complained about the "dual inventory" problem related to carrying the same titles in multiple formats, particularly since they were already compelled to stock LP, 8-track, and, increasingly, cassette versions of popular releases. Some record companies briefly offered some disks in multiple quadraphonic formats, but as early as 1975, A&M and EMI records announced that they would support only one, the former choosing to stick with CD-4 and the latter SQ. That year, *High Fidelity*'s editor complained that electronics dealers represented "the least enthusiastic group in the country where quad is concerned." Sales soon went into decline and the 1975 holiday season was a disappointment to retailers.

By the end of 1975, most large electronics chains began discounting quad equipment by up to 50 percent in order to clear it out. Harman Kardon, Sherwood, and other companies declared that they would stop quad production, and Radio Shack closed out its brand of quad equipment to make way for a more promising fad, the citizen's band radio.

One happy outcome of the sudden downturn was that it represented a boon for amateur musicians—the high-end recorders designed by TEAC and other companies for quad fans were hastily repackaged as multi-track "home studio" equipment, resulting in one of the first relatively affordable multi-track recorders with separate inputs, preamplifiers, and level controls for four channels.

By August of 1977, quad had run its course. Apparently the only manufacturer to offer a new product that year was Sansui, which had two quad receiver models in its catalog. Ironically, the FCC completed its tests of matrixed FM broadcasting and submitted its findings to the public for comment. In 1978, it issued standards for quad broadcasts, but by that time public interest had waned. As late as 1979, the audiophile press was still hyping quad, with well-known audio journalist Len Feldman claiming that four-channel broadcasting was still "very much alive." In fact, four-channel audio was not to be heard from again until the current fashion for "surround sound" television.

selections were available. They appealed to a smaller group: those interested in making recordings at home, musicians, and tinkerers. In fact, large numbers of "home" tape recorders in the 1950s were sold not to ordinary consumers but to institutions like schools, or to government agencies.

Part of the reason for this situation was the public's resistance to a technology that seemed to change almost continually, making the previous year's models obsolete. Standards for home tape recorders remained in flux, making the release of recordings a daunting task for record companies and retail stores. The introduction of stereo tapes in the early 1950s only confused matters further, adding several new configurations. Only in the late 1950s did a standard, the four-track stereophonic[92] format, come to dominate, but by this time the LP record was so well entrenched that there was little possibility of the open-reel tape recorder challenging it.

There were numerous efforts to introduce a successful cartridge-type tape player to supersede open-reel machines. Open reels of tape were, it was thought, difficult to thread into the machines, and many manufacturers firmly believed that a more convenient form of home tape player might take off in the market. The most notorious failure was RCA's 1958 stereo cartridge. Introduced the same year as RCA's first stereo LP disks, the cartridge player sold poorly for a few years and finally disappeared by about 1965.

The Lear Jet company's "Stereo 8," or 8-track technology, captured the fancy of millions of Americans in the late 1960s and early 1970s. Photo courtesy of the IEEE History Center

Along these same lines but adding a new twist were several endless loop cartridges that appeared in the 1960s. One, initially developed as a source of background music for shopping centers or other public places, made its way into the hands of a U.S. television manufacturer named Earl Muntz, who had cheap car tape players manufactured in Japan and arranged for the re-recording of popular albums onto the tape cartridges. William P. Lear, the American aircraft designer, noticed this stereo, four-track sys-

tem in 1964 and decided to adopt it for use in small business aircraft. Lear modified the design to hold twice the amount of music using half as much tape by increasing the number of parallel music "tracks" from four to eight. Envisioning a broad mass market for this new cartridge, he convinced the Ford Motor Company to sponsor the idea. With players made by the Motorola Company, Ford introduced the new "Learjet Stereo 8," informally known as the 8-track, in its 1966 luxury models. RCA Records agreed to offer a large catalog of popular records on 8-track tape, to be sold through record stores and Ford dealerships. The 8-track was enormously popular, and soon home players and battery portables also became available.[93]

Muntz and Lear struck a resonant chord when they introduced the combination of a convenient cartridge and an automobile player to the U.S. market. Soon, the notion of tape portability caught the imagination of people worldwide, and small, transistorized, but often "low-fidelity" tape players used almost to reproduce music began to appear. The most famous was the Compact Cassette designed by the Philips company in the Netherlands. Philips in 1958 had introduced a successful line of small dictating machines using a similar cartridge, and the Compact Cassette was an even less expensive system for the vaguely-defined "general purpose" recording. The Compact Cassette recorder, first marketed in the U.S. around 1964 as the Norelco Carrycorder, found a ready market among people already infatuated with transistor radios. Its greater portability, lower cost, and recording capability (which most 8-track machines did not have) endeared it to all sorts of people. Young people used it to make recordings of their albums and singles, or to record radio programs off the air. They cared little for high fidelity but wanted to take the music with them. Yet high-fidelity enthusiasts also saw a great deal of promise in the new format. By the late 1960s, several record companies tentatively offered albums on cassette for two very distinct segments of the music consumer spectrum: "teeny boppers" and classical music lovers. Sales of cassettes grew steadily through the 1970s, by 1980 surpassed the 8-track (which was discontinued a few years later), and eventually even overtook LP sales.

These success stories overshadow the numerous failures, which included not only magnetic tape devices but also many other audio formats. CBS and Peter Goldmark, riding high on the success of its LP disk, introduced automobile phonograph players in the 1950s, marketed through Chrysler Motors. After these failed, CBS introduced a cartridge tape player that was something of an engineering breakthrough but an utter commercial failure. Similarly, three quadraphonic formats for disk and two for tape competed simultaneously in the late 1960s and early 1970s before all failed. A number of Japanese companies introduced a line of remarkably high-quality "Elcaset" (for Large Cassette) tape recorders in the late 1970s, with price tags upwards of $500. Once again, sales

sputtered and died. These and others have imbued consumers with the sense that audio technology is a risky investment, and that one's collection of records was not likely to be useful for long. This pattern of obsolescence would re-emerge in the 1980s.[94]

Piracy, Counterfeiting, and Bootlegging

The unauthorized copying of recordings began around the turn of the century in the days of cylinder phonographs, and continues unabated to this day. There are several different kinds of illegal sound recordings according to the law. Record piracy, defined in legal terms as the unauthorized duplication and sale of copyrighted material, is somewhat different than the practice of counterfeiting, which is the unauthorized duplication and sale of copyrighted material with the intent to make consumers believe that the copies are actually original. Often these two phenomena are called "bootlegging," though technically this is a distinct category. A bootleg is a commercial release, usually by a third party, of a recording made surreptitiously or a recording not intended for commercial release. Before World War II, many bootlegs were 78-rpm re-recordings of the sixteen inch "transcription" phonograph records used by radio stations. With the advent of the tape recorder, many live concerts have been recorded and distributed on disk or tape. But the practice of bootlegging has only rarely resulted in a large financial gain for the bootleggers, who are often serving small but dedicated groups of fans. Both counterfeiters and pirates often sold hit records in large quantities to otherwise legitimate retailers at a deep discount.

The early postwar period also saw much (mostly undocumented) copying of phonograph disks for use in jukeboxes. One famous incident which came to light because the counterfeiters were brought to court involved a ostensibly legitimate but Mafia-operated record pressing plant in New Jersey. At night, people at the plant made masters and stampers by re-recording ordinary, purchased copies of hit records. While the sound quality of these second-generation masters was somewhat lower than the original, it was good enough to sell. These low cost disks were then distributed across New Jersey and played in jukeboxes, which were themselves operated by Mafia thugs. Some of the other cases of counterfeiting that came to light had less sinister players. The famous record retailer Sam Goody was convicted of purchasing and distributing large numbers of counterfeit records in New York in the 1950s. By 1960, the U.S. record industry estimated that it was losing approximately $20 million per year to counterfeiters and pirates, and renewed its efforts to get the Federal government to enforce copyright laws.

Illegal copying of sound recordings took on a new dimension in the 1970s, as the cassette tape became more popular. Tape recorder manufacturers since the 1950s had emphasized the recording capability

of their products, and encouraged consumers to do such things as make off-the-air recordings of radio programs. But the market for tape recorders was small compared to that for phonographs until the late 1960s, so the owners of copyrighted material that consumers might have taped did not feel threatened. The situation changed by about 1970, when the 8-track tape in the U.S. and the Philips Compact Cassette worldwide started to take off. Counterfeit 8-track tapes suddenly became a significant problem for record companies in the United States, one that was aggravated by the fact that the equipment to duplicate these tapes was relatively inexpensive.

The record industry was able to put pressure on Federal and state governments to close down most of the large illegal copying operations in the United States, though pirating remained a serious problem in most other countries. Interestingly, sound recordings themselves were not eligible for copyright before 1972 in the United States, but revisions to the Copyright Act of 1909 made it easier to prosecute record pirates.[95]

In addition to these woes was the problem of home duplication, a more widespread phenomenon that the record industry could address only by negotiation with equipment manufacturers. In 1971, amendments to the copyright laws specifically endorsed the right of individual consumers to make copies of broadcasts and purchased recordings for their own use, but these were reversed in 1976.[96] As late as the 1970s, only two major manufacturers of tape recorders, JVC and Philips, had strong economic ties to the record industry, and most recorder manufacturers simply refused to eliminate or restrict the recording features of their equipment. In fact, by the 1980s, several of the major Japanese consumer electronics companies were selling double-well cassette recorders expressly designed to make high-speed copies of tapes. A CBS study conducted in 1980 concluded that the record industry effectively lost 700 to 800 million dollars per year because of home taping. Many blank-tape manufacturers were similarly predisposed to let home taping continue. Several countries began to impose royalties on sales of tape recorders and/or blank tapes in the 1980s, including Argentina, Australia, Austria, the Congo, West Germany, Finland, France, Gabon, Hungary, Iceland, the Netherlands, Norway, Portugal, Spain, Sweden, Turkey, and Zaire.[97]

A new era in piracy began in the late 1970s with the introduction of Betamax and VHS video recorders. Now it was the motion picture industry, shocked by the new technology's capacity to record television programs, which attacked home-recording technology, even though home VCRs had made only the smallest of inroads into the home market. The announcement of the first Sony Betamax VCR in 1976 spurred MCA and Walt Disney to initiate a suit against Sony and several retailers, Sony's advertising agency, and an individual VCR user. The plaintiffs claimed that the Sony technology encouraged consumers to violate the copyright laws.

Initially, in 1979, the court ruled in favor of Sony, but after the case was appealed in 1981, a U.S. Court of Appeals ruled that the makers of VCR's and retailers selling them were liable for the copyright violations represented the off-air recordings of consumers. The case went to the Supreme Court in 1982, which by 1984 reversed the lower court's decision and once again made it legal to make a home videotape off the air.[98]

In the late 1980s, however, the home copying of audio tapes again returned to the forefront. Electronics manufacturers had successfully

Dolby Noise Reduction

Ray Dolby, born in 1933 in Portland, Oregon, got his start at the Ampex Corporation at the age of 16, where he helped design the first Ampex video tape recorders. After leaving Ampex, he set up a commercial research laboratory in London in 1965 with a staff of four and began designing an electronic device to reduce the background noise present in audio tape systems.

The first applications of the Dolby system in 1966 were the model A301 "black boxes," costing about $2000 each and used in conjunction with professional tape recorders. They were capable of a 10-15 dB reduction in tape hiss. Decca's first LP release incorporating the system was a 1966 recording of Georg Solti conducting Mahler's Symphony No. 2. Dolby announced his new system to the Audio Engineering Society in the United States in 1967, and it saw almost immediate use among several American record companies.

Dolby soon licensed a new version of the noise reduction system to KLH Corporation, a manufacturer of consumer high fidelity in the United States. KLH was the exclusive licensee of the new product, called Dolby B (to distinguish it from the original "professional" system, Dolby A), through 1970. The KLH Model 40 reel-to-reel tape recorder, at $650, was the first consumer product to incorporate Dolby B in 1968.

During 1968 and 1969, Dolby engineers began aggressively promoting the idea of Dolby-equipped cassette recorders to manufacturers. At first, the only taker was Advent Corporation, which offered an add-on Dolby box for home cassette decks in early 1970. But the new summer line in 1970 included three home cassette decks incorporating the new technology. All three were manufactured by Nakamichi in Japan and sold under other brands including Advent, Fisher, and Harman-Kardon. By the end of 1970, Ampex and Decca were offering recorded cassettes for playback on Dolby-equipped systems.

In the early 1970s, the Dolby company had also moved into the fields of noise reduction for motion pictures and broadcasting. Motion picture sound studios began using Dolby for pre-release recording as early as 1971, but since theaters were not equipped with suitable equipment, final release prints were not affected. It would be several years before standards and equipment would be available for reproducing Dolby-encoded soundtracks in theaters. By 1979, manufacturers of home VCRs had incorporated Dolby B into their equipment. Broadcasters also responded favorably to Dolby, with the FCC approving its use in conjunction with FM stereo in 1974. Already in 1975, 100 U.S. stations were using the system.

A later product for consumer electronics, Dolby C, was introduced in 1980 to take advantage of new tape technologies. By this time, Dolby products were in hundreds of films and hundreds of thousands of consumer tape recorders and receivers. The company would go on in the 1980s and 1990s to introduce several new consumer and professional products, especially for motion picture exhibition.

introduced the playback-only Compact Disc format (sponsored by Philips and Sony, both companies with equipment and content interests) to replace the LP, but the cassette lingered on. By this time, a number of Japanese and European equipment makers were pushing for new kinds of digital recorders, either optical or magnetic types, which promised to make perfect copies of originals.

Once again, the record companies stepped in to prevent such products from appearing in the American market. Congressional hearings in 1982, 1987, and 1990 led to a series of new laws aimed at forcing overseas manufacturers to incorporate a copy-protection scheme into their hardware. This Serial Copy Management System electronically prevented the making of second generation copies. The Audio Home Recorder Act of 1992 also put a royalty on sales of Digital Audio Tape recorders and blank tapes, to be paid to copyright owners and performers.

Portable Audio Technologies

Portable audio was becoming an important market by the 1960s. Sales of inexpensive transistor portables of the type available since the late 1950s picked up noticeably as they became associated with youth culture and rock and roll music. Though the older generation considered rock and roll annoying, or even lewd, parents seemed willing to give their children a way to listen to the new music as long as they did so out of earshot. The portable radio filled the bill nicely. The broadening acceptance of rock and roll and the transistor radio paved the way for a host of new "personal" audio technologies, such as portable AM-FM receivers, phonograph players, and tape recorders.[99]

The most successful of these was the Sony Walkman, introduced in 1979. Sony's manufacture of miniature, transistorized radios dated from 1957, and the company had been selling Walkman-size tape recorders since the early 1970s. Like Sony, the leading firms in the portable audio movement were not the American and European companies that had pioneered in selling transistor radios but Japanese firms, reflecting a larger shift in the consumer electronics industry. As early as 1959, American manufacturers began purchasing transistor radios from Japanese firms for resale under other brand names, a practice that spread to televisions and other products and which contributed to the steady decline of American production of consumer electronics. Import "penetration" in the radio and TV market in the U.S. had reached 59 percent by 1987. Zenith, the last American manufacturer of portable radios, shut down its last domestic production line in 1980.[100]

Japanese companies took virtually all of the radio, high-fidelity component, and tape recorder markets by the 1960s and then moved on to take most of the television and auto radio markets as well. Through this,

the emphasis on portability and small size persisted. Personal stereos, including those of the Walkman type but also larger "boom boxes," have come to enjoy much larger sales than home installations, and along with car stereos dominate the world market. The total market in the United States for car stereos, personal audio, and home audio was about $10.7 billion dollars in 1996. In addition to the equipment itself, Americans bought over $300 million worth of blank tapes and $2.7 million worth of batteries.[101]

The Digital Revolution

Experiments with the digitization of audio signals were underway in the 1950s at Bell Laboratories and elsewhere for the purpose of telecommunications. The NHK company in Japan began work on digital audio tape recorders in 1965, and the BBC in 1969. Heitaro Nakajima, a leader of the NHK project, moved to Sony in 1971, bringing with him his expertise in digital audio recording. Adapting pulse-code modulation processors originally designed to work with U-Matic or Betamax video tape recorders, the Sony team in the early 1970s produced a digital audio tape recorder using ordinary videotape cartridges. Sony, in 1975, marketed a consumer digital recorder based on a modified Betamax VCR, which was probably the first consumer digital audio product on the market.[102]

At about this time, the Philips company in the Netherlands introduced its optical videodisk technology. Sony had its own optical videodisk development program, and engineers at both companies believed that the optical disk would be suitable for digital audio. The two firms entered into a cooperative agreement to develop a smaller optical disk for digital audio. Part of the impetus for continued development of the optical disk rather than digital tape came from top management. Philips owned Polygram records, while Sony had a joint venture in Japan with CBS. "There was," Nakajima pointed out, "very strong backing within the two companies of the software side, the music side."[103] The Compact Disc offered the record companies a new format on which to offer recorded programs. The resulting product, the Compact Disc, appeared in 1982.[104]

Chapter 4

The Diversification of Home Entertainment Systems

HOME VIDEO

Since 1945, the range of electronic entertainment devices for the home has vastly expanded. At the end of World War II, electronic home entertainment consisted chiefly of AM radio, the phonograph, and the new medium of television. It was common in the postwar years to see comments in the press claiming that expendable income and leisure time were already stretched too thin, and that new technologies such as home audio recorders were doomed to failure. Indeed, many new devices did fail, as manufacturers experimented with different technologies trying to find a successful design. Technologies such as the home video recorder had a long and difficult birth, and many of the pioneers fell by the wayside before the new technology took off.

From Audio to Video Tape Recording

RCA president David Sarnoff expressed a strong interest in the development of a home television recorder in 1950, though the development process took longer and proved to be more complex than anyone in 1950 anticipated. Many in the 1950s believed that the audio tape recorder could be adapted to be a video recorder, and the Ampex corporation demonstrated such a video tape recorder in 1956. The Ampex recorder was expensive, larger than a household refrigerator, and very complex, but many people noted that while the first professional audio tape recorders had also been quite large and expensive, consumer versions had appeared within months of their introduction.

Several firms in the U.S., Europe, and Japan embarked on ambitious programs to develop home video recorder technology in the 1960s, but not all of them adopted magnetic tape as the recording medium. Many home video projects were based on the assumption that consumers would

prefer to purchase programs for reproduction on a home video player, analogous to the way they purchased phonograph records. Thus, a recording device was not necessary. Additionally, making a device that would simply play back pre-recorded material was simpler to design and produce than a recorder-reproducer. One of the most promising proposed home video players was the CBS Laboratories Electronic Video Recording system, which used electronically-scanned motion picture film cartridges. Despite its name, EVR in the home was to be a playback-only system, with all software manufactured by CBS or its licensees using a newly-developed electronic process.

CBS engineer Peter Goldmark, who had developed such commercially unsuccessful products as the automobile record player and a mechanical color television system, pushed the EVR system within CBS as early as 1958. He imagined that its initial use would be in classrooms as a closed-circuit television system. Research commenced in 1961 on a modest budget, and by 1964 a black-and-white system was ready for demonstration. A few licensees signed up to make the cartridges, and apparently a few machines were sold. Soon, the EVR was being announced with great fanfare in 1969-70 in the pages of widely-read publications such as the *New York Times* and *IEEE Spectrum*. However, just as CBS was negotiating with a subsidiary of IBM to manufacture the machines, CBS executives decided not to go through with the deal. They wanted more time to develop a color system. Motorola was enticed to produce the players, but as the company began preparing to manufacturer the machines in quantity problems began to arise. The problem seemed to be the production of films for distribution, which turned out to be more expensive than anticipated. By 1972, CBS decided to pull out of the business entirely, embittering Goldmark, who claimed that the project was "jinxed from the start" by poor management decisions. The technology lived on for a while in the educational market, with a European and several Japanese companies marketing cassettes.[105]

RCA, between the late 1960s and the early 1980s, developed two home video systems, both based on optical playback and both notorious failures. The first system used lasers and hologram technology to record television signals on plastic film. The company enthusiastically announced this "Holotape" technology, though it was still in prototype form, around 1970, under the trade name "Selectavision." Production problems apparently proved daunting, and within a year the product was discontinued.[106] Between 1973 and 1974, RCA announced and demonstrated a new product called Selectavision, this one based on magnetic videotape, but soon decided that the product would not be marketed. Instead, a third Selectavision would appear that used a grooved disk and a new type of playback technology. This was the CED (Capacitive Electronic Disk) Selectavision player, a metalized-plastic disk about twelve

inches in diameter onto which program information was stored in a phonograph-like groove. The pick up responded to changes in capacitance between a very fine stylus and the groove walls.[107]

Playback-only video disks in fact looked like the technology that the industry might choose. Telefunken in West Germany, RCA, MCA, Thomson in France, and Philips all demonstrated phonograph-type or optically-read videodisks before about 1982. The first laser-read disk system to have any success was introduced by MCA (under license from Philips) in 1978 under the name DiscoVision.[108] Later, competing video disk systems (particularly the one developed by Philips) appeared. By the early 1980s, laser video systems were selling well, though not as well as videotape.

A much more successful line of development has been the home videotape recorder, but paths to the current generation of products have been strewn with failures. Working from the base of the original Ampex Videotape recorder, many firms (including Ampex) tried to make a smaller, simpler, and cheaper version for the home. One of the first changes in the original Ampex technology was a movement in the 1960s away from transverse scan "quadruplex" recording and the substitution of helical scanning. Innovations in other areas of technology contributed to the falling cost, increased reliability, and smaller size of video recorders by the 1960s, as designs were squeezed into smaller and smaller packages through the use of transistors, integrated circuits, and smaller mechanical components. Helical-scan tape recorders began to take hold in the market, but not in broadcasting. Instead, they succeeded in the educational and institutional markets, where their somewhat degraded picture quality was offset by their lower cost. The first such lower-cost recorders included the Philips EL 3400 of 1964, which recorded only black and white images. Similar Sony helical scan VTRs were given a boost when Pan American Airlines chose them in 1964 as the basis of in-flight entertainment.[109]

By the early 1970s, the home videotape recorder seemed just around the corner. Ampex made a brief foray into consumer video electronics when it introduced a system called InstaVision (sometimes called InstaVideo). The Philips company of the Netherlands introduced their Video Cassette Recorder (the first use of the term VCR for a commercial product) about the same time, only to discontinue it a short time later. Similar ephemeral videotape systems included the Toshiba / Sanyo V-Cord, and the Matsushita AutoVision. The best-known failure was the U.S.-made Cartrivision recorder. AVCO, its manufacturer, was sponsored by a group of American businessmen, and the recorder / television combination was offered for sale briefly in Chicago-area Sears-Roebuck stores in 1972, selling a few thousand units before the company conceded defeat.[110]

Format Wars: Beta Versus VHS

Thus, the popular belief that Japanese companies invented the VCR on the one hand, or "stole" it from Ampex on the other, are both gross simplifications, as is the assertion that videotape was an instant success. Nonetheless, Sony did have considerable success in the early 1970s selling its relatively inexpensive U-Matic (so-named for the U-shaped tape path around the recording head) videocassette recorder. But its main market was not households as expected, but rather institutions such as television stations and schools. Several other Japanese electronics manufacturers decided to accept U-Matic standards and produce the machines under license, and the system remains in place to this day in many TV stations and "industrial" video studios. But Sony had no success in convincing these manufacturers to accept its standards for a smaller, less expensive version of the U-Matic developed by late 1974. Sony put this "Betamax" technology into production later that year, and it was introduced in the U.S. in April 1975.[111] One of the key technical innovations of the Betamax, resulting in a significant decrease in the size of the machine and the cassette, was a modified form of recording. Previous forms of video recording devised by American firms in the 1940s and 1950s and widely copied by other companies left unused blank spaces, known as "guard bands," between adjacent recorded tracks. This was said to prevent unwanted "cross talk" where magnetic fields emanating from one track affected the other track. Implicit in this type of design was the recognition that a substantial separation of tracks was necessary to compensate for irregularities in the production tolerances of playback heads. An engineer for the Tokyo School of Communications, Shiro Okamura, had invented a way to eliminate these bands in 1958 and devised an electronic means for the heads to seek the proper mechanical alignment with the recorded tracks. The process had originally been used in a professional recorder made by Matsushita in 1968. The process, by removing the guard bands and insisting on more accurate alignment of the heads during production, placed new demands on the factories turning out recording heads, which took considerable effort to accomplish. The Japanese character called beta is a heavy brush stroke that completely covers the paper underneath, and is the inspiration for the name Betamax. The first Betamax SL6300, a console model with built-in television, went on sale in the U.S. in 1975 at a price of $2295; it was followed in early 1976 by the SL7300, a deck priced at $1295. Blank tapes at that time cost about $15.[112]

Sony had met with its partners in the production of U-Matic recorders in 1974 to discuss the Betamax, but Matsushita did not seem interested. The company had been working on a very similar technology, which it would soon introduce as the Video Home System (VHS). Matsushita and a partner, JVC, decided to make only the VHS system, while a host of other Japanese companies signed up for one or the other,

or sometimes both. The two formats competed amongst themselves and with RCA CED videodisks in the crucial American market for several years, with the Betamax format enjoying a slight lead. In Europe, there was also competition from a new Philips videotape cartridge system called V2000. Sony and Zenith formed an alliance in 1977, by which time four other Japanese manufacturers were making VHS-format recorders. RCA and Sony reached an agreement in 1977 whereby the American company would distribute VHS recorders, and thus not only undermined its own videodisk sales but began to tip the balance in favor of the VHS format. By 1981, the RCA brand had captured 26% of the VCR market in the United States.[113]

One of the popular myths about the ensuing "format war" is that the Betamax technology was somehow superior. But while this assertion has appeared in print numerous times, it is apparently without a clear engineering basis. If anything, the two systems were nearly identical. Betamax recorders in the late 1970s and early 1980s consistently offered new features earlier than VHS recorders, but the sponsors of VHS always caught up. Aside from two-hour, three-hour, or eventually five-hour recording times, stereo sound, and other such features, the basic recording process was substantially the same. The real differences lay in marketing strategies, the proliferation of VHS manufacturers, the availability of recorded tapes, and prices. The battle was over by late 1987, when Sony's market share dropped to about 5%, and in 1988 the company offered its first VHS machines. VHS was given another big push when the first Korean-made VCRs, some selling for under $300, appeared on the market in 1985.[114]

Initially, motion-picture producers and television broadcasters were outraged by the Betamax and VHS systems. Universal Pictures and Disney filed suit against Sony in 1979, claiming that their technology encouraged consumers to violate copyright laws. The case was eventually settled in Sony's favor several years later, but in the meantime, copyright owners began to realize that sales of feature films on tape might well be profitable. Even in 1978/79, a few tape duplicators, operating under license from motion picture studios, had sold tens of thousands of video tapes to consumers at prices of $50-70 each. By 1978, an entrepreneur in Los Angeles had gone a step further, offering these releases as items that customers could rent for a small fee, and the video rental business was born. Further, studies of VCR usage in the early 1980s indicated that the most common use of the technology's recording feature was to "time shift" television programs to a more convenient hour. Since commercial announcements were typically left on the recording, broadcasters' objections to the practice seemed unfounded. The use of the VCR in homes grew steadily through the late 1980s and then leveled off, with subsequent sales often representing replacements. VCR sales in the United States peaked at over $5 billion in 1985, but dropped to $2.6 billion by 1996.[115]

The chart below illustrates the dominance that the VHS format had gained in the early 1980s.

VCR SALES BY FORMAT IN SELECTED COUNTRIES IN 1982

	VHS	V2000	Beta
West Germany	55%	25%	20%
U.K.	70%	10%	20%
Netherlands	48%	32%	20%
U.S.A.	75%	0%	25% (est. based on tape sales)

The VCR as an Alternative Form of Program Distribution

The use of the VCR represented a serious challenge to any corporation or authority that desired to control the flow of video information. This included movie production companies, television networks, and national governments. The Russian Elektronica brand VCRs in the mid-1980s, for example, cost the equivalent of a year's salary, but they were enormously popular in part because they offered what Soviet television denied. The Soviet Union had adopted the United States NTSC standard, potentially eliminating one major source of western influence. But European programs, or those electronically converted to SECAM format, began to filter in. Soviet tourists in Western countries often brought back VCRs with them, making government restrictions on their use difficult. The use of video recorders was tightly regulated in the Soviet Union and other Eastern Bloc nations as well; the Bulgarian government, for example, insisted that owners register them. Despite these restrictions, VCR ownership spread rapidly in the 1980s, and as the Soviet Union began to disintegrate, revolutionaries used the VCR as a medium of propaganda. The approximately 300,000 VCRs in Poland by 1986, for example, were used to spread the messages of the Solidarity movement there.

There is much additional anecdotal evidence to suggest that the VCR (and also the audio cassette recorder) acted as alternative — or underground— methods of program distribution, bypassing established broadcasting facilities. In the United States, many industry analysts credited the sales of erotic video tapes as one of the chief factors in the VCR's early success. They took the place of adult movie theaters, but also could be purchased in areas where they were legal and viewed at home. In some Arab nations where Western television programs were banned, the rich bought videotape recorders and imported tapes of the shows.[116]

The main "legitimate" use for the VCR before the days of video rentals was time shifting. This practice, which simply referred to the recording of broadcast programs for later viewing, threatened to revolutionize the television broadcasting business. By the early 1980s, one American broadcast network, ABC, was prepared to turn VCR time shifting to its advantage. The company initiated a new late-night service whereby scrambled video signals would be broadcast, electronically restored by a rented device located in the home, and presumably recorded on a VCR for later viewing. Such services have not been successful, and television networks still depend on large "prime time" audiences for their shows. However, usage of videotape continues to rise. In the United States in 1998, consumers watched an estimated fifty-four hours of prerecorded video per person, and over eighty percent of households had a VCR.[117]

VIDEO GAMES

Marvin Minsky and other pioneers of artificial intelligence paved the way in the 1950s for today's video games with their experiments in computer visual displays and simple visual versions of the "mouse in a maze." But it remained for William Higinbotham, working on an analog computer at the Brookhaven National laboratory in 1958, to invent one of the first "ping pong" type of games. Still, computer games did not become widespread even among the relatively small community of computer users until the hacker Steve "slug" Russel created an on-screen, real-time, two person game called Spacewar in 1962 while at MIT. The game involved two spaceships that could navigate and battle each other in a two-dimensional "galaxy" on screen. Spacewar developed through several generations and became a favorite among those who haunted MIT's computer room late at night.[118]

Nolan Bushnell, another young computer enthusiast, played Spacewar as an MIT student in the 1960s. Seized with the idea of selling computer games, he built his first one in 1970 in his house, using dedicated digital circuits instead of an expensive general purpose computer. By 1972, he organized a company, called Atari, to manufacture the games and hired his first engineer. The game he introduced was like tennis or ping-pong in two dimensions on a video screen. This game, called "Pong," was introduced first as a coin-in-the-slot arcade machine.[119]

Bushnell was clearly not the first to conceive of a computer or video game, but Pong's commercial success ensured that he would become famous and that all sorts of competitors would soon arise. Back in 1966, even before Bushnell had introduced Pong, another engineer named Ralph Baer had designed his first computer game as an employee at Sanders Associates in New Hampshire. Beginning in 1969, he tried to

license the design to major corporations such as Teleprompter, RCA, Zenith, GE, and Magnavox. Only Magnavox took a license, and the company introduced a home version of it in 1972, called Odyssey. By this time Pong had of course already appeared, and the tennis-like Odyssey game seemed to be an imitation of it. What the Odyssey game did demonstrate was that home video games could be as popular as arcade games, and since that time many games have appeared in both versions.[120]

Home and arcade video games grew in popularity and complexity during the 1970s. By 1976, Fairchild Camera and Instruments got involved in games through the introduction of "Channel F" — a cartridge-type game system priced at $170 that could be updated as new games came out. This would become the model for many other home game systems. A few years later, in 1979, sales of arcade video games experienced a 300 percent jump, mainly due to the influence of Space Invaders, developed by Taito of Japan and licensed to Bally's Midway division. The next year, Atari countered with another wildly popular arcade game called Asteroids, which sold 70,000 units at a cost of about $2700 each. Before long, arcades which had for decades rung with the sounds of electromechanical pinball games now bleeped and blipped with the sounds of games like Dig Dug, Centipede, Galaga, and Tranquillity Base. Books and magazines written entirely for games players appeared, promising to reveal the secrets of winning the games.[121]

By 1982-83, Atari's sales of home video games suddenly dropped off, apparently due to competition from other companies and a string of unpopular plug-in games for their latest home "game box." Articles in the popular press began to discuss video games in terms of a declining fad. No one was prepared for the dramatic resurgence of the industry led by Nintendo, a hundred year old Japanese game company headquartered in Kyoto. Nintendo got into electronic games after purchasing the Japanese manufacturing rights for the Magnavox game system, but by 1983 had decided to design a custom chip set for a new game machine of its own.[122]

By the early 1980s, several home game systems had appeared that were actually general-purpose computers that could also run game software. They were marketed on this dual-purpose basis, with the idea that children could use the machines as both a game and an educational tool. Nintendo bucked this trend and returned to the idea of a games-only machine, minimizing expensive components like memory chips and eliminating disk and tape drives, modems, and keyboards. Nintendo also returned to the idea of supplying software in the form of plug-in electronic cartridges, since unlike disks or tapes these were difficult for consumers to copy. Nintendo allowed other manufacturers to make cartridges for its games, but insisted that they use proprietary integrated circuits.[123]

Nintendo also entered into the arcade game field and produced a string of major hits in the early 1980s, including Donkey Kong and Super Mario Brothers. In 1989, they took the idea of home games one step further with the portable, hand-held Game Boy, a machine with a tiny LCD display that could run versions of the popular arcade and home games. The market for video games and game software for personal computers continued to grow in the 1990s. In the United States, the video games market amounted to over $5.1 billion in sales by 1996, and Americans over the age of twelve played an average of 26 hours per year.[124]

A hotly debated topic in the early 1980s was the effect of electronic games on the development and behavior of children. Researchers found that games with aggressive or violent features appealed to boys, and that boys populated the public arcades. Girls, however, were apparently attracted to less aggressive games, such as Donkey Kong. Despite allegations that video games had negative effects on the developing minds of children who played them, psychologists had mixed conclusions. Some saw the games as reinforcing anti-social tendencies, while others saw them as potential tools for teaching eye-hand coordination and problem solving skills.

Conclusion

Changes in broadcasting and entertainment technologies since 1945 have been no less dramatic than concurrent changes in computers, space communication, or military electronics. However, entertainment has not attracted the attention or admiration bestowed upon these other fields of electrical engineering. By contrast, historians, social scientists, and the general public seem to find the subject of entertainment technologies of great interest and importance, as demonstrated, for example, by the scores of books on the "impact" of television. This gap between the engineering community's appreciation of its own accomplishments and that of the general public is ironic, given the long-standing efforts of engineers to make the public more aware of technological achievements.

Clearly broadcasting and consumer electronics technologies are of great importance. New technologies such as the audio and video tape recorder have revolutionized the way radio and television stations operate. New broadcast services such as FM radio, television, cable, and satellite TV have extended and enhanced older media, creating huge new industries. In many countries today, the electronic media are a major conduit through which individuals experience and understand the world around them.

The coming of new technologies has often been marked by dissent, both within and outside the engineering community. Technical standards necessary to implement television, radio, home phonographs, and tape recorders have been the subject of considerable controversy. This kind of debate is important, because in cases where manufacturers, government regulatory agencies, or trade organizations have refused to agree on technical standards, good products were doomed to commercial failure. New technologies have also sparked heated debates among the public, the impact of television programming being the premier example. Some of the debate has been focused on economic issues, such as the

displacement of the much-loved movie theater by television or home video systems. Others have questioned whether the electronic media, especially television, represent progress or a social evil. Such controversy and debate over new technologies reflect the social processes underlying technological change. There is no one, correct, or logical course for change, but, instead, it is a path negotiated by engineers, corporations, governments, and the public.

As the 20th century draws to a close, even more recent innovations promise to raise some of the same issues seen in the past and introduce new ones. The impact of video games, an important commercial product only in the last twenty years, has not yet been fully evaluated. Computer-based technologies, including the internet, seem poised to become the major sources of home entertainment. Yet some of the problems of standards, equitable access, and regulation that surfaced in the history of earlier devices remain unresolved. It seems clear that the personal computer and related technologies represent a continuation-in-part of earlier systems of electronic entertainment, while presenting new opportunities and problems for engineers and the general public.

Conclusion

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displacement of the much-loved movie theater by television or home video systems. Others have questioned whether the electronic media, especially television, represent progress or a social evil. Such controversy and debate over new technologies reflect the social processes underlying technological change. There is no one, correct, or logical course for change, but, instead, it is a path negotiated by engineers, corporations, governments, and the public.

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Notes

1. International Telecommunications Union, *From Semaphore to Satellite* (Geneva: ITU, 1965), 183; William E. McCavitt, *Broadcasting Around The World* (Blue Ridge Summit, PA: TAB Books, 1981), 32.

2. Christopher Sterling, *Electronic Media: A Guide to Trends in Broadcasting and Newer Technologies*, 1920-1983 (New York: Praeger Publishers, 1984), 6-7, 113; See, for example, "A.M. Stereo for Europe?" *Electronics World*, 93, 1167, November 1987.

3. Burton Paulu, *Radio and Television Broadcasting in Eastern Europe* (Minneapolis: Univ. of Minnesota, 1974), 72-4; Sydney W. Head, *World Broadcasting Systems: A Comparative Analysis* (Belmont, CA: Wadsworth Publishing Co., 1985), 24.

4. A "hardened" national coaxial transmission trunk was put in place by AT&T during the 1960s, with buried lines, repeater stations, and switching offices. The latter were equipped with food for several weeks should a "disaster" (meaning a nuclear attack) occur. *Coaxial Cable: A Modern Communications Medium* (n.d.: n.p., AT&T); Sydney Head and John Kugblenu, "GBC-1: A Survival of Wired Radio in Tropical Africa," *Gazette*, vol. 24 (#2, 1978): 121-129.

5. Christopher Sterling and John M. Kittross, *Stay Tuned: A Concise History of American Broadcasting*, (Belmont, CA: Wadsworth Publishing Co., 1990), 277.

6. Head, *World Broadcasting Systems*, 14; A case study of the transfer of television broadcasting technology to Pakistan by Japanese representatives of the United Nations is in Iwao Nakajima, "Television in Pakistan," *Studies of Broadcasting*, vol. 5 (March 1967): 111-125.

7. Asa Briggs, *History of Broadcasting in the United Kingdom, vol. IV; Sound and Vision* (London: Oxford University Press, 1979), p. 562.

8. Briggs, *Sound and Vision*, 302; Head, *World Broadcasting*, 249-50; on the subject of international radio broadcasting, see James Wood, *History of International Broadcasting* (London: Peter Peregrinus, Ltd. 1992); *FCC Annual Report, 1948*, p. 36.

9. *Statistical Abstract of the United States 1956*, p. 838.

10. *FCC Annual Report, 1946*, p. 16.

11. A scholarly biography of Armstrong's life is not yet available. Readers should consult Lawrence Lessing's *Sentimental Man of High Fidelity: Edwin Howard Armstrong* (New York: J. B. Lippincott, 1956); also see Don V. Erickson, *Armstrong's Fight for FM Broadcasting: One Man vs. Big Business and Bureaucracy* (University, AL: University of Alabama Press, 1973).

12. *FCC Annual Report, 1955*.

13. A. Prose Walker, "Engineering Performance of Six Proposed Stereo Systems," *Electronics*, vol. 18 (November 1960), 85-90.

14. *The Froelich/Kent Encyclopedia of Telecommunications* (New York: Marcel Dekker, 1994), vol. 8, 173-183.

15. Andrew Ingliss, *Behind the Tube: A History of Broadcasting Technology and Business* (Boston, MA: Focal Press, 1990), 141.

16. Edwin H. Armstrong and John H. Bose, "Some Recent Developments in the Multiplexed Transmission of Frequency Modulated Broadcast Signals," *Proceedings of the Radio Club of America*, 30 (1953): 3 [reprinted in *The Legacies of Edwin Howard Armstrong* (n.p., Radio Club of America, 1990), 223.

17. McCavitt, *Broadcasting Around the World*, p. 96.

18. Raymond G. Guy, "AM and FM Broadcasting," *Proceedings of the IRE*, 50 (May 1962): 817.

19. Including Harris, Kahn/Hazeltine, Motorola, and Magnavox; Pat Hawker, "A.M. Stereo: What Went Wrong?" *Electronics World* 94 (September 1988): 936.

20. Ingliss, *Behind the Tube*, p. 105; "Woes of AM-Stereo," *Electronics World* 95 (January 1989): 98.

21. Head, *World Broadcasting*, pp. 112-117.

22. Don R. Brown, "The BBC and the Pirates: A Phase in the Life of a Prolonged Monopoly," *Journalism Quarterly* 48 (Spring 1971): 85-99; Paul Harris, *When Pirates Ruled the Waves* (London: Impulse Books, 1968); UNESCO, *Many Voices, One World* (New York: UNESCO, 1980) [also known as "The McBride Report"], 88.

23. Erik Barnouw, *Golden Web: A History of Broadcasting in the United States, vol 2, 1933-1953* (New York: Oxford University Press, 1968), 294-295.

24. Michael Biel's dissertation, at over 1100 pages, is a full account of network use of recordings before 1936, including the notable exceptions to the well-known ban. "The Making and Use of Recordings Before 1936," (Ph.D. diss., Northwestern, 1977): for information on the "Amos n Andy" show, see pp. 396-418.

25. Theodore Stuart DeLay, Jr., "An Historical Study of the Armed Forces Network to 1946," (Ph.D. diss., University of Southern California, 1951).

26. John T. Mullin, "Magnetic Recording for Original Recordings," *Journal of the Audio Engineering Society*, vol. 25 (October/November 1977): 697.

27. Steven Lubar, *Infoculture* (Boston: Houghton Mifflin Co., 1993): 34-235; Michael F. Wolff, "The Secret Six-Month Project," *IEEE Spectrum* (December 1985): 64-69.

28. Andre Millard, *America on Record: A History of Recorded Sound* (Cambridge: University of Cambridge Press, 1995).

29. *Statistical Abstract of the United States 1956*, 838.

30. "McBride Report," 61.

31. See, for example, the brief discussion in International Telecommunication Union, *From Semaphore to Satellite* (Geneva: ITU, 1965), 162.

32. ITU, *Semaphore to Satellite*, p. 195; Emery, *World Broadcasting Systems*, p. 101; McCavitt, *Broadcasting Around the World*, p. 64; Raymond C. Hills, "Fifty Years of High-Definition Television Transmission," *Journal of the Institution of Electronic and Radio Engineers*, vol. 56 (1986): 1-15; D. H. Pritchard and J. J. Gibson, "Worldwide Color Television Standards—Similarities and Differences," *Journal of the Society of Motion Picture and Television Engineers*, 89 (February 1980): 111-120.

33. Donald P. Leggatt, "The Evolution of Television Technology," *Electronic Engineering 60* (March 1988), 17; Pritchard and Gibson, "Worldwide Color Television Standards," 114-117.

34. Paulu, *Radio and Television Broadcasting*, 72-73

35. Asa Briggs, *Sound and Vision*, 483-500.

36. Seventy-channel UHF tuners with mechanical detents for each channel were mandated only in the mid-1970s; David J. Carlson, "The Evolution of Television Tuning Systems," *IEEE Transactions on Consumer Electronics*, vol. CE-30 (May 1984): 29-39.

37. Robert Buderi, *The Invention That Changed the World: How a Small Group of Radar Pioneers Won the Second World War and Launched a Technological Revolution*, (New York: Simon & Schuster, 1996) 71.

38. Ibid., 322, 252-3.

39. Robert G. Neuhauser, "Television Camera Tubes — A History But Yet an Obituary," *SMPTE Journal*, vol. 99 (September 1990): 711-712; Paul K. Weimer, "A Historical Review of the Development of Television Pickup Devices, 1930-1976," *IEEE Transactions on Electron Devices*, vol. ED-23 (1976).

40. Ingliss, *Behind the Tube*, 186-188; Sterling and Kittross, *Stay Tuned*, 280.

41. Ingliss, *Behind the Tube*, 218-219.

42. J. Fred Macdonald, *One Nation Under Television: The Rise and Decline of Network TV* (New York: Pantheon Books, 1990), 41.

43. Paulu, *Radio and Television Broadcasting*, 76.

44. One could compare this to European and American railroads of the 19th century, which displayed this same contrast between elegance and permanence in the one case and functionality and low cost in the other.

45. MacDonald, *One Nation Under Television*, p. 118.

46. Fairchild synchronized tape recorders were used by CBS to provide sound for Kinescope recordings, for example. See Mullin, "Magnetic Tape," 699.

47. The Stille Laboratories in Berlin announced its aim to record television signals on magnetic tape in 1929. See "The Blattner System of Electro-Magnetic Recording and Reproduction," *Electrician*, 103 (18 October 1929): 472.

48. "Videotape" was an Ampex trademark that has now passed into common usage; RCA for many years named its competing products Television Tape Recorders. See, for example, John Wentworth, "The Technology of Television Program Production and Recording," *Proceedings of the IRE*, 50 (May 1962): 833-4.

49. Stewart Wolpin, "The Race to Video," *Invention and Technology*, 10 (Fall 1994): 52-63; Charles P. Ginsburg, "The Birth of Videotape Recording," in *In Memoriam: Alexander M. Poniatoff, 1892-1980* (Redwood City, CA: Ampex Corporation, 1981), n.p.

50. Dennis Moralee, "30 Years of Professional Video Recording," *Electronics and Power*, 33 (November/December 1987): 726-730.

51. CBS did not become a successful electronics manufacturer. It sold Hytron in 1961, after losing about $100 million. MacDonald, *One Nation Under Television*, 41.

52. David E. Fisher and Marshall Jon Fisher, "The Color War," *American Heritage Invention and Technology*, 12 (Winter 1997): 8-18; MacDonald, *One Nation Under Television*, 40-43; Portions of David Sarnoff's testimony to the FCC in 1950 have been published as *Color Television* (New York: Radio Corporation of America, n.d. [1950]); MacDonald, *One Nation Under Television*, 41; Peter C. Goldmark, *Maverick Inventor: My Turbulent Years at CBS* (New York: Saturday Review Press, 1973), 84-124; *Statistical Abstract of the United States 1985*, p. 542l; Donald G. Fink, "Perspectives on Television: the Role Played by the Two NTSC's in Preparing Television Service for the American Public," *Proceedings of the IEEE* (1976): 1322-1331.

53. Sterling and Kittross, *Stay Tuned*, 290.

54. Edward W. Herold, "A History of Color Television Displays," *Proceedings of the IEEE*, 64 (September 1976): 1331-1338; Harold B. Law, "The Shadow Mask Color Picture Tube: How it Began—An Eyewitness Account of its Early History," *IEEE Transactions on Electron Devices*, vol. ED-23 (July 1976): 752-759; Sam H. Kaplan, "The History of Color Picture Tubes and Some Future Projections," *SMPTE Journal* (May 1990): 397-98.

55. Neuhauser, "Camera Tubes," 722.

56. Sterling and Kittross, *Stay Tuned*, 290, 292; Sony Corporation, *Genryu: Sony Challenges, 1946-1968* (Tokyo: Sony Corporation, 1986), 150-151.

57. Sterling, *Electronic Media*, 276; 278-9; 282; *Statistical Abstract of the United States 1997*, 760.

58. "More on Pay-TV," *Sound Merchandising* (July 1960): 6-37; Richard A. Gershon, "Pay Cable Television: A Regulatory History," *Communications and the Law*, 12, (June 1990): 3-27.

59. Sterling, *Electronic Media*, 26-27.

60. Ibid., 28.

61. Andrew Ingliss, "Satellite Television in the United States," *Combroad*, 50 (March 1981): 1-8.

62. Belgium, the Netherlands, and Denmark have the most extensive cable systems in Europe, in part because they lack television program resources, but border on countries with extensive domestic television enterprises. Head, *World Broadcasting Systems*, 47; Martii Sormanaki, "Finland's Experiences with Pay-TV," *Intermedia* (March 1982): 27-8.

63. Paulu, *Radio and Television Broadcasting*, 77 ff.

64. Head, *World Broadcasting Systems*, 39-41.

65. George Comstock, *The Evolution of American Television* (Newbury Park, Calif.: Sage Publications, 1989), 44.

66. Douglas Gomery, "Theater Television: A History," *SMPTE Journal* 98 (February 1989): 120-123.

67. R.M. Haynes, #-D Movies: A History and Filmography of Stereoscopic Cinema (Jefferson, NC: McFarland, 1989).

68. Salt, *Film Style and Technology*, 245.

69. J. D. Peters, "Satan and Savior: Mass Communication in Progressive Thought," *Critical Studies in Mass Communication*, vol. 6 (1989): 247-263.

70. Most influential was his 1927 *The Public and Its Problems* (New York: Henry Holt and Co., 1927).

71. David K. Perry, *Theory and Research in Mass Communication* (Mahwah, NJ: Lawrence Erlbaum Associates, Publishers, 1996), 14.

72. Harold Innes, *Changing Concepts of Time* (Toronto: University of Toronto Press, 1952); *The Bias of Communication* (Ibid., 1951).

73. Elihu Katz and Paul F. Lazarsfeld, *Personal Influence: The Part Played by People in the Flow of Mass Communications* (Glencoe, Il., The Free Press, 1955).

74. *Statistical Abstract of the United States 1985*, 542. That figure would rise to seven hours per day by 1983.

75. Payne Fund studies in the 1930s had indicated that even the limited depictions of sex in Hollywood films could lead to delinquency among both boys and girls, but later studies indicated that pornography might actually decrease the incidence of sex crimes. Perry, *Theory and Research in Mass Communication*, 174.

76. Hilda T. Himmelweit et al., *Television and the Child: An Empirical Study of the Effect of Television on the Young* (New York: Oxford University Press, 1958). Also see Wilbur L. Schramm, *Television in the Lives of our Children* (Stanford: Stanford University Press, 1961), which reached similar conclusions; Perry, *Theory and Research in Mass Communication*, 161.

77. Ibid., 177

78. Ibid., 176.

79. Ibid., 157. The 1986 Meese Commission was appointed to review findings on sexually explicit materials. Its report contradicted earlier findings. Ibid., 177. The Commission also had members with a predisposition to conservative findings; A 1992 article by B. S. Centerwall, "Television and Violence: The Scale of the Problem and Where to Go From Here," in *Journal of the American Medical Association*, vol. 267 (1992): 3059-3063, argued that televised violence contributes to at least 50 percent of all homicides in the U.S.

80. Sterling, *Electronic Media*, 6; Sterling and Kittross, *Stay Tuned*, 120, 276, 281. The trend carried over into television. Between 1951 and 1954, only 1 percent of programming in New York City was performances of classical music. New York represented one of the largest markets for high fidelity equipment and classical music records in the United States. Ibid., 282.

81. Oliver Read and Walter Welch, *From Tinfoil to Stereo: Evolution of the Phonograph* (Indianapolis: Howard W. Sams & Co., 1976), 339; Goldmark, *Maverick Inventor*, 126-127.

82. There was a fourth speed, 16 rpm, available on many phonographs though the disks were used mainly for spoken voice recordings. Recordings for the Blind, a non-profit organization, made use of 16-rpm disks to distribute audio books.

83. "U.S. Record Sales, 1921-1962," *Billboard*, 69 (3 August 1963): 13; "Annual U.S. Retail Sales of Phonographs, Radios, TV sets, and Tape Recorders," Ibid., 21.

84. Read and Welch, *From Tinfoil to Stereo*, 342; Electronic Industries Association, *EIA Yearbook, 1962* (New York: Electronic Industries Association, 1963), 20.

85. "Fine Arts Quartet on Binaural Tape," *Down Beat*, vol. 20 (21 October 1953): 10-5 [sic]; "Music on Tape," 29-30; Robert E. Benson, "Cream of the Crop," *Tape Recording*, 8 (December 1960): 28-32; RCA, one of the leading record companies in the United States, also offered 2-track stereo tapes in both the "stacked" and "staggered" arrangements, but only offered ten different titles, suggesting the low level of enthusiasm the company had for multiple formats. Advertisement, RCA-Victor Corporation, *High Fidelity*, vol. 6 (May 1956): 69; Lee Zhito, "4-Track Tape Gets Industry Accolade," *Billboard*, 8 August 1960, p. 1; Ralph Freas, "Science Lands Trio of Punches, Knocks Out 2-Track," Ibid., 1 September 1958, p. 1, 15.

86. H. E. Roys, "The Coming of Stereo," *Journal of the Audio Engineering Society*, 25 (October/November 1977): 824-827

87. "The Williamson Story," *The Audio League Report*, vol. 1 (August 1954): n.p.

88. A reprint of Williamson's articles appears as *The Williamson Amplifier* (Peterborough, NH: Audio Amateur Publications, 1990); *Current Industrial Reports*, 1964, p.6; Ibid., 1976, p 5; *United States Census of Manufactures 1972*, 36D-32.

89. "The Big Solid State/Vacuum Tube Debate," *Audio Fair*, vol. 1 (October 1965): 6-9; 46; Russel O. Hamm, "Tubes vs. Transistors," *Re/P*, 4 (September/October 1973): 35-40.

90. Daniel R. Von Recklinghausen, "Electronic Home Music Reproducing Equipment," *Journal of the Audio Engineering Society*, 24 (1977): 767.

91. *Statistical Abstract of the United States 1997*, 760; Eric Barbour, "The Cool Sound of Tubes," *IEEE Spectrum*, 35 (August 1998): 24-35.

92. Recording tape, because it is physically wider than it needs to be to record an audio signal, can be easily adapted to multi-track operation. Four-track stereo divided the width of a standard 1/4-inch wide tape into four parallel bands, each of which received a distinct recording corresponding to two, two-channel stereo signals.

93. A brief history of the 8-track is in Richard Rashke's *Stormy Genius: The Life of Aviation's Maverick, Bill Lear* (Boston: Houghton Mifflin, 1985), 254-256.

94. Peter Goldmark, *Maverick Inventor*, 148-155.

95. The Sound Recording Amendment of 1971 took effect in 1972.

96. S. Rep. 94-473, 94th Cong. 1st Sess. 47-50 (1975); *H.R. Report no. 94-1476*, 94th Congress, 2nd Sess., 46-50 (1976).

97. House Committee on the Judiciary, Subcommitee on Intellectual Property and Judicial Administration, *Hearing on Audio Home Recorder Act of 1991*, 19 February 1992 (1991) 101.

98. *Home Video and Cable TV Yearbook 1982-83*, 131; James Lardner, *Fast Forward: Hollywood, the Japanese, and the Onslaught of the VCR* (New York: Norton, 1987), 268.

99. Michael B. Schiffer, *The Portable Radio in American Life* (Tucson: University of Arizona Press, 1991), 173-177.

100. Schiffer, 205-8; 225; *Statistical Abstract of the United States 1990*, 749.

101. *Statistical Abstract of the United States 1997*, 760.

102. Mitsubishi/Teac and other firms also announced optical audio disks at this time. See, for example, Shiji Itoya and Takahiro Kubo, "Development of the PCM Laser Sound Disc Player," *IEEE Transactions on Consumer Electronics*, vol. CE-24 (1978): 443-452.

103. Interview with Heitaro Nakajima by William Aspray, 24 May 1994. Oral History Collection, IEEE History Center [hereafter IEEE OH], interview no. 207.

104. David Ranada, "Heitaro Nakajima: Digital Pathfinder," *Audio*, 76 (July 1992): 32-35.

105. Goldmark, *Maverick Inventor*, 162-201; Lardner, *Fast Forward*, 75-79.

106. Ibid., 80-81.

107. T. J. Chistopher, et al., "The Selectavision Player," *IEEE Transactions on Consumer Electronics*, vol. CE-27 (August 1981): 340-351.

108. Paul Mareth, "The Video Disc," *Channels*, 4 (March/April 1984): 24-30.

109. Yuma Shiraishi, "History of Home Videotape Recorder Development," *SMPTE Journal*, 94 (December 1985): 1257-1263; Shigeo Shima, "The Evolution of Consumer VTR's—Technological Milestones," *IEEE Transactions on Consumer Electronics*, vol. CE-30 (May 1984): 67.

110. Lardner, *Fast Forward*, 82-88.

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