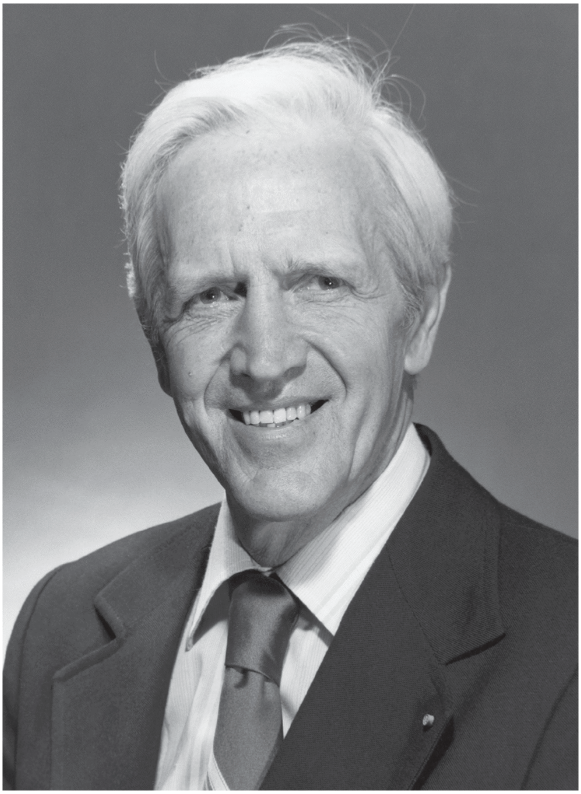

C. CHAPIN CUTLER

1914–2002

Elected in 1970

"Fundamental contributions to microwave electronics and to space engineering and applied science."

BY PING KING TIEN

CASSIUS CHAPIN CUTLER developed his character during the tumultuous years of the Great Depression (1929–34) and World War II (1941–45) and led a successful career of research in communication science for more than four decades. His inventions in radio, radar, signal coding, imaging, and satellite communications earned him more than 80 patents, numerous awards, and a worldwide reputation. He was an enthusiastic collaborator, and remained humble throughout. He was quoted in the spring 1992 issue of the *WPI Journal*, "I don't think I'm really that smart. I just think my imagination got turned on at an early age and that gave me tremendous motivation."

Chapin was born December 16, 1914, in Springfield, Massachusetts, to Paul A. and Myra (Chapin) Cutler. He was raised in a small-town environment and educated in the public school systems. His resourcefulness and ingenuity had their roots in his youth and later in his education at Worcester Polytechnic Institute (WPI).

At age 14 Cutler played with elementary crystal receivers and his grandfather's three-tube radio, mostly listening to the broadcasts. Radio technology was a mystery to him. When

Adapted with permission from *Biographical Memoirs of the National Academy of Sciences* (www.nasonline.org/memoirs).

school started that fall, he went to the library to look for books on radio. Eventually a friend gave him a copy of *Radio Craft* magazine, with an article titled "The Junk Box Radio." Cutler later wrote in his journal, "This, I believe to be the most crucial event of my life."

"That's how I started," he said, "I built the junk box radio receiver using parts from a defunct broadcast set. I screwed the parts onto a pine board and used a single old vacuum tube. I salvaged even the wire and the solder from the old radio and used my dad's soldering iron heated on the kitchen stove." When the radio was built he heard "dit, dit, dit, dah, dit, dit, dah" from a station in Mexico City, and he was forever hooked on radio.

Shortly after, his father took him to a popular talk, "The Wonders of Radio and Communication," by a visiting scientist from the newly established Bell Telephone Laboratories. The speaker modulated a neon bulb, talked over a light beam, and demonstrated inverted speech. That was when Cutler decided what he wanted to do with his career. Experimentation with electronics soon became his avocation, and he supported his hobby by baking beans and selling them to neighbors.

He graduated from Springfield Technical High School in 1933 but, although his parents were determined that he should go to college, no one in the family had college experience or any idea of how to go about enrolling. One day he was stopped by a neighbor, a graduate student at WPI, who encouraged Cutler to apply and gave him an application form. A week later he visited the campus, was interviewed, and learned that he was accepted provided he did well in the first semester. His whole family was elated.

Because these were the Great Depression years, however, finances were a problem. The money Cutler had saved from selling beans was less than $100. His mother gave him $300 from Grandfather Chapin's estate, and his father obtained a loan from an insurance policy. Cutler thus had enough to start for the first year: $135 for room, $270 for board, $350 for tuition, and some money for supplies.

He learned of the WPI Scholarship for Yankee Ingenuity, endowed in 1928 by WPI 1895 alumnus Henry J. Fuller.

Seeking to secure one of these scholarships, Cutler worked day and night cleaning up his radio station, photographing and writing up the project. He did not win but was runner-up, and so received special attention at WPI from professors and employers.

The Worcester Tech Wireless Association, later named the WPI Radio Club (call sign W1YK), is reputed to be the oldest college radio station in the United States. Cutler joined the club and, partly because he was the only ham with a two-letter call, was elected to chair the Transmitter Committee; later he was elected club vice president and president. As committee chair, he was charged with getting the radio station on the air. He redesigned the station, and the school provided a pair of high-power (100 W) transmitter tubes.

Having successfully completed his freshman year, in the summer of 1934 Cutler worked as a chauffeur for T. Hovey Gage, a lawyer in Worcester, for $105 a month. On Memorial Day weekend he drove Mr. Gage to his summer residence in Waterford, Maine. It was a 180-mile, eight-hour trip, with a top speed of 12 mph on backroads, sometimes dirt roads. On entering the town, Cutler observed two attractive girls, and that evening, at a party of young people at the Wilkins Community House, he got to meet them. The most attractive of the two was Virginia Tyler.

That summer Cutler drove often to Maine, where Mr. Gage provided a room for him at a local inn, the Lake House. He got to know Virginia and they enjoyed time and some adventures together. They got married in Waterford on September 27, 1941.

Cutler graduated in 1937 with distinction (seventh in his class) with a degree in general science. He applied for employment at Bell Telephone Laboratories, but jobs were scarce in 1937—the economy had not quite recovered from the Depression, and the laboratories, to reduce costs, were open only four days a week. There were no openings in the research departments in New York City, but Cutler was offered a position at a branch laboratory in Deal, New Jersey, where research and development centered on shortwave radio, high-power transmitter tubes, new antenna designs, and ionospheric radio propagation—all areas close to Cutler's interests. His subdepartment head and later department head was John C. Schelleng, and among his close associates was James Wilson McRae, a recent PhD graduate from Caltech.

Cutler and McRae shared an office and transmitter lab. Assigned to design a high-power transmitter at 23 MHz using 25 kW experimental tubes, they used a feedback amplifier configured as the transmitter stage. Cutler called his first invention the "self-neutralized amplifier" because it balanced the internal tube capacitances, plate to cathode and grid to plate, against each other to prevent capacitive feedback. The grid and cathode were driven by the signals opposite each other in the optimum ratio. It proved to be stable, gave sufficient radio frequency feedback, improved linearity, and provided reasonable input impedance.

After gaining experience on the 25 kW transmitter tubes, Cutler and McRae embarked on the development of a 200 kW transmitter to operate at frequencies switchable from 4 MHz to 23 MHz with feedback over four stages of amplification. The objective was to provide 12-channel, single-sideband, multiplex telephony between the United States and England. They worked for two years until 1940, when Bell Labs was diverted to military work in preparation for war.

In 1940 Schelleng asked Cutler to work on the proximity fuse. The idea was to install a radio circuit in an explosive shell that would be shot from the ground toward an enemy airplane. The circuit would sense the proximity of the plane and send a signal to the ground to detonate the shell. Cutler designed the circuitry and tested the fuse at Aberdeen Proving Ground and Indian Point, both in Maryland. The project was shortened by the success of a self-contained triggering circuit.

Late in 1941 McRae and Cutler were asked to design and build waveguide plumbing for an X-band aircraft antenna. With advice from a number of experts, Cutler successfully built waveguide elbows, rotating joints, and connectors.

At that time one had to build one's own testing gear, including power supplies. McRae built the assembly according to their design and mounted one antenna on the second floor of the main building and another in a remote location. They were able to measure the directivity pattern and field intensity versus elevation angle and azimuth. They obtained good pattern in the E or H plane but had to adjust the structure between measurements. The beam width was about three degrees as required, but side lobes were one-tenth as strong as the main beam in one plane or the other, not close to the one-half percent power level required. Cutler hastily constructed more apparatus for measurements of amplitude, phase, and polarization of the radiation from the antenna feed. He tried various configurations of the assembly. Nothing seemed to work.

In the midst of this work McRae was called to Washington to guide the Army Signal Corps into the new age of radar. Cutler was left alone with the antenna project. "Late in the night, abed," he wrote in his notes, "it all came together in my mind. In the morning, I slapped my vision together with copper foil, solder, and sealing wax, and I had quite a different horn structure and a good radiation pattern. I slimmed down the waveguide and channeled the energy into two relatively narrow slots on each side of the guide. I called it the Waveguide Splitting Head. By varying its shape and size, I found a simple way to match the impedances."

It was indeed a novel, ingenious design of the antenna feed. The two slots were located exactly half a wavelength apart. The radiations from the two slots reduced the energy in the side lobes and reinforced the energy in the main beam. He used a screw in the splitting head to adjust field distributions in the two slots. It was simple—and reliable.

The waveguide antenna system, dubbed the "Cutler feed," was produced by the thousands and was aboard every Allied bomber in the latter part of World War II. Overnight Cutler became known as a radar expert and was consulted on various antenna designs. In the meantime he invented a variety of antenna feeds, including the corrugated waveguide, later used in microwave devices. When radar was unveiled to the public in 1945, an artist's rendition of the Cutler feed appeared in the August 20 issue of *Time* magazine.

In March 1944 with the war winding down, work began on the huge backlog that had accumulated in the telephone plant. AT&T announced a crash program to build an intercity microwave relay system from New York to Boston for both television and telephone signals. The system involved the construction of a series of radio relay stations about 30 miles apart with 3 MHz of bandwidth in 4 GHz channels. The close-spaced triode was selected for the repeater amplifier.

Cutler was then asked to study the circuit problems of the traveling wave tube (TWT; invented by Rudolph Kompfner [NAE 1966]) and to move his laboratory to the newly constructed research center in Murray Hill, NJ. The TWT faced several difficult technical problems, and there was a flurry of activities designed to overcome them. John R. Pierce (NAE 1965, NAS 1955) started the analysis and Cutler started the measurements.

For years TWTs had been made in a specialized shop where it took weeks to construct a single tube. Cutler longed to be able to make his own tubes. He studied vacuum systems and built his own pumping station. It was not easy. He used a thoriated tungsten cathode button heated white-hot by electron bombardment from another electrode in the tube. In a matter of hours he could open the vacuum chamber and change the parts.[1]

Calvin F. Quate (NAE 1970) joined Bell Labs in 1950 and Rudi Kompfner in 1951. By then Cutler was department head reporting to Pierce, who was now director.

Pierce deduced that noise on the electron beam due to thermal emission of electrons should appear as waves on the beam. It was not obvious at the time that anything as random as noise could propagate in the form of waves. Cutler and Quate set up an experiment to verify Pierce's theory. They projected an electron beam through the center of a toroidal resonant cavity in the newly designed pumping station; the cavity moved along the beam. They measured noise level excited in

---

[1] Cutler CC. 1951. The calculation of traveling-wave-tube gain. *Proceedings of the IRE* 39(8):914–17.

the cavity and found the waves predicted by Pierce. That was the famous Cutler-Quate experiment.[2]

Cutler learned about the digitization of prefiltered TV signals using pulse coding modulation up to seven or eight bits per sample. Because each picture amplitude sample was very much like the preceding one, he thought that if the difference in signal amplitudes were coded, it would require only a fraction of eight bits per sample—a substantial saving. He concluded further that if one quantized the difference between signals, some of the quantizing error would be compensated to yield a more accurate representation. Based on those ideas he invented differential pulse code modulation (DPCM), from which many coding schemes were derived over the years—predictive coding is used in digital TV transmission, fax machines, and medical imaging systems. Cutler then extended his work to pulse heterodyne radar, stereoscopic radar, and stereothermography.

The 1957 launch of Sputnik generated, at Bell Labs as elsewhere, a great deal of activity and enthusiasm for rocketry and spacecraft guidance and control. Cutler wrote a technical memorandum, "A Space Vehicle Communication System" and organized an ad hoc committee to study the components that would be necessary for a long-life radio repeater in an orbiting satellite. Their frequent meetings paved the way for the Telstar experiment,[3] soon followed by Project Echo.

Early in 1958 NASA was planning to orbit a 100-foot-diameter aluminized Mylar balloon to measure the density of the atmosphere in near space, and the agency was receptive to a passive communication experiment in space using the balloon for the reflector. Suddenly Project Echo was underway. The experiment required setting up a transmitter-receiver station at Bell Labs in Crawford Hill, NJ, and an identical station

---

[2] Cutler CC, Quate CF. 1950. Experimental verification of space charge and transit time reduction of noise in electron beams. *Physical Review* 80(5):875–78.

[3] Crawford AB, Cutler CC, Kompfner R, Tillotson LC. 1963. The research background of the Telstar experiment. *The Bell System Technical Journal* 42(4):747–51.

at the Jet Propulsion Laboratory Earth Station in Goldstone, California. The balloon would orbit in low altitude with regular passes over North America. Radio signals would be sent from one station into space, reflected by the balloon, and received by the other station. Dozens of people were involved at Bell Labs, JPL, NASA, and NRL.

By mid-1960 they had a commercial 60-foot-diameter paraboloidal transmitting antenna, a novel 20-foot horn reflector receiving antenna, and a 10 kW Varian Klystron tube for the transmitter for each ground station. The newly invented maser was used for the first time as the low-noise amplifier. On August 12, 1960, *Echo 1* was launched into space, with a plan to transmit and receive a recording of President Dwight Eisenhower's voice during the first pass of the balloon. It was a day filled with excitement. "I remember starting the tape with my own fingers," Cutler said later in the *WPI Journal*, "It was probably the most exciting period in my life, because everything had to be done on the second. We had to have that antenna pointed exactly right, because this thing is whizzing from horizon to horizon in just 20 minutes." Goldstone reported back, "It was coming in loud and clear." There were excited cheers from those in the control room. They had succeeded with the first experiment in space communication![4]

After Project Echo and the Telstar experiment, the world was ready for commercial satellite communications. The federal government created a semipublic corporation, the Communications Satellite Corporation, as the sole owner of this business.

Cutler was promoted to assistant director of electronics research (1959) and then director of electronics systems research (1963–71) and of electronics and computer systems research (1971–78). Over the years hundreds of scientists reported to him. He hung the organization chart upside down in his office to remind himself that those at the bottom of the chart were the important ones. After a 40-year career at Bell Labs he retired in 1979.

[4] Cutler CC. 1961. Radio communication by means of satellites. *Planet and Space Science* 7:254–71.

In 1975, as Quate and his students worked on the acoustic microscope, he invited Cutler to spend time at Stanford. The acoustic microscope, a novel device, operated on the same principles as the optical microscope except that acoustic waves at microwave frequencies were used instead of visible light. The image from the microscope was taken with a single on-axis spherical lens with limited numerical aperture. Cutler wanted to circumvent the limit imposed by the small numerical aperture of the single lens; he suggested a multibeam arrangement with several off-axis lenses distributed over a wide angle. The wavelets emerging from the lenses acted constructively to form a coherent beam with a large numerical aperture according to the Huygens principle.[5] The difference in the images with and without Cutler's arrangement was striking.

After his retirement from Bell Labs, Cutler became a professor of applied physics at Stanford University, where he continued to work on acoustic imaging. He also was active as a member of Sigma Xi and a fellow of the American Association for the Advancement of Science and IEEE. He chaired the IEEE Awards Board (1975–76) and was editor of *IEEE Spectrum* (1966–67).

For his extraordinary contributions he was elected to the National Academy of Engineering in 1970 and the National Academy of Sciences in 1976. From the Institute of Electrical and Electronics Engineers (IEEE) he received the Edison Medal (1981), Centennial Medal (1984), and, for "the invention and development of predictive coding of pictures and picture sequences," Alexander Graham Bell Medal (1991). He was awarded an honorary doctor of engineering degree by the Worcester Polytechnic Institute in 1975 and received its Robert H. Goddard Alumni Award for Outstanding Personal Achievement in 1982.

Cutler greatly enjoyed physical activity, was a Boy Scout leader, and loved taking his children on adventures, teaching

[5] Bond WL, Cutler CC, Lemons RA, Quate CF. 1975. Dark-field and stereo viewing with the acoustic microscope. *Applied Physics Letters* 27(5):270–72.

them survival skills and the virtues of the compass. With family members, colleagues, and friends he skied and hiked much of the Appalachian Trail, climbed Mt. Rainier and Mt. Katahdin, and, with a Swiss team, ascended to the top of the Matterhorn. Most winters he spent skiing on the slopes of New England, often near the vacation property he acquired in Waterford.

He passed away December 1, 2002, in North Reading, MA, two weeks short of his 88th birthday. He was survived by his wife, Virginia; their children C. Chapin Cutler Jr. and Virginia Raymond; and four grandchildren.

Chapin Cutler was admired for his passion to discover and his unbounded energy for work. He will always be a role model cherished by all of us who work in science and engineering.

Acknowledgments

I was asked by Andreas Acrivos (NAE 1977, NAS 1991) to write this memoir for the National Academy of Sciences and was overwhelmed by the help I received. Most of the materials were collected from Cutler's personal notes supplied to me by the family. Several pieces were written by his close associates, Calvin Quate, William C. Jakes, and Herwig Kogelnik (NAE 1978). Searching through his old records, John R. Whinnery (NAE 1965, NAS 1972) found a nine-page text written by Cutler on his early experiences at the labs. Kogelnik retrieved a collection of email messages between Cutler and Nick Sauer discussing the lab at Deal. Roger N. Perry Jr. provided the information about Worcester Polytechnic Institute back in the 1930s and 1940s. Bruce Wooley made Cutler's files at Stanford University available. Gary Boyd and Susan Feyerabend helped to locate Cutler's old papers left in the lab. I also obtained files from the Lucent Archives and the IEEE History Center. My daughter edited the English of the first draft; Quate edited the final version of the text. I thank in particular Patricia A. Tier, who assisted me in every phase of this project.