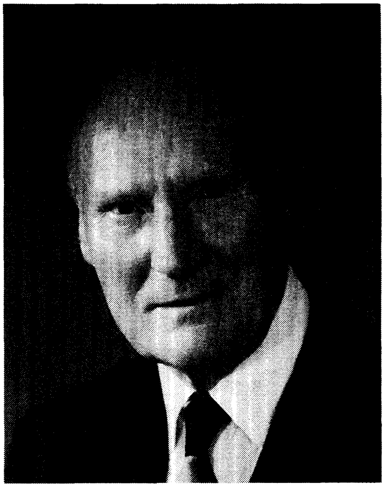

ERNST WEBER

Figure 1. Ernst Weber, first president of the IEEE, president emeritus of Polytechnic University, National Medal of Science winner, and current resident of Columbus, North Carolina.

CHAPTER 1

Bridger of Cultures

Ernst Weber as Researcher, Educator, and Statesman

> Young as I was, I hadn't yet understood at that time that life is the only school that counts, that its students are tested every hour of every day, and that providence calls on them to test their mettle. The limited opportunities at home, the desire to increase my knowledge, and an innate urge for action had made me cross the ocean and come to the US.

These lines come from the German author of travel and adventure stories, Karl May (1842–1912), one of the all-time best-selling authors of fiction in the world.[1] Though a popular writer, Karl May has won the esteem of many literary critics, and his books were an acknowledged influence on many German writers, including Robert Müller and Günter de Bruyn.[2] Among May's most popular novels were those set in North America, including *Winnetou* and *Der Schatz im Silbersee* (see Figure 2). These novels were full of accurate ethnographic and geographic detail, and they gave many European youngsters a strong desire to visit the New World. In 1912 one such youngster was Ernst Weber, a schoolboy in Vienna.[3] He recalls, "I practically ate up that literature; I had a great many of Karl May's works.... Already as a young boy I wanted to get to America."[4]

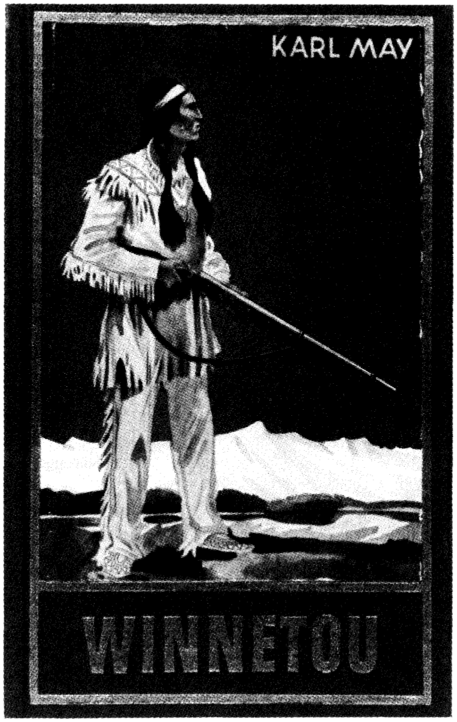

Figure 2. The cover of volume one of a 1951 reprinting of Karl May's Winnetou (Karl May Verlag, Bamberg). The novel first appeared in 1893.

Viennese Youth

Weber was born 6 September 1901 in Vienna, sixth largest city in the world and capital of the Austro-Hungarian Empire. His father, an employee of the Austrian railway system, encouraged his interest in things mechanical, giving him a construction set (trademarked *Steinbaukasten*) that came to be much used (see Figure 3). The boy was just turning thirteen when war broke out. The war—and, especially, the economic blockade of Austria that the Allies did not lift until late March 1919— caused severe hardship to the Viennese, and many starved to death. Weber, who helped his parents care for four younger sisters, remembers scouring the Vienna woods for anything edible.

After the war the family moved to a new apartment, one equipped with electricity. Weber recalls, "...the amazing thing, you push a button and the light comes on. One cannot describe the feeling."[5] Electricity seemed just short of magic and Weber made a hobby of building electrical gadgets, including a crystal radio.

But Weber had other interests. Like many Viennese at that time, he felt a *Drang zum Kulturellen* because the city, even after the demise of the empire, continued to be a world cultural capital. Franz Lehár, Richard Strauss, and Arnold Schönberg carried on in the traditions of Johann Strauss, Johannes Brahms, and Gustav Mahler. Vienna theater was at a

Figure 3. Ernst Weber with two of his sisters, Josephine (*left*) and Hilda circa 1910.

high point, presenting a great variety of plays, including those of native sons Franz Grillparzer and Hugo von Hofmannsthal. There were renowned artists and architects including Gustav Klimt, Oskar Kokoschka, Adolf Loos, and Joseph Hoffman; novelists such as Arthur Schnitzler and Stefan Zweig; and philosophers such as Ludwig Wittgenstein and the members of the Vienna Circle, whose logical positivism dominated academic philosophy for much of the century.

So it was easy for Weber to acquire a taste, which he has retained to the present, for music (especially Wagnerian opera), literature (above all, Goethe), and philosophy (primarily Schopenhauer and Nietzsche). The youth was also drawn to religion. Around 1920 he converted from the Catholic faith of his family to the Helvetic Confession, an undogmatic church whose roots go back to the sixteenth-century reformer Ulrich Zwingli.

Weber was an excellent student, helped by natural talents and remarkable industriousness. He learned languages easily, which later stood him in good stead as an immigrant to the United States and as an international ambassador for his professional organization. He taught himself shorthand to use in note-taking, and after graduating from high school he pursued a dual education, taking classes at both the humanistic university (*Universität Wien*) and the technical university (*Technische Hochschule Wien*, now *Technische Universität Wien*) and often running along the Ringstrasse the two or three miles separating the universities.

The cultural attractions and the variety of courses notwithstanding, Weber was not in doubt about his career choice. More than his hobby of electrical experimentation, it was the beauty and power of Maxwell's theory that made him decide on electrical engineering. In describing his university years, he said, "I loved Maxwell's theory! From the very beginning it was to me a marvel that you could, with a few mathematical symbols, describe what goes on."[6] What impressed Weber then and throughout his career was the usefulness of the equations, which, although expressed abstractly and mathematically, have "a tremendous power of direct physical interpretation."[7] In 1949 Weber wrote an introduction to a reprinting of Oliver Heaviside's 3-volume classic, *Electromagnetic Theory*. He wrote that a key to understanding Heaviside is his great admiration for Maxwell.[8] The same could be said of Weber.

At the technical university he chose the recently instituted program in electrical engineering, and in 1924 he received the engineering degree, thus becoming a *Diplom Ingenieur*. Though he then began full-time work, he continued his education at both universities. At the humanistic university he worked with the well-known physicist Felix Ehrenhaft and in 1926 completed a Ph.D. with a dissertation, based on Maxwell's theory, of the color produced by the diffraction of light by submicroscopic particles. In the following year he earned a Sc.D. at the technical university with a theoretical study of electric and magnetic field distributions.

WEBER: *. . . Since you could observe ultramicroscopic particles only by color specks, one needed to relate the color to particle size. The theory was developed by Mie. It's a classical theory of diffraction of light by submicroscopic particles. I used the theory, but I needed to explain color relating to size. From the electromagnetic field, Maxwell's theory, I could deduce the size and then, in a color triangle, relate the color that appears. And it happened that the color triangle gave a spiral for size and color relations. That explained that there were two [size] values for the same color.*

NEBEKER: *This work was entirely theoretical?*

WEBER: *Yes. . . . Another one of the same group had the assignment to carry out the experimentation. So we had additional evidence. . . .*

NEBEKER: *But you had no way, directly, to measure the size of these ultra-microscopic particles?*

WEBER: *No.*

NEBEKER: *Your confidence in your derivation came from the fact that it explained the discrepancy between Ehrenhaft's experiments and Millikan's?*

WEBER: *Yes.*

NEBEKER: *. . . How did you find the time to do this work while working for Siemens?*

WEBER: *Well, I was young. [Laughter]*

NEBEKER: *You were working a 40-hour week or so for Siemens?*

WEBER: *Usually.*

NEBEKER: *And then working evenings on this. Was that how it worked?*

WEBER: *Yes. And of course I had to use the slide rule—there was no computer at the time.*

NEBEKER: *There was a lot of calculation involved in all this work?*

WEBER: *Sure. In fact, I had to compute some of the Bessel functions for values that were not in the tables. I had the function tables of Jahnke-Emde—they were my lifesaver!*[9]

When Weber completed his engineering degree in 1924, jobs of any sort were extremely scarce in Austria. Fortunately, at his final oral examination, he so impressed one professor that the professor recommended him to the personnel manager of Siemens-Schuckert company. Siemens-Schuckert, based in Berlin, was one of the world's largest manufacturers of electrical equipment and had a major facility in Vienna. Invited to an interview, Weber was asked to look at the designs for some large generators, built for railroad electrification, whose operating efficiency was lower than expected. Weber noticed that the pole shoes were of massive iron and explained that losses could be reduced by using a laminated construction instead. This helped him to get the job of research engineer, and over the next five years he worked on the design of dynamos and electric motors. One of his assignments was to design motors for use in mines—DC motors that had to develop terrific starting moments.

In his work at Siemens, Weber constantly drew on his scientific training as he used conformal mapping and other techniques to calculate, for a variety of electrical machines, such things as mechanical forces, magnetic leakage, and the slot factor. He was fortunate in his choice of employer since the Siemens-Schuckert company was in the forefront of the effort to use electromagnetic theory to guide the design process. Werner von Siemens, the founder of the Siemens companies, believed strongly in the practical value of scientific training and research. At the Siemens-Schuckert facility in Berlin there was a development division headed by the illustrious engineer Reinhold Rüdenberg.[10]

After four years at Siemens in Vienna, Weber sought a job at the Berlin facility, which he believed would be a more challenging and stimulating environment. He was successful in this and in January, 1929, moved to Berlin, where he was design and research engineer at Siemens and adjunct professor in the department of electrical engineering at the technical university in Berlin-Charlottenburg. By the end of 1930 he had published eleven articles based on his work at Siemens; "Magnetic fields in synchronous machines under no-load conditions" and "The switching of magnetically saturated, separately excited direct-current machines" are two. They appeared in journals fostering the young science of electrical engineering: *Elektrotechnische Zeitschrift*, *Archiv für Elektrotechnik*, *Elektrotechnik und Maschinenbau*, and a research journal of the Siemens company. He also contributed to a conference that was a landmark in establishing ties between academia and industry; its proceedings, published in Berlin in 1932, were translated into English and published by MIT Press as *Theory of Functions as Applied to Engineering Problems*.[11]

United States Immigrant

Weber enjoyed the work at Siemens, but not the political atmosphere of 1930 Berlin. At this time the German economy was prostrate, and, in the view of many, war-reparation payments were holding it down. There were clashes in the streets between National Socialists (Nazis) and Communists while political moderates became fewer and fewer. The group Weber was part of at Siemens became absolutely polarized—those applauding the Nazis and those, like Weber, condemning them—and the two factions almost came to blows.

NEBEKER: *What impressions do you have of the Austrian and the German professional societies?*

WEBER: *Southern Germany, like Bavaria and regions along the Rhine, has an entirely different way of life and way of conceiving life than the northern part of Germany. The northern part is Prussian. They easily fall into regimentation. The southern people, no. The southerner is more like the Austrians, easy-going and absolutely no regimentation.*

NEBEKER: *Was that evident in these two professional societies?*

WEBER: *Yes, definitely. There were many sayings that illustrate that. A Prussian might say: "This is absolutely hopeless!" And an Austrian would say: "Yes, it's hopeless, but not impossible."*[12]

A chance acquaintance led to the offer of a one-year appointment to Polytechnic Institute of Brooklyn (later Polytechnic University) as a visiting professor in the electrical engineering department. Weber's strong desire to visit the United States—stemming from his reading of Karl May—and his unease in the German political atmosphere prompted his acceptance.[13] Granted a leave of absence from Siemens, he moved to New York City in the late summer. He recalls being shocked by the humid 90-degree heat in September and the prevalence of alcohol consumption (much greater than in Europe, and this in a country where the manufacture and sale of alcohol were unlawful).

But he found Polytechnic Institute much to his liking. It had an excellent EE program, and he was impressed with the students—"To a teacher this is the greatest compensation, that the students like what they do and want to learn"[14]—and with the New York area, which at the time was the center of radio engineering in the United States. So when, halfway through the academic year, he was offered a permanent position as research professor of electrical engineering (one of the first such professorships in the United States), he readily accepted.

The remarkable advances in engineering science in the interwar years, the increasing complexity of power networks and electrical machines, and the opening up of the realm of electronics engineering (not yet called that)—all these made employers more interested in engineers with graduate degrees.[15] Partly as a result, EE education began to make great advances, emerging from what have been called "the stagnant years" of 1900 to 1930.[16] It was in 1930 that Karl T. Compton, newly named to the presidency of MIT, began vigorously expanding graduate education at that institution. At about the same time, Frederick Terman began building an outstanding graduate EE program at Stanford University.

Weber too saw the need for graduate education in electrical engineering. Soon after his arrival at Polytechnic, he was placed in charge of graduate study in electrical engineering, for which he set high standards, both for the EE curriculum and for the faculty. His experience in industry had shown him the value of advanced training in mathematics and physics, and his experience in academia had convinced him that graduate training must be by people actively engaged in research.[17] When Weber had arrived at Polytechnic, all EE courses had to do with power engineering except for one radio course that was, as Weber says, "tolerated."[18] Weber immediately added a course on electromagnetic waves and saw to it that the usefulness of Maxwell's theory was emphasized in other courses.

Since few could afford to pursue a graduate education full time, Weber worked hard to expand an evening program that had begun at Polytechnic in 1926.[19] Most of his graduate students were simultaneously working in industry which had the advantage that they were, in general, more experienced, more motivated, and more demanding than "the day student who steps from his senior year into graduate study."[20] On the other hand, there was "the grave danger to consider as dissertation a well-written report on an assigned phase of a development program . . ." when "any good engineer would normally be expected to perform equally well just for his salary."[21] Weber always insisted that advanced degrees were more than that, and he jealously guarded the standards of achievement expected of the master's degree and doctorate. With each graduate student he visited the place of work and talked with the supervisor to ensure that the proposed project was the student's own work and that the company had no objection to the employee publishing a dissertation on his research.[22]

NEBEKER: *. . . in those years I take it the graduate program [at Polytechnic] did well?*

WEBER: *Terrifically! It grew by leaps and bounds. And it was in the middle thirties that a program of courses in engineering science, technology, and management was planned. A program to give background in electromagnetic theory principally, because in the U.S. at the time the main emphasis was on power. Communication engineering was very much subordinated. At Polytechnic there was one professor permitted to teach it. I say "permitted" because everybody else was concerned with power engineering and looked down on that playing about with little things.*

I found I learned an awful lot from my students [many of whom were working at Bell Laboratories]. Of course I knew general electrical theory; I knew magnetic circuits and electric circuits and so on well enough to realize what problems they had. Although I had started with generator design and so on, so I was also biased. I immediately became interested in propagation, partly because Maxwell's theory was an idol of mine. It was a remarkable synthesis of all electromagnetism. So along with the students I learned communication theory.

NEBEKER: *What do you mean by communication theory?*

WEBER: *The study of higher frequencies into the kilocycle range, then megacycle range. I gave courses in high-frequency analysis and so on. In fact, I laid out for Polytechnic a whole program of engineering science, technology, and management courses, with emphasis on ultrahigh frequency. That helped me in staying at Polytechnic during World War II—in spite of Radiation Laboratory trying to get everybody up*

> *to MIT—and in keeping my research group on ultrahigh frequency and, eventually, radar.*[23]

The result was that the program prospered, both in number of students and in esteem among engineers. Polytechnic awarded its first doctorate in electrical engineering in 1936. After Weber became department head in 1945, he introduced a grouping of courses for "electrophysics," which he defined as the application to electrical propagation and electrical devices of topics in theoretical physics and applied mathematics.[24] Under Weber's direction, the electrical engineering department grew steadily; by the late 1950s it comprised 38 percent of Polytechnic's total enrollment of 5500 undergraduate and graduate students in the nine fields of science and engineering at the school.[25]

Researcher of Ultrahigh Frequencies

In the 1930s Weber, interested in radio and television communication at high frequencies, investigated a part of the electromagnetic spectrum that had been little studied, the so-called ultrahigh frequencies (up to 600 MHz, which corresponds to a wavelength of 50 cm). He made studies of experimental electron tubes, some obtained from Bell Laboratories, for generating ultrahigh-frequency waves. With the outbreak of war and the need to develop effective radar systems, these and even higher frequencies (up to 10,000 MHz or 3 cm), which came to be called microwaves, suddenly assumed great importance. Weber decided to focus his efforts on techniques for accurately measuring frequencies, wavelengths, and power attenuation of microwaves.[26]

Radar—for airplane, ship, and submarine detection; for fire control; and for navigation—played a central role in World War II, but at the beginning of the war there was a need for an accurate and practical way to measure the power output of a radar transmitter and the sensitivity of a radar receiver. A radar transmitter might, because of a faulty tube or other malfunction, be emitting less power than the operator believed, in which case the range of detection would be less. So an operator might believe that he would detect any ship within fifty miles when the range of his radar was in fact thirty miles. The same effect could result from diminished sensitivity of the radar receiver.

Such problems could be discovered and corrected by frequent measurement of power output and of sensitivity, but at the outset of the war there were no simple ways to do this. Weber realized that an accurately calibrated attenuator, rugged enough to be used in the field, was needed. Working with Anthony Giordano and others at Polytechnic, Weber designed a coaxial device in which the inner conductor was a glass rod coated with a platinum–palladium alloy. In designing this device Weber used fundamental theory, especially as elaborated by himself and others in studies of the "skin effect," to calculate microwave resistance of thin films. Taking great care in the selection of materials and in the fabrication of the device, Weber's group soon succeeded in building an extremely durable instrument that was capable of precision measurement. When Weber demonstrated the device for Jerrold Zacharias of MIT's Radiation Laboratory, Zacharias asked if it was sturdy enough. Weber invited him to throw it on the floor, and when it did not break, Zacharias immediately ordered a thousand of them. Shortly thereafter Zacharias increased the order to ten thousand, and Weber saw the necessity of setting up a company to produce the attenuators.[27]

Thus in late 1943 PIB (Polytechnic Institute of Brooklyn) Products Company was founded. In the next several years it made attenuators of various types, each of which called for innovation in design and manufacturing. For example, when an attenuator for still higher frequencies was needed, Weber and colleagues developed an evaporative technique for depositing precisely controlled thicknesses of metal on glass. The work resulted in a score of patents, held jointly by Weber and colleagues. After the war the company, which in 1946 became Polytechnic Research & Development (PRD) Company, continued as a leading manufacturer of microwave components and instruments (see Figure 4).

Weber, who was director of PRD from its founding, also became president of the company in 1952. Running the company—its annual sales grew to $5 million—became increasingly demanding as the company grew, and Weber realized he had to make a choice between industry and academia. Since, as he says, "My heart was really in academic life,"[28] the decision was made in 1959 to sell PRD to Harris-Intertype Corporation. It continued under the name PRD Electronics as a division of that firm, and Weber worked as consultant to PRD Electronics from 1959 to 1981. The sale provided the first substantial endowment for Polytechnic.

NEBEKER: *Did PRD continue to grow after the war?*

WEBER: *Very much. We sold it in 1959 to the Harris-Intertype Corporation, and Harris-Intertype used it to build up its military-related business. They used to be a company for printing machinery, and they transformed eventually into a very large corporation, now called Harris Corporation. It's listed on the stock exchange.*

NEBEKER: *Who made the decision to sell?*

WEBER: *Well, it was really up to me as president of the company.*

NEBEKER: *I know that in 1952 you were named both president and director of PRD. But why sell? Things were going so well.*

WEBER: *Well, my heart was in teaching, and I realized that this decision* *comes for many people: Should they go industry or should they go academic? My heart was really in academic life. The other one was a transient phenomenon.*

NEBEKER: *You'd been doing that for quite a few years.*

WEBER: *Well, I started off with Siemens, so I had a kind of business indoctrination.*


POLYTECHNIC RESEARCH & DEVELOPMENT COMPANY, INC.

PRD Reports

APRIL 1953 Vol. 2 No. 1

NOISE FIGURE AND SOME MEASUREMENT ASPECTS

In its common usage, noise has an undesirable connotation. It denotes sound without meaning, harmony, or rhythm. The electrical phenomenon of random fluctuation has the quality of noise if it is translated into sound waves. Hence, the term was justified when it was first coined in the early days of radio. Today we can see noise on the television screen as well as hear it.

The reduction of noise level has assumed popular significance when manufacturers of television receivers started using this as a factor in advertising. With the general acceptance of the concept of noise figure as a measure of the merit of a receiver, it is important that engineers have a knowledge of the equipment types available for measuring this important quantity.

Thermal agitation and shot noise are the two main sources of random fluctuation manifest in radio receiving equipment. Shot noise is distinguished from thermal agitation noise in that it is caused by an unidirectional stream of electrons having a random velocity distribution.

Atmospheric and man made noise are forms of disturbance which are not random in the strict sense of the term. Rather, the disturbance is sporadic and originates outside the receiving system; hence, it may be regarded as a form of external interference. Its consideration does not fall within the scope of the present discussion and will not be treated further.

It is readily appreciated that the inevitable presence of noise sets an ultimate limit to the receiver's useful sensitivity. Threshold signals, comparable in amplitude to noise, are subject to its masking effect, and if the noise power exceeds that of the signal by a large enough factor, the signal will be rendered unintelligible.

In the absence of any noise contributed by the receiver, the noise power at the output of the receiver would be equal to the product of the input noise power, due to the generator or antenna radiation resistance, and the power gain of the receiver. In practice, however, the total output noise power exceeds this irreducible minimum by a factor called the noise figure, which depends on the receiver noise properties. The significance of noise figure is to be found in the fact that it fully defines an important characteristic of a receiver without reference to the magnitude of the noise present or the bandwidth of the receiver.

Figure 1. A Commercial Diode Noise Source, the PRD Type 904 VHF-UHF Noise Generator. The instrument utilizes a temperature limited coaxial type diode which permits noise figure measurements in the frequency range from 10 to 1000 mc/s. The output noise power is continuously adjustable up to a level 20 db above the noise from a reference 50 ohm resistor.

Noise Sources

In recent years, measurement of receiver sensitivity has been done increasingly by means of noise sources. Prior to the advent of suitable noise sources, receiver noise measurements were made with calibrated signal generators. Not only is the signal generator method of noise measurement cumbersome, but it also suffers from inaccuracies which are difficult to overcome.

The signal generator technique calls for the measurement of the noise bandwidth of the receiver. This measurement is very time consuming if reasonably accurate results are required. Furthermore, the accuracy of the low level calibration of high frequency signal generators is generally open to question. Usually, this calibration is the result of extrapolating a theoretical law of the attenuator

(Continued on page 3)

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Figure 4. The first page of a 1953 publication of Polytechnic Research & Development Company. The photograph shows a noise source manufactured by PRD.

NEBEKER: *But you worked many years with PRD, from the early war years all the way to '59. Was it getting to be a strain running PRD, teaching, being a college administrator, and doing research simultaneously?*

WEBER: *Oh, yes. Because I had to project for the company money to* *operate. When they sold the company, I think we had a business volume of $5 million.*

NEBEKER: *Annual sales?*

WEBER: *Yes. Because eventually we had a monopoly. Hewlett Packard only came into that with the War Department giving them all our drawings. This is why Bill Hewlett and Dave Packard are very good friends still.*[29]

Though dedicated to academia, Weber maintained ties to industry. In 1942 Polytechnic began offering off-campus courses at electronics companies, and in that year Weber taught linear transient analysis at the Sperry Gyroscope Company in Lake Success, Long Island.[30] Besides such work and his continuing association with PRD Electronics, he was a member of the Joint Technical Advisory Committee of the Institute of Radio Engineers and the Electronics Industry Association for most of the period from 1954 to 1962 and was a member of the New York State Advisory Council for the Advancement of Industrial Research and Development from 1959 to 1969. He was also a consultant to the military, serving on the Army Scientific Advisory Panel (1957 to 1969), the Defense Science Board (1963 to 1966), and the Army Electronics Command Advisory Group (1965 to 1970). In 1969 the US Army presented him with the Outstanding Civilian Service Award.

The research group Weber organized at Polytechnic early in the war became the Microwave Research Institute (MRI) in 1945, and Weber served as director until 1957. Weber's work in this area was well-known even before the war, and in 1941 he turned down an invitation to join MIT's Radiation Laboratory, where much of the wartime development of radar took place. He did, however, become a Rad Lab employee for a short time just after the war. This was to write up material on microwave measurements for the famous Rad Lab series of texts that were used as reference works by microwave engineers throughout the world.[31]

In the postwar years MRI became one of the leading centers of microwave research, and the research group received government recognition when Weber, in 1948, was awarded the Presidential Certificate of Merit. Between 1942 and 1956 MRI was awarded 86 research contracts with the federal government, totaling more than $5 million(see Figure 5).[32] Besides directing the institute and publishing technical papers himself, Weber organized the well-known Microwave Symposia from 1952 to 1959. These were annual international gatherings of leading microwave researchers, and the published proceedings were extremely useful as compendia of recent results. For these and other efforts, Weber was honored in 1977 with the Microwave Career Award of the Microwave Theory and Techniques Society. In 1986 MRI was renamed the Weber Research Institute.

Educator and University President

In the decade following World War II, college enrollments increased markedly and interest in electrical engineering, especially in what was bythen called electronics engineering, became intense. Indeed, in the postwar decade the number of EE graduate students in the United States increased tenfold.[33] One of the largest graduate programs in the country was Polytechnic's, which was under the direction of Weber.

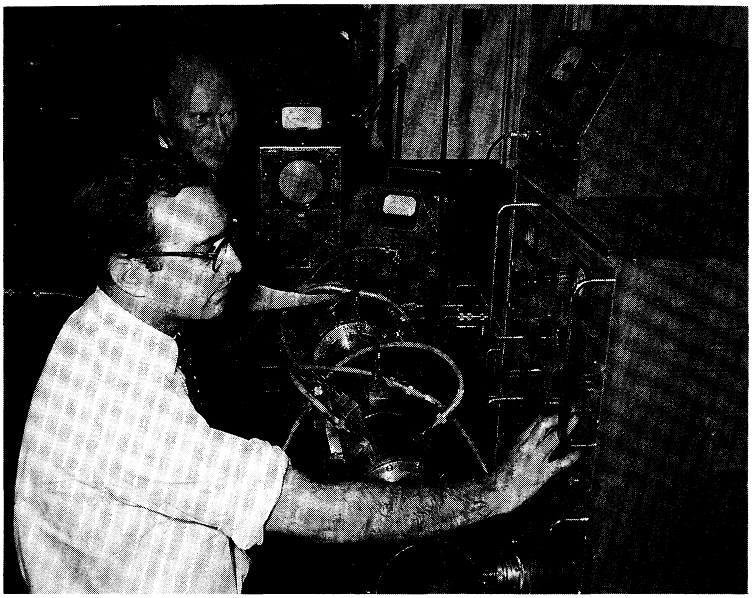

Figure 5. Weber and another member of the Microwave Research Institute observe measurements of the transmission of high-frequency waves in a waveguide.

Weber's involvement in research and in directing PRD caused no apparent diminution of his efforts as educator, and he has always taken pride in the success of his students, who include Leo Felsen, Anthony Giordano, and Nathan Marcuvitz.[34] In the postwar decade Weber wrote two widely used textbooks. The first, *Electromagnetic Fields, Theory and Applications* (published in 1950), was a mathematically rigorous treatment that suited the needs of engineers by considering applications and by including lengthy chapters on experimental mapping methods and on graphical and numerical plotting methods. The book was so well received that it was republished in 1965.[35] His other text was a two-volume treatment of linear transient analysis (published in 1954 and 1956).[36] Here Weber made clear the great value for circuit analysis (particularly when high frequencies or power surges are involved) of a mastery of the underlying field concepts—that is, of Maxwell's theory.

Weber also authored a score of articles on engineering education. He has been a member of the American Society for Engineering Education (ASEE) since 1935 and was instrumental in establishing its graduate studies division. The ASEE, embracing as it does electrical, civil, mechanical, chemical, and other branches of engineering, was a welcome forum for Weber, as he has long argued for greater cooperation between the various engineering fields. After pointing to new areas of engineering such as nuclear energy, aerospace, and biomedical instru mentation and prosthetics, Weber argued, "The lines of demarcation between the engineering disciplines, so easily drawn in 1933, have become diffused and have made the plea for solidarity of the profession not only desirable but, in fact, the only sensible one."[37] Weber also has argued for a broad education for engineers: ". . . the pressure is now for even broader education beyond engineering to include the disciplines involved in the decision-making process concerning the interaction of exploitation of technology and the effects of it upon society and its environment."[38]

In 1960 Weber was awarded the Education Medal of the American Institute of Electrical Engineers "for excellence as a teacher in science and electrical engineering, for creative contributions in research and development, for broad professional and administrative leadership, and in all, for a considerate approach to human relations." Weber feels strongly the lack, in the United States, of established standards of education. Whereas the German *Maturitätszeugnis* (a certificate awarded on passing the high school final examinations) means the same regardless of the institution awarding it, an educational degree in the United States can be evaluated only with reference to the institution. Weber laments that in this country it is, for the most part, up to individual teachers to maintain educational standards.[39]

The active role Weber assumed in institutional affairs at Polytechnic Institute, where he demonstrated an ability to organize collective efforts and to motivate individuals, led to his appointment in 1957 as the first vice president for research; later that year he became president (see Figure 6). In his inaugural address he expressed his educational philosophy: "No longer can the engineer just be equipped with skills, as it appeared desirable even twenty-five years ago. Today we must educate *scientific engineers*, well-founded in the fundamental laws of science and able to keep pace with new scientific developments."[40]

Weber served as president of Polytechnic from 1957 until June 1969, when he was elected president emeritus and professor emeritus. During those years, Polytechnic underwent a remarkable growth in university facilities, in academic programs, and in number of students. Soon after assuming the presidency, Weber directed the move to a new campus facing Jay Street in Brooklyn. A further expansion followed in the early 1960s when a campus exclusively for research and graduate studies was opened in Farmingdale, Long Island. Besides affording Polytechnic much needed space, the new facility made possible even closer ties between the university and industry, since many high technology companies were located nearby. Through an Industrial Research Associates Program, Polytechnic made consulting services, conferences, and seminars available to companies in the area; a Continuing Professional Studies Program was established to offer instruction—in intensive two-week sessions and in short courses—to company executives and engineers.

Weber's principal goal as president was to make Polytechnic a leading university for both research and graduate education in engineering and science. The success of this effort is indicated by the growth of the graduate programs. While the number of bachelor's degrees awarded annually remained fairly constant, the number of master's degrees increased from 150 in 1958 to 470 in 1970 and the number of doctoral degrees increased from 36 in 1958 to 108 in 1970. In the same period, the number of Ph.D. programs increased from seven to sixteen.[41] The success is indicated also by the high standing the university had achieved by the time Weber

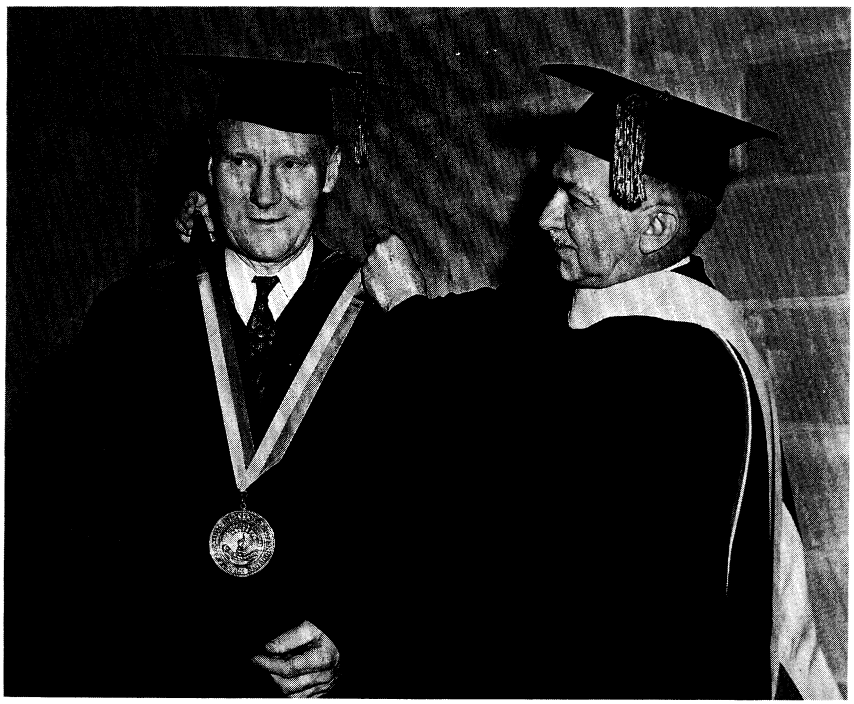

Figure 6. Weber's investiture as president of Polytechnic Institute of Brooklyn by Preston R. Basset, chairman of the Board of Trustees.

stepped down as president: A study conducted by the American Council on Education rated the graduate EE program at Polytechnic as sixth in the nation in quality of faculty and eighth in effectiveness of program.[42]

NEBEKER: *I know you had a lot of Japanese students.*

WEBER: *Yes. We had students from all over the world, in fact.*

NEBEKER: *How do you explain that?*

WEBER: *Because of our leadership during the war in radar. Also our symposia that started in '52. They helped a tremendous amount. . . .*

NEBEKER: *How did finances go in those years for Poly?*

WEBER: *Well, we established that Alumni Fund where alumni contributed rather substantially. . . .*

NEBEKER: *And you were able to expand in those years?*

WEBER: *Yes.*

NEBEKER: *Of course in those years you were also very active in professional societies, president of IEEE, for example. It must be very natural for someone to say, "Okay, now I just can't continue doing all these different things. I'll have to concentrate my energies."*

WEBER: *I just felt there are so many opportunities to do something that I wanted to use some of them. I probably shouldn't say this, but a member of the faculty called my period as president the* Blütezeit, *meaning the bloom period. So although I was president of the faculty, I knew them well enough to know both their strengths and their weaknesses. So this gave me greater power.*

NEBEKER: *To strengthen the faculty?*

WEBER: *Yes, we got very excellent faculty members at that time.*[43]

Contributor to the Science and the Profession of Electrical Engineering

Since his days at Siemens when he used conformal mapping and Maxwell's equations to solve problems of practical engineering, Weber has advocated the greater use of mathematics and physics in engineering. In 1937, perceiving a great interest in physics among members of the American Institute of Electrical Engineers (AIEE), Weber organized the Basic Science Group of the New York AIEE Section, which sponsored a series of lectures aimed at bringing more physics into engineering.[44] Weber himself maintained ties with the physics community—he joined the American Physical Society (APS) in 1931 and was named an APS Fellow in 1946. He was also for many years a member of the American Mathematical Society, and he has been active in the New York Academy of Sciences and the American Association for the Advancement of Science.

Another of Weber's abiding concerns was for the units and standards of electrical engineering. When he was working in Berlin, Weber was an active member of the *Ausschuss für Einheiten und Formelgrössen* (Commission on Units and Standards). He had already published two articles on electrical units when he was asked to write the section entitled "Physical units and standards" of the widely used *Handbook of Engineering Fundamentals* (1936).[45] His contributions in this area were honored in 1966 with the award of the Howard Coonley Medal of the American Standards Association.

Related to this concern was Weber's work on techniques of measurement. In his investigations of microwaves, he built attenuators, wave meters, and frequency meters. Indeed, shortly after the outbreak of World War II he delivered an attenuation standard for microwaves to the National Bureau of Standards. In both the AIEE and the Institute of Radio Engineers (IRE) he served as chairman of instrumentation and measurement committees.

Weber has contributed to his profession in many other ways. Since joining the *Österreichischer Verband für Elektrotechnik* (Austrian Association of Electrical Engineers) in 1923, Weber has been active in professional organizations. He joined the AIEE in 1931, was named a fellow in 1934, and served on many committees. He played an even larger role in IRE affairs, including ten years as a director (1952–1962) and terms as president (1959) and vice president (1962).[46] Like their successor (IEEE), the AIEE and the IRE were largely volunteer organizations, which succeeded only because members willingly gave of their time and energy. Weber, to an unusual degree, felt a social obligation to his professional organizations:

> Any social institution *is* what its members make it! If its members do not care, if they let "the others" worry, let "the others" be the fools to work—then that institution, however great it might appear at the moment, is *doomed*; it will crumble and disappear. If, on the other hand, there are enough members who *actively* support the institution, who freely devote time and effort to its tasks and obligations, who share in the belief of a common goal and of common interests in higher achievements, then that institution will grow strong and prosper.[47]

Weber also felt strongly that engineers are part of an international community, and he personally maintained a great many international ties.[48] (See Figure 7.) He was, for many years, a member of the US National Committee of the International Union of Radio Science (URSI), and is an honorary life member of URSI. In the late 1930s and early 1940s, Weber assisted Jewish refugees in finding positions in the United States. He regretted that Polytechnic was not then able to create new positions: "If I had had at that time real money, I could have built up a faculty unequaled anywhere."[49] In 1961 he was one of five past presidents of IRE sent to Europe to visit existing sections and create interest in new ones.[50]

On the first day of 1963 the Institute of Electrical and Electronics Engineers came into existence by the merger of the AIEE and the IRE.[51] These were two large organizations—AIEE had almost 70,000 members, IRE over 100,000, and together they published 39 journals—having different procedures and traditions. Their amalgamation was viewed nervously by many members. The joint merger committee "agreed that the first president would set the tone to be followed" andselected Ernst Weber for the position. John D. Ryder, one of the IRE representatives on the committee, said, "I don't remember any other name ever being discussed."[52]

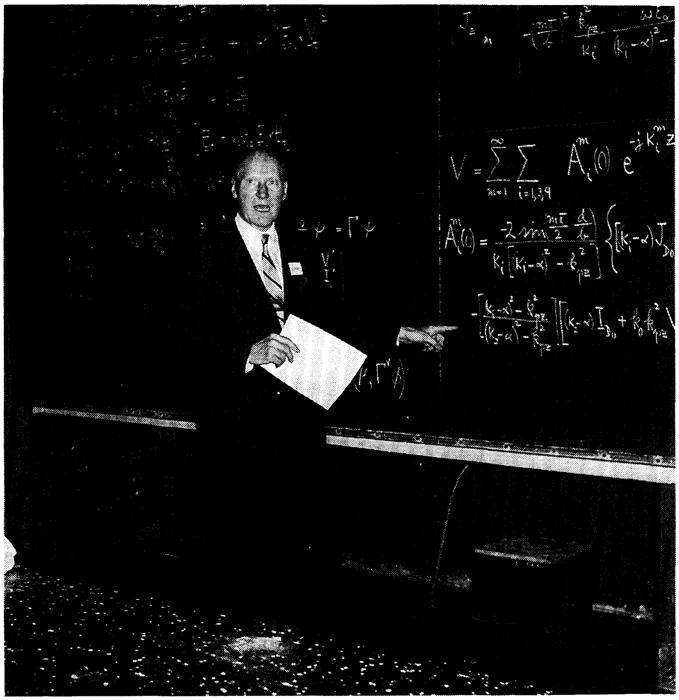

Figure 7. Weber lecturing during a 1954 visit to France. Weber, who could speak French, gave talks in France on several occasions.

In his year as president, Weber played a large part in the countless compromises necessary to make one organization of two. He had long been active, and was held in high regard, in both AIEE and IRE, and he had the skills of a mediator required for that difficult job. Clarence Linder, one of the AIEE representatives on the merger committee, recalled that Weber's "nature was to draw the parties together and try to have them work out their differences. . . ."[53] In 1963 Weber visited more than 40 of the 120 IEEE Sections, always conveying the feeling that the merger would be successful. He also made a two-month trip (at his own expense) around the world to stimulate interest in forming IEEE Sections abroad; in this he was helped by his many former students, quite a few of whom had attained positions of prominence in their native countries. Indeed, in Japan, Polytechnic had an alumni group.[54] Weber remained on the IEEE Board of Directors until 1965, and in 1971 he was honored with the IEEE Founders Award "For leadership of great value to the profession."

Weber has served his profession in other ways. He was a member of the New York Electrical Society from 1941 to 1954 and president in 1946 and 1947. From 1964 to 1972 he served on the board of directors of the Engineers' Council for Professional Development, and from 1968 to 1970 he was president of the Council. In 1978 he was honored by the Engineers' Council for Professional Development with the L.E. Grinter Award.

In 1964 Weber was named a founding member of the National Academy of Engineering, and he was also elected to the National Academy of Science. These two academies serve both the government and society in general by providing scientific and technical advice through the National Research Council (NRC). On Weber's retirement from Polytechnic in 1969, he was named chairman of the NRC's Division of Engineering. He agreed to give seventy percent of his time to this job and leased an apartment in Washington, which became his primary residence for the next nine years. He oversaw the NRC investigations of such issues as standards for fire safety, the possibility of earthquake prediction, and motor vehicle pollution. His constant concern was to see that all views were considered, and he was especially cognizant of the danger of industrial bias within investigative committees. After five years as chairman of the Division of Engineering, he served four years, part of the time as acting director, on the NRC's Commission on Sociotechnical Systems.

In this work Weber was following his own precept that "the engineer must assume a greater responsibility in the socioeconomic and political spheres of society. . . ."[55] In an article entitled "The engineer's responsibility to society," Weber quoted J. Douglas Brown, dean of the faculty at Princeton University: ". . . the engineer must be cognizant of the needs and aspirations of mankind while interpreting and implementing the knowledge science has discovered. The professional engineer must . . . be a bridge between the two worlds of science and humane values."[56] Weber was doing just this when, during his tenure as president of Polytechnic, he worked to establish at the university a Center for Urban Environmental Studies, which sought to improve urban transportation, to reduce air pollution, to optimize the structure of local government, and to upgrade urban communications systems.[57]

Bridger of Cultures

Through most of his career, Weber had the constant support of his wife Sonya. His first marriage, to Irma Linter, who came from the same neighborhood in Vienna, ended after eight years in 1933. Three years later he married Charlotte Sonya née Escherich, who had two daughters by a previous marriage. Sonya, also a native of Vienna, was the daughter of Theodor Escherich, a pediatrician and bacteriologist famous for the discovery of the intestinal bacteria named after him, *Escherichia coli*. Sonya's earlier marriage was to Hugo Eisenmenger, an Austrian engineer who had settled in the United States.

Sonya Weber became well known as a physiotherapist—she had earned a doctorate in physiotherapy in 1934—and was for many years a director of the children's clinic of the Presbyterian Hospital in New York City. She was in demand as a lecturer on physical fitness, and Ernst was in demand as speaker at IRE and AIEE meetings, so on many occasions the couple traveled together to give lectures in the same town. On the occasion of the establishment of the Sonya and Ernst Weber Scholarship Fund in 1975, James Flack, son-in-law of Sonya, said, "This scholarship fund in their names together is most fitting. They live and give of themselves as one. They have the same objectives, the same high standards. Each is the other's greatest supporter."[58] Sonya, who died in 1984, is lovingly remembered in a book that Weber wrote entitled, *A Brief History of the Family of Sonya Escherich-Eisenmenger-Weber*.[59]

Ernst and Sonya's acquaintance came about through a chance meeting, and it was also a chance meeting that led to Weber's invitation to come to the United States. Reflecting on these and other events in his own life, Weber has commented that few people sufficiently appreciate how much their lives are shaped by chance. The truth of that notwithstanding, it is certainly the case that Weber, like a Horatio Alger hero, benefited from many chance meetings partly because he made a very favorable impression on people. Colleagues describe him as a perfect gentleman, forward-looking and wise, holding to the highest standards of personal integrity and exercising a quiet leadership.

Weber's productive career as practicing engineer, researcher, educator, and leader in his profession has been abundantly honored. To the many distinctions already mentioned may be added his election to the American Academy of Arts and Sciences and his receipt of honorary doctorates from six institutions.[60] For his pioneering research in electromagnetic fields, linear and nonlinear circuits, and microwave measurements, Weber was awarded the National Medal of Science by President Reagan in 1987.

Throughout his life Weber has worked to build bridges between different cultures: between European electrical engineering and American electrical engineering, between industry and academia, between engineering and physics, and between the AIEE and the IRE. He has also provided a bridge from past to present with his longevity and continued activity and with his appreciation of the achievements of the past, manifested in his historical writing.[61] What is more, he has provided a bridge to the future through his students and the hundreds of others deeply influenced by him and through the professional and educational institutions that he helped sustain and give new life. According to Anthony Giordano, a colleague and friend of Weber's for over sixty years, Weber is exceptional in always looking to the future, searching out the potential of individuals and institutions and seeking ways to realize that potential, and in motivating people by providing them with an optimistic outlook on life that they did not have before.

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[1] *The New Encyclopaedia Britannica* (1991), vol. 7, p. 969. The quotation is from Michael Shaw's translation of *Winnetou* (New York: Seabury Press, 1977), p. 4.

[2] Suzanne Tyndel, "Karl May," in Walther Killy, ed., *Literatur Lexikon* (Gütersloh: Bertelsmann Lexikon, 1990), vol. 8, pp. 26–28, and Roland Smith, "Günter de Bruyn and *Neue Herrlichkeit,*" in Arthur Williams, et al. (eds.), *Literature on the Threshold: The German Novel in the 1980s* (New York: Berg Publishers, 1990), pp. 77–90.

[3] The information about Ernst Weber contained in this article comes mainly from the following sources: (1) an extensive oral history interview of Weber conducted by the author 11–12 April 1991 (from which an edited transcript has been prepared); (2) Weber's published writings; (3) copies of personal papers provided by Weber to the author; and (4) the tapes and transcript of an interview of Weber conducted by Trudy Bell and Don Christiansen on 9 March 1988. (Items 1, 3, and 4, as well as a full list of Weber's publications, are available at the IEEE Center for the History of Electrical Engineering.) For assistance with this and other chapters of the book, the author would like to thank William Aspray and Andrew Goldstein. An earlier version of this article appeared in *Proceedings of the IEEE*, vol. 81 (1993).

[4] Interview 1991, p. 34.

[5] Interview 1991, p. 11.

[6] Interview 1991, p. 12.

[7] Ernst Weber, "Historical notes on microwaves," *Proceedings of the Symposium on Modern Advances in Microwave Techniques* (New York: Polytechnic Press, 1954), vol. IV, pp. 1–23.

[8] Ernst Weber, "Oliver Heaviside—biography," introduction to Oliver Heaviside's *Electromagnetic Theory* (New York: Dover Publications, 1950), pp. xv–xvii.

[9] Interview 1991, pp. 16–17.

[10] Sigfrid von Weiher and Herbert Goetzeler, *The Siemens Company—Its Historical Role in the Progress of Electrical Engineering 1847–1980*, second English edition (Berlin: Siemens, 1984), p. 42; Sigfrid von Weiher, "Reinhold Rüdenberg," *Dictionary of Scientific Biography*, vol. XI (1975), pp. 588–589. Rüdenberg studied electrical and mechanical engineering at the Technische Hochschule in Hannover, where he earned a doctorate in 1906. After a

period as assistant to Ludwig Prandtl in Göttingen, he went to work in 1908 for Siemens-Schuckert in Berlin. His more than 300 patents speeded the development of engineering practice, and his more than 100 publications contributed to the establishment of the science of electrical engineering. His textbook on electrical switching processes (first edition, 1923; fourth edition, 1950) is a classic.

[11] P. Rothe, ed., *Funktionentheorie und ihre Anwendung in der Technik* (Berlin: J. Springer, 1932). The English translation was published by MIT Press in 1935.

[12] Interview 1991, p. 29.

[13] Ernst Weber, *A Brief History of the Family of Sonya Escherich-Eisenmenger-Weber* (Tryon, NC: M.A. Designs, 1990), p. 69, and Interview 1991, p. 22.

[14] Interview 1991, p. 38.

[15] See Ernst Weber's "The future role of graduate study in engineering" in *Journal of Engineering Education*, vol. 45 (1954), pp. 236–239; and Chapter 6, "The new world of electronics engineering," in A. Michal McMahon's *The Making of a Profession: A Century of Electrical Engineering in America* (New York: IEEE Press, 1984).

[16] John D. Ryder, "The way it was," *IEEE Spectrum*, vol. 21, no. 11, 1984, pp. 39–43.

[17] Ernst Weber, "Types of graduate subsidy and their relation to educational values," *Journal of Engineering Education*, vol. 44, 1953, pp. 188–191.

[18] Interview 1991, p. 31.

[19] Ernst Weber, "The challenges in the development of graduate programs," *IRE Transactions on Education*, vol. E-2, 1959, pp. 39–43.

[20] Ernst Weber, "The future role of graduate study in engineering," *Journal of Engineering Education*, vol. 45, 1954, p. 238.

[21] Ernst Weber, "Types of graduate subsidy and their relation to educational values," *Journal of Engineering Education*, vol. 44, 1953, pp. 188–191.

[22] Interview 1991, p. 68.

[23] Interview 1991, pp. 46–47.

[24] "Electrical engineering at Polytechnic" in *State-of-the-Art and the Future of Electrical Engineering* (program for "A Symposium Celebrating the Centennial of Electrical Engineering at Polytechnic University and Honoring Dr. Ernst Weber on his 85th Birthday, September 22–24, 1986").

[25] Ernst Weber, "The challenges in the development of graduate programs," *IRE Transactions on Education*, vol. E-2, 1959, pp. 39–43.

[26] "Ernst Weber," autobiographical article in *McGraw-Hill Modern Scientists and Engineers* (New York: McGraw-Hill, 1980), vol. 3, pp. 283–284.

[27] Most of the information in this and the preceding paragraph comes from an unsigned article entitled "A story of one of Poly's wartime research programs—attenuators" in the July 1946 issue of *Poly Men* and from a lengthy press release from Polytechnic headed "for release Saturday P.M.,

June 8th and Sunday A.M., June 9th" (no year is given, though it was probably 1946).

[28] Interview 1991, p. 58.

[29] Interview 1991, pp. 66–67.

[30] "Polytechnic's educational programs in cooperation with industry" in *State-of-the-Art and the Future of Electrical Engineering* (cited above).

[31] Chapter 12 ("Resistive attenuators"), coauthored with R. N. Griesheimer, and Chapter 13 ("The measurement of attenuation"), of *Technique of Microwave Measurements*, vol. 11, Radiation Laboratory Series (New York: McGraw-Hill, 1947).

[32] *Report from Polytechnic Institute of Brooklyn*, vol. 1, no. 3, February 1956.

[33] Ernst Weber, "The challenges in the development of graduate programs," *IRE Transactions on Education*, vol. E-2, 1959, pp. 39–43.

[34] Leopold B. Felsen, winner of the IEEE Heinrich Hertz Medal and member of the National Academy of Engineering, was named a Fellow of the IRE "For contributions to electromagnetic theory and measurement." Nathan Marcuvitz, who also is a winner of the Heinrich Hertz Medal and member of National Academy of Engineering, was named an IRE Fellow "For fundamental contribution to the solution to microwave field problems." Anthony B. Giordano, honored as an IRE Fellow "For his contributions to microwave measurements and modern communication curricula," has served as a Director of IEEE and as President of the American Society for Engineering Education.

[35] *Electromagnetic Fields—Theory and Applications*, vol. 1: *Mapping of Fields* (New York: John Wiley, 1950); republished as *Electromagnetic Theory: Static Fields and Their Mapping* (New York: Dover, 1965).

[36] *Linear Transient Analysis*, 2 vols. (New York: John Wiley, 1954 and 1956); volume 1 is subtitled *Lumped-Parameter Two-Terminal Networks*, and volume 2 is subtitled *Two-Terminal-Pair Networks, Transmission Lines*.

[37] Ernst Weber, "The engineer and society," *Electrical Engineering*, vol. 82, 1963, pp. 438–441.

[38] Ernst Weber, "Science and societal engineering," *Proceedings of a Symposium on Submillimeter Waves* (Brooklyn, NY: Polytechnic Press, 1971), pp. xiii–xix. See also Weber's "Technological challenges to educating engineers," *IEEE Spectrum*, vol. 2, 1964, pp. 119–120.

[39] Interview 1991, p. 83.

[40] "Inauguration and dedication ceremonies, April 19, 1958," Polytechnic Institute of Brooklyn.

[41] Most of the information in this and the preceding paragraph comes from a 12-page manuscript, "Dr. Weber's contributions as President of Polytechnic" (1992) by Anthony B. Giordano, a copy of which is available at the Center for the History of Electrical Engineering.

[42] Allan M. Cartter, *An Assessment of Quality in Graduate Education*

(Washington, DC: American Council on Education, 1966), pp. 74–75. Polytechnic was also ranked nationally in chemistry (faculty "Strong," program "Acceptable plus"), physics (faculty "Adequate plus," program "Acceptable plus"), chemical engineering (faculty "Good," program "Acceptable plus"), and mechanical engineering (faculty "Good," program "Acceptable plus"). (Faculty were classified as Distinguished, Strong, Good, Adequate Plus, or "not grouped"; programs were classified as Extremely Attractive, Attractive, Acceptable Plus, or "not grouped.")

[43] Interview 1991, pp. 87–88.

[44] For example, in the winter of 1941/42 the Basic Science Group presented a series of lectures by six different engineers, including Weber, on nonlinear circuit theory, and the following year Weber gave all six lectures in a series on ultrashort electromagnetic waves.

[45] Ovid W. Eshback, ed., *Handbook of Engineering Fundamentals* (New York: John Wiley, 1936). Weber's earlier articles were "A proposal to abolish the absolute electrical unit systems," *Transactions of the AIEE*, vol. 51, 1932, pp. 728–742, and "Ein Vorschlag zur Lösung des Problems der Electrischen Einheiten-systeme," *Elektrotechnik und Maschinenbau*, vol. 50, 1933, pp. 45–51. Weber was also the author of the section on radiation and light in *Handbook of Engineering Fundamentals*, and Weber prepared revised versions of his two sections for the second edition of this handbook, which appeared in 1952.

[46] He was a Director from 1952 to 1962, President for 1959, and Vice President for 1962. A listing of his service on IRE committees is impressive: AdCom of Board of Editors 1951; Annual Review 1950–51; Appointment 1959–61; Awards 1952–54, Chairman 1953–54; Awards, Coordination 1958; Board of Editors 1949–53; Circuits 1949–53; Editorial Administrative 1949–51; Education 1944–51; Executive 1957–61, Chairman 1959–60; Finance 1952, 1959–60; Instruments and Measurements 1948–52, Chairman 1949–51; Measurements and Instrumentation, Chairman 1945–55; Membership 1941–48; Chairman, Technical Program Committee, National Convention 1947, 1951; Nominations 1959–61; Policy Advisory 1952, 1956, Chairman 1960; Policy Study, Chairman 1960; Professional Groups 1951–60, Vice Chairman 1954–56, Eastern Division Vice Chairman 1957–59, Eastern Division Chairman 1960–62; Standards 1949–60, Vice Chairman 1951–54, Chairman 1954–56; Ex Officio 1957–59.

[47] Ernst Weber, "Why awards?" *Proceedings of the IRE*, vol. 39, 1951, p. 595.

[48] In 1937 Weber published an article in *Scientific Monthly* (vol. 44, pp. 171–173) on "The international mission of science" in which he argued that science promotes internationalism, not by propagandistic methods, but by engaging people in an international enterprise that requires keeping abreast of research worldwide and conduces to admiration of achievements made in other countries.

[49] Interview 1991, p. 55.

[50] Trudy Bell, "Piloting the IEEE through a critical first year," *IEEE Spectrum*, vol. 25, 1988, no. 10, pp. 42–44.

[51] The merger, which began more than a decade earlier, is well described in Chapter 12, "AIEE + IRE = IEEE" (pp. 209–231) of John D. Ryder and Donald G. Fink's *Engineers & Electrons: A Century of Electrical Progress* (New York: IEEE Press, 1984); in the section entitled "The path to merger: The founding of the Institute of Electrical and Electronics Engineers" (pp. 239–243) of A. Michal McMahon's *The Making of a Profession*; and in Trudy Bell's "Piloting the IEEE. . . ." The formation of IEEE is well documented in the archives of the Center for the History of Electrical Engineering; more than 1000 documents—meeting minutes, committee papers, legal documents, correspondence—deal with the merger itself.

[52] Quoted in Trudy Bell's "Piloting the IEEE. . . ."

[53] Ibid., p. 42.

[54] In 1963 Weber was named an honorary member of the Institute of Electrical Engineers of Japan and of the Institute of Radio Engineers of Japan.

[55] Ernst Weber, "The engineer and society," *Electrical Engineering*, vol. 82, 1963, pp. 438–441.

[56] Quoted in Ernst Weber, "The engineer's responsibility to society," *Michigan Quarterly Review*, vol. 4, 1965, pp. 206–211.

[57] Giordano, "Dr. Weber's contributions as President of Polytechnic."

[58] In Weber, *A Brief History of the Family of Sonya Escherich-Eisenmenger-Weber* (cited above), p. iv.

[59] Privately printed by M.A. Designs, Tryon, NC, in 1990.

[60] Sc.D., 1958 Pratt Institute; D.Eng., 1959 Newark College of Engineering; Sc.D., 1959, Long Island University; L.L.D., 1963, Brooklyn Law School; D.Eng., 1964, University of Michigan; and D.Eng., 1970, Polytechnic Institute of Brooklyn.

[61] These include "Historical notes on microwaves," *Proceedings of the Symposium on Modern Advances in Microwave Techniques*, vol. IV, 1954, pp. 1–23; "The engineer and society" *Electrical Engineering*, vol 82, 1963, pp. 438–441, which is a review of the history of the engineering profession; a biography of Oliver Heaviside, published in a 1950 reprint of Heaviside's *Electromagnetic Theory*; and the book, mentioned above, on his wife's family. He is presently at work on a book tentatively entitled *A Global Perspective on the Early Evolution of Electrical Engineering*.