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HENRY G. BOOKER
1910–1988

A Biographical Memoir by

WILLIAM E. GORDON

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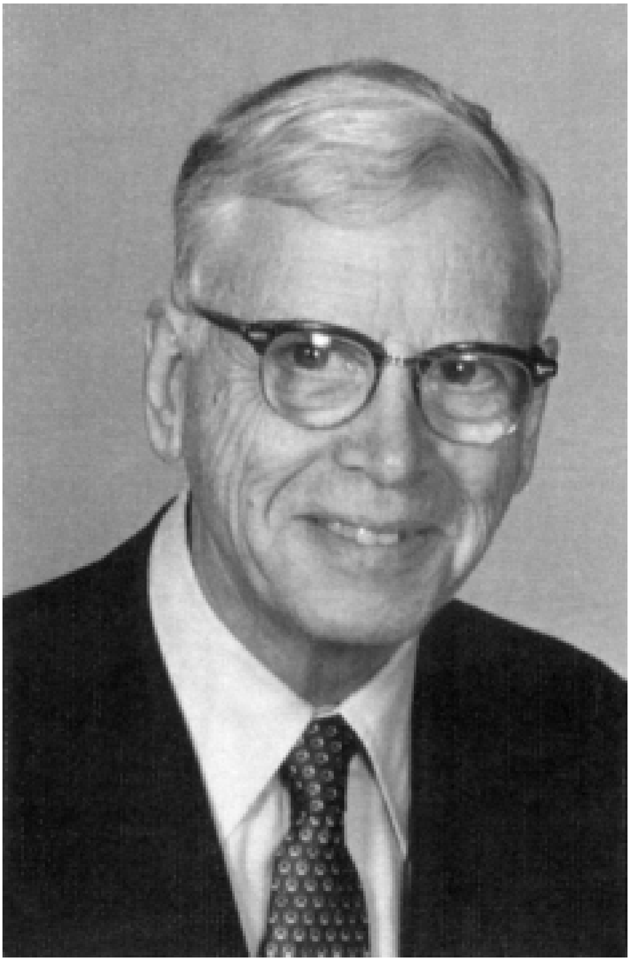

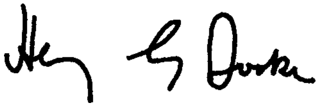

HENRY G. BOOKER

December 14, 1910–November 1, 1988

BY WILLIAM E. GORDON

HENRY G. BOOKER WAS a superb teacher and insightful researcher: He taught us electromagnetics, radio propagation, and antennas, among other things. He could present an argument in class with apparent simplicity, lulling the students into thinking they had grasped it all. The rude awakening to the complications came when the students on their own tried to reconstruct the argument. It took hours of work. It's the important part of the interaction between teacher and student and it's known as learning. In addition to teaching us the subject matter at hand, more importantly he taught us how to learn and that learning sustains life in its full measure. He was a pioneer in research on the theory of propagation of radio waves in the ionosphere and magnetosphere, and near Earth's surface, on antennas, and on other aspects of electromagnetism.

Henry George Booker was born in Barking, Essex, England, on December 14, 1910, and died in his home at La Jolla, California, from complications of a brain tumor on November 1, 1988. He was survived by his wife of 51 years, Adelaide, now deceased, and four children: John R. Booker, Robert W. Booker, Mary A. Booker, and Alice M. Booker.

Excelling in mathematics, Booker gained entrance to

Cambridge University, where he received a B.A. degree in 1933 and a Ph.D. degree in 1936, specializing in pure and applied mathematics and ionospheric physics. He was awarded the Smith Prize in 1935 and thereafter became a research fellow of Christ's College. Booker first traveled to the United States in 1937 as a visiting scientist at the Carnegie Institution in Washington, D.C. While there, he met and married Adelaide Mary McNish from San Francisco.

His career divides readily into three parts: (1) from 1933 to 1948 in England, largely at Cambridge University, but with an important 5-year segment at the Telecommunication Research Establishment during World War II, (2) from 1948 to 1965 at Cornell University, and (3) from 1965 to 1988 at the University of California, San Diego. The first phase of his career, starting with his education at Cambridge, led to papers concentrating on magneto-ionic theory in prestigious journals even while still a student. The war years left a gap due to military classification in an otherwise continuous publication record spanning 55 years (1934-89).

When Booker started research in 1933, he worked closely with the radio group in the Cavendish Laboratory, Cambridge, under J. A. Ratcliffe. His work was theoretical and concerned with the magneto-ionic theory that Sir Edward Appleton had recently formulated. He published four papers that were models of clear exposition and helped us to understand the physics of radio waves when they enter the ionosphere. The final paper of this group (1939) is still useful reading for students and has been hailed as one of the most important papers ever written on radio wave propagation. It deals with the physics of at least three important concepts: (1) the dispersion relation in a stratified medium expressed as a quartic equation, now called the Booker quartic; (2) the idea that a radio ray can be regarded as the path of a wave packet; and following from this (3) a method of ray tracing in an anisotropic stratified medium known as the Booker method of ray tracing.

Ratcliffe regarded radio science as a branch of physics and rarely used complicated mathematics. He did not want the mathematics to obscure the physics; he wanted it to illuminate the physics. Even though Booker was educated as a mathematician, he adopted Ratcliffe's philosophy. He taught students to try to understand the physics of every line of mathematics that they write down and never unnecessarily to show off the mathematics that they happen to know.

During World War II Booker was in charge of theoretical research at the Telecommunications Research Establishment in England, where he was involved in development of new ideas on antennas, electromagnetic wave propagation, and radar systems, all of which were critical to the defense of Britain. During this period he conducted radio meteorological investigations in England, India, Australia, and New Zealand on the phenomenon known as anomalous propagation or super-refraction. In some conditions the troposphere can act as a reflector of radio waves and with Earth's surface it forms a wave-guide in which radio waves can travel abnormally large distances. The paper by Booker and Walkinshaw (1946) extended the theory to deal with other types of guided wave propagation and is about the best of many papers on this subject written at that time. Booker maintained his interest in guided waves and published further papers on it.

For three years after the war Booker was university lecturer in mathematics at Cambridge producing, among others, classic contributions on slot aerials and their relation to complementary wire aerials (1946); the elements of wave propagation using the impedance concept (1947,1); the mode theory of tropospheric refraction and its relation to wave-guides and diffraction (1947,2); and diffraction from an irregular screen with applications to ionospheric problems (1950).

At the end of 1948 at the invitation of Charles R. Burrows, director of the School of Electrical Engineering and well-known researcher in radio propagation, Booker moved to Cornell and shifted his interest from smoothly varying media to irregular media; at Cornell he provided the stimulation for creative work by students and colleagues, while he moved a school of electrical engineering built on power generation and vacuum tubes into the postwar era of communications and information. His work at Cornell emphasized propagation through irregular media beginning with the troposphere and extending through the stratosphere and the ionosphere and into the magnetosphere. In each he made major contributions to the theory and usually joined with others in applying the results to practical communication systems. The paper "A New Kind of Radio Propagation at Very High Frequencies Observable over Long Distances" (1952) stands out not only because it led to ionospheric-forward-scatter communication, the mainstay of the Defense Early Warning System, but also because of the number of its authors (eight—a record for Henry).

Henry's research was elegant. That is not a word he would have used or that is used very often to describe research, but it fits. His work had beauty and style, and it was widely admired by those who understood it. He created ideas as a composer creates music or a sculptor creates art. All can be elegant. His teaching at Cornell was widely admired for its clear exposition, even of complicated subjects. Typical of his students' comments is that by Ken Bowles: "The best university level teacher that I ever experienced."

Two of his four books *An Approach to Electrical Science* (1959) and *A Vector Approach to Oscillations* (1965) were published while at Cornell. He also found time to write many memos on what was wrong with engineering education. Some of those appeared in print and many unpublished ones stimulated the faculty.

From 1958 until 1965 he was deeply involved in the Arecibo radar project and the incoherent radio scattering. In 1965 he was lured to the University of California, San Diego (UCSD), by the challenge of building a department of applied electro-physics as a part of the grand California master plan for higher education supported generously by then Governor Pat Brown. The plan included the creation of four major campuses, of which UCSD was one. It was to grow rapidly to 12 colleges, 27,000 students, and a faculty of world-class researchers using a combination of state and federal funds. When Reagan replaced Brown the master plan lost its energizer, the shrinking state funds were subject to higher education competition from stalwarts Berkeley and Los Angeles, and UCSD settled for 5, not 12, colleges. The faculty recruited by Booker, described by historian of science George Gilmore as "the finest ionospheric group ever assembled," became easy targets for other universities, and several left UCSD, a great frustration for Booker. The development of the new department was a remarkable success measured in terms of scholars attracted (e.g., Ken Bowles, Ian Axford, Peter Banks, Marshall Cohen, Vic Rumsey). This did not, however, interfere with Booker's scientific productivity. He wrote papers on the ionosphere, on irregularities, on wave propagation, two books, and a criticism of electrical engineering education. The department has evolved into electronic devices and communications theory and more recently into wireless communications with the title of Department of Applied Physics and Information,

Both the University of California and the economy of the San Diego region have benefited greatly as a result of

Henry's attracting faculty to UCSD during that early period. Part of the master plan envisioned strong ties with industry. Several of the faculty and their students have founded high-tech companies (e.g., Linkabit, Qualcomm). While the department did not develop as Henry had expected, it has become a highly ranked department with a significant impact on the region.

If Booker's scientific output can be characterized, it has an underlying theme of ionospheric physics with smoothly varying media being replaced by irregular media and with the irregularities, excursions into the troposphere, the stratosphere and the magnetosphere. There were early encounters with antennas and radio ducting, the latter stimulated by wartime radar operations (radio super-refraction, radio mirage).

Booker's work has set a pattern of clear thinking for which his numerous colleagues and research students will be grateful, and this will benefit the subject of radio propagation for many years to come.

The International Union of Radio Science has a major international scientific meeting every three years, the general assembly. For the past seven meetings one or more Henry G. Booker fellows has attended the assembly covered by the fellowship, and this will continue. It is assured by an endowment established by Henry's admirers, bearing the distinctive title, Henry G. Booker Fellow. That the fellows represent bright talent with promising futures is fitting, for Henry had always attracted the brightest young students.

Let me close on a more personal note by quoting from a speaker at Booker's memorial service. "He was a person who could both be close to you as a friend and at the same time inspire a feeling of awe. You knew that his mind was ranging somewhere between the Milky Way and the mysteries of subatomic physics while ordinary people were passing hors d'oeuvres and talking about the weather. He was a very hard man to preach to. Always sitting, as I recall, somewhere to the preacher's left and halfway back in the congregation, he would fix his gaze on the ceiling and take off into outer space, though probably a week later he could remember more of the sermon than anyone else. His mind was truly awe-inspiring."

My own warm feelings for Henry come in part from having known a very modest man and good friend and in part from having shared with him the joy of discovery—the discovery of ideas new to us and less frequently new to science. That joy was deep, spiritual, and exhilarating. All of us should have experienced it, and my hopes are that the Henry Booker fellows have the experience many times.

Booker received many awards and national and international recognition for his academic and scientific achievements (see list). Additionally, he was elected a fellow of the Institute of Electrical and Electronics Engineers in 1953 and a member of the National Academy of Sciences in 1960. For his activity in the International Union of Radio Science he was elected honorary president in 1978.

Throughout his life Professor Booker was most dedicated to the education of undergraduate and graduate students, many of whom are now eminent scientists and educators in their own right. In 1979 his former students, colleagues, and friends honored him with the establishment of a fellowship in his name at the National Academy of Sciences to support participation of "a young scientist of promise" at the general assembly of International Union of Radio Science. As emeritus professor he continued to teach full time and conduct research at the University of California and to consult with the RAND Corporation until the last few months of his life.

AWARDS

1934-35	Allen Scholarship, Cambridge University
1935	Smith Prize, Cambridge University
1947	Duddell Premium, Institution of Electrical Engineers
1948	Kelvin Premium, Institution of Electrical Engineers
1954-55	Guggenheim Fellowship
1970	50th Anniversary Medal, American Meteorological Society
1981	Honorary professor, Wuhan University, Hubei, China
1984	Centennial Medal, Institute of Electrical and Electronics Engineers

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