

James R. Wait—Remarkable Scientist

Ernest K. Smith, *Life Fellow, IEEE*

Abstract—James R. Wait was to the manor born in 1924. His father was the highest ranking officer in the Royal Canadian Air Force in World War II. Jim received all of his academic degrees from the University of Toronto, Canada, where he received the B.A.Sc. degree in 1948, the M.A.Sc. degree in 1949, and the Ph.D. degree in 1952, all in engineering physics. He spent three years in the Radio Physics Division, Defense Telecommunications Research Establishment (DTRE), before joining the Central Radio Propagation Laboratory, National Bureau of Standards, Boulder, CO, in 1955, where he remained until 1980, weathering several reorganizations. In 1980, he accepted a Professorship at the University of Arizona, Tucson, and was appointed Regents Professor in 1988, retiring in 1989. He died of a brain tumor in 1998. Jim Wait was one of our finest, as well as most prolific, electromagnetic theorists and published over 800 journal papers and eight books.

I. INTRODUCTION

JAMES Richard Wait, Electrical Engineer, Educator, and Scientist, was born in Ottawa, Canada, January 23, 1924, son of George Enoch and Doris Lillian (Browne) Wait. He married Gertrude Laura Harriet Norman on June 16, 1951. He and Gertrude had two children, Laura and George. The Wait family came to Boulder, CO, in 1955. Jim was naturalized as a United States citizen in 1960. The Waits called Boulder home from 1955 to 1980. He accepted a Professorship at the University of Arizona, Tucson, in 1980, and the family moved to Tucson, which was home thereafter. He died there of brain cancer on October 1, 1998.

Writing about Jim Wait is a challenging proposition. I was a good friend but our talents and interests were very different. Thus, I must rely on his colleagues statements for the import of his work.

His death has brought about an outpouring of commentary from colleagues and friends the likes of which I have never seen. The reasons I think are basically twofold. He was a superb theoretician in that he formulated problems clearly and accurately and attacked with tremendous energy, wheeling off a paper a week when in his stride. I can remember G. Sinclair, Jim's mentor, saying, "The thing that amazes me about Jim's papers is that they are all good." The other reason was Jim's humanity. He was a wonderful individual. He has been called humble and modest, but to me these terms do not quite hit the mark. He enjoyed his own success to the brim. When the Science Citation Index came to our library around 1960, Jim was one of the first people to check on who was, and how many people were, referencing his papers. Perhaps unpretentious would be a good way to describe Jim. He was a very competitive sportsman



Fig. 1. Profs. J. Wait (left center) and J. Beal, Electrical Engineering Department, Queens University (right center), flanked by Captains Fernandez and G. D. Loos [Royal Military College (RMC), Kingston—one of the places Jim lived as a child] and Dr. E. K. Yeung (Queens University). Jim was on a tour of the electromagnetics facilities at Queens University and the RMC following his Antennas and Propagation Society Distinguished Lecture at the University of Toronto, 17 September 1993.

(see G. Jean's piece in the Appendixes), but he did not enjoy demolishing colleagues in open debate for espousing opposing views to his. In fact, G. Brown has cited "compassion" as one of Jim's outstanding traits. Jim liked to see his colleagues and organizations do well. F. Barnes credits Jim with building up the electromagnetic area at the University of Colorado, attracting such luminaries as D. Chang and P. Beckmann. D. Dudley gives him similar credit for building up the electromagnetics program at the University of Arizona. Once he himself was elected to a position of honor, be it IEEE Fellow or NAE Member, he would do his best to get his colleagues similarly recognized.

II. THE EARLY YEARS 1924–1945

Gertrude Wait, Jim's wife, is the source of this material.

"As you know Jim's father was in the airforce, so they were stationed in numerous places before World War II. Jim started school in England about 1931, when his father was at an airbase in southern England. Then they returned to Canada to Kingston, Ontario, to the Royal Military College. Jim spoke of these years very happily—he had a sailboat, learned to shoot a .22 rifle, and

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The author is with the Electrical and Computer Engineering Department, University of Colorado, Boulder, CO 80309-0425 USA.

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Fig. 2. The Wait family in the 1960s (from left to right): Laura, Gertrude, George, and Jim.

generally got into mischief. He and his friends sent a mine car down a long incline only to discover his father waiting at the bottom. He never explained what his father did.

"Next, they moved back to Ottawa where he started high school at Lisgar Collegiate. When the war started, his grandmother insisted he needed more supervision since Jim's father would have been away. So he was enrolled in Asbury College, which he hated—chapel twice on Sunday. He was not a good student, except for science and math; a tutor was employed to get him through ancient history and Latin.

"He spent these years visiting his grandparents for Sunday lunch and skiing with his uncles. After high school, he spent his first year of College at McGill, Montreal, before serving in the military."

A. Love mentions that Jim had told him that he would have preferred enlisting in the Royal Canadian Air Force, but in view of his father's exalted rank, he thought it best to enter the Canadian Army, where he would enjoy the opportunity to make it entirely on his own. So he entered the Canadian Army as an enlisted man and, when he mustered out in 1945, he was a Staff Sergeant in charge of a radar maintenance unit in Kingston, ON, Canada. (This, incidentally, was one thing we had in common. I also mustered out as a Staff Sergeant in 1945, but from the United States Army.)

III. THE EARLY PROFESSIONAL YEARS 1945–1955

A. Love is our source for most of the material in this period.

At the end of World War II, instead of returning to McGill University, Jim chose to continue his college career at the University of Toronto. He chose engineering physics, graduated with a B.A.Sc. in 1948, and acquired his "T" on the Toronto ski team in the process. He went on for his M.A.Sc. in 1949 after which he became Prof. G. Sinclair's first Doctoral Student.

Dr. A. Brant, Department of Geophysics, University of Toronto, was setting up a company, the Newmont Exploration Limited, Jerome, AZ, a division of the Newmont Mining Corporation of New York. At Dr. Brant's invitation, Jim spent several summers in Jerome, AZ, where he became enamored of a lovely young lady, Gertrude Norman, the daughter of a prominent Canadian geologist who was working in Jerome for

Mingus Mountain Mining Company. When Jim approached Dr. Norman for his daughter's hand, all he got was a pat on the head and the advice, "Finish up your Ph.D. young man, get a full time job, then come back."

In the spring of 1951, Jim received his Ph.D. and accepted a full-time job as a Research Engineer with Newmont Exploration Ltd., and, ever the fast worker, married Gertrude in Jerome on June 16 of that year. Jim worked on the theory of induced polarization in disseminated ore bodies (where the desired ore is widely dispersed) and in analyzing raw data provided by the field crews. Jim's first 14 publications stemmed from this period and most had to do with radiation through the earth. However, mining at Jerome was petering out—ore reserves were yielding less than 1% copper and, possibly because Jim had become interested in the earth-ionosphere waveguide, Jim and Gertrude returned to Canada in 1952. Jim took a job in the Radio Physics Laboratory of the Defense Research Telecommunications Establishment (DRTE), Shirley Bay, Ottawa, where he became a Section Leader. Jim's scientific career took off at Shirley Bay and those three years accounted for 61 papers (numbers 15 to 75). While 17 of these 61 papers were coauthored, he did not coauthor more than twice with any one individual. Topics covered ground- and surface-wave propagation and radiation from electric and magnetic antennas in various media. His interest in the earth-ionosphere waveguide was yet to find expression.

IV. THE BOULDER PERIOD 1955–1980

In 1955, Jim was offered a faculty appointment at Brown University, Providence, RI, but declined and suggested it be offered to Dr. K. Davies instead. Ken accepted but, in due course, also migrated to Boulder. Jim was recruited into the Radio Propagation Engineering Division of the Central Radio Propagation Laboratory (CRPL), National Bureau of Standards (NBS), by K. A. Norton and J. Herbstreit, who had met Jim at an URSI meeting. Jack's memory is that they had interested Jim in the knife-edge diffraction problem, which had become crucial in Korea, but my assumption has been that the superb skiing in Colorado was high on Jim's reasons for joining CRPL.

CRPL had grown out of World War II military needs. During the war, the Interservice Radio Propagation Laboratory (IRPL) had been established at NBS to support the three services. In 1947, with continuing support from the military it had converted to CRPL (Division 14 in NBS). The 1949 decision to move CRPL to Boulder started to be implemented in 1951, but the Radio Building, the first structure owned by NBS to house CRPL, was not dedicated by President Eisenhower until 1954. As Division 14 reached Boulder, it split into three divisions: 82 Radio Propagation Physics; 83 Radio Propagation Engineering; and 84 Radio Standards. Radio propagation physics did ionospheric predictions (the original purpose of IRPL/CRPL) and research. Radio propagation engineering was a post-war addition addressed to tropospheric and ground wave problems. Radio standards had a more traditional NBS mission in time and frequency and equipment standards and moved out of CRPL. Coming in 1955, Jim Wait arrived for the period which came to be known as the golden age of CRPL—money was plentiful, so were talented engineers and scientists, and there were a host of



Fig. 3. From left to right, Jim Wait, Ezekiel (Ezzy) Bahar, and David Llanwyn Jones on the occasion of Jim receiving the IEEE Hertz Medal.

problems to examine. Jim added more propagation to the electromagnetics problems he had addressed before, with particular attention to ELF/VLF waves transmitted in the earth-ionosphere waveguide. A Professor Adjoint scheme was worked out with F. Barnes at the University of Colorado (CU) and Jim became one of the first Professors Adjoint in electrical engineering. This is an unpaid position but allows senior staff at the Commerce Laboratories to teach on released time and to enjoy some of the perks of the professorial faculty.

The director of the Boulder Laboratories from February 1954 until 1961 was F. W. Brown. Fred liked to make managers out of theoreticians since he felt that theoreticians could understand what experimenters and analysts were doing, but not *vice versa*. The procedure in finding someone for a management position was for upper management to prepare a prioritized list of individuals and then work their way down it until someone accepted. Jim was invariably high on Brown's lists but he never succumbed, whereas I could rarely resist when it got down to me. Fortunately, if Jim turned down a job, he felt a responsibility to help the person who accepted. That was one of the ways I got to know Jim.

After Jim got established in Boulder, he started taking on long-term coauthors. This is reflected in the following list, where all 90 of Jim's coauthors are listed. The parenthetical number after a year indicates the number of papers he coauthored with that individual. For example, Jim coauthored 12 papers with A. Conda between the years of 1957 and 1962 and coauthored 51 with K. Spies between 1960 and 1973. D. Hill tops the list with 83 coauthored papers with Jim between the years of 1971 and 1986. Jim's list of publications comes to more than 25 000 words—three times the allocation for this paper.

- 1) J. R. Leslie, 1949 (2), 1953 (4), 1954
- 2) J. E. T. Mousseau, 1953
- 3) W. C. G. Fraser, 1954
- 4) W. J. Surtees, 1954
- 5) W. A. Pope, 1954 (3), 1955
- 6) K. F. Hill, 1954
- 7) S. Kahana, 1954, 1955
- 8) C. Froese, 1954 (2)
- 9) J. Kates, 1956
- 10) H. H. Howe, 1956, 1957

- 11) M. O'Grady, 1956
- 12) D. G. Frood, 1956 (2)
- 13) R. E. Walpole, 1955
- 14) K. Okashimo, 1956
- 15) A. C. Murphy, 1957 (2), 1958, 1961
- 16) A. G. Jean, 1957 (2), 1960, 1961 (2), 1965
- 17) L. J. Lange, 1957 (2)
- 18) L. B. Perry, 1957
- 19) W. Meintke, 1957, 1959
- 20) J. Householder, 1957, 1959
- 21) A. M. Conda, 1957, 1958 (4), 1959 (2), 1960 (3), 1961 (2)
- 22) R. H. Frische, 1958
- 23) H. V. Buttlar, 1958
- 24) H. V. Cottony, 1959
- 25) R. S. Elliott, 1959
- 26) E. C. Jordan, 1959
- 27) V. H. Rumsey, 1959
- 28) K. M. Siegel, 1959
- 29) W. L. Taylor, 1960
- 30) N. F. Carter, 1960
- 31) K. Spies, 1960, 1961 (2), 1963, 1964 (3), 1965, 1966 (3), 1967 (2), 1968 (5), 1969 (7), 1970 (4), 1971 (7), 1972 (10), 1973 (5)
- 32) L. S. Collett, 1959, 1960
- 33) A. A. Brant, 1960
- 34) W. E. Bell, 1960
- 35) K. A. Ruddock, 1960
- 36) H. E. Taggart, 1961
- 37) D. F. Wasmundt, 1961
- 38) J. B. Reubens, 1961
- 39) C. M. Jackson, 1962, 1963 (3), 1964, 1965
- 40) L. C. Walters, 1962, 1963 (6), 1964 (2)
- 41) K. Tao, 1962
- 42) S. W. Maley, 1963, 1965, 1967
- 43) R. J. King, 1963, 1965, 1967, 1974, 1975, 1976
- 44) L. R. Branch, 1963
- 45) E. Bahar, 1964, 1966, 1967
- 46) D. B. Large, 1965, 1967 (3), 1968 (3)
- 47) E. A. Brackett, 1967
- 48) G. A. Schlak, 1967 (2), 1968
- 49) Y. S. Yeh, 1968
- 50) D. C. Chang, 1970 (2), 1974, 1976, 1978 (2)
- 51) R. Gabillard, 1970, 1971
- 52) P. Degauque, 1970, 1971
- 53) R. K. Rosich, 1970, 1977
- 54) F. Einaudi, 1971 (3)
- 55) D. A. Hill, 1971 (6), 1972 (6), 1973 (10), 1974 (8), 1975 (7), 1976 (10), 1977 (12), 1978 (6), 1979 (7), 1980 (6), 1981 (3), 1982, 1986
- 56) R. N. Grubb, 1971 (1)
- 57) J. A. Fuller, 1971, 1972 (3), 1973, 1976
- 58) R. E. Wilkerson, 1972
- 59) R. Ott, 1972, 1973 (3), 1974
- 60) J. A. Fuller, 1972 (2), 1973
- 61) J. T. Debettencourt, 1974
- 62) D. Davidson, 1974
- 63) S. F. Mahmoud, 1974 (5), 1976, 1979, 1981, 1988

- 64) T. Telfer, 1974
- 65) L. Thrane, 1975
- 66) W. J. Hughes, 1975 (2)
- 67) C. H. Stoyer, 1976, 1977
- 68) S. H. Cho, 1976, 1977, 1978 (2)
- 69) R. K. Arora, 1978
- 70) R. G. Geyer, 1978
- 71) D. B. Seidel, 1978 (2), 1979 (4)
- 72) K. R. Umashankar, 1978 (2)
- 73) R. L. Gardner, 1979
- 74) A. Z. Botros, 1979
- 75) K. Tsubota, 1980
- 76) M. A. Ralston, 1980
- 77) S. M. Ali, 1981
- 78) D. A. Henrot, 1982
- 79) K. A. Nabulsi, 1982, 1992 (9), 1993 (6), 1996 (2), 1997
- 80) P. Debroux, 1984, 1985 (2)
- 81) P. W. Flanagan, 1985
- 82) T. P. Guszka, 1985, 1986 (2), 1987, 1989
- 83) J. T. Williams, 1985 (2)
- 84) M. L. D. Lumori, 1986, 1989
- 85) G. Aguirre, 1986 1987
- 86) A. Sezginer, 1988
- 87) T. M. Habashi, 1988
- 88) S. G. Tantawi, 1988
- 89) J. L. Young, 1989 (2), 1990, 1991
- 90) T. C. Cetas, 1989
- 91) B. A. Baertlein, 1989
- 92) D. G. Dudley, 1989
- 93) L. Tsang, 1989
- 94) P. Teschan, 1990

Jim was frequently invited to visit foreign laboratories during the Boulder period. In 1961, he spent a memorable year at the Laboratory for Electromagnetic Theory, Copenhagen, and helped organize the *Symposium on Electromagnetic Theory*. He visited Cavendish Laboratories of Cambridge University, U.K., frequently in the 1960s and also Pergamon Press, Oxford, U.K., where he was a coeditor of the series of volumes on electromagnetic waves with A. L. Cullen and V. A. Fock. Volume 3 of this series “Electromagnetic Waves in Stratified Media,” by Wait (New York: Pergamon, 1962), became a citation classic, garnering over 1500 citations over the years. Jim also became a personal friend of I. Maxwell, the publisher of Pergamon Press. I had coauthored Volume 2 of the series and still have a vivid memory of the gracious lunch arranged by Jim with the Maxwell family at Pergamon mansion. It was impeccably served by liveried butlers. Jim later told me that the butlers were probably senior editors and that the 600 person staff of Pergamon were deployed, out of sight, in the bowels of the mansion. Jim spent academic year 1966/1967 as a Visiting Professor in the Applied Physics Department, Harvard University, Cambridge, MA (as close as Harvard got to engineering). J. Richardson was at Harvard’s Kennedy School and I was at the Harvard College Observatory at the same time.

In the 1950s, L. M. Branscom and J. Thomas pioneered a Joint Institute for Laboratory Astrophysics (JILA), joint between NBS and the University of Colorado. Fellows were chosen from both organizations, but the money came



Fig. 4. Jim and daughter Laura on the ski slopes.

largely from NBS. This was a much admired organizational structure. When CRPL was moved out of NBS in 1965 and lodged in the Environmental Science Services Administration (ESSA), a transitional organization, its name changed to the Institute for Telecommunication Science and Aeronomy (ITSA). Dr. C. G. Little remained its director. Then, in 1967, ITSA became three Laboratories and an Institute: Aeronomy (AL), Space Environment (SEL), Wave Propagation (WPL), and the Institute for Telecommunication Sciences (ITS). During the ESSA period George Benton and John Reinhart created the Cooperative Institute for Research on Environmental Sciences (CIRES) in JILA’s image. Jim Wait was appointed one of the first wave of permanent CIRES Fellows from the Commerce Labs and played a leading role in pulling the organization together. I can attest to that as I was a Visiting Fellow at the time. CIRES is now the largest scientific organization on the CU campus. D. Hill became Jim’s most frequent coauthor after spending a year as a Visiting Fellow of CIRES in AY 1970/71 (see Appendix A.3). ESSA became NOAA (the National Atmospheric and Oceanic Administration) in 1970 at which time ITS was attached to the Office of Telecommunications in Washington, later, in 1976, becoming part of the National Telecommunications and Information Administration (NTIA). Jim ended up as a Senior Scientist assigned to

the Director's office of NOAA's Environmental Research Laboratories office in Boulder as well as continuing as a Fellow of CIRES.

In 1971, Jim was a visiting Professor at the Catholic University, Rio de Janeiro, Brazil. Other mini-sabbaticals took him to Maquarie University, Sydney, Australia, Otago University, Dunedin, New Zealand, and to India and Egypt.

V. THE ARIZONA PERIOD 1980–1998

This section is drawn largely from the memorial articles by Dudley, Krider, and Sternberg and by C. Rodger in the October 1998 issue of the AP/S Magazine and March 1999 issue of Radio Science Bulletin.

"Jim Wait, now 56, and Gertrude moved to Tucson, AZ, in 1980 where he became Professor of Electrical Engineering with a joint appointment in geosciences at the University of Arizona. During this period, Jim was instrumental in the growth of the Electromagnetics Laboratory into a world-class facility. In addition to electromagnetic applications in geoscience, he was also very active in studies of lightning and atmospheric electricity. Some of his last papers were on the effects of "sprites" in the middle atmosphere and the electromagnetic fields produced by lightning. He was a Visiting Professor at the University of British Columbia in 1987. In recognition of his superior research and teaching influence, he was appointed to the prestigious position of Regents Professor in 1988. In 1989, at age 65, he retired from the University to become a private consultant (and Regents Professor Emeritus) specializing in electromagnetic methods and their use in subsurface probing. Interestingly enough his publication record in the ensuing five years more than doubled over the previous five."

VI. OVERVIEW

Jim received his share of recognition for his outstanding contributions in research, education, and service. Following is a list of some of the more significant awards he received.

- 1958: Department of Commerce Gold Medal.
- 1962: Samuel Wesley Stratton Award of NBS.
- 1962: Fellow of the IRE. "For contributions to electromagnetic theory and radio wave propagation."
- 1964: Arthur S. Flemming Award by Washington D.C. Chamber of Commerce.
- 1964: IEEE Harry Diamond Award. "For contributions to electromagnetic wave theory."
- 1973: Research and Achievement Award, NOAA.
- 1977: Member of the National Academy of Engineering.
- 1977: Fellow, Institution of Electrical Engineers (U.K.).
- 1978: URSI Balh van der Pol Gold Medal.
- 1983: Founders Award, IEEE Electromagnetic Compatibility Society.
- 1990: Distinguished Achievement Award, IEEE Antennas and Propagation Society.
- 1992: IEEE Heinrich Hertz Medal.
- 1993: Honorable Membership Award of the Society of Exploration Geophysicists.

He was active in the U.S. National Committee of the International Scientific Radio Union (URSI) and served as Secretary

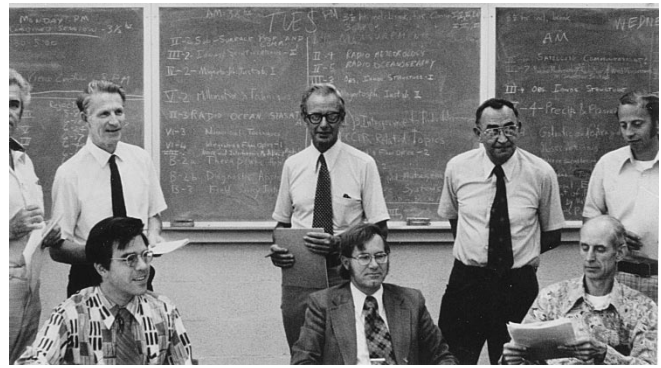


Fig. 5. USNC/URSI Technical Program Committee 1975 meeting in Boulder, CO, to line up the October National Radio Science Program. In the back row (left to right) are Bill Wright (partially in view), Tom Senior, Jim Wait, Doug Crombie, and Dave Hill. Seated, left to right, are an unidentified gentleman, Bill Guy, and Howard Bussey.

of the U.S. National Committee and chaired the Technical Program Committee for the USNC/URSI-IEEE National Radio Science Meeting in 1976–1978. He was a delegate to seven URSI General Assemblies: Boulder 1957, London 1960, Tokyo 1963, Ottawa 1969, Warsaw 1972, Lima 1975, and Helsinki 1978. In 1959, Jim had taken over the editorship of the NBS Journal of Research Part D, Radio Propagation. In 1965, the first issue of Radio Science, jointly supported by NBS and USNC/URSI, came out and Jim represented NBS as Editor until 1968. In due course, Radio Science was taken under the wing of the American Geophysical Union, but as an URSI journal.

He was also active in the Institute of Radio Engineers (IRE)/Institute of Electrical and Electronic Engineers (IEEE). He served as chairman of the Boulder Chapter of the Antennas and Propagation Society from 1957 to 1958 and was a member of the National Administrative Committee of that society from 1966 to 1972. When he arrived in Tucson, AZ, in 1980, he organized local chapters of several IEEE Societies. Then, in 1995, he became an Associate Editor of the URSI Radio Science Bulletin.

Jim's publication rate peaked from age 45 to 49, but was amazingly steady throughout his career. This is shown in percentage of his 831 papers by five-year age blocks in Table I. The old adage that theoreticians are most productive around age 30 doesn't seem to hold for Jim Wait, at least in terms of numbers.

A decade or so after Jim had left Boulder, I wrote a column for the Antennas and Propagation Society Magazine in which I facetiously proposed two new units. The Bartlett equal to delivering the same lecture 1000 times, and the Wait equal to 1000 published papers. Prof. A. A. Bartlett, Physics Department, University of Colorado, Boulder, had just finished giving his famous lecture on exponential growth 1200 times (1.2 Bartletts). I was confident that Jim, since leaving Boulder in 1980, must be over 1000 by this time. But no—Jim was finally slowing down and was only at 0.8 Waits.

The following fields to which Jim Wait contributed are perhaps best represented by the areas in which papers were solicited for this special issue:

- geophysical prospecting and induced polarization;
- scattering from cylindrical and spherical objects;

TABLE I
JIM WAIT'S PUBLICATION RECORD AS A FUNCTION OF HIS AGE

JRW Age	Calendar Years	Percent of Total
25-29	1949-1953	4.2
30-34	1954-1958	10.5
35-39	1959-1963	11.9
40-44	1964-1968	15.4
45-49	1969-1973	18.7
50-54	1974-1978	15.2
55-59	1979-1984	6.4
60-64	1984-1988	5.0
65-69	1989-1994	8.5
70-74	1994-1998	4.2



Fig. 6. Jim and his dog Maxwell (see Appendix A.1).

- mathematical methods in wave propagation;
- ionospheric, tropospheric and ground-wave propagation;
- mixed-path propagation and nonuniform waveguides;
- curved surfaces and whispering gallery modes;
- rough surface scattering;
- propagation in mine tunnels;
- subsurface electromagnetics;
- propagation along conductors and cables;
- wire grids and shielding;

- impedance boundary conditions;
- transient electromagnetics;
- atmospheric electrodynamics.

APPENDIX COMMENTS BY A. G. JEAN

"I cannot recall just when I met Jim Wait at Boulder, but one of my first contacts with Jim occurred in the 1950s. I requested he prepare a paper on ground wave propagation of an electromagnetic impulse over sea water. The paper was completed promptly and the formulations were used in recording electromagnetic pulses at a range of 2000 km in the Castle nuclear test series at Bikini Atoll, Marshall Islands. The observational data remain classified and Jim never asked nor learned how the experiments turned out.

"We became friends and hiked (ran) up and down Green Mountain together. Jim stayed in top physical condition. He frequently ran Green Mountain with a huge, equally athletic dog. The dog would sometimes bump Jim in narrow rocky parts of the trail. Jim would minimize the threat of being bumped by throwing a huge stick down into the bushes and rocks for the dog to retrieve. On one occasion when he did this, the dog caught up with him from the rear, faithfully carrying a long stick horizontally in his mouth. The stick managed to get between Jim's legs and Jim took a nasty fall, cracking several ribs.

"Jim was on the University of Toronto ski team in college. He tried for several years to get me to try out the sport. He had me put on some old wooden skis to paddle around on in the foothills, but skiing is not an inbred trait of a guy born in Tennessee. I still resisted attempts by Jim to take up skiing. Finally, I bought a second car so Kaye could drive the kids around and shop. I had no further excuses.

"Jim preferred not to drive, so I did—more and more frequently. Once, then twice a week, we would go skiing together. Jim always wanted to leave early—so early that we arrived at Winter Park before the lifts opened. Jim liked that; this gave him an opportunity to hike up the slope and ski down with the patrolmen who were opening up the area.

"At first, Jim was fairly patient with me—to the point where instruction interfered with his skiing. I guess after a couple of years I began to catch on and we would go up to the top of the mountain together and ski down together maybe once or twice, then Jim would burn up the slopes on his own until we had lunch together. Skiing with Jim was an event; I learned that one is not supposed to stop on the way down and how my thighs would burn skiing downhill with him. I recall skiing with Jim and his son George one very cold day. About half way down, my goggles fogged over and I stopped to clear the lenses. George skied over to me and said, 'Jim says you are not supposed to stop on the way down, unless you are very tired or hurt.'

"Jim was an Arlberg skier; plant both poles and jump around the turn. The Arlberg technique was giving out to newer techniques that I preferred. Trying to ski both ways was impossible for me and, as my skill increased, I would ski along with Jim for several runs before the differential in our times to the bottom lapped. Then Jim would go in for a cup of hot chocolate. On one

occasion, at mid morning, I was cold and getting tired and skied down to the lodge. I was taking off my skies when Jim emerged from the lodge with a hot chocolate mustache and said, 'Glenn, ready to go up again?' Jim was competitive and just didn't want anyone to know he ever took time out while skiing.

"We had some memorable overnights together. At Vail we would go to the "Slope" after a hard day of it and have a beer. The Slope was a sports movie house with prop up lounges on the floor to rest tired legs. Then Jim would soak in a hot tub for half an hour, then out to a good dinner. These were the times we got into technical discussions—engineer to mathematician. Jim was the greatest mathematician I ever met—but he never got into the use of computers and he handwrote all of his papers.

"Jim had great respect for imaginative scientists. He gave me a set of Richard Feynman books and several other classical texts. He was also intrigued with Nikola Tesla, whom I had not heard of before. Nikola envisioned the earth-ionosphere cavity in which radio waves would propagate. Nikola succeeded in blowing up the electric power plant at Colorado Springs with his megavolt experiments. There is a Tesla Museum in Colorado Springs.

"I attended two international URSI meetings with Jim, who always had some exciting new papers to discuss."

APPENDIX COMMENTS BY LOYS BALSLEY

I had the pleasure of working for Jim Wait for four years, from the summer of 1969 until 1973 (at that time I was Loys Gappa). This period included both his tenure as Senior Scientist for the Institute for Telecommunications Sciences (ITS) as well as a period following his transfer to the University of Colorado as one of the original Fellows of the Cooperative Institute for Research in Environmental Sciences (CIRES). I had known of Jim Wait for many years before that, since I worked directly across the hall from him in the early 1960s. (I should say, 'worked directly across the hall from his closed door,' since I saw him only on the rare occasions when he emerged from behind that door to dash down the hall at breakneck speed.)

In the summer of 1969, following the retirement of his long-time secretary, Eileen Brackett (deceased), I applied for and was selected for that job. I loved the work. It required a full-time effort to type all of the many technical papers he produced with astonishing frequency. His papers always included many lengthy and highly complex mathematical equations. Many people thought I was completely insane because I actually enjoyed that type of work, although it was many years prior to the time when computers were standard office equipment. There were electric typewriters of course and copy machines (thank goodness), but making corrections to his prolific scientific output often involved major retyping. He was always so apologetic when he had to return a manuscript to me for retyping, particularly if he had made the error that necessitated revision of several pages of highly technical and complex text. Others have mentioned that he always preferred to handwrite his manuscripts and that he did! His handwritten pages used every available blank space on both sides of the paper in the margins and sometimes between the lines. On



Fig. 7. Jim relaxing as Regents Professor Emeritus at his home in Tucson, AZ.

occasion, he even wrote round and round in circles to get to the end of his thought. I now realize that one of the things I liked most about working for Jim Wait was the fact that he would always set out a certain amount of work for me to do and then leave me alone to get it done, with only occasional interruptions.

We had little interaction socially. However, as a supervisor, I considered him to be fair and almost always very considerate. He knew what he expected from an employee and, as a result, we worked well together.

Jim Wait was a "health and exercise enthusiast" long before it was the "in" thing to do in Boulder and I always admired his energy and stamina. During the years I worked for him, he made several (unsuccessful, I might add) attempts to interest me in things athletic, often suggesting that I try skiing, biking, or swimming. Since I had never been inclined in that particular direction, I generally managed to come up with some lame excuse. I did, however, attempt to take swimming lessons one summer during my lunch hour (at that time we were across the street from Scott Carpenter Pool). I succeeded only in nearly drowning myself and returned to work in the afternoons considerably waterlogged, disheveled, and decidedly very unprofessional in appearance. After that experience, he seemed to give up trying to urge me to become involved in athletic activities!

I last saw Jim Wait just before he moved to Arizona (I don't recall the year). I had been working for a number of years in

a family-owned business in Denver, and when I heard he was leaving Colorado, I came to Boulder for a farewell lunch. I had missed his retirement party and wanted to at least say goodbye. Several years later, I asked for, and graciously received from him, a recommendation for a job within the government structure. I am certain that it was because of his positive comments that I got that job, particularly since I had been out of the technical and scientific field for over 15 years. His willingness to help others is a trait I often remember. Although I was saddened to learn of his death, I know he was the type of person who lived life to the fullest, enjoying every minute. Not only has the world lost an eminent scientist, it has also lost an energetic, productive, and very sincere human being.

APPENDIX COMMENTS BY DAVE HILL

"I first became aware of Jim Wait's outstanding work in electromagnetics when I was a graduate student at Ohio State University in the late 1960s. My Ph.D. thesis involved sources and scatterers located near interfaces and a literature search quickly revealed that Jim had already published most of the necessary solutions for various dipole types (horizontal and vertical, electric, and magnetic) in journal articles or in his classic book, *Electromagnetic Waves in Stratified Media* (New York: Pergamon, 1962). After making full use of this work in completing my thesis, in 1970 I applied for and was awarded a postdoctoral position under Jim at the Cooperative Institute for Research in Environmental Sciences (CIRES) in Boulder.

"Jim was a founding member and Permanent Fellow of CIRES and he was one of the main forces in making this small (at that time) organization such a stimulating, productive place to work. He liked having both young and well-established researchers (Dick Dowden was a Visiting Fellow the same year) in CIRES and worked well with both. Initially, I was nervous about working with a world-famous scientist who was so well known for his speed in solving problems and writing papers, but Jim quickly put me at ease with his friendly, relaxed style. He was not only a good mentor in electromagnetics, but he was also an outstanding skier who was glad to pass on a few tips to a novice like me.

"Jim generated a continuous stream of mathematical derivations in a wide variety of electromagnetic problems and he liked to see what others could add in the way of extensions, applications, or numerical results. This style was the most unselfish I have ever encountered and he never worried about whose name was first on the resulting paper. (But he did require that the paper be all meat and no fat.) I chose to follow up some of Jim's interesting results on pulse propagation in ionized media even though I had no background in the area. It was always comforting to know that Jim had researched the area thoroughly and knew which problems were unsolved and important. To this day, I have never known anyone else who knew the electromagnetic literature in such detail and over such a broad range.

"In 1971, when I finished my visiting year, positions in the Boulder Laboratories were hard to come by. Even so, Jim used

his significant influence to help me obtain a permanent position in Boulder and I have been grateful ever since. Although we were in different Boulder organizations through the remainder of the 1970s, Jim and I continued to work together in several areas (subsurface electromagnetics, ground-wave propagation, scattering by wire mesh structures, and leaky cable communications). He always felt that organizational boundaries and missions (such as remote sensing, telecommunications, or electromagnetic standards) should not get in the way of solving electromagnetic problems that are fundamental to all electromagnetic laboratories. So Jim kept close connections with all the Boulder Laboratories and the University of Colorado Electromagnetics Group and stimulated electromagnetic research throughout Boulder.

"When Jim moved to the University of Arizona in 1980, it was Boulder's loss and Tucson's gain. Even so, Jim continued to return to Boulder and I had the opportunity to lecture in one of his short courses on Geophysical Electromagnetics (probably his first love in electromagnetics). I also enjoyed seeing Jim at the January Boulder URSI Meetings and we even got in a couple of ski days. Most of all, I appreciated the fact that he continued to send his classic handwritten mathematical derivations on new electromagnetic problems to see if I wanted to collaborate. Sometimes I did and it was always fun to try to produce papers up to his usual high standards. I guess I thought that Jim's handwritten letters full of mathematics would continue arriving forever and now I regret the cases where I did not respond.

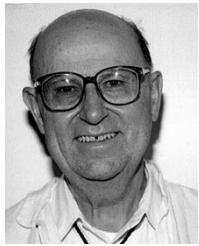
"I last saw Jim at the *Denver Electromagnetic Compatibility Symposium*, August 1998, and our conversations ranged from electromagnetics to mountaineering. So it was a shock when I learned of his rapidly progressing cancer. Jim's enthusiasm for electromagnetics continued, even during his illness, and he sent me one last set of mathematical notes on ground wave excitation by an idealized lightning return stroke. I am still working on the problem and I hope to publish it as partial thanks for all that Jim has done for me and has meant to me."

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The author was a friend and colleague of Dr. Wait's from 1955 to 1976.

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Ernest K. Smith (M'48–SM'55–F'65–LF'88) was born in Peking, China, May 31, 1922. He received the B.A. degree in physics from Swarthmore College, Swarthmore, PA, in 1944, and the M.Sc. (electrical engineering) and Ph.D. degrees from Cornell University, Ithaca, NY, in 1951 and 1956, respectively.

He came to the United States in 1940. Drafted in March 1944, he spent his Army period in the Signal Corp's Ionosphere Utilization Unit, renamed the Radio Propagation Unit (1944–1945). From 1946 to 1949 he was with the Mutual Broadcasting System (Chief Plans and Allocations Engineer, 1949). He joined the Central Radio Propagation Laboratory (CRPL) of the National Bureau of Standards (NBS), Boulder, CO, in 1951, became Chief of the Ionospheric Research Section in 1957, and Division Chief in 1960. During the tumultuous period of reorganization in the 1960s he had the following assignments among others: 1960 Chief NBS/CRPL Division 82 Ionosphere Research and Propagation; 1962 Chief NBS/CRPL Division 87 Upper Atmosphere and Space Physics 1964 Chief NBS/CRPL Division 587 Aeronomy; 1964/65 NBS/CRPL representative in Rockville, MD to stage 2 of the reorganization committee (RESAC 2) leading to NOAA in 1970, 1965/66 Visiting scientist at the Harvard College Observatory; 1966 Director ESSA Aeronomy Laboratory; 1967 Director ESSA Institute for Telecommunication Sciences (ITS); 1968 Visiting Fellow of CIRES, Lecturer in Astro-geophysics at CU; 1969 ESSA/ERL Director of University Relations. In 1970, he transferred back to ITS as Associate Director as it became part of the Office of Telecommunications. He retired from the Federal Civil Service in 1976 to join the Caltech Jet Propulsion Laboratory (JPL), Pasadena, CA, as a Member of the Technical Staff where, from 1980 until his retirement in 1987, he was JPL manager of the NASA University Earth-Space Propagation Program. Other academic associations included service as Affiliate Professor in atmospheric sciences, Colorado State University, Fort Collins (1963–1965) and Adjoint Professor in electrical engineering, University of Colorado, Boulder (1969–1976), and Associate of the Harvard College Observatory, Cambridge, MA (1965–1975). He has been a Professor Adjunct in the Electrical and Computer Engineering Department, University of Colorado, since 1987. His research interests have been in ionospheric sporadic E, atmospheric effects on microwave propagation, and natural noise.

Dr. Smith has been active in the International Scientific Radio Union (URSI) since 1951 and in the International Radio Consultative Committee (CCIR) of the ITU from 1959 (Diplome d'Honneur 1978). He is a member of Sigma Xi, and Fellow of the AAAS. His IEEE service includes the founding of the Boulder Chapter of the Antennas and Propagation Society (AP-S), service on the AP-S Fellow Committee (1980s), the IEEE Fellow Committee (1993–1995), and the Radio Propagation Standards Committee (chair 1983–1986). He is an Associate Editor (propagation) of the AP-S Magazine. He, along with Prof. W. E. Gordon, organized the Henry G. Booker Fellowship in URSI in 1978. Nonprofessional interests since 1987 include First Congregational Church of Boulder (Moderator 1995–1997), Boulder chapter 189 of the United Nations Association of America (Convenor 1995), CU chapter 21 of Sigma Xi (officer since 1995), Elderhostel (over 25), and tennis. He and his wife live in Boulder.