Both of these classes of modes are hybrid, since neither E_z nor H_z (f_3 or g_3) is zero. However, the modes are TM and TE, respectively, with respect to the θ coordinate, a result due to the inverse square dependence of ϵ_r which uncoupled (5) and (8).[1] For the case that $n=0$, so that $\beta=0$, the above modes reduce to the TE and TM waves found by AhSam and Klinger.

It should also be pointed out that the "cutoff condition" of (14)[1] may more correctly be called a "killoff" condition, as discussed by Zucker.[2] The modes cease to exist altogether when $k_0^2 l$ becomes less than $1+n^2$. Cutoff occurs at the frequency for which $k_z=0$, below which the wave might still exist although evanescent. The cutoff conditions can be determined by solving (13) and (18).

Lastly, it may be noted that there *have* been previous "analytic solutions for both TE and TM type modes in inhomogeneous media in cylindrical coordinates." As with AhSam and Klinger's example, the previous examples were also for a special case of permittivity variation, but included full discussion of the complete sets of hybrid modes. Representative references for these examples of propagation in cylinders with inhomogeneous media are for closed waveguides[3] and for open structures.[4]

[2] F. J. Zucker, "Electromagnetic boundary waves—an introduction," Air Force Cambridge Research Laboratories, Bedford, Mass., Rept., June 1963.

[3] P. J. B. Clarricoats, "Propagation along unbounded and bounded dielectric rods, pt. 2," *Proc. IEE* (London), vol. 108C, p. 177, October 1960.

[4] S. P. Schlesinger, P. Diament, and A. Vigants, "On higher-order modes of dielectric cylinders," *IRE Trans. Microwave Theory and Techniques, (Correspondence)*, vol. MTT-8, pp. 252–253, March 1960.

ACKNOWLEDGMENT

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Authors' Reply[5]

We are indebted to Richter for pointing out these modes which we overlooked. The cutoff conditions equation (14) or (18)[1] apply to these modes too.

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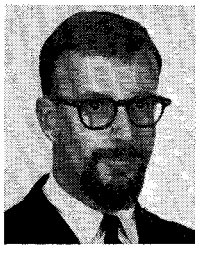
[5] Manuscript received May 10, 1967.

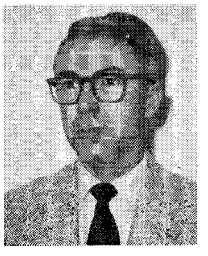
Contributors



Joel E. Becker (S'53–M'56–SM'66) was born in New York, N. Y., on April 7, 1934. He received the B.E.E. and M.E.E. degrees from the Polytechnic Institute of Brooklyn, New York, in 1955 and 1960, respectively.

Since 1955 he has been employed by Wheeler Laboratories, Inc., Smithtown, N. Y., where he is presently a Senior Development Engineer. His initial assignments included development of various communication antennas, work on a waveguide multiplex system, design of horn and flush missile antennas, and development of an optimum monopulse feed utilizing multimode techniques. He has supervised the design of a novel double-layer pillbox antenna incorporating a coupler-type bend. Recently, he has been in charge of a program for development of test antennas and techniques to be used in the evaluation of a large array radar. For the past five years he has supervised several projects involving design of radar fences to control site environment.

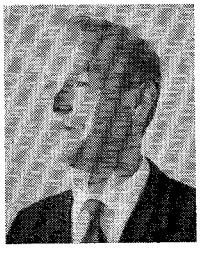
Mr. Becker is a member of Eta Kappa Nu and Tau Beta Pi.



Pierce A. Brennan was born in New York, N. Y., on April 23, 1925. He received the A.B. and M.S. degrees in physics from Fordham University, New York, N. Y. in 1948 and 1950, respectively.

From 1948 to 1949 he was with the Evans Signal Laboratory, Belmar, N. J., where he was engaged in radar receiver design and from 1950 to 1956 in microwave tube research, particularly in the field of traveling wave tubes. In 1956 he joined the Electron Tube Laboratory at Stanford University, Stanford, Calif., where he continued work in the microwave tube field. From July, 1959, to December, 1959, he was with International Telephone and Telegraph at Nutley, N. J., where he developed electrostatically focused traveling wave tubes. Since 1960 he has been at the IBM Watson Research Center, Yorktown Heights, N. Y., where he has been primarily concerned with packaging problems associated with high-speed circuit technology.

Mr. Brennan is a member of the American Physical Society, American Association of Physics Teachers, and Sigma Xi.



J. B. Davies was born in Liverpool, England, on May 2, 1932. He received the B.A. degree in mathematics from Jesus College, Cambridge, England, in 1955, the M.Sc. degree in mathematics, in 1957, and the Ph.D. degree in mathematical physics, in 1960, both from the University of London, England.

Since 1955 he has worked at Mullard Research Laboratories, Salfords, Surrey, England, except for the period 1958 to 1960 which he spent at University College, London. He is now with the University of Sheffield, Sheffield, England. His work has been concerned with problems of electromagnetic theory.

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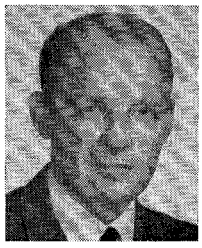
Henry Guckel (S'57–M'60) was born in Hamburg, Germany, on July 19, 1932. He received the B.S. degree in electrical engineering from the University of Buffalo, Buffalo, N. Y., in 1958. He received the M.S. and Ph.D. degrees in electrical engineering from the University of Illinois, Urbana, in 1960 and 1963, respectively.



He joined the Digital Computer Laboratory at the University in 1958 as a Research Assistant and was engaged in work on hardware problems connected with Illiac II. Interconnection problems in computers led to his active interest in distributed networks. He joined the staff of the IBM Watson Research Center, Yorktown Heights, N. Y., in 1964. He is currently on leave of absence to Washington University, St. Louis, Mo., where he is doing work in distributed semiconductor devices.

Dr. Guckel is a member of Sigma Xi.

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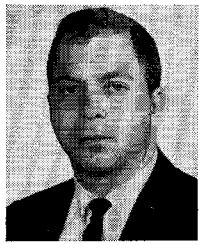

Richard A. Kolker (S'59–M'61) was born in Jamaica, New York, on February 14, 1937. He received the B.S., S.M., and Engineer degrees in electrical engineering from the Massachusetts Institute of Technology, Cambridge, Mass., in 1958, 1959, and 1961, respectively.

In 1962, after serving eighteen months in the U. S. Army, he joined Hazeltine Research Corporation, Plainview, N. Y., where he participated in analytical studies of radar systems, signal processing techniques, and waveform generation in pulse-compression systems. He joined the staff of Stanford Research Institute, Menlo Park, Calif., in June, 1965, and has been engaged in ECM vulnerability studies of missile and aircraft defense systems. From 1962 to 1965, he was a part-time lecturer at the Polytechnic Institute of Brooklyn. He is now a part-time Assistant Professor at San Jose State College, San Jose, Calif.

Mr. Kolker is a member of Eta Kappa Nu and Sigma Xi.

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Vincent Mazzola (S'59–M'61) was born in Brooklyn, N. Y., on May 17, 1938. He received the B.E.E. degree from Cooper Union, New York, in 1960, and the M.S.E.E. degree from the Polytechnic Institute of Brooklyn, New York, in 1964.

From 1960 to 1967, he was with Wheeler Laboratories, Inc., Smithtown, N. Y., where he was involved in the design and development of directional couplers, double-layer pillbox antennas, crystal mixers, and antenna elements for phased arrays. Recently, he joined Sedco Systems, Inc., Farmingdale, N. Y., where he has been engaged in phased array studies.

Mr. Mazzola is presently chairman of the Long Island Chapter of Microwave Theory and Techniques.

❖

G. C. McCormick (A'54–M'60) was born in Paradise, Nova Scotia, Canada, on September 20, 1915. He received the B.S. degree from Kings'-Dalhousie University, Halifax, Nova Scotia, in 1935, the M.S. degree from Acadia University, Wolfville, Nova Scotia, in 1945, and the Ph.D. degree from McGill University, Montreal, Canada, in 1953.

He was a Lecturer at Acadia University from 1949 to 1951. During 1953 to 1954 he was an Assistant Professor of physics at the University of New Brunswick, Fredericton, Canada, and in 1954 he joined the staff of the National Research Council of Canada. His work has been mainly in the field of microwave antennas.

Dr. McCormick is a member of the Canadian Association of Physicists.

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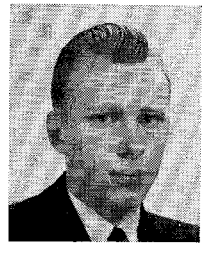

Cornelis A. Muilwyk (S'62–M'67) was born in Ridderkerk, The Netherlands, on May 6, 1941. He received the B.Sc. degree in electrical engineering from the University of Alberta, Edmonton, Canada, in 1964. In October, 1964, he started research towards a Ph.D. degree in electrical engineering at the University of Sheffield, England.

During the summer of 1964 he was with the National Research Council of Canada, Ottawa, Ontario, where he was engaged in model antenna studies. He is currently with General Staff Engineering, Alberta Government Telephones, Edmonton, Canada. His research project is concerned with the numerical solution of waveguide problems.

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István Palócz (SM'59) was born in Budapest, Hungary, on September 24, 1920. He received the Engineering Diploma (equivalent to the M.S. degree) from the University of Technical Sciences, Budapest, in 1945, and became Docent at the same university in 1954. He received the Ph.D. degree in electrophysics from the Polytechnic Institute of Brooklyn, Brooklyn, N. Y., in 1962.

From 1943 to 1944 he was associated with the University of Technical Sciences, Budapest, as a Research Assistant; he joined the faculty in 1950 and was an Associate Professor from 1954 to 1956. He also worked for Hungary's largest electronics firm, Tungsram Company, from 1945 to 1950, first as a Research Staff Member, then as Manager of Quality Control. He was retained as a consultant for the Research Department from 1950 to 1956. From 1957 to 1965 he was with IBM Corporation, first as a Staff Member at the Watson Laboratory, Columbia University, New York, N. Y., then at the IBM Watson Research Center, Yorktown Heights, N. Y., working on electromagnetic theory, microwave electronics, applied mathematics, and memory research. In 1965 he joined the Department of Electrical Engineering at New York University, New York, N. Y., as an Associate Professor. He is currently conducting research and teaching graduate and undergraduate courses.

Dr. Palócz was the recipient of the Hungarian National Award for Excellent Teaching in 1956. He is a member of Tau Beta Pi, Eta Kappa Nu, and the New York Academy of Sciences.

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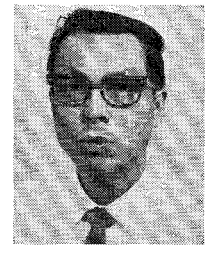

Y. J. Seto (M'58) was born in China, on July 31, 1930. He received the B.S E.E. degree from the University of Idaho, Moscow, Idaho in 1957, the M.S. degree in electrical engineering from the University of Washington, Seattle, Wash., in 1960, and the Ph.D. degree in electrical engineering from the University of Texas, Austin, in 1964.

From 1957 to 1960 he was employed by the Boeing Company in Renton, Wash. Subsequently, he taught electrical engineering at the University of Houston, Houston, Tex. for the academic year 1960 to 1961. From 1961 to 1964, he was an Instructor in the Electrical Engineering Department and a Faculty Research Engineer in the Plasma Dynamics and Quantum Electronic Laboratories at the University of Texas. He returned to his former position at the University of Houston in 1964 where he continued teaching and research until 1966. Since 1966, he has been an Associate Professor of Electrical Engineering at Tulane University, New Orleans, La., and also an Adjunct Professor in the Graduate School at the University of Houston. He was a NASA-ASEE faculty fellow at Stanford University and Ames Research Center, NASA, Palo Alto, Calif., during the summers of 1964 and 1965.

Dr. Seto is a member of Tau Beta Pi, Eta Kappa Nu, Sigma Xi, American Association for the Advancement of Science, and the American Physical Society. He is also a chartered member of the American Society for Oceanography.