Equation (5) can be solved simultaneously for the a's. The results are:

$$a_1 = s_{21}^{(1)} + s_{22}^{(1)}\left[\frac{R_F - s_{11}^{(1)}}{s_{12}^{(1)}}\right]$$
$$a_2 = \frac{T_F}{s_{12}^{(2)}}$$
$$a_3 = s_{22}^{(2)}\frac{T_F}{s_{12}^{(2)}}$$
$$a_4 = \frac{R_F - s_{11}^{(1)}}{s_{12}^{(1)}}. \tag{7}$$

Following the same procedure, with the unit-reference signal introduced from the right, the following relations are obtained:

$$b_4 = b_1 S_{11} + b_3 S_{12}$$
$$b_2 = b_1 S_{21} + b_3 S_{22} \tag{8}$$

where

$$b_1 = s_{22}^{(1)}\frac{T_R}{s_{12}^{(1)}}$$
$$b_2 = \frac{R_R - s_{11}^{(2)}}{s_{12}^{(2)}}$$
$$b_3 = s_{22}^{(2)}\left[\frac{R_R - s_{11}^{(2)}}{s_{12}^{(2)}}\right] + s_{21}^{(2)}$$
$$b_4 = \frac{T_R}{s_{12}^{(1)}}. \tag{9}$$

Equations (6) and (8) constitute four equations with four unknowns, namely, the desired two-port scattering parameters. These four equations break up into two pairs with two unknowns in each and consequently can be easily solved for the unknown scattering parameters. Substituting the values of the a's and b's, the following results are obtained:

$$S_{11} = \frac{(R_F - s_{11}^{(1)})[s_{22}^{(2)}(R_R - s_{11}^{(2)}) + s_{21}^{(2)}s_{12}^{(2)}] - s_{22}^{(2)}T_R T_F}{D}$$
$$S_{12} = \frac{T_R s_{21}^{(1)} s_{12}^{(2)}}{D}$$
$$S_{21} = \frac{T_F s_{12}^{(1)} s_{21}^{(2)}}{D}$$
$$S_{22} = \frac{(R_R - s_{11}^{(2)})[s_{22}^{(1)}(R_F - s_{11}^{(1)}) + s_{12}^{(1)}s_{21}^{(1)}] - s_{22}^{(1)}T_R T_F}{D} \tag{10}$$

where

$$D = [s_{12}^{(1)}s_{21}^{(1)} + s_{22}^{(1)}(R_F - s_{11}^{(1)})][s_{21}^{(2)}s_{12}^{(2)} + s_{22}^{(2)}(R_R - s_{11}^{(2)})] - s_{22}^{(2)}s_{22}^{(1)}T_R T_F.$$

These expressions, although somewhat tedious for hand computation, can be directly evaluated by computer without requiring an iterative technique.

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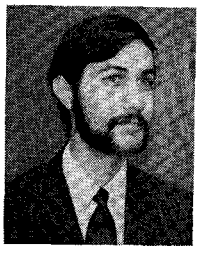
Contributors



Richard M. Arnold (S'66–M'70) was born in St. Louis, Mo., on December 25, 1944. He received the B.S.E.E., M.S., and D.Sc. degrees in electrical engineering from Washington University, St. Louis, Mo., in 1966, 1968, and 1970, respectively.

From 1966 to 1970 he was a Research Assistant in the Microwaves Laboratory at Washington University where he was engaged in research on microwave biased photodetectors and wave propagation in semiconductor loaded waveguides. He held a NDEA fellowship during the academic years 1967–1969. He has been with Bell Telephone Laboratories, Columbus, Ohio, since June, 1970.

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After completing his studies he was appointed to a two-year research fellowship at the California Institute of Technology, Pasadena. He then worked for a year in the Department of Mathematics at Glasgow University before undertaking research fellowships for one year in the Technische Hochschule, Aachen, Germany, and for a further year in the Laboratory for Electromagnetic Theory in Copenhagen, Denmark. Since 1967 he has been a Lecturer in the Department of Electrical and Electronic Engineering at the University of Leeds, Leeds, England.

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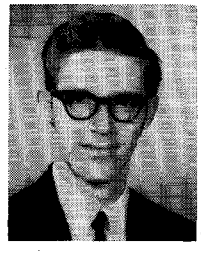

Edgar J. Denlinger (S'59–M'67) was born in Lancaster, Pa., on June 17, 1939. He received the B.S. degree in engineering science from Pennsylvania State University, University Park, in 1961, and the M.S. and Ph.D. degrees in electrical engineering from the University of Pennsylvania, Philadelphia, in 1964 and 1969, respectively.

From 1961 to 1963 he was in the RCA Graduate Study Program while working in the RCA Applied Research Department, Camden, N.J. Until 1965 he was engaged in research on solid-state travelwave masers, superconducting magnets, and experimental transistors. From 1965 to 1967 he held a University of Pennsylvania Research Assistantship during which he did research on a bulk-effect oscillator. Since July 1967, he has been a Staff Member at Lincoln Laboratory, Massachusetts Institute of Technology, Lexington, working on problems in microwave integrated circuits and phased array antennas.

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Robert B. Dybdal was born in Dayton, Ohio, on August 2, 1941. He received the B.E.E. and M.S. degrees in 1964 and the Ph.D. degree in 1968 in electrical engineering, all from Ohio State University, Columbus.

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Roland B. Ekinge (S'67) was born in Örebro, Sweden, on August 20, 1942. He received the Civilingenjör (M.Sc.) degree in electrical engineering in 1965 and the Technologie Licentiat (Ph.D.) degree in 1970, both from Chalmers University of Technology, Gothenburg, Sweden.

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William J. English (S'63–M'69) was born in Oil City, Pa., on November 29, 1941. He received the A.B. degree in mathematics with honors from Saint Vincent College, Latrobe, Pa. in 1963 and the B.S.E.E. and M.S.E.E. degrees from Carnegie-Mellon University, Pittsburgh, Pa. in 1964 and 1965, respectively.

While completing his doctoral dissertation on variational solutions of the Maxwell equations, he taught in the Department of Electrical Engineering, Carnegie-Mellon University. He has held summer positions with the U. S. Steel Research Laboratories, NASA Manned Spacecraft Center, I.B.M. Components Division, and the Pennsylvania Electric Company. He is currently a Member of the Technical Staff, R. F. Transmission Laboratories, Communications Satellite Corporation (COMSAT), Clarksburg, Md., and on the Professional Staff of the Department of Electrical Engineering and Computer Science of George Washington University, Washington, D. C. His present interests include the application of variational principles to hybrid-mode waveguides and spacecraft antennas.

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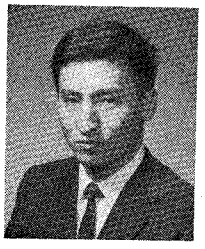

Tatsuo Itoh (S'69–M'69) was born in Tokyo, Japan, on May 5, 1940. He received the B.S. and M.S. degrees in electrical engineering from the Yokohama National University, Yokohama, Japan, in 1964 and 1966, respectively, and the Ph.D. degree in electrical engineering from the University of Illinois, Urbana, in 1969.

Before coming to the United States in 1966, he held a teaching position at Tamagawa University, Tokyo, Japan. From September, 1966, to February, 1969, he was a Research Assistant in the Antenna Laboratory, University of Illinois, where he is now a Research Associate. His research has been on open resonators, quasi-optical gratings, waveguide discontinuity problems, and microstrip transmission lines.

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❖

Ralph Levy (SM'64) was born in London, England, on April 12, 1932. He received the M.A. degree in physics from St. Catherine's College, Cambridge University, Cambridge, England, and the Ph.D. degree in electrical engineering from the University of London, London, England, in 1953 and 1966, respectively.

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Raj Mittra (S'54–M'57–SM'69–F'71) received the Ph.D. degree in electrical engineering from the University of Toronto, Toronto, Ont., Canada, in 1957.

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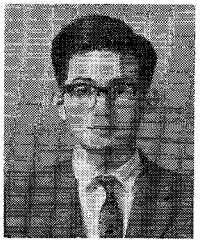

Yoshiyuki Naito was born in Oita Prefecture, Japan, on November 22, 1936. He graduated from the electricity course in 1959 and received the Doctor of Engineering degree in 1964, both from the Tokyo Institute of Technology, Tokyo, Japan.

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William H. Peake was born in Binghamton, N.Y., on June 10, 1926. He received the B.S. degree from the Massachusetts Institute of Technology, Cambridge, in 1946, the M.A. degree from Columbia University, New York, N.Y., in 1950, and the Ph.D. degree from Ohio State University, Columbus, in 1959.

From 1947 to 1949 he was a Research Assistant at the Ordnance Research Laboratory, Pennsylvania State University, University Park, and from 1950 to 1952 he was a Physicist at the Naval Ordnance Laboratory, Silver Spring, Md. Since 1952 he has worked at the Antenna Laboratory (now the ElectroScience Laboratory); Department of Electrical Engineering, Ohio State University, where he is now Professor of Electrical Engineering. His recent research has been in the area of microwave scattering and emission from terrestrial surfaces.

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Leon Peters, Jr. (S'50–A'51–SM'60) was born in Columbus, Ohio, on May 28, 1923. He received the B.E.E., M.Sc., and Ph.D. degrees from Ohio State University, Columbus, in 1950, 1954, and 1959, respectively.

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John David Rhodes (M'67) was born in Doncaster, Yorks., England, on October 9, 1943. He received the B.Sc. and Ph.D. degrees in electrical engineering from the University of Leeds, Leeds, Yorks., England, in 1964 and 1966, respectively.

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Fred J. Rosenbaum (S'57–M'63) was born in Chicago, Ill., on February 15, 1937. He received the B.S., M.S., and Ph.D. degrees in electrical engineering from the University of Illinois, Urbana, in 1959, 1960, and 1963, respectively.

While working toward the Ph.D. degree he was a Graduate Assistant at the university and carried out research on Cerenkov radiation in ferrites. In 1963 he joined the Research Division of McDonnell Aircraft Corporation, St. Louis, Mo., where he worked on masers and dielectric resonators. In 1965 he became a member of the faculty of Washington University, St. Louis, Mo., where he is now an Associate Professor of Electrical Engineering working in the area of microwave devices.

Dr. Rosenbaum is a member of Eta Kappa Nu, Sigma Xi, and Sigma Tau.

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Harrison E. Rowe (S'49–A'53–M'58–SM'65–F'71) was born in Chicago, Ill., on January 29, 1927. He received the B.S., M.S., and Sc.D. degrees from Massachusetts Institute of Technology, Cambridge, in 1948, 1950, and 1952, respectively.

He joined Bell Telephone Laboratories, Inc., Holmdel, N. J., in 1952. His fields of interest have included parametric amplifier theory, noise and communication theory, propagation in random media, and related problems in waveguide, radio, and optical systems.

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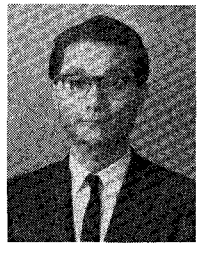

Kunihiro Suetake (SM'62) was born in Hokkaido, Japan, on May 14, 1920. He graduated from the Department of Electrical Engineering and received the Doctor of Engineering degree, both from the Tokyo Institute of Technology, Tokyo, Japan, in 1944 and 1957, respectively.

He was employed as an Assistant Professor in the Research Laboratory of Precision Machinery and Electronics, Tokyo Institute of Technology, and later as a Professor in the general electrical engineering course of the Institute's Faculty of Science and Engineering. In 1961 he was invited to the Microwave Research Institute, Polytechnic Institute of Brooklyn, Brooklyn, N.Y. He is presently a Professor in the Department of Physical Electronics Engineering, Faculty of Engineering, Tokyo Institute of Technology, where he is in charge of the electromagnetic wave engineering course. He has engaged in research on lossy microwave circuits and the development of small matched loads and various absorbing walls. In addition, he has constructed more than ten dark rooms for various laboratories. He is also interested in education engineering, including audio-visual methods. His writings include *Microwave Circuits* (Ohm-sha, 1958) and *Applied Vector Analysis for Electrical Technicians* (Ohm-sha, 1960).

Dr. Suetake is a member of the Institute of Electrical Engineers of Japan. He has received an Inada Award, a Treatise Award, and a Toyo Rayon Research Grant in 1968.

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