

to parallel antenna feeds, balanced mixers, or circulator elements. A similar structure has been developed by the Hughes Aircraft Co., and is presently being manufactured by Airtron. In the design shown here, the matching elements, which consist of a small round bump in the junction and an inductive iris in the *E* arm, achieve match within 0.8 db swr (1.10 vswr) in the *E* arm, and within 1.6 db swr (1.20 vswr) in the *H* arm, over the 12 per cent *X* band (see Fig. 11).

All the designs described have been carried to completion in one particular waveguide size (RG-51/U); the principles, however, are adaptable to any other size desired. By choosing a type of junction with inherent isolation in one pair of arms, it is necessary only to match that pair while maintaining symmetry in order to complete the junction design. The basic matching element for the *E* arm is a space-filling insert which acts as a power-divider; for the *H* arm, a resonant stub which couples the *H* arm to the side arms. Further matching may be achieved by introducing reactive irises or resonant windows in the *E* and *H* arms. Any symmetrical position of the side arms can be incorporated into a matched design; the extreme positions are represented in the designs described.

These design principles have resulted in waveguide hybrid junctions with simple matching elements, having good impedance match, isolation in both pairs of arms, and high power-handling capability.

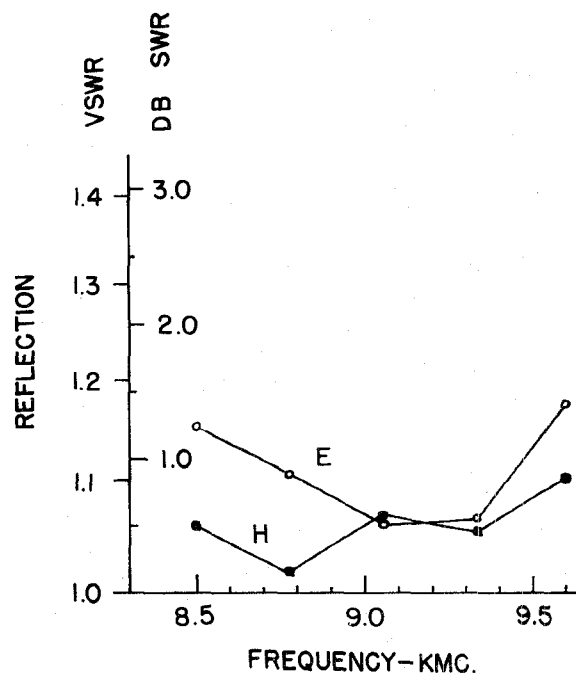


Fig. 11—Reflection of model 202 forked hybrid.

This work has been conducted under the direction of H. A. Wheeler and has been sponsored by the Bell Telephone Laboratories in connection with an Armed Services contract.

## Contributors

Philip J. Allen was born in Whitinsville, Mass., on December 30, 1919. Following two years of subprofessional employment with the General Radio Company, Cambridge, Mass. Mr. Allen entered Pennsylvania State University, and in 1944 received the B.S. degree in physics.



P. J. ALLEN

That same year, he joined the Tracking Branch, Radar Division at the Naval Research Laboratory, Washington, D. C., where he has been engaged in developing special microwave components and antenna

feeds, and in the development of automatic tracking radar systems. Since 1951, he has been serving as head of the New Techniques Section of this same branch, engaged in investigating new ideas for the improvement of tracking radar systems.

Mr. Allen is a member of RESA.



Helmut M. Altschuler (S'47-A'49-M'54-SM'55) was born in Germany, in 1922. He received the B.E.E. degree in 1947 and the M.E.E. degree in 1949 from the Polytechnic Institute of Brooklyn, New York, where he is continuing his graduate studies at the present time.

In 1947-48 Mr. Altschuler held a Research Fellowship at the Microwave Research Institute of the Polytechnic Institute of Brooklyn, and since then has been employed there, presently in the capacity of research associate.



H. M. ALTSCHULER

His work has been concerned chiefly with the development of impedance meters, microwave measurement techniques, and equivalent network representations.

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

Tore N. Anderson (S'49-A'49-SM'55) was born on May 1, 1920, in Sweden. In 1943 he completed the electrical engineering program at Oregon State College, and in 1948 received the B.S.E.E. degree from Cooper Union.



T. N. ANDERSON

During the war, Mr. Anderson served with the Engineering Research and Development Agency as project officer on underwater mine detectors and as chief of the Laboratory and Test Section, engaged in the design and development of mine detectors. After the war he was engineer-in-charge of radio frequency measurements at Electrical Testing Laboratories in New York.

He has been associated with Airtron, Inc. since 1948, working on the development of transmission line components and on the development of rigid and flexible waveguide components. In 1951, he was appointed Chief Engineer, and in 1953, was elected to the Board of Directors and appointed Vice-President. He is now Director of Engineering and in charge of the Research and Development Division.

He is a member of AIEE and Tau Beta Pi.



Franklin S. Coale (A'53) received the B.S. degree in engineering physics from Lehigh University in 1952, subsequently taking post graduate work in applied mathematics at N.Y.U. In 1953 he joined Sperry Gyroscope Co. as an associate engineer in microwave components and antennas engineering. In 1955, he joined Stanford Research Institute in the Microwave Group of the Antenna Systems Laboratory. He



F. S. COALE

is engaged in research and development on filters, multiplexers, ferrite devices, and antennas.

He is a member of the American Physical Society and the Research Society of America.



Albert D. Frost (S'45-A'52) was born in Boston, Mass., in 1922. He received the B.S. degree from Tufts College in 1945, the A.M. degree in applied science from Harvard in 1947, and the Sc.D. degree in physics from M.I.T. in 1952. Since 1947, he has been a faculty member of the Department of Physics and a research associate in the Research Laboratory of Physical Electronics at Tufts University.



A. D. FROST

Presently, Dr. Frost is assistant professor of physics.

He is a member of Phi Beta Kappa, Sigma Xi, Sigma Pi Sigma, the Acoustical Society of America, and the American Association of Physics Teachers.



Georg Goubau (A'49) was born in Munich, Germany, on November 29, 1906. He received the M.S. and Ph.D. degrees in physics from the Munich Technical University. From 1931 to 1939 he was employed in research and teaching in the physics department of the same university, under Professor Zenneck. During this time, he established and was in charge of the first German ionospheric research station. In 1939, Dr. Goubau was appointed professor and director of the department of applied physics of the Friedrich-Schiller University in Jena, Germany.

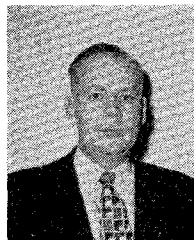


G. GOUBAU

Since 1947, he has been a member of the research staff of the Signal Corps Engineering Laboratories in Fort Monmouth, N. J. His chief research activities have been principally concerned with wave propagation and microwave circuits.



John W. E. Griemsmann (A'45) was born May 31, 1916, in Brooklyn, N. Y. He received the B.E.E. degree in 1936 and the M.E.E. degree in 1938 from the Polytechnic Institute of Brooklyn, and remained there as a research fellow until September, 1939.



J. W. E. GRIEMSMANN

From 1939 to 1942 he was associated with the Westinghouse Research Laboratories as a research engineer in the Insulation Department. During this time he studied at the University of Pittsburgh toward the Ph.D. degree in physics.

In 1942 he returned to the Polytechnic Institute of Brooklyn as a research associate working on radar components and microwave measuring instruments under O.S.R.D. He received the D.E.E. degree from the Polytechnic Institute of Brooklyn in 1946. Since that time, Dr. Griemsmann has been associated with the Microwave Research Institute, becoming associate director in 1952, and research professor at P.I.B. in 1953.

Since 1945 he has also been active in standardization work on microwave transmission lines and components, as a participant in the Army-Navy RF Cable Coordinating Committee, a member of the R.D.B.

Sub-Panel on Transmission Lines and Components, and a member of RETMA active in the Special Quality Components group. He was joint chief delegate for the United States to Subcommittee 12-5 of the International Electrotechnical Commission at the 1954 meeting in Philadelphia and the 1955 meeting in London.

Dr. Griemsmann is a member of Eta Kappa Nu, Sigma Xi, the American Association for the Advancement of Science, and the AIEE Insulation Conference (NRC).



Walter K. Kahn (S'50-A'51-M'56) was born on March 24, 1929, in Mannheim, Germany, and came to the United States in 1938.



W. K. KAHN

He completed his undergraduate studies at the Cooper Union School of Engineering, receiving the Bachelor's degree in electrical engineering in 1951.

Upon graduation, Mr. Kahn was employed at the Wheeler Laboratories, New York where he was engaged in micro-

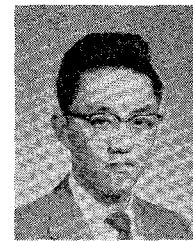
wave radar system development. Concurrently he engaged in graduate study at the Polytechnic Institute of Brooklyn, receiving the Master's degree in electrical engineering in 1954.

At that time he joined the staff of the Microwave Research Institute of the Polytechnic Institute of Brooklyn, where he is presently studying general diffraction theory and propagation in multimode waveguides.

Mr. Kahn is an associate of Sigma Xi.



George Kasai (S'49-A'49) was born April 28, 1927, in San Francisco, Calif. He received the B.S. degree in electrical engineering from the University of California in Berkeley in 1949.



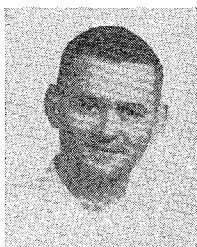
G. S. KASAI

From 1949 until 1952, he was engaged as Electronic Engineering Assistant at the Evans Signal Laboratory of the Signal Corps Electronic Laboratory in Belmar, N.J. In 1952 he was granted a Junior Research Fellowship

at the Polytechnic Institute of Brooklyn where he participated in a research program at the Microwave Research Institute. He received the M.E.E. degree in 1954. Mr. Kasai is presently employed at the North American Aviation Corporation in Downey, Calif.

Mr. Kasai is a member of Sigma Xi, Eta Kappa Nu, and Tau Beta Pi.

Patrick J. Kelly (S'54-M'56) was born in Minneapolis, Minn., on June 13, 1930. He attended the University of Minnesota, Macalester College and the U. S. Naval Academy where he received the B.S. degree in 1953. After one and one-half years in the Navy he came to the Moore School of Electrical Engineering, University of Pennsylvania to study for advanced degrees. Mr. Kelly is currently on the staff of the Moore School where he is a Research Engineer.



P. J. KELLY

Ralph W. Klopfenstein (S'44-A'46-M'50-SM'54) was born on June 3, 1923, in Aberdeen, S. D. He received the B.S. in E.E. degree from the University of Washington in 1944 and the M.S. and Ph.D. degrees in applied mathematics from Iowa State College in 1951 and 1954.



R. W. KLOPFENSTEIN

From 1945 to 1946, he was a radio materiel officer in the U. S. Naval Reserve. He became an instructor in the mathematics department of South Dakota School of Mines and Technology in 1946. In 1948, he joined RCA Victor in Camden, N. J., where he worked on the advanced development of television and fm transmitting antennas and filters. After three years as an instructor in mathematics at Iowa State, from 1950 to 1953, he returned to RCA Laboratories Division in Princeton, N. J., where he is now a member of the research staff.

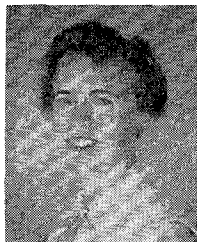
Dr. Klopfenstein is a member of Sigma Xi, Phi Kappa Phi, the Mathematical Association of America, and the Society for Industrial and Applied Mathematics.



P. P. LOMBARDINI

Pietro P. Lombardini (A'53) was born in Bologna, Italy. He received the degree of Doctor of nautical science in 1937 in Naples, Italy and the degree of Doctor in physics in 1950 in Pisa, Italy. From 1938 to 1941 he served in various capacities in the Italian Navy. From 1941 to 1943 he was engaged in radar research for the Italian Navy. From 1945 to 1946 he was with the National Research Council in Rome, Italy. From 1946 to 1952 he was engaged in microwave research and radar design at the

Center for Microwave Physics, National Research Council, Florence, Italy. In the summer and fall of 1950 he held a UNESCO Fellowship for work with the National Research Council of Canada in Ottawa. Since 1952 he has been engaged in microwave research at the Moore School of Electrical Engineering, University of Pennsylvania, Philadelphia, where he is an Assistant Professor. He is the author of several technical papers. He is a member of Sigma Xi.



P. A. LOTH

Patricia A. Loth (A'48-SM'55) was born in New York, N. Y. in 1921. She graduated from St. Joseph's College for Women in Brooklyn, N.Y., in 1942 with the B.A. degree in mathematics, and is presently doing graduate study in the physics department of the Polytechnic Institute of Brooklyn. She was employed until 1943 as an assistant engineer in the Physical and Electrical Standardization Laboratory of the Western Electric Company in Kearny, N.J. From 1943 to 1947, she was a member of the Test Laboratory at Hazeltine Electronics Corp., in Little Neck, N.Y., eventually being in charge of the group. In 1947, she joined the engineering staff of the Wheeler Laboratories in Great Neck, N.Y. and is presently a project supervisor specializing in microwave design.

She is an associate member of Sigma Xi.



C. R. MCGEOCH, JR.

Charles R. McGeoch, Jr. was born in Pelham, Mass., on October 23, 1928. He received the B.S. degree in mathematics from the University of Massachusetts in 1952 and the M.S. degree in physics from Tufts University in 1956.

Formerly associated with the department of physics at Tufts, Mr. McGeoch is presently employed at Bomac Laboratories, located in Beverly, Mass., where he holds the position of development engineer working on microwave electron tubes.

Mr. McGeoch is a member of Sigma Pi Sigma and Sigma Xi.

Charles R. Mingins (A'36-SM'46) was born in Lawrence, Mass., in 1899. He received the A.B. degree from Wesleyan University in 1925. During 1928-1929 he was Heckscher research assistant in wave propa-

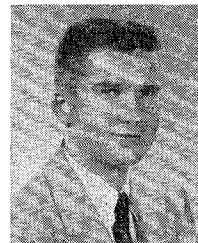
gation at Cornell University. He remained at Cornell as an instructor in physics, and was in charge of the electric wave laboratory from 1930 to 1935. He received the Ph.D. degree in 1935. For two years thereafter, Dr. Mingins was acting instructor in physics at State College in Albany, N. Y. He is presently at Tufts College as professor of physics and director of the Research Laboratory of Physical Electronics.

He is a member of Sigma Xi, Phi Beta Kappa, and the American Physical Society.



C. R. MINGINS

Edward A. Ohm (S'51-A'54) was born on July 4, 1926 in Milwaukee, Wis. He received the degrees of B.S., M.S. and Ph.D. in Electrical Engineering from the University of Wisconsin in 1950, 1951, and 1953, respectively. Since 1953 he has been a member of the technical staff of the Bell Telephone Laboratories in the Radio Research Department at Holmdel, N. J. Dr. Ohm is presently working on extremely broad-band microwave filter and channel branching problems, including many with ferrite devices.



E. A. OHM

He is a member of Tau Beta Pi and of Sigma Xi.

John Reed (A'48-SM'53) was born in Cambridge, Mass., on March 9, 1922. He received the B.S. degree in applied physics from M.I.T. in 1943, and for two years thereafter was on the staff of the M.I.T. Radiation Laboratory in the Radio Frequency Components Group. After graduate study at Cornell University he joined the Submarine Signal Company in 1947 and then transferred to the Raytheon Manufacturing Company in 1948, where he is currently employed as consultant on microwave problems.



J. REED

Sloan D. Robertson (S'37-A'40-SM'45) received the B.E.E. degree from the University of Dayton in 1936 and the M.S. and

Ph.D. degrees in communication engineering from Ohio State University in 1938 and 1941. In 1940 he taught electrical engineering at the University of Dayton.



S. D. ROBERTSON

From 1940 to 1956 Dr. Robertson was with Bell Telephone Laboratories, Holmdel, N.J., where he was engaged in research on microwave radar, microwave circuits, millimeter-wave amplifiers, and finline circuits. He is now Engineering Sec-

tion Head with Goodyear Aircraft Corp., Litchfield Park, Arizona.

Dr. Robertson is a registered Professional Engineer in New Jersey and is a member of Tau Beta Pi, Eta Kappa Nu, and Sigma Xi.



Richard F. Schwartz (S'43-A'45-M'53-SM'55) was born in Albany, N. Y. on May 31, 1922. He attended Rensselaer Polytechnic Institute where he received the B.E.E. degree in 1943, and the M.E.E. degree in 1948. He served with the U. S. Army Signal Corps from 1944 to 1946. From 1946 to 1948 he was an instructor in electrical engineering at Rensselaer Polytechnic Institute. From 1948 to 1951 he was with the



R. F. SCHWARTZ

Radio Corporation of America in Camden, N. J. where he did advanced development work on transmitting systems. Since 1951 he

has been engaged in teaching and research at the Moore School of Electrical Engineering, University of Pennsylvania, where he holds the title of Associate in electrical engineering. He holds two patents and is the author of several technical articles. He is a member of AIEE, Sigma Xi, Eta Kappa Nu, the American Association for the Advancement of Science, and the American Society for Engineering Education.



Jorgen P. Vinding (A'54) was born in Copenhagen, Denmark, on January 9, 1925. He received the M.S. degree in electrical engineering from the



J. P. VINDING

Technical University of Denmark in January, 1950. After a few months in commercial engineering he joined Storno, a division of the Great Northern Telegraph Company in Copenhagen, where he designed vhf transmitters and receivers for mobile communication. After a year of study at Brooklyn Polytechnic Institute under the Rotary Foundation program during 1951-1952, he rejoined Storno to plan a microwave relay system for tv and telephone and to design the microwave parts of this system.

Since 1954, Mr. Vinding has worked for Cascade Research Corporation, Los Gatos, Calif., where he has designed microwave load isolators and other ferrite components and is now directing the development of a series of special microwave test instruments.

He is a member of the Institution of Danish Engineers and of the American Society of Danish Engineers.

Max T. Weiss (S'43-A'45) received the B.S. degree in electrical engineering from the College of the City of New York in 1943, and



M. T. WEISS

the M.S. in E.E. and Ph.D. in physics from M.I.T. in 1947 and 1951, respectively. He worked for the Radio Corporation of America in Camden, N. J., from 1943 to 1944 and then served in the U. S. Navy, working on underwater mines at the Naval Ordnance Laboratory. From 1946 to 1950 he was connected with the Research Laboratory of Electronics at M.I.T. He joined Bell Telephone Laboratories in 1950 and for one year was concerned with dielectric waveguide transmission. Since then he has chiefly done research in microwave properties and applications of ferrites.

He is a member of the American Physical Society, Sigma Xi, and Eta Kappa Nu.



Gershon J. Wheeler (SM'54) was on the staff of Radiation Laboratory, M.I.T., from 1942 to 1945. From 1945 to 1949 he was



G. J. WHEELER

an engineer at Naval Research Laboratory Field Station in Boston, and from 1949 to 1950, was a project engineer at Andrew Alford Company. Since 1950 he has been at Raytheon Manufacturing Company where he is currently a consultant on special microwave problems.

