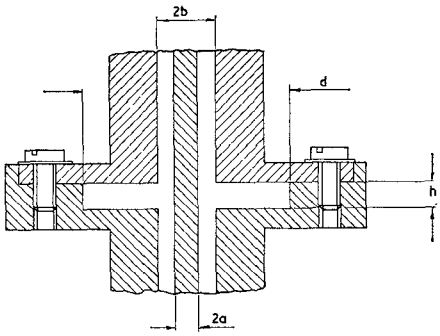

Fig. 1—Radial line cavity assembly.

were constructed of brass to the configuration of Fig. 1. Center-of-band rejection was at least 25 db in all cases: this was adequate for our purposes. For greater rejection, electro-formed cavities are described by de Loach should be adopted, and to broaden the rejection band a number of cavities can be coupled in series.

The author is indebted to the Managing Director of G. and E. Bradley, Ltd. for permission to publish this communication. He also wishes to thank R. G. Amos and J. A. Dodson for making the necessary measurements.

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Correction to "Electrolytic Pointing of Fine Wire"

In the above correspondence,[1] the final line should have read 0.0002 inch instead of 0.002 inch.

J. W. Dozier
Advanced Technology Corp.
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Manuscript received July 9, 1964.
[1] J. W. Dozier and J. D. Rodgers, IEEE Trans. on Microwave Theory and Techniques, vol. MTT-12, p. 360; May, 1964.

Microwave and High-Frequency Calibration Services of the National Bureau of Standards—Part II

Introduction

Following the series of presentations on microwave and high-frequency calibration services of the National Bureau of Standards which began in the July, 1964 issue of these Transactions, the services for the measure-

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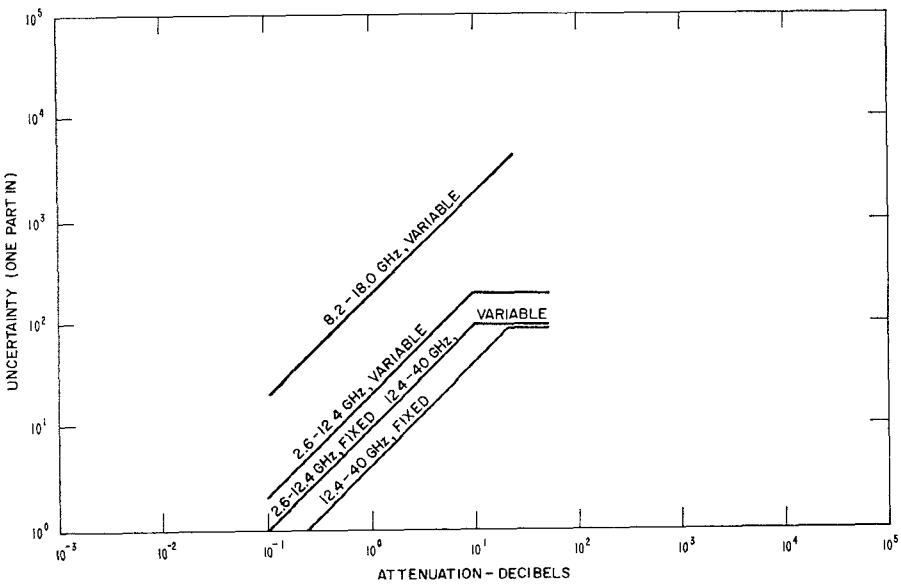


Fig. 1—Microwave attenuation calibrations (rectangular waveguide).

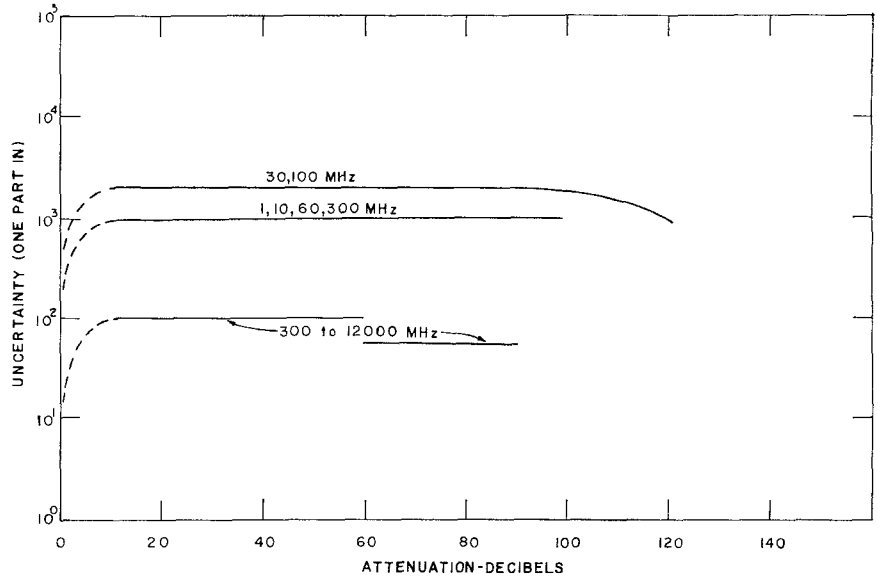
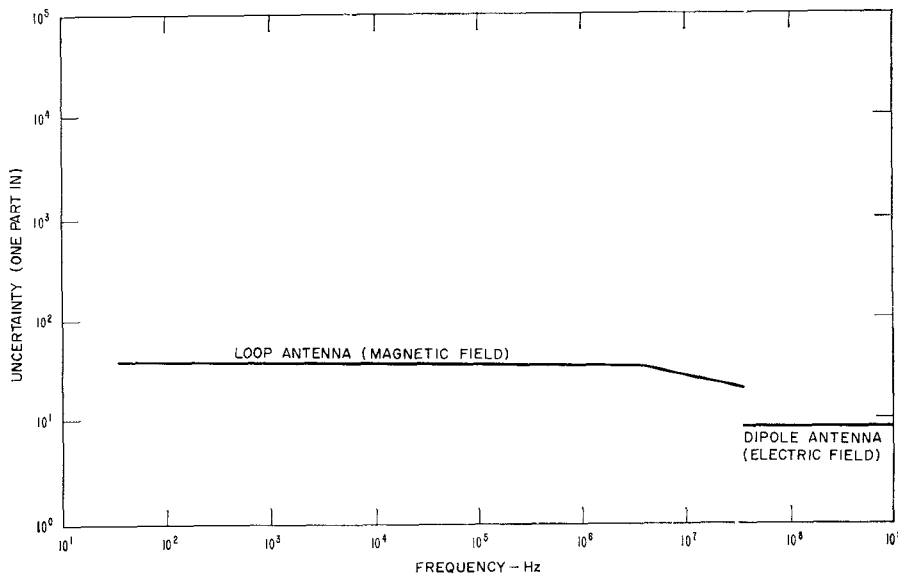


Fig. 2—High-frequency attenuation calibrations (coaxial).



ment of attenuation and field strength are presented below. As before, following the listing of calibration services is a series of charts (Figs. 1, 2, and 3) indicating the magnitudes of quantities, the frequency range, and the over-all estimated accuracy of calibrations performed.

MICROWAVE REGION

201.940 *Attenuation difference measurements on variable attenuators.*

a) Attenuation difference measurements are made on step or continuously variable attenuators usually with the zero dial setting used as the reference position.

b) Attenuation measurements are made for attenuation values from 0 to 50 db. This range of attenuation values can be extended to 70 db in some frequency ranges.

c) Variable attenuators should have a repeatability of dial setting better than ±0.1 db.

d) Variable attenuators should have a VSWR less than 1.1 at each waveguide port.

Item	Description
	Measurement of attenuation difference of direct-reading variable attenuator at an initial prescribed dial setting at a single frequency of the following waveguide sizes terminated with standard waveguide connectors.
201.940a-1	WR284 (2.60–3.95 GHz)
201.940a-2	WR187 (3.95–5.85 GHz)
201.940a-3	WR137 (5.85–8.2 GHz)
201.940a-4	WR112 (7.05–10.0 GHz)
201.940a-5	WR90 (8.2–12.4 GHz)
201.940a-6	WR62 (12.4–18.0 GHz)
201.940a-7	WR42 (18.0–26.5 GHz)
201.940a-8	WR28 (26.5–40 GHz)
201.940a-20	Measurement of attenuation difference of direct-reading variable attenuator at each prescribed dial setting additional to the initial dial setting at the same frequency and on the same attenuator as 201.940a-1 to 201.940a-8.
	Calibration of dial setting vs attenuation difference for indirect-reading variable attenuator at an initial prescribed attenuation difference value at a single frequency of the following waveguide sizes terminated with standard waveguide connectors:
201.940b-1	WR284 (2.60–3.95 GHz)
201.940b-2	WR187 (3.95–5.85 GHz)
201.940b-3	WR137 (5.85–8.2 GHz)
201.940b-4	WR112 (7.05–10.0 GHz)
201.940b-5	WR90 (8.2–12.4 GHz)
201.940b-6	WR62 (12.4–18.0 GHz)
201.940b-7	WR42 (18.0–26.5 GHz)
201.940b-8	WR28 (26.5–40 GHz)
201.940b-20	Calibration of dial setting vs attenuation difference for indirect-reading variable attenuator at each prescribed attenuation difference value additional to the initial attenuation difference value at the same frequency and on the same attenuator as 201.940b-1 to 201.940b-8.
201.940z	Special calibrations not included in the above schedule.

201.941 *Insertion loss measurements on fixed attenuators.*

a) Insertion loss measurements are made on fixed two-port attenuators.

b) Insertion loss measurements are made for insertion loss values from 0 to 50 db. This range of attenuation values can be extended to 70 db in some frequency ranges.

c) Fixed attenuators should have a VSWR less than 1.1 at each waveguide port.

Item	Description
	Measurement of insertion loss of fixed attenuator at a single frequency of the following waveguide sizes terminated with standard waveguide connectors:
201.941a-1	WR284 (2.60–3.95 GHz)
201.941a-2	WR187 (3.95–5.85 GHz)
201.941a-3	WR137 (5.85–8.2 GHz)
201.941a-4	WR112 (7.05–10.0 GHz)
201.941a-5	WR90 (8.2–12.4 GHz)
201.941a-6	WR62 (12.4–18.0 GHz)
201.941a-7	WR42 (18.0–26.5 GHz)
201.941a-8	WR28 (26.5–40 GHz)
201.941z	Special calibrations not included in the above schedule.

HIGH-FREQUENCY REGION

201.840 *Dissipative fixed coaxial attenuators.*

a) Dissipative fixed coaxial attenuators normally are calibrated in a system having a characteristic impedance of $50+j0$ ohms.

graded by any deviation or uncertainty in this characteristic impedance, the types of allowable connectors are limited. Precision connectors having a known plane of reference or the Type N meeting Procurement Specification MIL-C-71 or MIL-C-39012 are required. All measurements are made by the substitution method which requires that the connectors used be asexual or the attenuator have a male connector at one port and a female connector at the other port. If an adapter is required to comply with the foregoing, it must be supplied with the attenuator and the combination will be calibrated as one unit. Attenuators having a VSWR of 1.30 or greater at either port are not acceptable.

b) Maximum power to any attenuator will not exceed 20 mw unless prior arrangements for higher power levels have been made.

Item	Description
201.840a-1	Measurement of insertion loss of fixed attenuator at one of the following frequencies: 1, 10, 30, 60, 100, and 300 MHz. Range: 0 to 100 db.
201.840a-2	Each additional attenuator at the same frequency and over the same range as item 201.840a-1.
201.840b-1	Measurement of insertion loss of fixed attenuator at any frequency between 300 MHz and 8 GHz. Range: 0 to 60 db.
201.840b-2	Each additional attenuator at the same frequency and over the same range as item 201.840b-1.
201.840z	Special calibrations not covered by the above schedule.

201.841 *Dissipative variable coaxial attenuators.*

a) These attenuators are calibrated in accordance with item 201.840 except that the zero or other specified setting of the attenuator is used as the reference. Because only attenuation difference is measured, both ports may have the same connector.

b) Variable attenuators must have a repeatability of setting better than 0.1 db; incremental attenuators must have a repeatability of 0.01 db or better.

Item	Description
201.841a-1	Measurement of one increment on dissipative variable attenuator or at one of the following frequencies: 1, 10, 30, 60, 100, and 300 MHz. Range: 0 to 100 db.
201.841a-2	Each additional increment at the same frequency and over the same range as item 201.841a-1.
201.841b-1	Measurement of one increment on a dissipative variable attenuator at any frequency between 300 MHz and 8 GHz. Range: 0 to 60 db.
201.841b-2	Each additional increment at the same frequency and over the same range as item 201.841b-1.
201.841z	Special calibrations not covered by the above schedule.

201.842 *Waveguide below-cutoff (piston) attenuators.*

a) Waveguide below-cutoff attenuators are normally calibrated in a system having a characteristic impedance of $50+j0$ ohms. As only attenuation difference measurements are made on this type of attenuator, Type BNC, C, TNC, etc., connectors are acceptable but precision type connectors are preferred.

b) An insertion loss measurement at the attenuator zero setting can be made. Maximum power to any attenuator will not exceed 20 mw unless prior arrangements for higher power levels have been made.

c) Calibrations are performed at the following frequencies: 1, 10, 30, 60, 100, and 300 MHz.

Item	Description
201.842a-1	One increment on a waveguide below-cutoff attenuator at one of the following frequencies: 1, 10, 30, 60, 100, and 300 MHz. Range (including initial insertion loss): up to 110 db.
201.842a-2	Each additional increment at the same frequency and over the same range as 842a-1.
201.842z	Special calibrations not covered by the above schedule.

201.843 *Coaxial fixed directional couplers.*

Fixed directional couplers are calibrated in accordance with item 201.840. Terminations must be supplied for any arm not used during a measurement.

Item	Description
201.843a-1	Single insertion loss measurement between any two arms of a coaxial fixed directional coupler at one of the following frequencies: 1, 10, 30, 60, 100, and 300 MHz. Range. 0 to 100 db.
201.843a-2	Each additional insertion loss measurement between any two arms at the same frequency and over the same range as item 201.843a-1.
201.843b-1	Single insertion loss measurement between any two arms at any frequency between 300 MHz and 8 GHz. Range. 0 to 60 db.
201.843b-2	Each additional insertion loss measurement between any two arms at the same frequency and over the same range as item 201.843b-1.
201.843z	Special calibrations not covered by the above schedule.

201.844 *Coaxial variable directional couplers.*

a) Coaxial variable directional couplers are calibrated in accordance with item 201.841. Terminations must be supplied for any arm not used during a measurement.

b) The change in coupling to the sidearm relative to the minimum setting on the device is normally measured.

Item	Description
201.844a-1	Single coupling increment between input and variable arm of coaxial variable directional coupler at one of the following frequencies: 1, 10, 30, 60, 100, and 300 MHz. Range (including initial coupling loss): up to 110 db.
201.844a-2	Each additional increment at the same frequency and over the same range as item 201.844a-1.
201.844b-1	Same measurement as in item 201.844a-1 at any frequency between 300 MHz and 8 GHz. Range (including initial coupling loss): up to 60 db.
201.844b-2	Same measurement as in item 201.844a-2 at the same frequency and over the same range as item 201.844b-1.
201.844z	Special calibrations not covered by the above schedule.

201.850. *Field strength meters.* Field strength standards and field strength meters are calibrated in terms of CW signals in the frequency range from 30 Hz to 1000 MHz. Loop antennas are calibrated in the frequency range from 30 Hz to 30 MHz, and horizontally polarized dipole antennas are calibrated from 30 to 1000 MHz. The magnitude of the calibrating fields varies from approximately 25 to 200 mv/m for loop antennas, and approximately 50 mv/m for dipole antennas.

The internal characteristics of field strength meters, such as the over-all linearity of the receiver, accuracy of the signal input attenuators, and the accuracy of the receiver as a two-terminal RF voltmeter, can be measured at frequencies from 30 Hz to 1000 MHz.

When field strength standards or meters are submitted for calibration, an instruction manual and all accessories should be included, and the instrument should be in excellent operating condition.

Item	Description
201.850a-1	Calibration of loop antenna at one frequency, 30 Hz to 30 MHz.
201.850a-2	Calibration of loop antenna at frequencies additional to item 201.250a-1, 30 Hz to 1 MHz.
201.850a-3	Calibration of loop antenna at frequencies additional to item 201.850a-1, 1 to 30 MHz.
201.850z	Special calibrations not covered by the above schedule.
201.851a-1	Calibration of dipole antenna at one frequency, 30 to 1000 MHz.
201.851a-2	Calibration of dipole antenna at frequencies additional to item 201.851a-1, 30 to 400 MHz.
201.851a-3	Calibration of dipole antenna at frequencies additional to item 201.851a-1, 400 to 1000 MHz.
201.851z	Special calibrations not covered by the above schedule.
201.852a-1	Calibration of input attenuators at one frequency, initial step.
201.852a-2	Calibration of additional steps of input attenuator in addition to item 201.852a-1.
201.852b-1	Calibration of the over-all linearity of receiver and output circuit at one frequency and the one attenuator setting, initial point.
201.852b-2	Calibration of over-all linearity of receiver at other points in addition to item 201.852b-1.
201.852c-1	Calibration of the receiver as a two-terminal RF voltmeter, 1 to 10,000 μv, 0 to 400 MHz, at one frequency.
201.852c-2	Calibration of the receiver as a two-terminal RF voltmeter at other frequencies additional to item 201.852c-1, 0 to 400 MHz.
201.852c-3	Calibration of the receiver as a two-terminal RF voltmeter at other frequencies additional to item 201.852c-1, 400 to 1000 MHz.
201.852z	Special calibrations not covered by the above schedule.

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Contributors

Morris E. Brodwin (A'49–M'55) was born in New York, N. Y., on July 14, 1924. He received the B.S. degree in electrical engineering from the University of Nebraska, Lincoln, in 1947, the M.S. and Dr.Eng. degrees from The Johns Hopkins University, Baltimore, Md., in 1951 and 1957, respectively.

He was a member of the Martin Company in 1948. In 1949 he joined the Radiation Laboratory of The John Hopkins University where he was appointed Research Scientist in charge of microwave research. In September, 1958 he joined the faculty at Northwestern University, Evanston, Ill., and is presently Professor of Electrical Engineering. He is currently engaged in the study of microwave physics.

Dr. Brodwin is a member of Sigma Xi, Eta Kappa, Nu, Pi Mu Epsilon, and the Physical Society.

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O. R. Cruzan was born near Cushing, Okla., on July 4, 1914. He received the B.S. degree in physical science from Oklahoma State University, Stillwater, in 1947.

In 1941 he joined the staff of the National Bureau of Standards as a Physicist in the Field Test Section of the Ordnance Development Division. In the same organization, he worked as a Mechanical Engineer from 1945 to 1948. From 1948 to 1952 he worked again as a Physicist, and as a Mathematical Physicist from 1952 to 1954. In 1953 he became a member of the staff of Harry Diamond Laboratories, Washington, D. C., through the transfer of the Ordnance Development Division to the Department of the Army. From 1954 to the present, he has worked as an Applied Mathematician.

Mr. Cruzan is a member of the American Physical Society.

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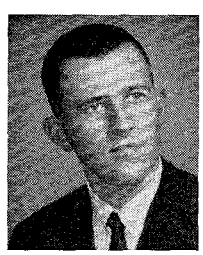
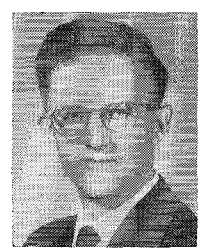


Clay S. Durrett (S'60–M'61) was born in Tuscaloosa, Ala., on November 15, 1939. He received the B.S. degree in electrical engineering from the University of Alabama, University, in 1961.

While undertaking graduate study at the University of Alabama during the academic years 1961 to 1963, he served as a Research Assistant with the University's Bureau of Engineering Research. In 1963 he joined Space Craft, Inc., Huntsville, Ala., where he has worked with solid-state signal sources.

Mr. Durrett is a member of Eta Kappa Nu.



Robert V. Garver (M'57) was born in Minneapolis, Minn., on June 2, 1932. He received the B.S. degree in physics from the University of Maryland, College Park, in 1956.

In 1956, he became affiliated with the Microwave Development Section of Diamond Ordnance Fuze Laboratories, Washington, D. C., where he has been working on microwave semiconductors.

Mr. Garver is a member of the American Physical Society.

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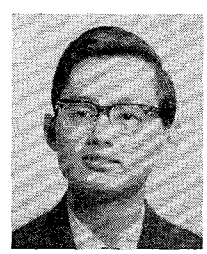

Jin-Twan Lim (S'64) was born in Rangoon, Burma on October 29, 1936. He received the B.Sc.(Eng.) degree in electrical engineering from the University of Rangoon, Burma, in 1960.

From 1960 to 1962 he was trained as a graduate apprentice in electronics and telecommunications with the General Electric Company Limited of Great Britain in their laboratories at Coventry and North Wembly, England. In 1962, he joined the Electrical Engineering Department of Leeds University, England as demonstrator and has been doing research for the Ph.D. degree on broadbanding of microwave amplifiers.

Mr. Lim is a graduate member of the IEE, Great Britain.