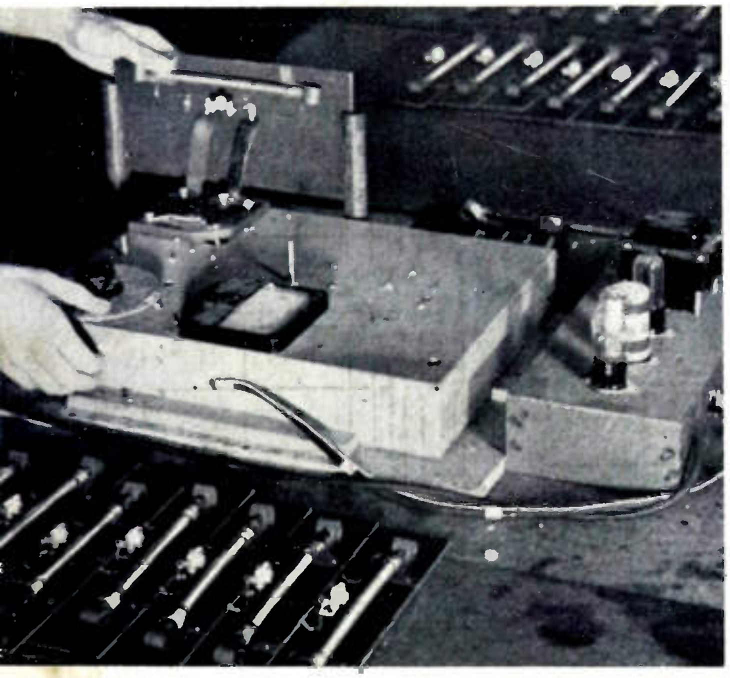
Proceedings of the I·R·E

A Journal of Communications and Electronic Engineering

December, 1952

Volume 40 Number 12



Heppner Manufacturing Company

ANTENNA TESTING TECHNIQUES

Ferrite rod antennas for small personal radio receivers are individually tested for cube permeability and inductance after they are mounted, to insure uniform performance characteristics.

PROCEEDINGS OF THE I.R.E.

Table of Contents, Indicated by Black-and-White Margin, Follows Page 64A

The IRE Standards on Receivers: Definitions of Terms, appears in this issue.

The Institute of Radio Engineers

IRE Swings to the Southwest!

1953 Seventh Regional IRE Conference

To be held on the campus of the University of New Mexico, in beautiful Albuquerque, New Mexico, the heart of the "Land of Enchantment" on

January 26 and 27, 1953

Technical sessions will be held in the following fields:

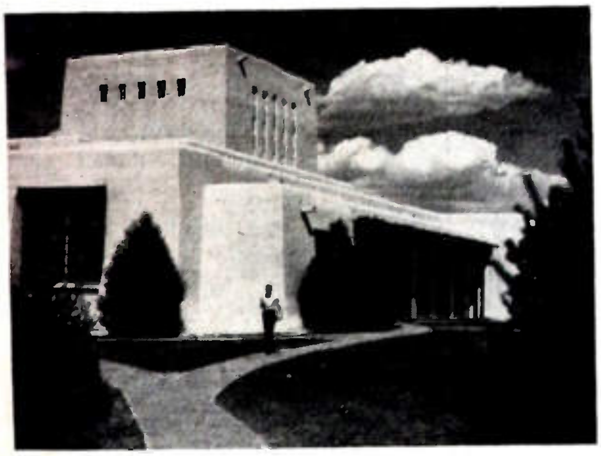
1. **Nuclear Resonance Techniques and Applications.** A full day symposium, the first to be held under IRE auspices in this rapidly growing field.
2. **Guidance and Control.** Papers by several of the foremost experts in the field.
3. **Computers.** Including a sound film describing the "Maniac," developed by the Los Alamos Scientific Laboratory.
4. **Microwaves and Propagation.** This session will contain a paper by Dr. Haeff on "Novel Methods of Microwave Energy Amplification," and a paper on microwave applications of ferrites.
5. **Circuit Analysis.** Servomechanism theory and applications, a new treatment of noise in linear systems, etc.
6. **Miniaturization.** Papers by leading exponents of this art.
7. **Engineering Education.** Prognostications by leading educators and industry representatives of the Southwest.

Field Trip. Los Alamos Scientific Laboratory January 28 (advance clearance required; those interested should contact Capt. J. L. Crone, 1314 13th Loop, Sandia Base, Albuquerque, New Mexico)

Manufacturer's Exhibits. 26 booths now allocated—the rest going fast, available through Hoyt Westcott, 107 Washington St., S.E., Albuquerque, New Mexico.

Social Activities. Banquet, luncheon, cocktail party. Special events for the ladies include a tea, luncheon, Southwestern fashion show, and a tour of quaint Santa Fe on Jan. 28. Special tours of the region around Albuquerque, Indian Pueblos, etc., may be arranged through Fred Harvey, Indian Detour.

The Conference Hotel will be the Alvarado.



Fifth Southwestern IRE Conference

February 5-6-7, 1953

Plaza Hotel

San Antonio, Texas

•

Eleven Important Technical Sessions

- △ Television
- △ Broadcast
- △ Medical Electronics
- △ New Components
- △ Audio
- △ Petroleum Electronics
- △ Microwave Communications
- △ Instrumentation
- △ Servo Mechanisms
- △ Telemetering
- △ Student Prize Papers

Ladies Program • Placement Service

Radio Industry Products Show

IRE Meetings and Exhibits Promote Electronic Progress!

Proceedings of the I.R.E. December, 1952, Vol. 40, No. 12. Published monthly by the Institute of Radio Engineers, Inc., at 1 East 79 Street, New York 21, N.Y. Price per copy: members of the Institute of Radio Engineers $1.00; non-members $2.25. Yearly subscription price: to members $9.00; to non-members in United States, Canada and U.S. Possessions $18.00; to non-members in foreign countries $19.00. Entered as second class matter, October 26, 1927, at the post office at Menasha, Wisconsin, under the act of March 3, 1879. Acceptance for mailing at a special rate of postage is provided for in the act of February 28, 1925, embodied in Paragraph 4, Section 412, P. L. and R., authorized October 26, 1927.

Table of Contents will be found following page 64A

Meetings with Exhibits

● As a service both to Members and the industry, we will endeavor to record in this column each month those meetings of IRE, its sections and professional groups *which include exhibits.*

Δ

December 10, 11 & 12, 1952

Joint IRE-AIEE Computers Conference Park Sheraton Hotel

Exhibits: Perry Crawford, 373 Fourth Avenue, New York City.

Δ

January 26, 27, 1953

1953 7th Regional IRE Conference, University of New Mexico, Albuquerque, N.M.

Exhibits: Hoyt Westcott, 107 So., Washington St., Albuquerque, N.M.

Chairman: C. W. Carnahan, 3169 41st Place, Sandia Base, Albuquerque.

Δ

February 5, 6 & 7, 1953

Southwestern IRE Conference Plaza Hotel, San Antonio, Tex.

Exhibits: M. B. Lampl, Box IRE, St. Mary's University, San Antonio, Texas

Δ

March 23, 24, 25 & 26, 1953

Radio Engineering Show Grand Central Palace, New York City

Exhibits Manager: Wm. C. Copp, 303 W. 42nd St., New York 36, N.Y.

Δ

April 11, 1953

NEREM—New England Radio Engineering Meeting, University of Connecticut, Storrs, Conn.

Exhibits: H. W. Sundius, The Southern New England Tel. Co., 227 Church St., New Haven, Conn.

Δ

April 18, 1953

Spring Technical Conference of the Cincinnati Section, Cincinnati, Ohio

Exhibits: R. W. Lehman, Baldwin Piano Co., 1801 Gilbert Ave., Cincinnati 2, Ohio

Δ

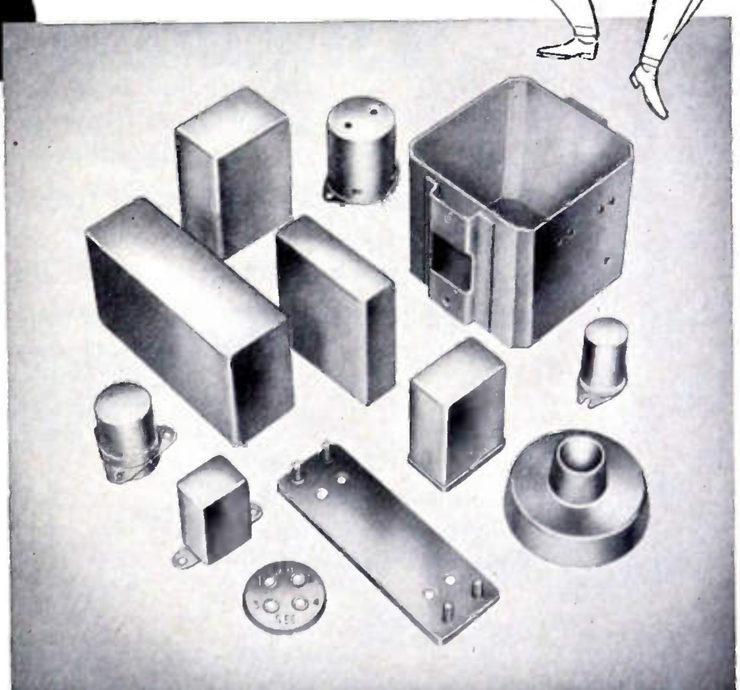
May 11, 12 & 13, 1953

National Conference on Airborne Electronics Hotel Biltmore, Dayton, Ohio.

Exhibits: Paul D. Hauser, 1430 Gascho Drive, Dayton 3.

IF YOU'RE SINGING THOSE "case and cover blues"

LET HUDSON chase your troubles away!



IF waiting for cases, covers and specification metal stampings stymies your production, it will pay you to check with Hudson, now! For Hudson standard cases and covers — mass produced to meet all but the most unusual closure requirements—are available in scores of shapes and sizes.

Consult the new Hudson catalogs for a practical, economical solution to your problems. Just call or write today for complete information and data by return mail! Please address inquiries to Desk 210.

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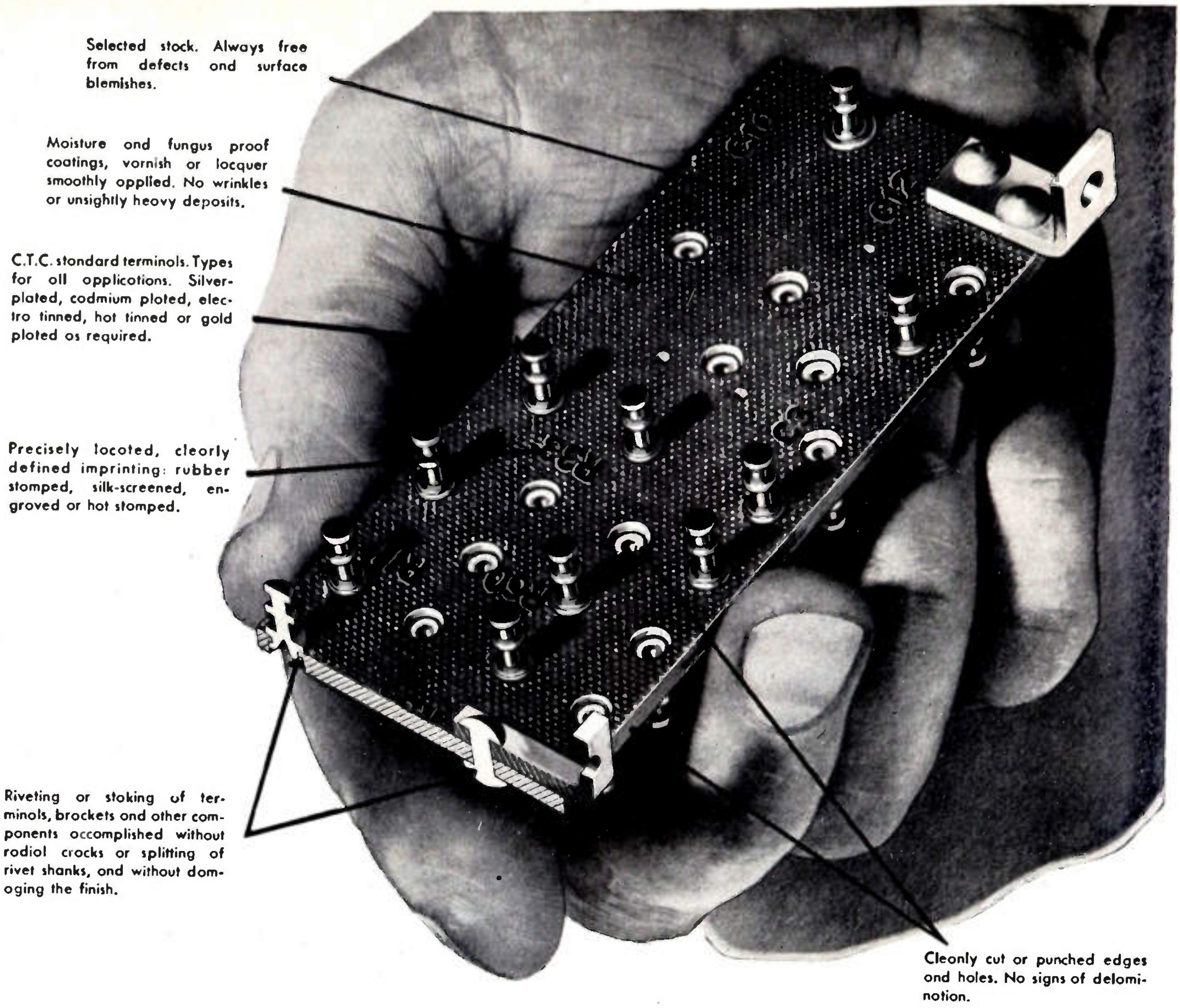


Little details on terminal boards
...*make the big difference in quality*

C.T.C. is constantly supplying special terminal boards to the top names in electronics. These boards are built to strict government specifications, are fabricated of certified materials to fit the job. Among the specifications involved are: MIL-P-3115A, MIL-P-15037, MIL-P-15035, MIL-P-15047, MIL-P-997A.

Our Custom Engineering Service is well-equipped to fill these specifications for you. We are thoroughly familiar with the JAN and MIL-approved materials and finishes in accepted usage by government agencies and the armed forces. This, combined with assembly know-how developed over many years of supplying electronic components and equipment to the government, enables us to meet your needs for quality above and beyond the basic government standards.

Boards can be made of cloth, paper, nylon or glass laminates (phenolic, melamine or silicone resin), and can be lacquered or varnished to specifications: JAN-C-173, MIL-V-173 and JAN-T-152. Lettering and numbering is done by rubber stamping, silk screening, hot stamping, engraving. Inks used in rubber stamping contain anti-fungus and fluorescent additives.

For complete information write: Cambridge Thermionic Corporation, 456 Concord Avenue, Cambridge 38, Mass. West Coast manufacturers, contact: E. V. Roberts, 5014 Venice Blvd., Los Angeles, or 988 Market St., San Francisco, Cal.

CAMBRIDGE THERMIONIC CORPORATION

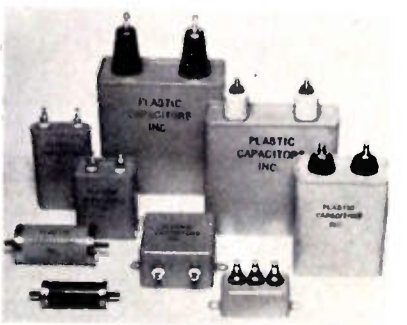
custom or standard... the guaranteed components

NEWS and NEW PRODUCTS

December 1952

New Capacitor Firm

A new firm in the field is **Plastic Capacitors, Inc.**, 2511 West Moffat St., Chicago 47, Ill. Stephen Meskan, President and General Manager, was previously chief engineer and president of the Condenser Products Co., with twelve years prior experience in the aircraft communications field.



The products which the new firm will manufacture include plastic-film dielectric capacitors, high-voltage, low-current power supplies, and pulse forming networks. Capacitor customers will be aided in proper choice of solid dielectric film capacitors to accentuate the electrical characteristics and increase the circuit efficiency. Power supplies for 400 cps and other primary sources will cover ranges of 2,000 to 50,000 volts and 1 to 5 ma.

A complete catalog of Plastic Capacitors, Inc. products is available without charge.

Bandwidth Compressor

The Rafax Bandwidth Compressor developed by **Haller, Raymond & Brown, Inc.**, State College, Pa., operates on radar data from a search radar. In a typical case, it accepts video of about 2-5-mc bandwidth and reduces it to about 3-kc bandwidth. The reduction takes place by means of data storage on the face of an intensity-modulated circular trace on the face of the cathode-ray tube. The circular trace is scanned at a slow rate by means of an optical system and photomultiplier tube. The instrument's advantages are that it simplifies data handling in systems where video is to be transmitted over telephone lines or stored on magnetic drums and that it builds up weak signals through integration.

Detailed information will be furnished on request.

Omnirange Test Set

A new portable unit manufactured by **American Electroneering Corp.**, 5025-29 Jefferson Blvd., Los Angeles, Calif., provides simulated omniphase, ILS, and tone ILS signals for laboratory or ramp test of airborne VHF and navigation radio gear.

The set checks omnibearings continuously variable from 0° to 360° and assures accuracy to 1°. In addition, it will check left-center-right and up-center-down on 90-150 localizer and glide slope. A self-contained, regulated dual power supply utilizes either 105-130 volts ac 60 cps or 22-30 volts dc at 5 amperes. Dimensions are 11×18×12 inches. The unit is called ILS Signal Generator model AEC-200

Microwave Signal Generator

A new series of signal sources for microwaves from 1245 mc to 9660 mc is announced by **Kay Electric Co.**, 14 Maple Ave., Pine Brook, N. J.

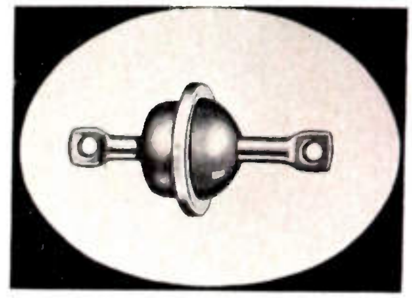
These instruments are called "Centilators" and each consists of a reflex klystron oscillator, an output transmission line system with an attenuator and a crystal detector, a sawtooth generator which provides signal for sweeping the klystron frequency, and a regulated power supply. The Centilator 8596 has, in addition, a calibrated wavemeter for frequency measurement. Centilators 6274 and 8596 use waveguide output, while the other models terminate in standard "N" type coaxial connectors.

Five frequency ranges are available, each in a separate Centilator. They are, 8,500 to 9,660 mc, 6,250 to 7,425 mc, 4,240 to 4,910 mc, 3,400 to 3,960 mc, and 1,245 to 1,460 mc.

The power supply is 105 to 125 volts, 60 cps, 110 watts, self-contained electronically regulated.

Thermo-Setting Plastic

A new plastic material that withstands continuous temperatures of 200°C, and also possesses a high dielectric strength, is in production by **Melkor Research Laboratories, Inc.**, 11731 Detroit Ave., Cleveland 7, Ohio, in the manufacture of the complete hermetic-seal terminal illustrated.



Custom production will be available on all special types of applications for manufacturers of finished products requiring high-temperature insulation combined with hermetic sealing. The terminal shown is being manufactured in three sizes, $\frac{3}{16}$-inch, $\frac{5}{16}$-inch, and $\frac{3}{8}$-inch mounting holes. The most advantageous applications for this new terminal are in assembly of instruments, meters, and various types of electric and electronic equipment requiring hermetic sealing. This new material is known as "Melkorite."

Specifications

Dielectric strength	8000 v-60 cps
Corona starting voltage	2000 v-60 cps
Air-pressure test	30 lbs
Terminal pull	25 lbs
Continus operating temperature	200°C
Short period temperature 5 minutes	260°C
Thermol cycling 4 cycles	−70°C to 200°C
Thermol cycling 4 cycles when soldered ceases	−65°C to 150°C

"Premium" Twin Diode

Tube Dept., Radio Corp. of America, Harrison, N. J., has a new Model 5726 high-perveance, miniature twin diode especially useful as a detector in circuits utilizing wide-band amplifiers. Constructed to give dependable performance under shock and vibration, this "premium" version of the 6AL5W is particularly suited for use in mobile and aircraft equipment.

The two coiled heaters used in the 5726 are internally connected in series to provide fail-safe operation in applications which require that burnout of either heater will make the heaters of both units simultaneously inoperative. These heaters are pure tungsten.

(Continued on page 96A)

It's that Simple...

...Automatic Push-Button Tuning

An Exclusive Feature of the New

DAVEN

Distortion and Noise Meter Type 35-A

The DAVEN Type 35-A, Distortion and Noise Meter, is a new, skillfully engineered instrument that provides a rapid, accurate means of measuring distortion, noise and hum level in audio frequency equipment.

Of particular importance is the fact that there is no balancing or laborious time consuming tuning required to make measurements. The user need only push a button and the unit is automatically balanced.

This is accomplished by the use of a series of 8 fixed band rejection filters covering the range 50 cycles to 15 K.c., followed by a stable, high quality, wide range (50 cycles to 45 K.c.), high gain amplifier. There are no tube circuits or other sources of inherent distortions, making it possible to measure low levels of distortion accurately over a wide level range.

SPECIFICATIONS

RESIDUAL DISTORTION: No tube circuits or non-linear devices between input of set and filter input.

DISTORTION MEASUREMENTS: Filters provided for 50, 100, 400, 1000 cycles, 5 Kc, 7.5 Kc, 10 Kc, and 15 Kc with cut off of −70 db. Distortion measurements to 0.1% full scale meter deflection with zero level input.

NOISE MEASUREMENTS: With zero db input, limit is −80 db. At +40 input, limit is −115 db below input.

AMPLIFIER FREQUENCY RANGE: 50 cycles to 45 Kc.

ACCURACY: Filters are down 70 db at fundamental frequencies, and within ±0.5 db of flat response at the second harmonic. Absolute accuracy of measurement can be depended upon to be within ±5%.

RESIDUAL NOISE LEVEL: Below −80 db at gain control full on. Multiple gain control employed so that residual noise drops to −90 db. when gain control is set at −30, −100 db when gain control is set at −20, etc.

Write for detailed information

THE DAVEN CO.
195 CENTRAL AVENUE
NEWARK 4, N. J.

494 feet above Philadelphia's busiest streets

Most city building codes are easily complied with, but nature's caprices are unpredictable. So, when both the building's owners and WPEN's engineers laid plans for a new AM-FM station atop their new mid-town building they called on Blaw-Knox to design, fabricate and erect a *safe* antenna tower. Their choice was based on the fact that Blaw-Knox has an unequaled record for successful tower installations in congested areas. WPEN's structure is designed to carry the additional load of TV bays if and when required.

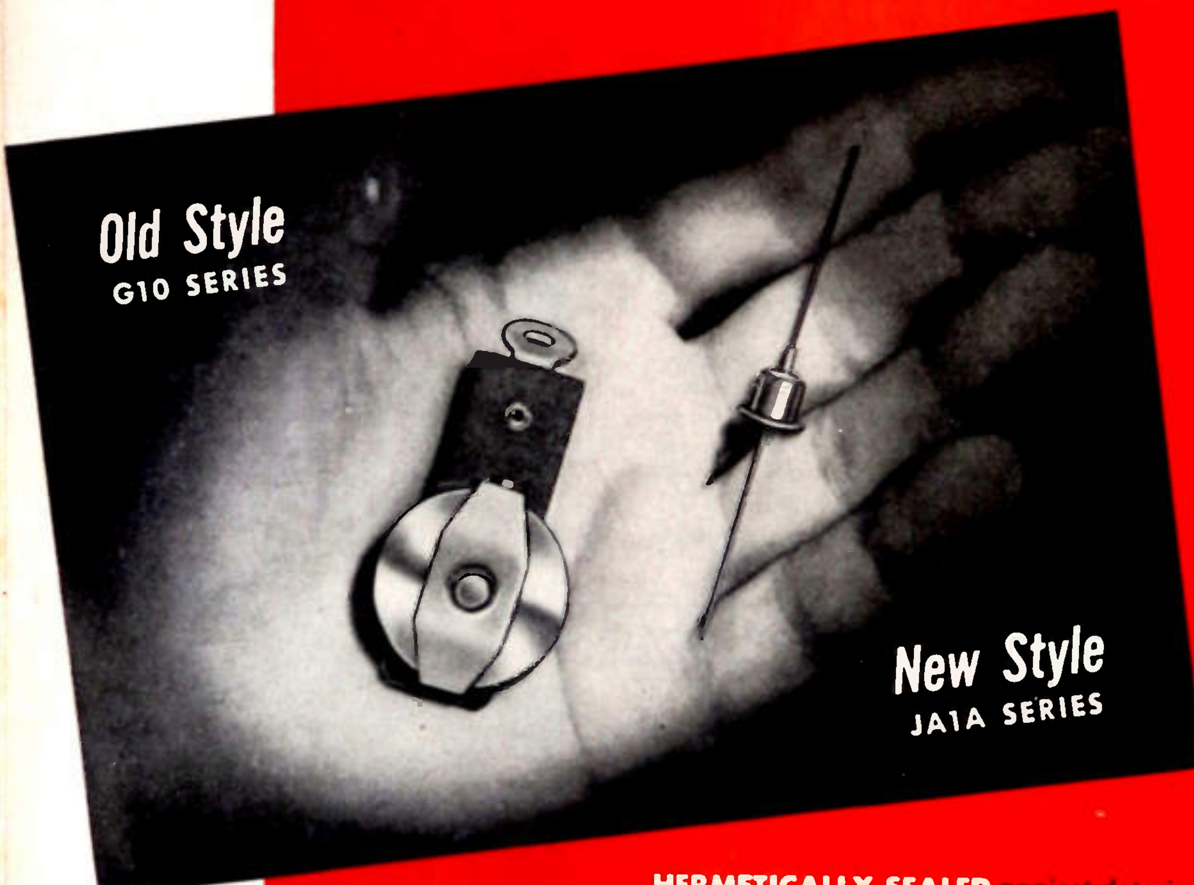
BLAW-KNOX DIVISION
OF BLAW-KNOX COMPANY
2037 Farmers Bank Bldg.
Pittsburgh 22, Pa.

BLAW-KNOX ANTENNA TOWERS

Distributed by Graybar

G-E Diffused Junction

NOW RATED



CHECK THESE NEW CHARTS

HERMETICALLY SEALED against deteriorating elements. Glass-to-metal seals throughout.

MINIATURE SIZE to facilitate use in all electronic equipments, yet heat losses are dissipated efficiently.

REDESIGNED to meet all military humidity tests and shock and vibration requirements.

HIGH OUTPUT VOLTAGE and improved back current characteristics.

MODEL 4JA2A4 designed for use in TV power supplies. DC output voltage is 10 to 15 volts higher than with comparable selenium rectifiers in a typical voltage doubler circuit.

Germanium Rectifier

AT 55°C!

ABSOLUTE MAXIMUM RATINGS • T-55°C • RESISTIVE LOAD				
DIFFUSED JUNCTION RECTIFIER	4JA1A1	4JA1A2	4JA1A3	4JA2A4
PEAK INVERSE VOLTAGE* (volts)	100	200	300	400
PEAK FORWARD CURRENT (amps)	0.47	0.31	0.25	1.57
D.C. OUTPUT CURRENT* (Ma)	150	100	75	500
D.C. SURGE CURRENT (amps)	25	25	25	25
FULL LOAD VOLTAGE DROP (volts peak)	0.5v	0.5v	0.5v	0.7v
FORWARD RESISTANCE AT FULL LOAD (ohms)	1.1	1.5	1.9	0.5
CONTINUOUS REVERSE WORKING VOLTAGE (volts D.C.)	30	30	30	185
FREQUENCY OF OPERATION (kc)	50	50	50	50
STORAGE TEMPERATURE (°C)	85	85	85	85

*Typical absolute maximum ratings. For other combinations refer to Fig. 1.

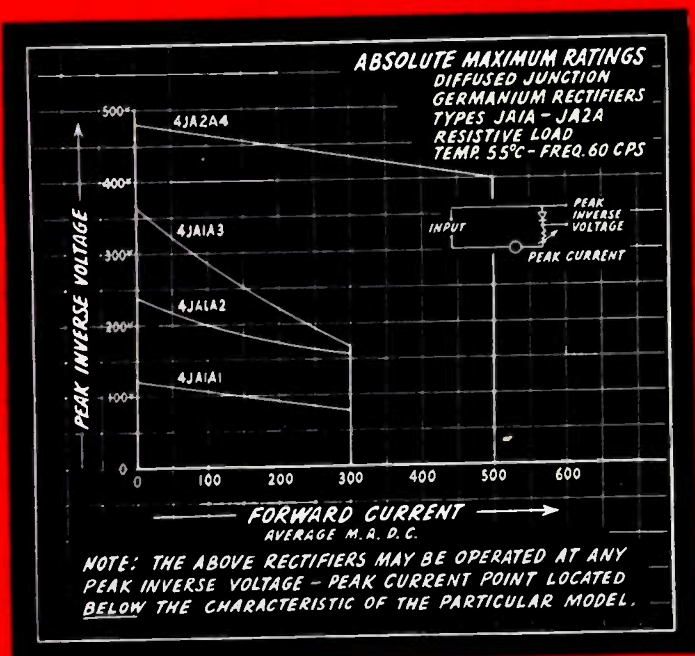
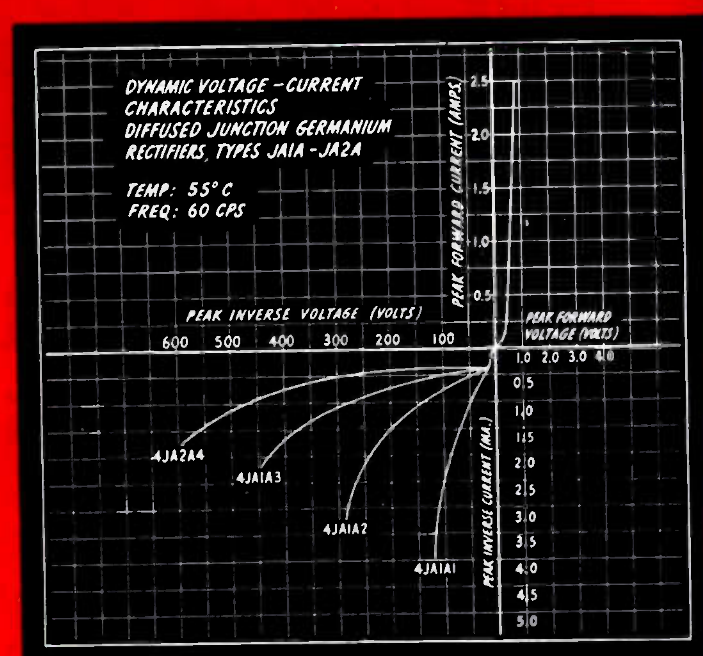


Fig. 1

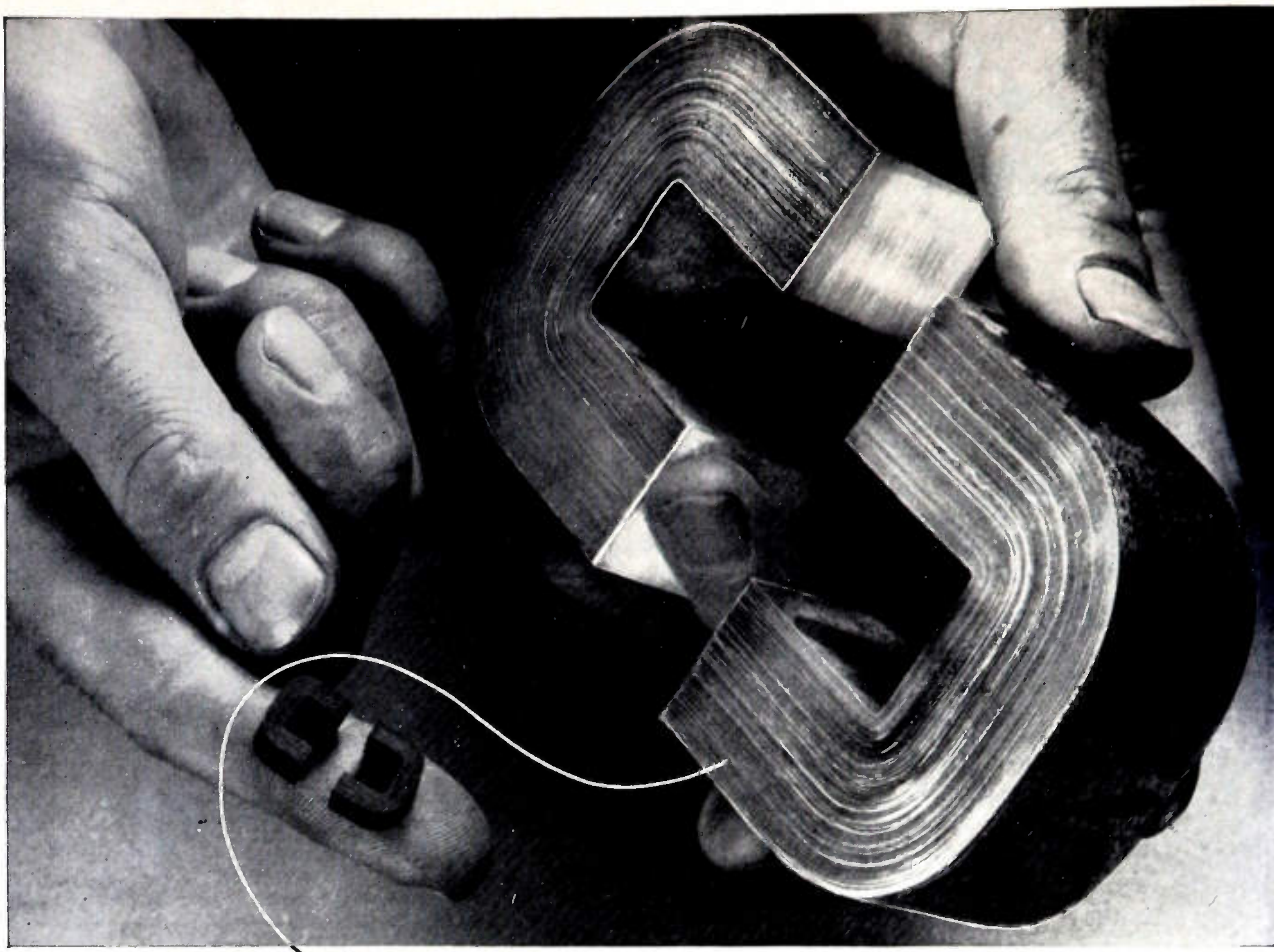


Suggested Application Fields

Originally developed for military use, the new JA1 and JA2 Rectifiers may be adaptable to fields other than radar and military communications. Among them are the following: Computers, magnetic amplifiers, TV receiver power supplies, telephone switchboards. Application information on other uses can be supplied. Write or wire us!

NEW BULLETIN—Complete specifications on the diffused junction rectifiers are contained in this illustrated bulletin. It's yours on request. Write: General Electric Co., Section 52122, Electronics Park, Syracuse, N. Y.

GENERAL ELECTRIC

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GLIDESLOPE
RECEIVER
irline Reliability
• New automatic gain control.
• Dual-conversion superheterodyne design.
• Control circuits conform to industry standards for integration with any existing ILS system.
• Any of 20 world-wide channels by insertion of crystal.
• Built to the same exacting standards of perfection as the famous Wilcox 440A!
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For Immediate Delivery
Write today for complete specifications.
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ELECTRIC COMPANY, INC.
Fourteenth and Chestnut
Kansas City 27, Missouri, U.S.A.

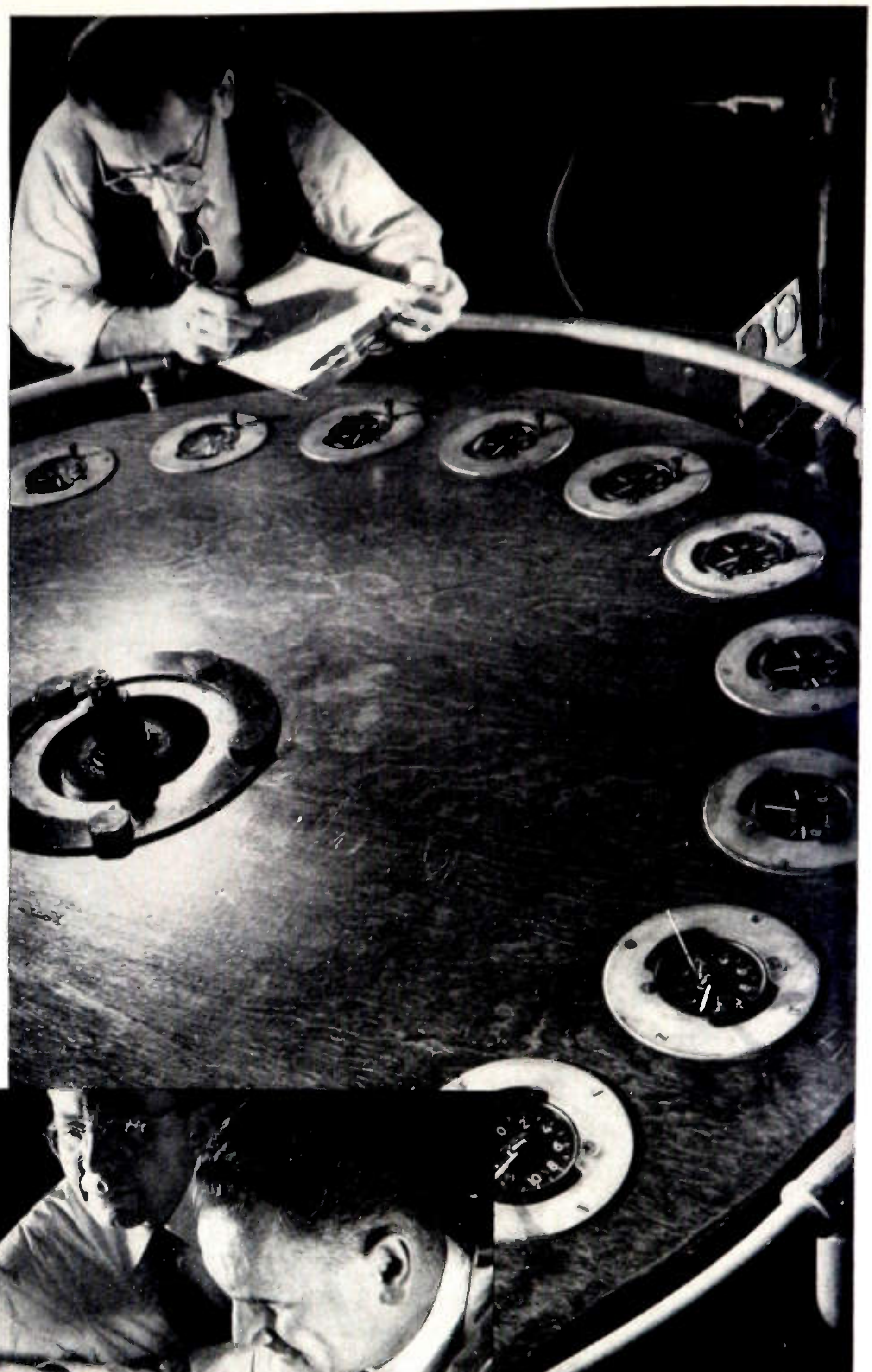
Designed for dependability

...tested (and re-tested) for precision

KOLLSMAN devises, develops and manufactures high-precision

Aircraft Instruments and Controls Miniature AC Motors for Indicating and Remote Control Applications • Optical Parts and Optical Devices • Radio Communications and Navigation Equipment

While our manufacturing divisions are engaged largely in defense production, the Kollsman Instrument Corporation welcomes the opportunity to apply its research experience to the solution of problems in instrumentation and control.



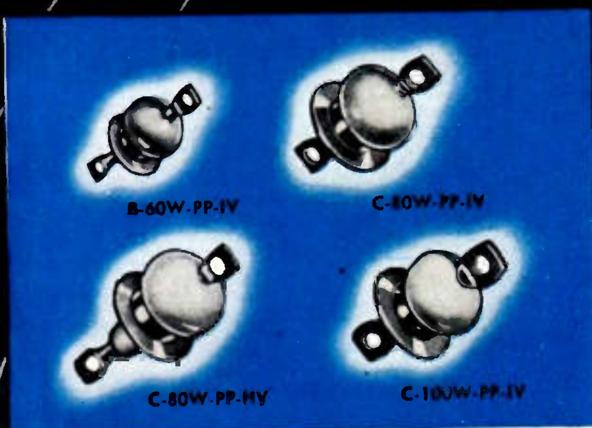
KOLLSMAN INSTRUMENTS

KOLLSMAN INSTRUMENT CORPORATION

ELMHURST, NEW YORK — GLENDALE, CALIFORNIA

SUBSIDIARY OF *Standard* COIL PRODUCTS CO. INC.

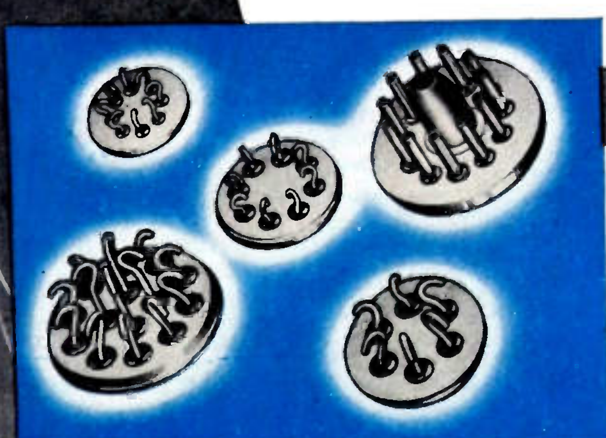
The Complete Answer to TRANSFORMER TERMINAL PROBLEMS



E-I High Creepage Terminals

—WITH LONG LEAKAGE PATHS TO COUNTERACT HIGH MOISTURE AND CORROSION TROUBLES

E-I Terminals of this type provide maximum protection against leakage due to moisture or surface films. The glass bead is specially shaped to increase the leakage path yet the terminal requires no larger mounting area. Double protection is afforded by a silicone treating of the terminal. Rugged construction, plus carefully annealed glass permits rough handling in shop assembly thereby reducing rejects of assembled components. All E-I terminals are hot-tinned



E-I Rigid Multiple Headers

— FOR EVERY GROUPED TERMINATION REQUIREMENT INCLUDING PLUG-IN TYPES

E-I Rigid Headers feature an entirely new method of hermetic sealing developed by Electrical Industries. This method of construction which includes solid metal blanks in place of the usual thin metal stamping, yields a header that is far more rugged than any other type yet produced. The result is effective, permanent sealing under the most extraordinary conditions of shock and vibration.

E-I . . . YOUR HEADQUARTERS FOR HERMETICALLY-SEALED MULTIPLE HEADERS, OCTAL PLUG-INS, TERMINALS, COLOR CODED TERMINALS, END SEALS, etc. WRITE FOR CATALOGS.

DIVISION OF AMPEREX ELECTRONIC CORP.

ELECTRICAL INDUSTRIES

44 SUMMER AVENUE, NEWARK 4, NEW JERSEY

DIGEST

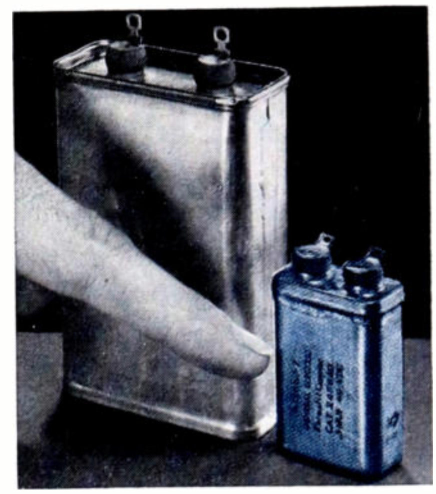
TIMELY HIGHLIGHTS ON G-E COMPONENTS

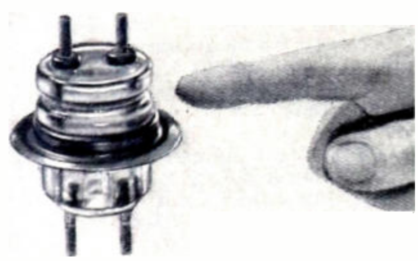
Permafil d-c capacitors have 80% less weight, bulk

They operate in ambients up to 125C for 10,000 hours without derating

High *or* low temperatures have little effect on the electrical stability of G-E permafil capacitors. Their paper dielectric is impregnated with a solid plastic compound—they can't leak. Insulation resistance is high, and change in capacitance with temperature is slight. With proper derating, these units can be used at temperatures as high as 150C.

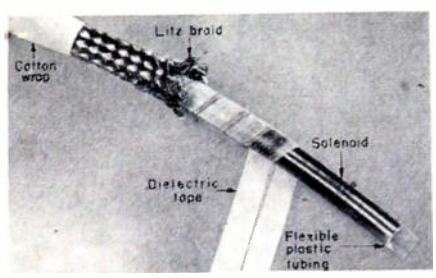
Permafil capacitors average about 1/5 the size and weight of liquid-filled capacitors properly derated to operate at 125C. Because of their small size and excellent electrical characteristics they are ideal for most high-ambient blocking, by-pass, filtering, coupling and timing applications. They are available in ratings of 0.05 to 1.0 muf, 400 volts d-c. All are housed in hermetically sealed metal containers, with G-E all-silicone bushings. Check coupon for Bulletin GEC-811.





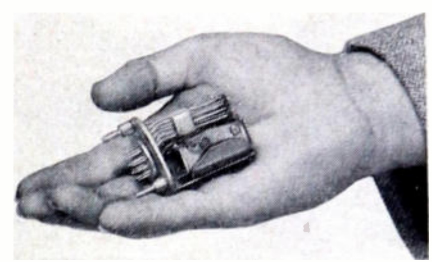
Bushings for hermetic sealing

More and more designers are specifying G-E glass bushings—the type used on capacitors, rectifiers, and instrument transformers. For use where permanent hermetic sealing of electric apparatus is desired, these bushings are easily attached by soldering, brazing, or welding to form a permanent, vacuum-tight seal. Bulletin GEA-5093.



Immediate shipment on delay line

G-E delay line, ideal for delaying signals in electronic circuits, is now available for immediate shipment. Nominal 1000-ohm line delays signals ½ microsecond per ft. Light weight and flexible, it is used widely in military and industrial electronics. Can be obtained in bulk to be cut to desired lengths. Bulletin GEC-459.



New relay doubles tip pressure

This new ***hermetically sealed*** relay has a larger magnet delivering double average tip pressure yet doesn't exceed Air Force-Navy size and weight specs. Sealed in a standard-size enclosure against dirt, salt, moisture, and pressure changes, it withstands 50g shocks and instantaneous voltage surges up to 1500 volts. Bulletin GEA-5729.

EQUIPMENT FOR ELECTRONICS MANUFACTURERS

Components

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Capacitors
Transformers
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Rectifiers
Timers
Indicating lights
Control switches
Generators
Selsyns
Relays
Amplidynes
Amplistats
Terminal boards
Push buttons
Photovoltaic cells
Glass bushings

Development and Production Equipment

Soldering irons
Resistance-welding control
Current-limited high-potential tester
Insulation testers
Vacuum-tube voltmeter
Photoelectric recorders
Demagnetizers

**Reg. Trade-mark of General Electric Co.*

General Electric Company, Section B 667-23
Schenectady 5, New York

Please send me the following bulletins:

✓ for reference only

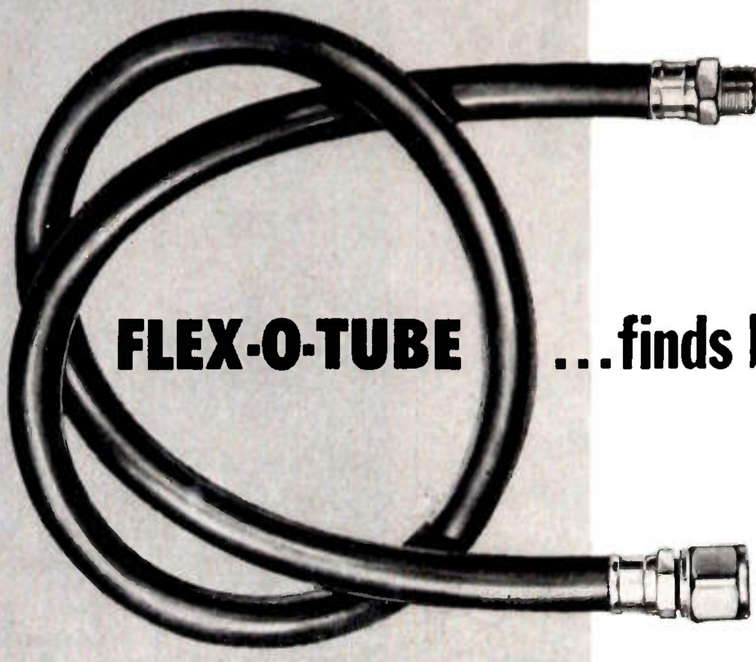
X for planning an immediate project

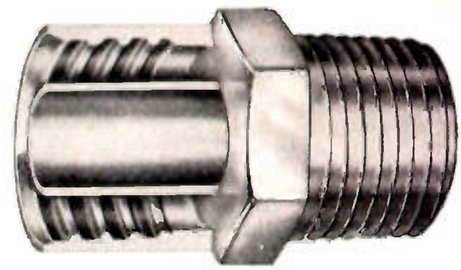
☐ GEA-5093 Glass Bushings
☐ GEA-5729 Hermetically Sealed Relays
☐ GEC-459 Delay Lines
☐ GEC-811 Permafil Capacitors

Name ....

Company ....

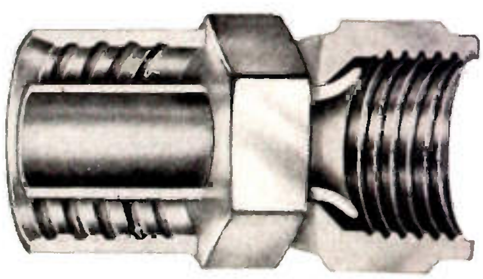
City .... State ....





Flex-o-Tube Hose, and cross section of machined male fitting.

FLEX-O-TUBE ...finds brass makes fine fittings



Cross Section of machined and flared female fitting.

For quick, accurate and economical machining, free-cutting brass rod is preferred by many companies, such as Flex-O-Tube, Division of Meridan Corporation, Detroit, Mich. This company makes hose assemblies and fittings to conduct air-oil-water-gasoline and hydraulic power for the automotive, farm implement, machine tool and aircraft industries. Some of these hoses have a minimum bursting pressure of 20,000 pounds per square inch, which gives an indication of the tightness required, which can be obtained only by strength and accuracy.

Flex-O-Tube has found six points of superiority for brass over other metals, as follows:

1. Brass "flows," or is ductile, so that no cracks result during the crimping operation required to fasten the fittings to the hose.

2. Ductility and strength inherent in brass act to provide a superior seat to fittings designed to control fluid flow. Competitive metals are either too hard or too soft to give positive closing and tend to leak.

3. Where the design of the fitting is intricate, necessitating removal of considerable metal by machining, the automatic screw machines can be run faster with free-cutting brass rod.

4. Brass has a high scrap value, and the scrap sold back to the mill increases brass supplies.

5. The break-even point between brass and other metals is especially favorable to brass in the sizes of rod that Flex-O-Tube buys.

6. Customer preference is for brass, which is universally recognized as a quality metal. Hence brass fittings are more readily sold, and in fact often are specified regardless of size or price differentials.

Included in the Flex-O-Tube operations are machining, flaring, crimping, and annealing to assure the proper ductility for flaring and crimping.

Revere is an important supplier of brass rod to Flex-O-Tube, and has also collaborated with this customer through the Revere Technical Advisory Service.

If you wish information about brass and how one or more of the Revere brasses can add to the economy and saleability of your product, get in touch with the nearest Revere Sales Office. See your telephone directory or write direct.

REVERE

COPPER AND BRASS INCORPORATED

Founded by Paul Revere in 1801

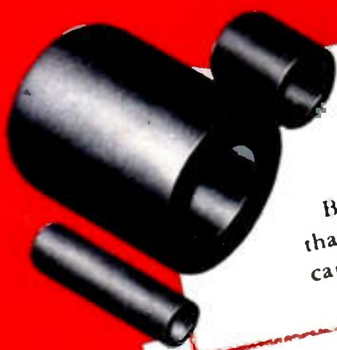
230 Park Avenue, New York 17, N. Y.

• • •

Mills: Baltimore, Md.; Chicago and Clinton, Ill.; Detroit, Mich.; Los Angeles and Riverside, Calif.; New Bedford, Mass.; Rome, N. Y. Sales Offices in Principal Cities. Distributors Everywhere.

SEE REVERE'S "MEET THE PRESS" ON NBC TELEVISION EVERY SUNDAY

Are you missing any of these IRON CORE ENGINEERING POSSIBILITIES?



Smaller tuning units
Less critical materials

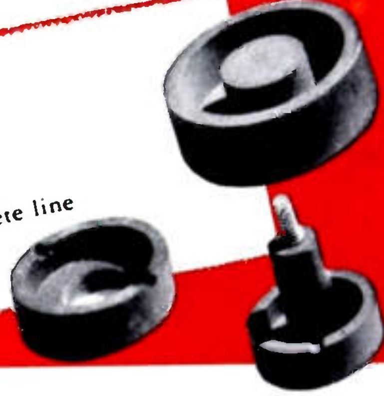
By providing electrostatic and electromagnetic protection over that supplied by the can, *Stackpole sleeve cores* permit use of a smaller can and enable it to be made from less critical and costly materials.

Higher Q
Smaller assemblies
Simplified tuning

Stackpole threaded type iron cores eliminate the usual brass core screw from the field of the coil, thus greatly increasing efficiency.

Better, more accurate permeability tuning

Extra density of molding pressure extends evenly over the entire length of *Stackpole side-molded cores* to assure highly uniform permeability.



No shielding problems
High Q in small space

Pioneers in *cup cores*, Stackpole offers a complete line of standard and special self-shielding types.

There's no substitute for molded iron cores in a long list of applications—electrically, mechanically or economically!

Besides all regular styles for high, low and standard frequencies, Stackpole offers full facilities for the quality-controlled production of almost any needed special type. Write for Catalog RC-8 to Electronic Components Division, Stackpole Carbon Company, St. Marys, Pa.

STACKPOLE

CABLE BY PHELPS DODGE

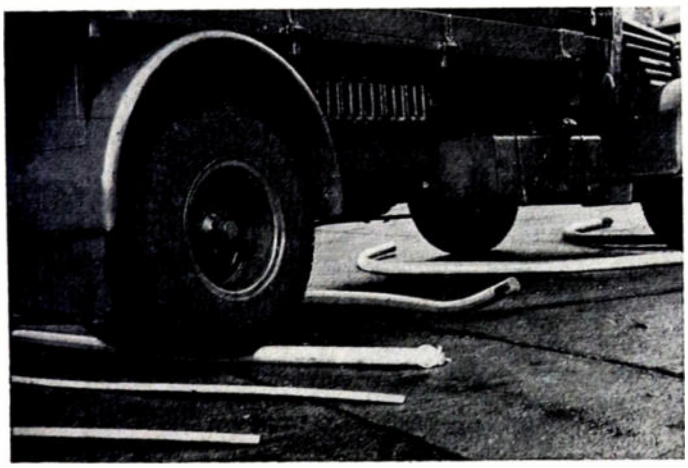
in semi-flexible 1000-ft. lengths without joints!

Reflections Reduced to Absolute Minimum in AM, FM, TV and Microwave Applications

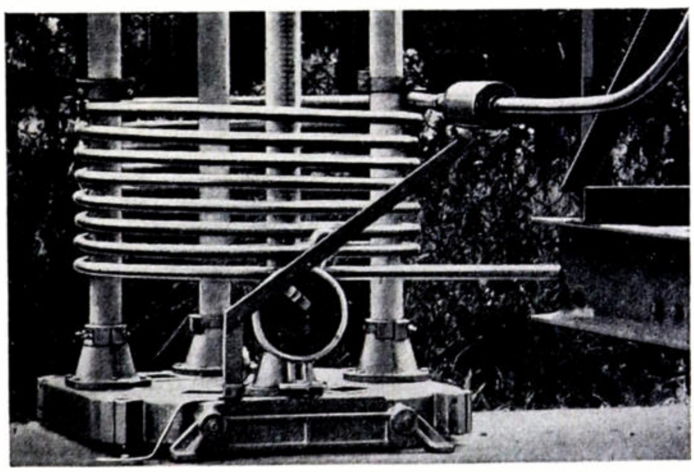
Phelps Dodge Copper Products Corporation's new semi-flexible, aluminum sheathed Styroflex cable is specially designed to meet the need for a high-power, efficient low-loss coaxial cable in the AM, FM, TV and microwave fields. The cable reduces reflections—which cause ghost images in television and distortions in communications—to an absolute minimum.

It was developed by Felten & Guilleaume Carlswerk, of Cologne, Germany, which has made a great many successful installations of the cable throughout Europe. Phelps Dodge is currently making the cable for sale in the United States in standard American sizes and impedances under a working agreement with the Cologne firm. The cable is manufactured in continuous 1000-foot lengths, without joints, and shipped on reels.

Outstanding feature of the cable is the use of insulating Styroflex film to form a helix. This helix, built up of hundreds of precision-wound Styroflex tapes, firmly supports and centers the inner conductor coaxially in an aluminum sheath at all times, assuring retention of excellent electrical properties. Essential flexibility of the Styroflex tape is obtained by special manufacturing techniques.



• In test of strength and ruggedness of Styroflex coaxial cable, heavy truck drives over several samples without damaging them.



• Perfect centering of inner conductor is maintained by Styroflex tape helix, regardless of bending or load cycling both during installation and in service.

PHELPS DODGE COPPER PRODUCTS

CORPORATION

40 WALL STREET, NEW YORK 5, N.Y.

You can use a pogo stick to make it fit...

BUT it's simpler to design the radio around the battery!

National Carbon offers a complete range of "Eveready" "Nine Lives" radio batteries. Just design your new model receiver—any type or size—around *standard*, compact, long-lasting "Eveready" batteries and forget you ever had a battery problem.

Users prefer them, too. They enjoy *better* listening *longer* . . . and when replacements *are* necessary, "Eveready" brand radio batteries are sure to be available wherever radio batteries are sold.

Write to our Battery Engineering Department for full details and specifications of "EVEREADY" radio batteries.

"Eveready" No. 964 "A" battery and "Eveready" No. 477 "B" battery for "personal" receivers—lowest priced complement of its size on the market—feature lowest cost per hour of listening plus a new high in balanced life of the two components.

EVEREADY
TRADE-MARK
RADIO BATTERIES

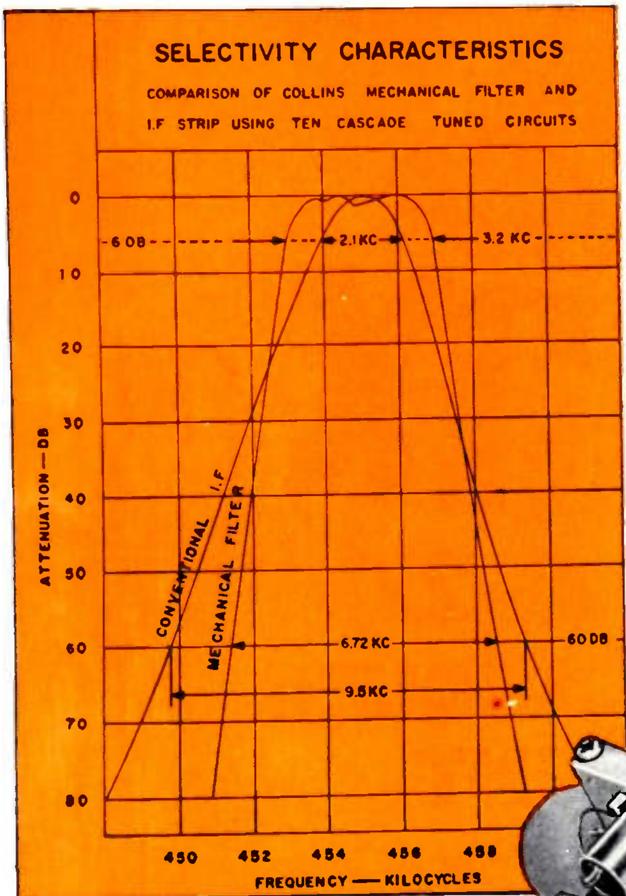
The terms "Eveready", "Nine Lives" and the Cat Symbol are registered trade-marks of Union Carbide and Carbon Corporation

NATIONAL CARBON COMPANY
A Division of Union Carbide and Carbon Corporation
30 East 42nd Street, New York 17, N. Y.

District Sales Offices: Atlanta, Chicago, Dallas, Kansas City, New York, Pittsburgh, San Francisco

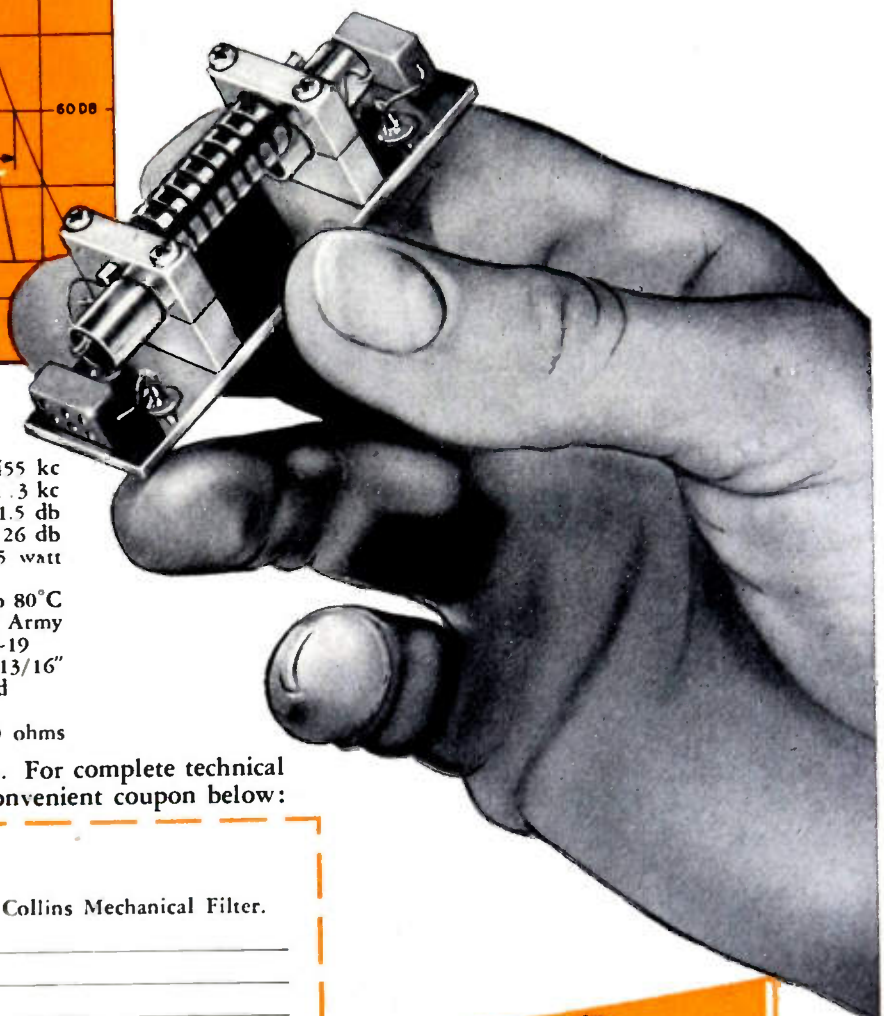
IN CANADA:
National Carbon Limited, Montreal, Toronto, Winnipeg

The *NEW* Collins Mechanical Filter...



ANOTHER outstanding result of Collins Research and Development — the Mechanical Filter — has been engineered to fill a long-standing need in the field of electronics for a compact, permanently tuned band pass filter for intermediate frequency amplifier applications. Mechanical elements of the Collins Filter provide selectivity characteristics approximating the ideal rectangular shape needed for very close spacing of adjacent voice communication channels. Space requirements are reduced to a minimum with this hermetically sealed component that *requires no adjustment.*

Production of the Collins Mechanical Filter in quantity is going ahead at an increased rate in anticipation of the many applications in industry for which this NEW Filter will be found ideally suited. Characteristics of Filters in current production are shown in the specifications below. Filters having other characteristics are in development and will be announced in the future.



SPECIFICATIONS

Operating Frequency	455 kc
Nominal Band Width	3 kc
Peak to Valley Ratio	1.5 db
Insertion Loss	26 db
Overload Input Power Level	.035 watt
Operating Temperature Range (without temperature compensation)	15°C to 80°C
Vibration	Satisfies Requirements of Army Navy Specification AN-E-19
Case Size (Filter Shown with Hermetically Sealed Shield Removed)	1" x 15/16" x 2-13/16"
Input and Output Impedance	6,500 ohms

Engineering samples are now available. For complete technical data and price information, use the convenient coupon below:

Collins Radio Company (Dept. 23)
Cedar Rapids, Iowa
Please send complete Information on The Collins Mechanical Filter.

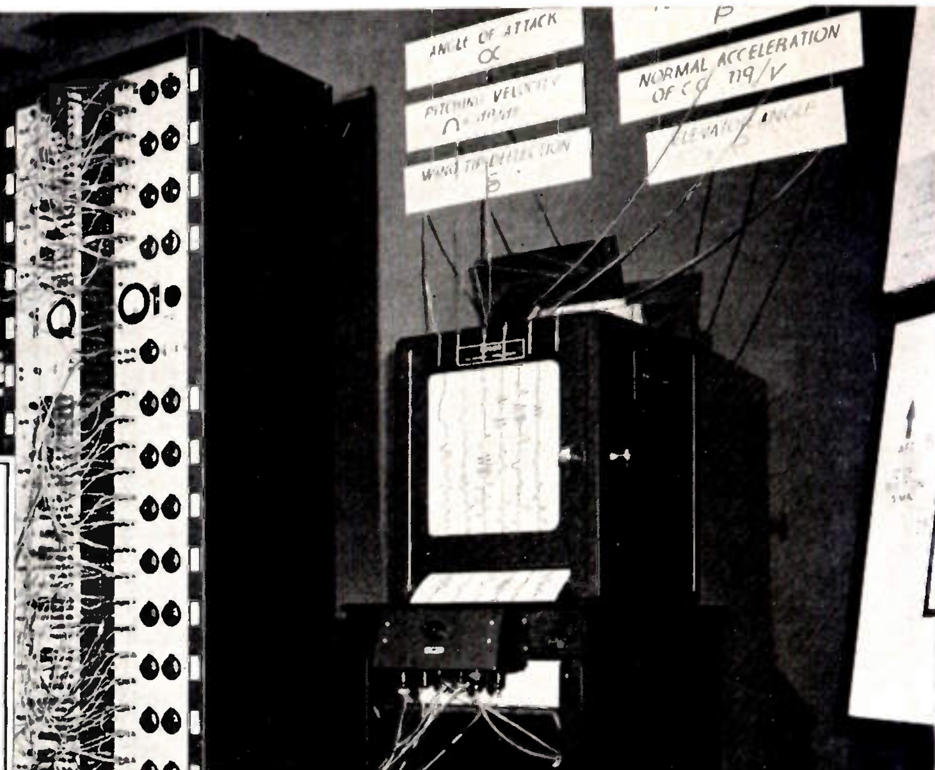
NAME ____________
TITLE ____________
ADDRESS OR FIRM ____________
CITY ____________ STATE ____________

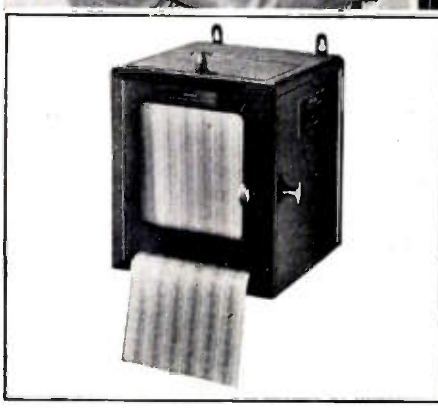
For advanced electronic development, it's . . . COLLINS

COLLINS RADIO COMPANY, Cedar Rapids, Iowa

11 W. 42nd Street, NEW YORK 36 — 1930 Hi-Line Drive, DALLAS 2 — 2700 W. Olive Avenue, BURBANK

Electronic Computer gets the answers...
BRUSH PUTS THEM IN WRITING!





RECORDS SIX VARIABLES SIMULTANEOUSLY. The Brush six-channel Magnetic Oscillograph is designed for simultaneous recording of six electrical and/or mechanical phenomena, with a chart record instantaneously available. This instrument facilitates multiple strain measurement, vibration analysis, wind tunnel work, circuit analysis, etc. Built-in gear changer provides instantaneous shift from high to low speed; wide choice of chart speeds available. Furnished for ink writing or combination electric and ink writing.

RECORDS SIX VARIABLES CONSECUTIVELY. If simultaneous strain measurements are not necessary, consecutive measurements can be made with substantial saving in equipment cost. The Universal Bridge Switch, when coupled with a Brush Universal Analyzer and two-channel Magnetic Oscillograph, permits consecutive recording of strain measurements from six different locations on the structure or specimen being tested. One of the two channels of the oscillograph records strain, the other channel indicates the location of the particular strain measurement.

This Electronic Analog Computer, developed and manufactured by the Boeing Airplane Company, permits engineers to explore problems in all their variations at one time. Hours of laborious calculations are eliminated.

With the use of the Brush six-channel Oscillograph, results from as many as six different computations are recorded simultaneously. Plotting of results is not necessary, since the Brush Oscillograph provides permanent chart records—immediately!

Boeing uses Brush Recorders extensively in their analog computer activities and indicates that their experience with this equipment has been very satisfactory.

Investigate Brush Recording Analyzers for your studies . . . in the laboratory, on the test floor, in the field. Expert technical assistance from Brush representatives located throughout the U.S. In Canada: A. C. Wickman, Limited, Toronto.

For complete information write The Brush Development Co., Dept. F-43, 3405 Perkins Ave., Cleveland 14, Ohio.

PUT IT IN WRITING WITH A BRUSH RECORDING ANALYZER

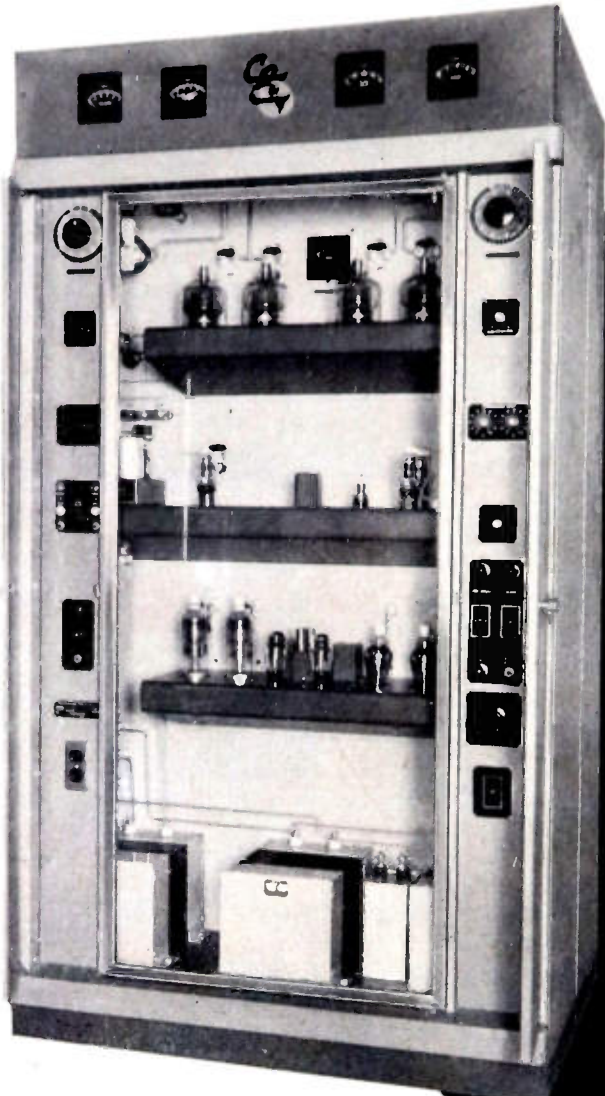
THE Brush DEVELOPMENT COMPANY

BRUSH

Piezoelectric Crystals and Ceramics
Magnetic Recording Equipment
Acoustic Devices
Ultrasonics
Industrial & Research Instruments

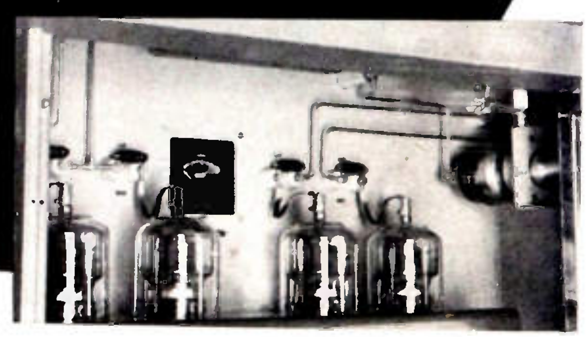
NEW

To AM Broadcasting



Continental Electronics type 314-2 transmitter

Continental Electronics'
One kilowatt transmitter
goes
On the Air
with
Eimac Tetrodes



Eimac 4-400A's in high level stages.

By employing 4-400A radial-beam power tetrodes, and other up-to-the-minute developments in its one kilowatt transmitter, Continental makes a significant advancement in the field of AM broadcasting.

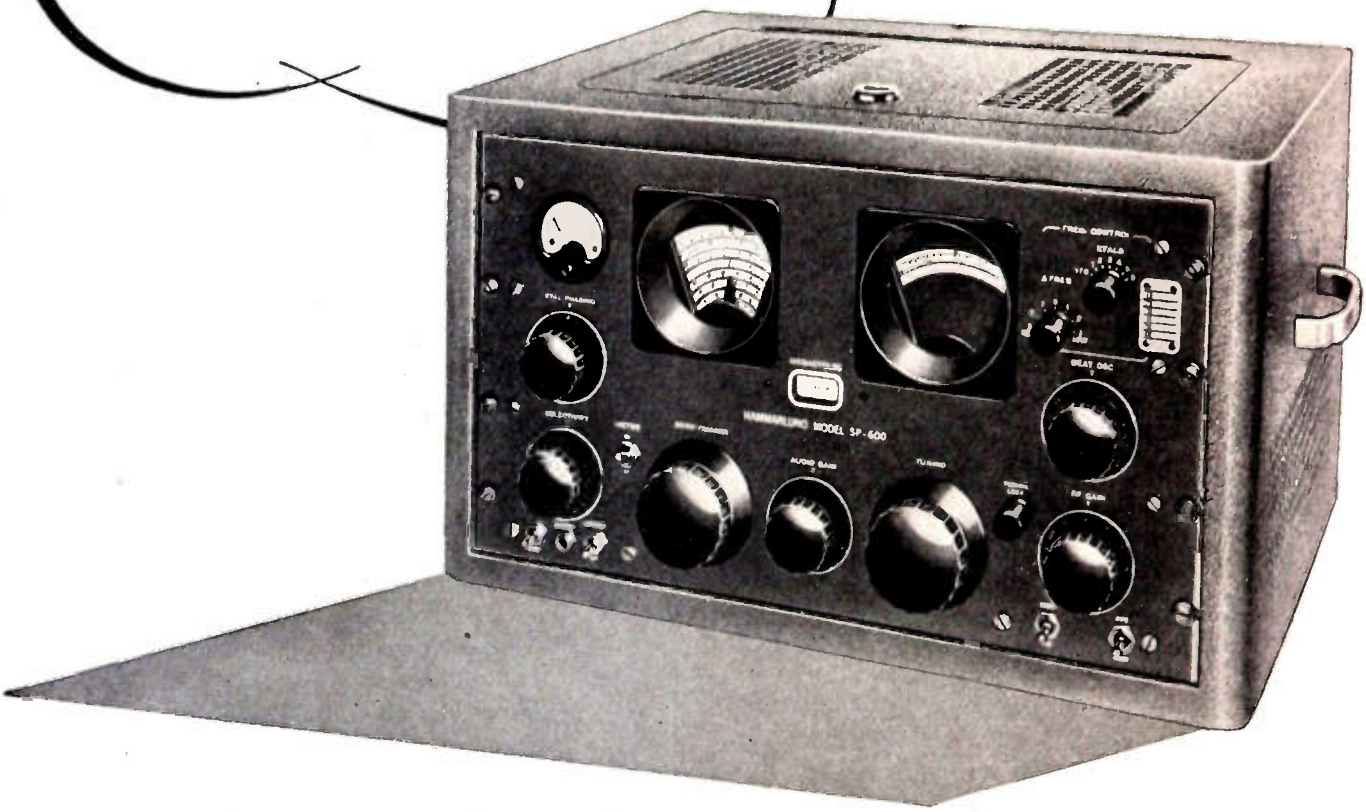
As power amplifiers a pair of Eimac 4-400A tetrodes give outstanding performance. Only two RF amplifiers are used in the 314-2, including the output stage which takes advantage of the low driving power requirements, high power gain and stability of Eimac 4-400A's.

As modulators two 4-400A's are driven by a high quality, resistance coupled audio amplifier with fixed audio feed-back. As in the power amplifier these tetrodes make possible the adaptation of simple, straight-forward circuitry.

For data about the 4-400A write Eimac's Application Engineering department.

Follow the Leaders to Eimac Tubes

EITEL-McCULLOUGH, INC.
SAN BRUNO, CALIFORNIA
Export Agents: Frazar & Hansen, 301 Clay St., San Francisco, California



Another NEW Shunt Diode by

UNITED

High peak power capabilities of type X-80 in relation to its physical size have been accomplished through an unusually forceful combination of design features.

1. Exclusive UNITED bonded *thoria tungsten core filament* for high electron emissivity.

2. Exclusive UNITED *graphite anode* for maximum thermal dissipation.

3. Exclusive UNITED *isolated getter traps* for retention of hard vacuum and high voltage internal insulation.

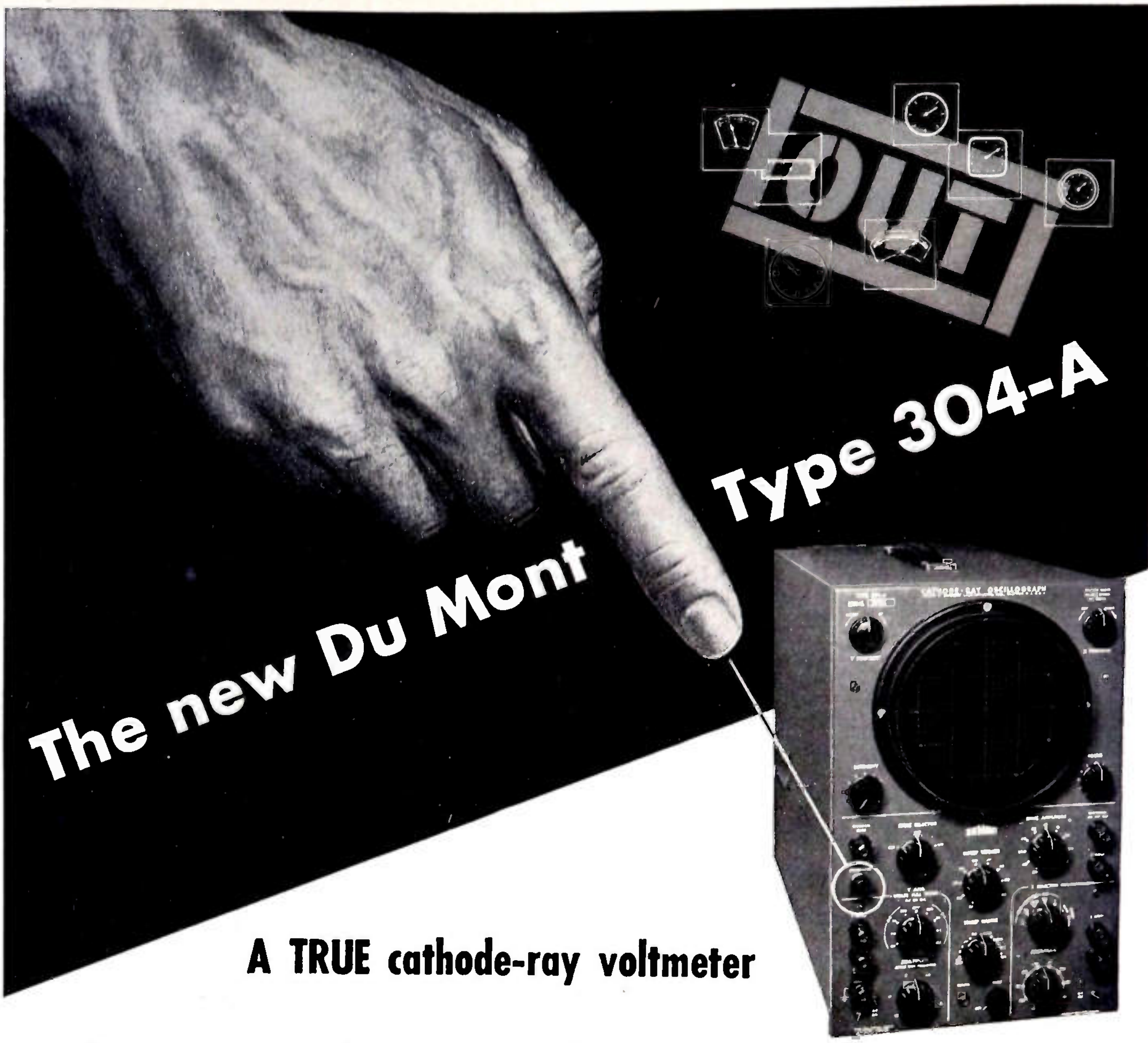
Type X-80 will serve importantly as a high current clipper tube in radar equipment employing the large hydrogen thyratrons, as well as in power supply rectifier applications.

Write for detailed specifications.

40 Kilovolts **Inverse Peak**	80 Amperes **Peak Plate Current as shunt diode**
800 mAdc **(average) as a rectifier**	Filament Ratings **11 Volts Nominal 15.5 Amperes**

TYPE X-80
(actual size)

UNITED ELECTRONICS, 42 Spring Street, Newark 2, N. J.
(TRANSMITTING TUBES EXCLUSIVELY Since 1934)



AT THE PUSH OF A BUTTON...

Once you zero-set a new Du Mont Type 304-A it is almost automatic to measure potentials of the waveforms on the screen of the cathode-ray tube. And you'll be surprised to find out how much more you know about your circuit; how much easier circuit development and production testing become when amplitude calibration is in front of you every time you examine a waveform. The new Du Mont Type 304-A will make your job easier, will greatly simplify measurements that formerly were difficult or inconvenient to make. The Type 304-A is not just another oscillograph; it is a true cathode-ray voltmeter, made possible by a precision calibrator and the tight-tolerance, flat-face Type 5ADP- Cathode-ray Tube. Only through the combined facilities, unique in the industry, of the Du Mont Cathode-ray Tube and Instrument Divisions could the Type 304-A Cathode-ray Oscillograph have evolved.

SPECIFICATIONS:

- Tight-tolerance, flat-face Type 5ADP- Cathode-ray Tube
- Vertical and horizontal amplifiers flat to d.c., 10% down at 100 KC
- Direct voltage measurement — Range, 0.1 to 1000 volts full scale, read directly from oscillograph scale; 5% overall accuracy
- High sensitivity — At full gain, 0.025 volts/inch
- Undistorted vertical and horizontal deflection more than 4 inches
- Expansion equivalent of 20 inches vertically and 30 inches horizontally with full positioning
- Driven and recurrent sweeps with sync limiting — Range, 2 to 30,000 cps; provision for extra-low frequency sweeps by externally connected capacitor; maximum writing rate, 1 inch/μsec
- Illuminated, numbered scale and suitable filter provided; scale illumination variable from zero to more than adequate for viewing and photography
- Improved stability of vertical amplifier

Price **$333.00**

DU MONT INSTRUMENT DIVISION, ALLEN B. DU MONT LABORATORIES, INC., 1500 MAIN AVE., CLIFTON, N. J.

Introducing.. Bliley FUSED QUARTZ *Ultrasonic Delay Lines*

LONG DELAY TIME WITH EXTREMELY HIGH STABILITY UNDER TEMPERATURE VARIATION ...

FUSED QUARTZ ultrasonic delay lines offer decided advantages when it is necessary to delay pulsed or pulse modulated signals for a precise time interval. Bliley, long recognized as the leading manufacturer of precision quartz crystals, is now prepared to DESIGN and CUSTOM BUILD this new electronic tool for your individual application.

In fused quartz delay lines electrical energy is converted into sound energy, passed through the fused quartz, and re-converted into electrical energy by means of piezo-electric quartz transducers which are bonded to either or both ends of the line. Delay time or transit time in the fused quartz, can be held to close tolerance by utilization of proper techniques.

STABILITY $\pm$.2% between $-35°$C and $+85°$C. For example, a 1000 microsecond delay line will change less than ± 2 microseconds over this ambient range.

DELAY TIME values from 5 to 1500 microseconds are feasible depending upon related end use requirements.

PHYSICAL SIZE In the range 5-50 microseconds cylindrical shaped lines are employed, as indicated in the accompanying illustration. Other configurations may be used to meet requirements up to 1500 microseconds. For example, a 15 microsecond (reflection type) delay line including an hermetically sealed case would be a cylinder approximately 2" long x 1" diameter.

FREQUENCY RANGE is 5-100 mc with delay time values as indicated above.

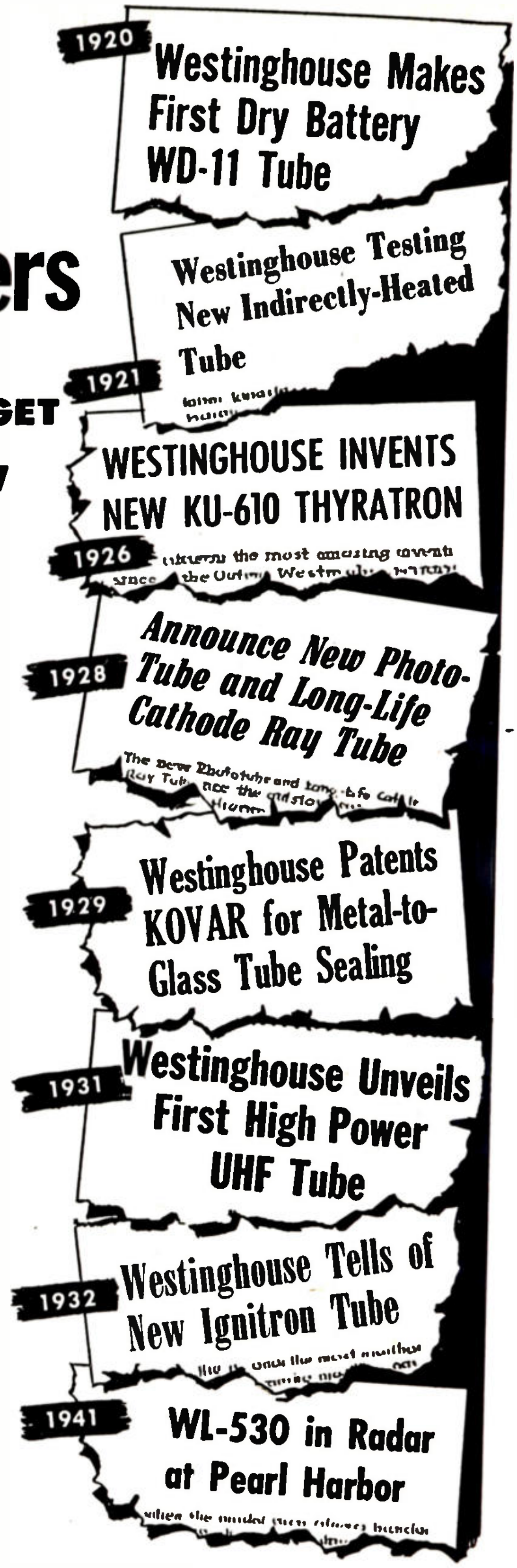
***Inquiry* INFORMATION** Please include, if practicable, information concerning the general function of the delay line in your end use application. In any event, it is necessary to consider the following conditions:

(a) delay time
(b) frequency (carrier) and pulse frequency
(c) attentuation at mid-band
(d) bandwidth at 6 db down points
(e) attenuation of spurious responses below main signal
(f) normal operating temperature
(g) service temperature range
(h) dimensional limitations (if any)

Technical Bulletin No. 45 giving more complete details will be furnished upon request.

BLILEY ELECTRIC COMPANY UNION STATION BUILDING **ERIE, PA.**

These "Firsts" Helped Westinghouse Customers



USERS OF WESTINGHOUSE TUBES GET FIRST BENEFITS FROM MANY NEW TUBE DEVELOPMENTS

These are only a few of the "firsts" that Westinghouse created in the electronic tube industry. In each case, designers using Westinghouse Tubes gained advantages by having first chance to use these innovations.

Today, Westinghouse still pioneers in electronic tubes and tube making. For instance, Westinghouse 40 KV and 20 KV rectifying tubes are under 9 ounces, only 2¾" high. Designers seeking the ultimate in space and weight savings will find them in these new WL-6102 and WL-6103 tubes.

Radical new developments in other power tubes and receiving and television picture tubes are now being engineered at the *NEW* Westinghouse Electronic Tube Division at Elmira and Bath, New York.

NEW SERVICE, NEW DISTRIBUTION

Westinghouse plans for Electronic Tube Division expansion are in operation. New service facilities, new warehousing policies, and new distributors are opening rapidly.

New merchandising methods will aid distributors in serving industrial users—many of these business-building programs are totally new in the tube industry. Here, as elsewhere, Westinghouse plans to provide industry leadership in service.

It pays in profits to deal with Westinghouse and with Westinghouse distributors. For full information on how Westinghouse can help you with problems of design, service, or supply, call your nearest Westinghouse representative, or write to Department C-112.

RELIATRON™ TUBES

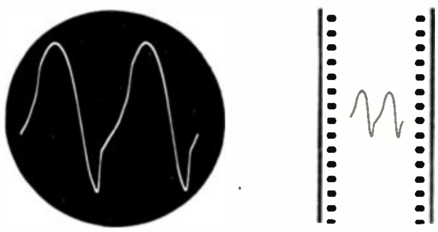
YOU CAN BE SURE... IF IT'S **Westinghouse**

ELECTRONIC TUBE DIVISION

Westinghouse Electric Corporation
Box 284, Elmira, N. Y.

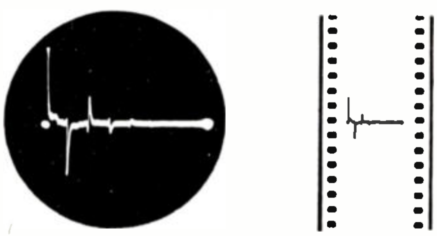
ET-95003

How much can you expect an oscilloscope camera to do?



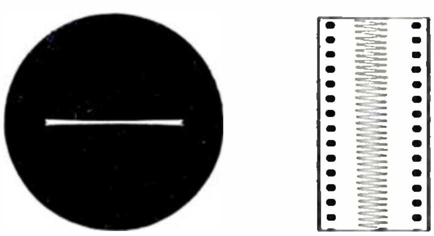
Scope Image | Film Recording

1. Single-frame photography of stationary patterns using a continuously running sweep.



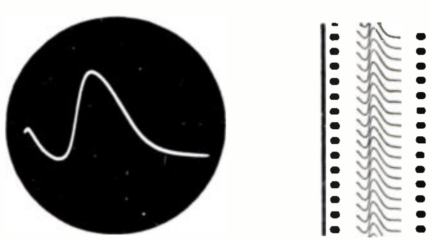
Scope Image | Film Recording

2. Single-frame photography of single transients using a single sweep.



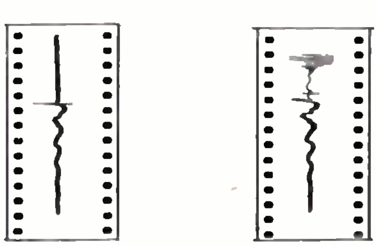
Scope Image | Film Recording

3. Continuous-motion photography employing film motion as a time base.



Scope Image | Film Recording

4. Continuous-motion photography employing oscilloscope sweep as a time base.



FILM MOTION TIME BASE | FILM MOTION & SCOPE SWEEP

5. Continuous-motion photography employing combination of film motion and oscilloscope sweep as a time base.

It's only reasonable that you should expect the oscilloscope camera you buy to record what you see on an oscilloscope screen during any period. But can it be expected to do any more? We think so.

For example, did you know that the *Fairchild Oscillo-Record Camera*—our idea of the most versatile 35-millimeter oscilloscope camera now available—can GREATLY EXTEND THE USEFULNESS OF YOUR OSCILLOSCOPE?

As you know, many non-recurring phenomena occur too rapidly to permit adequate visual study. Others occur so slowly that continuity is lost. Sometimes you have combinations of very slow-speed phenomena and occasional high-speed transients. In any one of these cases, the Fairchild Oscillo-Record Camera will take over where your eye and the oscilloscope leave off.

This extremely versatile instrument is now being used daily by many hundreds of engineers in widely divergent fields. For an idea of what it can do for you, study the five scope images and recordings illustrated at left. Each solves a particular problem.

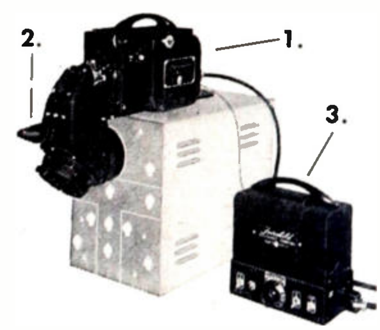
Oscillo-Record users especially like its:

CONTINUOUSLY VARIABLE SPEED CONTROL—1 in./min. to 3600 in./min.

TOP OF SCOPE MOUNTING that leaves controls easily accessible.

PROVISION FOR 3 LENGTHS OF FILM—100, 400, or 1000 feet.

For more data write *Fairchild Camera Instrument Corp., 88-06 Van Wyck Blvd., Jamaica 1, N.Y. Dept. 120-16C2.*

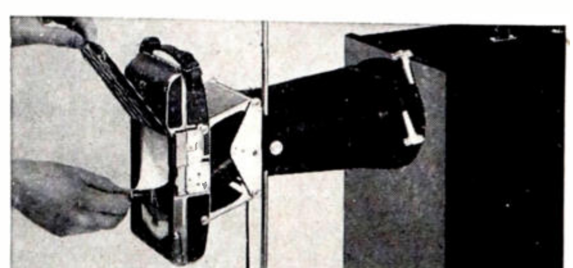


FAIRCHILD OSCILLO-RECORD CAMERA — 1. camera, 2. periscope, 3. electronic control unit. Available accessories include external 400 and 1000 foot magazines, magazine adaptor and motor, universal mount for camera and periscope, binocular split-beam viewer.

VALUABLE RECORDS FOR IMMEDIATE EVALUATION

The Fairchild-Polaroid® Oscilloscope Camera produces a photographic print in a minute

Valuable but inexpensive oscillograms for immediate evaluation; automatic one-minute processing without a darkroom; a set up time of two minutes or less—they're just three of the many advantages that are yours when you use the Fairchild-Polaroid Oscilloscope Camera. Wherever individual exposures meet your recording requirements—where you'd like to have permanent records of the traces you're now sketching or carrying in your memory, this is the camera that can bring new speed, ease and economy to your job. Prints are 3¼ x 4¼ and each records two traces exactly one-half life size. Write today for details.



A minute after you've pulled the tab a finished print is ready for evaluation

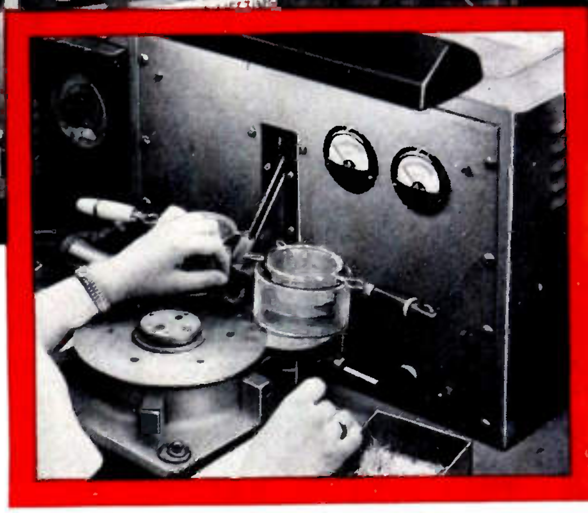
FAIRCHILD

OSCILLOSCOPE RECORDING CAMERAS

marion

INDUCTION SOLDERING UNIT
MODEL PM1
for soldering small metal parts and assemblies

SPEEDS UP PRODUCTION
REDUCES COSTS
IMPROVES QUALITY



The Marion Model PM1 Induction Heating Units, pictured above, are in service at the Clyde, New York, plant of the General Electric Company.

Germanium diodes, diffused junction rectifiers and transistors are manufactured at the Clyde plant and the Model PM1 Induction Heater plays an important role in a sub-assembly operation on the whisker diode line. A very small pellet of germanium metal is soldered to the end of a nickel pin and the Induction Heater is used to elevate the temperature to the desired value.

This Marion low cost, low powered, portable Induction Soldering Unit (Model PM1) simplifies, improves and speeds up the production of magnet assemblies, relay armatures, connectors, capacitors, transformer cans, germanium diode assemblies and other parts and assemblies in the manufacture of electrical and electronic components. In addition, the Marion PM1 Induction Soldering Unit has many applications in other fields such as jewelry, watches, toys, automotive parts, household fixtures, etc. Wherever the application of intense heat to small units is required chances are that it can be done better, faster and easier with this Marion Unit.

The unit was originally designed and has been used successfully for many years by Marion in the true glass-to-metal sealing of Ruggedized and other hermetically sealed instruments.

SPECIFICATIONS

Power Supply: 115 volts, 60 cycles
Size: 15¾" x 21½" x 15"
Mounting: Standard relay rack cabinet
Weight: 150 pounds

Power: 775 watts at full power output, 100 watts standby.
The entire unit is rigidly assembled and mounted to prevent arc-over and failure of components. It easily meets latest F.C.C. requirements on radiation.

For further information write Marion Electrical Instrument Co., 407 Canal Street, Manchester, N.H., U.S.A.

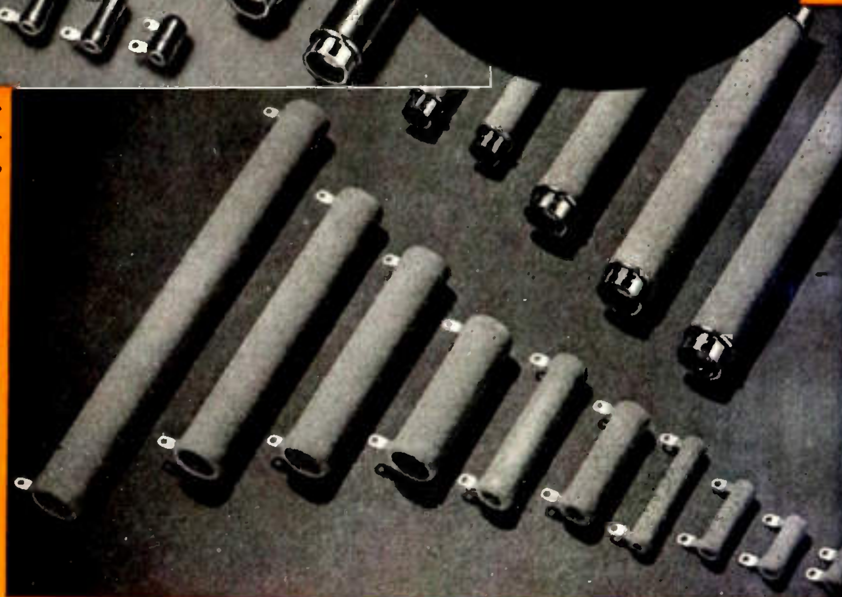
marion meters

Reg. U.S. Pat. Off.

MANUFACTURERS OF RUGGEDIZED, HERMETICALLY SEALED AND STANDARD PANEL INSTRUMENTS

The Ohmite line of tab-terminal, ferrule-terminal, axial-terminal, and flat type resistors that meet JAN-R-26A, Characteristics "G" and "J."

OHMITE JAN TYPE WIRE-WOUND *Resistors*



Ohmite tab-terminal and ferrule-terminal type resistors that meet JAN-R-26A, Characteristic "F."

STYLES AND SIZES

TAB-TERMINAL TYPE
Characteristics G, J, and F

Style	Over-all length	Diameter	*Watts
RW-29	1-3/4"	1/2"	8
RW-30	1"	19/32"	8
RW-31	1-1/2"	19/32"	10
RW-32	2"	19/32"	12
RW-33	3"	19/32"	18
RW-34	3"	29/32"	30
RW-35	4"	29/32"	38
RW-36	4"	1-5/16"	60
RW-37	6"	1-5/16"	78
RW-38	8"	1-5/16"	110
RW-39	12"	1-5/16"	166

TAB-TERMINAL TYPE
with terminal hole to clear No. 8 screw Characteristics G, J, and F

Style	Over-all length	Diameter	*Watts
RW-40	3"	29/32"	24
RW-41	4"	29/32"	32
RW-42	4"	1-5/16"	49
RW-43	6"	1-5/16"	74
RW-44	8"	1-5/16"	100
RW-45	12"	1-5/16"	160
• RW-46	10-1/2"	1-5/16"	135
RW-47	10-1/2"	1-9/16"	145

FERRULE-TERMINAL TYPE
Characteristics G, J, and F

Style	Over-all length	Diameter	*Watts
RW-10	11-7/16"	1-5/16"	140
RW-11	9-5/8"	1-5/16"	116
RW-12	7-7/16"	1-5/16"	86
RW-13	5-1/8"	1-1/16"	50
RW-14	4-7/16"	1-1/16"	40
RW-15	2-15/16"	3/4"	20
RW-16	2-3/8"	3/4"	14

FLAT TAB-TERMINAL TYPE
(Stack Mounting) Characteristics G and J

Style	Over-all length	Width of Core	Thickness of Core	†Watts
RW-20	2-1/2"	1-3/16"	1/4"	15
RW-21	3-1/4"	1-3/16"	1/4"	22
RW-22	4-3/4"	1-3/16"	1/4"	37
RW-23	6"	1-3/16"	1/4"	47
RW-24	7-1/4"	1-3/16"	1/4"	63

AXIAL-TERMINAL TYPE
Characteristics G and J

Style	Length of Core**	Diameter	†Watts
RW-55	1-3/8"	5/8"	5
RW-56	2"	5/8"	10

**2-1/2" wire leads

*Watts free air JAN Characteristic "F" or "G"

†Watts free air JAN Characteristic "G"

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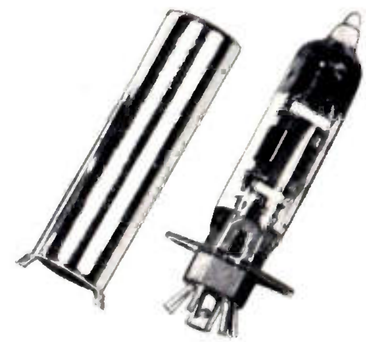

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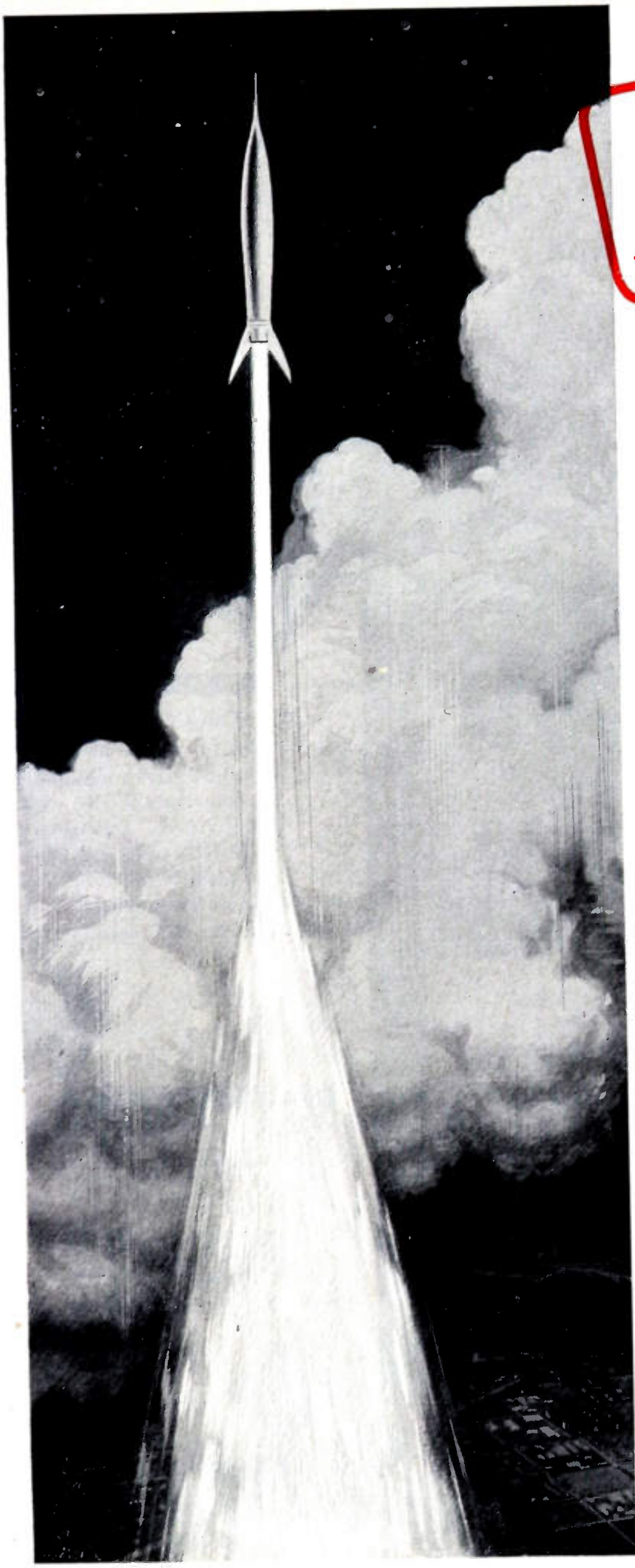

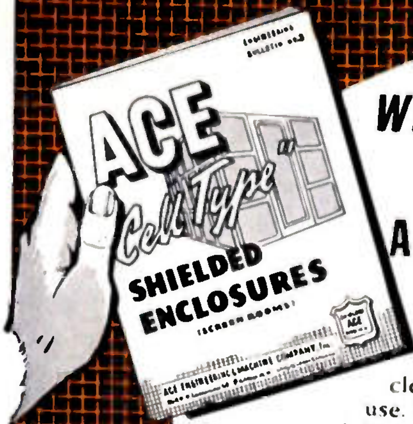

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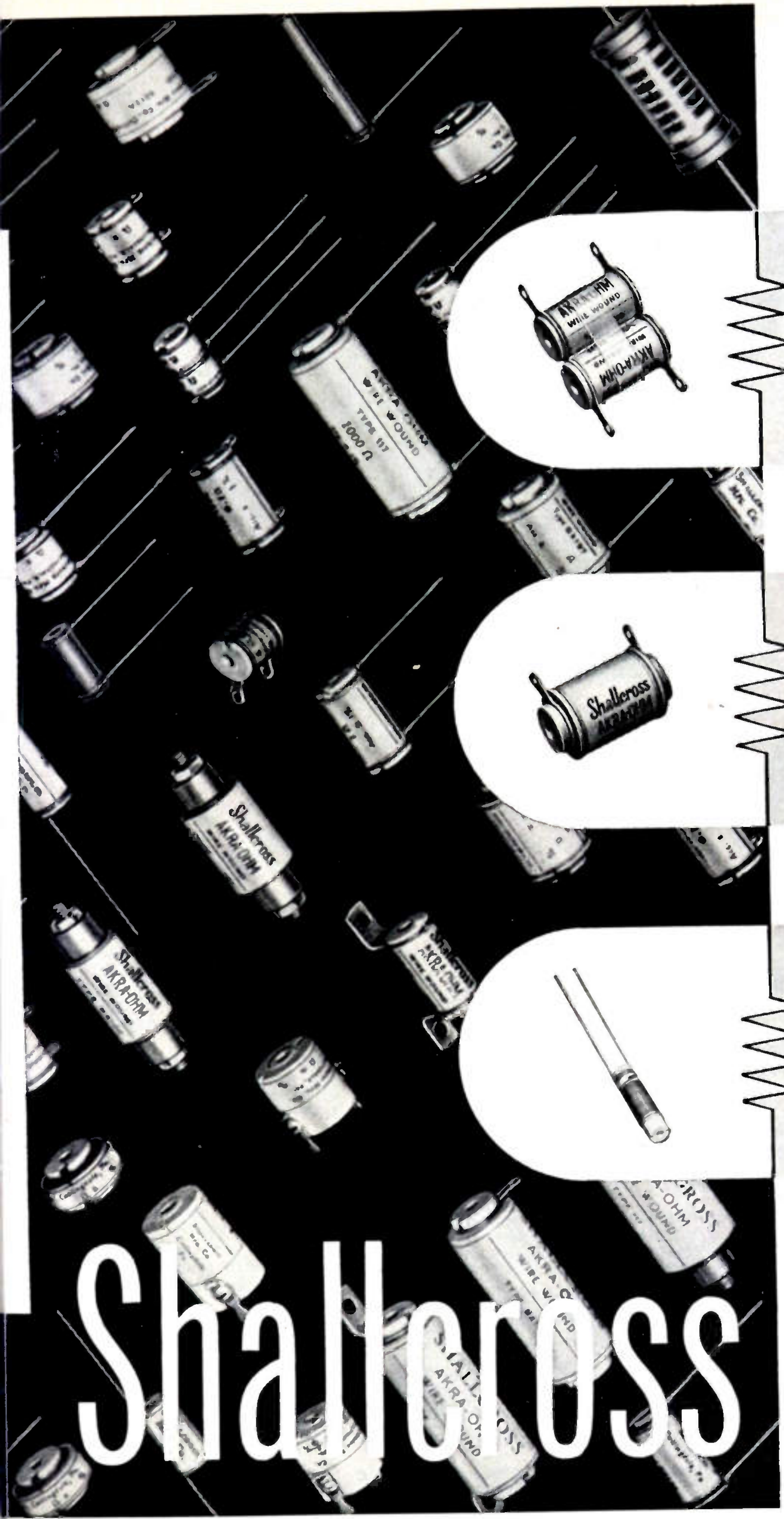

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INSTITUTE NEWS AND RADIO NOTES SECTION

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Robert L. Sink

DIRECTOR, 1952-1953

Robert L. Sink, Pacific IRE Regional Director, was born in Terra Haute, Ind. He received the B.A. and E.E. degrees from Stanford University in 1936 and 1939, respectively.

After a short association with the Litton Engineering Company and the Hewlett-Packard Company in California, Mr. Sink joined the General Electric Company in Schenectady, N. Y., in 1940, where he completed their courses in advanced engineering. His work at General Electric included the development and design of frequency-modulated equipment used in police communications, entertainment broadcasts, and aural TV transmitters, as well as the development and design of several types of airborne gun-laying radar systems.

In 1945, Mr. Sink returned to the West Coast where he assumed his present position as chief electrical engineer for the Consolidated Engineering Corporation in Pasadena, Calif.

At Consolidated Engineering, Mr. Sink has been closely allied with the development and design of numerous types of instruments, such as mass spectrometers, carrier amplifiers and oscillator power supplies, transducers, oscillographic recording equipment, and data handling systems.

Mr. Sink became a Student Member of the IRE in 1937, an Associate in 1941, and transferred to Senior Member in 1948. His many associations with Institute activities include his work with the IRE Western Conventions and Electronics Shows, Vice Chairman of the Los Angeles IRE Section in 1949, and Chairman in 1950–1951. Recently, he proposed and participated in establishing the Pacific IRE Region Electronic Achievement Award.

Instrumental in the formation of the IRE Professional Group on Electronic Computers, Mr. Sink is presently Vice Chairman. He also is the representative for the 1953 Components Symposium.

Radio Unlimited

Sir Ernest T. Fisk

Vision, guided by knowledge and experience, is both inspiring and constructively creative. The following guest editorial, by a distinguished Fellow of the Institute, who was as well its Vice President and one of its Directors, is written in a farsighted vein and carries a message in which imagination and wisdom are judiciously blended. His thoughts and conclusions are accordingly commended to the readers of these Proceedings.—*The Editor.*

It has been my privilege to witness and participate in the development of radio from its earliest days to the present time. From the days of the spark-coil transmitter and the coherer receiver up to television, with vhf and uhf, and television in color. Also to radar, telemetering, guided missiles, proximity fuses, and blind landing devices.

I was fortunate to be associated with the Marchese Marconi in the development of world-wide telecommunications, first through high-power long-wave stations and later through short-wave radio beams, including very high-speed morse telegraphy and radio telephone world-wide links.

Rudyard Kipling in his poem "MacAndrew's Hymn" makes one of his characters say 'What I hae seen since steam began leaves me no doot about the machine but what about the man?'

Every few years the science and technique of radio have broken into new ground and in every such case the new technological developments have become more complex. Even more noticeable has been the opening of more and more avenues in the radio spectrum with increasingly high frequencies. We are still some distance from direct generating of the visible frequencies and even the infrared. Who shall say that their elements will not be mastered some time in the future.

It would be unwise for an engineer to expound speculative theories of development. Two things in my opinion stand out as fundamental in our field of radio. We deal with the electron which may be regarded as one of the fundamental elements in the structure of our material universe, and we also deal with periodicities which I have no doubt that most engineers and physicists regard as being among the fundamental phenomena of nature. I think it was Aristotle who was reported to have said "the universe is made up of number and motion." Number and motion are the essentials of periodicity. It, therefore, seems that the radio physicist and the radio engineer are prospecting on the edge of the infinite, and if they continue, they will probably unfold discoveries in the future far greater than anything we have yet known, even more spectacular and more beneficial than the parallel discoveries in nuclear fission. Alternatively, radio and nuclear physics may meet somewhere on their paths—we hope not at the destruction of our human civilization, but at a place where men shall know the truth and the truth shall make them free.

Radio saw its beginnings in providing for safety of life at sea, was later advanced to the field of international communication, and moved in other directions toward world-wide mass education and entertainment. It always has been and always will be a fascinating subject and a satisfying activity for all who are privileged to participate in it.

Science and Society*

R. J. F. BOYER†

IT HAS OFTEN BEEN stated that the scientific and technical expert is not really concerned with the use to which his discoveries are put. In a sense this is true. Those of us who seek to extend human knowledge in any field must, I think, continue to regard all knowledge as good in itself, widening the horizons of truth and opening the door to new avenues of human mastery over the world we live in.

Nevertheless, no scientist surely can be completely indifferent to the results of his work in the society in which he lives. We are all citizens and family men as well as physicists or engineers. Apart from this general impossibility of being nothing but a specialist, there is the natural pride of the scientist or technician in seeing new scientific discovery taking its place in the betterment of human life.

Perhaps this new and immediate interest of the technologist in what happens to his work has been most dramatically shown in the field of nuclear physics where quite a number of scientists both here and abroad, have found their chair at the test tube rendered uncomfortable by the thought of what use was being made of atomic energy. Most atomic scientists have, I think, come to the conclusion that the possible misuse of the results of their work should not deter them in any way from pushing on with new discoveries. They feel that there is so much potential good for the human family in the employment of nuclear energy that even immediate misuse by friend or foe cannot and should not inhibit further research. At the same time, scientists are far more interested today in the practical results of their work. The era of the bespectacled recluse seems to be over; instead, scientists are applying their knowledge to human affairs in such a way that the greatest personal satisfaction may be derived.

This, I think, is equally true in the field of electronics, easily one of the most spectacular of modern sciences. In effect, advances in this field, stripped of technical phraseology, have had the effect of increasing out of all knowledge our human powers of communication and even of sight. The probing finger of radar stretches into the darkness of the night and across the expanse of the seas, to fill out the deficiencies of optics. More recently, in television, it seems that we are extending the range of the human eye to a degree previously unheard of. On the auditory side, it has become almost commonplace to remark that the range of our voices and our ears is limited by no distance within the compass of the globe we inhabit.

All this can give us—and the electronic expert in particular—immense satisfaction, but I suggest that, as with nuclear physics, the interest of the scientist and technician cannot wholly stop at this point. He is intensely interested in seeing these new expansions of human power used in a way which give him satisfaction, the satisfaction of seeing beneficent advances in his own time. The real problem of the world today is how to use the sharp-edged tools which it possesses. Have we the wisdom and the moral insight to employ them in our generation in a way which will give us all real satisfaction? What I would say on this subject, first, is this: that what the nuclear physicist and the electronic researcher have done for this generation is to expose its weaknesses. What, for example, have we done with international broadcasting other than to use it to reflect our international antipathies. Up to date, it is very doubtful whether the international short-wave bands have carried more fraternal goodwill than mutual vituperation. I know of no field where science's first high hopes of uniting the people of the world and of modifying historic prejudices have fallen so short of fulfillment. And yet, the possibility is still there, and little by little I feel sure that short-wave broadcasting will become one of the major influences for a peaceful world. But here, as in nuclear physics our discoveries have so far served rather to further our shortcomings and enmities than to promote self betterment.

The most pertinent—because the most recent—case in the subject we are discussing is, of course, television. Here is a medium which is not only fascinating as a miracle, but is obviously capable of brightening and enriching the lives of millions of people; yet it is having a very mixed reception, particularly among people who are concerned with the moral and intellectual progress of humanity. What is happening, of course, is simply that television is going through precisely the same stages as radio and nuclear energy. It is taken up by each community and used to further the ends which that community at that time considers the most important. In times of war they become weapons of war; in times of peace they reflect our values, material and spiritual.

It is not surprising, therefore, that television has proved to be self-revealing to any people which employs it. It holds the mirror in a most striking fashion to let us see what we really are and what our values are. Some of it is not pleasant simply because there are unpleasant aspects in our society and in our social and moral standards. On the other hand, it can and does hold up for public appreciation and emulation the best that is in us. Again, it is very much like nuclear energy. If wrongly used, that force can come very close indeed to destroying everything, good and bad. If rightly used, it is perhaps the chief hope on the material side for the future of human civilization.

That, as I see it, is the problem of the use of television, and indeed of any of the media made available by electronic scientists. It can spread and defy the evil that is in us to a point which may make us rue the day that this weapon was forged for our unworthy hands. Alternatively, it can become a major and even revolutionary influence towards filling out our lives with color and interest and informing our minds of wider areas of truth; but whichever way it goes, we in this generation—the scientist as much as the ordinary citizen—will be responsible. No one of us can contract out of the responsibility which has come to us through these new weapons. My personal fear is that each section of the community may be content to shut itself up in its own particular specialization and allow this issue to go by default. I think it is right and proper that atomic scientists should voice what they feel should be the laws and control the use of their discovery. It is equally fitting that those engaged in research of electronics or the manufacture of its equipment should take a more than usual interest in and responsibility for the highest employment of their science in human affairs.

The problem of how best to use radio and television in the public interest is perhaps even more difficult and complicated than the technical perfection of the physical means employed for transmission and reception, and it is one in which we shall probably never reach complete finality and certainly not unanimity. This fact has been highlighted by the report this month of Lord Beveridge's committee on broadcasting and television in Britain, where the various lines of argument representative of all manner of British thought are well set out. Fundamentally, the problem of the best use of radio and television derives from the fact that they impinged so closely and immediately on our own life. The set is in the home, not in a public hall to which you may or may not feel inclined to go, and it is even different from a newspaper to which you either subscribe or do not subscribe according to your general estimate of its tone or readability. Television and radio are permanent members of the family, and there is nothing so touchy as having guests in your home who either irritate or bore you. Consequently, reactions are sharp and even emotional to likes and dislikes and, of course, for very good reasons. On the radio receiver or the television screen there comes to us a continuous stream of all sorts of presentations, including news, politics, religion, music and entertainment. Here, however, is the nub of the matter: the choice of these things must be made by the program authority initiating the program. It is quite futile to write off the responsibility of determining television or radio programs as merely giving people what they want. Indeed, we do not know what we want until we see or hear the fare provided and make our judgment. One can go further and say that we come to like what we are accustomed to having put before us. This is as true in art and radio as in the food we eat. The problem, therefore, remains primarily at the door of the broadcaster. He cannot blame the public if his matter is poor or damaging to public taste. He simply has to make the decision in the last resort. Nevertheless, public reactions

* Decimal classification: R000×507.2. Reprinted from the *Proc. IRE, Australia*, vol. 12, pp. 220–221, July, 1951, by the courtesy of the *Proceedings of the Institution of Radio Engineers, Australia*.

† Chairman, Australian Broadcasting Commission, Sidney, Australia.

are of prime importance. No broadcasting institution can operate in an ivory tower, and the encouragement or lack of it from the community when efforts are being made to use the medium for the highest purposes daily affects decisions of program makers.

It is here that community responsibility becomes obvious. If the better things are ignored and are given no encouragement, they will tend to lose in favor of less worthy material. If any citizen feels that these new media are not operating in the best interests of the community, it is his duty to become vocal about it. If the reverse is true, he should support the new media with his encouragement. Indeed, it is the community ultimately which determines the final fate of the electronic media as public services. We, as citizens, determine the general national policy through our elected representatives, and we can depress or elevate its day-to-day use in our lives. It is in the exercise of these ordinary citizen privileges that, I would suggest, the electronic scientist and engineer has a more than ordinary interest and responsibility. It is his skill which has brought this power into being, and it is surely of great concern that the child of his brain should grow into worthy and honored manhood.

A Profile of the Man in Industrial Research*

ELMER W. ENGSTROM†, FELLOW, IRE AND ELIZABETH H. ALEXANDER†

Summary—**In order to recruit and cultivate the scientific talent which is needed for industrial research today, it is necessary to know something about the requirements for a good research man and also something about the character and motivation of the individual man now engaged in research. A number of desirable characteristics for the research man are described. The result of an informal survey taken at RCA Laboratories indicates that creativeness, training in the fundamentals of science, and integrity of character are the prime requirements. Among the most important sources of motivation for a man in research are his intellectual curiosity and the satisfaction of his ego. A discussion of the place of financial incentive in the research man's motivation is included. The types of team relationships in the daily work life of research men are also discussed.**

Introduction

The uppermost problem of the research profession today is not so much one of selling research to industry, to the government, or to the public. It is rather the problem of recruiting and cultivating scientific talent. The need for such talent has greatly exceeded the number of research scientists now available.

Today, forward-looking industries are fully aware of the possibilities of research. They are investing more and more in research. They are teaming up business administrative planning with research and they are doing all of this because they are convinced that research is necessary for long-term benefits.

On the other hand, we have talked and heard much recently about the great shortage of engineering and scientific talent. Yet America does have a large reservoir of scientific talent. It is not of course unlimited, but it is there. *Our* problem, that of the research profession, is one of recruitment, of stimulation and encouragement. Do we know what to look for as we recruit men for research? How can we make the best use of the people now engaged in research?

We would gain insight into this problem if we had a better understanding of the kind of men needed for industrial research and of the character and motivation of the individual man now engaged in research.

In order to gain a broader and more objective view of this question, an informal survey was made among our associates at RCA Laboratories. We discussed industry's requirements for the research worker and we also discussed the character and motivation, as we understand it, of the individual man in research. Much of what follows is a synthesis of our associates' views and conclusions and to this have been added opinions based on the experience of one of the authors.

It is obvious that it is not possible to draw one profile, an absolute standard for the man in industrial research—that is, neither an *ideal* profile of the researcher as we should like to have him nor one which would be true to the *actual* man as we know him in the industrial research laboratory. This is fortunate, for even in the case of the ideal research man, the requirements will vary for different units of industry, will vary for the differing outlooks toward research and will vary depending upon the particular persons administering the research. It is also obvious that as we look at research men as people, as we examine their personal likes and dislikes, as we take into account their individual and collective characteristics, many variations are to be found—as many as there are individual research workers. Nevertheless, in the analysis of the research worker undertaken in our survey, a pattern of the nature of the research man seemed to develop; it is this pattern we shall examine.

Industry's Requirements for the Research Worker

First of all, what does industry look for as it recruits men to carry on its research program? What are the requirements for a successful industrial research worker?

1. Creativeness

There was general agreement among all the groups interviewed that the quality of creativeness must be placed at the top of the list.

* Decimal classification: R070. Original manuscript received by the Institute, June 24, 1952.
† RCA Laboratories Division, Princeton, N. J.

Creation of new understandings, new principles, new products, and new services *is research*. Creativeness on the part of research workers is the first basic requirement. Members of research staffs are not equally creative. In fact, a staff of all highly creative members would be unmanageable. A staff of essentially non-creative members would be sterile. An effective staff is one where all members respond to originality, where all have some degree of originality and where a portion are highly creative.

Creativeness does not respond to attempts at definition or specification for an individual during pre-employment interviews. Creativeness in an applicant is something about which one learns by observation in watching him practice life itself and especially in a research environment.

For gauging creativeness there are opinions and convictions on the part of those who conduct interviews for employment. However, our experienced interviewers do not feel that they can estimate creative ability with any practical degree of accuracy in an interview. In general, the interviewers recommend employment if the young man shows good reasoning ability and a good grasp of fundamentals, almost regardless of other desirable qualities which they feel he may lack. Interview reports on those offered employment frequently contain such phrases as "very intelligent," "follows through on new problem," "capable of original thinking," "clear thinker," "sharp," and "good approach to unfamiliar problems." These are usually coupled with "good basic knowledge of physics," "well grounded in basics," and "answered technical questions well." Some who had creative qualities were approved for employment even when such comments were made as: "less aggressive than some I have talked with," "too theoretical approach to problems," "personality and reliability an unknown quantity," "superficial outlook," and "somewhat lacking in drive."

The interviewers are evidently concerned about creative ability or promise of creativeness, although they make few positive statements in their interview reports regarding this important characteristic. It seems that the emphasis on the ability to reason clearly from fundamentals stems partly from a belief that persons who cannot do so are not very likely to be creative in research. Similarly, some of the concern of our interviewers for broad knowledge and interest is, it seems, due considerably to the relationship of these characteristics to imagination, drive to learn or investigate, and so to creativeness.

All this is important because research thrives if the organization recruits creative members for its staff and the research man prospers if he possesses it. The research administrator needs to know the man's promise of creativeness and the prospective research man should, for his own good, desire to know the degree to which he can be creative.

Therefore, industry expects its research workers to possess originality and, even if in varying degrees, to possess creativeness.

2. Training

Training in the fundamentals of the sciences is second to creativity as a requirement for the research worker. We placed scientific training second because unless the person possesses the proper creative mental traits just described, all other assets, including good scientific training, become meaningless.

Specific knowledge and training are valued but are definitely secondary to understanding of the fundamentals of mathematics, physics, chemistry, or engineering. Creative ability must be backed by fundamental knowledge and specific skills if the research worker's creation is to mature into useful form. Just as all research workers do not possess equal creative talents, so training to a standardized degree is in no wise a requirement. It is usual for candidates for research positions to acquire or to desire university training at graduate level. This graduate preparation is of value to industry not only because of the additional training and knowledge acquired by the individual but because it adds another stage to the selection process in establishing that a particular person is interested in and suited for research.

The educational process, the acquiring of knowledge, the development of skills should never diminish nor cease for the research worker. The research process is itself subject to the same obsolescence it brings to the objects of its research. The research worker, therefore, must continue to be a scholar of science.

Knowledge gained in the university can be looked upon as a set of tools. All agree that certain basic tools are needed. The essential thing is the ability to put the tools to use and to accumulate supplementary tools as one goes along.

Thus, the proper training in basic scientific fundamentals plus the "know-how" in using these tools is the second important asset which industry expects of the research worker.

Therefore, industry expects its workers to continue to improve their knowledge and skills throughout their research careers.

3. Character

When these criteria were first set down, character was placed as the first item. While it is still considered the basic requirement, it must for practical reasons follow *creativeness* and *training* in an orderly recitation of requirements. The criterion of character is often not given appropriate consideration by younger research workers nor do they appreciate the importance attached to this characteristic by research administrators. Perhaps research administrators themselves have not adequately evaluated the importance of character. Whether expressed or not, character really is a prime requirement. Integrity of purpose in research is vital. Research deals with nature. Nature is a cruel and exacting taskmaster when it comes to technical or scientific accuracy and honesty. Reliability in prosecuting a work program is rarer than one might think and is richly rewarded.

Therefore, industry expects its research workers to be reliable and of good character.

4. *Vision*

The research man must also have imagination and vision. He needs the ability to visualize the possible results of an investigation. He can see the application of a technique before its development is complete. Creativeness coupled with vision to give the creation objectivity makes for the great in research.

5. *Energy—Drive*

Under this heading we include several characteristics which directly or indirectly affect the intensity of the prosecution of research work. Having the creative insight, one must then look to the characteristic of initiative to get underway. Once underway, one thinks of enthusiasm to support the drive for progress. One thinks of courage to take large steps in the territory of the unknown. One thinks of perseverance as the going becomes difficult and discouraging. One thinks of determination to overcome the hurdles or obstacles along the way. One also thinks of persuasiveness in dealings with assistants, associates, and superiors. These all represent manifestations of energy and intensity of drive. They represent, assuming other abilities, the potentials for depth of progress into the new. They reduce the speculation in research by insistence upon positive and useful results.

Industry expects research workers to be energetic and to have drive in the conduct of research.

6. *Scientific Inquisitiveness*

Research workers having records rich in new ideas are persistent in expressing scientific curiosity or inquisitiveness. They have a continuing and almost unquenchable thirst to understand old and new situations and to relate these to other situations. Progress seems to be made in an atmosphere of discontent with the current order of things accompanied by a drive toward improvement and enhancement. This goes on with an outlook which is so searching as to give minute coverage.

Therefore, industry expects its research workers to be scientifically inquisitive in fields assigned and for objectives established for the research programs.

7. *Practical Outlook*

Industrial research is done for the benefit of the organization engaging in the work. To be of greatest benefit, the research results must be based upon a work program having a practical outlook. Not all research results are positive. Many results are of only nominal worth but a well-executed program should provide some returns rich in current and potential value. Such research can best be done in an atmosphere of common sense. Research is sometimes thought of in lay circles as an ivory-tower enterprise. This is certainly an outmoded if not an erroneous impression. Just as in all other matters, research results are enhanced by common sense objectives and work prosecution.

A practical outlook develops with training and environment. This, therefore, should be the subject of constructive action while the prospective research worker is still in the educational institution. The educational institution should be certain that its staff members are equipped to build by example from their experience. The new research worker in industry should be given early indoctrination as to these values and he should respond to this through development.

Therefore, industry expects its research workers to have and to develop a practical outlook—a common sense approach to their work.

8. *Attitudes*

The characteristic of attitude makes itself felt from the time of the pre-employment interview and continues as long as employment lasts. For the prospective research worker the initial approach is important—does he show interest, does he indicate willingness to work and prove his value, does he give the feeling of being suited for research? These same characteristics become more important in a practical sense as the research worker faces his first, second, and succeeding tasks. Then, too, begins his record of attitudes and approaches in dealing with associates and superiors.

The complexity of modern research demands that the work be performed by a team. This necessitates a balance between personal ambition and an understanding of the rights and proper objectives of one's associates. It also implies an interest in the function of the laboratory as a whole, which will generate ideas for other groups as well as for one's own, together with an understanding of the place of one project in the entire group activity. A research organization can tolerate a few self-centered, temperamental, individual workers, but if the group is to thrive, nearly all its members must be co-operative, able to get along with each other, and imbued with the spirit of team play.

Therefore, industry expects its research workers to have wholesome attitudes toward their work and toward the persons with whom they come in contact, and to understand and to practice co-operation.

9. *Research Environment*

Organizations with research groups having an established record of fruitful results have also developed an understanding of research and of the research staff. Those organizations, in the administration of research, are tolerant of the new staff members during the starting period. They understand the speculative nature of research. They appreciate the need for and the desire of the research worker to renew and keep up-to-date his knowledge and training by study and outside contacts.

The research worker is, as a result, in an atmosphere having certain freedoms regarding the use of his time. Direction of his work may be more by suggestion than by specification. This is purposeful, for experience indicates that in such environment, research thrives. Understanding and respect is required from the research worker in order that these freedoms and tolerances be put to the uses intended.

Therefore, industry expects its research workers to make appropriate use of the freedoms of the research environment.

10. Mental Youth

While the evidence is by no means conclusive, there are indications and experiences to show that the most revolutionary creative thoughts have come to a few research workers during their first decade of work. For the average research worker, it seems that his best original and creative work comes before the close of the second decade. Again for the average, probably his best balanced effort of original work tempered by experience is likely to occur during the second and third decades. Once again for the average, it seems that beyond the third decade the qualities of judgment, leadership, and training of younger staff members are the strong characteristics. For some, however, the averages do not apply—they go through their entire career with creativeness undiminished.

Here we are in a field of the relatively unknown. We have too few facts and no current knowledge that we possess controls so far as the individual is concerned. What we seem to require is a continual intake of young research workers and an understanding of how best to use those of advancing age.

Therefore, industry expects to continually freshen its research staff by adding young members and hopes for a share of research workers who have continuing mental youth.

11. Other Desirable Qualities

a. Salesmanship. Industry also expects its research workers to be salesmen. The research worker must be able, first of all, to sell his ideas for a research project to the director before work on the project begins. After finishing the job, he must also be able to sell the completed project to those in charge of commercial activities.

b. Manual Dexterity. A degree of manual dexterity is also of considerable value in today's research. Since a large part of modern research is accomplished by experimental rather than theoretical techniques, the research worker who is adept with his hands can quickly transfer his ideas into successful practical experimentation.

c. Ability to Speak and Write Clear English. The ability to express oneself well in speech and writing also cannot be overlooked since the results of research are primarily transmitted by means of clear reports. The research worker who lacks a good command of the English language has a severe handicap because he is unable to communicate the results of his research satisfactorily to those who could make good use of it.

12. Summary

Thus, if industrial laboratories could choose, they would pick for their research teams men who are creative and well trained in the fundamentals of science. They would choose men of good character, men of vision, of energy and drive. They look for men who have scientific curiosity but who have at the same time a practical outlook; men who practice co-operation and can make use of the freedoms of the research environment. They hope for research workers with continuing mental youth. Industrial laboratories also value research workers who can express themselves in speech and writing, who are adept with their hands, and who are good salesmen of research ideas.

Of course, we do not always weigh the qualities desired in the same order when research qualifications are discussed generally as when we are considering a person with reference to a particular job. In other words, we do not want exactly the same type of person to fill all of the industrial research jobs. Because of the nature of the job, any one or two qualities just discussed may be required to a greater degree than the others. Proper balance of men with varied characteristics is the secret of an able research team.

The Research Man, a Human Being

1. Motivation

Any list of desirable qualifications for men in research, stated in general terms, runs the risk of being utopian and over-idealized. It is, without doubt, necessary to have an understanding of the essential qualifications which make for the successful researcher. But it is not enough. We also need to know concretely the actual men in research. We need to know the makeup of the researcher, how he is motivated, what factors draw him into research as a career and what keeps him satisfied year after year.

In short, taking the research man as he is—not as we would like to have him—we need to know something about his thinking, about his desires and needs as a human being. Then with these facts in mind, we can discuss how he will fit into the modern research team and what we can expect of him as a member.

Although there was a wide difference of opinion regarding the characteristics of a research man, our associates seemed to agree fairly well on his motives.

a. Intellectual Curiosity. At the top of the list of motives everyone placed intellectual curiosity. The urge to investigate and explore is the mainspring of the research man. This curiosity is a cumulative process. Satisfying yesterday's curiosity stimulates more curiosity for tomorrow, and so on into the future. As we said earlier, progress seems to be made in an atmosphere of discontent with the current order of things, and reinforcing this discontent is a drive to change and to improve.

When does this intellectual curiosity—this urge to investigate—first begin to show itself? There seems to be good evidence that it begins in childhood or early adolescence. Little by little, the scientist-to-be accumulates a large store of knowledge through his interest in scientific phenomena and his scientific observations. By the time he reaches high-school or college age, many of the "building blocks" which go to make up the research man are there. Because of the great store of knowledge built up subconsciously, he is able even at that age to reject almost automatically many alternatives in his scientific problems. He finds that he excels in school as soon as he begins to take courses in science. He finds a joy in learning that he has never experienced before. The subject matter becomes of compelling interest and his curiosity grows under the stimulation of scientific education. Sooner or later, he becomes almost like a religious person—such is his burning desire to explore beyond the obvious and the known.

Not all research workers have the same degree of intellectual curiosity. Because the opportunities and facilities of research are so well advertised today, some young men drift into research. They find it a pleasant, comfortable, and socially acceptable way to spend their lives. They drift into research, just as they drift to college because it is "the thing to do." Naturally, this kind of worker is not nearly so productive as the one with strong motivation. It is, therefore, necessary to distinguish the real researcher from those who simply respond to attractive opportunities.

b. Will to Create. Another very important motivation for the good research man is the will to create. Most scientists take pleasure in creating something new. There are many in research who would pursue their investigations for their own personal satisfaction—regardless of papers presented, credit given, patents granted, financial rewards, or other types of recognition.

This is fortunate. For as we know from experience, public recognition of research comes slowly. Quite often the work of a research man is not recognized by the public for a long time. And by the time it is, he may have lost all identity with the product or the service as it finally appears on the market. On the other hand, the research worker does crave recognition from those with whom he works and eventually by those in his scientific field throughout the world.

Some say that the satisfaction that the research worker gets in his creating is a satisfaction of his ego. There is evidence that the scientist has a strong ego. It may be the same kind of ego that is satisfied by a man taking up a hobby. He enjoys demonstrating excellence, even if only to himself. He takes pride in showing himself what he can do.

c. Financial Incentive. How strong is the motive of financial reward? Does the dedicated life of the research scientist mean he is not interested in money? Certainly not! But it does seem clear that financial incentive is not all-important—if he has the facilities and opportunities to satisfy his curiosity, and if he is recognized for his contributions.

This does not mean, however, that the research worker disregards financial compensation. Neither does it mean that he disregards the dollar as a measure of success. But it does mean that the average research worker is not a fortune seeker, nor is he envious of those with large personal fortunes.

On the other hand, research men do want to be comfortably well off. And there is a compensation level which is necessary to satisfy the research man's standard of living. Because a research worker is apt to have intellectual and cultural interests, he does require a substantial financial return.

While a research man is not by nature a fortune seeker, he should be properly compensated for his creations. This is particularly so where his creations add to the position of the group which he serves. There is no doubt that in the present day, the research man finds himself in a dilemma where money is concerned. Scarcity of supply and competition have brought about upward revisions and corrections for those just starting and for those on the bottom rungs of the ladder. Like others in salaried professional and business pursuits, the average research man has been caught in the press of inflation.

Beginnings have been made to evaluate a research man's performance in comparison with other producers whose output may be more readily measured. Experience is accumulating on incentive awards to research men for their outstanding creations and performances. These awards are tokens to indicate appreciation and to add to income. It is important that all this be continued. It is important too that magnitudes should not be confused and limited because of current inflation spiral.

d. The Role of the Wife in the Research Man's Motivation. We should note that very often the research man's wife is much more apt to become concerned with recognition for her husband than he is himself. Part of this may be true respect for his ability and performance. Part of this may be due to ambitions of "more than" keeping up with the Joneses. Someone has said that it might be more effective to give to the wife the prizes, the awards, the recognition, the compensations, the titles, than to her scientist husband. No matter what the source of the wife's ambitions, they are a real factor in the happiness and performance of the research man. Thus, they become another element in the research environment.

e. Idealism. If a research worker is not strongly motivated by financial desire, is he on the other hand a strong idealist? Here the evidence is not too clear. It is true that some enter the field of research with a vision of the opportunities for benefiting mankind. On the other hand, many others see in a research career an occupation no more worthwhile than many other professions—but one to which they are well fitted by their particular abilities.

Sooner or later, the idealist may come to see that a scientific discovery is not of itself good or bad. It is neither moral nor immoral—but rather amoral. The true scientist will reach out to discover the unknown regardless of the consequences to humanity and regardless of moral implications. But this leads some into a dilemma. Cases in point developed during the war period when research men were "brought-up short" in contemplating the death-producing instrumentalities they were creating. A more current case in point are those atomic scientists who are unable to reconcile themselves morally to the new order they helped to create.

2. Personal Characteristics

Most of those questioned in the survey believe that, as far as human characteristics or personality traits are concerned, the research man shows as much variation as a cross section of any other group of human beings. Nevertheless, they believe that he does have a certain tendency to a few particular personal characteristics.

For one thing, we often find that the research man is essentially an *individualist.* He usually has strong opinions. He may object to being told what to do or how to do it. On the other hand, he is also apt to be *tolerant* even if to a limited extent. He has proved himself wrong just as often as right. Consequently, he does not insist that his way of thinking is the only way

The research man is sometimes apt to be *introverted* rather than outgoing in personality. He may not start out this way, but his single-minded interest in research may make him so.

The research worker is also a *straight thinker* or logical-minded. He is able to reason objectively, particularly in matters of scientific research. He proceeds from a premise to a conclusion, and he will not be persuaded of the truth of a certain scientific theory until he is able to prove it by logical processes.

The Best Use of the Research Man

The purpose of this investigation into the requirements for the research worker and into his motivations and characteristics was to give us a basis on which to answer the question: How can industry make the best use of people now engaged in research, and how can they be integrated into the modern research team?

1. The Research Man Working Alone

There is, of course, the case of the scientist who must work alone. Some research workers are "lone wolves" by nature. Their habits and methods make it difficult for them to think or work in co-operation with others. Others are such extreme individualists that they will not tolerate being told what to do—nor will they submit to the mildest forms of control.

Then, there are those research workers whose pride and ego have made them completely self-centered. So much so that they will push everything out of the way which may interfere with their own work. These are the people who often become the "credit grabbers."

Finally, there are those who are emotionally immature. This emotional immaturity may be manifested in many ways, including the behavior of the previous three types of people. Particularly, it is also found in the kind of person who is unable to accept constructive criticism.

Many of the research scientists who fall into these categories may also be outstanding technically. So, we have the very real problem of making the best use of their talents, but at the same time preventing their personalities from disrupting the rest of the team. In the final analysis we must look at their contributions from a long-range point of view. We cannot always count on them for a specific contribution at a particular time. The research administrator must weigh the long-range technical contributions of such men against the problems they cause as members of a team.

2. The Research Man as a Member of a Team

We are all, of course, aware of the change that has taken place in the methods of research over the last few decades—a shift from individual effort to teamwork. This has been made necessary by the tremendous complexity of the problems attacked. In organizing the research team, our objective is a group which is productive, and which, at the same time, satisfies the research man's strong motivation. In fact, we cannot gain the first objective without satisfying the second.

First, the team must be constituted so that its members work smoothly together. Secondly, the team must be organized so that there are proper co-operation and understanding between the research workers and the non-technical service personnel. And, thirdly, there must be co-operation between the members of the team and the development and production engineers who must carry their ideas into commercial production.

3. Team Relationships

Despite the fact that the research man is apt to be a strong individualist with a dominant ego, we have had less trouble in forming and maintaining harmonious team relationships than one would have thought. One of the reasons for this may be that the problem of human relations among research people is simplified by their common focus on the task at hand, which is concerned with the properties of matter rather than human personalities.

What then are some of the methods which the research administrator can use to mold his team into a cohesive, effective working force—bearing in mind that it is made up of many different personalities?

First, there is the matter of communication and guidance. The supervisor must always be sure that the technical problem is completely understood by the research worker. The supervisor must also know how far to go in giving guidance. He must know how far to go in making suggestions to each of the individuals on his team, without compromising their freedom and their initiative.

Insofar as it is practical, the principle of self-starting should be encouraged in research. Administration should seek to have concepts and plans stem from the lowest possible organization level. Then the programs become self-made in the team—pride of authorship adds to the external desires for progress and answers.

The supervisor must also be sure that he places the research worker in the right job. He must realize that a man who is not productive in one field is not necessarily unproductive in all fields. Thus, the supervisor must help the research man find the place which best utilizes his training and ability. He must also find the place where the man who has passed his most productive years can contribute the most.

The supervisor must also strive to overcome boredom or staleness in the members of his team. All research projects have long periods of routine work with no guarantee that the problem will be solved. The good supervisor must be able to encourage and inspire his team at such difficult periods.

The supervisor must also know how to give a feeling of recognition to the individual members of his team. One of the most important forms of recognition a supervisor can give is that of listening to the ideas of his research workers. This is both the act of listening and how he listens, so as to inspire confidence. Even if the research worker has discovered that something will not work, he should be recognized for this type of discovery.

For outstanding contributions, special financial awards may prove of value, but they must be wisely administered. The disappointment of those who do not receive awards must not outweigh the encouragement it gives to others.

Probably in the final analysis the reader will agree that these precepts for the effective management of a research team would hold true in the management of any sort of creative group. No creative person can work in a vacuum, or in the improper job, or when he is overcome by boredom.

4. Research Man's Relationship to Nontechnical Service Personnel

So far, we have been speaking strictly of relationships among the individual members of a research team. We must also consider the relationship of the team to the nontechnical service personnel in the laboratory, and to the production and development engineers who will take over a laboratory product and turn it into a commercial reality.

A laboratory services staff is an important cog in any smoothly functioning modern laboratory. This is formed of the people who must make the drawings and models, keep the libraries functioning, and the accounts straight. The group interviewed reported that they have found little or no friction between the scientist and the nontechnical worker. There seem to be just as many prima donnas among skilled craftsmen as among technical research scientists, but mutual respect seems to govern the relations between these groups.

5. Research Man's Relationship to Development and Production Engineers

The relationship between the research scientist and the production and development engineer is one of great importance. The key to a good relationship between them lies in an understanding of the basic differences in their objectives.

The research scientist is a man of ideas. He is seeking basic knowledge, new approaches to old principles, and new principles on which to base new products and new services. The production, or development engineer, is concerned with making a commercial product which will sell or serve well and make a profit. The development engineer is more concerned with the *how* than the *why*.

Now, it is obvious that a research scientist cannot be an expert on all the commercial aspects of a new development, and at the same time, be a productive source of new ideas. Because of this, the research man often finds it difficult to understand why the laboratory model he presents to the manufacturer cannot be made commercially at once—or why the model he submits bears little resemblance to the actual product as it finally appears on the market. So much background is necessary to understand all the elements involved in commercial production, that the research man should confine himself to basic ideas and principles, leaving the problem of commercial production to others. It is in this transition stage that problems arise, problems in the human elements of the research and production teams.

Even so—and although the research scientist may not understand the problems involved in commercial production, he may often have much better vision and imagination than the man closer to the immediate problem of profit-making sales next year. He can see how the new product he has devised will perform a new and useful service, while the newness of the idea causes it to be accepted reluctantly by the production engineer who only sees the difficulties of its introduction. It is at this point that the research scientist must be a good salesman, must understand the psychology of the commercial people, and must try to transfer his enthusiasm to them. Support from management at this stage means a great deal to the man in the laboratory.

In RCA, for example, most research projects undertaken are a joint effort—that is, they are a joint effort between the research man and the development engineer once the fundamental ideas and principles have been developed by the research workers. The transition from research to development is usually a gradual one. In fact, our manufacturing engineers say that when a research man presents what he calls a "completed product" to the manufacturing division, it is then that problems between people are most likely to arise.

Ideally, it is desirable for the development engineer to know what the research worker is doing in his particular field, even when he cannot see how the idea can be used commercially at the time. In other words, there should be a gradual exchange of ideas between the research laboratory and the production department. Then, when a particular project is submitted to development engineers, they have the research background for it—and the research man is in a position to continue giving valuable consulting assistance. There may at times be conflicts caused by the differing objectives of research and development people. But these apparent conflicts are more often than not a good thing. They bring about an open discussion of various points of view and act as a spur to each group for greater accomplishment. Good results are almost always obtained when research and development engineers work together during the transition period.

Conclusion

We have already said that it is not possible to draw one profile or standard for the man in research—that this "standard member-of-staff" should in fact be avoided. It would be a matter for concern if we should consider setting up standardized criteria and if we should begin to apply these rigorously in employing members of a research staff. Research thrives on freshness of viewpoint and differences of approach to the solution of problems. This we achieve by varying environments of training, by differences in prominence of the several characteristics we have been discussing, and by a continual flow of persons new from the disciplines of educational training.

Our great problem today is the proper cultivation and exploitation of the nation's intellectual resources. We must learn to make the most effective use of our research staffs. We must know what we want and what we expect of the research worker. We must understand his motivations and characteristics. Based on our understanding of these things, we must provide environments conducive to good results. We must use creative imagination in the administration of research. We must follow this by sound engineering and good business planning. This is effective research. This is the kind of research which means position and control of destiny tomorrow.

Microstrip—A New Transmission Technique for the Kilomegacycle Range*

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Summary—**A novel approach to microwave transmission and components is described. In place of the more familiar waveguide or coaxial structures, this technique utilizes a single conductor supported above a ground plane. Such a configuration is equivalent to a parallel-wire system for the image of the conductor in the ground plane produces the required symmetry. Losses in this system are approximately equal to those of coaxial structures. The extent of the field spread about the conductor is small, thus making possible compact configuration. Printed-circuit techniques are particularly applicable to the construction of compact, rugged, inexpensive, and noncritical microwave components. A general description, background theory, and laboratory experiments are given in this and other papers.[1,2]**

1. Introduction

THREE PRINCIPAL TYPES of structures have been utilized in microwave systems: waveguides, coaxial lines, and parallel wires. Waveguides have comparatively low losses and, in common with the coaxial configurations, provide complete shielding and, hence, high Q, if required. Decoupling between components is more readily achieved than with other systems. Waveguide structures, on the other hand, are heavy, bulky, dimensionally critical, and expensive to manufacture. Coaxial components can be made smaller for a given wavelength than the waveguide equivalent, but usually require critical tolerances that make them still more expensive and difficult to manufacture. The third type, the parallel-wire system, while avoiding the disadvantages of the previous systems, possesses severe limitations so far as microwaves are concerned in that rigid symmetry is necessary to avoid perturbations and corresponding radiation and losses.

Other types of systems have also been considered. One type is the so-called G line involving the propagation of a TM mode along a single dielectric-coated conductor.[3,4] The relatively large spread of the fields about the conductor and the wave launching and collecting mechanisms have limited the usefulness of this system to antenna transmission lines and similar applications. More recently, a transmission line which corresponds to a flattened coaxial with the sides removed has been described.[5] This approach, while yielding configurations

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that are somewhat simpler to fabricate, still requires that close tolerances be maintained as in the case of coaxial construction. In addition, the parallel outer conductors subject the system to problems of transverse modes of transmission.

The relative simplicity of the parallel-line system suggested further study of this type or of some equivalent "open" system. This work has resulted in an interesting variation of the parallel-line system which avoids the requirements for extreme accuracy and dimensional symmetry. Because of the ease of manufacture and the apparent similarity to conventional wiring, the generic name of microstrip has been given to this transmission system. More specific forms, which are described in this and the accompanying papers,[1,2] have been termed "wire-above-ground, strip-line" and the corresponding "strip-plumbing," as well as "conductor-ground-plane" configurations.

2. General Description

The basic principle of this transmission system is illustrated in Fig. 1. For reference purposes, a parallel-wire system is shown at (a). If a ground plane of theoretically infinite width is inserted between the conductors and if the lower conductor is removed, the configuration at (b) results. If we assume as a first-order theory that the electostatic case applies, then an image of the upper conductor will exist in the ground plane when a field is present. The significance of the image is represented at (c).

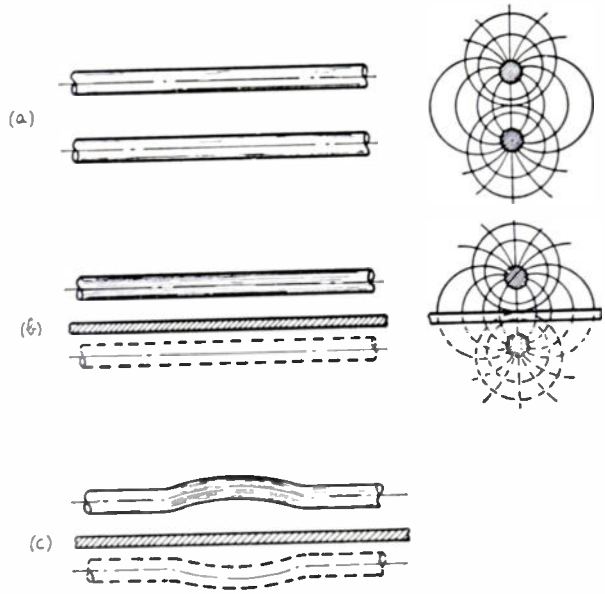

Fig. 1—Evolution of line above ground.

If the upper conductor is disturbed by moving it upward, the image oblingingly moves downward to compensate and maintain structural symmetry. Similarly, if the conductor diameter is modified or the conductor disturbed longitudinally, the image compensates in a corresponding manner. While the picture gives, of course, a first-order description only, it does serve to illustrate the basic principle involved. If the perturbations of the conductor are small compared to the wavelength, symmetry will be maintained.

A cross section of the wire-above-ground system, as well as a cross section of a variation of this system using a strip conductor in place of the round wire, is shown in Fig. 2.

In the idealized case using a single uniform dielectric and a lossless conductor, the types of transmission corresponds to the TEM mode. This has been confirmed approximately by theoretical work and by measurments performed on practical systems comprising composite dielectrics and finite conductor dimensions.

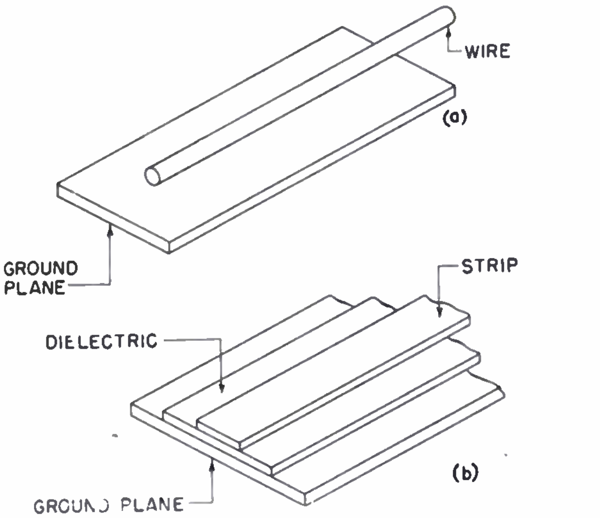

Fig. 2—Cross section of transmission system. (a) shows the wire above ground and (b) illustrates the strip line.

On the basis of the TEM mode of transmission, the system can be considered as approximating the characteristics of the familiar parallel-wire system. While this assumption neglects such things as fringing effects, in addition to the finite conductor and dielectric characteristics, the equivalence has been found useful as a guide to the design of various components.

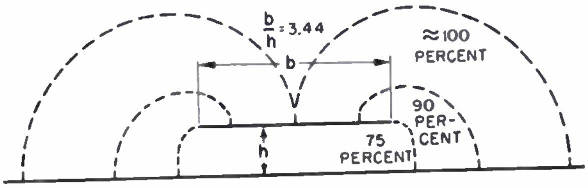

Fig. 3—Power-flow distribution.

An important characteristic of the system is the power-flow distribution between the conductor and ground plane. Fig. 3 gives the results of calculations of the ratio of power flow in a particular cross section to the total flow of power for a given b/h, where b is the radius of the wire and h is the distance from the center of the wire to the ground plane.

While the distribution shown is approximate only, the interesting conclusion that can be drawn from the mapping is that most of the power flow is adjacent to the conductor. In the case of the strip line, essentially all of the power is confined to a region of the ground plane equal to approximately three times the strip width for large b/h.

A comparison between the calculated losses for the various types of transmission systems and for the conductor-ground-plane system at different frequencies is given in Table I. Calculations are given for both air and polystyrene dielectrics.

TABLE I

CALCULATED ATTENUATION IN DECIBELS PER FOOT

Frequency in mc	Rectangular waveguide		Coaxial line		Wire above ground	
	Air	Polystyrene	⅜-inch air	RG-8/U	Air	Polystyrene
1,000	—	—	0.031	0.085	0.018	0.047
5,000	0.021	0.18	0.070	0.250	0.041	0.155
10,000	0.076	0.48	0.099	0.420	0.058	0.270

As can be seen from the table, the waveguide system using air dielectric yields the lowest attenuation values as would be expected because of the large copper area involved. The conductor-ground-plane system, however, has somewhat lower losses than the coaxial system.

In general, measured values for all the transmission systems are somewhat higher due to errors introduced by the physical condition of the conductors and dielectrics and to the presence of errors involved in the measurement process. Actual measurements have shown reasonable correspondence with the calculated values given. From both the calculated and measured data, the general conclusion can be drawn that this system yields losses that are closely comparable to those obtained with coaxial systems.

In view of the open type of construction of the microstrip structures, the radiation losses are of direct interest. Sterba and Feldman[6] have shown that the power radiated by a terminated parallel-wire line has a magnitude approximately twice that radiated by a doublet antenna of length equal to the line spacing and whose current is equal to the current in the line. In the above, for a line spacing small compared to the wavelength and for a line terminated in its characteristic impedance, the following expression is derived:

$$\frac{P_r}{I^2} = 160\left(\frac{\pi D}{\lambda}\right)^2, \quad \text{watts per ampere}^2, \qquad (1)$$

where P_r is the radiated power, D/λ is the line spacing, and I is the rms current in the line.

An approximation for the wire-above-ground case can be made by assuming that power is radiated in one hemisphere only, which divides the numerical constant by a factor of 2 and by writing for D the quantity $2h$, h being the height above ground. If the characteristic impedance Z_0 is used to determine the power in the line (1) becomes

$$\frac{P_r}{P} = \frac{320}{Z_0}\left(\frac{\pi h}{\lambda}\right)^2, \qquad (2)$$

where P is the power in the line and λ is the wavelength. Fig. 4 illustrates the radiated power ratios for a 50-ohm line for different conductor-ground-plane spacings and frequencies. It is seen from the data presented that within the assumptions inherent in the use of (2), the radiated power is a small percentage of the total power transmitted for small ratios of h/λ.

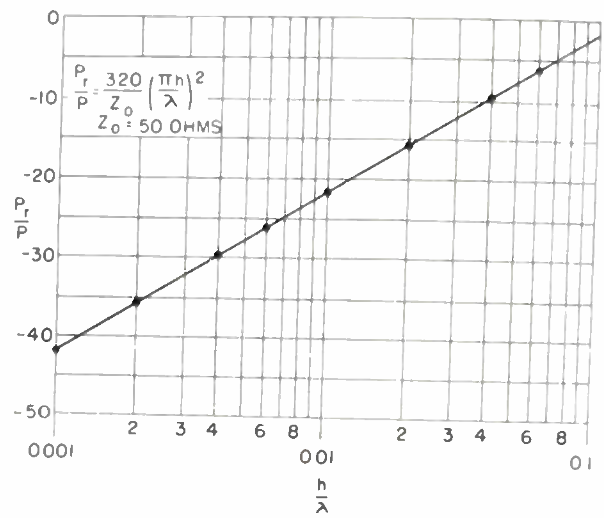

Fig. 4—Radiated power ratios as a function of h/λ.

3. Design and Structural Details

It is apparent that the basic idea of using a wire above a ground plane as a transmission-line system is not new, and in fact this general type of system was described in the early literature of radio.[7,8,9] The novelty is that it is applicable to microwaves and that particular configurations give optimum electrical and mechanical characteristics.

Several different types of configurations, each having their particular advantages and applications, might be visualized. Two main types of microstrip have been investigated to date. These are

A. wire above ground, which consists of a cylindrical conductor suspended above a ground plane;
B. strip line, which consists of a narrow ribbon conductor separated from the ground plane by a dielectric material.

Table II gives some of the characteristics of a practical microstrip system. The wire-above-ground structure may be of the air-dielectric type with the center

[6] E. J. Sterba and C. B. Feldman, "Transmission lines for short-wave radio system," Proc. I.R.E., vol. 20, pp. 1163–1202; July, 1932.

[7] "Reference Data for Radio Engineers," Federal Telephone and Radio Corp., New York, N. Y., 3rd ed., p. 324; 1949.

[8] W. H. Timbie and V. Bush, "Principles of Electrical Engineering," John Wiley and Sons, Inc., New York, N. Y., 3rd ed., pp. 299–304; December, 1947.

[9] A. A. Alford, U. S. Patent 2,159,648; May 23, 1949.

conductor supported by dielectric beads or by equivalent stubs. Alternatively, the wire may be supported above the ground plane by a continuous dielectric strip or be immersed in the dielectric. Because of the absence of sharp corners, the wire-above-ground line possesses the higher power-handling capabilities. In addition, the air-dielectric line yields the lowest losses.

TABLE II

STRIP-LINE AND WIRE-ABOVE-GROUND STRUCTURES

	Strip line	Wire above ground
Characteristic impedance	50 ohms	50 ohms
Conductor dimensions	0.220 by 0.002 inch	0.125-inch diameter
Conductor material	Copper	Copper
Ground-plane width	3 times conductor width	3 times conductor diameter
Conductor support	0.064 polystyrene sheet	Polystyrene bead
Height above ground plane	0.064 inch	0.024 inch

Table III gives the ratios h/b for various optimized characteristics. As in the coaxial case, equivalent impedances of the order of 50 ohms represent a close-enough compromise between the various characteristics listed.

TABLE III

DIMENSIONS FOR OPTIMIZED CHARACTERISTICS

	h/b	Characteristic impedance of air line in ohms
Maximum voltage between conductors	2.45	92.6
Maximum power transfer	1.60	62.6
Minimum attenuation	2.45	92.6
Minimum resonant impedance	1.0	0
Maximum resonant impedance	5.55	144

For the particular wire-above-ground dimensions given, an estimation of the radiation can be made using (2). For $h=0.025$ inch, $Z_0=50$, and $\lambda=7$ cm the ratio of power radiated to power in the line is -23 db. If it is assumed that all this power impinges on an adjacent line then, since the efficiency of the line as a receiving antenna is down at least the same 23 db, the coupling of the radiation fields between two similar lines is a minimum of -46 db.

Since the radiation varies directly with the square of the spacing, radiation coupling can be reduced still further by decreasing h. To maintain the same impedance, the diameter of the wire in this case must also be reduced. While this reduces the copper area and thus increases the line losses, for most applications to microwave circuity where line lengths are short, the increase in attenuation should not be a determining factor. An additional factor, which is a second-order magnitude and which further increases losses as the spacing of the wire above ground is decreased, is the "proximity effect" and is due to the increased concentration of the field nearest the ground plane.[10] This factor is present to a much lesser degree in strip-line type configuration.

Another item of interest is the power-handling capabilities of the line as a function of spacing. If we assume an air breakdown characteristic of 30 kv per centimeter, the breakdown voltage for the example cited is 1.9 kv. For a 50-ohm impedance, this yields a theoretical power-handling capacity of approximately 70 kw. In the actual case, projections in the wire and the condition of the conductors and dielectric can reduce this value considerably. Tests on an experimental sample have given a breakdown voltage of 1.8 kv and a corresponding peak power capability of 65 kw.

On the basis of the above, it is apparent the preferred configuration for the wire-above-ground or equivalent system for application to microwaves should maintain h/λ as small as is practicable. For the more popular range of microwave frequencies (e.g., approximately 1,000 to 10,000 mc) this spacing is of the order of a few thousandths of an inch.

The dielectric-supported wire above ground suggests a second configuration that is more amenable to simple fabrication processes. This is the strip-line system, an experimental design of which is described dimensionally in Table II.

Fig. 5—Mechanical stripping process.

The strip line can be constructed in many ways. An extremely useful method for experimental work utilizes as the starting material a dielectric of the proper dimensions sandwiched between two high-conductivity metals such as copper and silver. Sandwich material utilizing several different types of dielectrics can be purchased on the commercial market. The transmission-line con-

[10] J. R. Carson, "Waves propagation on parallel wires; the proximity effect," *Phil. Mag.*, series 6, vol. 41, pp. 607–633; April, 1921

figuration is scribed on one of the conductors and the excess material removed as illustrated in Fig. 5. The unscribed metal backing serves as the ground plane and the dielectric is utilized as the support for the transmission-line configuration. It has been found that the tolerances of the dielectric thickness for the commercial product, which may run ±5 per cent, is adequate for most of these purposes.

Alternatively, the strip configuration can be printed by photographic methods on one of the conductors and the excess material removed by a chemical process. This latter method, utilizing a ferric-chloride etching process, has been used quite successfully. Fig. 6 illustrates the printing of a batch of strip-line components by this process. One group of hybrids and a second group of directional couplers are shown. The individual components are cut apart later.

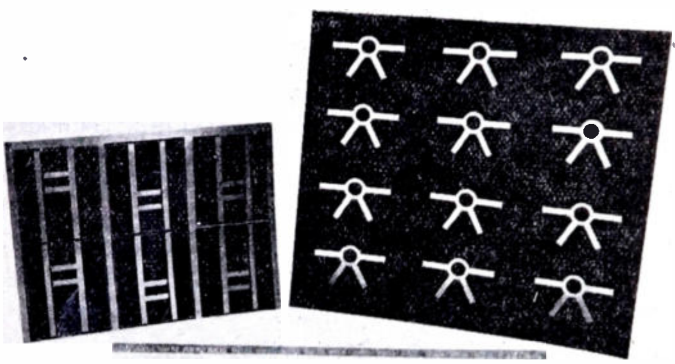

Fig. 6—Method of producing printed strip-line components.

Various materials and alternate processes may, of course, be used in place of those described above. For low dielectric losses and for good temperature characteristics, a metal-and-dielectric sandwich using teflon may be used.

Printing, embossing, or evaporation methods can, of course, be used instead of removing material in the fabrication process. In general, the strip line lends itself to fabrication by most of the printed-circuit methods.

A variation of the strip line is a construction in which a layer of dielectric is placed over the strip conductor. The strip conductor may be deposited in a fashion similar to that described or, alternatively, may be independently cut from strip stock in the required configuration and sandwiched between the dielectric and the ground plane.

It would be expected that radiation effects, power-handling capabilities, and their relation to the spacing of strip would be comparable to the wire-above-ground structure. Experimental evidence has essentially confirmed this. Measurements made on two adjacent strip lines using the configurations of Table II yielded coupling values of the order of −35 db for separations of approximately $\frac{3}{8}$ wavelength. This value includes not only the coupling of the near fields but leakage introduced by the coaxial transitions used in the experimental setup. Measurements have also been made of the voltage breakdown and power capabilities for 0.05-inch separation of polystyrene. Maximum voltage has been found to be 15 kv and the corresponding peak power capability, 4×10^6 watts.

4. Components and General Application

From the basic transmission-line elements, many different types of components having application to microwave systems can be designed. In general, it has been found possible to construct most of the applicable components utilizing wire-above-ground or strip-line configurations. For microwave systems, the total length of line required for the components is relatively short. Since insertion losses are therefore small, a greater freedom of choice exists in determining the materials of construction and the type of system.

The strip line particularly lends itself to satisfactory fabrication processes, and thus many components have been constructed utilizing it. Dielectrics actually used for the development of components have been polystyrene and laminated phenolic plastics. Fibrous sheet materials impregnated with a thermosetting resin have had their use limited to guide-wavelength studies only, because of excessive attenuation.

These products are available commercially in sheet form with either or both sides coated with copper, and have been used with the mechanical stripping, photoengraving, and etching processes. In the case of polystyrene, cementing of metal conductors to the surface has proved successful without introducing appreciable dissipation. Preformed shapes of line conductor can thus be cemented in place to form a particular configuration. Sandwich-type construction is readily accomplished by cementing under pressure.

Components have been successfully operated in several frequency bands, such as 1,000, 5,000, and 10,000 mc. In view of the availability of special test equipment, most of the experimental work has been done in the 4400-to-5000-mc region. A partial listing of components that have been constructed follows.

A. Transitions

Wideband transducers have been designed to operate in several regions of the microwave spectrum, including the 5,000- and 10,000-mc regions. Fig. 7 illustrates a strip-to-coaxial transition as compared to the equivalent coaxial-to-waveguide type for the 5,000-mc range. VSWR as low as 1.2 over a 10-per cent band utilizing this type of component have been achieved.

Transitions for waveguides have also been constructed. In general, while it has been found feasible to couple the waveguide directly to the strip line, a more convenient design has been the use of a cross-bar-feed waveguide-to-coaxial transition and then that of the coaxial-to-strip-line transition of the type described.

B. Crystal Mounts

Wide-band crystal mounts have been designed for the various types of lines. For the strip line, a successful design is the type utilizing a coaxial transition with the

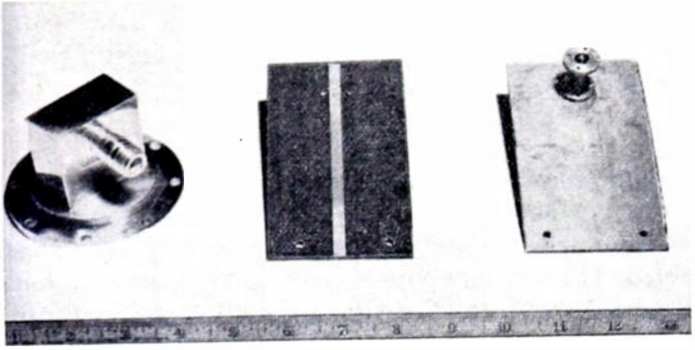

Fig. 7—Comparison of a 2- by 1-inch waveguide type-*N* transducer and a 3/8-inch coaxial-line-to-microstrip transducer for the same frequency range.

crystal holder as an integral part of the coaxial. Fig. 8 illustrates a unit designed for operation in the 4,400-to-5,000-mc band. VSWR of less than 1.5 have been measured utilizing 1N21-B and 1N23-B types of crystals.

C. Magic Tees

The magic tee, which is useful for balanced mixers, automatic-frequency-control circuits, hybrid junctions,

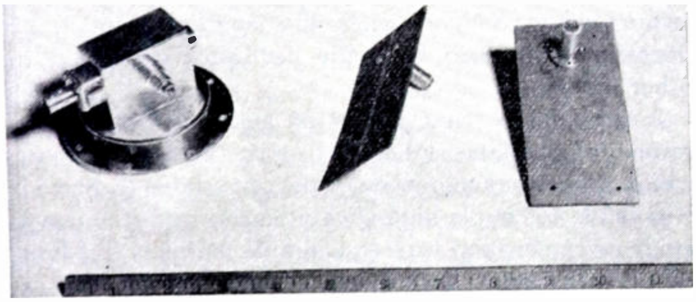

Fig. 8—Comparison of crystal mounts on a 2- by 1-inch waveguide and on a microstrip-to-coaxial structure using the same type of crystal for a similar frequency band.

and the like, has been constructed in microstrip. Fig. 9 illustrates the comparison of a strip rat race compared to the waveguide equivalent for operation in the 4,400-to-5,000-mc region. This type of hybrid junction has been utilized with the two arms terminated in crystal holders and the third arm in a matched load. Measurements have shown negligible radiation, balanced crystal response, and extremely low vswr over the bandwidth.

D. Attenuator Pads and Loads

Fig. 10 illustrates a type of fixed load utilizing the microstrip techniques. The line is coated with a lossy

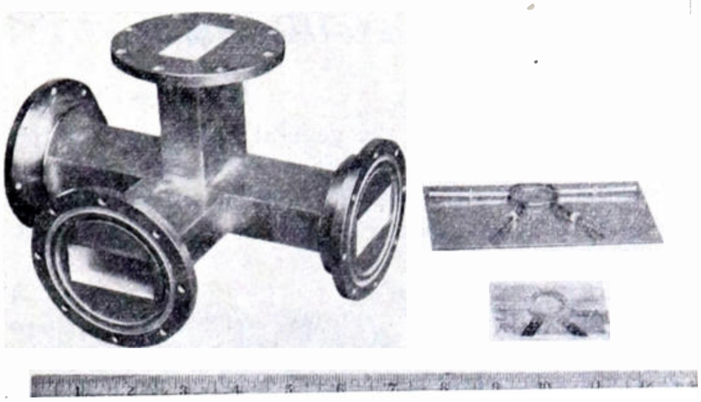

Fig. 9—Comparison of waveguide magic tee and microstrip rat race.

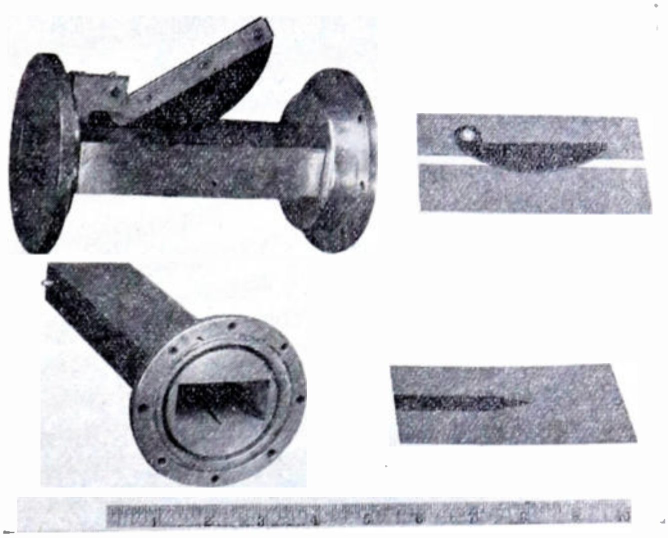

Fig. 10—Loads and variable attenuators of rectangular guides and printed strip lines.

dielectric of appropriate characteristics. Graphited paint has been used in some cases. To obtain a proper match, the lossy dielectric can be tapered as shown in the figure. The load illustrated gives a matched termination over a 4,000-to-5,000-mc range.

A variable attenuator, counterpart of the waveguide flap attenuator, is also shown. Variation of attenuation is obtained by rotation of the flap, which adjusts the length of the dielectric run with respect to the strip line. This attenuator has a range of zero to 15 db.

E. Miscellaneous Components

The preceding components have been described briefly in order to illustrate the various possibilities. Other types of components not described have included directional couplers, filter elements, and similar structures. The use of this technique has also been applied to the construction of antennas. By slotting the ground plane at an angle to the strip conductor, radiation in the direction at right angles to the ground plane may be obtained. Various patterns can be built up by increasing the number of slots and varying the length of the strip feed between slots. The ground-plane slot has also been used to couple external cavities and in this manner high-Q configurations can be constructed.

F. Microwave Receiver

As an illustration of the general application of the techniques described, the front end of a microwave receiver designed for the 4400-to-5000-mc region is shown in Fig. 11. The microwave portion of the receiver consists of the following:

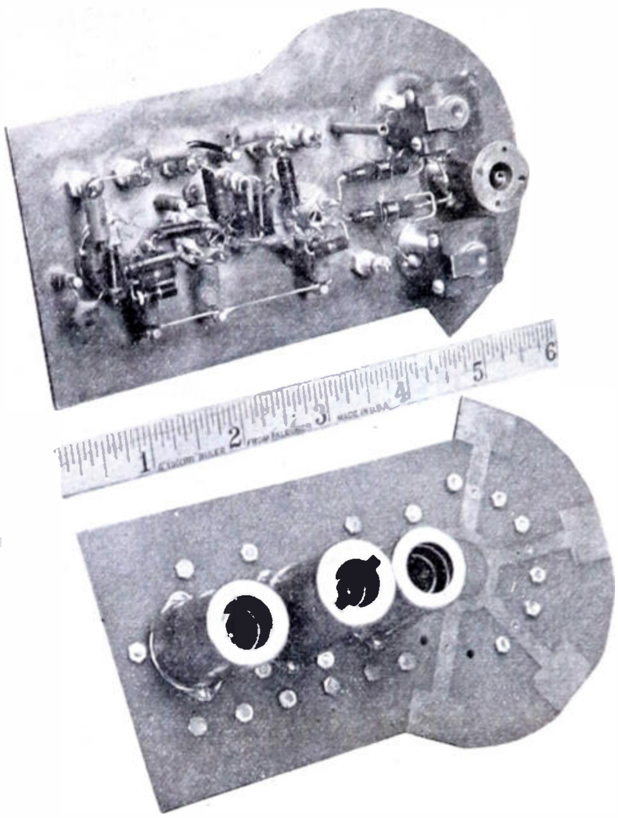

Fig. 11— Front end of microwave receiver showing top and bottom views.

1. Coaxial-to-strip-line transition and matching element, which permits its connection to a coaxial antenna feed.
2. Balanced rat-race mixer for low noise figure. Included in the mixer are two balanced crystal holders and matching elements.
3. Coaxial transition for the local oscillator and matching elements.

It should be noted that the ground plane is used as the chasis for the conventional low-frequency stages. The low-noise input stages and the first two stages of the intermediate-frequency amplifier are illustrated in the figures. The top view of the receiver shows the stubs used for matching the various transitions. In practice, an extremely accurate match for these elements can be obtained by successively cutting away portions of the terminating-line capacitance. Receivers of the type shown have yielded noise figures of better than 16 db and conversion losses limited only by the crystal characteristics.

5. Conclusions

While the idea of a conductor above a ground plane is not new and has been used at the lower frequencies, its application to microwaves seems to have been neglected. The fact that simple forms such as the strip line can be utilized at microwaves should prove useful in those applications where the more bulky and expensive-to-manufacture conventional plumbing is at a disadvantage.

There are, of course, a number of limitations to microstrip. The fact that an open structure is used leads to a somewhat greater coupling between side-by-side configurations as compared to waveguide or coaxial systems. The absolute value of this coupling is small however. Also, the fact that complete circuits can be fabricated in one piece avoids the use of transitions or flanges, which in practice is often the dominant coupling element for the closed transmission systems.

A second factor is the somewhat higher attenuation of the system as compared to waveguide structures. While this item may limit its usefulness in systems where extremely low losses are required, for many applications losses are sufficiently small. In systems such as microwave receivers, where line lengths are small, the insertion losses can be made negligible compared to other losses.

A third factor that should be mentioned is the low resonant impedance inherent in structures of this sort, which limits the magnitude of the obtainable Q. Since it is possible to couple high-Q cavities of either the waveguide or the coaxial type in a simple manner, this limitation for practical designs can be overcome by combining the desirable features of the different systems.

On the basis of the preceding, it is concluded that the techniques described should prove useful for application to microwave systems particularly where a practical compromise must be made between the extremes of maximum electrical performance and optimum physical realization.

Simplified Theory of Microstrip Transmission Systems*

F. ASSADOURIAN† AND E. RIMAI†

Summary—Properties of TEM-mode propagation are examined for a wire or a strip of finite width immersed in a uniform infinite dielectric above a ground plane. Characteristic impedance, power flow, and conductor and dielectric losses are considered. The discussion of the TEM mode is in the complex plane.

1. Introduction

THIS PAPER is concerned with properties of electromagnetic propagation in transmission systems consisting of an infinitely long circular wire or strip above an infinite ground plane and having uniform cross sections. If the surrounding dielectric (air or solid) is uniform and infinite and the system is lossless, then the transverse electromagnetic (TEM) mode can be propagated. However, practical strip lines involve a solid dielectric on which a strip is placed, and an air region above the dielectric. Since these strip lines involve composite dielectrics, they cannot support a pure TEM mode. Nevertheless, both theory and experiment indicate that the fields and power flow are concentrated in the dielectric between the conductors, so that the assumption of a single infinite dielectric leads to useful results even though it is not rigorous.

It is assumed henceforth that the conductors are immersed in an infinite uniform dielectric. The further assumption of perfect conductors and lossless dielectrics permits computations on the basis of a TEM mode. Either a rigorous or a first-order analysis is followed to derive equations for characteristic impedance and concentration of power flow through the cross sections. Transmission losses are calculated wherever possible from the field solutions for the lossless cases.

The analysis of the TEM mode is reduced to an investigation of its corresponding electrostatic distribution which is made, not in the original transverse cross-sectional plane of a given configuration, but in a new plane obtained by a conformal transformation. Calculations of desired quantities are carried out more readily in the image plane. Most of the discussion about characteristic impedances has appeared previously in the literature in terms of related capacitances. Much of the discussion about the distribution of power flow and transmission losses may not be well known. Practical mks units are employed in all equations unless otherwise indicated.

2. Electrostatic Approach to TEM Mode

The electrostatic approach to the analysis of the TEM mode is well known.[1] If the electric field is written as $E(x, y)$ multiplied by factors involving time and the direction of propagation ξ, then $E(x, y)$ is an electrostatic field.

One may write $E=-\nabla\phi$, where the scalar potential ϕ satisfies $\nabla^2\phi=0$ and takes specific values, for example ϕ_1 and ϕ_2, at the conductor boundaries.

If q is the charge per unit length on either conductor, then the capacitance C per unit length and the characteristic impedance Z_0 are given by

$$C = q/(\phi_2 - \phi_1) \tag{1}$$

and

$$Z_0 = (\mu\epsilon)^{1/2}/C. \tag{2}$$

The average power P flowing through an entire cross section is found from

$$P = \frac{1}{2}\left(\frac{\epsilon}{\mu}\right)^{1/2}\int |E|^2 dS = (\phi_2 - \phi_1)^2/2Z_0, \tag{3}$$

where dS is an element of area and the limits are the conductor boundaries.

First-order estimates of conductor and dielectric losses are found in the usual way[1] from the previously found field for the lossless case.

One may write

$$\alpha = \frac{P_{c1} + P_{c2} + P_d}{2P} = \alpha_{c1} + \alpha_{c2} + \alpha_d = \alpha_c + \alpha_d, \tag{4}$$

where P_{c1}, P_{c2}, and P_d are power losses per unit length along ξ in the two conductors and the dielectric. The average power dissipated in a conductor per unit distance along ξ is

$$P_c = \frac{\eta}{2}\frac{\epsilon}{\mu}\int |E|^2 ds, \quad \eta = (\pi f\mu/\sigma_c)^{1/2}, \tag{5}$$

where ds is an element of length along the conductor boundary, f is frequency, and σ_c is conductivity.

The power loss P_d in the dielectric per unit length along ξ is given by

$$P_d = \frac{1}{2}\sigma_d\int |E|^2 dS, \tag{6}$$

evaluated over the dielectric portion of a cross section. Since P_d and P involve the same region of integration, one has immediately

$$\alpha_d = \frac{\sigma_d}{2}\left(\frac{\mu}{\epsilon}\right)^{1/2}, \tag{7}$$

which is independent of the geometry of the conductors.

* Decimal classification: R117×R423.17×R310. Original manuscript received by the Institute, May 22, 1952; revised manuscript received on October 8, 1952. Presented at the National Convention of the Institute in New York, N. Y., March 5, 1952.

† Federal Telecommunication Laboratories, Inc.; Nutley, N. J.

[1] S. Ramo and J. R. Whinnery, "Fields and Waves in Modern Radio," John Wiley and Sons, Inc., New York, N. Y.; 1944.

The conductivity σ_d is obtained from the complex dielectric constant

$$\epsilon' = \epsilon - j\epsilon_1 = \epsilon(1 - j\sigma_d/\omega\epsilon), \qquad \sigma_d = \omega(\epsilon_1/\epsilon)\epsilon, \tag{8}$$

where the loss ratio ϵ_1/ϵ is assumed to be small.

3. Electrostatic Calculations in the Complex Plane

The quantities listed in the previous section require knowledge of E and ϕ. The method for their calculation followed in this paper uses functions of a complex variable.[2]

A brief summary of the complex-variable method is useful for an understanding of subsequent calculations. If the cross section of a transmission line is drawn in the complex $z = x + jy$ plane, the complex potential $F(z)$ is an analytical function given by

$$F(z) = \phi(x, y) + j\psi(x, y), \tag{9}$$

where ϕ and ψ satisfy the Cauchy-Riemann and Laplace equations. Curves of constant ϕ are equipotential lines, and the orthogonal curves of constant ψ are flux lines.

The electric intensity vector E can be represented in complex form by

$$E(z) = -\overline{(dF/dz)}, \tag{10}$$

where the bar indicates that the complex conjugate should be taken. The problem of finding $F(z)$ is frequently simplified by using a conformal mapping $z = f(w)$ to map the z plane into an image w plane where $F(w)$ is more readily set up.

If $E(w)$ is the electric field in the w plane, then

$$E(z) = -\overline{(dF/dw)}\overline{(dw/dz)} = E(w)\overline{dw/dz}. \tag{11}$$

For small elements $|dz|$ and $|dw|$, one has approximately

$$|E(z)|\,|dz| = |E(w)|\,|dw|. \tag{12}$$

This is the fundamental relation that permits the calculation of all desired quantities in the w plane.

Although the integration of (12) around a conductor boundary and multiplication by ϵ will yield the total charge per unit length along ξ, this charge q is found more quickly from

$$F(w) = \phi(u, v) + j\psi(u, v) \tag{13}$$

by taking ϵ times the change in ψ over a circuit of either conductor boundary. It is evident from (12) that both q and hence Z_0 are invariant under a conformal mapping if corresponding conductors in the two planes have the same potentials.

Let dz_1 and dz_2 be two orthogonal elements at a point z with orthogonal images dw_1 and dw_2 at the image point w. Then $|dz_1|\,|dz_2|$ and $|dw_1|\,|dw_2|$ are areas of elementary rectangles. If now (12) is written twice for dz_1 and dz_2 and the results are multiplied, one obtains

$$|E(z)|^2 dS_z = |E(w)|^2 dS_w. \tag{14}$$

Reference to (3) shows that $P(z) = P(w)$, so that the total power flow is also invariant under a conformal mapping. Furthermore, the portion of P bounded by the conductors and any pair of flux lines remains the same if their images are considered.

One may write

$$|E(z)|^2\,|dz| = |E(w)|^2\,|dw|\left|\frac{dw}{dz}\right|. \tag{15}$$

Integration of the left-hand side along conductor boundaries or of the right-hand side along the boundary images and substitution in (5) gives the conductor losses. It should be noted that this calculation gives losses for the original conductors but not for their images.

In summary, it is evident that q, C, Z_0, P, and suitably defined portions of P are invariant, but α_c is not invariant under conformal mappings. All of these quantities may be calculated in the image plane.

4. Circular Wire above Infinite Ground

The cross section for a transmission system of a circular wire above an infinitely wide ground conductor is

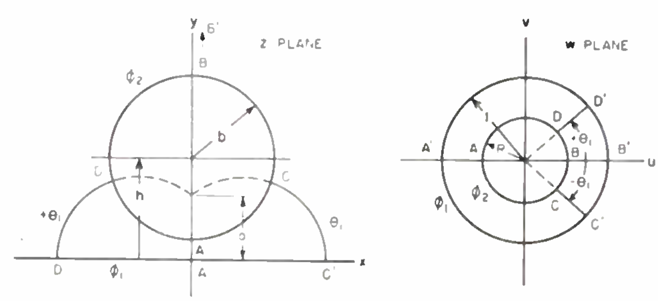

Fig. 1—Conformal mapping for a wire above an infinite ground plane.

shown in Fig. 1. The quantity a is related to height h and radius b by

$$h^2 = a^2 + b^2. \tag{16}$$

The bilinear transformation

$$z = ja(1 + w)/(1 - w) \tag{17}$$

converts wire and ground plane into a coaxial pair of concentric circles as shown in Fig. 1. The complex potential in the image plane is

$$F(w) = (\phi_2 - \phi_1)\ln w/\ln R + \phi_1 = \phi(u, v) + j\psi(u, v), \quad R = b/(h + a) \tag{18}$$

and leads to the well-known results,

$$\phi = \frac{\phi_2 - \phi_1}{\ln R}\ln r + \phi_1, \quad \psi = \frac{\phi_2 - \phi_1}{\ln R}\theta, \quad w = re^{j\theta}. \tag{19}$$

$$E(w) = -\frac{\phi_2 - \phi_1}{\ln R}\frac{1}{w^2} \tag{20}$$

[2] E. Weber, "Electromagnetic Fields—Theory and Applications," John Wiley and Sons, Inc., New York, N. Y., vol. I; 1950.

and

$$q = 2\pi\epsilon \frac{\phi_2 - \phi_1}{\ln R}, \qquad C = \frac{2\pi\epsilon}{\cosh^{-1}(h/b)},$$
$$Z_0 = \frac{1}{2\pi}\left(\frac{\mu}{\epsilon}\right)^{1/2} \cosh^{-1}(h/b). \qquad (21)$$

The radial flux lines are images of

$$(x + a \cot \theta)^2 + y^2 = a^2 \operatorname{cosec}^2 \theta. \qquad (22)$$

Some aspects of the following discussion may not be as well known. If k is the fraction of power P flowing through the sectorial region bounded by the conductors and the flux lines $\theta = \pm\theta_1$, then

$$k = (\pi - \theta_1)/\pi. \qquad (23)$$

It should be noted again that k is the same in either plane. The choice of several values for θ_1 in (23) yields a picture of power flow distribution in the TEM mode.

The application of (4), (5), and (15) to each conductor in the w plane yields

$$\alpha_c = \frac{1}{2a}\left(\frac{\pi f\epsilon}{\sigma_c}\right)^{1/2} \frac{1 + h/b}{\cosh^{-1}(h/b)},$$
$$\left(\frac{\pi f\epsilon}{\sigma_c}\right)^{1/2} = \eta\left(\frac{\epsilon}{\mu}\right)^{1/2}. \qquad (24)$$

A plot of the variable part of α_c (a fixed) is given in Fig. 2. The minimum value of α_c is given by

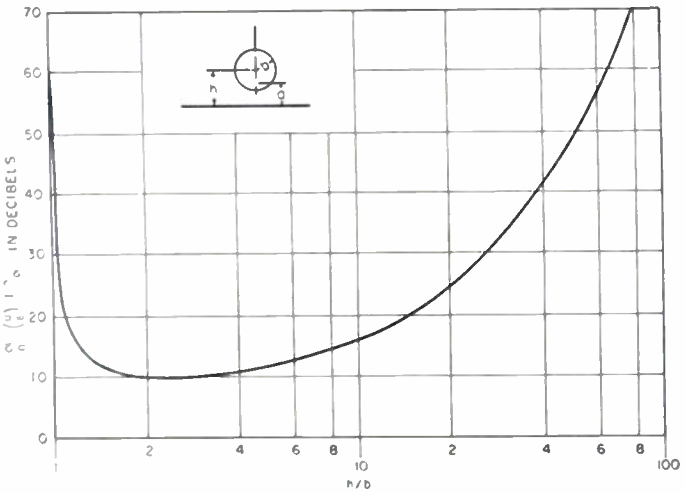

Fig. 2—Conductor attenuator for a wire above an infinite ground plane.

$$\alpha_c = \frac{4.34}{a}\eta\left(\frac{\epsilon}{\mu}\right)^{1/2}\frac{1 + h/b}{\cosh^{-1} h/b}$$

in db per unit length.

$$\eta = \left(\frac{\pi\mu f}{\sigma_c}\right)^{1/2}.$$

$$h/b = 2.447,$$
$$(\alpha_c)_{\min} = \frac{1.117}{a}\left(\frac{\pi f\epsilon}{\sigma_c}\right)^{1/2} \text{ nepers/meter.} \qquad (25)$$

For a numerical illustration, consider a wire of radius 0.0625 inch and height 0.0850 inch. Copper conductors are assumed. For a frequency of 5,000 mc and a normalized dielectric constant of 2.54 with a loss ratio of 4×10^{-4} (polystyrene), one obtains

$$a = 0.0576 \text{ inch}, \qquad (\pi f\epsilon/\sigma_c)^{1/2} = 7.80 \times 10^{-5},$$
$$\alpha_c = 0.20 \text{ db/ft}, \qquad \alpha_d = 0.09 \text{ db/ft},$$
$$\alpha = \alpha_c + \alpha_d = 0.29 \text{ db/ft}, \qquad Z_0 = 31 \text{ ohms}.$$

By choosing $\theta_1 = \pm 0.25\,\pi$, $\pm 0.10\pi$ and $\pm 0.05\pi$ in (23) and using (21), one finds the bounding flux lines for 75, 90, and 95 per cent of the power flow in the TEM mode. These regions are indicated in Fig. 3.

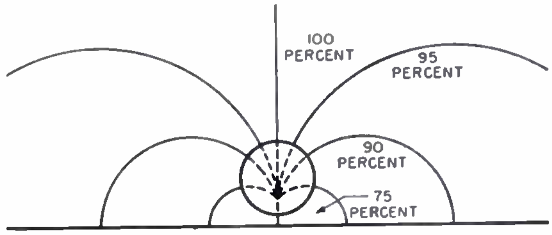

Fig. 3—Distribution of power flow for a wire above an infinite ground plane.

5. Wide Strip of Zero Thickness above Infinite Ground

This section considers a strip of zero thickness, width b, and height h above an infinitely wide plane conductor, as shown in Fig. 4, with $b \gg h$. For a semi-infinite strip parallel to an infinitely wide ground conductor, it is

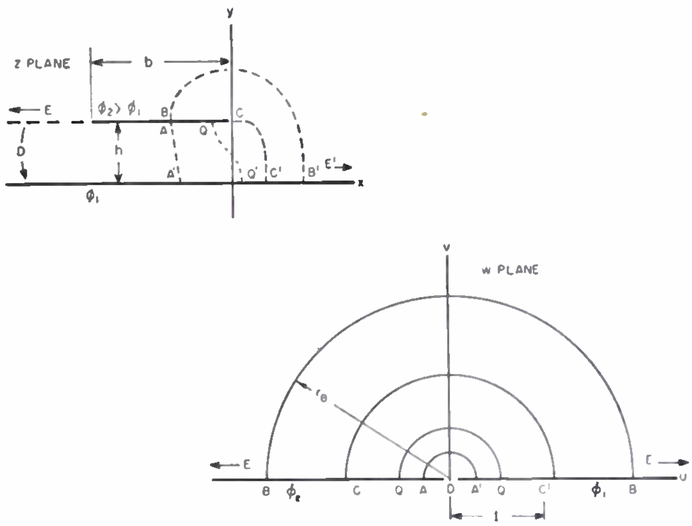

Fig. 4—Conformal mapping for a wide strip of zero thickness above an infinite ground plane.

known[2] that the electric field is infinite at the strip edges and, as one proceeds along the underside of the strip, approaches the homogeneous field that would result from two infinite conductors with the same spacing. The actual field is within 1 per cent of the homogeneous field beyond a distance approximately equal to the spacing.

The preceding suggests that the effect of the strip edges should become negligible as the center of the underside of the strip is approached in Fig. 4. It appears reasonable therefore to calculate the electrostatic distribution for the right half of the configuration by assuming that the strip extends to infinity at the left. The field to the left of the line of symmetry through A then follows by symmetry.

The conformal mapping given by

$$\pi z/h = 1 + w + \ln w \tag{26}$$

transforms the revised upper z plane into the upper w plane. The images of the semi-infinite strip and infinite ground are the two halves of the u axis. The regions of interest are those bounded by $BCAA'C'B'B$ in both planes. The fact that the flux line leaving B in the z plane should be vertical but is not reveals the approximateness of the mapping. The worst inaccuracy is in the region of lowest field intensity.

The complex potential in the image plane is

$$F(w) = -j\frac{\phi_2 - \phi_1}{\pi}\ln w + \phi_1$$

$$= -j\frac{hE_0}{\pi}\ln w + \phi_1 = \phi + j\psi, \tag{27}$$

where E_0 is the constant field that would result if the strip were infinitely wide. By using $w = r\exp(j\theta)$ in (26), one sees that the equipotential and flux lines are given by

$$\pi x/h = 1 + r\cos\theta + \ln r, \quad \pi y/h = \theta + r\sin\theta. \tag{28}$$

From (27) one obtains for the electric fields

$$E(w) = -jhE_0/\pi\bar{w}, \quad E(z) = -jE_0/\overline{w+1}. \tag{29}$$

If r_A and r_B are the radii of flux lines in the w plane through A and B, they are found from (28) to satisfy

$$-\pi b/2h = 1 - r + \ln r, \quad \ln r_B/r_A = r_B - r_A. \tag{30}$$

For large b/h, it is seen that

$$\ln r_A \approx -1 - \pi b/2h,$$

$$r_B \approx \ln r_B/r_A \approx 1 + \pi b/2h + \ln(1 + \pi b/2h). \tag{31}$$

The charge q_{AB} between A and B is

$$q_{AB} = \epsilon(hE/\pi)\ln r_B/r_A.$$

The total charge on the actual strip is $q = 2q_{AB}$. The characteristic impedance is

$$Z_0 = \frac{\pi}{2}\left(\frac{\mu}{\epsilon}\right)^{1/2}\frac{1}{\ln r_B/r_A}$$

$$\approx Z_0'\Big/\left\{1 + \frac{2h}{\pi b}\left[\ln\left(1 + \frac{\pi b}{2h}\right) + 1\right]\right\},$$

$$Z_0' = \frac{b}{b}\left(\frac{\mu}{\epsilon}\right)^{1/2}, \tag{32}$$

where Z_0' corresponds to a constant field in the absence of fringing and leakage flux. This result has been derived by Maxwell[3] in terms of capacitance.

A rigorous mapping for the entire strip[4] has been previously used to find the accurate electrostatic distribution and, for $b \gg h$, gives rise to the result

$$Z_0 \approx Z_0'/[1 + (2h/\pi b)(1 + \ln \pi b/h)]. \tag{33}$$

For large b/h, (32) and (33) approach each other. A plot of both expressions is given in Fig. 5.

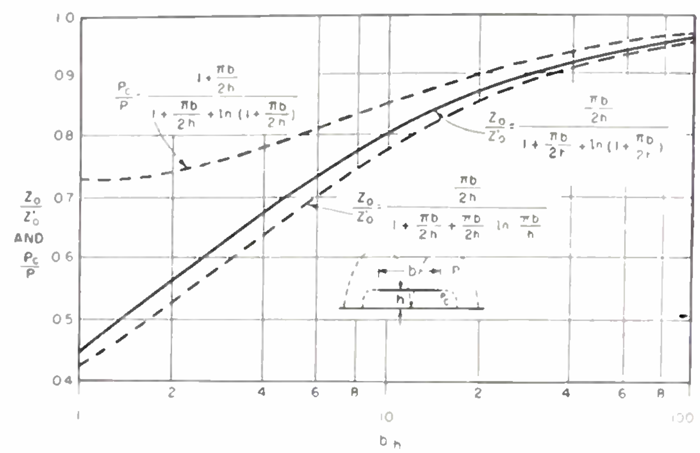

Fig. 5—Characteristic impedance and power flow for a wide strip of zero thickness above an infinite ground plane.

$$Z_0' = \frac{b}{h}\left(\frac{\mu}{\epsilon}\right)^{1/2}.$$

If P represents the power flow bounded by pairs of flux lines starting at A and B, and if P_Q is the power bounded by a pair of flux lines through A and any other symmetrical pair of which one starts at the point Q, then P_Q/P is given by

$$\frac{P_Q}{P} = \frac{\ln r_Q/r_A}{\ln r_B/r_A}, \tag{34}$$

where $r_Q < r_B$ corresponds to the second pair of flux lines.

For example, $r_c = 1$ for flux lines leaving the strip edges and P_c/P is then given by

$$\frac{P_c}{P} = \frac{-\ln r_A}{\ln r_B - \ln r_A} \approx \frac{1 + \pi b/2h}{1 + \pi b/2h + \ln(1 + \pi b/2h)}. \tag{35}$$

A plot of P_c/P versus b/h for $r_Q = 1$ is given in Fig. 5. It is apparent from Fig. 5 that, for large b/h, most of the power flow is confined between the lower surface of the strip and the ground conductor and that fringing and leakage fields become negligible.

[3] J. C. Maxwell, "Electricity and Magnetism," 3rd. ed., p. 309; 1904.

[4] H. B. Palmer, "Capacitance of a parallel plate capacitor by the Schwartz-Christoffel transformation," *Trans. AIEE*, vol. 56, p. 363; March, 1937.

6. Wide Strip of Small Thickness Above Infinite Ground

The procedure of the previous section is now altered o take into account a small strip thickness d, where $\gg h \gg d$. The mapping (26) is replaced by

$$\frac{\pi z}{h} = \frac{p+1}{p^{1/2}} \tanh^{-1} R + \frac{p-1}{p^{1/2}} \frac{R}{1-R^2} + \ln \frac{Rp^{1/2}-1}{Rp^{1/2}+1}, \tag{36}$$

vhere R and p are defined by

$$R = \left(\frac{w+1}{w+p}\right)^{1/2},$$

$$p = -1 + 2\beta^2 + 2\beta(\beta^2-1)^{1/2}, \quad \beta = 1 + d/h. \tag{37}$$

The geometry of the mapping is indicated in Fig. 6. The electrostatic problem is again solved for the right half of a cross section on the assumption that the left half is infinite.

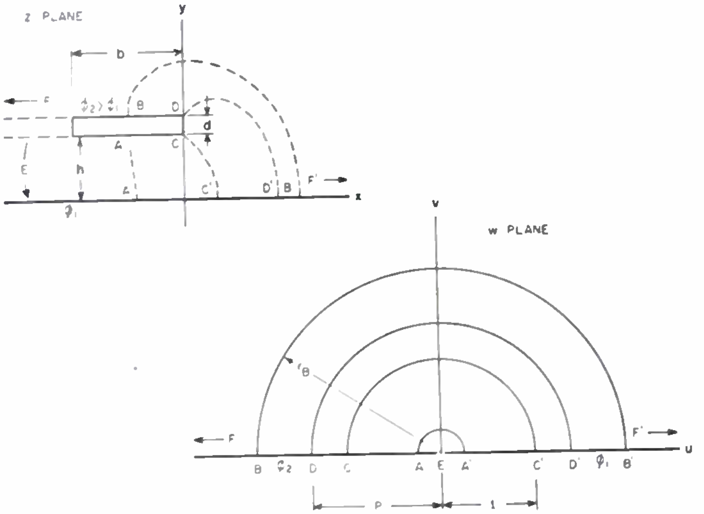

Fig. 6—Conformal mapping for a wide strip of small thickness above an infinite ground plane.

Since the w plane is the same as in the previous section, the expressions for $F(w)$, $E(w)$, Z_0, and P_Q/P remain unaltered. For $E(z)$, one now has

$$E(z) = -jE_0 p^{1/2}/[(w+p)(w+1)]^{1/2}. \tag{38}$$

For $h \gg d$, one may write $p = 1 + \delta$ in (36) and obtain

$$\pi z/h \approx 1 + w + \ln w - (w+1)\delta/2, \quad \delta = p - 1. \tag{39}$$

The equations for the equipotential and flux lines are

$$\pi x/h = (1 - \delta/2) r \cos\theta + 1 + \ln r - \delta/2,$$
$$\pi y/h = \theta + r(1-\delta/2)\sin\theta, \tag{40}$$

which indicate that the electric field for the zero-thickness case is pulled into the region between the conductors.

The quantities r_A and r_B now satisfy the common equation.

$$-\pi b/2h \approx (1-\delta/2)(1-r) + \ln r. \tag{41}$$

If r' is a root of (30) and r is a root of (41), then

$$r \approx r'(1 + \delta/2). \tag{42}$$

Relations (32) and (34) indicate that Z_0 does not change while P_Q/P changes slightly to a first order.

A calculation of conductor losses using (5) and (15) yields

$$\alpha_{c1} \approx \frac{\eta}{2h}\left(\frac{\epsilon}{\mu}\right)^{1/2} \frac{1 + \pi b/2h}{1 + \pi b/2h + \ln(1 + \pi b/2h)},$$
$$\alpha_{c2} \approx \frac{\eta}{2h}\left(\frac{\epsilon}{\mu}\right)^{1/2} \frac{\pi + 1 + \pi b/2h - 2\ln \delta/4}{1 + \pi b/2h + \ln(1 + \pi b/2h)}. \tag{43}$$

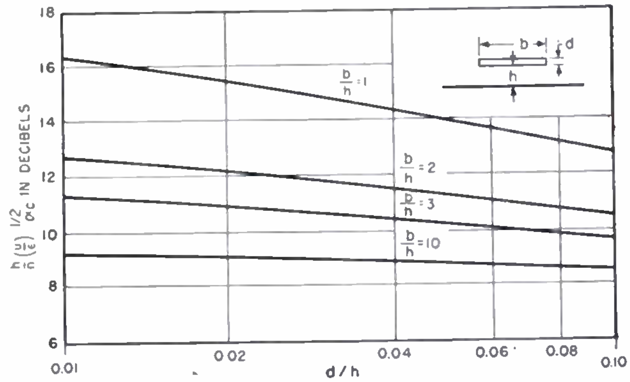

Fig. 7—Conductor attenuation for a wide strip of small thickness above an infinite ground plane.

$$\alpha_c = 8.6859 \frac{\eta}{h}\left(\frac{\epsilon}{\mu}\right)^{1/2} \frac{1 + \frac{\pi b}{2h} + \frac{\pi}{2} + \ln\frac{4}{8}}{1 + \frac{\pi b}{2h} + \ln\left(1 + \frac{\pi b}{2h}\right)} \text{ in db/unit length.}$$

$$\eta \equiv \left(\frac{\pi\mu f}{\sigma_c}\right)^{1/2}, \delta = p - 1. \quad p = -1 + 2\beta^2 + 2\beta(\beta^2-1)^{1/2}.$$

$$\beta = 1 + d/h.$$

Fig. 7 shows plots of $\alpha_c = \alpha_{c1} + \alpha_{c2}$ against d/h for various values of b/h. For copper conductors, polystyrene dielectric, and a frequency of 5,000 mc, the value of $\eta(\epsilon/\mu)^{1/2}$ is 7.80×10^{-5}.

As a numerical illustration, consider a laboratory setup consisting of a strip of width 0.110 inch, height 0.032 inch, thickness 0.001 inch, copper conductors, polystyrene dielectric, and a frequency of 5,000 mc. Calculations yield

$$r_A \approx 2.30 \times 10^{-3}, \quad r_B \approx 10.92, \quad Z_0 \approx 45.0 \text{ ohms},$$
$$\alpha_{c1} \approx 0.10 \text{ db/ft}, \quad \alpha_{c2} \approx 0.20 \text{ db/ft}, \quad \alpha_d = 0.09 \text{ db/ft},$$
$$\alpha = \alpha_c + \alpha_d = 0.39 \text{ db/ft}.$$

The use of (34) for $P_Q/P = 0.75$ and 0.90 gives rise to the regions shown in Fig. 8. These regions indicate the approximate distribution of power flow in the TEM mode for the present case. As mentioned previously, the 100-per cent region should rigorously be infinite, but is not because of the approximateness of the mapping used to derive Fig. 8.

7. Wide Strip Above Finite Ground, Zero Thicknesses

The present section differs from Section 5 in that the ground conductor is now assumed to have a finite width $s+d$. The conformal mapping to be used is indicated in Fig. 9 and is given by

$$\pi\tau z/h = -w^2/2 - (1-\tau)w + \tau \ln w - 1/2 + \tau, \quad (44)$$

where τ satisfies

$$\pi s/2h = \ln \tau + \tau/2 - 1/2\tau, \quad \tau \geq 1. \quad (45)$$

The region of the w plane that is used for final calculations corresponds to $r_A \leq r \leq r_B$.

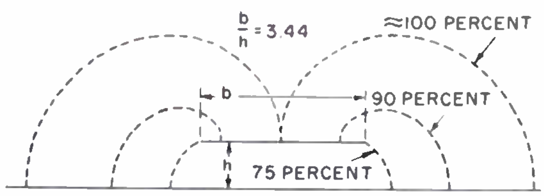

Fig. 8—Distribution of power flow for a wide strip of zero thickness above an infinite ground plane.

The expressions for $F(w)$, $E(w)$, Z_0, and P_Q/P are the same as in the two preceding sections. For $E(z)$ one now has

$$E(z) = jE_0\tau/(w+1)(w-\tau). \quad (46)$$

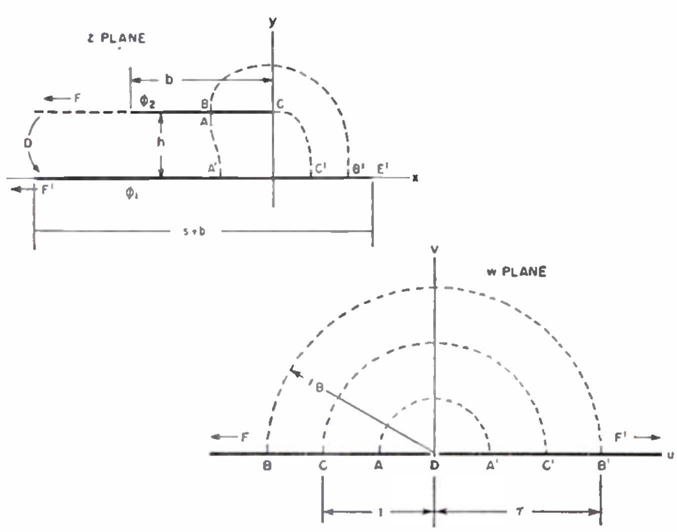

Fig. 9—Conformal mapping for a wide strip of zero thickness above a finite ground plane.

The equipotential and flux lines are given by

$$-\pi\tau x/h = (r^2/2)\cos 2\theta + (1-\tau)r\cos\theta - \tau \ln r + 1/2 - \tau$$

$$-\pi\tau y/h = (r^2/2)\sin 2\theta + (1-\tau)r\sin\theta - \tau\theta. \quad (47)$$

Both r_A and r_B satisfy

$$\pi\tau b/2h = 1/2 - \tau + r^2/2 + (\tau - 1)r - \tau \ln r, \quad (48)$$

where τ is first found from (45).

The magnitude of $E(z)$ along the conductors ($\theta = 0$ or π) is

$$|E(z)| = E_0\tau/|\pm r - 1||\pm r - \tau|. \quad (49)$$

The effect of finite s on Z_0/Z_0' and P_C/P, where the latter is determined from flux lines starting at A, B, and the strip edges, is shown graphically in Fig. 10. Curves are given for $s=0$ and $s=\infty$. Corresponding curves for nonzero finite s are not shown but fall between those for $s=0$ and ∞. Fig. 10 indicates that there is not much change in Z_0/Z_0' and P_C/P as s is varied from 0 to ∞. Change is negligible for s greater than $2b$.

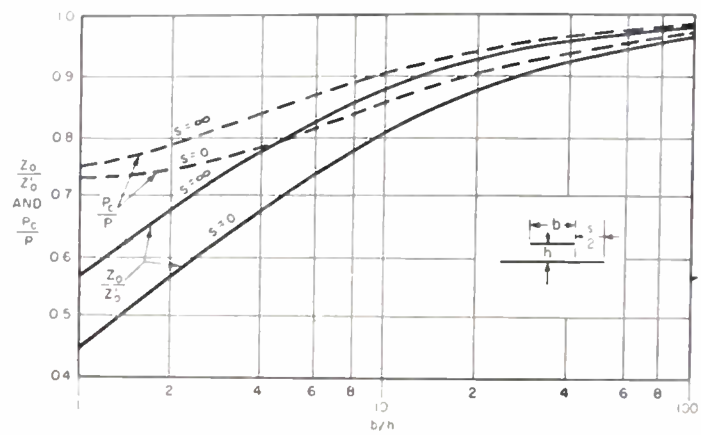

Fig. 10—Characteristic impedance and power flow for a wide strip of zero thickness above a finite ground plane. Z_0/Z_0' is the solid line, P_c/P is the broken line, and

$$Z_0' = \frac{b}{h}\left(\frac{\mu}{\epsilon}\right)^{1/2}.$$

8. Narrow Strip of Zero Thickness above Infinite Ground

It is now assumed that $b \ll h$. The present case is treated by applying limiting considerations to Fig. 11. The two mappings that are used are given by

$$z = t/2 + B^2/2t, \quad t/j = A(1+w)/(1-w) - H, \quad (50)$$

where

$$B = b/2, \quad H = 2h, \quad \text{and} \quad A^2 = H^2 - B^2.$$

The $t \rightarrow z$ mapping transforms the configuration for wire above ground into that for a strip of zero thickness above a curved ground plane. The $t \rightarrow w$ mapping converts the first configuration into a coaxial system. One sees from (50) that the minimum and maximum vertical distances between strip and ground are

$$h(1 - b^2/16h^2) \quad \text{and} \quad h.$$

If now b/h is made small, the ground conductor becomes straight.

The point $t = j(A - H)$ goes into $w = 0$ and the circle $|t| = B$ goes into the circle $|w| = R$ with

$$R = (H - A)/B = B/(H + A). \quad (51)$$

The points C or D in the z or t plane go into corresponding points in the w plane with

$$w_D = R\exp(j\theta_1),\quad w_C = R\exp(-j\theta_1),\quad \tan\theta_1 = A/B. \tag{52}$$

By writing $w=\rho\exp(j\theta)$, one sees that the equipotential and flux lines are given by

$$x = -A\rho(\sin\theta)(A_1+B_1)$$

$$y = \frac{-B^2-(A+H)^2\rho^2+2H\rho(A+H)\cos\theta}{2(A+H)}(A_1-B_1), \tag{53}$$

where A_1 and B_1 are defined by

$$A_1 = \frac{1}{1+\rho^2-2\rho\cos\theta},$$

$$B_1 = \frac{B^2(A+H)^2}{B^4+\rho^2(A+H)^4-2B^2\rho(A+H)^2\cos\theta}. \tag{54}$$

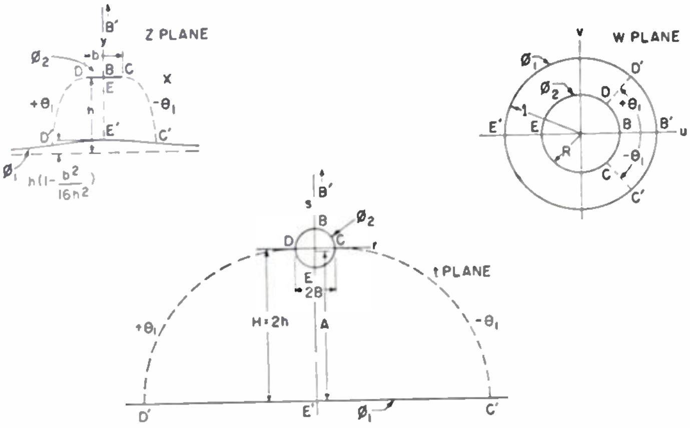

Fig. 11—Conformal mapping for a narrow strip above an infinite ground.

The flux line from point D leaves horizontally and meets the ground conductor at the point D' for which

$$x_{D'} = -\frac{(H+B)(H^2+HB+B^2)}{2H^2+2BH+B^2},$$

$$y_{D'} = -\frac{H^2(H+B)}{2H^2+2BH+B^2}. \tag{55}$$

For narrow strips, $H \gg B$ and (55) reduces to

$$x_{D'} \approx -H/2,\qquad y_{D'} \approx -H/2. \tag{56}$$

Since the characteristic impedance Z_0 is invariant under conformal mappings, one has

$$Z_0 = \frac{1}{2\pi}\left(\frac{\mu}{\epsilon}\right)^{1/2}\cosh^{-1}\left(\frac{H}{B}\right) \approx \frac{b}{2\pi h}Z_0'\ln\frac{8h}{b}, \tag{57}$$

where Z_0' corresponds to a uniform field between parallel conductors of width b and separation h. This result has been published[6] in terms of capacitance.

The terminations of flux lines on the ground conductor are given by

$$x \approx -H\cot\theta/2,\qquad y \approx -H/2. \tag{58}$$

The fraction of power flow bounded by flux lines corresponding to $\pm\theta_1$ is given by $k=(\pi-\theta_1)/\pi$ as in Section 4.

Flux lines leaving the strip edges have ground terminations at $x \approx -H/2$ and, since $\theta \approx -\pi/2$ in this case, bound 50 per cent of the power flow. For $k=0.75$, θ is $\pm\pi/4$ and the bounding flux lines have ground terminations at $x \approx \pm 4.8\, h$. Finally, for $k=0.90$, one obtains $\theta = \pm 0.1\pi$ and $x \approx \pm 12.6h$.

9. Conclusions

In the case of a wire above an infinitely wide ground conductor, all results are exact except those for conductor and dielectric losses.

Calculations for a wide strip of zero thickness above an infinitely wide plane conductor reveal that the characteristic impedance and distribution of power flow differ to a first order from those that a uniform field would yield. The introduction of a small strip thickness or a finite ground width (conductor widths large compared to their spacing) alters these results slightly. If the ground width is greater than three times the strip width, it may be considered to be infinite. The introduction of a small strip thickness permits the calculation of both conductor losses. The case of a narrow strip of zero thickness above an infinitely wide plane conductor is also considered.

The above results are not rigorous but remain useful for transmission systems that are imbedded in a solid dielectric of finite height. Numerical calculations indicate that many of the transmission systems discussed in this paper do not have excessive losses, have reasonable characteristic impedances and most of their power flow confined to the region between the conductors. They appear to be feasible at microwave frequencies.

[6] F. E. Terman, "Radio Engineers' Handbook," McGraw-Hill Book Co., Inc., New York N. Y., p. 113; 1943.

Microstrip Components*

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Summary—**Broad-band microwave components of many and varied types may be realized in microstrip construction. Complete radio-frequency systems in line-above-ground design are shown to be entirely feasible and offer significant advances in economy, size, and weight.**

Introduction

Heretofore RF components in the microwave region have been limited to the metallically enclosed waveguide type of transmission line. Open systems such as lecher wires, dielectric-rod guides, parallel plane, and G lines have been limited to just a few special applications.

Studies were initiated to develop a new type of microwave transmission line that would be expressly adaptable to development of wide-band communication-power-level components at a reasonable cost.

Microstrip successfully employs an open system consisting of two parallel conductors, one as a line and the other as a ground plane.

The preceding papers[1,2] of this series have presented a general descriptive and comparative viewpoint stressing the fundamental simplicity of design and ease of construction as well as offering a first-order theoretical analysis of the transmission properties of these lines.

This paper concludes the series with corroborative experimental data obtained prior to and during the development of microwave components.

1. Electrical Characteristics

A. Geometry of the Transmission System

Three types of lines have been examined in some detail. They are:

1. Cylindrical conductor suspended above a ground plane (wire-above-ground).
2. Narrow ribbon conductor separated from the ground plane by a dielectric material (strip line).
3. Similar to 2 but with the strip immersed in the dielectric (dielectric-sandwich line).

On the basis of simple skin-depth considerations, printed circuit techniques may be used to produce a conducting ribbon of sufficient thickness. Transverse and longitudinal cross sections of these types appear in Fig. 1.

The ground conductor is a sheet of high-conductivity metal such as copper, silver, or aluminum. In wire lines, the line conductor is a cylinder that may be completely or partially immersed in a dielectric. If the dielectric is solid and is in contact with the ground plane and the wire, the preservation of proper spacing is assured. When air spacing is required, bead supports may be used.

In the case of strip lines, the line conductor is a thin narrow ribbon of metal either cut from sheet or deposited. Conductor thicknesses of approximately 1 to 5 mils have proved to be adequate.

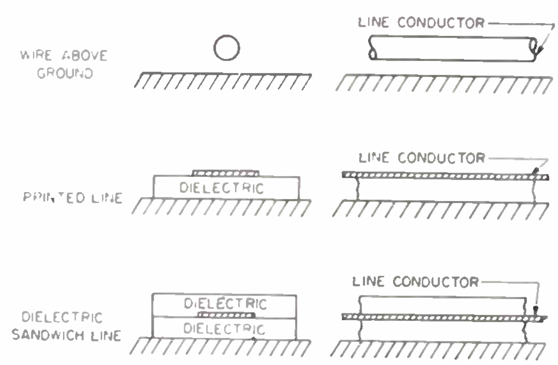

Fig. 1—Open transmission lines of the microstrip type.

The dielectric, which is used as a separating medium between the ground plane and the ribbon or strip, should have fairly flat surfaces; otherwise, the homogeneity of the dielectric may be upset by inclusion of air pockets. Slight irregularities are not too serious as regards power transfer. However, in making vswr measurements, erratic readings are directly traceable to such a condition and it becomes rather difficult to obtain extremely good correlation in phase-wavelength measurements, for example, over a wide frequency band because, in general, the voltage minima positions change with frequency.

The dielectrics actually used have been polystyrene and laminated phenolic plastics (Dilecto XXXP-22). Fibrous sheet materials impregnated with a thermosetting resin (Synthane GLF and others) have had limited use because of excessive attenuation.

B. Measuring Instruments

The fundamental piece of microwave test equipment is the standing-wave detector. Two different models were made for this work, the slot type and the overhead type.

The slot type consists of an accurately ground plate with a narrow longitudinal slot to receive an exploring coaxial probe. The plate serves as the ground plane for wire and strip lines. In use, it is assumed that the slot does not appreciably alter the external RF field structure nor does it much influence the impedance or phase

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[1] D. D. Grieg and H. Engelmann, "Microstrip—a new transmission technique for the kilomegacycle range," Proc. I.R.E., vol. 40, pp. 1644–1650; December, 1952.

[2] F. Assadourian and E. Rimai, "Simplified Theory of Microstrip Transmission Systems," Proc. I.R.E., vol. 40, pp. 1651–1657; December, 1952.

avelength of the line. To a first order, this is undoubtedly true provided the ratio of slot width to line-conductor width is small.

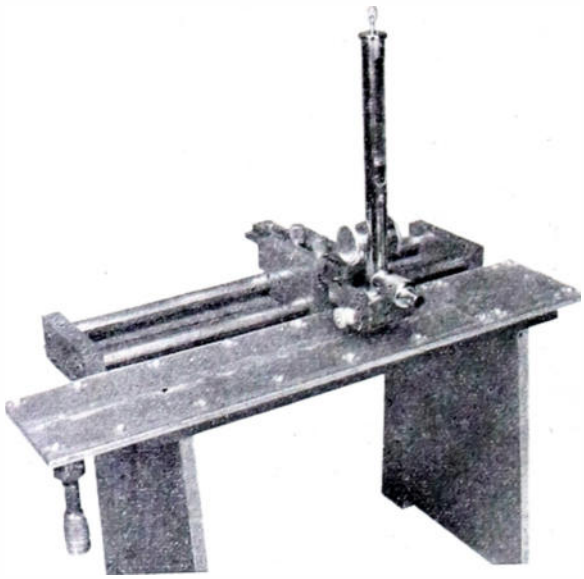

Fig. 2—Overhead type of standing-wave detector.

Fig. 2 shows the overhead type of detector used in conjunction with a dielectric-sandwich test line. The probe is accurately positioned in air in the vicinity of the line conductor, the line section under test being provided with its own ground plane. An advantage of this type of instrument is that the ground plane is not mutilated in the least.

Both types of instruments were used for phase-wavelength studies and impedance measurements. Precise comparative data have not been taken. In connection with relative advantages or disadvantages of one type over the other, it should be mentioned that queer effects have been observed when the slot is not symmetrically disposed with reference to the line conductor. Air pockets in strip lines, presumably unsymmetrically disposed to the slot, may cause radiation out of the slot. In attenuator designs, it was observed that dissymmetry above a slot may cause leakage or radiation, whereas the same type of dissymmetry over a solid ground plane may not necessarily produce such effects.

C. Phase Wavelength

In the theory paper,[2] TEM propagation is assumed in which case low-frequency approximations are admissible. A basic prerequisite for such realizability is that the dielectric in which the conductor is imbedded be completely homogeneous.[3] The printed and dielectric-sandwich lines are obviously nonhomogeneous and, therefore, must depart from TEM behavior.

A practical complication is introduced by the fact that in a composite-dielectric case, very little is known about the value to be assigned to the "equivalent" dielectric constant. Consequently, experimental procedures were resorted to in evaluating the phase wavelength (or guide wavelength) of these lines as a function of operating frequency, line-conductor width, dielectric constant, and the separation between line and ground conductors.

[3] S. Ramo and J. R. Whinnery, "Fields and Waves in Modern Radio," John Wiley and Sons, Inc., New York, N. Y., p. 353; 1944.

Fig. 3 shows the variation of λ_g for some printed lines over the 4400-to-5000-mc band.

Comparison of the curves yields the following information:

1. For an air-dielectric wire-above-ground line, $\lambda_g = \lambda_0$.
2. For a given width of line conductor, λ_g decreases as the thickness of the dielectric increases.
3. For a given thickness of dielectric, λ_g decreases as the width of the line conductor increases.
4. For a given thickness of dielectric and line-conductor width, λ_g decreases as the dielectric constant of the material increases.
5. The ratio of λ_0/λ_g is not equal to $\epsilon^{1/2}$, where ϵ is the value of the dielectric constant of the dielectric layer (measured either at low or high frequency).

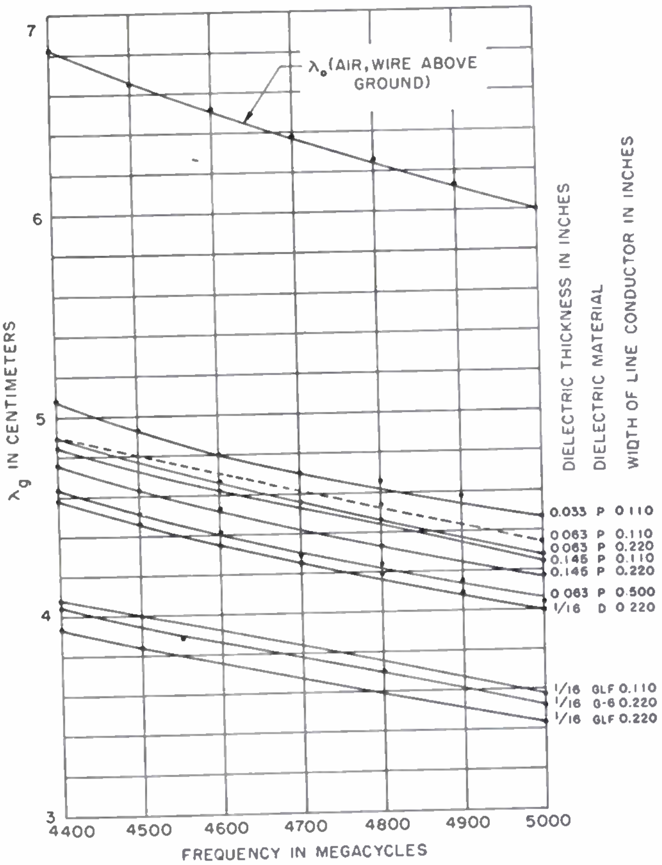

Fig. 3—Wavelength of the propagation along a printed line (phase wavelength) plotted against frequency. The upper curve is for a wire above ground plane in air and corresponds to λ_0. The dielectrics are polystyrene = P, XXXP22 Dielecto = D, G-6 Formica = G6, and Synthane = GLF.

The printed line then departs from pure TEM behavior. But to what extent? A rough comparison may be made on the basis of per cent departure of observed λ_g to the theoretical norm or ideal, λ_{TEM}. In the case of an infinite-extent polystyrene dielectric, the phase wavelength, λ_g, for TEM transmission would be as shown in the TEM curve of Fig. 4. This curve, serving as the norm for the 4400-to-5000-mc band, holds irrespective of the conductor geometry. On this basis, the printed-line characteristic is 14 per cent off.

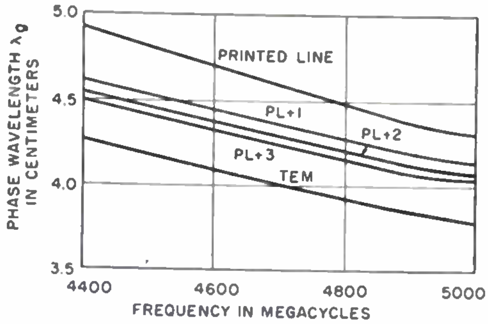

Fig. 4—Phase wavelength plotted against frequency for polystyrene printed lines having a strip conductor 0.220-inch wide and a dielectric spacing of 0.063 inch. The computed equivalent dielectric constants $(\lambda_0/\lambda_g)^2$ are $\epsilon(PL)\approx 1.97$, $\epsilon(PL+1)\approx 2.16$, $\epsilon(PL+2)\approx 2.21$, and $\epsilon(PL+3)\approx 2.25$.

From other sources,[4] if a composite-dielectric coaxial line may be used for pattern-behavior predictions for the printed line, it would appear that as the composite-dielectric region is filled more and more with dielectric, the ratio of $(\lambda_c/\lambda_g)^2$ should approach an ϵ value determined by the dielectric layer only, i.e., the wave structure should approximate TEM behavior closer and closer. This tendency was verified by observations on the dielectric-sandwich type of line. Again referring to Fig. 4, the curve marked (PL+3) shows 6-per cent departure from TEM behavior. (PL+3 means the original printed line plus 3 layers of polystyrene on top to form a dielectric-sandwich line.)

Identical conclusions are reached on the basis of an equivalent dielectric constant for a composite-dielectric line. If ϵ (equivalent) is defined as $(\lambda_0/\lambda_g)^2$, Fig. 4 shows that it increases with increasing over-lying layers of dielectric and presumably would eventually approach ϵ (polystyrene), a value of 2.55.

D. Dispersion

An item of interest is dispersion,[5] a measure of frequency-rate-of-change of (λ_0/λ_g) for printed and dielectric-sandwich lines. To this end, a series of measurements were made over a 5-to-1 frequency range for strips having widths of 0.110, 0.220, and $\frac{1}{2}$ inch. One set of curves is shown in Fig. 5. For all practical purposes, the variation may be considered a constant to a first order over a band of frequencies extending from 2000 to 10,000 mc.

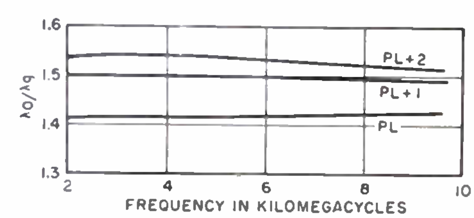

Fig. 5—Phase wavelength plotted against frequency for a strip line having a conductor 0.220-inch wide and polystyrene spacing of 0.063 inch.

E. RF Impedance

Another item of importance is the relative RF impedance of a section of line, especially for construction of hybrids, tees, and the like. No means has as yet been devised to measure this quantity directly. Indirect methods,[6] which are used in evaluating sharply defined discontinuities, may lead to profitable results. Preliminary attempts have not led to reliable data, however.

So far for printed lines, the relative RF impedance has been assumed to be inversely proportional to line-conductor width. Hybrid rings have been successfully fashioned, but observations are limited to a conductor-width range from 0.110 to 0.220 inch. The behavior for other widths cannot be predicted with certainty.

In the case of a wire-above-ground line completely imbedded in air, RF component designs based on the characteristic-impedance formula given by electrostatic considerations have proved successful, although observations are limited to 50-to-70-ohm line sections with $\frac{1}{8}$- and $\frac{1}{16}$-inch line conductors.

In connection with Fig. 5, a word might be added about the absolute characteristic impedance of strip lines at radio frequencies. As is well known, the quantity λ_g/λ_0 plays an important part in determining Z_0, the characteristic impedance. Since (λ_0/λ_g) versus frequency is a constant (over the band shown), then Z_0 may be expressed as some constant divided by C, where C is the capacitance per unit length. It yet remains to be definitely established that C remains invariant as a function of frequency. Therefore, the characteristic impedance evaluated at low frequency and by low-frequency techniques may be held in question at high frequency.

F. Attenuation versus Width of Ground Plane

To study the effects of width of ground plane, a 50-ohm, $\frac{1}{8}$-inch wire-above-ground air line with brass conductors was selected. Since the attenuation of a 12-inch length of line could not be measured with any degree of accuracy at 4700 mc, only the per cent change in transmitted power was recorded as a function of width of ground plane. The transmitted power increased by approximately $2\frac{1}{2}$ per cent when the width of ground plane was changed from 2 to 5 times the line-conductor diameter.

[4] J. A. Kostriza, "The Composite Coaxial Line," Master's Thesis, Brooklyn Polytechnic Institute, Brooklyn, N. Y.; 1949.
[5] L. Page, "Introduction to Theoretical Physics," D. Van Nostrand Co., Inc., New York, N. Y., 2nd ed., p. 250; 1935.
[6] N. Marcuvitz, "Representation and measurement of waveguide discontinuities," PROC. I.R.E., vol. 36, pp. 728–735; June, 1948.

G. Summary

At this point the highlights may be summarized.

1. Air-dielectric wire-above-ground type of line operates essentially in the TEM mode.
2. Strip and dielectric-sandwich lines for some applications may be approximated to TEM behavior.
3. The width of the ground plane required is not excessive.

2. RF Components

The components to be discussed have been developed for communication power levels in the 5000-mc region. Transitions to coaxial line, crystal holders, loads and pads, directional couplers, and hybrid structures are practical in wire, printed, and dielectric-sandwich types of line. Only representative structures are presented, since space does not permit illustration of each type. It should be noted that the results presented are not necessarily the optimum that may be realized.

A. Transitions to $\frac{3}{8}$-Inch 50-Ohm Coaxial Line

Wide-band transitions have been designed to operate in the 4400-to-5000-mc band from $\frac{3}{8}$-inch coaxial line to wire, printed, and sandwich lines.

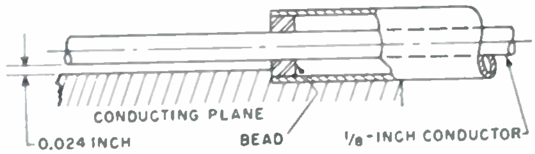

Fig. 6—Straight-through transition for a wire-above-ground and a coaxial line.

Fig. 6 shows a straight-through transition from a 50-ohm wire line. When the coaxial line is terminated in a matched load, the input vswr on the wire system is less than 1.5 over the band, the average value being about 1.2. Preliminary measurements indicate that the discontinuity susceptance at the junction of the two lines is essentially inductive and that transmission-line matching techniques may be used. The dielectric bead at the junction of the two lines is used as a rigid support and as a matching element.

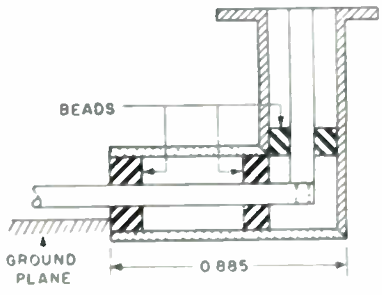

Fig 7—Right-angle transition for a wire-above-ground and a coaxial structure.

A second type of transition from wire to coaxial is shown in Fig. 7. In this unit, the coaxial line forms a right angle with the wire line. This transition has a worst vswr of 1.33 over the complete band, being poorer than the previously described unit in comparison with 1.5 for the previously described unit.

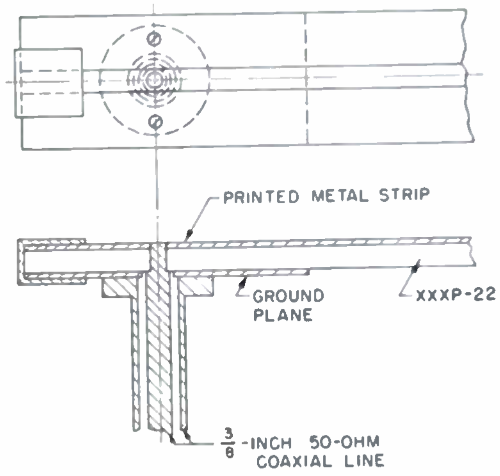

Fig. 8—Transition for a printed line and a coaxial line.

Two types of transitions have been developed for printed lines, both using XXXP-22 material as the dielectric.

The first type, which contains an integral dc return path between the line and ground conductor, is shown in Fig. 8. This unit was developed for narrow-band applications and has not been checked over a wider band than required. From 4750 to 5000 mc, the measured vswr is less than 1.2.

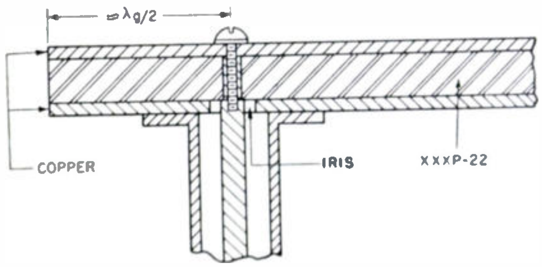

Fig. 9—Transition for a printed line and a coaxial line.

A second type, shown in Fig. 9, was tested over the total band. The two types differ in the manner in which the short section of printed line is terminated past the junction of the printed line and the coaxial line. In this case, the printed line is open-circuited. The $\frac{1}{2}\lambda_g$ termination and iris dimensions in the ground plane are the broad-banding elements. For a 0.220-inch-wide strip, the vswr is less than 1.20 over the band. Similar constructions are used and similar results are realized for polystyrene printed-type transitions.

A transition to a polystyrene sandwich line is shown in Fig. 10. This unit varies its vswr from 1.08 to 1.35 at the band edges.

B. Attenuator Pads and Loads

Specific designs are given for wire-above-ground applications to pads and loads because observations were made over a wide band of frequencies for only this type. Printed-line pads and loads have been made, but observations are limited to spot frequencies and will therefore not be included.

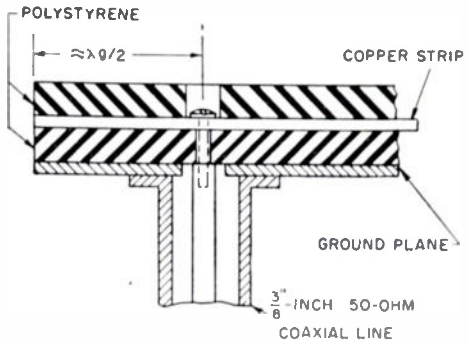

Fig. 10—Transition for a sandwich line and a coaxial line.

The dielectric used as the lossy medium is Synthane L-564, which is obtainable in a wide variety of sheet thicknesses.

A transverse cross-sectional view of a variable attenuator is shown in Fig. 11. Synthane L-564 standard sheet thicknesses of $\frac{1}{16}$, $\frac{1}{8}$, and $\frac{1}{4}$ inch were found adaptable. The flap-type attenuator depicted may be made variable by controlling the dimension h. For unit longitudinal length, maximum attenuation is a function of t, w, W, and θ, when $h=0$. Increasing the longitudinal length of the sheet increases the attenuation.

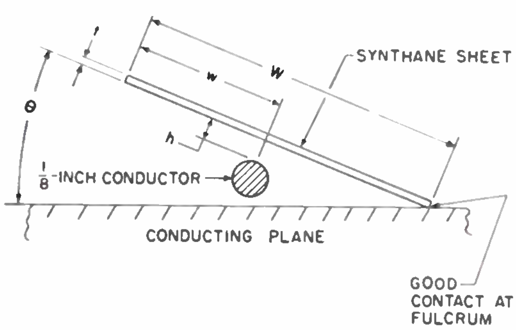

Fig. 11—Variable attenuator for a wire-above-ground transmission line.

In general, this type of attenuator may have a tendency to radiate out of the open end of the triangle, radiation decreasing with decreasing angle θ. A shield may be used to minimize the effect on neighboring circuits.

Increasing the longitudinal length of attenuators will naturally produce matched loads. For strip lines, a much easier method of fashioning a load is simply to taper the leading edge of a thin sheet of Synthane. This is such an obvious solution that sketches are entirely extraneous.

C. Crystal Mounts

Wide-band crystal mounts have been designed for wire-above-ground, printed, and sandwich-type lines.

A crystal holder or mount for wire-above-ground was designed to operate over the 4400-to-5000-mc band with an input vswr of less than 2, using Sylvania 1N21-B crystals. The operating conditions are a 50-to-100-ohm load resistance and a rectified current of $\frac{1}{2}$ ma. A longitudinal cross section of the unit is shown in Fig. 12. The dc return path must be provided in the RF circuit external to the crystal mount.

A right-angle unit, similar to Fig. 7 in external appearance only, has a frequency characteristic similar to that of the mount shown in Fig. 12.

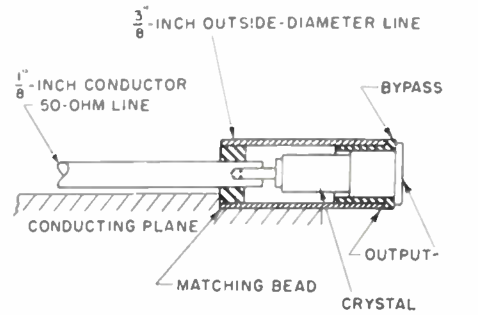

Fig. 12—Wide-band fixed-tuned crystal mount for a wire-above-ground transmission line.

Fig. 13 illustrates a longitudinal section of a crystal mount in a 0.220-inch dielectric-sandwich line. As in transitions, $\frac{1}{2}\lambda_g$ terminations and iris dimensions are useful broad-banding elements. The vswr is less than 1.5 over the complete band for a dozen somewhat-selected 1N23-B crystals. This is a fixed-tuned unit.

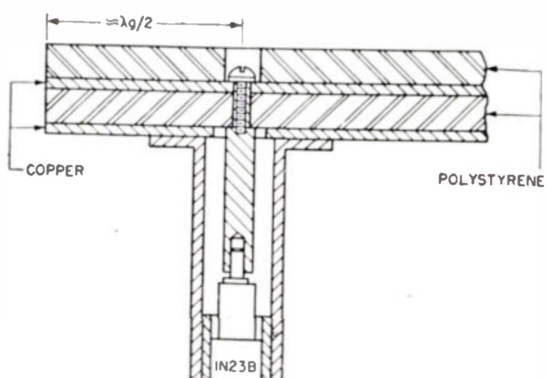

Fig. 13—Crystal mount for a dielectric-sandwich line.

D. Directional Couplers

Two basic types of directional couplers have been examined to a limited extent, specifically, a two-probe and a long-slot equivalent. Work on directional couplers has been limited to establishing feasibility of use of structures only and not to optimizing directivity or design for a particular value of attenuation.

1. *Two-Probe Type.* Very briefly, a two-probe coupler is an arrangement whereby two probes, when similarly point coupled into a transmission line but separated by some fraction of a wavelength, are further so interconnected that the resultant destructive wave interfer-

nce in the probe lines results in directional properties.[7]

The plane view of a quarter-wave double-probe directional coupler is shown in Fig. 14. It is a forward-coupling type. With the dimension X set for maximum directivity at 4700 mc, crystal current A was substantially zero from 4400 to 4800 mc, indicating a substantial value of directivity.

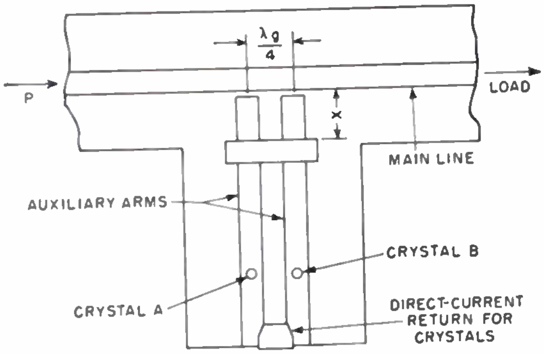

Fig. 14—Two-probe type of directional coupler.

2. *Long-Slot Type.* A long-slot coupler is formed when two transmission lines are coupled uniformly along their longitudinal dimension, either by a rather long slot (as a waveguide) or by leakage or mutual coupling. Theoretically, a half-wave uniformly coupled line should display directional properties. This was verified on a wire-above-ground line and on a polystyrene printed line.

The half-wave coupler was extended to a length approximately 6 wavelengths, a long-line coupler. A polystyrene printed-line was used. When tested over the entire band (4400 to 5000 mc) the lowest directivity observed was 6 db, the highest directivity being of the order of 10 db.

E. *Hybrid Ring Structures*

Fig. 15 illustrates the comparative simplicity of wire- and strip-type construction of ring circuits of the parallel-connection type.[8]

Coaxial-line design techniques have been successful, as regards quarter-wave spacings and ratios of arm and ring impedances. Note the narrower width of ring strip in comparison with the side arms.

In the wire case, with the ring terminated in crystal mounts and load as in a balanced mixer, the crystal response was strikingly close as the frequency was varied over the band. Strip units have not been checked over the complete band. Some at center design frequencies gave vswr of the order of 1.05 to 1.10.

F. *Shunt-T Junction*

Junctions with three arms in which the branching takes place in the H plane is termed an H-plane T

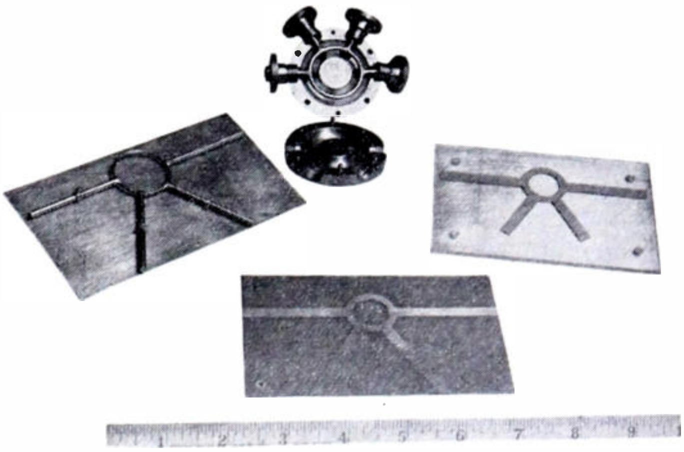

Fig. 15—The familiar rat race in wire-above-ground and strip forms compared with the coaxial type.

junction. At low frequencies, the junction is a shunt junction.

Fig. 16 illustrates a right-angle type of power divider. When power is fed into A or B, with the other arms terminated, it was found that both arms received power though, in general, not in equal amounts. This division of power can be controlled for a given thickness t of the auxiliary ground plane by varying the opening radius R.

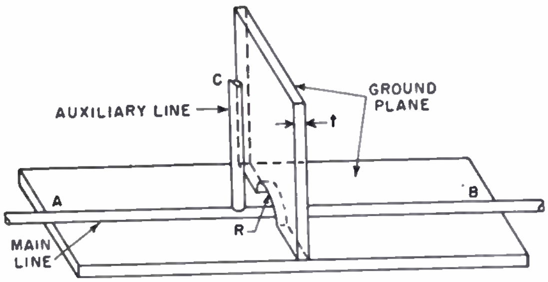

Fig. 16—Power divider.

When R was adjusted for approximately equal power split between B and C or A and C, a movable short-circuit on B could be so positioned that the power in C was either a maximum or very nearly zero. For the condition of (almost) zero power transfer into arm C, an impedance measurement in the two sections, A-to-junction and junction-to-B, gave an almost coincident short circuit at the junction, indicating that the junction is an equivalent shunt-T junction. The measurement was performed at 4700 mc. The location of actual planes for the equivalent circuit has not been attempted nor has the frequency sensitivity of the structure been examined.

3. Acknowledgment

Appreciation is expressed to H. Seidel for his work on directional couplers and to P. Terranova for the exhaustive experimental work entailed.

[7] C. G. Montgomery, "Technique of Microwave Measurements," McGraw-Hill Book Co., Inc., New York, N. Y., Chap. 14; 1947.

[8] W. A. Tyrrell, "Hybrid circuits for microwaves," Proc. I.R.E., vol. 35, pp. 1294–1306; November, 1947.

A Telemetering System for a Large Electrostatic Accelerator*

C. W. JOHNSTONE†, SENIOR MEMBER, IRE, J. F. KALBACH‡, SENIOR MEMBER, IRE, AND H. J. LANG†, ASSOCIATE, IRE

This paper is published with the approval of the IRE Professional Group on Radio Telemetry and Remote Control.—*The Editor*

Summary—**A telemetering system is described for controlling and monitoring the ion source, focusing, and belt charging in the high-voltage electrode of the large dc electrostatic accelerator nearing completion at Los Alamos. Time-modulated pulsed light beams are the transmission media from grounded electrode to high-voltage electrode and provide 16 independent channels.**

ONE OF THE PROBLEMS associated with the operation of an electrostatic accelerator of the Van de Graaff type is that of controlling and monitoring the ion source, focusing electrodes, and the down-run belt charging power supply located in the high-voltage electrode. Obviously, the use of isolating transformer circuits becomes impractical when the high-voltage electrode is to operate at millions of volts dc with respect to ground.

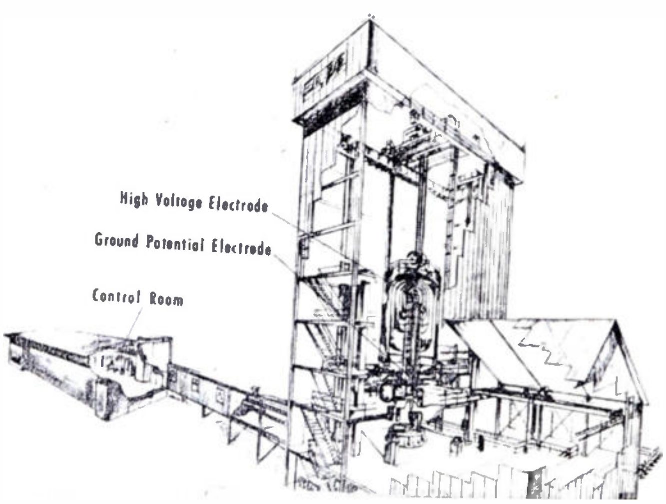

Fig. 1—Cut-away Sketch of 12-mev Van de Graaff installation at Los Alamos.

A common solution which has been used on a number of electrostatic accelerators is to provide control strings or rods made of insulating material between the high-voltage electrode and ground. These may be moved by hand or through a Selsyn system to actuate rheostats, variacs, or mechanical screw adjustments located in the high-voltage head. The number of control strings or rods can be reduced to two by using one to select a function and the other to control the selected function. The controlled voltages, currents, and mechanical movements are then usually monitored through a telescope focused upon the desired instruments in the high-voltage electrode.

One difficulty with such a simple system for high-voltage accelerators is that of placing the telescope where the operator can see the instruments in the electrode, and still permit the operator to be adequately shielded from radiation produced by the machine or an experimental target. Another difficulty arises in controlling more than one function at a time or controlling a function very quickly. Consequently, in the planning of a 12-mev[1] electrostatic accelerator at Los Alamos, N. M.,

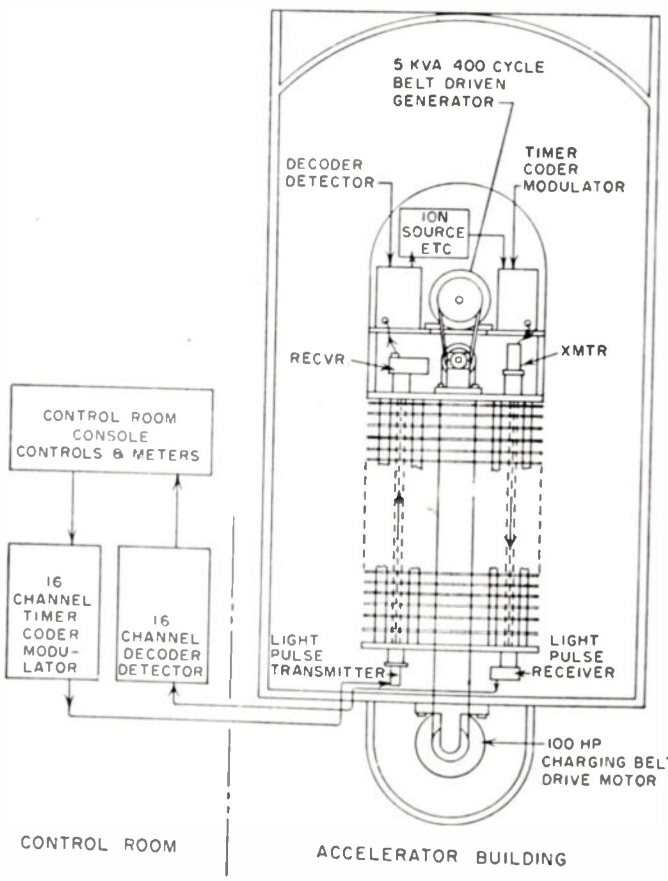

Fig. 2—General arrangement for telemetering of 12-mev Van de Graaff.

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† University of California, Los Alamos Scientific Laboratory, Los Alamos, N. M.

‡ William Miller Corp., 325 N. Halstead Ave., Pasadena 8, Calif.

[1] This machine is called a 12-mev accelerator because its general design does not preclude eventual attainment of such a potential difference. However, accelerating tube breakdown has limited maximum operating voltage to 5 mev.

t appeared desirable to develop a telemetering system which would permit rapid and continuous control and monitoring of all desired currents, voltages, and mechanical positions from a control desk located in a safe remote location. See Fig. 1.

After investigating the use of radio, light, and ultrasonic communication links between the high-voltage electrode and ground, a modulated light beam was selected and developed for the purpose.

Fig. 2 illustrates the use of the two light-beam links for both control and monitoring. In most respects, the link from the control room to the high-voltage electrode is similar to the return link, so one description will suffice for both links.

The transmitting end of each link contains a timer, a coder, and 16 modulated delay circuits, or channels. As indicated in Fig. 2, input signals are supplied to the 16 channels, which control a series of time-modulated pulses. These, together with four double-pulse codes, are transmitted as intensity modulation over a light beam. The phototube receiver reconverts the light-beam pulses into electrical pulses which are then amplified and sorted in a decoder, according to code groups, polarity, and sequence. Finally, the separated signals are demodulated to give output signals corresponding to the 16 input signals.

Fig. 3 is a list of the control and monitoring functions performed by the two light-beam links. The functions of the control link utilize only about half the 16 channels, whereas the monitoring channels are nearly all used, even with the multiplex feature which permits two meter readings to be transmitted on a single channel. As the development of the Van de Graaff machine proceeds, it is expected that fewer functions will need to be controlled and monitored remotely. Thus, the trend should be toward simplicity rather than toward more and more complication.

Figs. 4 through 9 are photographs which show the telemetering system as it is used with the Van de Graaff machine at the present stage of development. (See page 1667 for Fig. 9.)

CONTROL LINK CHANNEL FUNCTIONS

CHANNEL	SIGNAL	FUNCTION
1A	40-	SPARE RELAY
1B	40- OR 400-	CALIBRATE PANEL METERS ZERO OR FULL SCALE
1C	0-C	DOWN RUN SPRAY CONTROL
1D	40- OR 400-	OSCILLATOR PLATE RELAY OR SPARE RELAY
2A	400- OR 40 • 400	RAISE (OR LOWER) ANY OF 4 FUNCTIONS SELECTED BY CHANNEL 2B
2B	NO SIGNAL	POSITIVE PROBE VOLTAGE
	40-	SCREEN VOLTAGE
	4 0-	SPARE
	40• 400-	NEGATIVE PROBE VOLTAGE
2C	400- OR 40• 400	RAISE (OR LOWER) ANY OF 4 FUNCTIONS SELECTED BY CHANNEL 2 D
2D	NO SIGNAL	LEAK HEATER VOLTAGE
	40-	FOCUS VOLTAGE
	400-	SPARE
	40 • 400-	SPARE
3A 3B 3C 3D		4 SPARE CHANNELS
4A 4B 4C 4D		4 SPARE CHANNELS

Fig. 3(a)—Control link channel functions.

CHANNEL	SIGNAL	FUNCTION	CHANNEL	SIGNAL	FUNCTION
1A • 3A	AUDIO	MICROPHONE TO SPEAKER	3A • 1A	AUDIO	SEE CHANNEL 1A
1B	400 -	GENERATOR VOLTAGE MONITOR	3B	0-C	SPARE
1C	0-C	SPARE D C CHANNEL	3C	0-C	SPARE
	40 OR 400-	BELT POSITION INDICATORS	3D	0-C	SPARE
1D - X	0-C	TIME SHARE { POS. PROBE CURRENT	4A	40-	SYNC. SIGNAL FOR TIME SHARING
1D - Y	0-C	LEAK HEATER VOLTAGE	4B - X	0-C	TIME SHARED { SPARE
2A	4 0-	PRIMARY [illegible] NEG. PROBE	4B - Y	0-C	FOCUS ELECTRODE POSITION
2B - X	0-C	TIME SHARED { OSC SCREEN VOLT	4C - X	0-C	TIME SHARED { DOWN RUN SPRAY CURR
2B - Y	0-C	SPARE	4C - Y	0-C	ION SOURCE GAS PRESS.
2C - X	0-C	TIME SHARE { SPARE	4D - X	0-C	TIME SHARED { SPARE
2C - Y	0-C	SPARE	4D - Y	0-C	POS. PROBE VOLT.
2D - X	0-C	TIME SHARE { FOCUS ELECTRODE VOLT			
2D - Y	0-C	NEG. PROBE CURRENT			

Fig. 3(b)—Monitoring link channel functions.

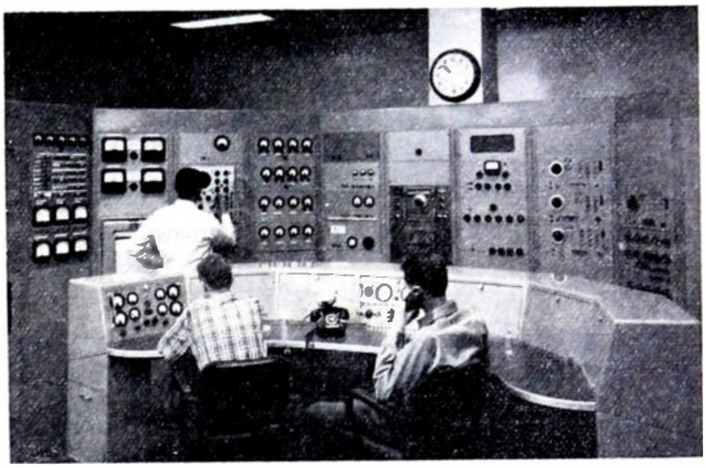

Fig. 4—General view of control room for Los Alamos 12-mev Van de Graaff.

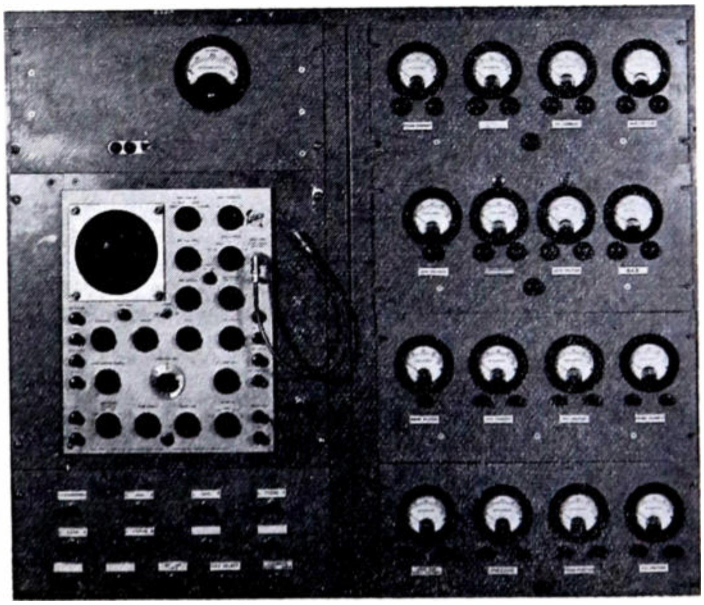

Fig. 5—Close-up view of control-room end of telemetering system.

A Telemetering System for a Large Electrostatic Accelerator*

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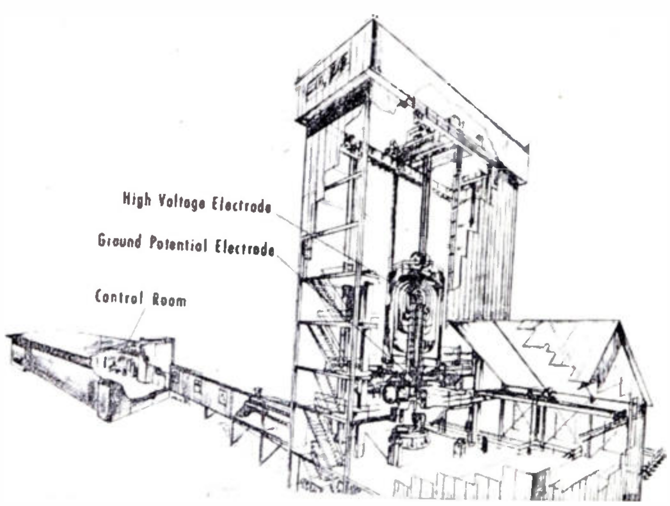

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A common solution which has been used on a number of electrostatic accelerators is to provide control strings or rods made of insulating material between the high-voltage electrode and ground. These may be moved by hand or through a Selsyn system to actuate rheostats, variacs, or mechanical screw adjustments located in the high-voltage head. The number of control strings or rods can be reduced to two by using one to select a function and the other to control the selected function. The controlled voltages, currents, and mechanical movements are then usually monitored through a telescope focused upon the desired instruments in the high-voltage electrode.

One difficulty with such a simple system for high-voltage accelerators is that of placing the telescope where the operator can see the instruments in the electrode, and still permit the operator to be adequately shielded from radiation produced by the machine or an experimental target. Another difficulty arises in controlling more than one function at a time or controlling a function very quickly. Consequently, in the planning of a 12-mev[1] electrostatic accelerator at Los Alamos, N. M.,

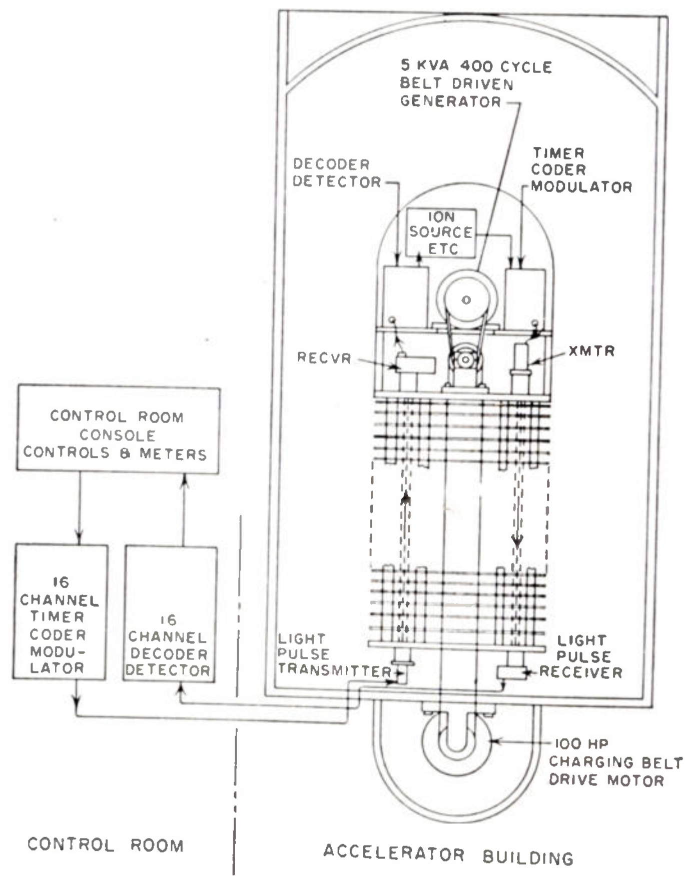

Fig. 2—General arrangement for telemetering of 12-mev Van de Graaff.

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† University of California, Los Alamos Scientific Laboratory, Los Alamos, N. M.

‡ William Miller Corp., 325 N. Halstead Ave., Pasadena 8, Calif.

[1] This machine is called a 12-mev accelerator because its general design does not preclude eventual attainment of such a potential difference. However, accelerating tube breakdown has limited maximum operating voltage to 5 mev.

it appeared desirable to develop a telemetering system which would permit rapid and continuous control and monitoring of all desired currents, voltages, and mechanical positions from a control desk located in a safe remote location. See Fig. 1.

After investigating the use of radio, light, and ultrasonic communication links between the high-voltage electrode and ground, a modulated light beam was selected and developed for the purpose.

Fig. 2 illustrates the use of the two light-beam links for both control and monitoring. In most respects, the link from the control room to the high-voltage electrode is similar to the return link, so one description will suffice for both links.

The transmitting end of each link contains a timer, a coder, and 16 modulated delay circuits, or channels. As indicated in Fig. 2, input signals are supplied to the 16 channels, which control a series of time-modulated pulses. These, together with four double-pulse codes, are transmitted as intensity modulation over a light beam. The phototube receiver reconverts the light-beam pulses into electrical pulses which are then amplified and sorted in a decoder, according to code groups, polarity, and sequence. Finally, the separated signals are demodulated to give output signals corresponding to the 16 input signals.

Fig. 3 is a list of the control and monitoring functions performed by the two light-beam links. The functions of the control link utilize only about half the 16 channels, whereas the monitoring channels are nearly all used, even with the multiplex feature which permits two meter readings to be transmitted on a single channel. As the development of the Van de Graaff machine proceeds, it is expected that fewer functions will need to be controlled and monitored remotely. Thus, the trend should be toward simplicity rather than toward more and more complication.

Figs. 4 through 9 are photographs which show the telemetering system as it is used with the Van de Graaff machine at the present stage of development. (See page 1667 for Fig. 9.)

CONTROL LINK CHANNEL FUNCTIONS

CHANNEL	SIGNAL	FUNCTION
1A	40-	SPARE RELAY
1B	40- OR 400-	CALIBRATE PANEL METERS ZERO OR FULL SCALE
1C	D-C	D[illegible]N RUN SPRAY CONTROL
1D	40- OR 400-	OSCILLATOR PLATE RELAY OR SPARE RELAY
2A	400- OR 40 + 400	RAISE (OR LOWER) ANY OF 4 FUNCTIONS SELECTED BY CHANNEL 2B
2B	NO SIGNAL	POSITIVE PROBE VOLTAGE
	40-	SCREEN VOLTAGE
	400-	SPARE
	40+ 400-	NEGATIVE PROBE VOLTAGE
2C	400- OR 40+ 400	RAISE (OR LOWER) ANY OF 4 FUNCTIONS SELECTED BY CHANNEL 2 D
2D	NO SIGNAL	LEAK HEATER VOLTAGE
	40-	FOCUS VOLTAGE
	400-	SPARE
	40 + 400-	SPARE
3A 3B 3C 3D		4 SPARE CHANNELS
4A 4B 4C 4D		4 SPARE CHANNELS

Fig. 3(a)—Control link channel functions.

CHANNEL	SIGNAL	FUNCTION	CHANNEL	SIGNAL	FUNCTION
1A + 3A	[illegible]	[illegible]	3A + 1A	AUDIO	SEE CHANNEL 1A
1B	[illegible]	[illegible]	3B	D-C	SPARE
1C	D-	[illegible]	3C	D-C	SPARE
	40 & 400-	[illegible]	3D	D-C	SPARE
1D + [illegible]	D-C	TIME SHARED: [illegible] PROBE CURRENT	4A	40-	SYNC. SIGNAL FOR TIME SHARING
1D + [illegible]	D-C	[illegible]	4B + [illegible]	D-C	TIME SHARED: SPARE
2A	[illegible]0-	[illegible]	4B [illegible]	D-C	FOCUS ELECTRODE POSITION
2B + [illegible]	D-C	TIME SHARED: [illegible] SCREEN VOLT	4C + [illegible]	D-C	TIME SHARED: DOWN RUN SPRAY CURR
2B + [illegible]	D-C	SPARE	4C + [illegible]	D-C	ION SOURCE GAS PRESS.
2C + [illegible]	D-C	TIME SHARED: SPARE	4D + [illegible]	D-C	TIME SHARED: SPARE
[illegible]	D-C	SPARE	4D + [illegible]	D-C	POS. PROBE VOLT.
2D + [illegible]	D-C	TIME SHARED: [illegible]			
[illegible]	D-C	NEG PROBE CURRENT			

Fig. 3(b)—Monitoring link channel functions.

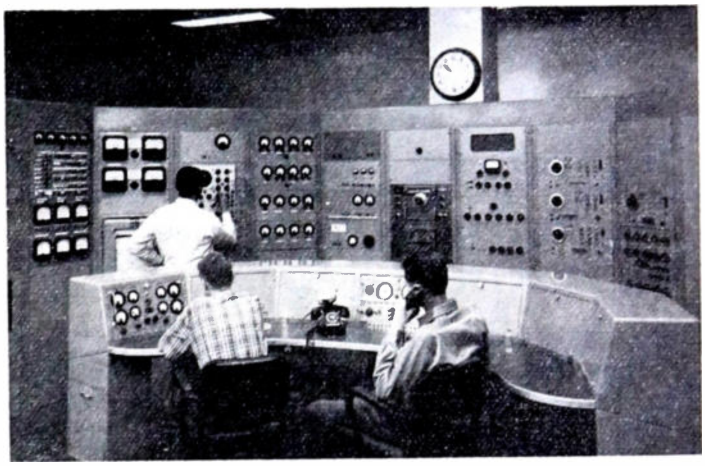

Fig. 4—General view of control room for Los Alamos 12-mev Van de Graaff.

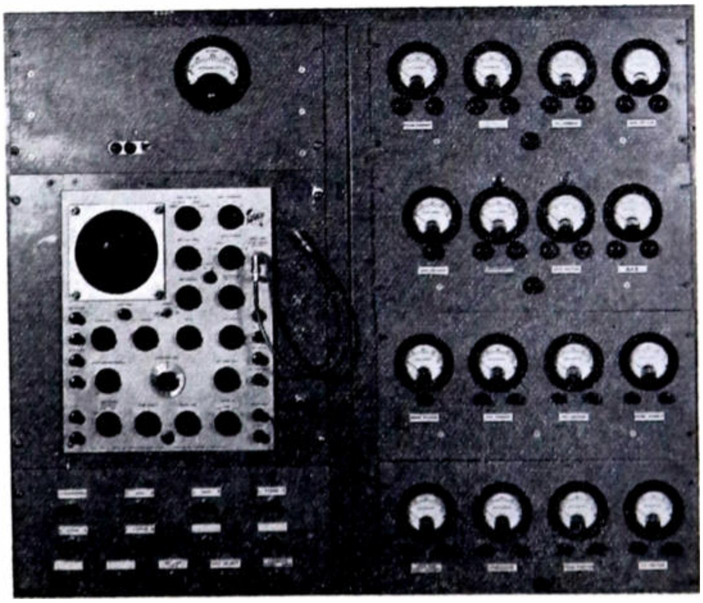

Fig. 5—Close-up view of control-room end of telemetering system.

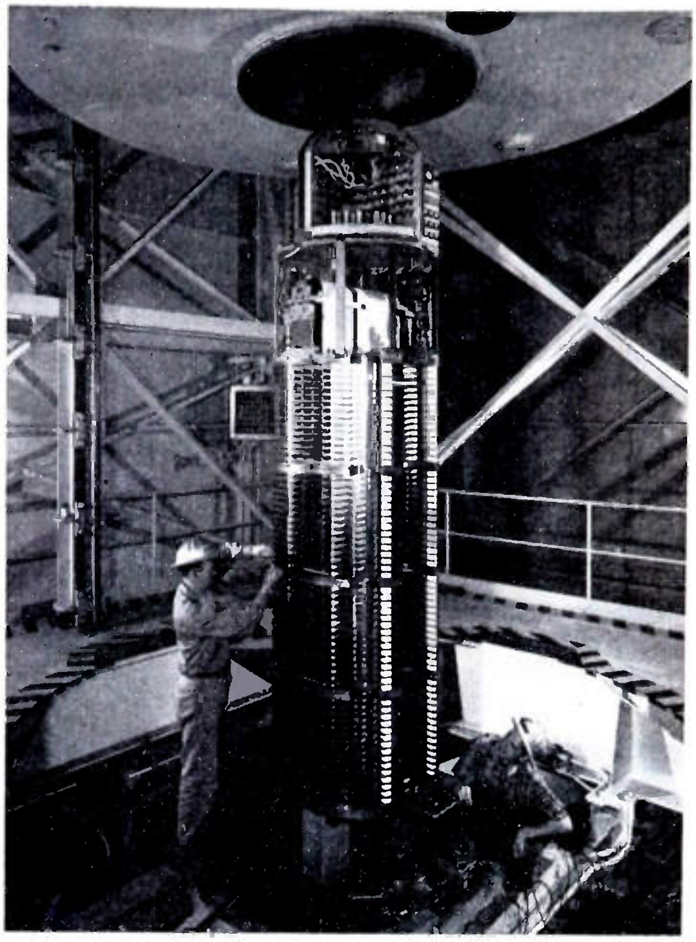

Fig. 6—Insulating column and high-voltage electrode of Los Alamos 12-mev Van de Graaff.

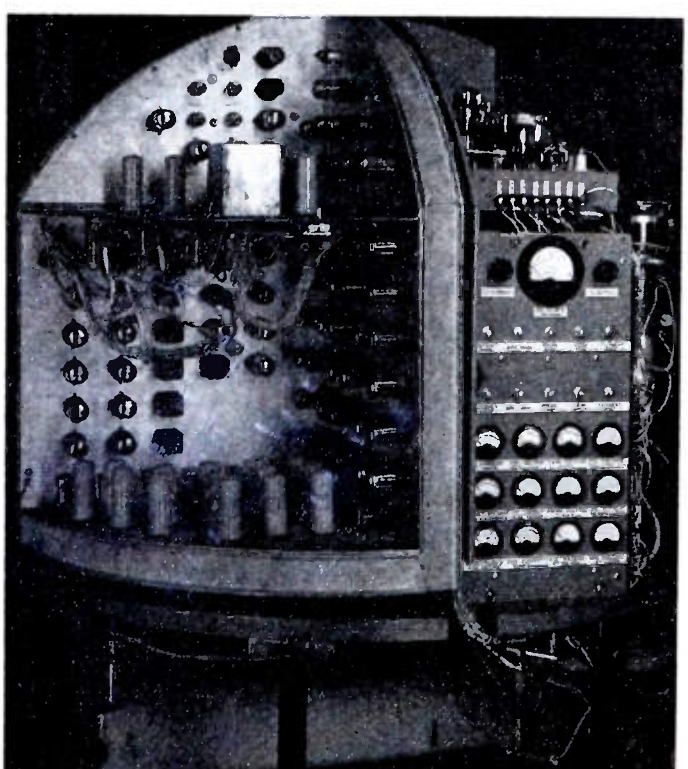

Fig. 7—Telemetering installation in high-voltage electrode of Los Alamos 12-mev Van de Graaff.

Pulse Time Modulation

Before describing a 16-channel system in detail, the basic operation may be more easily understood by considering a single-channel system using the same principle of operation for the transmission of data (Fig. 10).

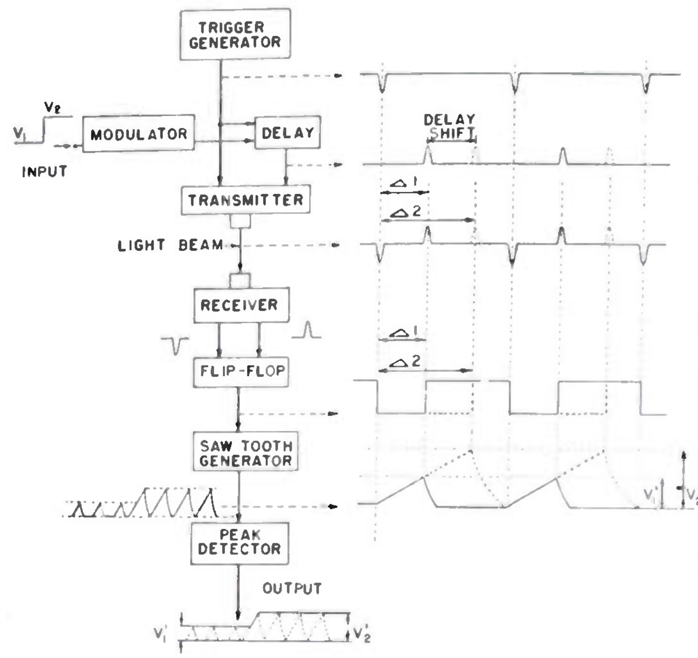

Fig. 10—Simplified telemetering system using pulse-time modulation.

Two pulses are required for the single channel, a trigger pulse and a delayed pulse, repeated continuously at some repetition rate. The two pulses must be distinguishable in some way; for instance, they may be of different amplitudes or widths, or as shown, of opposite polarity. The interval or "delay" between the two pulses may be made a linear function of an input modulating voltage.

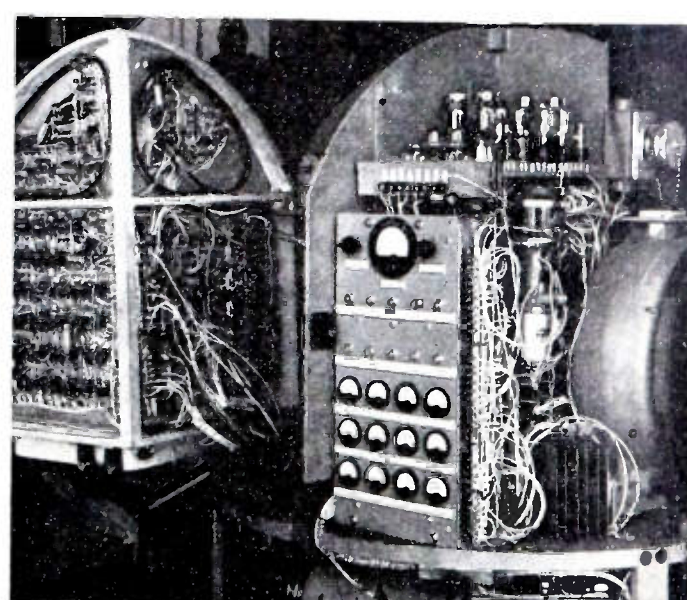

Fig. 8—Telemetering installation in high-voltage electrode with chassis open for servicing.

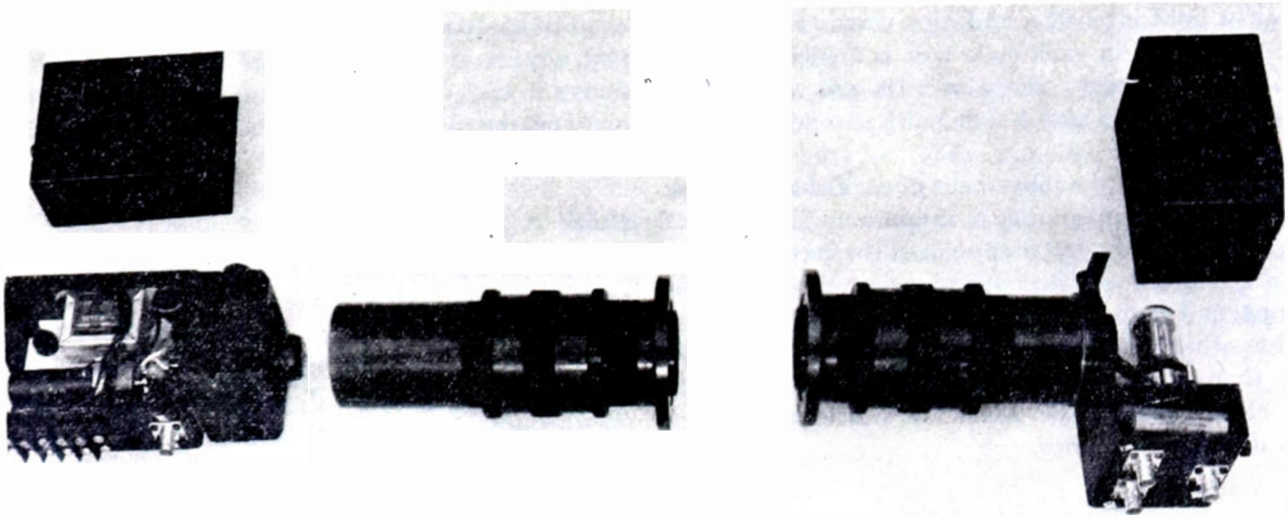

Fig. 9—Light-beam transmitter and receiver units for telemetering system of Los Alamos 12-mev Van de Graaff.

After transmission over a modulated light beam, the pulses may be amplified, separated, and used to control a flip-flop circuit in such a way that a square wave of voltage is generated, whose duration corresponds to the delay between the two original pulses. From the square wave, a sawtooth wave is generated, and the latter applied to a peak detector and filter. The output is a relatively steady voltage which will reproduce any changes in the input or modulating voltage.

In order to expand such a simple sytem to carry a number of pieces of information over a single light beam, some means must be employed for identifying all the pulses at the receiving end. It was desirable to devise a system in which if one channel fails because of a defect at either end of the system, all other channels will in general continue to operate properly.

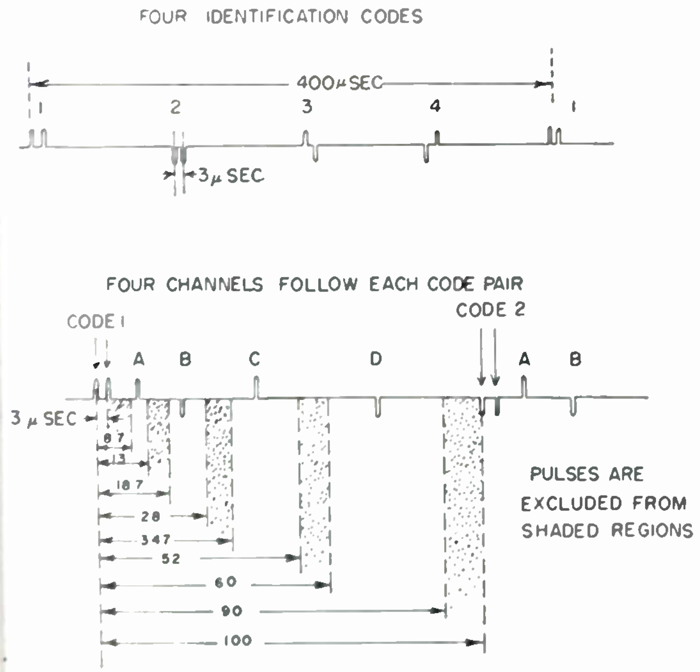

Fig. 11—Code and channel pulse-timing diagram.

Fig. 11 shows the sequence of pulses which are employed in the 16-channel system. Pulse spacing and polarity are used for identifying the different channels. Four different double-pulse "codes" are employed as triggers, each of which identifies a group of four channels. The four channel pulses following each identifying code are alternately positive and negative, and the delay times of pulses of the same polarity in a given group are sufficiently different to be separately distinguished by flip-flop circuits having different resolving times.

The pulses as transmitted by the glow tube have an effective width of about 2 μsec. Positive pulses cause an

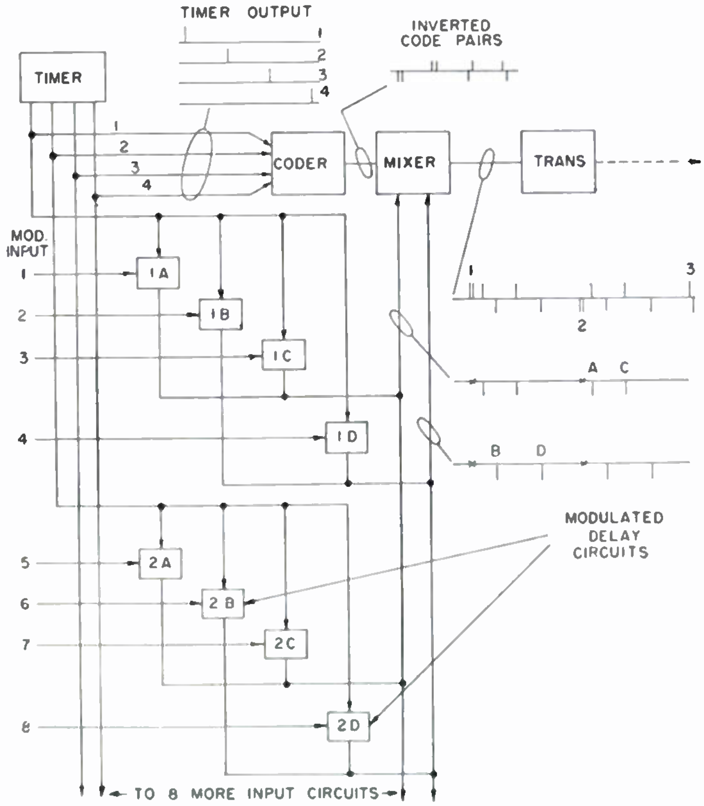

Fig. 12—Block diagram of transmitting end of 16-channel system.

increase in light intensity, and vice versa. The spacing of the two pulses in each code pair is 3 μsec., and the separation of different code pairs is 100 μsec. The entire cycle of 16 channels and 4 code pairs is repeated 2,500 times per second.

Limits are set on the movement of each channel pulse to allow a ratio of maximum to minimum delay time of 1.5/1, measured from the first pulse of the corresponding code pair. The pulse-exclusion regions are chosen so that if channel and code pulses vary in timing by 2½ per cent no pulses other than the code pairs will ever be closer together than 5 μsec. This is necessary to avoid "false-code" pairs which would seriously interfere with the proper decoding sequence.

Transmitting End

Fig. 12 is a block diagram of the transmitting end of the 16-channel system. Reference may be made to the individual circuit diagrams for further details (Figs. 13–17 inclusive).

Timer

The timing circuit is a twin phantastron oscillator. Each half "runs down" for 100 μsec. while the other half is recovering. A scale-of-two frequency divider is triggered by the oscillator. Outputs of both phases are taken from both circuits and mixed in four different combinations at the grids of four separate pulse-forming stages. Thus, for each cycle of operation of the timer, four separate "trigger" pulses are generated and brought to separate outputs. The timer generates a total of 10,000 equally spaced pulses a second, but only 2,500 per second appear at a given output terminal. Each output serves to trigger a group of four phantastrons, and also operates the coder to make a characteristic double-pulse "code pair."

Coder

A positive pulse applied to any one of the four inputs to the coder will produce one of the double-pulse "codes" by the process of mixing an undelayed and a delayed pulse. The four different characteristic "codes" are produced by mixing selected polarities of undelayed and delayed pulses. Unity gain stages are used to obtain inverted pulses. Mixing of all the desired delayed and undelayed pulses is accomplished at the output end of a single delay line which is both fed and terminated by the proper impedance to prevent reflections. A 3-μsec line of the helical-wound coaxial type is used.

Modulated Delay Circuits

A phantastron delay generator is used for each of the 16 channels. Each of the four trigger pulses from the timer is applied to a group of four phantastrons. The output pulses from the phantastrons occur in sequence, corresponding to pulses *A*, *B*, *C*, and *D* in Fig. 11. A modulator circuit is used to control the "run-down" time of each phantastron so that the resulting delay is a linear function of the input voltage throughout the useful range.

It was possible to standardize most of the input signals to correspond to a range of zero to plus 10 volts.

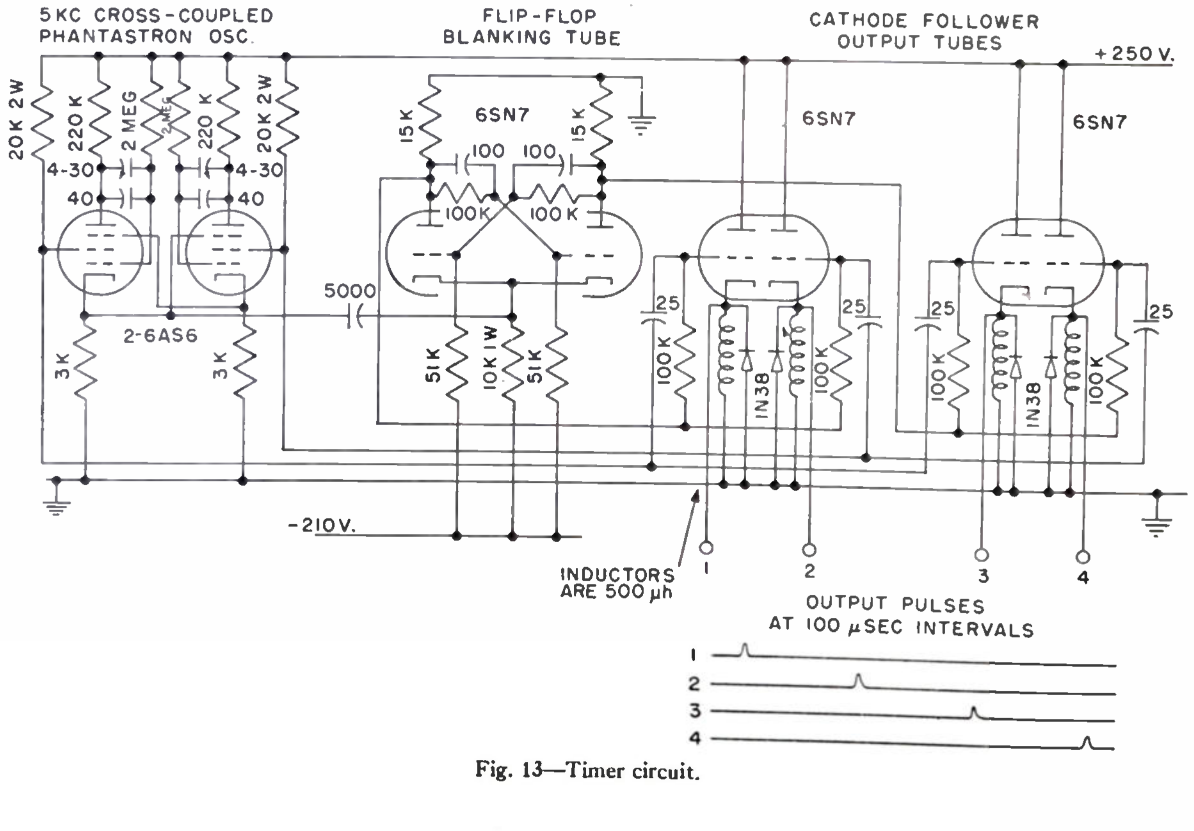

Fig. 13—Timer circuit.

This input voltage range causes the phantastron delay to change by a ratio of 1.5/1. Care must be taken to insure that the delay of every phantastron stays within the proper limits, in order to prevent "false codes."

The outputs of all phantastrons are negative pulses. Pulses for all *A* and *C* channels are mixed together directly through crystal diodes on a common bus. Pulses for all *B* and *D* channels are likewise mixed.

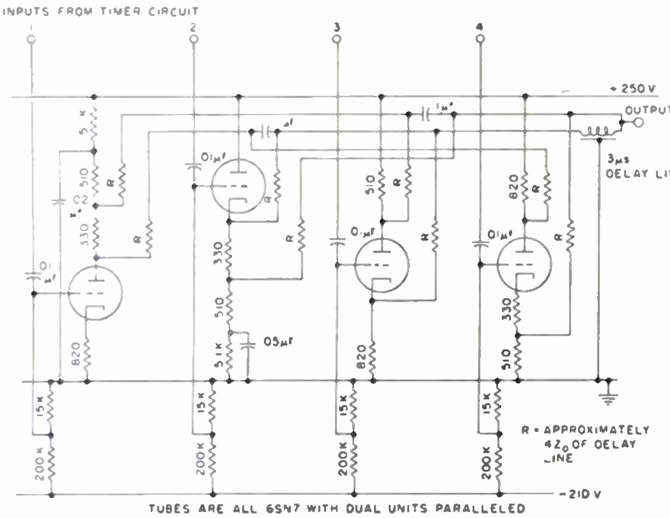

Fig. 14—Coder circuit.

Mixer

The four coded pulse pairs from the coder are amplified and mixed with the two sets of channel pulses from the modulated delay circuits (Fig. 16). In the process, pulses from channels *A* and *C* are inverted with respect to the pulses from channels *B* and *D*. A cathode-follower output tube sends the signals to the light-beam transmitter, over RG-71/U coaxial cable. For the control link this cable is several hundred feet long.

It is of interest to note that in the transmitted signal there are a total of 60,000 pulses per second.

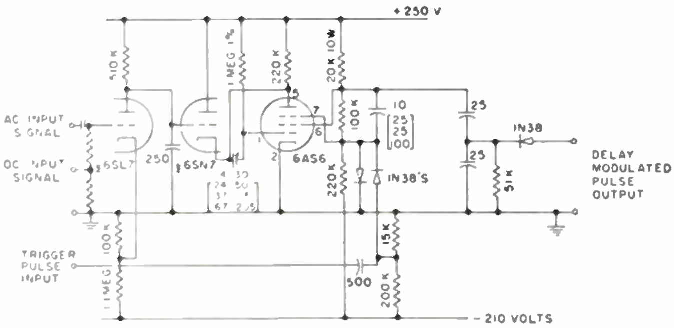

Fig. 15—Typical phantastron circuit.

Light Source and Driver

A Sylvania Type R-1131C glow tube is used in the plate of a 6AG7 amplifier (Fig. 17). Although the published characteristics of the R-1131C tube indicate a cut-off frequency of about 12,000 cps, both positive and negative pulses of approximately 2-μsec duration may be transmitted.

The glow tube tends to cause a certain amount of undershoot following either polarity of pulse. This is unfortunate because, with sufficient amplification, the undershoot will constitute a pulse of the wrong polarity, although of rather more width than a proper pulse. This was fairly well eliminated by adding predistortion in the form of low-frequency "boost" to all but the double-pulse codes of opposite polarity. The double-pulse codes of like polarity are predistorted in the coder, and all the channel pulses are predistorted in the mixer.

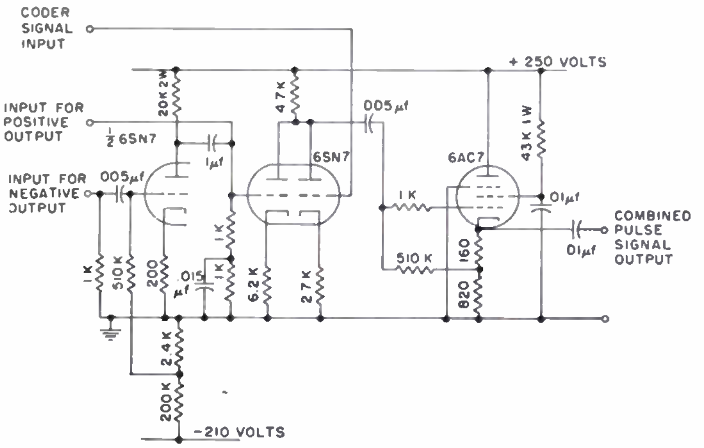

Fig. 16—Mixer circuit.

The average R1131C tube life has been about 200 hours in this service. The brilliance of the light generally decreases by a factor of 2 or 3 during its useful life. The useful life of the R1131C is ended when it begins to go out intermittently.

The light beam is collimated by a lens and directed through the high-voltage insulating column to fall on the lens of the phototube receiver unit. See Fig. 9.

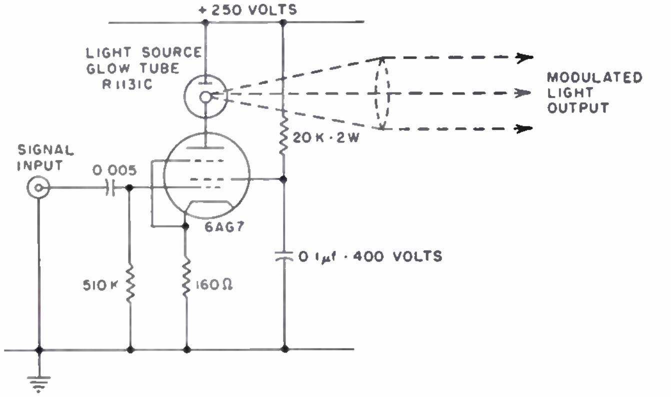

Fig. 17—Light source and driver circuit.

Receiving End

Phototube Receiver and Amplifier (Fig. 18)

The phototube receiver unit brings the light beam to a focus on the cathode of a 931-A photomultiplier tube. To prevent the photomultiplier from "seeing" extrane-

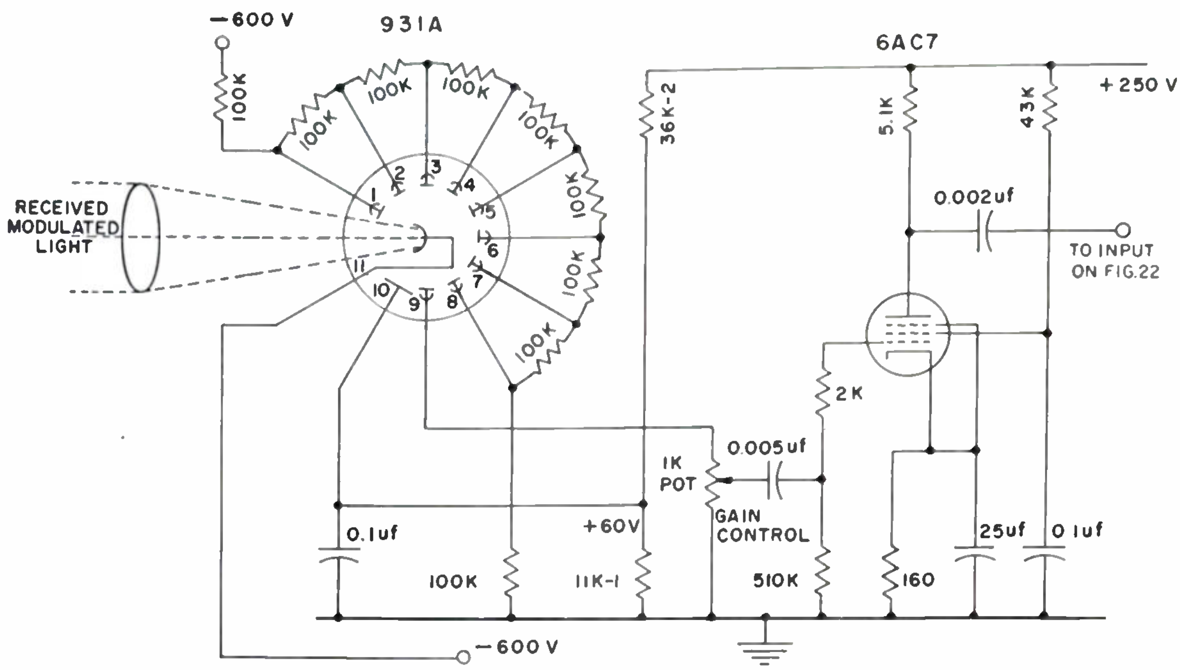

Fig. 18—Photomultiplier receiver and amplifier stage.

ous light from corona or sparks, a mask with a small hole to admit only the focused light beam is placed in front of the photomultiplier tube.

The 931-A is operated in such a way that a fairly wide range of light intensity can be tolerated without overloading or starving the output signal. For convenience in the circuits to follow, the proper polarity of signal is obtained from the 9th dynode instead of the anode.

At the high-voltage electrode the photomultiplier receiving tube feeds a 2-stage amplifier directly, but in the return link, a cathode follower supplies the signal through coaxial cable to a 2-stage amplifier. The additional gain is necessary to obtain large enough pulses to operate the decoder.

Decoder

Fig. 19 illustrates the operation of the decoder. The pulse pairs are decoded in four separate coincidence circuits, after four different versions of the amplified signal are obtained, namely,

(a) normal signal as in Fig. 11
(b) ditto delayed 3 μsec
(c) inverted signal
(d) ditto delayed 3 μsec.

By bringing all combinations of undelayed with delayed signals to individual coincidence circuits, one output pulse per cycle is obtained from each. In this way the four trigger pulses generated by the timer at the sending end are duplicated at the receiving end, although the 4 trigger outputs from the decoder are negative and all are delayed 3 μsec in the decoding process.

The only treatment required for the channel pulses is that the two polarities must be separated. This is easily done by two stages, supplied with signals (a) and (c) above, operated a little below cutoff. Thus, channel pulses B and D may be brought out, separated from all A and C pulses, and vice versa.

It does not matter that, mixed in with the channel pulses, there exist some extra pulses from the code pairs. The flip-flop detector circuits do not respond to them.

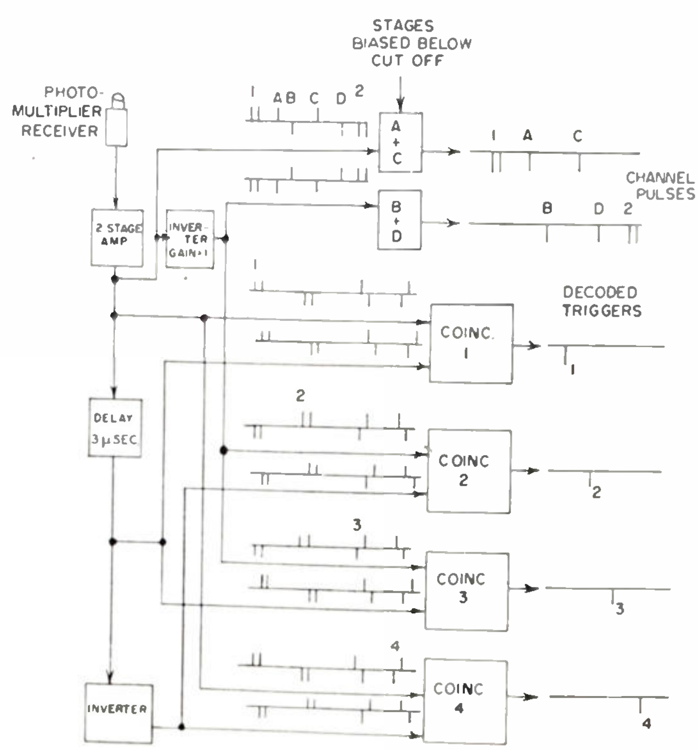

Fig. 19—Operation of decoder.

Fig. 20 gives the circuit diagram for the decoder. It will be noted that the A and C channel pulses are actually brought out on two separate lines, one of which

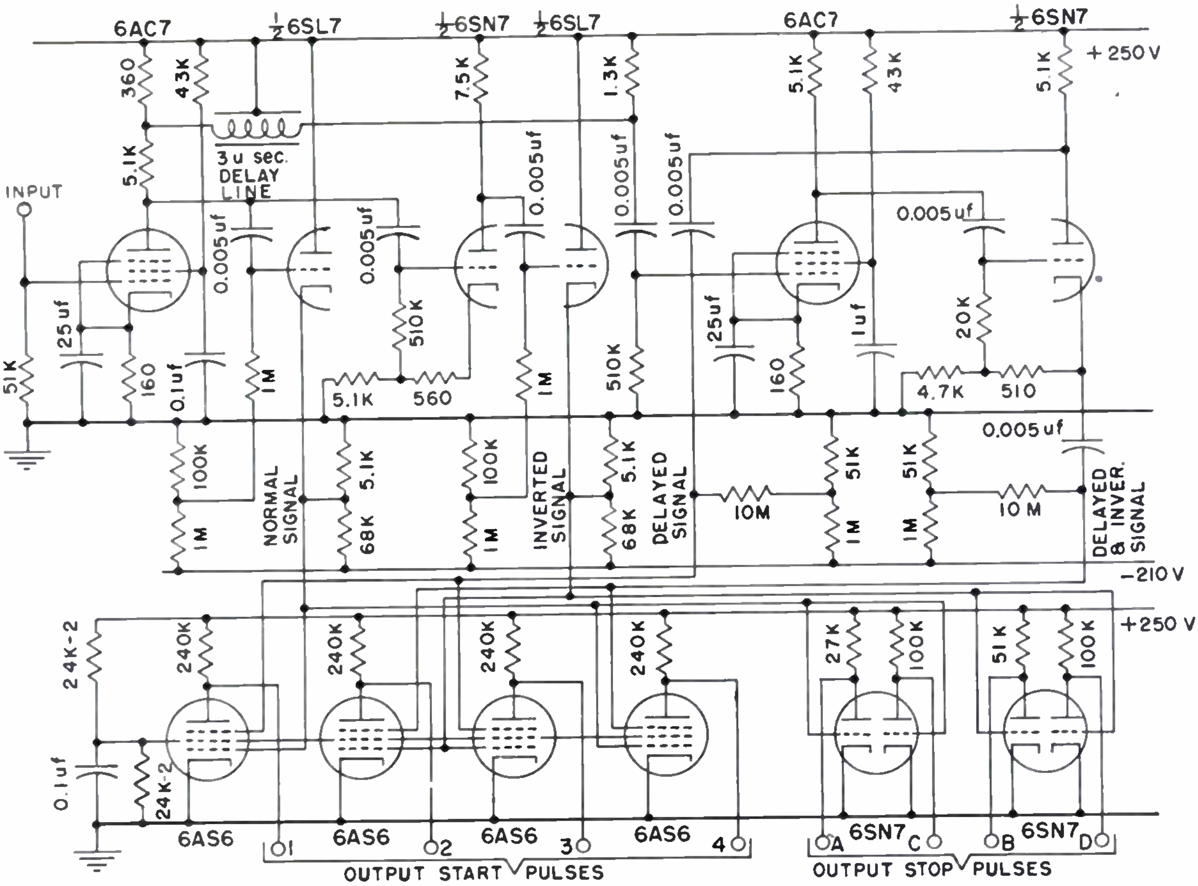

Fig. 20—Decoder.

goes only to the *A* flip-flops and the other to the *C* flip-flops. This is done to prevent interaction, and is the same for the *B* and *D* circuits.

Detectors

For convenience the term "detector," as used here, includes all the circuitry required by each channel between the decoder and the output voltage or current.

Fig. 21 shows the sequence of operation of a group of 4 flip-flops. After being triggered simultaneously by the decoded trigger pulse, they are restored in sequence to their original condition by the next four channel pulses, each flip-flop responding to a different channel pulse. The response time of the *A* flip-flop is made short, but the *C* flip-flop is purposely made with such a poor resolving time that it waits for the *C* pulse instead of responding to the *A* pulse. A similar explanation holds for the *B* and *D* flip-flops.

The triggering action of the flip-flops must be such that the decoder trigger can overpower a simultaneous pulse which occurs in some cases on the channel pulse line.

Each flip-flop produces a square-wave output of fairly low-duty cycle. The duration of a given square wave corresponds to the time between the second pulse of the appropriate code pair and the channel pulse which acts on the flip-flop. Just as in the case of the single-channel system described earlier and shown in Fig. 10, in each channel a sawtooth voltage is then generated, followed by a peak detector. Typical detector circuits are shown in Fig. 22(a) and (b).

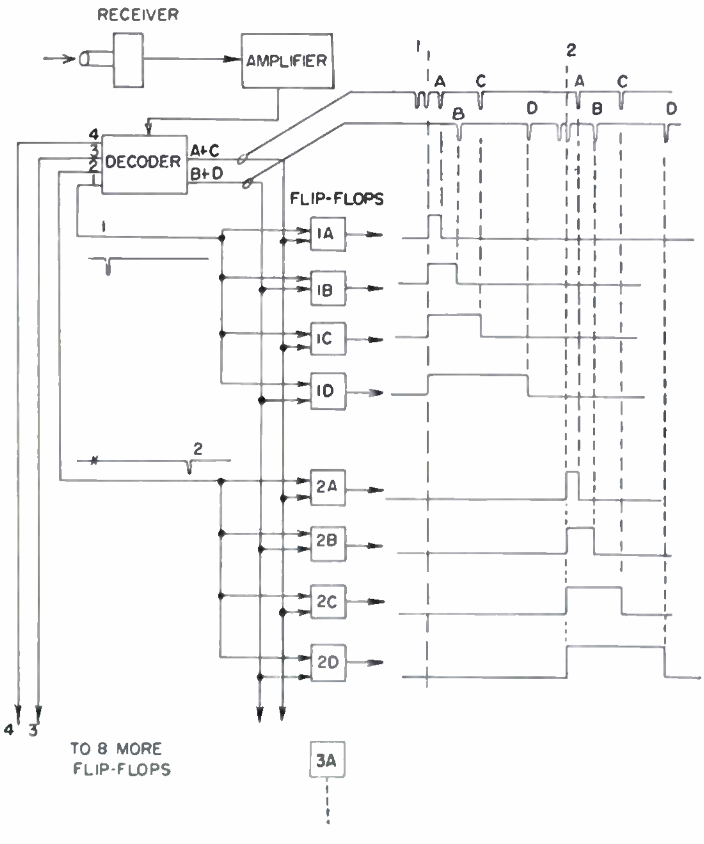

Fig. 21—Operation of flip-flops.

For operating a dc panel meter, and for some other purposes, a very nearly linear response is required. For linear output a boot-strap sawtooth generator is used. For detecting ac signals, however, a "cheaper" sawtooth circuit is used, which is nothing more than an RC integrator.

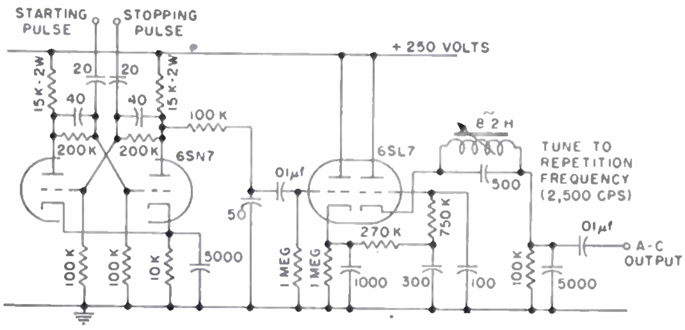

Fig. 22(a)—Typical detector for ac output.

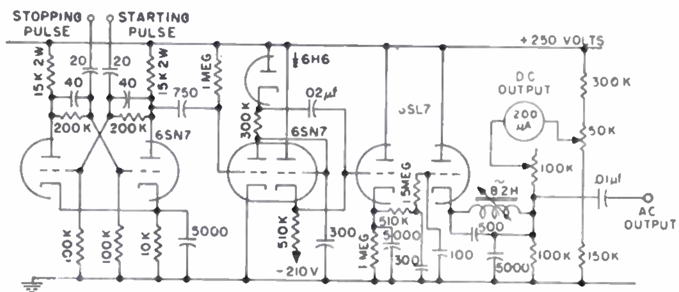

Fig. 22(b)—Typical detector for ac and linear dc outputs.

The panel meters are equipped with zero and full-scale adjustments so that when each input signal at the transmitting end is varied from zero to maximum, the corresponding detector may be adjusted to give an output current of zero or full scale on the panel meter.

For easy calibration of the panel meters during the operation of the Van de Graaff, two multiple-pole relays are included in the high-voltage end. These relays are operated through the control link and can switch all meter channel inputs from their normal signals to the calibrating input voltages corresponding to zero and full scale.

Channel Multiplex

Since 16 channels are not sufficient in the monitoring link to permit the use of an entire channel for each piece of information, two pieces of information must be combined in nearly every channel. Making channels do double duty represents a considerable saving in the number of tubes, bulk, and power requirements. Some multiplexing is used even in the control link, although it has many spare potential channels. See Fig. 23.

It is true that many different frequencies of ac signals can be sent simultaneously over one channel, so long as the peak to peak delay shift of the channel pulse does not exceed the permitted limits and the frequencies do not exceed one half the repetition frequency. After detection, these frequencies can then be separated by means of filters and used to energize relays or perform other functions. A useful limit, however, imposed by considerations of signal-to-noise ratio, drift, and simplicity seems to be to limit to 2 the number of signals carried by any one channel.

At present, 40- and 400-cycle frequencies are combined and then separated by simple RC filters after detection. Also, one dc signal plus either of the above two frequencies are combined on a single channel. The detector for this combination is shown in Fig. 22(b).

Two dc signals are combined on a single channel in a rather more complicated manner involving "time sharing." An ac voltage is used to switch the phantastron modulator between 2 different dc inputs so that each input is effective approximately one-half the time. The switching is done electronically and at a 40-cps rate. The output of such a channel after detection is electronically switched between two panel-meter circuits, and to obtain synchronization it is necessary to use a channel to transmit the 40-cps signal over the same link. This system is not economical unless several channels are time shared with the same synchronizing signal.

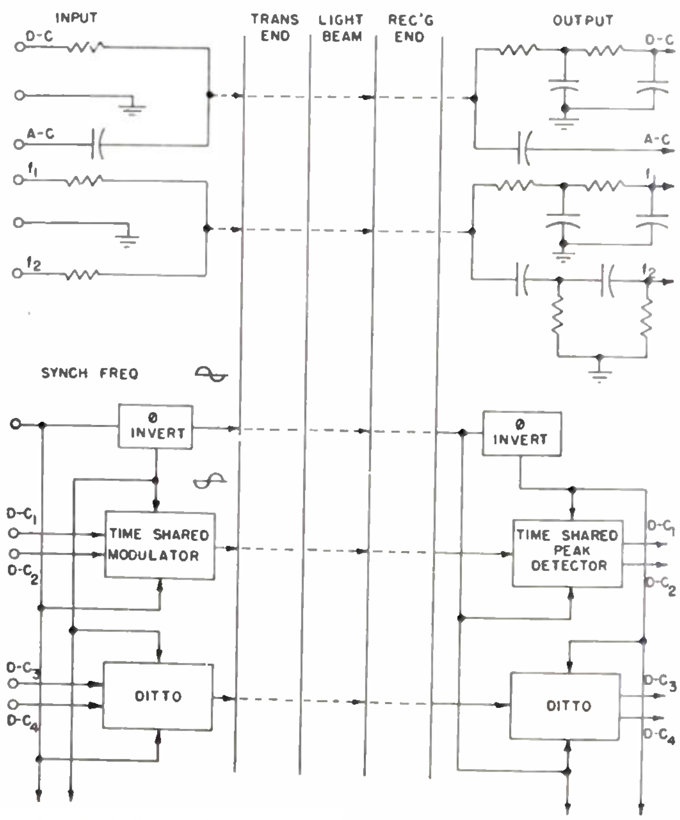

Fig. 23—Methods of multiplexing to economize on channels.

nal. For the past year, 14 dc panel meters have been operated in this way from the monitor link, thus using only 7 time-shared channels plus one channel for the synchronizing signal. See Fig. 24.

If a telemetering channel of higher frequency response is desired, it is possible to increase the upper fre-

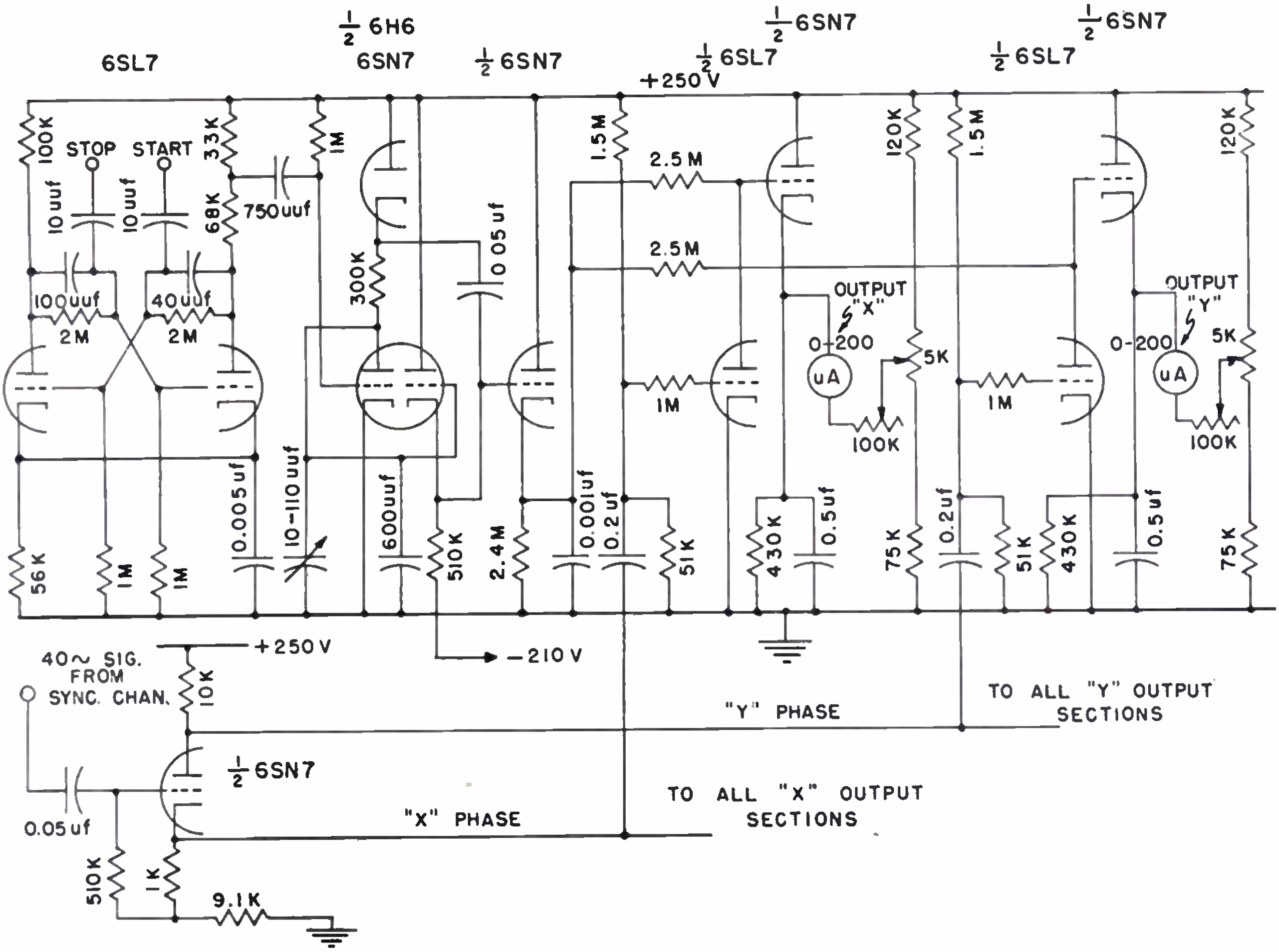

Fig. 24—Typical time-shared detector providing two dc outputs.

quency limit of a telemetered signal merely by paralleling the inputs of two or more channels which operate at equally spaced time intervals. For example, an audio channel has been operating satisfactorily in the telemetering link between high-voltage electrode and control room so as to permit the operator to listen for unusual noises from equipment in the electrode. This link was established by effectively paralleling channels 1A and 3A in order to double the repetition rate. Of course, the quality of reproduction was not outstanding since a 2,000-cycle low-pass filter was used to hold back the doubled carrier frequency, as well as some of the basic carrier frequency. However, the quality is not objectionable, and it is hoped that the audio channel will be useful in detecting and diagnosing troubles. A better audio system might be obtained by paralleling, say, channels 1A, 2A, 3A, and 4A.

General Remarks

The receiver and transmitter in the high-voltage electrode are powered by a 400-cycle generator driven from the charging belt, whereas the control-room transmitter and receiver use 60-cycle power. This, together with the unique space and shape limitations in the high-voltage electrode, account for the differences in power supply circuits and general appearance of the units used in the two telemetering links.

Although the electrostatic accelerator at Los Alamos is not yet completed at the time of this writing, the telemetering system described has been in operation for several years. It was operated for a year on Laboratory bench set-ups. It has since been run under actual operating conditions in the partially completed accelerator, and has withstood normal operating gas pressure, vibration, temperature variations, and severe transitory electrical discharges or sparking. Although the insulating column of the incompleted accelerator has been erected to only a fraction of its ultimate height, and although the telemetering has not been tested with more than 6-million volts on the high-voltage electrode, it is felt that neither the ultimate greater distance for light beams to travel nor the ultimate greater voltage will introduce serious problems.

Troubles thus far have been caused by inadequate shielding of units in the high-potential electrode. Overheating and transients caused by high-voltage sparks have in the past resulted in germanium crystal-diode failures. Adequate shielding and ventilation, however, have essentially eliminated such troubles. Some particularly vulnerable crystal diodes have been replaced by vacuum-tube diodes.

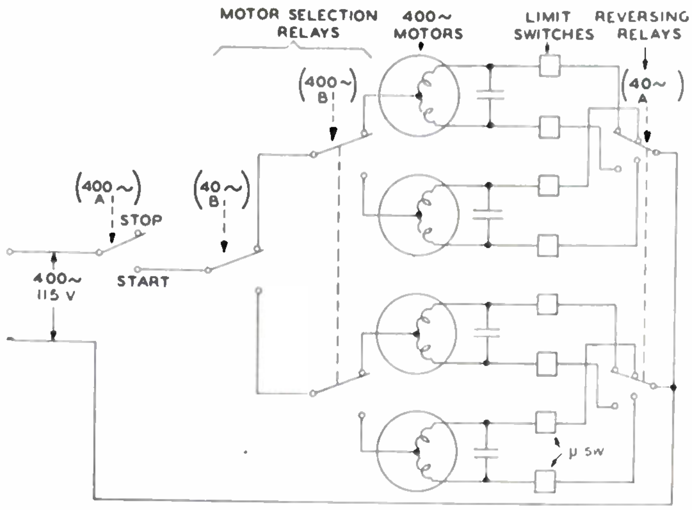

Fig. 25—Motor-control circuit.

Failure of tubes, particularly in the high-potential electrode, was initially a problem because of the vibration there and operation in gas pressures as high as 150 pounds per square inch. The use of vibration isolating mountings, the use of ruggedized "Red" tubes, and the gradual elimination of poor tubes by replacement, however, have reduced this problem. When a tube fails, it usually takes out one or two channels. Less often, a bad tube may take out many channels, depending upon the tube, of course. However, tube failure has not been a really difficult problem since an earlier uncoded pulse-time system was abandoned for the coded system. In this earlier system, the turn-on pulse of each channel was produced by the turn-off pulse of the preceding channel (except for channel 1), and failure of a tube in any channel usually rendered all the following channels inoperative.

Initial developments, adjustments, and diagnosis of troubles were greatly facilitated through use of an A R-type oscilloscope, DuMont type 256-D, although the Tektronix 511-A oscilloscope has recently proven to be adequate for such work.

It is felt that although this telemetering system is well suited to transmission over a pulsed light beam, there are other transmission media which might be equally suitable. Ultrasonics through fluids or solid materials may prove to be suitable for this type of pulse transmission. Carrier-shift modulation in high-frequency radio channels may also be suitable.

Acknowledgment

The authors wish to acknowledge the efforts of H. G. Weiss, who initiated this project by suggesting and working out one of the first forms of telemetering for the then proposed 12-mev electrostatic accelerator, and R. L. Henkel who assisted with the development and construction of the most recent form. This work has been done under the auspices of the Atomic Energy Commission.

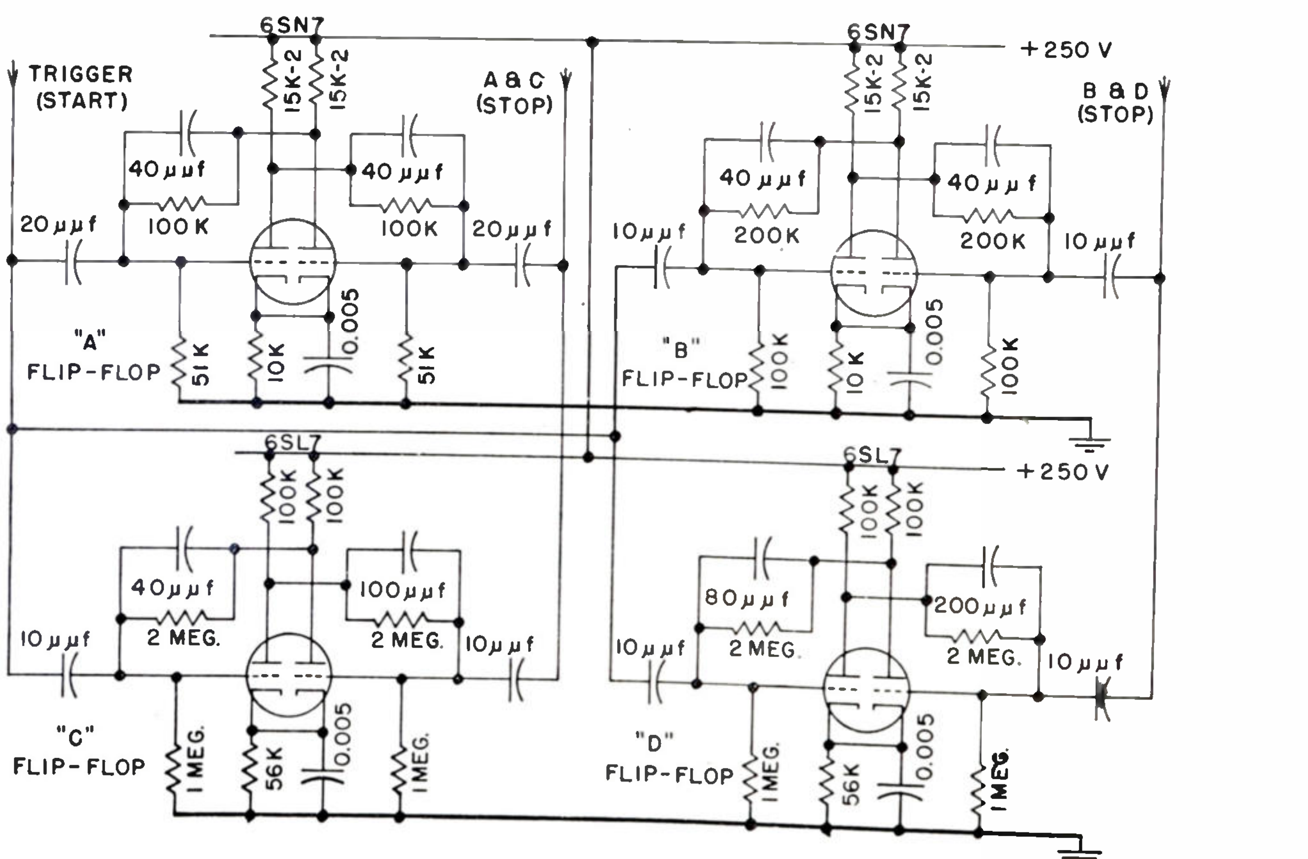

Fig. 26—Basic flip-flop circuits.

A New Method of Calculating Microwave Noise in Electron Streams*

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Summary—**The noise in a temperature-limited electron beam in a drift space is calculated by a new means. Noise maxima and minima are found. The results agree with calculations made by the Rack-Llewellyn-Peterson method.**

I. Introduction

Hitherto the most successful approach in calculating noise in electron streams at frequencies for which the transit angle is large has been that based on the work of Rack, Llewellyn and Peterson.[1] In such calculations, the actual multivelocity electron stream is replaced by an electron stream in which the electrons passing a given plane at a given time all have the same velocity. Certain averages taken over the electrons of the multi-velocity flow are identified with fluctuations of the electron velocity and the electron density of the single-velocity stream. It is very hard to justify this physically, although it can be argued that the calculations apply after the electrons have been sufficiently accelerated.[2] This makes it desirable to explore other approaches in order to see whether other assumptions will lead to the same or to other results.

The purpose of this paper is to present an alternative way of making approximate noise calculations. In this approach one uses linearized equations to calculate a frequency component of the noise excited in an electron stream by a charge which passes through the flow with a velocity different from the mean velocity of the stream. This approach is essentially that used by Thompson, North and Harris[3] in calculating the noise in a diode at low frequencies. To the author it is more physically appealing than the Rack-Llewellyn-Peterson approach. Also, it offers possibility of further refinement, although this is not exploited.

The present memorandum presents an approximate calculation according to the new approach concerning a very simple but a physically meaningful case. The same case is treated by the Rack-Llewellyn-Peterson method. To the approximation used the new method agrees with the old. Thus, the chief contribution of this work is to confirm earlier results subject to certain approximations.

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[1] J. R. Pierce, "Traveling-Wave Tubes," chap. 10, D. Van Nostrand Co., Inc., 1950.

[2] F. N. H. Robinson, "Space charge smoothing of microwave shot noise in electron beams," *Phil. Mag.*, vol. 43, pp. 51–62; January, 1952.

[3] B. J. Thompson, D. O. North, and W. A. Harris, *R.C.A. Review*, pp. 269–285; January, 1940; pp. 441–473; April, 1940.

II. Assumptions

The example treated is an approximation to the physical situation indicated in Fig. 1. An electron stream is drawn from a cathode which gives temperature-limited emission. The electrons are accelerated by a grid which is close to the cathode and which is held at a relatively high potential V_0. Thus, the transit angle and space charge between cathode and grid are both very small. Subsequently, the electron stream travels with a constant diameter through a constant-potential drift tube. We may imagine the electron stream to be confined by a strong magnetic field.

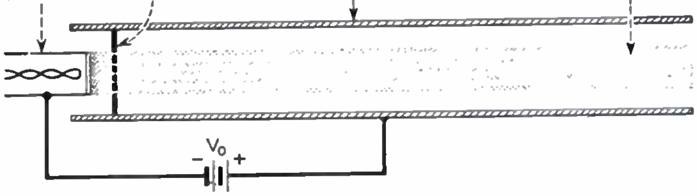

Fig. 1—A stream of electrons is accelerated from a temperature-limited cathode by a positive grid close to the cathode and is injected into a drift space.

Under the circumstances described above we can reasonably assume that the probability of an electron passing any part of the grid in any interval of time is independent of the passage of other electrons. This means that the fluctuation in the whole current passing the grid or in any part of it, associated with any small area of the grid or with any velocity class of electrons, is pure shot noise, and the fluctuation in any part of the current passing the grid is uncorrelated with the fluctuation in any other part.

In the approximate calculations which follow, some rather drastic simplifications have been made. These are listed and explained below.

(1) An infinite-parallel-plane, or one-dimensional flow has been assumed. Thus, the convection current which produces noise may be thought of as consisting of planes of charge moving through the flow.

(2) It is assumed that the total excitation produced by n charges moving through the flow is the sum of the excitations produced by each separately. This is equivalent to saying that the system is linear.

(3) The excitation of the beam is calculated as if all the charge except the exciting charge is smoothed out, and acts merely as a "circuit" driven by the exciting charges. We should note that the nature of the excitation of the electron stream by the moving charge depends on the velocity of the charge. Let us call the velocity of a single charge shot into a smoothed-out stream

$v(t)$, and let the total velocity in the presence of other charges be $v(t)+\tilde{v}(t)$, where $\tilde{v}(t)$ is the velocity due to the ac fields produced by other charges; i.e., $\tilde{v}(t)$ is the perturbation of the velocity $v(t)$ caused by noise in the electron stream. By our assumption of linearity we can get the total response to $v(t)+\tilde{v}(t)$ by adding to the response to $v(t)$ the response due to $\tilde{v}(t)$. Now the effect of motions of a charge caused by noise fields is calculated as if the charge were smoothed out. Hence, while in computing the effect of $v(t)$ we consider the charge as discrete, in computing any effect of $\tilde{v}(t)$ we consider the charge as smoothed out. Thus, because of this approximation the effect of $\tilde{v}(t)$ cannot depend on the relation between times of entry of charges.

(4) The exciting current flows through the impedance provided by the smoothed-out charge and the space in which the charge is. Thus, there is an implicit assumption that the total ac current in the flow, convection and displacement is zero.

(5) We assume that the velocity of a single charge shot through the uniform flow remains constant. Actually, the disturbance caused by the passage of the charge through the smoothed-out flow will cause the charge to slow down gradually because of excitation of oscillations in the flow,[4] but as the retarding force is very small it will be disregarded.

(6) In actual calculations, it will be assumed that the velocity spread in the flow is very small. Thus, only terms involving the lowest significant power of the velocity spread will be retained

One remark should be made concerning the whole approach to the problem. It is assumed that the exciting charge sticks together in its movement through the flow, just as an electron does. This amounts to assuming some non-coulomb forces which keep it together. The inclusion of these such forces might cause the result of the calculations to differ in some respect from the result obtained when the whole flow is assumed to be smoothed out and noise is introduced as a fluctuation in the velocity distribution at some plane. If significantly different results were obtained by the two methods, it could only be due to the inclusion in the treatment given here of something which is characteristic of the actual physical system.

III. The Nature of the Result

The problem which must be solved in order to get the answer sought is that of finding the disturbance in a uniform electron flow caused by a charge which moves through it with a constant velocity v. The flow is assumed to act as a linear system, and the problem is one of finding the response of this linear system to a driving force.

The response will consist of two parts. There will be a special solution of the linear partial differential equations involved. In general this will be a "driven" disturbance of constant shape moving with the velocity of the charge. There will also be an excitation of free oscillations or normal modes of the flow, dependent in magnitude on how the charge achieves its uniform motion through the flow.[5]

We cannot get away from the driven disturbance. It depends on local circumstances and not on how the beam is formed. Fortunately, the convection current associated with the driven disturbance or special solution turns out to be very small compared with the impressed convection current; the space charge suppresses this sort of noise very effectively.

The excitation of the normal modes commonly accounts for by far the largest excitation in the electron flow. How large this is depends on the initial conditions; that is, on how the beam is formed. Indeed, until someone shows otherwise we may imagine that some ingenious inventor will think of a way of accelerating electrons such that the normal modes of the flow will be excited little if at all by the electrons forming the beam.

In the calculation to be presented here the above features will be shown in a very simple case; in which the driving current corresponds to a charge suddenly set in motion with a constant velocity at some point $z=0$.

IV. Simple Case

We wish to consider the excitation caused by a charge in the form of a plane which is suddenly set into uniform motion with a velocity v at $z=0$. The current represented by such a pulse consists of a very broad spectrum of frequencies, of infinite width if the charge has zero width. We will be concerned with a narrow range of frequencies only, and it is most convenient to consider an exciting current of a single frequency ω. Such an impressed current I_i is represented by the integral

$$I_i = \frac{ie^{j\omega[t-(\omega/v)z]}}{2\pi j}\int_C \frac{e^{pz}}{p}\,dp$$

$$I_i = \frac{ie^{j\omega t}}{2\pi j}\int_C \frac{e^{[p-j(\omega/v)]z}}{p}\,dp, \tag{1}$$

where the contour is along the imaginary axis indented to the right at the origin. The integral may be identified as an inverse Laplace transform. The amplitude of this current is zero for $z<0$ and i for $z>0$. For $z>0$ the phase velocity, which must be equal to the velocity of the moving charge, is v.

This current will act on the electron flow to produce some electric field and some convection current. Let the total convection current, including both the total impressed current I_i and the convection current excited in the smoothed-out flow, be I_t. Let i_i be a component of impressed current which varies with time and distance as

$$e^{j\omega t}e^{-j\beta z}.$$

[4] D. Pines and D. Bohm, "Collective description of electron interactions—II," *Phys. Rev.*, vol. 85, pp. 338–353; January 15, 1952.

[5] If a mode has a velocity independent of frequency and a charge with the same velocity excites it, the disturbance grows with distance. Presumably other queer things can happen in equally pathological cases.

This will give rise to some component i_t of total convection current with the same spatial and temporal variation.

$$i_t = F(\beta)i_i. \tag{2}$$

Here $F(\beta)$ is a function of frequency and of the dc parameters of the electron flow (distribution of dc charge density with velocity).

Formally, from (1) and (2), the required total convection current is given by

$$I_t = \frac{ie^{j\omega t}}{2\pi j}\int_C \frac{F\left(\frac{\omega}{v}+jp\right)}{p} e^{[p-j(\omega/v)]z}dp, \tag{3}$$

where the contour is along the imaginary axis indented to the right at any poles on the imaginary axis.

It will prove convenient to use β rather than p as a variable of integration, giving

$$I_t = -\frac{ie^{j\omega t}}{2\pi j}\int_C \frac{F(\beta)e^{-j\beta z}d\beta}{\left(\beta-\frac{\omega}{v}\right)}. \tag{4}$$

The contour is now along the real axis of β, from $\beta=-\infty$ $(p=+j\infty)$ to $\beta=\infty$ $(p=-\infty)$, indented above any poles on the real axis. The minus sign comes from changing the direction of integration along the contour.

I_t as given by (4) is the total convection current as a function of distance for an exciting current of frequency ω, velocity v, and amplitude zero for $z<0$ and i for $z>0$.

To proceed further we need an expression for the transfer function $F(\beta)$. We obtain this by considering a single component of impressed current i_i of frequency ω and propagation constant β. For an average charge density of electrons $d\rho$ moving with a velocity u the convection current density di produced by a field E having the spatial and temporal variation assumed is

$$di = -j\omega\epsilon\left(\frac{\frac{e}{m}d\rho}{\epsilon}\right)\frac{E}{(\omega-\beta u)^2}. \tag{5}$$

Let

$$d\rho = \rho_0 f(u)du, \tag{6}$$

$$\int_{u_1}^{u_2} f(u)du = 1, \tag{7}$$

$$\omega_p^2 = \frac{\frac{e}{m}\rho_0}{\epsilon}. \tag{8}$$

Then the total convection current i produced by the field F will be

$$i = -j\omega\epsilon\omega_p^2 E\int_{u_1}^{u_2}\frac{f(u)du}{(\omega-\beta u)^2}. \tag{9}$$

It is assumed that $f(u)$ is zero outside of the limits u_1 and u_2.

The total convection current component will be

$$i_t = i_1 - j\omega\epsilon\omega_p^2 E\int_{u_1}^{u_2}\frac{f(u)du}{(\omega-\beta u)^2}. \tag{10}$$

The total ac charge density ρ_t will be

$$\rho_t = \frac{\beta}{\omega}i_t. \tag{11}$$

From Poisson's equation

$$\rho_t = -j\epsilon\beta E, \tag{12}$$

and from (11), (10) and (9)

$$\frac{i_t}{i_1} = F(\beta) = \frac{1}{1-\omega_p^2\int_{u_1}^{u_2}\frac{f(u)du}{(\omega-\beta u)^2}}. \tag{13}$$

We will now consider a very simple case; that in which

$$\begin{gathered} f(u) = \frac{1}{\delta}, \\ u_0-\frac{\delta}{2} < u < u_0+\frac{\delta}{2} \\ f(u) = 0, \\ u < u_0-\frac{\delta}{2} \quad \text{or} \quad u > u_0+\frac{\delta}{2}. \end{gathered} \tag{14}$$

In this case the integral in the denominator of (12) is

$$\frac{1}{\delta}\int_{u_0-\delta/2}^{u_0+\delta/2}\frac{du}{(\omega-\beta u)^2} = \frac{1}{(\omega-\beta u_0)^2-\beta^2\frac{\delta^2}{4}}. \tag{15}$$

This result is certainly valid if $\omega-\beta u$ is not zero in the range of integration. We can make this so if β is real by allowing ω to have a small imaginary part. We see that no matter how we let this go to zero we obtain (15) for ω and β real.

Accordingly, the transfer function of (13) will be

$$F(\beta) = \frac{(\omega/u_0-\beta)^2-\beta^2\delta^2/4u_0^2}{(\omega/u_0-\beta)^2-\beta^2\delta^2/4u_0^2-\omega_p^2/u_0^2}. \tag{16}$$

The function $F(\beta)$ can be written in the form

$$F(\beta) = \frac{(\beta-\beta_1)(\beta-\beta_2)+\frac{(\omega_p/u_0)^2}{(1-\delta/2u_0)^2}}{(\beta-\beta_1)(\beta-\beta_2)} \tag{17}$$

$$\beta_1 = \frac{\frac{\omega}{u_0}+\frac{\omega_p'}{u_0}}{1-(\delta/2u_0)^2} \tag{18}$$

$$\beta_2 = \frac{\frac{\omega}{u_0}-\frac{\omega_p'}{u_0}}{1-(\delta/2u_0)^2} \tag{19}$$

$$\omega_p' = \omega_p\sqrt{1-(\delta/2u_0)^2((\omega/\omega_p)^2-1)}. \tag{20}$$

From (4) the total convection current is given by

$$I_t = -\frac{ie^{j\omega t}}{2\pi j}\int_c \frac{\left[(\beta-\beta_1)(\beta-\beta_2)+\frac{(\omega_p/u_0)^2}{(1-(\delta/2u_0)^2)}\right]e^{-j\beta z}d\beta}{(\beta-\omega/v)(\beta-\beta_1)(\beta-\beta_2)}. \tag{21}$$

This has 3 poles, all on the real axis. We can evaluate this integral for $z>0$ by integrating around a contour enclosing the poles. Each pole will be circled in the clockwise direction and hence will contribute $-2\pi j$ times the function which multiplies the pole, evaluated at the pole.

It would be possible at this point to proceed without further approximations. However, we may note that the lowest power in which the quantity $(\delta/2u_0)$—which expresses the spread in velocity—appears is the square. Provisionally we will neglect $(\delta/2u_0)^2$ and subsequently retain similar quantities only if they appear to the first power. This means we will take

$$\beta_1 = \frac{\omega}{u_0} + \frac{\omega_p}{u_0}$$

$$\beta_2 = \frac{\omega}{u_0} - \frac{\omega_p}{u_0}. \tag{22}$$

We then find that

$$I_t = -ie^{j\omega t}\left((\omega_p/u_0)^2\left[\frac{e^{-j\beta_1 z}}{\left(\beta_1-\frac{\omega}{v}\right)(\beta_1-\beta_2)}+\frac{e^{-j\beta_2 z}}{\left(\beta_2-\frac{\omega}{v}\right)(\beta_2-\beta_1)}\right]+\left[1+\frac{(\omega_p/u_0)^2}{\left(\frac{\omega}{v}-\beta_1\right)\left(\frac{\omega}{v}-\beta_2\right)}\right]e^{-j(\omega/v)z}\right). \tag{23}$$

We see that

$$\beta_1 - \beta_2 = 2\frac{\omega_p}{u_0}, \tag{24}$$

$$\beta_1 - \frac{\omega}{v} = \epsilon\frac{\omega}{u_0} + \frac{\omega_p}{u_0} \tag{25}$$

$$\beta_2 - \frac{\omega}{v} = \epsilon\frac{\omega}{u_0} - \frac{\omega_p}{u_0}, \tag{26}$$

where

$$\epsilon = \frac{v-u_0}{v}. \tag{27}$$

Now, since δ is the total velocity spread among electrons, u_0 is the average velocity, and v lies within the range of electron velocities, ϵ is of the order of δ/u_0 and we should retain powers of ϵ up to the first only. To this approximation we obtain

$$I_t = ie^{j\omega t}e^{-j(\omega/u_0)z}\left(\cos\left(\frac{\omega_p}{u_0}z\right) + j\frac{\epsilon\omega}{\omega_p}\sin\left(\frac{\omega_p}{u_0}z\right)\right). \tag{28}$$

This is a frequency component of the total convection current in the electron stream caused by a charge of velocity differing from the mean velocity u_0 of the stream by an amount ϵu_0. The expression is valid to the first order in ϵ.

While (28) is valid to the first order in ϵ and in δ/u_0, we note that when $\cos[(\omega_p/u_0)z]$ is not zero an expansion of the expression for the amplitude of I_t in terms of powers of ϵ has no term in ϵ to the first power. Was it wrong to discard terms in $(\delta/u_0)^2$? An examination shows that the effect of including these terms is (1) to alter the arguments of the sine and cosine while leaving them equal, (2) to alter the magnitude of the cosine term by a term in $(\delta/u_0)^2$ and of the sine in a term in $(\delta/u_0)^2$ times ϵ. Thus, for any correct value of the argument which makes the cosine zero, the amplitude is given correctly to the first order in ϵ. For other values of the argument, for which the amplitude is much larger, the amplitude is not in error to the first order in (δ/u_0) or ϵ, though terms in ϵ^2 may be in error.

We should note that the special solution has no component of amplitude to the first order in ϵ.

In obtaining (28) a special velocity distribution was assumed. We should note that the location and intensity of the poles was not affected to the first order in the spread in velocity by the velocity distribution. Thus, up to (28) the answer to the first order in ϵ has really been obtained by assuming the velocity distribution to be very narrow. We might infer that to the first order in ϵ the same answer would have been obtained by going to a very narrow distribution from any reasonable distribution rather than from the particular simple one chosen.

Let us now regard (28) as correct. Let $|I_t|^2$ be the mean square amplitude of the frequency component considered,

$$|I_t|^2 = i^2\left(\cos^2\left(\frac{\omega_p}{u_0}z\right) + \epsilon^2\left(\frac{\omega}{\omega_p}\right)\sin^2\left(\frac{\omega_p}{u_0}z\right)\right). \tag{29}$$

This is the square of the total current due to an injected current of mean square amplitude i^2. Let I_n be the electron current carried by electrons with velocities in some narrow range about v_n, a velocity specified by a value ϵ_n of the parameter ϵ. The impressed noise current i_n^2 due to this current is taken as shot noise

$$i_n^2 = 2eI_nB. \tag{30}$$

At $z=0$, total current must be equal to i_n^2, so the part of $|I_t|^2$ due to electrons in this velocity range must be

$$|I_t^2|_n = 2eI_nB\left(\cos^2\left(\frac{\omega_p}{u_0}z\right) + \epsilon_n^2\left(\frac{\omega}{\omega_p}\right)^2 \sin^2\left(\frac{\omega_p}{u_0}z\right)\right). \quad (31)$$

We assume that the noises due to electrons in different velocity ranges add in a mean square manner. For the total mean square noise current we obtain

$$|I_t^2| = 2eIB\left(\cos^2\left(\frac{\omega_p}{u_0}z\right) + \overline{\epsilon^2}\left(\frac{\omega}{\omega_p}\right)^2 \sin^2\left(\frac{\omega_p}{u_0}z\right)\right) \quad (32)$$

$$I = \sum_n I_n \quad (33)$$

$$\overline{\epsilon^2} = \frac{1}{I}\sum_n I_n\overline{\epsilon_n^2} = \frac{1}{u_0^2}\sum \frac{I_n}{I}(v_n - u_0)^2 \quad (34)$$

That is, $\overline{\epsilon^2}$ is the mean square deviation in velocity divided by the square of the mean velocity.

If we assume (34) to be true, the noise at the noise minima is

$$|I_t^2|_{min} = \overline{\epsilon^2}\left(\frac{\omega}{\omega_p}\right)^2 2eIB. \quad (35)$$

These minima occur at

$$\frac{\omega_p z}{u_0} = \frac{\pi}{2} + n\pi. \quad (36)$$

V. Treated by Rack-Llewellyn-Peterson Method

According to the Rack-Llewellyn-Peterson approach, we assign to the electron convection current passing the grid both a current fluctuation $\overline{i^2}$ and a velocity fluctuation $\overline{v^2}$. The current fluctuation is just shot noise

$$\overline{i^2} = 2eI_0B. \quad (37)$$

The velocity fluctuation is the mean square fluctuation in the velocity of electrons passing the grid. In obtaining this, one considers the electron flow to be divided up into a large number of classes of electrons, the nth class having a velocity v_n and constituting a part I_n of the total current.

$$I_0 = \sum_n I_n. \quad (38)$$

Each current I_n is assumed to have a mean square fluctuation

$$\overline{i_n^2} = 2eI_nB. \quad (39)$$

The average velocity u_0 is

$$u_0 = \frac{1}{I_0}\sum_n I_n v_n. \quad (40)$$

The change in u_0 due to a change dI_n in I_n is

$$du_0 = \left(-\frac{1}{I_0^2}\frac{dI_0}{dI_n}\sum_n I_n v_n + \frac{v_n}{I_0}\right)dI_n \quad (41)$$

$$du_0 = \frac{1}{I_0}(v_n - u_0)dI_n. \quad (42)$$

From (42) and (39) we find total mean square fluctuation in the average velocity, which we will call $\overline{v^2}$, to be

$$\overline{v^2} = \frac{2eB}{I_0}\frac{1}{I_0}\sum_n I_n(v_n - u_0) \quad (43)$$

$$\overline{v^2} = \frac{2eB}{I_0}\overline{\epsilon^2}\, u_0^2. \quad (44)$$

The noise fluctuations in current and velocity will each excite a different pair of equal space-charge waves. Each wave of a pair varies with distance as $\exp j(\omega/u_0 \pm\omega_p/u_0)z$. For each wave the ratio of convection current to velocity is $\mp(\omega/\omega_p)(I_0/u_0)$. The two waves excited by the initial convection current initially have their convection currents in phase and the total convection current carried by the pair varies as $\cos(\omega_p z/u_0)$. The two waves excited by the initial velocity fluctuation initially have their convection currents opposing and the total convection current carried by these waves varies as $\sin(\omega_p z/u_0)$.

Thus shot noise (37) will excite a noise current in the beam

$$\overline{i_1^2} = 2eI_0B\cos^2\left(\frac{\omega_p z}{u_0}\right). \quad (45)$$

The velocity fluctuation (44) will excite a mean square convection current in the beam

$$\overline{i_2^2} = \left(\frac{2eB}{I_0}\overline{\epsilon^2}\, u_0^2\right)\left(\frac{\omega}{\omega_p}\frac{I_0}{u_0}\sin\left(\frac{\omega_p z}{u_0}\right)\right)^2$$

$$\overline{i_2^2} = 2eI_0B\left(\frac{\omega}{\omega_p}\right)^2\overline{\epsilon^2}\sin^2\left(\frac{\omega_p z}{u_0}\right). \quad (46)$$

The total mean square noise current is

$$\overline{i^2} = \overline{i_1^2} + \overline{i_2^2}$$

$$\overline{i^2} = 2eI_0B\left(\cos^2\left(\frac{\omega_p z}{u_0}\right) + \overline{\epsilon^2}\left(\frac{\omega}{\omega_p}\right)^2\sin^2\left(\frac{\omega_p z}{u_0}\right)\right). \quad (47)$$

This has minima at

$$\frac{\omega_p}{u_0}z = \frac{\pi}{2} + n\pi, \quad (48)$$

and the noise current at the minima is

$$\overline{i^2} = 2eI_0B\left(\frac{\omega}{\omega_p}\right)^2\overline{\epsilon^2}. \quad (49)$$

We see that (48) and (49) are the same as (36) and (35) of IV.

VI. Discussion

We have now obtained the same result by two methods. Within the assumptions made we may trust this result. What does it tell us?

For the physical system of Figure 1 there is space-charge reduction of noise at high frequencies. The noise minima occur at distances z from the grid such that

$$\frac{\omega_p z}{u_0} = \frac{\pi}{2} + n\pi, \tag{50}$$

and the noise current at the minima is

$$\overline{i^2} = 2eI_0 B\left(\frac{\omega}{\omega_p}\right)^2 \overline{\epsilon^2}. \tag{51}$$

We see that space-charge-limited emission is not necessary for space-charge reduction of noise at microwave frequencies, a fact already noted by Robinson.[2]

Consider the factor $(\omega/\omega_p)^2$. The noise minima will be deeper the larger the plasma frequency. In fact, the ratio between noise at the minima and noise at the maxima is inversely proportional to dc current density.

It is interesting to note that if N is the number of cycles drift between a current maximum and a current minimum,

$$\frac{\omega}{\omega_p} = 4N. \tag{52}$$

We see that the noise is proportional to the relative mean square velocity spread $\overline{\epsilon^2}$. Suppose that all electrons are accelerated from the cathode without interaction and by the same dc voltage V_0. For this case, if $(eV/kT)\gg 1$,

$$\overline{\epsilon^2} = \frac{1}{4}\left(\frac{kT}{eV_0}\right)^2 = \frac{1}{4}\left(\frac{T}{11{,}600V_0}\right)^2. \tag{53}$$

This is usually very small. For instance, if

$$T = 1{,}160^\circ K$$
$$V_0 = 1{,}000 \text{ volts}$$
$$\overline{\epsilon^2} = 2.5 \times 10^{-9}. \tag{54}$$

We should note, however, that $\overline{\epsilon^2}$ may be very much larger than this for a variety of reasons. In other than Brillouin flow, space-charge depression of potential can cause the central electrons to travel more slowly than the outside electrons. If we assume this spread among electrons traveling at different radii to have the same effect as the spread among electrons at the same radius, flow other than Brillouin flow might lead to increased noise.

Assume for instance that the electrons comprising a cylindrical beam of constant current density are constrained to move in the axial direction only. This may be approximated by immersing the whole structure, cathode included, in a strong constant magnetic field. In this case it can easily be shown that approximately

$$\overline{\epsilon^2} = \frac{1}{1536\pi^2\epsilon^2(e/m)}\,\frac{I_0^2}{V_0^3}$$

$$\overline{\epsilon^2} = 4.78 \times 10^6\,\frac{I_0^2}{V_0^3}. \tag{55}$$

The units are amperes and volts.

A perveance of 10^{-6}, that is, $I_0/V_0^{3/2}=10^{-6}$, is a reasonably large perveance. For this value of perveance, from (55)

$$\overline{\epsilon^2}=4.78 \times 10^{-6}.$$

Thus, the mean square deviation in velocity caused by space charge is not large.

Such experiments on noise minima as have been made[6] show minima which are not nearly as deep as those calculated above. The observed minima are for space-charge limited emission, for which the noise at the minima, as ordinarily calculated by the Rack-Llewellyn-Peterson method, is zero.

We can say that at least for the case treated the new method gives the same result as the Rack-Llewellyn-Peterson method. This indicates that there is something important missing either in the idealized case treated or in the approximations made in the analysis. More refined experiments and further mathematical analysis will presumably enlighten us as to what this is.[7]

[6] C. C. Cutler and C. F. Quate, "Experimental verification of space charge and transit time reduction of noise in electron beams," *Phys. Rev.*, vol. 80, pp. 875–878; December 1, 1950.

[7] Dean Watkins uses a power-series approach and attains the same noise at the first minimum as that calculated here in a paper, "The effect of velocity distribution in a modulated electron stream," *Jour. Appl. Phys.*, vol. 23, pp. 568–573; May, 1952, appearing since the preparation of this paper.

Standards on Receivers: Definitions of Terms, 1952*

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[1] *Chairman '51–'52.*
[2] *Chairman '49–'51.*

Adjacent-Channel Attenuation. See **Selectance.**

Adjacent-Channel Interference. Interference (q. v.) in which the extraneous power originates from a signal of assigned (authorized) type in an adjacent channel.

Amplitude Modulation (AM). Modulation in which the amplitude of a carrier is the characteristic varied.

Antenna. A means for radiating or receiving radio waves.

Aspect Ratio. In television, the ratio of the frame width to the frame height.

Audio Frequency. Any frequency corresponding to a normally audible sound wave.

Note—Audio frequencies range roughly from 15 to 20,000 cycles per second.

Automatic Gain Control. A circuit arrangement which adjusts the gain in a specified manner in response to changes in input.

Background Noise (in Receivers). The noise in the absence of signal modulation on the carrier.

Baffle. A shielding structure or partition used to increase the effective length of the external transmission path between two points in an acoustic system as, for example, between the front and back of an electroacoustic transducer.

Bandwidth. (Of a wave) The least frequency interval outside of which the power spectrum of a time-varying quantity is everywhere less than some specified fraction of its value at a reference frequency.

Caution—This definition permits the spectrum to be less than the specified fraction within the interval.

Note—Unless otherwise stated, the reference frequency is that at which the spectrum has its maximum value.

(Of a device) The range of frequencies within which performance, with respect to some characteristic, falls within specific limits.

Bar Generator. In television, the generator of pulses which are uniformly spaced in time and are synchronized to produce a stationary bar pattern on a television screen.

Beat Note. The wave of difference frequency created when two sinusoidal waves of different frequencies are supplied to a nonlinear device.

Beating. A phenomenon in which two or more periodic quantities of different frequencies produce a resultant having pulsations of amplitude.

Channel, Radio. See **Radio Channel**

Coaxial Transmission Line. A transmission line consisting of two coaxial cylindrical conductors.

Co-channel Interference. Interference between two signals of the same type in the same radio channel.

Cross-Modulation. Modulation of a desired signal by an undesired signal.

De-emphasis. A process complementary to pre-emphasis.

Delay Distortion. That form of distortion which occurs when the rate of change of phase shift with frequency of a circuit or system is not constant over the frequency range required for transmission.

Demodulation. The process of recovering the modulating wave from a modulated carrier.

Detection. See **Demodulation.**

Detector (in Receivers). (1) A device to effect the process of detection. (2) A mixer in a superheterodyne receiver.

Note—In definition (2), the device is often referred to as a "first detector" and the device is not used for detection as defined above.

Deviation Distortion. Distortion in an FM receiver caused by inadequate bandwidth, inadequate amplitude-modulation rejection, or inadequate discriminator linearity.

Deviation, Frequency. See **Frequency Deviation.**

Deviation Sensitivity (in FM Receivers). The least frequency deviation that produces a specified output power.

Distortion. An undesired change in wave form.

Downward Modulation. Modulation in which the instantaneous amplitude of the modulated wave is never greater than the amplitude of the unmodulated carrier.

Dummy Antenna. A device which has the necessary impedance characteristics of an antenna and the necessary power-handling capabilities, but which does not radiate or receive radio waves.

Note—In receiver practice, that portion of the impedance not included in the signal generator is often called "dummy antenna."

Dummy Load. A dissipative but essentially nonradiating substitute device.

Electric (Magnetic) Field Strength. The magnitude of the electric (magnetic) field vector.

Fidelity. The degree with which a system, or a portion of a system, accurately reproduces at its output the essential characteristics of the signal which is impressed upon its input.

Field Strength, Electric or Magnetic. See **Electric (Magnetic) Field Strength.**

Flutter. In communication practice, (1) distortion due to variations in loss resulting from the simultaneous transmission of a signal at another frequency, (2) a similar effect due to phase distortion, or (3) distortion which occurs in sound reproduction as a result of undesired speed variations during the recording, duplicating, or reproducing.

Free-Running Frequency. The frequency at which a normally synchronized oscillator operates in the absence of a synchronizing signal.

Frequency Departure. The amount of variation of a carrier frequency or center frequency from its assigned value.

Note—The term "frequency deviation" which has been used for this meaning, is in conflict with this essential term as applied to phase and frequency modulation, and is therefore deprecated for future use in the above sense.

Frequency Deviation. In frequency modulation, the peak difference between the instantaneous frequency of the modulated wave and the carrier frequency.

Frequency Modulation (FM). Angle modulation of a sine-wave carrier in which the instantaneous frequency of the modulated wave differs from the carrier frequency by an amount proportional to the instantaneous value of the modulating wave.

Note—Combinations of phase and frequency modulation are commonly referred to as "frequency modulation."

Harmonic Distortion. Nonlinear distortion characterized by the appearance in the output of harmonics other than the fundamental component when the input wave is sinusoidal.

Hum. Interference at power supply frequency or harmonic thereof.

Hum Modulation. Modulation of a radio-frequency or detected signal by hum.

IF. See **Intermediate Frequency.**

Image Frequency. In heterodyne frequency converters in which one of the two sidebands produced by beating is selected; an undesired input frequency capable of producing the selected frequency by the same process.

Note—The word "image" implies the mirror-like symmetry of signal and image frequencies about the beating oscillator frequency or the intermediate frequency, whichever is the higher.

Image Ratio. The ratio of (1) the field strength at the image frequency to (2) the field strength at the desired frequency, each field being applied in turn, under specified conditions, to produce equal outputs.

Intercarrier Sound. The method employed in those television receivers which make use of the television picture carrier and the associated sound carrier to produce a frequency-modulated signal whose center frequency is equal to the difference between the two carrier frequencies.

Interference. In a signal transmission system either extraneous power which tends to interfere with the reception of the desired signals, or the disturbance of signals which results.

Intermediate Frequency (IF). The frequency in superheterodyne reception resulting from a frequency conversion before demodulation.

Intermediate-Frequency-Harmonic Interference (in Superheterodyne Receivers). Interference due to radio-frequency-circuit acceptance of harmonics of an intermediate frequency signal.

Intermediate-Frequency Interference Ratio. See **Intermediate-Frequency Response Ratio.**

Intermediate-Frequency Response Ratio. The ratio of (1) the field strength at a specified frequency in the intermediate frequency band to (2) the field strength at the desired frequency, each field being applied in turn, under specified conditions, to produce equal outputs.

Intermodulation. The modulation of the components of a complex wave by each other in a nonlinear system.

Limiter. A transducer whose output is constant for all inputs above a critical value.

Note—A limiter may be used to remove amplitude modulation while transmitting angle modulation.

Limiting. The action performed upon a signal by a limiter.

Local Oscillator. An oscillator whose output is mixed with a wave for frequency conversion.

Loudspeaker. An electroacoustic transducer usually intended to radiate acoustic power effectively at a distance in air.

Masking (Audio). The amount by which the threshold of audibility of a sound is raised by the presence of another (masking) sound. The unit customarily used is the decibel.

Maximum-Deviation Sensitivity (in FM Receivers). Under maximum system deviation, the least signal input for which the output distortion does not exceed a specified limit.

Maximum Output (in Receivers). The greatest average output power into the rated load regardless of distortion.

Maximum Sensitivity (in FM Systems). The least signal input that produces a specified output power.

Maximum System Deviation (FM Systems). The greatest frequency deviation specified in the operation of the system.

Note—In the case of FM broadcast systems in the range from 88 to 108 megacycles per second, the maximum system deviation is 75 kilocycles per second.

Maximum Undistorted Output (Maximum Useful Output). For sinusoidal input, the greatest average output power into the rated load with distortion not exceeding a specified limit.

Microphone. An electroacoustic transducer which responds to sound waves and delivers essentially equivalent electric waves.

Modulating Signal (Modulating Wave). A wave which causes a variation of some characteristic of a carrier.

Modulation. The process or result of the process whereby some characteristic of one wave is varied in accordance with another wave.

Modulation Factor. The ratio of the peak variation actually used to the maximum design variation in a given type of modulation.

Note—In conventional amplitude modulation the maximum design variation is considered that for which the instantaneous amplitude of the modulated wave reaches zero.

Monoscope. A signal-generating, electron-beam tube in which a picture signal is produced by scanning an electrode. parts of which have different secondary-emission characteristics.

Noise Factor (Noise Figure). Of a linear system at a selected input frequency, the ratio of (1) the total noise power per unit bandwidth (at a corresponding output frequency) available at the output terminals, to (2) the portion thereof engendered at the input frequency by the input termination, whose noise temperature is standard (290°K) at all frequencies. (See **Noise Temperature.**)

Note 1—For heterodyne systems there will be, in principle, more than one output frequency corresponding to a single input frequency, and vice versa; for each pair of corresponding frequencies a noise factor is defined.

Note 2—The phrase, "available at the output terminals," may be replaced by "delivered by the system into an output termination," without changing the sense of the definition.

Noise Factor (Noise Figure), Average. Of a linear system, the ratio of (1) the total noise power delivered by the system into its output termination when the noise temperature of its input termination is standard (290°K) at all frequencies to (2) the portion thereof engendered by the input termination. For heterodyne systems, portion (2) includes only that noise from the input termination which appears in the output via the principal frequency transformation of the system, and does not include spurious contributions such as those from image-frequency transformations.

Note 1—A quantitative relation between Average Noise Factor, $\bar{F}$ and Spot Noise Factor, $F(f)$ is

$$\bar{F} = \frac{\int_0^\infty F(f)G(f)df}{\int_0^\infty G(f)d},$$

where f is the input frequency and $G(f)$ is the ratio of (a) the signal power delivered by the system into its output termination to (b) the corresponding signal power available from the input termination at the input frequency. For heterodyne systems, (a) comprises only power appearing in the output via the principal frequency transformation of the system; in other words, power via image-frequency transformations is excluded.

Noise Factor (Noise Figure), Spot. See Noise Factor. Used where it is desired to *emphasize* that the noise factor is a point function of input frequency.

Noise Temperature. At a pair of terminals and at a specific frequency, the temperature of a passive system having an available noise power per unit bandwidth equal to that of the actual terminals.

Noise Temperature (Standard). The standard reference temperature T_0 for noise measurements is taken as 290 degrees K.

Note—$kT_0/e=0.0250$ volt, where e is the electron charge and k is Boltzmann's constant.

Nonlinear Distortion. Distortion caused by a deviation from a desired linear relationship between specified measures of the output and input of a system.

Note—The related measures need not be output and input values of the same quantity; e.g., in a linear detector, the desired relation is between the output signal voltage and the input modulation envelope.

Oscillator. A nonrotating device for producing alternating current, the output frequency of which is determined by the characteristics of the device.

Percentage Modulation. The modulation factor expressed as a percentage.

Phase Modulation (PM). Angle modulation in which the angle of a sine-wave carrier is caused to depart from the carrier angle by an amount proportional to the instantaneous value of the modulating wave.

Note—Combinations of phase and frequency modulation are commonly referred to as "frequency modulation."

Pickup. (1) A device that converts a sound, scene, or other form of intelligence into corresponding electric signals (e.g., a microphone, a television camera, or a phonograph pickup). (2) The minimum current, voltage, power, or other value at which a relay will complete its intended function. (3) Interference from a nearby circuit or system.

Pre-emphasis. A process in a system to emphasize the magnitude of some frequency components with respect to the magnitude of others.

Quieting Sensitivity (in FM Receivers). The least signal input for which the output signal-noise ratio does not exceed a specified limit.

Radio Channel. A band of radio frequencies allocated for a radio transmission.

Radio Frequency. A frequency at which coherent electromagnetic radiation of energy is useful for communication purposes.

Radio Receiver. A device for converting radio waves into perceptible signals.

Retrace Line. The line traced by the electron beam in a cathode-ray tube in going from the end of one line or field to the start of the next line or field.

Ringing. An oscillatory transient occurring in the output of a system as a result of a sudden change in input.

Ripple. The ac component from a dc power supply arising from sources within the power supply.

Note—Unless otherwise specified, per cent ripple is the ratio of the root-mean-square value of the ripple voltage to the absolute value of the total voltage, expressed in per cent.

Root-Sum-Square. The square root of the sum of the squares.

Note—Commonly used to express the total harmonic distortion.

Rumble, Turntable. See **Turntable Rumble.**

Second-Channel Interference. Interference (q. v.), in which the extraneous power originates from a signal of assigned (authorized) type in a channel two channels removed from the desired channel.

Second-Channel Attenuation. See **Selectance.**

Selectance. The reciprocal of the ratio of the sensitivity of a receiver tuned to a specified channel to its sensitivity at another channel separated by a specified number of channels from the one to which the receiver is tuned.

Note 1—Unless otherwise specified, selectance should be expressed as a voltage or field-strength ratio.

Note 2—Selectance is often expressed as "adjacent-channel attenuation" (ACA) or "second-channel attenuation" (2 ACA).

Selectivity (of a Receiver). That characteristic which determines the extent to which the receiver is capable of differentiating between the desired signal and disturbances of other frequencies.

Sensitivity. The least signal input capable of causing an output signal having desired characteristics.

Sidebands. (1) The frequency bands on both sides of the carrier frequency within which fall the frequencies of the wave produced by the process of modulation. (2) The wave components lying within such bands.

Note—In the process of amplitude modulation with a sine-wave carrier, the upper sideband includes the sum (carrier plus modulating) frequencies; the lower sideband includes the difference (carrier minus modulating) frequencies.

Speaker. See **Loudspeaker.**

Spurious Response Ratio. The ratio of (1) the field strength at the frequency which produces the spurious response to (2) the field strength at the desired frequency, each field being applied in turn, under specified conditions, to produce equal outputs.

Note—**Image Ratio** and **Intermediate Frequency Response Ratio** are special forms of **Spurious Response Ratio.**

Square Wave. A wave which alternately assumes two fixed values for equal lengths of time, the time of transition being negligible in comparison with the duration of each fixed value.

Squelch. To automatically quiet a receiver by reducing its gain in response to a specified characteristic of the input.

Tracking. (1) The maintenance of proper frequency relations in circuits designed to be simultaneously varied by gang operation, (2) the process of keeping radio beams set on a target, or (3) the following of a groove by a phonograph needle.

Transfer Characteristic (in Electron Tubes). A relation, usually shown by a graph, between the voltage of one electrode and the current to another electrode, all other electrode voltages being maintained constant.

Tube (Electron). An electron device in which conduction by electrons takes place through a vacuum or gaseous medium within a gas-tight envelope.

Tube, Vacuum. See **Vacuum Tube.**

Turntable Rumble. Low-frequency vibration mechanically transmitted to the recording or reproducing turntable and superimposed on the reproduction.

Vacuum Tube. An electron tube evacuated to such a degree that its electrical characteristics are essentially unaffected by the presence of residual gas or vapor.

Video. A term pertaining to the bandwidth and spectrum position of the signal resulting from television scanning.

Note—In current usage, video means a bandwidth in the order of megacycles per second, and a spectrum position that goes with a dc carrier.

Wow. A low-frequency flutter.

An Antenna Impedance-Measuring Instrument*

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Summary—**This paper describes an antenna impedance-measuring instrument of the indicating type, designed to have a small capacitive loading effect when connected directly to the terminals of an antenna. The model constructed operates at freqencies up to 30 mc and has a loading effect no greater than that of a conducting sphere 1.5 inches in radius. It appears feasible to extend these limits considerably merely by mechanical refinement.**

The smallness in effective size is obtained by isolating those conducting components of the instrument which are not part of the RF circuit and by operating the antenna under test as a receiving antenna so that the instrument does not have to contain a signal generator. No power or control wires are connected to the instrument, and it is possible for the operator to remain outside the immediate field of the antenna during the measuring process.

Introduction

It is useful to be able to measure the impedance of an antenna with the measuring equipment connected directly to the antenna terminals. One of the problems encountered when this is tried is that the presence of the measuring equipment may alter the value of the impedance being measured. This impedance alteration is associated with the effects of the equipment upon the electric and magnetic fields of the antenna. It is usually found that more difficulty is encountered when the equipment is connected to points in the antenna where the RF charge density is relatively high. This suggests that the problem is primarily one of reducing the capacitive loading effect rather than one of reducing the effect upon the magnetic field.

Other things being equal, the capacitive loading effect of any instrument becomes smaller as its physical size is reduced. There are at least two ways in which the physical size can be reduced. One way is to make each of the component parts of the instrument as small as possible. Another way is to adopt a principle of operation which allows the instrument to work with a minimum number of these component parts. The latter method is the one which has received primary attention in the design of the instrument described in this paper, although the former has not been neglected.

In the instrument described here, the number of component parts has been reduced by removing the signal generator from the measuring circuit and connecting it to an auxiliary loop some distance away, so that the antenna under test acts as a receiving antenna. Also, those conducting parts of the instrument not intended to be part of the RF circuit have been insulated from it, so that the effective size of the instrument is considerably less than the actual size.

The effective size of an instrument may be measured by a comparison method, using conducting spheres of different radii as standards. A dipole antenna about 5 meters long is suspended from the ceiling of the laboratory and its resonant frequency in this position is measured by means of a grid-dip meter. The instrument is then placed in contact with the dipole at a point about 1 meter from an end and the change in the resonant frequency of the system is noted. The instrument is then removed and spheres of different sizes are substituted for it until one is found which produces the same change in the resonant frequency. In this way, the instrument described here was found to have the same loading effect as that of a conducting sphere 1.5 inches in radius.

The instrument is one of the indicating type, rather than the null type, and is consequently not highly precise. However, when compared with a high-quality conventional RF bridge in the measurement of circuit components, results are in agreement within a few per cent. It should be noted that the same conventional bridge, because of its large size and consequent loading effect, could not begin to compete with this instrument when connected directly to an antenna at any point outside of the region of low RF charge density.

Principle of Operation

The operating principle is based upon the reactance variation method[1] of impedance measurement, with the antenna under test acting as a receiving antenna. The signal generator is connected to a transmitting loop located far enough away so that the presence of the loop does not affect the value of the impedance being measured. If the loop current remains or is held constant, the antenna under test may be treated as a constant voltage generator connected in series with an internal impedance which is the unknown in question.[2,3] The concept of the internal impedance of an antenna does not depend upon the direction from which the radio waves arrive, so that accurate placement of the loop with respect to the antenna is not important.

The equivalent circuit of the antenna and the instrument is shown in Fig. 1. The voltage which is induced by the loop current is represented by the symbol E. Its value is not important as long as it remains constant.

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[1] D. B. Sinclair, "Parallel-resonance methods for precise measurements of high impedances at radio frequencies and a comparison with the ordinary series-resonance methods," Proc. I.R.E., vol. 26, p. 1466; December, 1938. (See especially the bibliography accompanying this article.)

[2] F. E. Terman, "Radio Engineering," McGraw-Hill Book Co., Inc., New York, N. Y., 3rd ed., pp. 725–728; 1947.

[3] J. R. Carson, "Reciprocal theorems in radio communication," Proc. I.R.E., vol. 17, p. 952; June, 1929.

The unknown resistance and reactance are represented by the symbols R and X. The two equal capacitive reactances marked X_c are known values with respect to which the other values are normalized in the solution. The symbols R_1 and X_1 represent the total series resistance and reactance of the instrument when the switch is in position 1. These values are associated with stray effects and the meter circuit, which is more complicated than the simple meter symbol might suggest.

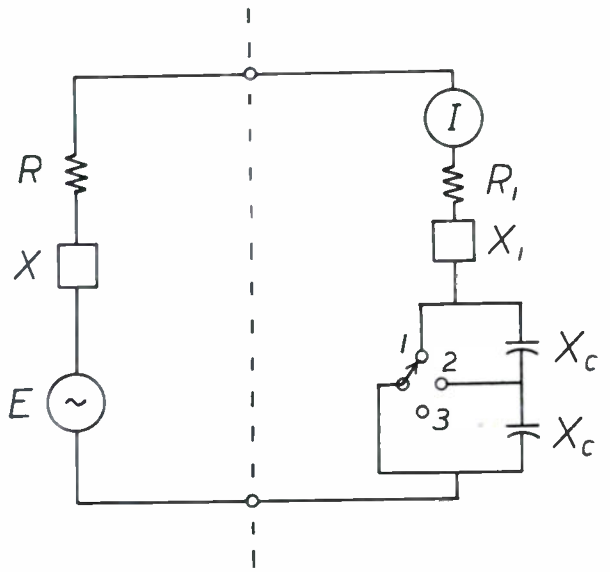

Fig. 1—The equivalent circuit of the antenna is at the left and that of the instrument at the right. The two equal capacitive reactances marked X_c are the standards.

The three-position switch is driven slowly through a repeating sequence by a small battery-operated motor, and the relative current values are noted by the operator. The ratios of these relative current values are used with a special graph to find the values of R and X, normalized with respect to X_c. For each switch position, an expression can be written for the magnitude of the current, as in (1), (2), and (3), where the subscripts correspond to the switch position numbers:

$$I_1 = \frac{E}{\sqrt{(R+R_1)^2+(X+X_1)^2}} \tag{1}$$

$$I_2 = \frac{E}{\sqrt{(R+R_1)^2+(X+X_1-X_c)^2}} \tag{2}$$

$$I_3 = \frac{E}{\sqrt{(R+R_1)^2+(X+X_1-2X_c)^2}}. \tag{3}$$

These three equations can be combined into a more useful form by defining

$$A = \frac{I_1}{I_2} \tag{4}$$

and

$$B = \frac{I_3}{I_2} \tag{5}$$

and re-arranging as shown in (6) and (7):

$$\left(\frac{R+R_1}{X_c}\right)^2+\left(\frac{X+X_1}{X_c}-\frac{1}{1-A^2}\right)^2=\left(\frac{A}{1-A^2}\right)^2 \tag{6}$$

$$\left(\frac{R+R_1}{X_c}\right)^2+\left(\frac{X+X_1}{X_c}-\frac{1-2B^2}{1-B^2}\right)^2=\left(\frac{B}{1-B^2}\right)^2. \tag{7}$$

Equations (6) and (7) lead to a simple graphical solution since each represents a family of circles in a normalized resistance-reactance plane. This can be seen by comparing them with the familiar equation for a circle in the x-y plane,

$$(x-x')^2+(y-y')^2=r^2, \tag{8}$$

where x' and y' are the co-ordinates of the center point and r is the radius of the circle.

Inspection of (6) and (7) reveals that the A and B circles have equal radii for the condition $A=B$. In addition, simultaneous solution of (6) and (7) gives the line $(X+X_1)/X_c=1$ as the locus of intersections of the circles for the same condition. Further inspection reveals that the centers of all circles lie on the line $(R+R_1)/X_c=0$. From these three facts it follows that the A and B families of circles are images of each other with respect to the line $(X+X_1)/X_c=1$ and that each family is the image of itself with respect to the line $(R+R_1)/X_c=0$. This means that each of the four quarter-planes bounded by these two lines contains the same information, so that a single quarter-plane will suffice as a basis for a graphical solution.

A graph covering the most important part of one of these quarter-planes is shown in Fig. 2, in which the locus of centers lies along the right-hand edge and the image axis for the A and B pairs of circles lies along the bottom. Values of A and B, determined experimentally by using the instrument, are used to locate a datum point on the graph, and the normalized resistance and reactance are then read directly from the scales along the bottom and left side. When B exceeds A, the solid circles represent B values, the dashed circles represent A values, and reactance scale No. 1 is used. When A exceeds B, the reverse is true and reactance scale No. 2 is used. The encircled labels along the bottom edge apply to both the solid and the dashed circles, while those along the sides and top apply to the solid circles only.

Once the equipment has been set up and adjusted, the procedure for operating the instrument consists of the following four steps:

1. Note the values of I_1, I_2, and I_3 during the switching cycle, and evaluate A and B according to (4) and (5).
2. Use these values of A and B and the graph in Fig. 2 to evaluate $(R+R_1)/X_c$ and $(X+X_1)/X_c$.
3. Multiply by X_c to obtain $(R+R_1)$ and $(X+X_1)$.
4. Subtract R_1 and X_1 to obtain R and X.

In connection with step 2, if it is found that the datum point does not fall within the graph, the impedance range of the instrument is changed by changing the standard capacitors, or else standard elements are placed in series or parallel with the unknown in the same way as with other measuring instruments. In connection with step 4, it is interesting to observe that both R_1 and X_1 are very small in the model of the instrument which has been constructed, making it possible to omit the last step in many cases.

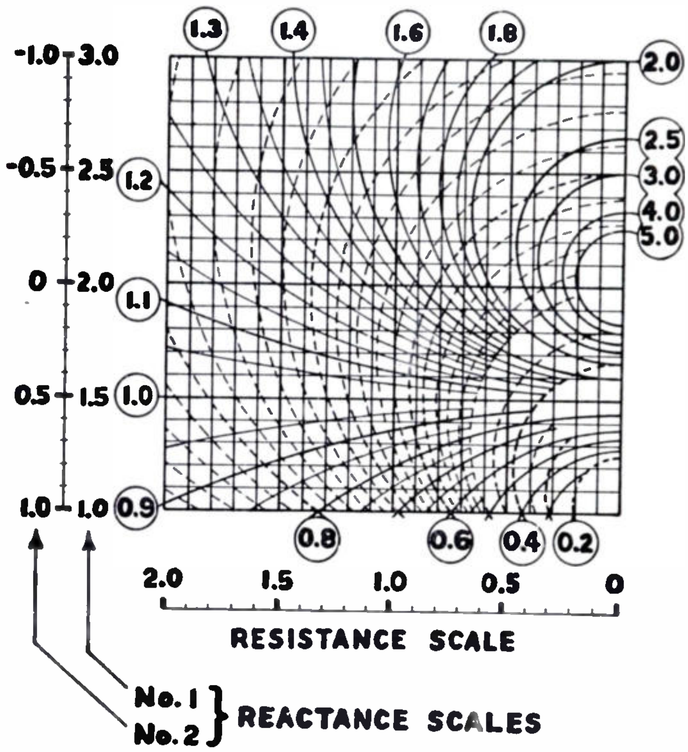

Fig. 2—This graph is used to find the normalized resistance and reactance after A and B have been evaluated from (4) and (5).

When this procedure is followed, it is important that the loop current remain constant. If the operator observes that the loop current does not change during the switching cycle, he has some assurance that the presence of the loop is not altering the value of the impedance being measured. If the spacing between antenna and loop is close, the distribution of current around the loop may change during the switching cycle in such a way that there is no apparent current change at one point on the loop while there may be a change at another point. To guard against such an occurrence, in cases where close spacing is necessary, two or more loop meters should be used.

An alternative method for evaluating A and B in step 1 of the above procedure consists of adjusting the loop current so that the antenna current remains constant during the switching cycle. If the three values of loop current corresponding to the three switch positions are denoted as I_{L1}, I_{L2}, and I_{L3}, respectively, A and B may be redefined as

$$A = \frac{I_{L2}}{I_{L1}} \tag{8}$$

and

$$B = \frac{I_{L2}}{I_{L3}}. \tag{9}$$

This procedure has the disadvantage of always requiring adjustment of the loop current during the switching cycle, and it does not avoid the spacing difficulty; but it has the advantage of placing the well-calibrated meter in the more accessible loop rather than in the instrument. This may be important in cases where the presence of the operator near the antenna affects the value of the antenna impedance, so that the instrument has to be observed through a telescope. In such cases, the meter in the instrument can be designed to have a greatly expanded upper scale with perhaps only one mark other than zero, and (8) and (9) can be used to evaluate A and B. Steps 2, 3, and 4 of the procedure are not changed.

It should be pointed out that this instrument and procedure can be used to measure the impedance of circuit components as well as of antennas. This is done by placing the unknown, the instrument, and a signal generator in a closed-series circuit, holding the generator terminal voltage constant and following the procedure first outlined.

Physical Description

A photograph of the instrument is shown in Fig. 3. It consists of two main parts, the circuit unit at the extreme right and the motor-indicator unit at the left and center. From an RF standpoint, these two units are insulated from each other. The circuit unit contains

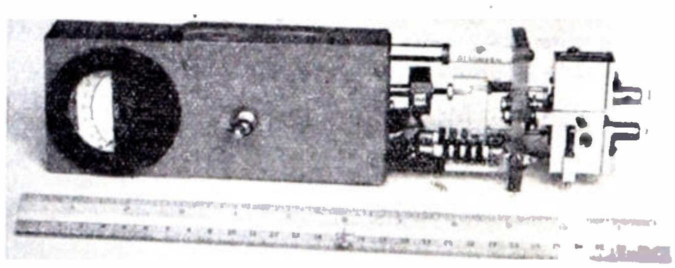

Fig. 3—The circuit unit is at the extreme right. Direct current from the germanium diode inside this unit flows through the two RF choke coils to the meter at the left. The motor and cam are in the central box and the cam action is carried to the circuit unit through the plastic linkage.

the two standard capacitors, the three-position switch, and a capacitance-shunted germanium diode used to convert RF to dc. The dc is carried through the two visible RF choke coils to the specially calibrated dc microammeter at the left.

The motor-indicator unit contains the battery, motor, gear train, and cam which actuate the three-position switch. The mechanical action of the cam is carried to the switch through the plastic linkage visible between the two units. A rotating drum projecting from the motor-indicator unit has its cylindrical surface marked so that the operator can readily identify each meter indication with the proper switch position. Position 2 presents itself in this picture.

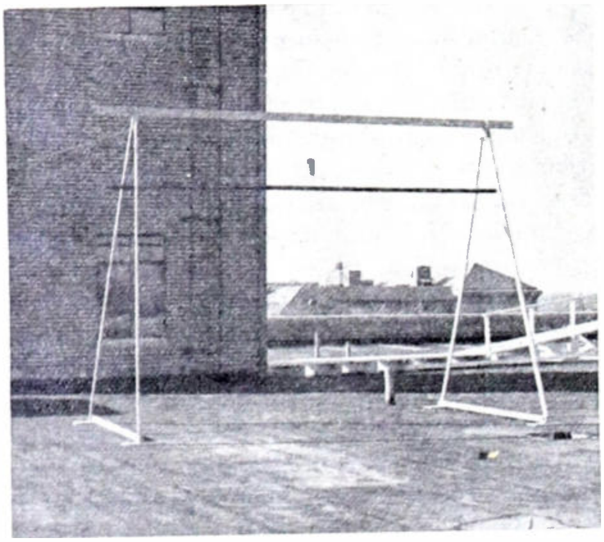

Fig. 4—A dipole antenna mounted in a wooden frame for measurements at 30 mc. The signal generator and loop are inside the brick structure in the background. The roof beneath the frame is covered with wire screen

Fig. 4 shows a dipole antenna in a wooden test frame undergoing measurements near 30 mc. The dipole is made of 2-inch copper pipe, and the instrument is barely visible just above the center of the dipole. Both the instrument and the dipole are suspended from the test frame by common string. The roof of the building beneath the frame is covered with wire screen. The brick structure in the background houses both the signal generator and the loop. The loop is made of $\frac{1}{2}$-inch copper tubing formed into a circle about 4 feet in diameter, and it is mounted in a horizontal plane at about the same height as the dipole under test.

In the case pictured here, the spacing between the antenna and the loop is quite small—only about one wavelength. Generally, a somewhat greater spacing is recommended. However, it is worth noting that in the particular situation pictured here, the loop current is not apparently altered by the cycling of the instrument switch. No investigation has been made to determine whether this beneficial effect is due primarily to absorption in the brick walls or to the characteristics of the signal circuit.

The signal generator used in these measurements is a 100-watt radio transmitter of standard design. The possibility of using lower power, like the possibility of using greater spacing, is limited by the sensitivity of the instrument. Sensitivity was sacrificed in the design of this instrument because it was desired that the values of R_1 and X_1, mentioned previously, be small fractions of one ohm and because the relatively powerful signal generator was available. Full-scale deflection of the meter corresponds to an RF antenna current of about 50 ma and separation is limited to less than 100 feet. Presumably, it should not be difficult to increase the separation-to-power ratio considerably by quite simple techniques.

In the matter of frequency limitation, the model constructed is easily operated at frequencies up to about 40 mc. Above this frequency, stray inductance and capacitance affect the operation to the point where several corrections have to be made to the values of X_1 and X_0 and to the meter calibration for different switch positions. Consequently, the procedure is tedious at higher frequencies. However, it should be noted that no unusual problems in fabrication of parts arose in the construction of the instrument, so that it should not be difficult for a machinist of average skill to construct a model suitable for higher frequencies simply by making smaller parts and taking reasonable care in assembly.

Conclusion

The advantage in measuring the impedance of an antenna while operating it as a receiving antenna rather than as a transmitting antenna is that the measuring equipment can be made smaller. This is true because the equipment connected to the antenna no longer includes a signal generator. Making the measuring equipment smaller means that it can be connected directly to the terminals of an antenna without having an undue capacitive loading effect. The measuring procedure used with the instrument described here is relatively simple and direct, and the degree of accuracy, while not comparable with that of null methods, is reasonably high.

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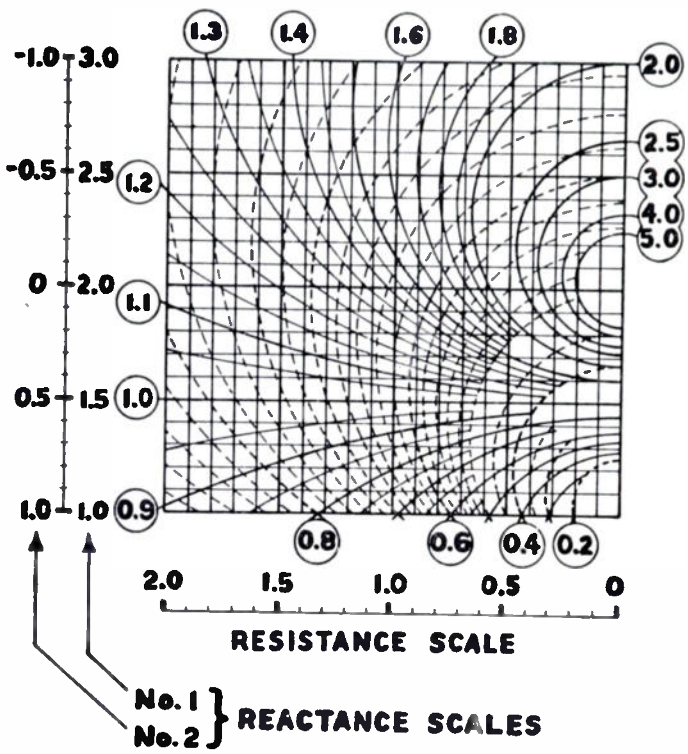

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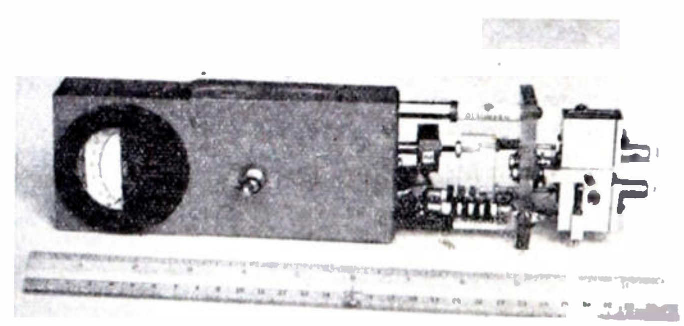

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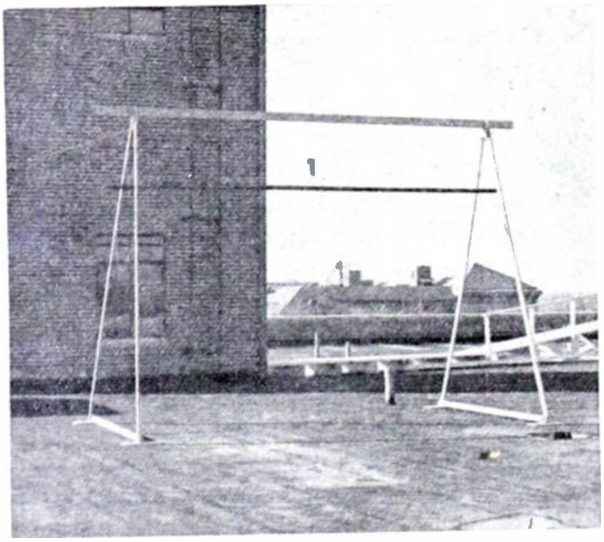

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The Determination of Impedance with a Double-Slug Transformer*

R. C. ELLENWOOD† AND E. H. HURLBURT†, ASSOCIATE, IRE

Summary—Formulas are derived and techniques given by means of which impedance measurements can be made by the use of a double-slug transformer. The required parameters are the length, spacing, position, and "effective" dielectric constant of the slugs, and the wavelength. A means for the experimental determination of the "effective" dielectric constant is described. The only quantitative measurements required are of length. A qualitative recognition of the electrically matched condition is needed.

I. Introduction

DIELECTRIC double-slug transformers have been widely used for some time as broad-band impedance matching devices in both waveguide and coaxial transmission lines. The impedance transformation needed to match a given load is accomplished by inserting two dielectric slugs in the transmission line and adjusting their relative positions until the field reflected from the slugs cancels that reflected from the load.

The lengths of the dielectric slugs are chosen so as to effectively correspond to one-quarter of a wavelength at the center of the frequency band for which the transformer is designed. This frequency will be described as the "center frequency." For the coaxial transmission line the free-space "center-frequency" wavelength λ_c is equal to $4a\sqrt{\epsilon}$, where a is the length of each slug and ϵ is the dielectric constant. For the rectangular waveguide, we have

$$\lambda_c = \frac{4a\sqrt{\epsilon}}{\sqrt{1 + \left(\frac{2a}{w}\right)^2}},$$

where w is the width of this guide.

Analyses of the parameters of the double-slug transformer in terms of the load being matched for the center-frequency case have been made by Moreno,[1] and Tomiyasu.[2] These analyses have shown that at center frequency the transformer can match loads having values of vswr (voltage-standing-wave ratio) less than or equal to ϵ^2. The results of these analyses are of limited use in making impedance measurements, as they only apply to the center-frequency case. In this paper a more general analysis is made, whereby the calculations of the impedance can be made for any frequency. They have been experimentally applied only over the range 0.5 to 1.5 of the center frequency. A further advantage in this analysis permitting the use of frequencies removed from the center frequency is, as will be shown, that a self-calibrating measurement of the "effective" dielectric constant of the device can be made.

The double-slug transformer offers certain advantages over other types of impedance-measuring instruments, particularly the slotted line. Foremost is the fact that the only electrical measurement required is the recognition of a matched condition, whereas the slotted line requires the evaluation of the relative magnitudes of electric fields. New and improved devices,[3] including directional couplers, magic tees, multi-arm bridges, multi-probe systems, used with movable, "reflectionless" loads,[4] have made the determination of a matched condition to the required degree of accuracy a relatively simple problem. Further advantages of this instrument were found in the course of the measurements, where it appeared that the effects of lateral motions of the slugs and irregularities in the conductors produced no detectable effects, whereas similar effects produce serious disturbances in the results obtained from a slotted line. It should be pointed out that the width of the narrow slot of the double-slug transformer employed could be reduced as it serves only a mechanical need. Of course, since the instrument requires no probe, errors from that source disappear. An additional advantage in the coaxial application of this device is that the slugs themselves serve as supports for the center conductor. Thus, the length of the instrument can be increased and measurements made at lower frequencies. In a precise slotted line the sag of an unsupported center conductor limits the length of the instrument and sets a minimum usable frequency.

The principal disadvantage in the method is that an accurate measurement of the "effective" dielectric constant must be made. An error in this determination can be the most serious cause of error in an impedance measurement.

II. Derivation of Formulas

The determination of an arbitrary impedance by a double-slug transformer requires suitable expressions which are dependent only upon the measurable parameters of the transformer. The normalized impedance of Z of any load can be expressed as[5] $Z = R + jX = \coth\theta = \coth(\rho + j\phi)$. If S is the length of transmission line from the load to a voltage minimum, transformed nor-

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† U. S. Department of Commerce, National Bureau of Standards, Washington 25, D. C.

[1] T. Moreno, "Microwave Transmission Design Data," McGraw-Hill Book Co., Inc., New York, N. Y., pp. 108–110; 1948.

[2] K. Tomiyasu, "A Technical Memorandum on Double-Slug Impedance Matching," T. M. 6 Cruft Laboratory, Harvard University, Cambridge, Mass.; August, 1949.

[3] E. Ginzton and P. Goodwin, "A note on coaxial Bethe-hole directional couplers," Proc. I.R.E., vol. 38, pp. 305–309; March, 1950.

[4] R. Grantham, "A reflectionless waveguide termination," *Rev. Sci. Inst.*, vol. 22, pp. 828–834; November, 1951.

[5] R. King, "Transmission-line theory and its application," *Jour. Appl. Phys.*, vol. 14, pp. 570–600; November, 1943.

malized impedance looking in at this minimum will be $Z_s = R_s = \coth\ \theta_s = \coth\ (\rho + k_0 S + j\phi)$, where $k_0 = \alpha_0 + j\beta_0$ is the complex propagation constant for an air-filled transmission line, either coaxial or waveguide. Now at a voltage minimum we have $Z_s = 1/r$, where r = vswr, and the phase angle appearing in the hyperbolic cotangent must be $\pi/2$. Hence, we may also write $Z_s = \coth\ (\rho_s + j\pi/2) = 1/\coth\ \rho_s = 1/r$. Equating the real and imaginary parts of these relations, we have $\rho_s = \rho + \alpha_0 S$ and $\phi + \beta_0 S = \pi/2$. For a transmission line of either kind filled with a dielectric other than air, the complex propagation constant is $k = \alpha + j\beta$ and the dielectric constant may be regarded as complex, being $\epsilon = \epsilon' - j\epsilon''$.

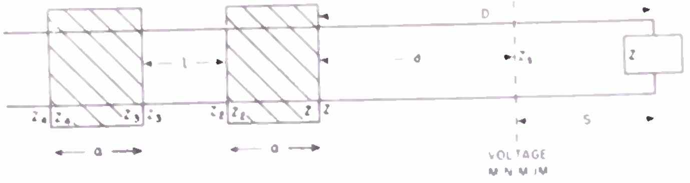

Fig. 1—Dielectric slugs inserted in an arbitrary transmission line terminated with an impedance Z.

If a load Z is attached to the double-slug transformer as shown in Fig. 1, the normalized impedances presented on each side of the four boundaries may be written as:

$$Z_1 = \coth\ \theta_1 = \coth\ (\theta_s + k_0 d)$$
$$= \coth\ [\rho_s + \alpha_0 d + j(\pi/2 + \beta_0 d)],$$

$$Z_1' = \coth\ \theta_1' = \sqrt{\epsilon}\, Z_1 = \sqrt{\epsilon} \coth\ \theta_1 = \sqrt{\epsilon} \coth\ (\theta_s + k_0 d),$$
$$Z_2' = \coth\ \theta_2' = \coth\ (\theta_1' + ka),$$

$$Z_2 = \coth\ \theta_2 = \frac{1}{\sqrt{\epsilon}} Z_2' = \frac{1}{\sqrt{\epsilon}} \coth\ \theta_2',$$

$$Z_3 = \coth\ \theta_3 = \coth\ (\theta_2 + k_0 l),$$

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$$Z_4' = \coth\ \theta_4' = \coth\ (\theta_3' + ka),$$

$$Z_4 = \coth\ \theta_4 = \frac{1}{\sqrt{\epsilon}} Z_4' = \frac{1}{\sqrt{\epsilon}} \coth\ \theta_4',$$

where the unprimed Z's are normalized impedances in the air-filled line and the primed Z's are normalized impedances in the dielectric filled line, taken at each interface. The length of each slug is a, the distance between the slugs is l, and the distance from the first slug to the voltage minimum is d. If the transformer is adjusted by varying l and d so that a matched condition prevails to the left of the fourth boundary, we will have $Z_4 = 1$.

These eight equations, together with the expression for Z_s given previously, may be combined to give:

$$\frac{1 + r \coth\ k_0 d + \sqrt{\epsilon}\, r \coth\ ka + \sqrt{\epsilon} \coth\ ka \coth\ k_0 d}{\sqrt{\epsilon}\, r + \sqrt{\epsilon} \coth\ k_0 d + \coth\ ka + r \coth\ ka \coth\ k_0 d}$$
$$= \frac{\epsilon \coth\ ka \coth\ k_0 l - \sqrt{\epsilon} \coth\ k_0 l - \epsilon \coth\ ka + \epsilon\sqrt{\epsilon}}{\sqrt{\epsilon} \coth\ ka \coth\ k_0 l - \epsilon \coth\ k_0 l + 1 - \sqrt{\epsilon} \coth\ ka}, \qquad (1)$$

where all Z's and θ's have been eliminated, Z_4 being unity as indicated above. While r could be evaluated from the above equation, some simplifying assumptions can be made without serious loss of accuracy. First, the air-filled transmission line may be assumed lossless. Then $\alpha_0 = 0$ and $k_0 = j\beta_0$, $\coth\ k_0 d = -j \cot\ \beta_0 d$, and $\coth\ k_0 l = -j \cot\ \beta_0 l$. The second simplifying assumption is that the dielectric material itself is lossless. In this case $\epsilon'' = 0$ and $\alpha = 0$ so that $\epsilon = \epsilon'$, $k = j\beta$ and $\coth\ ka = -j \cot\ \beta a$.

The introduction of these simplifications into (1) permits a ready separation of the real and imaginary terms into two separate equations, each of which is solved for $\cot\ \beta_0 d$. By eliminating $\cot\ \beta_0 d$ between these equations, the following quadratic equation in r is obtained:

$$r^2 - (b + 2)r + 1 = 0, \qquad (2)$$

where

$$b = \left\{ \frac{1}{2}\left(\epsilon - \frac{1}{\epsilon}\right)(1 - \cos 2\beta a) \sin \beta_0 l - \sqrt{\epsilon}\left(1 - \frac{1}{\epsilon}\right) \sin 2\beta a \cos \beta_0 l \right\}^2. \qquad (3)$$

Solving (2), we have

$$r = 1 + \frac{b}{2} + \sqrt{b + \left(\frac{b}{2}\right)^2}. \qquad (4)$$

Thus the vswr of the load can be calculated from a knowledge of ϵ, a, β_0, β, and the spacing l between the slugs when the matched condition is obtained. The constants of the particular slugs used are ϵ and a, and, as usual, $\beta_0 = 2\pi/\lambda_0$ and $\beta = 2\pi/\lambda$, where λ_0 is the wavelength in the air-filled line and λ_s is the wavelength in the dielectric-filled line. In the coaxial case λ_0 will be the free-space wavelength and $\lambda_s = \lambda_0/\sqrt{\epsilon}$. In the waveguide case

$$\lambda_0 = \lambda_g = \lambda \sqrt{1 - \left(\frac{\lambda}{2w}\right)^2}$$

(the guide wavelength) and

$$\lambda_s = \lambda \sqrt{\epsilon - \left(\frac{\lambda}{2w}\right)^2},$$

where λ is the free-space wavelength and w the guide width.

In order to fully determine the impedance, the distance S from the load to a voltage minimum must be found, as well as r. S is not directly measurable, but the distance D (as shown in Fig. 1) from the first slug to the load can be directly measured. Since $S = D - d$, the distance to the voltage minimum can be found by using the following equation:

$$\cot\ \beta_0 d = \frac{m}{2}\left(1 + \frac{n}{m}\sqrt{\left(\frac{2}{n}\right)^2 + \left(\frac{m}{n}\right)^2}\right), \qquad (5)$$

where

$$m = \frac{[(\epsilon - 1)^2 - (\epsilon + 1)^2 \cos 2\beta a] \sin \beta_0 l - 2\sqrt{\epsilon}(\epsilon + 1) \sin 2\beta a \cos \beta_0 l}{\sqrt{\epsilon}\,[(\epsilon + 1) \sin 2\beta a \sin \beta_0 l - 2\sqrt{\epsilon} \cos 2\beta a \cos \beta_0 l]} \tag{6}$$

and

$$n = \frac{(\epsilon^2 - 1)(1 - \cos 2\beta a) \sin \beta_0 l - 2\sqrt{\epsilon}(\epsilon - 1) \sin 2\beta a \cos \beta_0 l}{\sqrt{\epsilon}\,[(\epsilon + 1) \sin 2\beta a \sin \beta_0 l - 2\sqrt{\epsilon} \cos 2\beta a \cos \beta_0 l]}. \tag{7}$$

The form of (5) gives cot $\beta_0 d$ without any ambiguity of sign arising from the radical. Thus, d can be calculated from a knowledge of the same parameters used to obtain r.

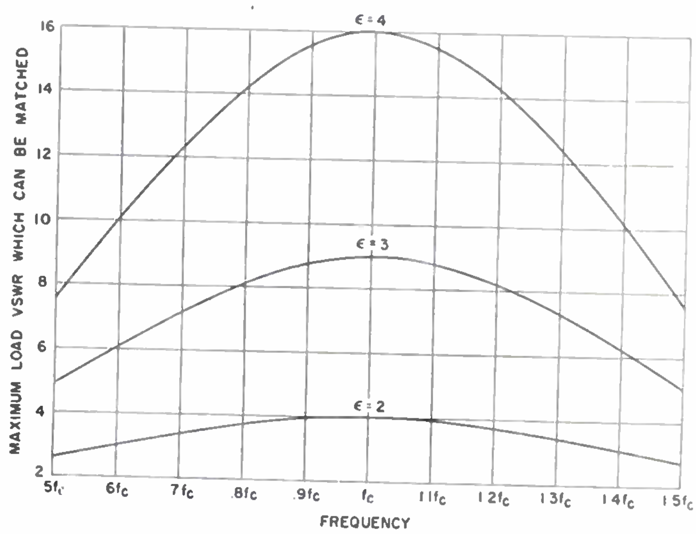

Fig. 2—Matching capabilities of double-slug transformers using slugs with various dielectric constants.

For frequencies other than center frequency the maximum vswr which can be matched by the transformer is less than ϵ^2. Fig. 2 is a graph of the effect of frequency variation upon the matching capability of transformers

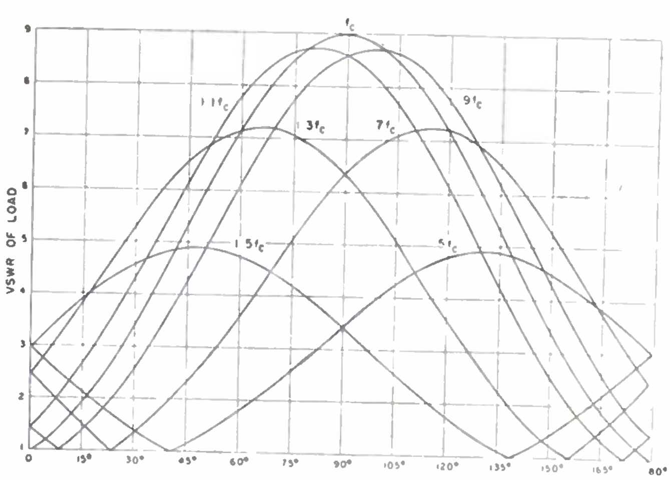

Fig. 3—VSWR versus slug separation. ($\epsilon = 3$)

having dielectric constants of 2, 3, and 4. Fig. 3 is a graph for $\epsilon = 3$ of (4), giving the vswr of the load versus $\beta_0 l$ for frequencies from 0.5 f_c to 1.5 f_c (f_c being center frequency). A graph of $\beta_0 d$ versus $\beta_0 l$ from (6) is shown in Fig. 4. Here, also, $\epsilon = 3$ and the frequency range is from 0.5 f_c to 1.5 f_c.[6]

Since the dielectric slugs are required to slide freely in the transformer, they cannot have a perfectly tight fit.

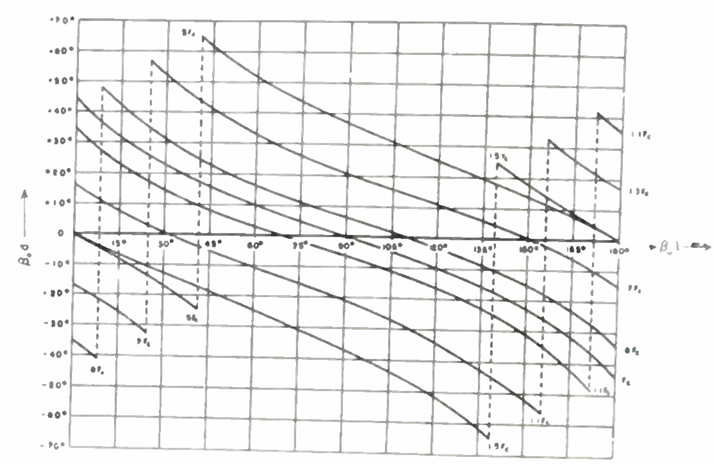

Fig. 4—Position of voltage minimum versus slug separation. ($\epsilon = 3$)

The effect of this looseness of the slugs is to produce an "effective" dielectric constant that is less than the nominal value for the material used.[7] It is possible to obtain the "effective" value of the dielectric constant from an experiment upon the transformer itself. Here it is necessary to know the value of l corresponding to the maximum possible vswr at some frequency different from f_c. This value of l will be designated l_m. For example, the distance l at the maximum point of the 1.1 f_c curve of Fig. 3 is the l_m at this frequency. Since r is maximum when b is maximum, we may set the derivative with respect to l of (3) equal to zero, obtaining

$$\tan \beta_0 l_m = -\frac{\epsilon + 1}{2\sqrt{\epsilon}} \tan \beta a, \tag{8}$$

where β is dependent on ϵ, being $2\pi\sqrt{\epsilon}/\lambda$ in the coaxial case and $\beta = 2\pi\sqrt{\epsilon - (\lambda/2w)^2}/\lambda$ for waveguides. It can be seen from Fig. 3 that there are two values of l, l_1 and l_2 both less than $\lambda_0/2$, for a specified frequency, at which any vswr less than the maximum can be matched. Since the curves of Fig. 3 are symmetrical about their maxi-

[6] The graphs are drawn for the coaxial case for which $2\beta a = \pi(f/f_c)$. In the waveguide case where $2\beta a = \pi(f/f_c)\sqrt{1 + (2a/w)^2(1 - f_c^2/f^2)}$ the corresponding curves will not coincide with those drawn except for $f = f_c$. The difference will be small if f is near f_c and $(2a)^2 \ll w^2$.

[7] A. Von Hippel, D. Jelatis, and W. Westphal, "The Measurement of Dielectric Constant and Loss with Standing Waves in Coaxial Waveguides," Report P41, M.I.T., Cambridge, Mass., eq. 69; April, 1943.

mum points, $l_m=(l_1+l_2)/2$. Thus, using an arbitrary load having a vswr less than the maximum possible for the frequency used (the exact vswr need not be known), the two positions of match l_1 and l_2 can be found. Then l_m is the average of these and can be introduced into (8) along with the appropriate expression for β in terms of ϵ. The resulting transcendental expression can be solved by successive approximations, yielding the "effective" value of ϵ for the particular slugs used, taking into account the looseness of the fit. This "effective" value of ϵ should be used in (3), (6) and (7) in obtaining r and d. An error in the determination of the effective dielectric constant of the slugs produces an error of the same order in the measurement of vswr.

III. Experimental Procedure and Data

The experimental data presented in this paper were obtained using a coaxial transmission-line system. The coaxial transformer used was representative of the commercially available double-slug type having a center frequency of approximately 1,050 mc. The procedure described above leads to an "effective" dielectric constant of $\epsilon=2.97$ for this transformer. This value of ϵ, together with $a=3.95$ cm (as measured for this instrument) were substituted into (3), giving

$$\sqrt{b} = 1.313\left(1-\cos 27.26\frac{\pi}{\lambda}\right)\sin 2\pi\frac{l}{\lambda} - 1.143\sin 27.26\frac{\pi}{\lambda}\cos 2\pi\frac{l}{\lambda}, \tag{9}$$

where λ is the free-space wavelength in cm.

To test the accuracy of the double-slug method, the transformer and a slotted-line were each used to measure the vswr of two loads at several frequencies. In setting the slug positions to obtain the matched condition, the following procedures were followed: The slugs were first brought into contact so that $l=0$, and d was adjusted to obtain the best match. Then l was increased, d being readjusted at each step, until the residual vswr was 1.02 or less. At center frequency the error this residual vswr introduces into the calculated vswr can be determined from the following equation:

$$\frac{\Delta r}{r} = \delta\left(\frac{r-1}{r+1}\right)\left(\frac{\epsilon^2+1}{\epsilon^2-1}\right) + \delta^2\left\{\frac{r}{r^2-1} - \left(\frac{r-1}{r+1}\right)\frac{1}{(\epsilon^2-1)}\right\}, \tag{10}$$

where $\Delta r/r$ is the fractional error in vswr and $\delta=p-1$, p being the vswr of the residual mismatch.

The slotted-line measurements were made using a bolometer in conjunction with a precise standing-wave machine. This machine was known to have inaccuracies of ± 2 per cent in the indication of relative voltages. The signal source had an output of 1 to 10 watts so that only small probe coupling was required. A tuned detector probe was used, and low-pass filters and an attenuation pad were inserted between the generator and the measuring equipment. Comparative data are tabulated in Table I, the vswr for the double-slug transformer being obtained by using in (4) the value of b calculated from (9). The data show agreement within 5 per cent for vswr measurements made by the two methods.

To measure the phase angle, the above values of ϵ (2.97) and a (3.95) were substituted into (6) and (7), and from the resulting two equations d was calculated using (5).

TABLE I

Freq mc	vswr by slotted line	vswr by Dbl-slug trans	vswr by slotted line	vswr by Dbl-slug trans
700			3.03	2.96
800			3.10	3.00
900			3.20	3.12
940	7.00	7.22	2.85	2.78
1000	4.80	4.73	2.65	2.57
1070	3.35	3.28	2.30	2.20
1100	2.60	2.62	2.05	1.95
1150	2.85	2.98	2.10	2.06
1220	4.00	3.81	2.10	2.08
1270	5.20	5.04	2.20	2.25
1300			2.30	2.28
1400			2.20	2.26

The average differences between S measured with the transformer and as measured by the slotted line were 0.065 cm and 0.21 cm in two cases. In terms of one-half wavelength as a unit, these differences were 0.5 per cent and 1.1 per cent, or in electrical degrees they were 0.9° and 2.0°.

In most cases, the discrepancies in both vswr and phase angle between measurements made with the double-slug transformer were of the order of magnitude of errors commonly encountered in slotted-line measurements.[8] Although the transformer was not designed as a precise measuring instrument, the results obtained were comparable with those of a good-quality slotted-line, and measurements made showed good repeatability.

IV. Conclusion

Formulas and techniques have been described by means of which impedances can be measured with a double-dielectric-slug transformer. A relatively crude instrument of this type has made measurements comparable in accuracy with a precision slotted-line. The measurements were easily made and readily repeated. Errors due to excessive probe penetration and unknown or uncertain law of the detector and amplifier response are eliminated. The slotted-line ordinarily requires a calibrated indicating system, whereas the double-slug transformer requires only the recognition of a matched condition and the measurement of a fundamental quantity, length.

[8] H. E. Sorrows, W. E. Ryan, and R. C. Ellenwood, "Evaluation of coaxial slotted-line impedance measurements," Proc. I.R.E., vol. 39, pp. 162–168; February, 1951.

Field Strengths Recorded on Adjacent FM Channels at 93 MC Over Distances from 40 to 150 Miles*

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Summary—Field strengths of KE2XCC (93.1 mc, Alpine, N. J.) and WBZ-FM (92.9 mc, Boston, Mass.) have been recorded for more than a year at two locations (Hauppauge and Riverhead) on Long Island. Statistical analysis of data for the evening hours reveals a broad seasonal trend toward higher intensities in the summer, with larger over-all variation on the longer transmission paths. Based on analysis of one summer month, refraction effects appeared to vary independently in the two directions. During periods of rapid and violent fading, hourly median field strengths of WBZ-FM varied over a range of 32 db at Riverhead and 25 db at Hauppauge. Furthermore, for the above-mentioned fading conditions, it was observed that on the 150-mile path, the hourly curves of field-strength distribution with time approached a log-normal distribution when the median field was less than 10 db above 1 μv per meter, and a Rayleigh distribution when the median field was greater than 15 db above 1 μv per meter.

Introduction

The results of duplicating frequency assignments in the present television and frequency-modulation broadcasting bands quickly revealed that a knowledge of field-strength variability at these frequencies is an important factor in planning a nationwide service. At times, refraction of signals over the horizon provided service to greater distances than was anticipated, and, consequently, some areas received usable signals from two or more transmitters on the same frequency.

In order to obtain additional data relative to the field strengths and field-strength variations involved in the problem of co-channel interference, RCA Laboratories initiated a program of field-strength recording in the Spring of 1949. The plan was to observe continuously the signals of two frequency-modulated stations, on adjacent channels, but arriving from considerably different directions. To supplement and amplify the information desired, the measurements would be made at two separated locations, rather than at just one. The stations selected for observation were WBZ-FM, 92.9 mc, at Boston, Mass. and KE2XCC, 93.1 mc, at Alpine, N. J. The receiving locations were Riverhead and Hauppauge, Long Island.

Transmission Paths

The transmission paths are shown on the map of Fig. 1. The receiving site at Riverhead is located on level ground about 20 feet above sea level. The Hauppauge receiving site is on top of a hill which is 195 feet above sea level and about 125 feet above the average terrain. Profiles of the transmission paths from Boston have been plotted in Figs. 2 and 3. On the path from Alpine, the Hauppauge receiving antenna lies approximately 50 feet below line-of-sight, on a 4/3 earth's radius profile. The Riverhead antenna is roughly 600 feet below a similar line-of-sight.

Calculated values of free-space field strengths at the two observation points, expressed in decibels above 1 μv per meter, are given in Table I.

TABLE I

FREE-SPACE FIELD STRENGTHS

Transmitter	Receiving Location	E_0 db above 1 μv/m
KE2XCC, Alpine	Hauppauge, L. I.	87.6
KE2XCC, Alpine	Riverhead, L. I.	83.2
WBZ-FM, Boston	Riverhead, L. I.	73.7
WBZ-FM, Boston	Hauppauge, L. I.	72.2

Transmitters

The effective radiated power of WBZ-FM was 20 kw, with an antenna height of 495 feet above the average terrain. KE2XCC operated with 50-kw effective radiated power, with the antenna 795 feet above the average terrain.

The schedule of WBZ-FM was from 8:15 a.m. to 10 p.m., local time, each day. The normal schedule for KE2XCC was from 4 p.m. to 11 p.m., but this was revised to include more daylight time during the last six months of the recording. All time notations have been expressed in Eastern Standard Time, to avoid confusion during the period when Daylight Time was in effect.

Receiving Antennas

All receiving antennas were located at a height of 30 feet above ground. For the Boston signal, where maximum gain was needed, an array of two rhombics, stacked one above the other, was employed. The individual rhombics were separated by a half wavelength (5 feet) vertically, and displaced a quarter wavelength with respect to each other along their major axes, for increased front-to-back ratio. Each rhombic was two wavelengths per leg, with a tilt angle of 54°. Identical antennas were used for the reception of WBZ-FM at both Riverhead and Hauppauge.

For reception of Alpine at Riverhead, a 90-degree corner reflector, with sides 8 feet long by 7 feet wide, was used. A folded dipole was located at a point in the reflector calculated to match the impedance of RG-22/U twin-conductor transmission line. At Hauppauge, the relatively strong fields from Alpine permitted the

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† Radio Corporation of America, RCA Laboratories Division, Riverhead, L. I., N. Y.

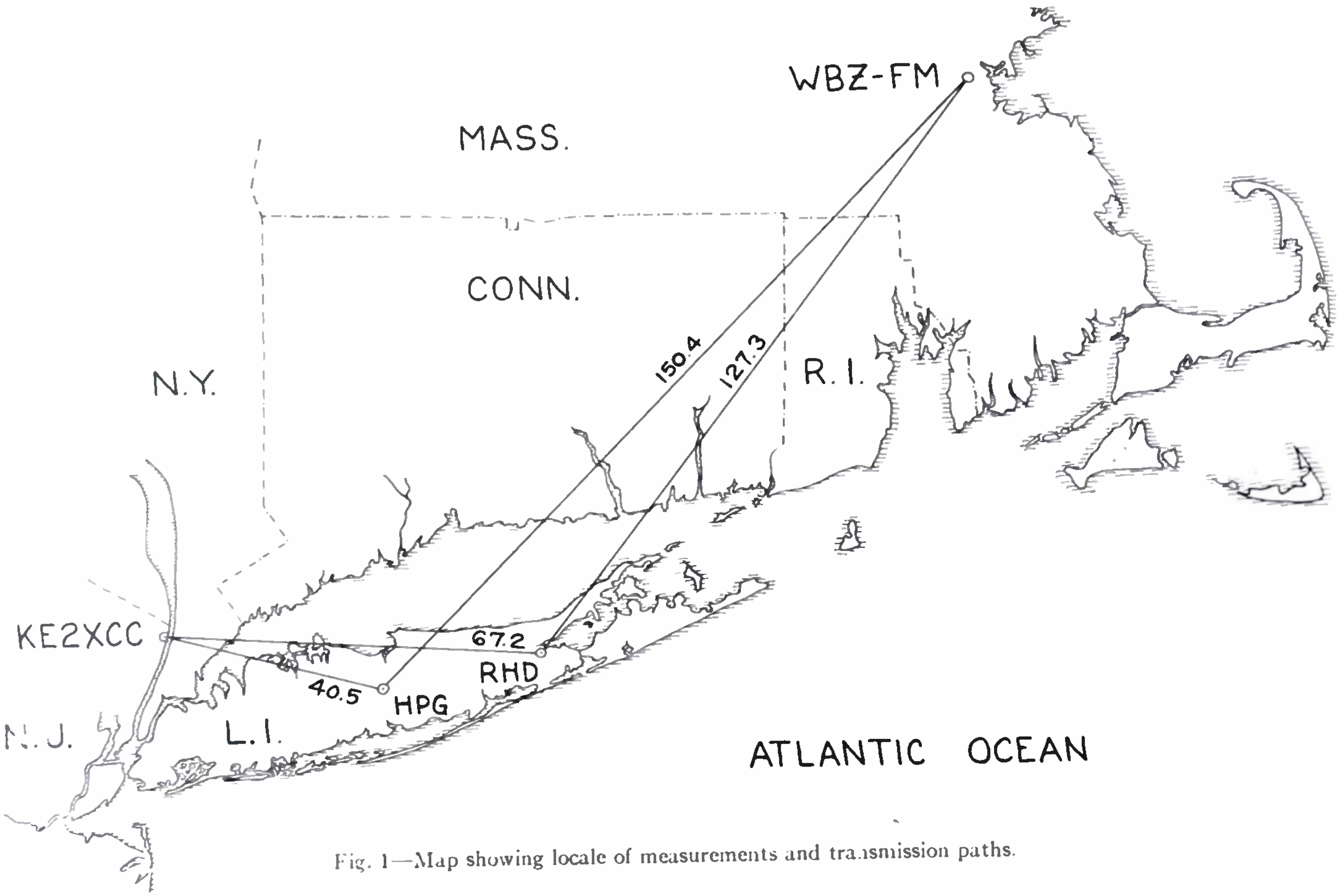

Fig. 1—Map showing locale of measurements and transmission paths.

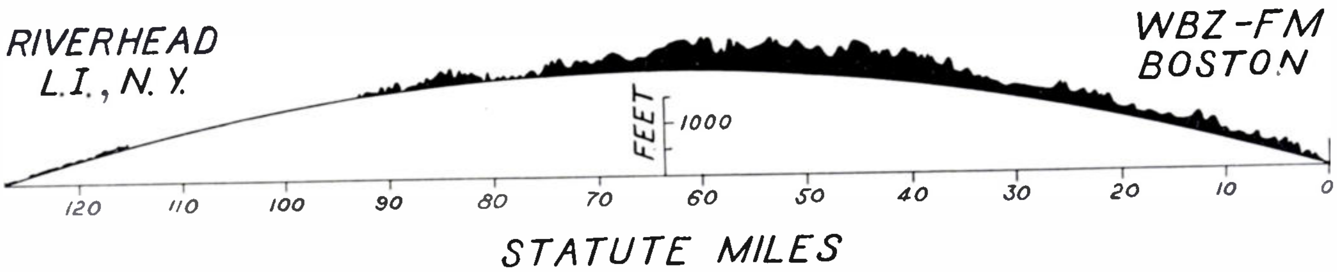

Fig. 2—Profile from WBZ-FM, Boston to Riverhead, 4/3 earth's radius.

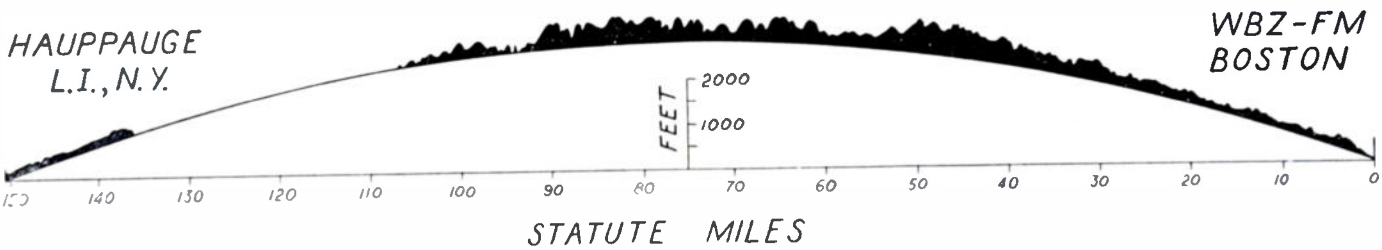

Fig. 3—Profile from WBZ-FM, Boston to Hauppauge, 4/3 earth's radius.

use of a simple half-wave dipole, connected to the receiver by 75-ohm, balanced transmission line.

Receiving and Recording Equipment

The receiving equipment at both locations was placed in temperature-controlled, insulated rooms to improve the stability of the receivers. Heat was supplied electrically, and a ventilating fan, drawing air from beneath the building, provided a means of cooling. All receivers were of the double-conversion type of superheterodyne, with bandwidths of 150 kc at 3 db down from maximum response.

Records of the receiver outputs were made by means of Engelhard recording microammeters, having a chart speed of $\frac{3}{4}$ inch per hour. This type of recorder operates mechanically every 15 seconds to mark a dot at the deflection of the galvanometer at that instant. Automatic totalizers[1] having twelve adjustable levels were

[1] R. W. George, "Signal strength analyzer," *Electronics*, vol. 24, pp. 75–77; January, 1951.

installed on all except the Alpine receiver at Hauppauge at various times between June, 1949 and January, 1950. However, the Engelhard recorders were also kept in operation as monitors on signal performance. The totalizer equipment included a 16-mm camera with electrical timer to take a single-frame picture of the counter readings every hour. This proved quite flexible, in that individual hours could be abstracted if desired, or longer periods considered, such as separating days into daytime and evening hours.

Method of Analysis

The most useful type of signal-strength analysis appears to be in the form of a curve showing per cent of time above any given field-strength level. In this paper, the data have been summarized in periods of one month each. This is long enough to average out the effects of individual days, and short enough to show seasonal trends if they are present.

The various comparisons reported herein were made on the basis of hourly medians, as derived from the totalizer films. Although comparisons made over shorter periods might be desirable, different measuring techniques would be required, and it is felt that the comparison of hourly medians gives an indication of general transmission characteristics.

Results and Discussion

Field-Strength Studies

Fig. 4 is the form in which the monthly data for the entire period of measurements were drawn up.

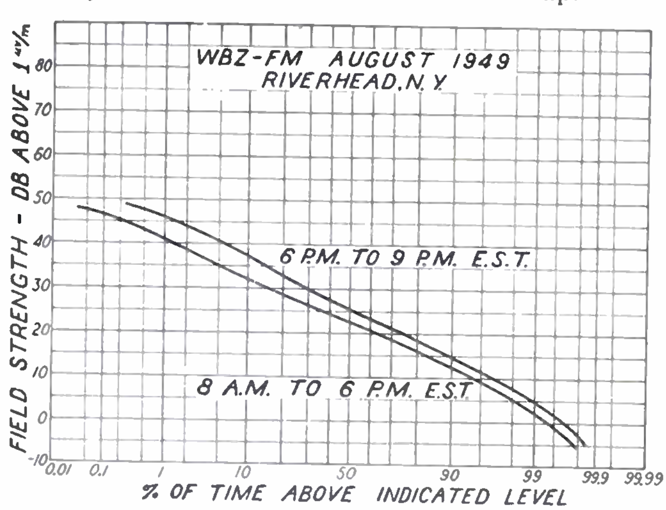

Fig. 4—Typical field-strength distribution for day and evening hours, August, 1949.

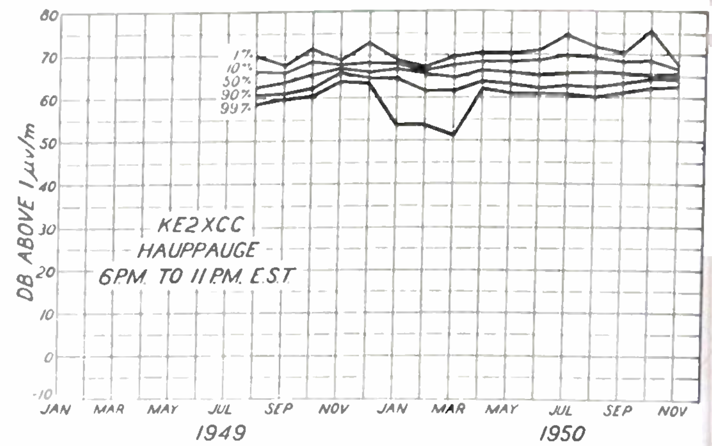

Fig. 5—Summary, field-strength analysis during evening hours, KE2XCC at Hauppauge.

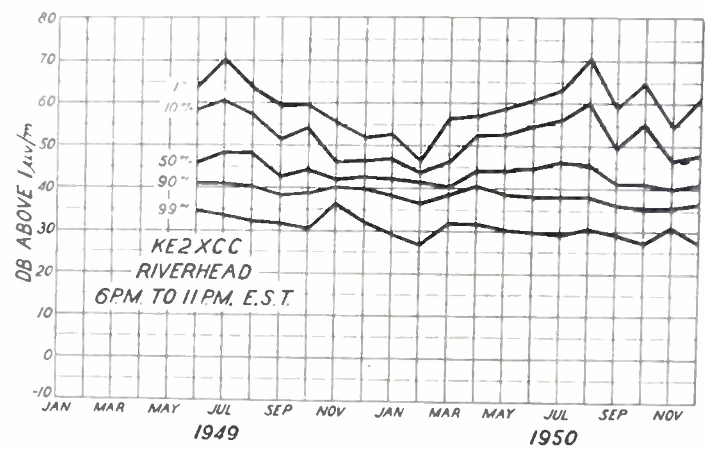

Fig. 6—Summary, field-strength analysis during evening hours, KE2XCC at Riverhead.

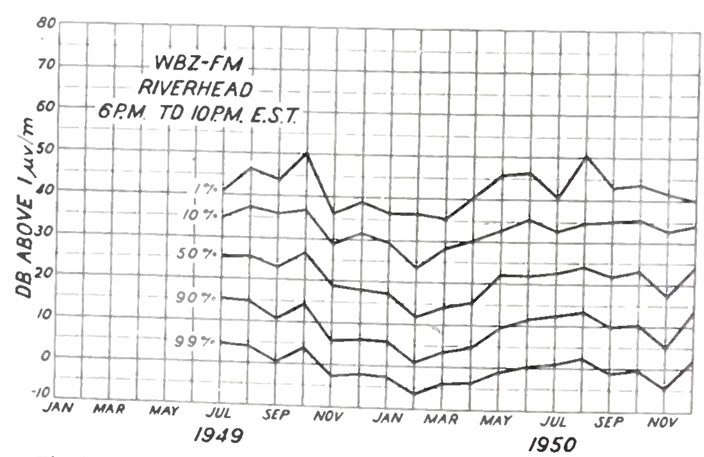

Fig. 7—Summary, field-strength analysis during evening hours, WBZ-FM at Riverhead.

Figs. 5 through 8 have been prepared as summaries of all signal recordings for the evening hours. These have been derived from the monthly time-analysis curves similar to Fig. 4. The Alpine signal at Hauppauge was observed to fade to lower levels for short periods during the winter months (Fig. 5). At Riverhead, there was a seasonal variation toward higher maximum levels during the summer months. On a monthly basis, the maximum level at Riverhead occasionally approached the corresponding level at Hauppauge (Fig. 6).

The graphs for Boston fields, in Figs. 7 and 8, exhibit a seasonal trend at all time levels, with somewhat more variation at the greater distance. The times of strongest refraction do not occur in the same month in the two years, nor do they occur in the same months at the two locations.

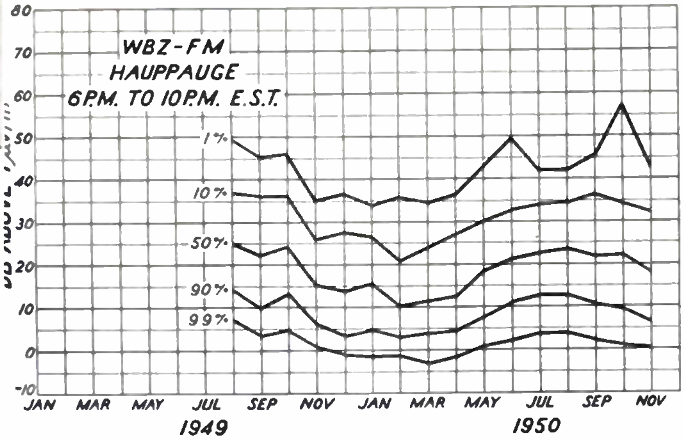

Fig. 8—Summary, field-strength analysis during evening hours, WBZ-FM at Hauppauge.

Fig. 9 is a comparison of the adjacent-channel signals on the basis of hourly median values at Riverhead. To simplify the comparison, the individual hourly medians have been compared to the monthly median for each signal, and the results, expressed as departure from the monthly medians, plotted in Fig. 9. From the general appearance of this plot, it appears that the adjacent-channel fading at Riverhead is not simultaneous, when considered on an hourly basis. To further illustrate this point, the original data from which Fig. 9 was derived have been replotted in Fig. 10. This is a direct comparison of hourly median field strengths, analyzed with respect to time. Assuming that KE2XCC, Alpine, is the desired signal, this plot is a statistical analysis of the ratio between the desired and the adjacent-channel signal strengths. The shape of the curve indicates a log-normal distribution of this ratio, extending plus and minus 18 db from the monthly median value.

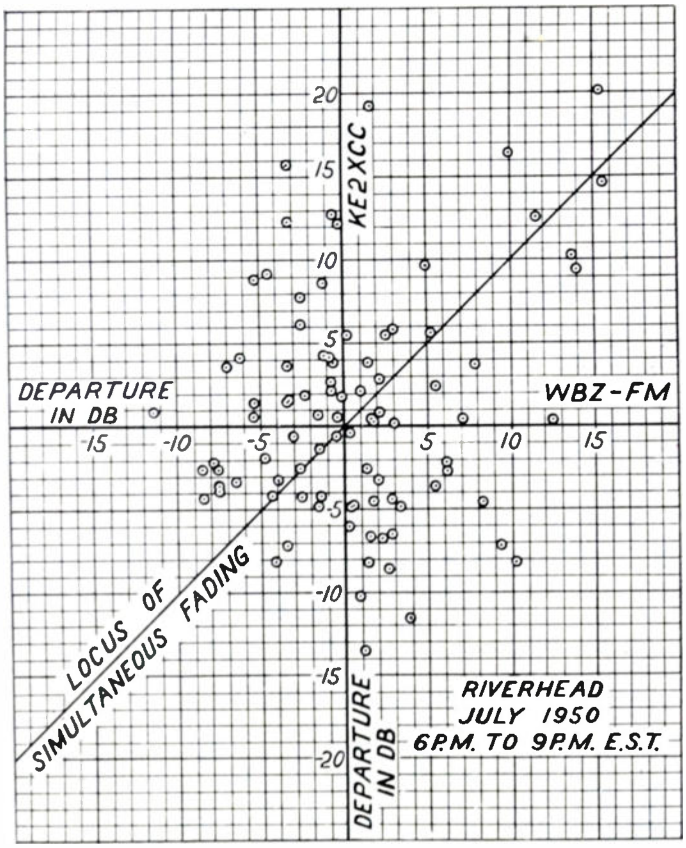

Fig. 9—Comparison of fading, simultaneous hourly medians at Riverhead, evening hours, July, 1950.

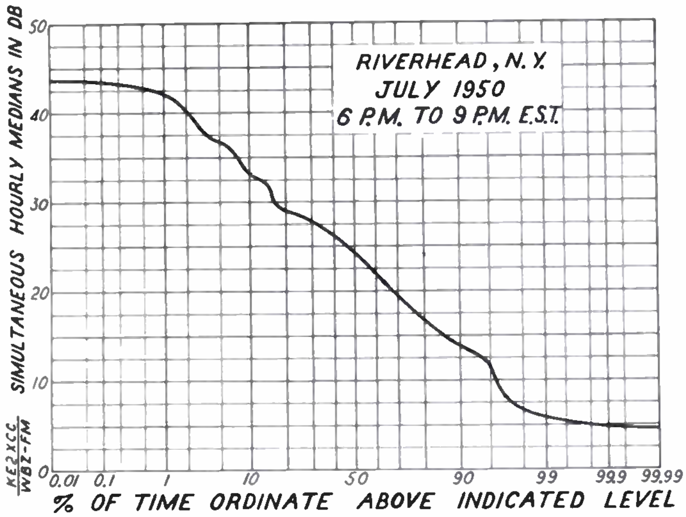

Fig. 10—Fading analysis, comparison of simultaneous hourly medians at Riverhead, evening hours, July, 1950.

Scatter Fading

The behavior of the Boston signal was studied during periods of fairly rapid and random fading, when propagation might be expected to be by way of tropospheric scattering. Atmospheric stratification is less common during the colder months of the year and at these times propagation is more likely to take place by way of reflections from small tropospheric irregularities. Accordingly, the recorded charts for the two longest paths were inspected for a period in November, 1950, and the hours

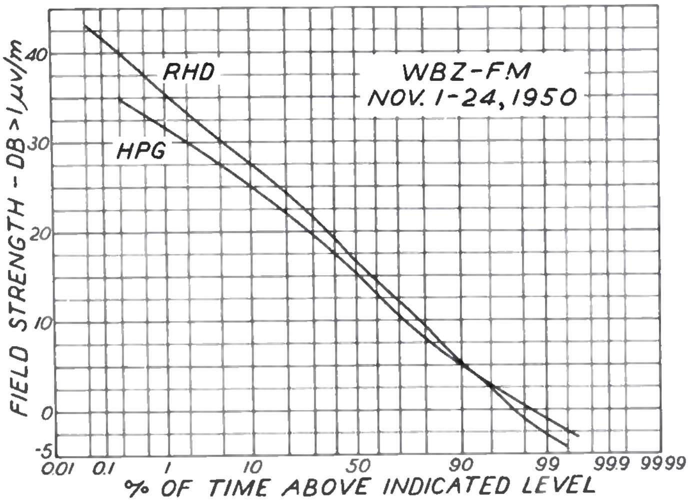

Fig. 11—Field-strength analysis under conditions of rapid and random fading, WBZ-FM received at Riverhead and Hauppauge, November, 1950.

tabulated when the record indicated scatter fading. Field-strength data were then transcribed from the totalizer films for these individual hours. The summation of 201 such hours is shown in Fig. 11. Both curves approach a log-normal distribution of field strength, with the Hauppauge signal exhibiting somewhat less over-all variation.

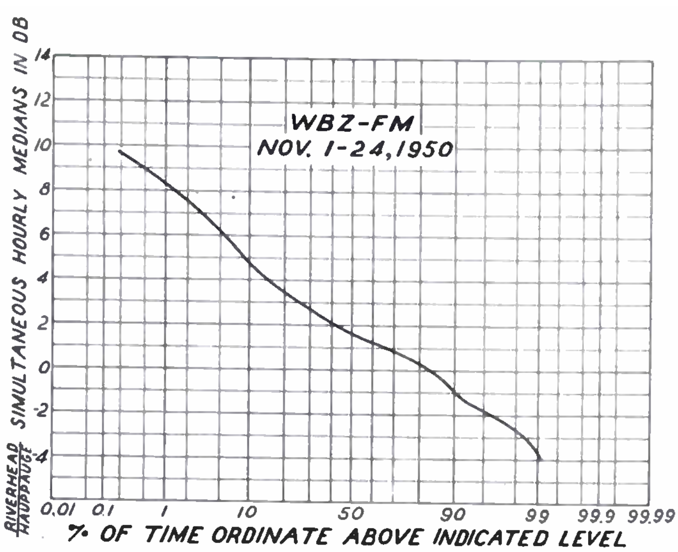

Fig. 12—Analysis of simultaneous hourly medians under scatter-fading conditions, WBZ-FM received at Riverhead and Hauppauge, November, 1950.

Variation of field strength with distance under conditions of scatter fading was studied in more detail by plotting curves of field-strength distribution with time for each hour, for both receiving locations. From these curves, values of hourly median field strength were obtained. Comparisons of median field strengths at Riverhead and Hauppauge were analyzed with respect to time, and the result plotted in Fig. 12.

In plotting time distribution curves for the individual hours of scatter fading, it was observed that the shape of the curves varied between a Rayleigh distribution and a log-normal distribution. More careful study indicated that when the signal level was relatively high, the distribution of field strength with time was essentially Rayleigh, while at lower levels the distribution was more nearly log-normal. It should be emphasized that the higher levels referred to are those received under conditions of rapid and random fading, and not the much higher levels attributed to abnormal refraction. As might be expected, there were a number of hours when the time analysis was neither Rayleigh nor log-normal, but rather a combination of the two general types.

A striking example of the change in character of the time-field distribution for different levels took place on November 20, 1950. Fig. 13 is a replot of the day's record. This record is not representative of usual propagation conditions over the path, for the reasons that scatter fading was observed over the entire day, and the normal diurnal trend of field strength was reversed. Although the record is unique, it does provide an excellent illustration of the point under discussion. Two well-defined levels of reasonably steady median fields, differing by some 14 db, are evident. These are separated by a transition period lasting less than an hour.

Individual field-strength distribution curves for all hours of the day shown in Fig. 13 are depicted in Fig. 14. These were plotted from the corresponding totalizer data. The curves for the higher level approach the Rayleigh distribution. Those for the lower level are more nearly log-normal, being symmetrically disposed about their median values on a logarithmic scale of field strength. The curve for the hour of transition lies between the two groups of curves, its median being very near the median value for all hours of scatter fading analyzed.

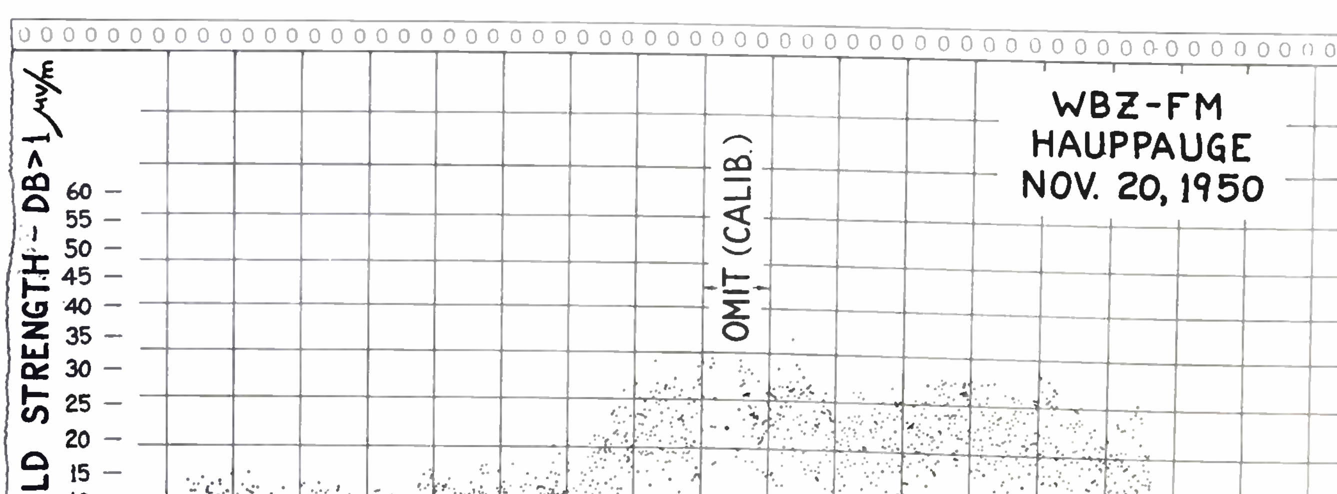

Fig. 13—Recorder chart showing scatter-type fading at two field-strength levels.

The importance of avoiding changes in level during any period under study will be evident from the effect on signal distribution caused by the transition above. As a rule, it was difficult to find periods as long as an hour in which a noticeable change in the median level did not occur. In this respect, the record of November 20 is most unusual.

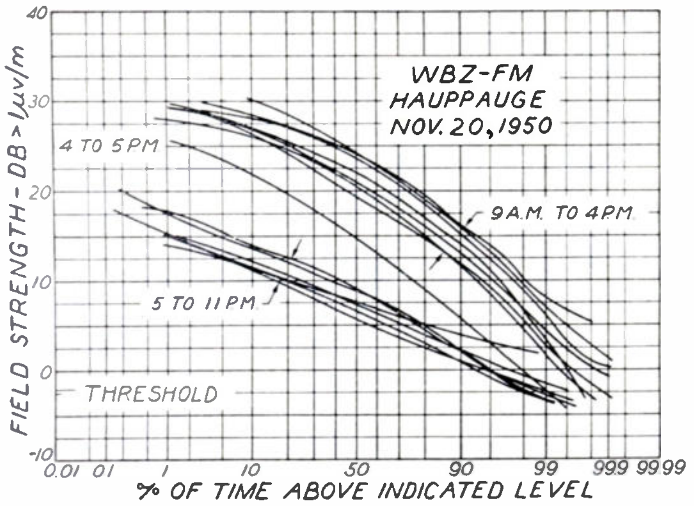

Fig. 14—Field-strength distributions for individual hours of recording shown in Fig. 13.

It is interesting to note that if a large enough number of the fading periods in question are analyzed as a whole, the curve obtained is essentially log-normal (cf., Fig. 11). The reason for this will be apparent if one visualizes the low-level section of the record of Fig. 13 to be superimposed on the high-level section. The sparsely occupied lower portion of the high-level trace will, in effect, be filled in, resulting in a more uniform over-all distribution of field.

It would appear that on these particular transmission paths, when the signal is weak, scatter fading is caused by reflection in a turbulent medium, which at any instant may be represented by a multiplicity of relatively small atmospheric discontinuities of random sizes and shapes. The phase relationships of the reflected components would be random, and their amplitudes would be determined by the effective coefficients of reflection at the various discontinuities. When the signal is stronger, but still scattered, propagation possibly takes place in a less turbulent medium, where more or less stratification exists. The reflected components become more nearly equal in amplitude, while the phase relationships remain random. The first set of conditions would account for a log-normal distribution of field strength with time; the latter conditions would satisfy the definition of the Rayleigh law. It is, of course, to be expected that varying degrees of combination of these two conditions may be found at a given time.

Conclusion

Field-strength studies based on data taken during the evening hours revealed somewhat different performance on all transmission paths. At a distance of 40 miles, over a nonoptical path, the fading range was relatively small, with occasional short fades to lower levels in the winter months. At a distance of 67 miles, a seasonal trend toward appreciably higher maximum values in the summer was noted. On the 127- and 150-mile paths, the variation was greater throughout the year, with consistently higher field strengths recorded in the summer. Refraction effects appeared to vary independently in the two directions, based on analysis of one summer month. At Riverhead, the ratio between Alpine and Boston fields varied from 42.3 to 5.1 db, when simultaneous hourly medians were compared.

Analysis of field-strength data recorded on the 150-mile path during periods of rapid and random fading revealed several interesting points. When data from all such periods were considered together, the field-strength distribution with time was found to be substantially log-normal. For median fields less than 10 db above 1 μv per meter, the hourly distribution was also log-normal. For medians exceeding 15 db, the corresponding distribution was found to be essentially Rayleigh. Thus it appears that the shape of the hourly distribution curves may provide a clue to the method of propagation.

A Comparison of CW Field Intensity and Backscatter Delay*

W. L. HARTSFIELD† AND R. SILBERSTEIN†, SENIOR MEMBER, IRE

Summary—Determination of failure and recovery times from backscatter records at 15 mc on a 2700-km path was done with good agreement. Certain disturbed days gave anomalous scatter records. Rapid changes in these records were compared with motion of ionospheric irregularities, rates being of the same order of magnitude.

This paper is essentially a condensation of National Bureau of Standards Report No. 1297, November 16, 1951.

I. Objective

EXPERIMENTS by various investigators have indicated that one prominent group in most observed scatter-echo patterns should be ground-scatter propagated via F_2 layer[1,2,3,4,5,6] because of focus effects at the edge of the skip distance.[7] The objective of this experiment was to study the relationship of backscatter to skip phenomena by comparing the field intensity of the 15,000-kc WWV signals received at the White Sands Proving Ground, New Mexico, with the recorded delay times for the backscatter received at Sterling, Virginia from a pulse transmitter operating at approximately 15,000 kc.

II. Equipment

The White Sands receiving station was equipped with a conventional field-intensity recorder. Calibrations were made in terms of microvolts input to the receiver. The transmitter at Sterling, Virginia had a 500-kw peak power output of 40-μsec pulses 25 times per second.

The directional antenna for the pulse transmitter, with characteristics similar to those of the antenna in footnote reference 2, was oriented at an azimuth of 263 degrees from true north. The receiver was a communications type modified for pulse reception, and a Loran indicator was used to display A-scope patterns for single-frame photography. In later stages of the work a range-time recorder was used. The receiving antenna was a sloping vee adjacent to the transmitting antenna and oriented in the same direction. A precise oscillator and frequency divider unit supplied trigger pulses to the transmitter as well as trigger pulses and marker pulses to the range-time recorder.

III. Description of Range-Time Backscatter Records

Fig. 1 is an illustration of a typical range-time record. The abscissas represent time in GCT running from left to right, and the ordinates represent delay in milliseconds. (This figure and other photographs were retouched, where necessary, for reproduction.)

On a normal day, such as that represented in Fig. 1 (if one can distinguish a trace which is normal from among the great variety of patterns which are obtained on the range-time records over a period), there is a fairly dense line running along the time axis at the delay time associated with the F_2-layer skip distance. In the early evening this line starts increasing in delay time and runs out as the skip distance increases. Usually this distance increases to a point where the echoes are too weak to record, being limited by low-angle antenna response. A normal ground-scatter return is frequently seen to be composed of a group of separate echoes which start up, change in range, and die out while overlapping echoes at slightly different ranges do the same thing. Possible reasons for this type of structure are discussed under 6 below.

At dawn, the F_2 ground scatter returns with rapidly diminishing range, but is mixed with a great deal of close-in scatter which may possibly be caused by stratification in the E region at the time of regular ionization increase. Later, these complex echoes disappear, perhaps because of increased ionospheric absorption, and leave the ground-scatter echoes at the regular F_2 skip distance, except under certain disturbed conditions where the F_1 layer may control propagation.

Fig. 2 illustrates a normal day with strong, steady, nearby echoes, which remain at about the same delay as the ground-scatter echo propagated via F_2 increases in delay with increase of skip distance. This effect seems to be caused by the presence of strong sporadic-E ionization. Figs. 3 and 4 are two very dissimilar records for disturbed days. They are discussed in further detail under 6 below.

IV. Method of Extracting the Data

Backscatter records of the general type of Figs. 1 through 4 for spring, summer, and late fall of 1950, and in some cases A-scope records, were examined and the

* Decimal classification: R113.242. Original manuscript received by the Institute, November 19, 1951; revised manuscript received June 4, 1952.

† U. S. Department of Commerce, National Bureau of Standards, Washington 25, D. C.

[1] A. H. Benner, "Predicting maximum usable frequency from long distance scatter," Proc. I.R.E., vol. 37, p. 44; January, 1949.

[2] W. L. Hartsfield, S. M. Ostrow, and R. Silberstein, "Back scatter observations by the central radio propagation laboratory—August, 1947 to March, 1948," *Jour. Res. Nat. Bur. Stand.*, vol. 44, pp. 199–214; February, 1950.

[3] W. Dieminger, "The scattering of radio waves," *Proc. Phys. Soc.* (London), vol. 64, pt. 2, no. 374B, pp. 142–158; February, 1951.

[4] A. M. Peterson, "The mechanism of F-layer Propagated back-scatter echoes," *Jour. Geophys. Res.*, vol. 56, pp. 221–237; June, 1951.

[5] W. G. Abel and L. C. Edwards, "The source of long distance back scatter," Proc. I.R.E., vol. 39, pp. 1538–1541; December, 1951.

[6] O. G. Villard and A. M. Peterson, "Instantaneous prediction of radio transmission paths," *QST*, vol. 36, pp. 11–20; March, 1952.

[7] T. L. Eckersley, "Studies in radio transmission," *Jour. IEE* (London), vol. 71, no. 429, pp. 405–459; September, 1932.

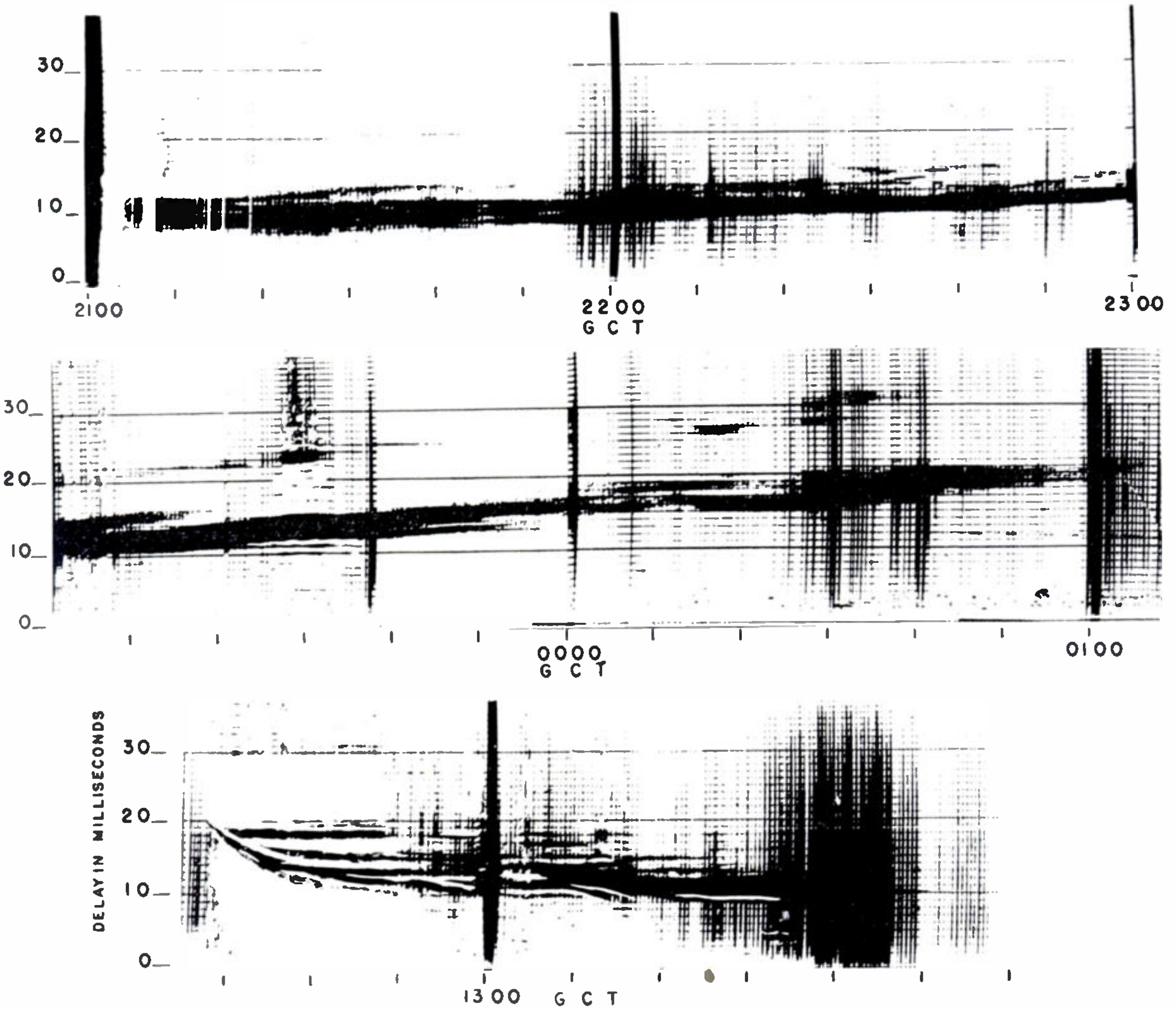

Fig. 1—Normal day record. December 4–5, 1950.

delay times in milliseconds between the transmitted pulse and the earliest peak of energy in the F_2-propagated ground-scatter group were plotted against Greenwich Civil Time. In some ambiguous cases traces at different ranges were plotted simultaneously.

The field-intensity record for the same day as that of a given scatter record was examined and, using the same time scale, a smoothed curve of the corresponding field intensity in decibels above 1-μv input to the receiver was plotted, so that it was possible to compare field intensity of the WWV 15,000-kc signals at White Sands, New Mexico, and the pulse delay times recorded at Sterling, Virginia. On each graph are placed two ionospheric disturbance figures, the Washington I figure and the North Atlantic Q figure (disturbance criteria in use by the National Bureau of Standards) for the periods covered, for qualitative evaluation of propagation conditions. Fig. 5 is a set of such plots.

In the experimental comparison of backscatter and point-to-point field-intensity records, the degree of complexity of the field-intensity records was such that it was difficult to establish the exact time of path failure and path recovery consistently from record to record. Therefore, a specific characteristic of the field-intensity record had to be defined as indicative of the start of path failure and the end of path recovery. The complexities appeared to be a result of ionospheric irregularities,[8,9] which cause different rates of failure and sometimes temporary partial recovery during a failure period. Almost all of the records exhibited a period of increased field intensity because of the focus at the edge of the skip distance just prior to an initial sudden sharp drop.[9,10] It was the start of the initial sharp drop which was taken as the start of path failure and compared with the scatter records, since it was deemed that partial recoveries did not represent a pure mode and often not a great-circle mode. The end of a sharp rise was treated in the same manner with regard to path recovery. Furthermore, the length of time after the initial drop that these modes could be observed was highly variable, being a

[8] E. N. Bramley and W. Ross, "Measurement of the direction of arrival of short radio waves reflected at the ionosphere," *Proc. Royal Soc. A*, vol. 207, pp. 251–267; June 22, 1951.

[9] R. Silberstein, "Interpretation of High-Frequency C-W Field Intensity Records with the Aid of Simultaneous Pulse Data," NBS Report No. 1085; July 27, 1951. Also to appear in Proc. I.R.E., vol. 40, pp. 974–976; August, 1952.

[10] E. V. Appleton and W. J. G. Beynon, "The application of ionospheric data to radio communication problems:" Part II, *Proc. Phys. Soc.* (London), vol. 59, p. 58; 1947.

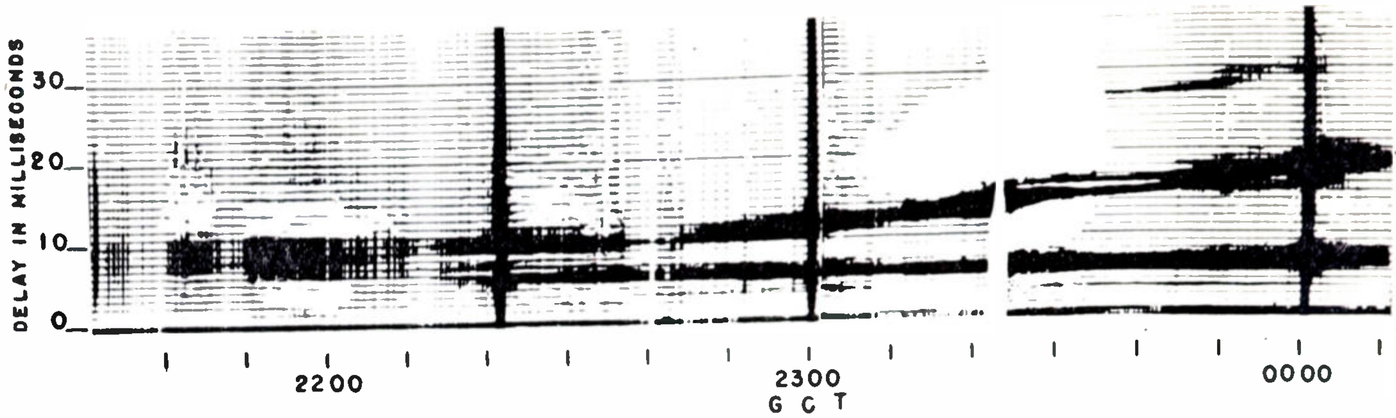

Fig. 2—Normal day record with close-in reflections. December 28, 1950.

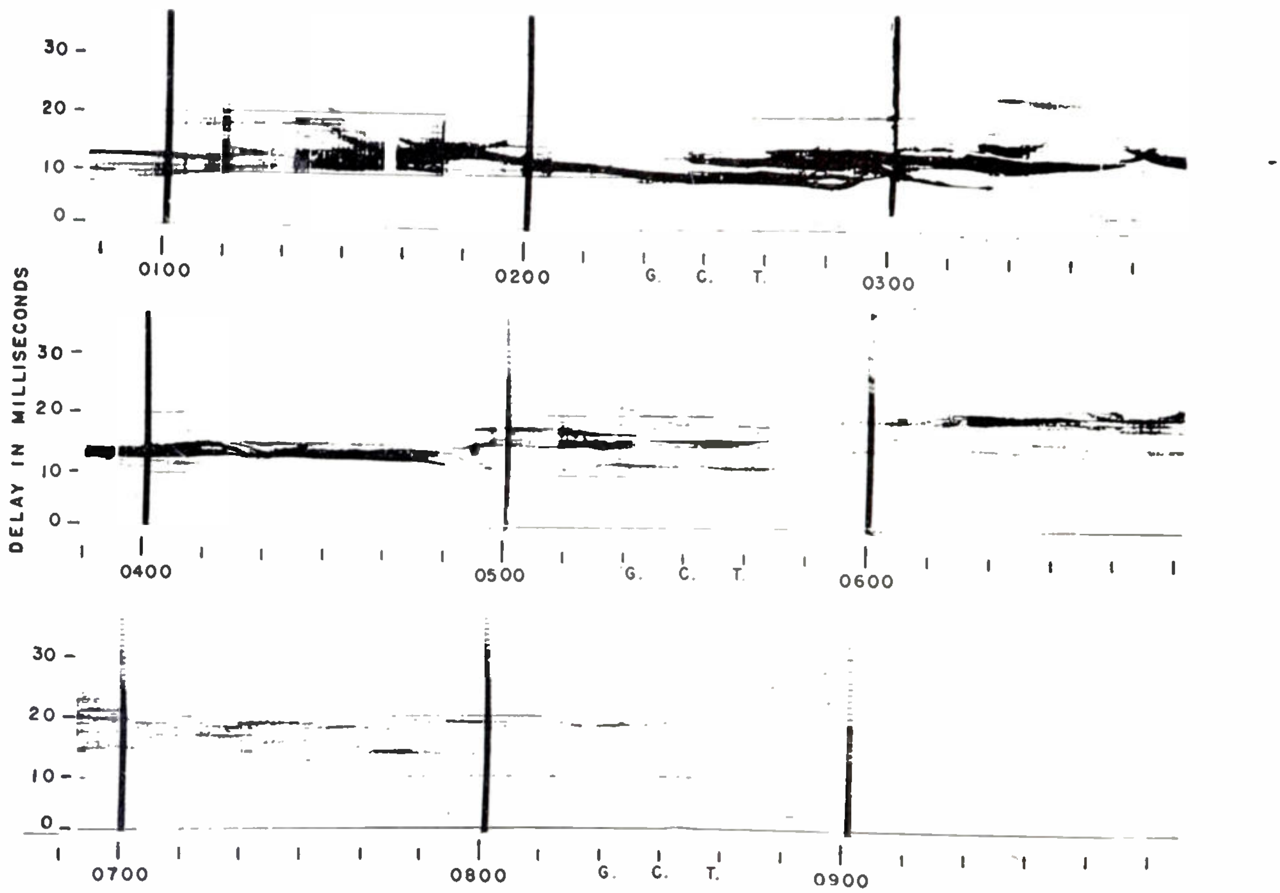

Fig. 3—Disturbed day record. June 30, 1950.

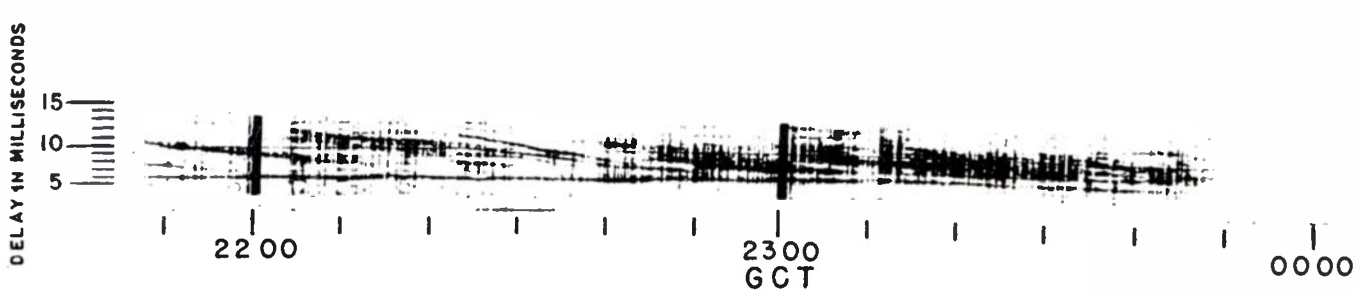

Fig. 4—Record near start of disturbance. November 22, 1950.

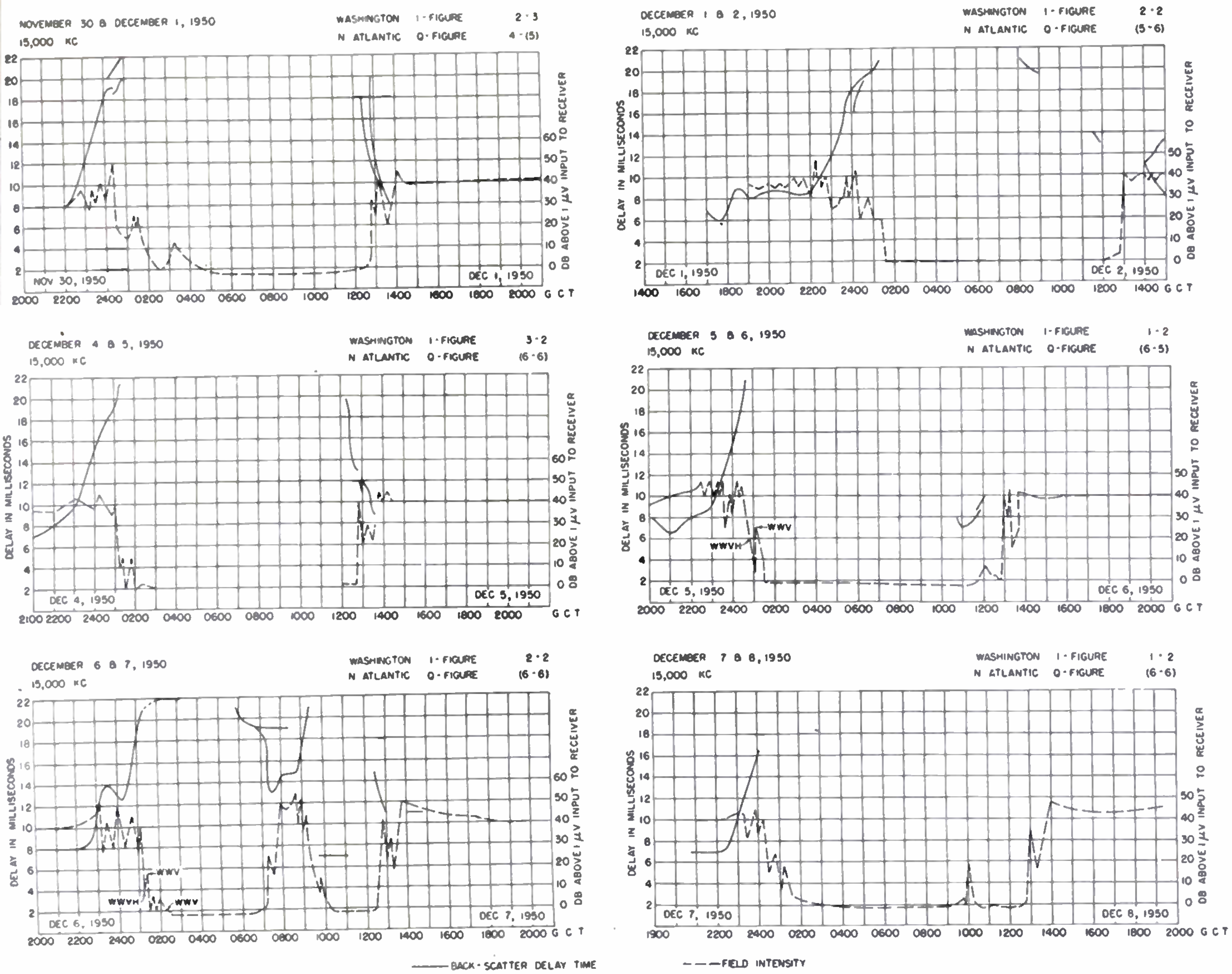

Fig. 5—Simultaneous plots of field intensity of WWV. Recorded in New Mexico and Sterling, Va. Backscatter delay times.

function of such diversified factors as ionospheric turbulence and the noise level at the receiver.[9]

Throughout the text, the time of the start of path failure and the time of the end of the path recovery are referred to, for the sake of brevity, as the time of path failure or failure time, and the time of path recovery, or recovery time.

Identification of which group of scatter constituted ground scatter propagated via F_2 layer required some knowledge of day-to-day conditions over the path and an appreciation of what other types of scatter might exist. For the distance and frequency involved, the identification was fairly easy at the time of path failure except on disturbed days, such as that of Fig. 3, and on certain anomalous records. "Short-scatter" echoes directly from the E layer, and ground scatter propagated by sporadic-E ionization, when visible, occurred at very much smaller delay times. At the time of path recovery, identification was frequently uncertain, partially because of the existence of many short-distance echoes.

In analyzing the data, average values of virtual heights at the times of path failure and recovery were assumed for the summer (spring and summer) and winter (late fall) group. This assumption was based upon values obtained by scaling Washington and White Sands vertical-incidence ionosphere records with a 2,700-km transmission curve for each day of the experiment, using records on which this transmission curve, for a 15-mc operating frequency, fell tangent to the h'-f curve. The final round figures were 400 km for summer and 300 for winter, corresponding to delay times of 19.3 msec and 18.8 msec, respectively, for ground scatter at 2,700 km. These delay values were used on the scatter records to estimate the times of path failure and recovery for comparison with the times of day when failure and recovery of the recorded WWV signal occurred. Again, the times of failure and recovery of this signal were applied to the scatter record to obtain delay times which yielded apparent skip distance, for comparison with the true distance.

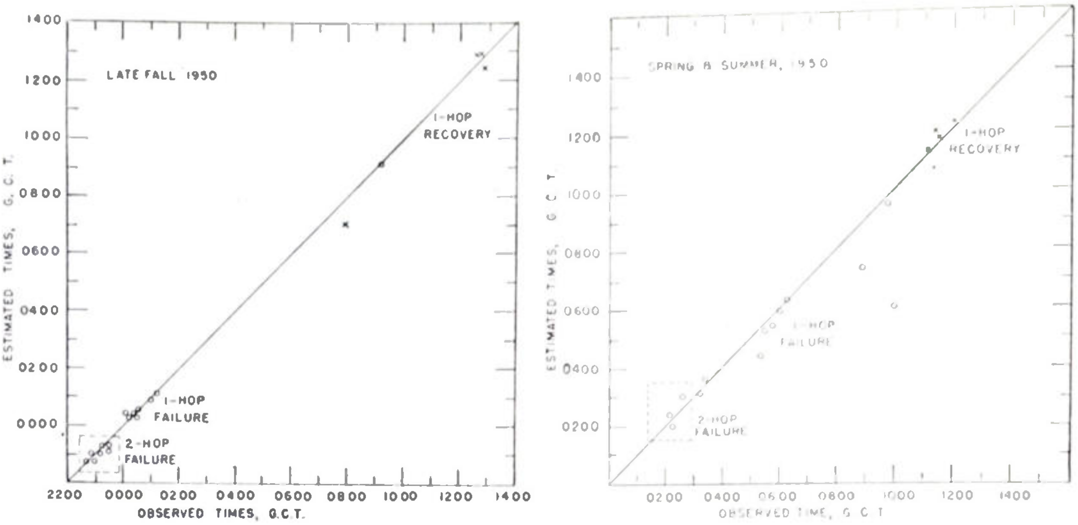

Fig. 6—Comparison of estimated and observed failure and recovery times.

V. Results

Fig. 6 shows plots of observed versus estimated path failure and recovery times scaled from figures like Fig. 5, one group being spring and summer, and one, late fall. Both 45-degree lines are loci of points of perfect agreement.

In the spring and summer group most of the errors were within 20 minutes, but May 10, June 16, and June 21 had large errors. The 4-hour error of June 21 was partly due to the difficulty of defining a failure time because of the slow decay of the signal. However, if interference had been less, it is possible that scatter peaks would have been observed at close enough range to account for propagation. The other errors may have been caused by lack of detailed information on the scatter records because of the presence of interference.

In the late-fall group the largest error was 15 minutes. The apparent improvement over the summer results was due to the rapid rate of change of skip distance under winter conditions.

Skip distances were estimated at the observed time of path failure by using the delay times and the assumed virtual heights. Errors are within about 12 per cent for the summer group and 8 per cent for the winter group, the rms errors being 5.7 per cent and 3.4 per cent, respectively.

The variation of estimated time of path failure with assumed virtual height was calculated for May 12. Changes of height of ± 50 km produce only small changes in the estimated failure time (6 or 7 minutes). These are typical results for the summer type of record since the rate of change of delay time with time of day is typical. Discrepancies would be smaller for winter conditions because of the greater rate of change, showing that the larger errors of estimating are not produced by erroneous height choices.

The change of estimated skip distance with change of assumed virtual height was also calculated for that day. Changes of the assumed virtual height of ± 50 km made changes in the estimated skip distance of less than 2 per cent, and for a typical winter day the error would have been still smaller because of the lower assumed virtual height.

Because of interference contaminating most of the records, only four sunrise path recoveries appear on Fig. 6 for spring and summer, and only three for late fall. They appear to have the same order of magnitude of error as the failures. However, the complexity of recovery periods at shorter delay times is such as to make interpretation of shorter skip distances than the one used here rather difficult.

Two-hop failure times are plotted on Fig. 6 for reasons of general interest, and surprisingly good results are obtained.

It is also desirable to point out that literal application of a simple rule of scaling the strongest peak seen, or of scaling the first peak, may lead to completely erroneous results in cases where close-in scatter groups representing ground-scatter propagated via E or direct E-layer short scatter are seen. On days such as are represented by the range-time record of Fig. 2 the echoes at about 4 or 5 msec might be regarded as one-hop ground scatter propagated by F_2, and the echoes at about 11-msec two-hop of the same type of propagation, and indeed on the A-scope both echoes would have similar characteristics, with equal possibility of either one being the stronger. It is only by watching trends as time progresses that one can see that the second group moves out with the F_2 skip distance and the first does not change much, identifying it with the next most likely source of short- or long-scatter reflections, the E-layer. In all cases where it is desired to determine F_2 skip distance, it is necessary to distinguish, by experience, which group is the ground-scatter group propagated via F_2.

Although there is apparent good agreement between the estimated failure and recovery times and observed failure and recovery times on most undisturbed days, it does not follow that signals will not be detectable and even usable for many hours outside the periods bounded by the estimated times of recovery and failure of transmission. It will be recalled that the start of path failure was defined as the start of the initial sharp drop after skip focus. Although this drop for this path is usually of the order of 20 to 40 db, and usually very rapid, there are times when it is not at all rapid; it is usually followed by one or more temporary partial signal recoveries, and the time at which the signal is last heard may be hours later. Listening observations made during field-intensity recording of WWV at White Sands on November 30, and December 1, 1950 showed that WWV could be detected at least 1 hour and 42 minutes on the first day and 2 hours and 25 minutes on the second day, after the defined start of path failure.

VI. Structure of Scatter Echoes on Range-Time Records

The frequent appearance of ground-scatter echoes as a number of close, but separated, echoes with the behavior described under Section 3 above suggests the fact that some things on the ground are better scatterers than others. Dieminger[3] believes that specific objects play an important part. The frequent appearance of cusps on the records suggested a mechanism whereby different regions of an irregular ionosphere pick up and lose the same or different objects as the ionization change causes the skip range to change.

It was first thought that if everything in the region just beyond skip distance were contributing equally to the echoes insofar as their scattering efficiency was concerned cusps could not appear since, if the ionization changed, echoes would come in at about the same strength from the new skip distance and any one part of a range-time record would be just as uniform and just as dense along a line marking the skip distance as any other part. However, such cusps could well exist without the help of specific good scatterers on the ground.

A possible explanation of cusps and discontinuities in the range-time records without the requirement of specific good scatterers is an ionosphere with irregularities in it many miles long, with velocity components in various directions. If the area became smaller, it would reach a critical size that would no longer produce a trace on the backscatter record. In general, changes in the tilt, ion density, ion distribution, and size of these areas should cause the backscatter echoes to vary in range and at times become too weak to record.

It should be noted that ionospheric irregularities and turbulence cause anomalies in the field-intensity records as well. One possible source of error due to nongreat-circle transmission may exist if an omnidirectional antenna such as that of WWV is used for transmitting. It is possible for the receiver to receive a signal reflected from an area not in the beam of the pulse transmitter and produce a field-intensity recording after the backscatter has exceeded the delay time corresponding to the skip distance for the region in which the receiver is located. However, appreciable discrepancies in time of failure of this type require very large horizontal gradients (tilts) in regions off the great circle path.

Fig. 3 for June 30, 1950 is, for a fairly disturbed day, one with an ionosphere character figure of 5. Near the beginning of the record, wisps coming downward represent echoes with rapidly decreasing range, the rapid changes terminating at a closer range. Thus, one of these traces has a delay time of 18.0 msec at 0128 GCT and 14.0 msec ten minutes later. Assuming the cause to be a change of skip distance, the change was found to be equivalent to a 41.2-per cent increase of ion density in 10 minutes, the rate of change being of the same order as that of a sunrise period. The apparent skip distance moved in under these circumstances at a rate of 3,600 km per hour. Other traces seen on the June 30 record are very baffling but not too unusual.

Fig. 4 for November 22, 1950, taken near the beginning of an ionospheric disturbance, shows a whole series of wisps representing echoes starting at about 12-msec delay, decreasing rapidly in range, and dying out just ahead of a steady, solid short-distance echo running along at about 6- or 7-msec delay. Since the rates of ionization change assumed for these disturbances seem so fantastic, one is led to speculate upon the possibility that the traces represent real changes of range of reflecting areas, particularly since on a night like that of June 30 the field intensity of WWV received at White Sands did not recover when the scatter delay times diminished. Direct reflections from fast-moving waves of sharp density gradient somewhere in the ionosphere might account for the heavy black traces which change range over about an hour and sometimes cross one another in range.

A possible explanation of the very fast-moving traces with receding range is the entry of corpuscular matter into the ionosphere from great heights, producing scattering regions which would reflect energy as they came down through the whole ionosphere. The phenomenon would correlate with that noted at vertical incidence by Wells, Watts, and George,[11] where discontinuities were seen to travel down the h'-f curve during an ionospheric disturbance. The rates of travel noticed by these observers, 1 to 2 km per second, agree very well with the 3,600-km per hour noted above. The slower-moving traces have velocities of the order of 200–300 km per hour, suggesting Meek's observations of fast-moving scattering regions in the E and F_2 layer at high latitudes.[12] The rates of travel are similar to the velocities of irregularities in F_2 noted by Munro[13] and others.[14] The F_2 scattering regions are apparently identical with Dieminger's G-scatter,[3] associated with auroral disturbances. It is significant that such scattering regions are unofficially reported for temperate zone stations in the United States about a half a dozen times a year, so that

[11] H. W. Wells, J. M. Watts, and D. E. George, "Detection of rapidly moving ionospheric clouds," *Phys. Rev.*, vol. 69, p. 540; 1946.
[12] J. H. Meek, "Sporadic ionization at high latitudes," *Jour. Geophys. Res.*, vol. 54, p. 339; December, 1949.
[13] G. H. Munro, "Travelling disturbances in the ionosphere," *Proc. Roy. Soc. A*, vol. 202, p. 208; July, 1950.
[14] "Winds and turbulence in the upper atmosphere," *Nature*, vol. 167, pp. 626–628; April 21, 1951.

it is reasonable to assume that records like that of Fig. 3 are a manifestation of the motion of such regions over the western part of the United States during an ionospheric disturbance.

VII. Conclusions

As a result of comparison of backscatter and field-intensity records obtained for transmissions over a 2,700-km path on 15 mc, during several months of the year, the following is concluded for such a frequency and path:

1. An echo group nearly always appears which is identified with the ground at the one-hop F_2-layer skip-distance range. The group follows the skip distance throughout 14 hours, being close in during the day and far out at night, and changes its range suddenly when the skip distance changes suddenly.

2. It is possible to determine approximate F_2-layer skip distance over a path by measuring the delay time to the leading edge of the ground-scatter group. However, this can be done only at a fixed location where average ionosphere heights for the path can be estimated and where the normal pattern which the scatter echoes follow is well known, so that abnormal close-in echoes coming from abnormal ionization regions in the E layer and echoes coming from regions excited by side lobes from the antenna can be recognized.

3. The simple technique of measuring the delay time to the first peak of an echo group, or to the strongest echo peak of a group, may result in completely erroneous results if the spurious echoes mentioned above are not recognized and discarded.

4. On ionospherically disturbed days, and a few other anomalous days, positive identification of the F_2-propagated ground-scatter echo may be difficult or impossible. However, close study of records taken daily on a continuous basis at one location should do much to reduce the number of doubtful records.

5. The range beyond which a signal is usable can generally be determined with fair accuracy.

6. The range within which no signal can be received cannot be determined because propagation by nongreat-circle and scatter modes at lower intensity than normal (particularly after the first major signal drop corresponding to the start of path failure, but also before the first major signal rise corresponding to the end of path recovery) may persist for many minutes or hours.

7. The times during which a signal at a given range is usable may be determined with fair accuracy when the rate of change of skip distance with time is rapid, as in the case of late fall, winter, and early spring conditions.

8. The times during which a signal from a given range may be detected (whether usable or not) cannot be determined reliably, even when the rate of change of skip distance is rapid, because of the considerations of 7 above.

9. Examination of a variety of experimental records indicates that backscatter data, because of the striking difference in the day-to-day records and their sensitivity to disturbed conditions, may provide an indicator of ionospheric disturbances which is even better than the direction-finder technique at present employed in disturbance forecasting. Tracking of these disturbances by use of a rotary beam antenna also seems possible.

Coaxial Transmission-Line Filters*

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Summary—**Microwave filters based upon coaxial structures are not difficult to construct, and for wide-band applications they have an advantage over cavity types in that the terminal matching problems are more easily met. For narrow-band work the cavity is superior because of its higher Q. A tentative analysis of coaxial transmission-line band-pass filters is given and experimental work in support of the analytical results is included. A TE-mode high-pass filter is discussed and experimental data presented.**

Introduction

IT HAS been shown[1] that a band-pass filter may be constructed by introducing a number of equispaced short-circuiting elements into a coaxial transmission line. The transmission which occurs past such a group of shunt obstacles may be of the dominant TEM mode, or it may be of the TE type. TE transmission is found when the conducting shunt obstacles in a given obstacle group are arranged so that the electric field of the TE mode considered has a distribution such that no impressed electric field impinges upon the shunt obstacles. This kind of transmission has been adequately demonstrated[1] by the simple expedient of providing rotatable shunt obstacles in a band-pass coaxial transmission-line filter. When TE transmission occurs, the rotation of successive shunt-obstacle groups will cause the electric field from one group to be intercepted by the next with a high resultant attenuation. If the shunt obstacle groups are lined up, TE transmission may go on undisturbed and the structure will be a high-pass one. TEM transmission, on the other hand, is based upon the reactive behavior of the shunt obstacles and not upon the "fitting" of the electric field between the conductors

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[1] D. E. Mode, "Spurious modes in coaxial transmission-line filters," Proc. I.R.E., vol. 38, pp. 176–180; February, 1950.

making up a shunt obstacle. When the shunt obstacle is antiresonant, it will present a fairly effective open circuit to the TEM field and transmission occurs. Thus the structure is band pass in nature if higher-order modes are not allowed to propagate.

The synthesis of coaxial transmission-line filters requires the use of shunt obstacles of both the so-called inductive and capacitive types. It would be better if these names were discarded in favor of others which describe the transmission-line behavior of such shunt obstacles. In the microwave bands, none of the reactive elements in a filter structure should be considered as a lumped element; for very narrow-band work the lumped element idea is a useful approximation. Inductive obstacles usually take the form of conducting rods which connect the inner and outer conductors of the coaxial line. Capacitive obstacles are most symmetrically constructed of conducting discs which may be attached to either the inner or outer conductor, but which must not be of sufficient extent to short circuit the line.

Coaxial transmission-line filters have certain advantages over cavity types. For example, a coaxial structure may be a low-pass filter—a cavity cannot provide low-pass action. For broad-band applications the coaxial transmission-line filter offers a less severe terminal matching problem, for only taper transitions are necessary. The cavity structure is a superior narrow-band filter as it has a much higher Q and the transitions introduce little difficulty for narrow bands.

Analytical Approach

The analysis of the band-pass filters considered in this paper is based upon TEM transmission. Equivalent circuits based upon the usual low-frequency circuit theory may be used, and from these the image impedance may be drawn. Such image versus frequency graphs may be drawn. Such image impedance data is sufficient to define the filter cutoff frequencies and, to a certain extent, the insertion loss. An equation for the image impedance of a mid-shunt filter section is

$$Z_{0\pi} = \frac{2}{Y_2\sqrt{\frac{4Y_1}{Y_2}+1}}, \tag{1}$$

where Y_1 and Y_2 are the total series and shunt admittances of the filter section, respectively.

The series admittance is introduced by the coaxial line which connects the shunt obstacles. If this transmission line is replaced by its exact lumped pi representation, then the series admittance Y_1 is known directly. The shunt admittance Y_2 contains a term coming from the pi representation of the series transmission line plus others describing the shunt obstacles. The shunt obstacles may be synthesized in various ways. If it is possible to represent Y_1 and Y_2 analytically, the filter behavior may be predicted from graphs of (1) versus frequency.

Band-Pass Coaxial Transmission-Line Filters

The simplest of the coaxial band-pass filters is the wide-band one, in which each shunt obstacle is constructed of four wires as shown in Fig. 1 [1]. An equivalent circuit for one section of this filter is shown in Fig.

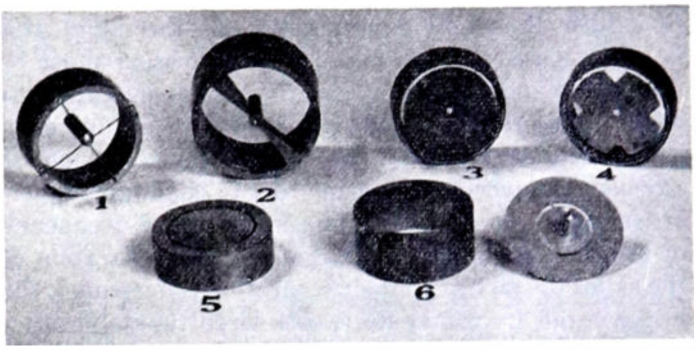

Fig. 1—Typical shunt-element structures. A wide band structure is illustrated in 1, a TE-mode high-pass structure in 2, and TEM narrower-band structures in 3 and 4. Experimental structures are indicated in 5 and 6.

2. The series transmission line between shunt obstacles is replaced by its equivalent pi section in which ϕ is one half the electrical length of the line and Z_k its characteristic impedance. The shunt-obstacle structure is represented by a single equivalent transmission line of characteristic impedance Z_{01} and of length equal, electrically, to the mechanical length of the shunt wires. No method of calculating the parameter Z_{01} is known al-

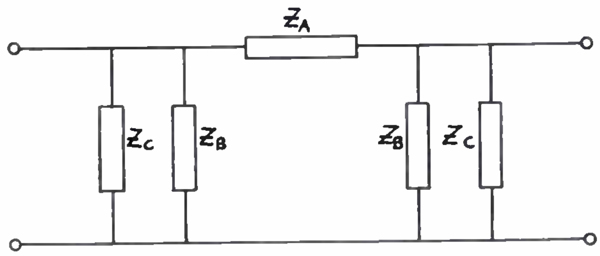

Fig. 2—The equivalent circuit for a wide-band filter. $Z_A = jZ_K \sin 2\phi x$, $Z_B = -jZ_k \cot \phi x$, $Z_C = 2jZ_{01} \tan \theta_1 x$.

though an approximate equation has been given in a previous paper.[2] The total shunt admittance per section is

$$Y_2 = \frac{2j}{Z_k}\tan\phi x - \frac{j}{Z_{01}}\cot\theta_1 x, \tag{2}$$

in which x is a normalized frequency (normalized to 1,152 mc in this paper) and ϕ and θ_1 are computed at the normalizing frequency. The image impedance of the filter is given by

$$\frac{Z_{0\pi}}{Z_k} = \frac{1}{A\sqrt{\frac{2\csc 2\phi x}{A} - 1}} \tag{3}$$

$$A = \tan\phi x - \frac{Z_k}{2Z_{01}}\cot\theta_1 x.$$

[2] D. E. Mode, "Coaxial transmission line elements in low-pass filters," Proc. I.R.E., vol. 36, pp. 1376–1383; November, 1948.

The shunt-wire group has sensitive control over the lower cutoff frequency of the filter. If larger diameter wires or more wires of the same diameter are used in a shunt group, the parameter Z_{01} is decreased and (3) indicates that the filter lower cutoff frequency is increased. Although it might be thought that either a single large shunt wire or a number of smaller wires could be used in the shunt structure (for Z_{01} the same), this is not the case. Spurious mode transmission must be considered and for this reason the use of several shunt wires per section is necessary. Even with a number of shunt wires per section it may be necessary to transpose adjacent shunt-wire groups in order to eliminate higher-order mode propagation.[1] The upper cutoff frequency of the filter is determined largely by the separation of the shunt obstacles. As their separation is decreased, the upper cutoff frequency decreases. Unfortunately, other characteristics such as the width of the upper primary attenuation band are also affected so that if a filter of narrower bandwidth is required it should not be synthesized through change in shunt-obstacle separation alone.

In order to obtain a narrower-band coaxial transmission-line filter, a more complicated shunt-obstacle structure must be used. If one refers to the low-frequency theory of K-type band-pass filters, it is seen that the bandwidth is dependent upon the L/C ratio of the shunt reactive elements. Carrying this idea over to the microwave band-pass filter, it appears that an additional shunt reactive element, such as a metal disc, must be introduced. Such a structure is shown in Fig. 1 [3].

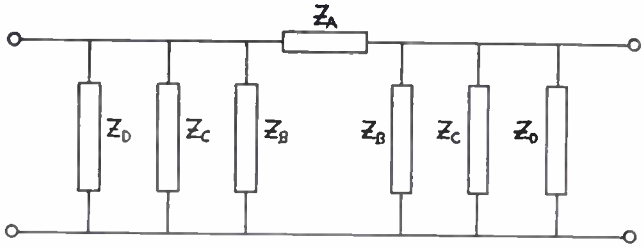

Fig. 3—The equivalent circuit of a narrower-band filter. $Z_D = -2jZ_{02} \cot \theta_2 x$.

where a large metallic disc is shown together with four tiny wires which attach the disc to the outer body of the coaxial structure. The treatment of this structure posed a problem, for the way in which the disc and shunt wires should be introduced into the equivalent circuit was not clear. Mechanically, the disc and shunt wires are connected in tandem. A tandem connection, however, would neglect the greater part of the disc terminal electric field which is not influenced by the shunt wires. A parallel connection for these elements was tentatively adopted and the equivalent circuit is shown in Fig. 3. The shunt reactive structure is seen to be the same as for the wide-band filter, except that another reactive element, representing the disc, is added. The shunt disc is represented as a transmission line; and although this is an approximation, the results warrant the simplification, at least in a first treatment. The parameters of the equivalent transmission line for the shunt disc may be obtained by use of an equation given by Marcuvitz[3] for the reactance of such a disc. The disc reactance is computed at the band center frequency, and this is set equal to the reactance of an open-circuited transmission line of length θ_2 and characteristic impedance Z_{02}. As the length θ_2 is the radial extent of the shunt disc, only Z_{02} is unknown, and it may be solved for directly. No analytical method is available for computing Z_{01}. The length θ_1, however, is equal to the mechanical length of the shunt wires (converted to electrical measure at the normalizing frequency). With these approximations, then, the total filter shunt admittance per section is

$$Y_2 = j\left[\frac{2}{Z_k}\tan\phi x + \frac{1}{Z_{02}}\tan\theta_2 x - \frac{1}{Z_{01}}\cot\theta_1 x\right], \qquad (4)$$

and the image impedance becomes

$$\frac{Z_{0\pi}}{Z_k} = \frac{1}{B\sqrt{\dfrac{2\csc 2\phi x}{B} - 1}}$$

$$B = \tan\phi x + \frac{Z_k}{2Z_{02}}\tan\theta_2 x - \frac{Z_k}{2Z_{01}}\cot\theta_1 x. \qquad (5)$$

The effect of varying ϕ is indicated in Figs. 4–8. It is seen that as ϕ is increased the primary and first secondary pass bands begin to squeeze the upper primary attenuation band. Fig. 7 is computed for ϕ equal to 25 degrees, and here the primary and secondary pass bands have just about merged so that only a very narrow attenuation band exists between them. Eventually, as in Fig. 8, the pass bands have merged and the first secondary attenuation band becomes the upper primary one. The parameter θ_1 controls the lower cutoff frequency of the filter. Beginning with Fig. 4, where θ_1 is 2.2 degrees, Fig. 9 shows the filter behavior for θ_1 equal to 4, 6, and 8 degrees. As θ_1 is increased, the lower cutoff frequency is decreased and the band center frequency is also somewhat depressed. The shunt disc has control over the upper cutoff frequency. As the diameter of this disc is increased, the upper cutoff frequency is reduced. A narrow-band filter, therefore, involves values of θ_2 which are large. Although the matter has not been mentioned, the shunt disc must be kept thin if the equivalent circuit of Fig. 3 is to be valid. Otherwise, the disc will introduce series elements into the equivalent circuit. In the filters described, the disc thickness has been held to $\frac{1}{2}$ per cent of the coaxial-line diameter.

High-Pass Coaxial Transmission-Line Filters

The use of shunt fan-type leads, Fig. 1 [2], is interesting. If a number of filter sections are arranged so that the fan-type leads are all in line, then a TE mode set up at the input will pass by the successive shunt obstacles

[3] N. Marcuvitz, "Waveguide Handbook," McGraw-Hill Book Co., Inc., New York, N. Y., p. 229; 1951.

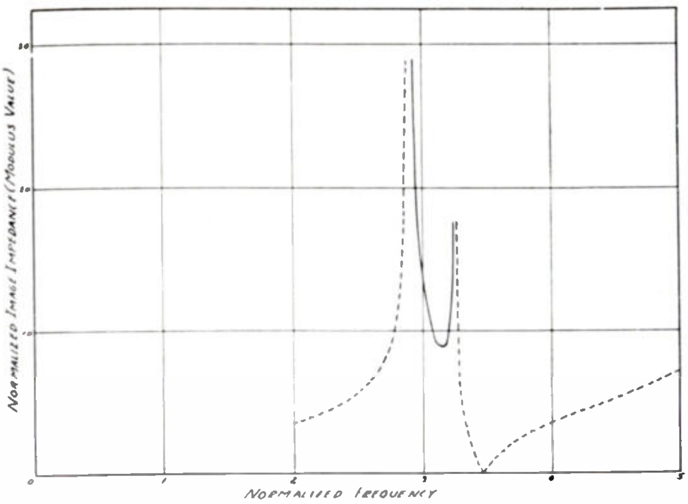

Fig. 4—Calculated image-impedance behavior of a band-pass filter having $\phi=10°$.

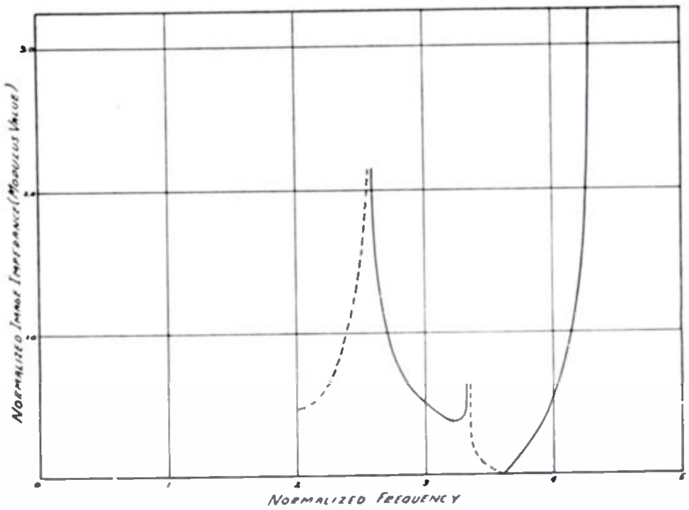

Fig. 7—Calculated image-impedance behavior of a band-pass filter having $\phi=25°$.

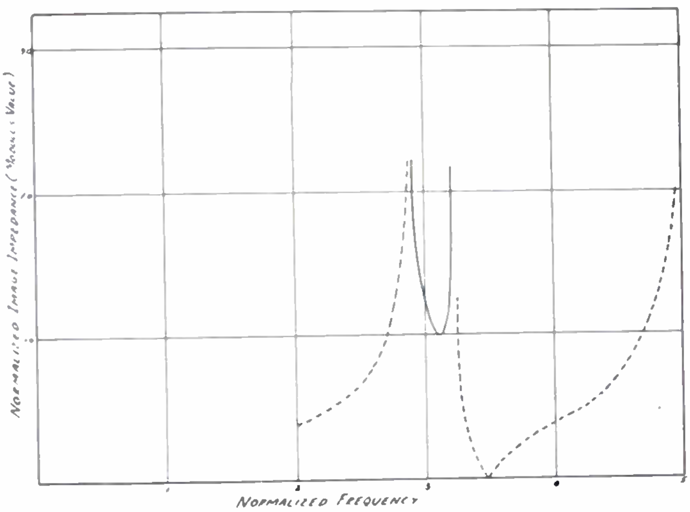

Fig. 5—Calculated image-impedance behavior of a band-pass filter having $\phi=14°$.

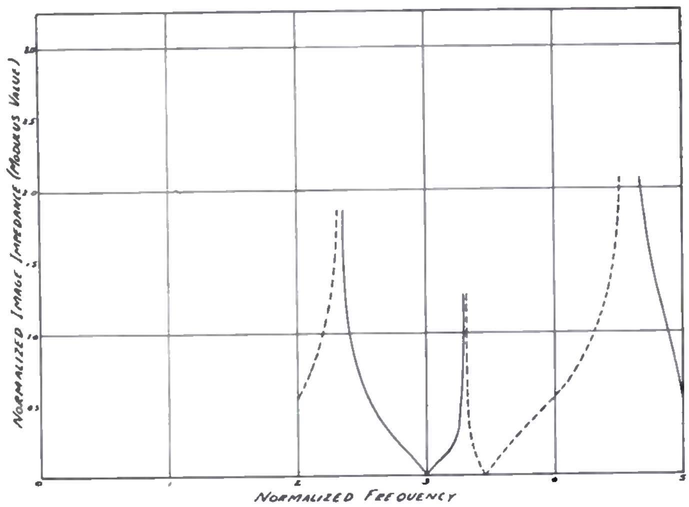

Fig. 8—Calculated image-impedance behavior of a band-pass filter having $\phi=30°$.

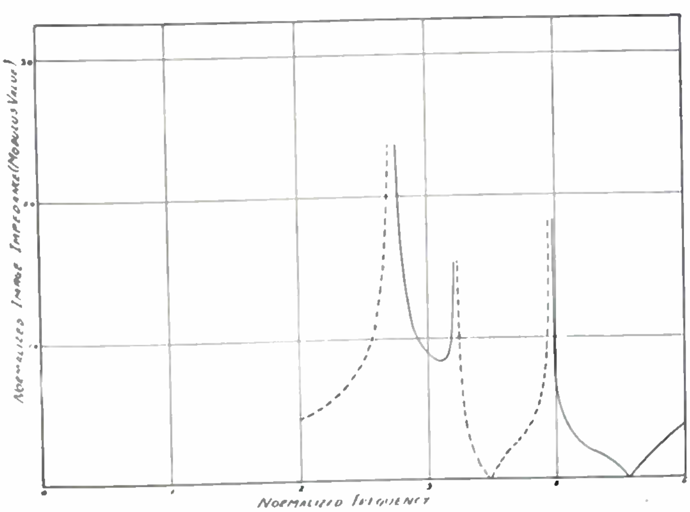

Fig. 6—Calculated image-impedance behavior of a band-pass filter having $\phi=20°$.

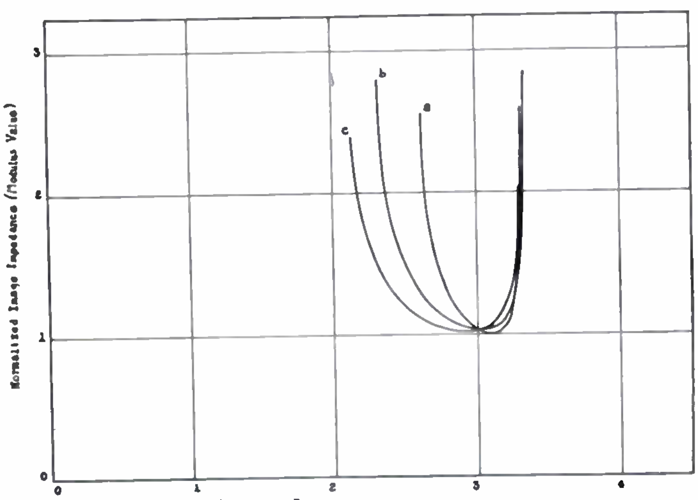

Fig. 9—A family of image-impedance characteristics showing the effect of varying the parameter θ_1. The θ_1 values are 4° for curve a, 6° for curve b, and 8° for curve c.

undisturbed. There is no reactive mechanism by which the transmission may be attenuated, and so the arrangement is a true high-pass filter. As the interfan space is made greater, the TE and TEM cutoff frequencies approach each other so that the cutoff frequency may be determined by either mode. In cases where it is TEM, the TE mode usually enters before the TEM mode cuts off, and the action is still high pass.

$$\frac{Z_k}{2Z_{01}} = \frac{\tan\theta_2 x_1\left[\tan\phi x_2 - \dfrac{2}{\sin 2\phi x_2}\right] - \tan\phi x_1 \tan\theta_2 x_2}{\tan\theta_2 x_1 \cot\theta_1 x_2 - \cot\theta_1 x_1 \tan\theta_2 x_2} \tag{6}$$

$$\frac{Z_k}{2Z_{02}} = \frac{\cot\theta_1 x_1\left[\tan\phi x_2 - \dfrac{2}{\sin 2\phi x_2}\right] - \tan\phi x_1 \cot\theta_1 x_2}{\tan\theta_2 x_1 \cot\theta_1 x_2 - \cot\theta_1 x_1 \tan\theta_2 x_2} \tag{7}$$

Experimental Results

The variation of the lower cutoff frequency of the wide-band filter with the parameter Z_{01} has been shown[1] to follow the trend indicated herein. No data is available concerning the upper cutoff frequency as this occurs in a frequency band out of the range of the test equipment. Complete test results are available in the case of the narrower-band filter, and these are based upon a model having the following dimensions:

Inner conductor, O.D.,	0.25 inches
Outer conductor, I.D.,	1.75 inches
Length (2ϕ)	variable
Disc O.D.,	$1\frac{3}{8}$ inches
Thickness	0.010 inches

4–0.010 inch diam. shunt wires, 1/16 inch long.

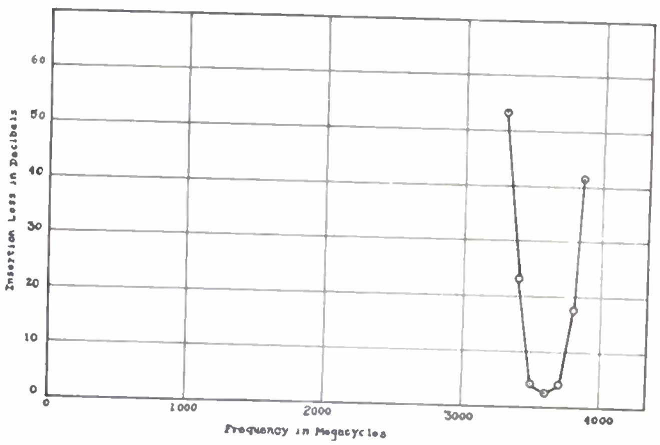

Fig. 10—Experimental insertion-loss characteristic for a 6-section band-pass filter, $\phi=14°$.

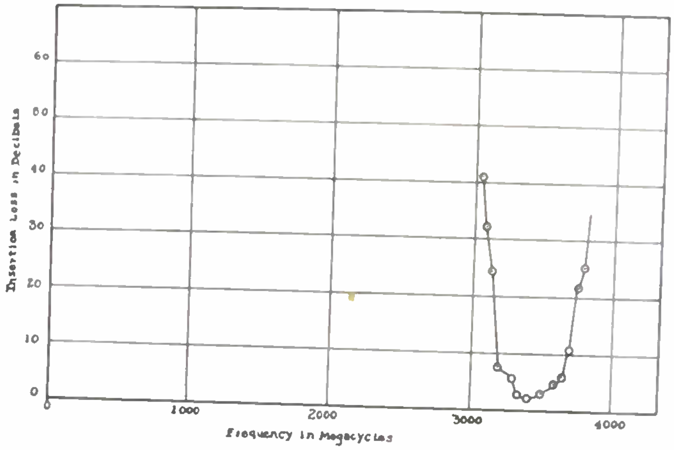

Fig. 11—Experimental insertion-loss characteristic for a 6-section band-pass filter, $\phi=20°$.

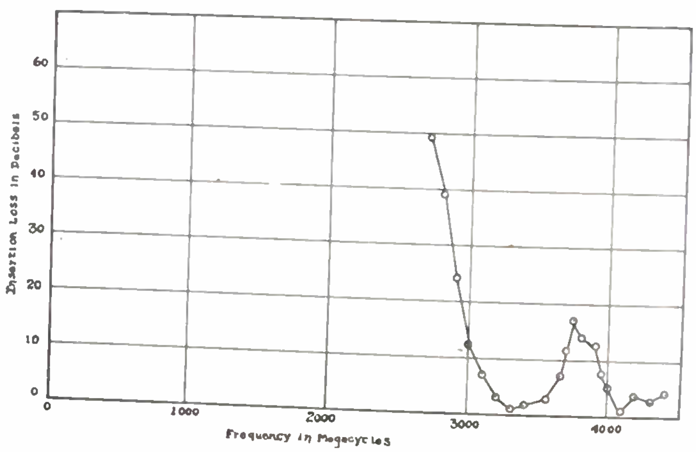

Fig. 12—Experimental insertion-loss characteristic for a 6-section band-pass filter, $\phi=27°$.

The effect of the parameter ϕ is of interest. Figs. 10, 11, and 12 show the insertion loss versus frequency for ϕ equal to 14, 20, and 27 degrees. It is particularly interesting to note the attenuation band which occurs in the neighborhood of 3,800 mc, in Fig. 12, for this is just what is predicted from the theoretical data of Fig. 7. The filter which gives the characteristic shown in Fig. 10 has the characteristic impedances Z_{01} and Z_{02} of 131 and 63 ohms, respectively. These are computed from equations obtained from the cutoff frequencies of the filter. Designating the lower cutoff frequency by x_1 and the upper one by x_2,

Using these relations the disc reactance at the midband frequency, which is 3.12 normalized units or 3,600 mc, is about 15 ohms. Calculations made from the waveguide handbook[8] give a value of about 13 ohms for this parameter.

The parameter θ_1 was also investigated, although at first it was difficult to see how this could be varied without changing the shunt-disc diameter. It was finally decided to notch the shunt disc and connect the shunt wires at various points on the disc, the idea being that the shunt-disc reactance would not suffer much because of the small notches. The notched shunt disc with the shunt wires connected between the notches is shown in Fig. 1[4]. Tests of this filter showed the same insertion-loss characteristic as that of Fig. 10. When the shunt wires were connected to the notch centers, however, the radically different insertion-loss characteristic of Fig. 13 resulted. Here the shunt-wire length is about 8 degrees. Both the lower cutoff frequency and the band center are seen to be lowered by this change in θ_1, a behavior predicted by the theoretical work of the preceding section.

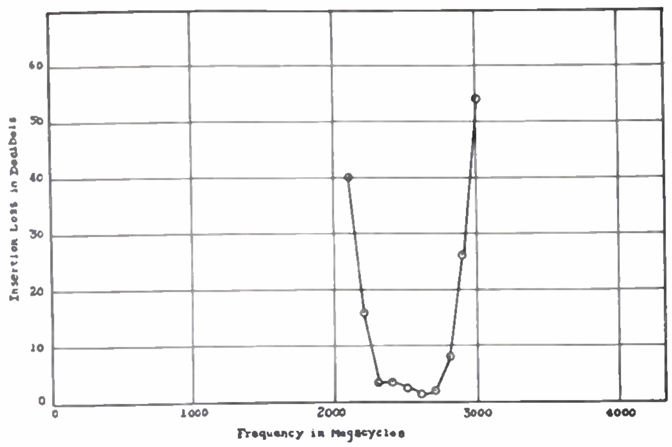

Fig. 13—Experimental insertion-loss characteristic for a 6-section band-pass filter, $\theta_1=8°$.

Some experimental work on TE high-pass filters is worth reporting. The insertion loss of a filter composed of shunt sections, such as shown in Fig. 1-3, is interesting. First, with the shunt sections alternately transposed, the insertion-loss characteristic is as shown in Fig. 14(a). With the sections lined up, the insertion-loss characteristic becomes that of Fig. 14(b). The difference between the two characteristics is easily explained in that in one case the TEM mode governs the cutoff frequency and in the other the TE mode has command.

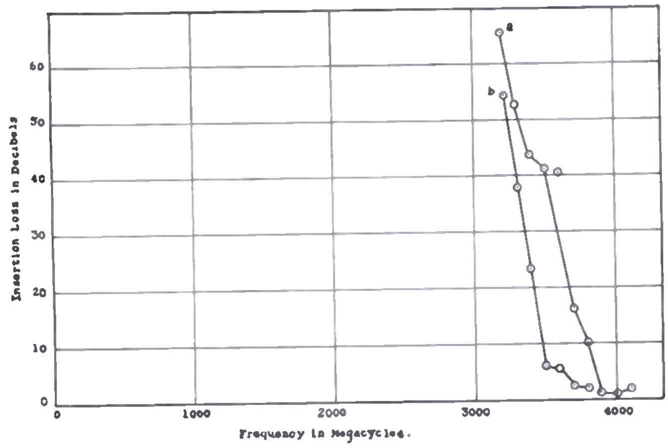

Fig. 14—Experimental insertion-loss characteristic for a 6-section TE-mode high-pass filter. Curve a is for transposed adjacent sections, and curve b for the sections lined up.

Conclusions

None of the filters described in this paper are narrow-band filters, for the smallest bandwidth reported is about 10 per cent. As the mechanical design is difficult to work out in order to achieve even this bandwidth, it is evident that coaxial structures are not suitable for narrow-band applications. The coaxial structure is valuable in situations where wide pass bands are required or in low-pass ladder structures where cavities cannot be used. The terminal transition is another factor which favors the coaxial structure as it may be constructed of a simple taper which has perhaps the widest useful bandwidth of any of the common transitions.

The Parallel-T Resistance—Capacitance Network*

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Summary—A network solution is given of the well-known RC parallel-T driven by a generator of finite resistance and terminated in a resistance load. It is shown that by properly relating the source and load resistances the network presents a loss at low frequencies equal to the loss at high frequencies, and under this condition the transfer characteristic conforms to a circle diagram in the complex plane. This, the "symmetrical parallel-T," is shown to have a transfer characteristic like that of a simple "equivalent" series-resonant circuit.

Introduction

THE PARALLEL-T RC EQUIVALENT of the Wien Bridge has been of considerable interest in recent years, and a number of papers on the subject can be found in the literature. The analytical studies to date have been restricted by the assumption of zero generator impedance and infinite load impedance. For most applications, and especially as applied to the feedback amplifier, the assumption of zero generator impedance and infinite load resistance is neither correct nor, as is shown below, to be desired.

This paper presents the solution of the complete network. It is found that the loaded parallel-T has a transfer characteristic identical with that of the simple form so long as the load and source impedances are selected in such a manner that the loss at low frequencies is equal to the loss at high frequencies. The loaded parallel-T may, however, be made to have a rejection band narrower by a factor of almost two than that of the simple circuit.

The Network Solution

Consider a parallel-T network having a generator impedance Z_1 and a load impedance Z_0, as shown in Fig. 1. The mesh equations for this network are

$$\begin{aligned}
e_1 &= +i_1(Z_1+Z_2+Z_3) - i_0Z_3 + i_3(Z_2+Z_3) - i_4Z_3\\
0 &= -i_1Z_3 + i_0(Z_0+Z_2+Z_3) - i_3Z_3 + i_4(Z_2+Z_3)\\
0 &= +i_1(Z_2+Z_3) - i_0Z_3 + i_3(Z_2+Z_3+Z_4+Z_5) - i_4(Z_3+Z_5)\\
0 &= -i_1Z_3 + i_0(Z_2+Z_3) - i_3(Z_3+Z_5) + i_4(Z_2+Z_3+Z_4+Z_5).
\end{aligned} \tag{1}$$

The fourth-order determinant Δ of the impedance coefficients is

$$\Delta = \begin{vmatrix} Z_1 & 0 & -Z_4-Z_5 & Z_5 \\ 0 & Z_0 & Z_5 & -Z_4-Z_5 \\ Z_2 & Z_2 & Z_2+Z_4 & Z_2+Z_4 \\ -Z_3 & Z_2+Z_3 & -Z_3-Z_5 & Z_2+Z_3+Z_4+Z_5 \end{vmatrix}. \tag{2}$$

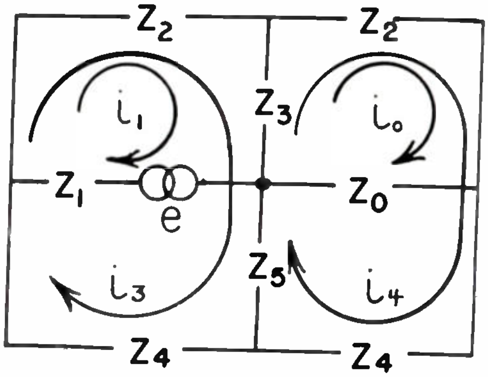

Fig. 1—General parallel-T network.

From the above it is easily shown that

$$\begin{aligned}
\Delta = {} & Z_1Z_0(Z_2+Z_4)(Z_2+2Z_5+Z_4+2Z_3)\\
& + (Z_1+Z_0)\left[Z_2(Z_2+2Z_3)(Z_4+Z_5)\right.\\
& \left. + Z_4(Z_4+2Z_5)(Z_2+Z_3)\right]\\
& + Z_2Z_4(Z_2+2Z_3)(Z_4+2Z_5)
\end{aligned}. \tag{3}$$

The input current i_1 is, therefore,

$$\begin{aligned}
i_1 = {} & \frac{Z_0(Z_2+Z_4)(Z_2+2Z_3+Z_4+2Z_5)+(Z_2+Z_3)(Z_2+Z_4)(Z_4+2Z_5)}{\Delta}\,e_1\\
& + \frac{Z_2Z_3(Z_4+2Z_5)-Z_2Z_5(Z_2+2Z_3)}{\Delta}\,e_1
\end{aligned}. \tag{4}$$

The output current i_0 is

$$i_0 = \frac{Z_2Z_5(Z_2+2Z_3)+Z_3Z_4(Z_4+2Z_5)}{\Delta}\,e_1. \tag{5}$$

* Decimal classification: R143. Original manuscript received by the Institute, November 6, 1952; revised manuscript received July 15, 1952.

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As is to be expected, (5) shows that the transfer admittance i_0/e_1 is symmetrical as regards the input and output impedances, and the existence of a null is independent of the terminating impedances.

The network of Fig. 1 reduces to the customary form of the parallel-T resistance-capacitance filter of Fig. 2 by making Z_2 and Z_5 pure resistances,

$$Z_2 = r, \quad \text{and} \quad Z_5 = \frac{p^2 r}{2},$$

and Z_3 and Z_4 pure capacitances,

$$Z_3 = -jtr/2p, \quad \text{and} \quad Z_4 = -jtpr,$$

where $t = \omega_0/\omega$.

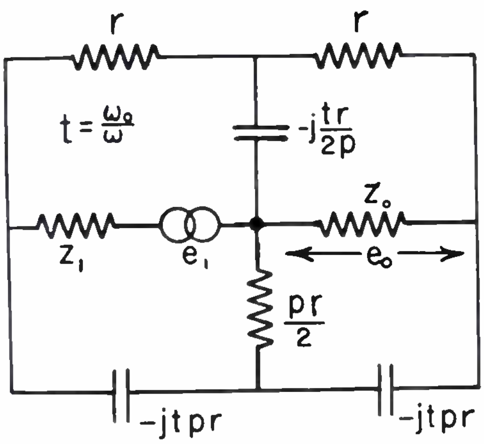

Fig. 2—Parallel-T RC filter.[1]

These relations insure that a null is obtained when $t = 1$. The design parameter p controls the ratio of the impedances in one T relative to those in the other. In the discussion following, Z_1 and Z_0 are assumed to be pure resistances.

By substitution, (4) and (5) reduce to

$$\frac{i_1}{e_1} = \frac{2\dfrac{Z_0}{r}(1+p^2)(1-jpt) + p(2p-jt)(1-jpt) - p(p+jt)}{(Z_1+Z_0)\left(1 - t^2 - 2jt\dfrac{p^2+1}{p}\right)\dfrac{p^2}{2} + \dfrac{Z_1 Z_0}{r}(1+p^2)(1-jpt) - p^2 t(t+jp)} \tag{6}$$

$$\frac{i_0}{e_1} = \frac{(1-t^2)}{(Z_1+Z_0)\left(1 - t^2 - 2jt\dfrac{p^2+1}{p}\right) + 2\dfrac{Z_1 Z_0}{r}\left(\dfrac{p^2+1}{p^2}\right)(1-jpt) - 2rt(t+jp)}. \tag{7}$$

Equations (6) and (7) for the input and transfer admittances are still too complex to be of much practical use. However, a study of the transfer admittance shows that the ratio of the load voltage to the generator voltage e_0/e_1 follows a path in the complex plane resembling a pair of deformed semicircles having unequal diameters. Because the null condition is satisfied, the diameters of the semicircles lie on the real axis with one end at the origin. The lengths of the diameters are given, respectively, by the loss at zero frequency,

$$\left.\frac{e_0}{e_1}\right|_{\omega=0} = \frac{Z_0}{Z_0 + 2Z_2 + Z_1} = \frac{1}{1 + \dfrac{2r}{Z_0} + \dfrac{Z_1}{Z_0}} \tag{8}$$

and the loss at infinite frequency,

$$\left.\frac{e_0}{e_1}\right|_{\omega=\infty} = \frac{1}{1 + \dfrac{2Z_1}{Z_2} + \dfrac{Z_1}{Z_5} + \dfrac{Z_1}{Z_0}} = \frac{1}{1 + 2\dfrac{Z_1}{r} + 2\dfrac{Z_1}{p^2 r} + \dfrac{Z_1}{Z_0}}. \tag{9}$$

As expected, both of the extreme frequency losses increase or decrease with corresponding changes in the ratio Z_1/Z_0. Additional terms are present which make the low-frequency loss a function also of the ratio r/Z_0, whereas the high-frequency loss is a function of the ratio Z_1/r. This interesting circumstance makes it possible to adjust separately the loss at zero frequency and the loss at infinite frequency. Whenever these losses are made equal, the response curve becomes symmetrical with respect to the frequency ω_0, the polar diagram is a circle, and the equations for the transfer and input admittances become simplified.

The case for which the response curve is symmetrical will be discussed in detail. The nonsymmetrical case will be illustrated briefly by an example.

Nonsymmetrical Response

As an example of the nonsymmetrical response, let $p = 1$, $Z_0 = \infty$, and $Z_1 = r$. The resulting frequency characteristic and polar diagram calculated from (7) are shown as the dashed curves in Figs. 3 and 4, respectively. If, on the other hand, one makes $Z_1 = 0$ and $Z_0 = r/2$, the solid curve results. In both figures the solid curve is a reflected image of the dashed curve. In the polar diagram, Fig. 4, it is of interest to note that the phase shift exceeds 90 degrees as the higher amplitude approaches the origin. Data for the case in which the generator impedance is zero and the load impedance is finite have been compiled by the Bureau of Standards Mathematical Tables Project.[2]

[1] Due to draftsman's error Fig. 2 is incorrect. Lower resistor in Fig. 2 should read $\frac{p^2 r}{2}$, instead of $\frac{pr}{2}$.

[2] "Characteristics of Resistance-Capacity Electrical Networks," National Bureau of Standards Mathematical Tables Project.

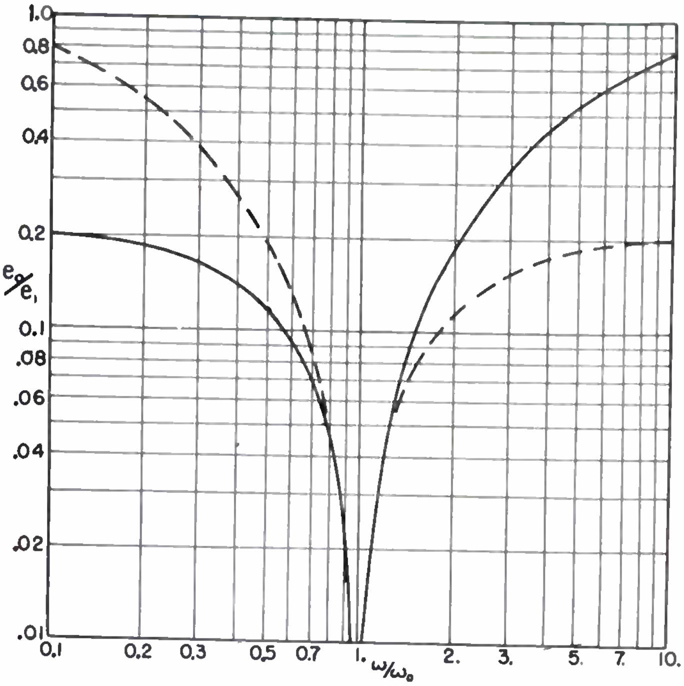

Fig. 3—Nonsymmetrical parallel-T frequency characteristics.

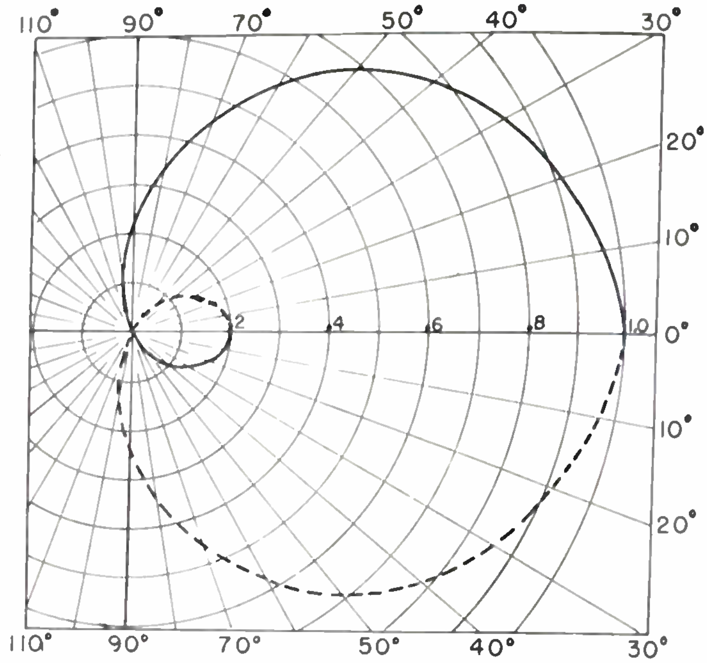

Fig. 4—Nonsymmetrical parallel-T polar diagrams.

The Symmetrical Parallel-T

The case for which the transfer admittance has the same loss at high as at low frequencies is of most common interest and, fortunately, leads to a considerable simplification of the network equations. A parallel-T connected between input and output impedances Z_1 and Z_0 will have equal zero and infinite frequency losses if Z_1 and Z_0 are related as

$$Z_1 Z_0 = \frac{2Z_2{}^2 Z_5}{2Z_5 + Z_2}, \tag{10}$$

or

$$\frac{Z_1 Z_0}{r^2} = \frac{p^2}{p^2 + 1}. \tag{11}$$

Hereafter, the term "symmetrical parallel-T" will refer to any parallel-T working between real Z_1 and Z_0 such that (11) is valid.

From here one might proceed by inserting (11) in (6) and (7) so as to eliminate either r or p. For reasons given later, interest is largely in the case for which $p=1$; whereupon it is a simple matter to select suitable Z_1, Z_0, and r directly from (11). We choose, therefore, to insert (11) in (7) so as to simplify the form of the equations. Doing this, the transadmittance of the symmetrical parallel-T can be put in the relatively simple form,

$$\frac{i_0}{e_1} = \frac{1-t^2}{(Z_1+Z_0)\left(1-t^2-2jt\dfrac{p^2+1}{p}\right)+2r(1-t^2-2jpt)}, \tag{12}$$

and hence,

$$\frac{e_0}{e_1} = \frac{Z_0(1-t^2)}{[Z_1+Z_0+2r](1-t^2)-2jt\left(2rp+[Z_1+Z_0]\dfrac{p^2+1}{p}\right)}. \tag{13}$$

The locus of e_0 is now, obviously, a circle in the complex plane having a diameter on the axis of reals with the point $t=1$ at the origin. The circle has a diameter of length Z_0/Z_1+Z_0+2r.

In polar notation (13) becomes

$$\frac{e_0}{e_1} = \rho\epsilon^{\theta}, \tag{14}$$

with the amplitude-frequency and phase-frequency response characteristics given by

$$\rho = \frac{Z_0}{Z_1 + Z_0 + 2r}\cos\theta, \tag{15}$$

and

$$\theta = \cot^{-1} Q\left(\frac{1}{t} - t\right), \tag{16}$$

where

$$Q \equiv \frac{\dfrac{Z_1+Z_0}{r}+2}{2\dfrac{p^2+1}{p}\dfrac{Z_1+Z_0}{r}+4p} \quad \text{and} \quad t \equiv \frac{\omega_0}{\omega}. \tag{17}$$

The reason that the quantity (17) is referred to as the "Q" of the parallel-T follows from the fact that the simple series resonant circuit of Fig. 5 may be represented by the same equations.

It is interesting to observe that the phase characteristic of *any* symmetrical parallel-T can be calculated at any frequency for which one knows the loss relative to the loss at the extreme frequencies. The phase shift is a function only of the relative loss. For example, from (14) and (15) it is easily shown that

$$\theta = \cos^{-1} \frac{Z_1 + Z_0 + 2r}{Z_0} \left| \frac{e_0}{e_1} \right| ; \tag{18}$$

hence,

$$\theta_f = \cos^{-1} \frac{\left| \frac{e_0}{e_1} \right|_f}{\left| \frac{e_0}{e_1} \right|_{f=\infty}} . \tag{19}$$

For a given T structure the coefficient Q is easily calculated. All symmetrical parallel-T's conform to a circle diagram with differences in the make-up of the T's resulting only in different frequency scales associated with the circle diagram.

An examination of (15) and (16) discloses that the bandwidth of the symmetrical T is minimized by maximizing the coefficient Q. Differentiating Q with respect to p, it is found that the condition for a minimum bandwidth is

$$p^2 = \frac{2 \frac{Z_1 + Z_0}{r}}{2 \frac{Z_1 + Z_0}{r} + 4} . \tag{20}$$

Now, for all practical purposes, the ratio Z_0/r must exceed unity; otherwise the loss at the extreme frequencies becomes excessive. For the same reason the ratio Z_1/r must be less than unity. Hence, from (20) the ratio p must fall somewhere between 0.6 and 1.0 if one desires the minimum band with reasonable extreme frequency losses. With this in mind, a study of (17) brings one to the conclusion that the specific value chosen for p is of so little importance that further discussion of the narrow-band problem can be restricted to the case for which $p = 1$.

Accordingly, the bandwidth factor will be represented simply as

$$Q = 0.25 \frac{\frac{Z_1 + Z_0}{r} + 2}{\frac{Z_1 + Z_0}{r} + 1}, \quad p = 1. \tag{21}$$

This relation for Q shows that the bandwidth of the parallel-T is not changed greatly by loading. As the source and load impedances are made small relative to r, the Q approaches twice that of the nonloaded parallel-T. For practical amounts of loading and $p = 1$, Q is approximately 0.33. For the nonloaded case Q is 0.25.

Wolf[3] has shown that by introducing circuit dissymmetry in a parallel-T operating between a zero-impedance source and an infinite-impedance load one may secure a similar improvement in discrimination. It is interesting to note, in passing, that Wolf's circuit also gives a response curve represented by a circle diagram in the complex plane.

Symmetrical Parallel-T Equivalent Circuit

The amplitude and phase characteristics of the symmetrical parallel-T are completely expressed by (15) and (16). However, the significance of the equations is much more easily understood when it is realized that the transfer characteristic of the simple circuit of Fig. 5 has amplitude- and phase-frequency characteristics exactly equivalent to those of the symmetrical T.

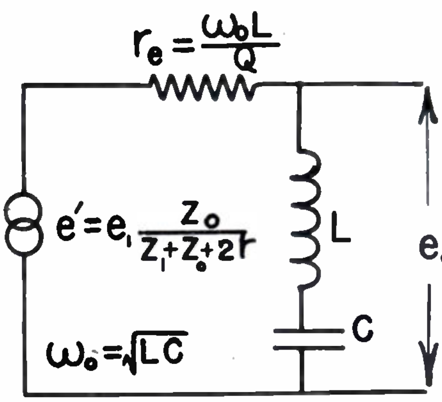

Fig. 5—Parallel-T "equivalent circuit."

In the circuit shown the generator voltage e' is equal in magnitude to the voltage output of the symmetrical parallel-T at the extreme frequencies. The inductance L and the capacitance C are ideal loss-free elements series resonant at the null frequency ω_0. By making the resistor $r_e = \omega_0 L/Q$, the two circuits have identical amplitude- and phase-frequency characteristics.

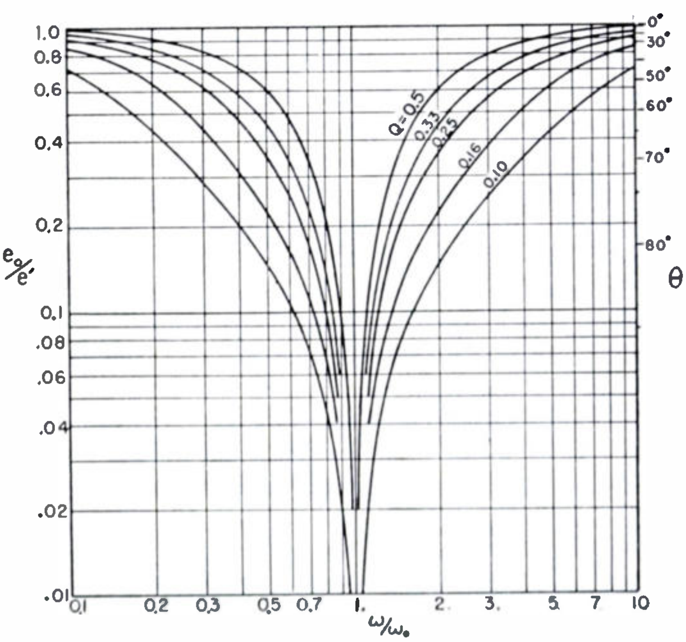

Fig. 6—Symmetrical parallel-T frequency characteristics—normalized.

[3] A. Wolf, "Note on the parallel-T resistance-capacitance network," Proc. I.R.E., vol. 34, p. 659; September, 1946.

There is, of course, no similarity in the impedance characteristics of the two circuits, but the similarity of the transfer characteristics is of considerable help in effecting an understanding of the parallel-T network. Since the series-resonant structure is of the minimum-phase type, one may conclude that the symmetrical parallel-T can be treated also as a minimum-phase structure. This fact is useful in its application to feedback amplifier problems.

Fig. 6 shows amplitude and phase characteristics of the symmetrical parallel-T with Q as the parameter.

Design Procedure

There is no difficulty in designing a narrow-band parallel-T having a symmetrical response characteristic, and the procedure will be outlined for a network of the form shown in Fig. 7. It is assumed, of course, that the source and load impedances are pure resistances.

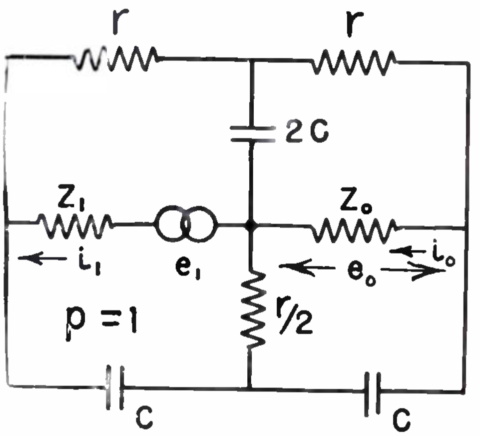

Fig. 7—Narrow band parallel-T filter, $p=1$.

The narrow band is secured by making $p=1$, hence (11), which insures a symmetrical response characteristic, requires that r in the parallel-T be related to the source and load impedances as

$$r = \sqrt{2Z_1Z_0}.$$

In other words, r should be 1.4 times the geometric mean of the source and load impedances.

If the source and load impedances are not necessarily fixed, the selection of suitable Z_1 and Z_0 may be effected by choosing a compromise between (a) Approximately equal values of Z_1 and Z_0 which by (21) result in values of Q approaching one-half, and, by (8), give a loss of 14 db at frequencies removed from ω_0. (b) High Z_0 and low Z_1 which result in a Q of one-quarter and no loss at frequencies removed from ω_0.

The null in the response characteristic falls at the frequency ω_0 by making the capacitor $C=1/r\omega_0$.

The resulting response curve can be seen by reference to the family of curves in Fig. 6, using the appropriate Q as given by (17). The loss at zero and infinite frequency is obtained from either (8) or (9), and is to be added to the loss shown in Fig. 6. From the appropriate response curve one can readily affix a frequency scale to a circle representing the response in the complex plane.

Parallel-T Feedback Amplifiers

One of the common applications of the parallel-T is its use as a frequency selective network in feedback amplifiers. The results secured by placing a nonloaded parallel-T in the feedback or β path of the amplifier have been discussed recently, but little attention, if any, has been given to the condition usually met in practice whereby the source and load resistances cannot be entirely neglected. For the feedback amplifier applications correct loading of the parallel-T is extremely important.

The behavior of a feedback amplifier having a parallel-T in the transmission circuit or in the feedback path can be treated exactly by use of the transfer equations (5) and (7). For practical purposes, however, the principal difficulty arises because neglect of the source and load impedances seen by the parallel-T may result in phase shifts in excess of 90 degrees and instability of the amplifier. Adjustment of these impedances so as to produce a "symmetrical-T" insures that the parallel-T does not introduce phase shifts in excess of 90 degrees and that as the phase shift approaches 90 degrees the transmission approaches a null.

Hastings[4] has shown that the shunt resistor in the parallel-T can be varied so as to make a stable amplifier or oscillator, as desired, but, as his equations show, there is a shift in the frequency at the null point. Bowers[5] has shown that by varying the shunt elements in both T's, holding their RC product constant, the resonant frequency remains unchanged, whereby one can secure controlled regeneration without a shift in the frequency. The transfer equation of the loaded parallel-T, as presented here, does not permit a simple analysis along the lines used by Hastings and Bowers, so it must be assumed that their results are modified by loading. Experimental observations of the polar diagram of the loaded symmetrical-T indicate that the circle of Fig. 8 simply moves to the right or left of the origin along the real axis as unbalance is introduced by small changes in the elements of the T's. An increase in the RC product of the elements in the high-pass branch of the network moves the circle inside the origin and results in less than 90 degrees phase shift near the point of minimum transmission. An increase in the RC product of the elements in the low-pass branch causes the circle to move to the left and enclose the origin. The shift in frequency at the null point seems to be relatively small, if the circle is moved by changing the shunt elements only, in such a way that their RC product remains constant.

In general, there has not been a clear picture available of the behavior of the parallel-T feedback amplifier.[6] For

[4] A. E. Hastings, "Analysis of a resistance-capacitance parallel-T network and applications," Proc. I.R.E., vol. 34, pp. 126–129; March, 1946.

[5] J. L. Bowers, "RC band pass filter design," *Electronics*, pp. 131–133; April, 1947.

[6] L. Stanton, "Theory and applications of parallel-T resistance-capacitance frequency-selective networks," Proc. I.R.E., vol. 34, pp. 447–457; July, 1946.

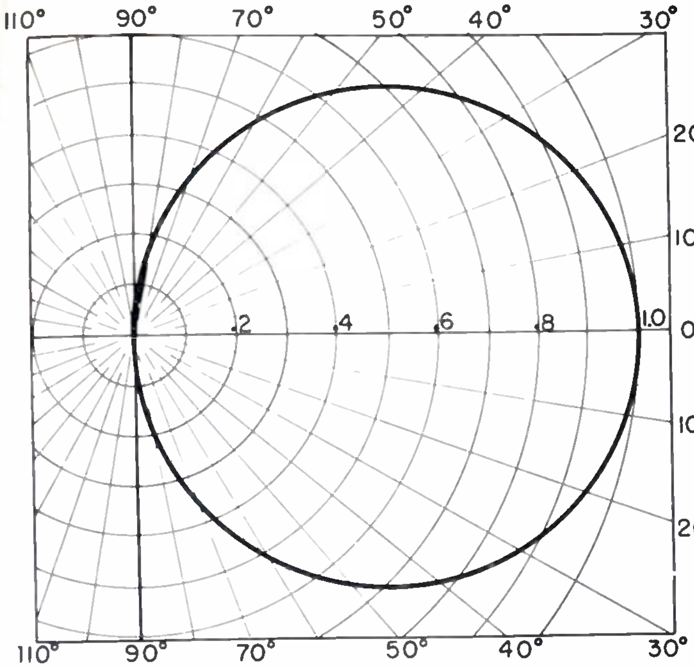

Fig. 8—Symmetrical parallel-T polar diagram—normalized.

the benefit of persons working with this type of amplifier, it is easy to give a picture of its behavior in terms of familiar elements. Recalling that the simple series-resonant circuit of Fig. 5 has a transfer characteristic equivalent to that of the symmetrical parallel-T, one can visualize the behavior of the parallel-T feedback amplifier as follows: When the network is placed in an amplifier having constant over-all feedback, the effect of feedback is approximately that of improving the Q of the filter. When the T is placed in the feedback path, the amplifier has a gain characteristic approximately inverse that of the equivalent series-resonant circuit, except that the maximum gain cannot exceed that of the amplifier without feedback unless there is regenerative feedback.

It is believed that many workers would appreciate having response curves of the parallel-T feedback amplifier which could be computed fairly easily from the data here presented.

Synthesis of Cascaded Three-Terminal RC Networks with Minimum-Phase Transfer Functions*

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Summary—**The method of synthesis presented in this paper shows how to obtain an RC network that can have real or complex zeros and real poles in its transfer function. It differs from methods given in previous papers in that the final network contains only three-terminal structures connected in cascade. For the realization of a particular transfer function that includes complex zeros, this method yields a network with fewer elements, simpler configurations, and higher level of transmission than any method given heretofore.**

Introduction

IN ORDER FOR a transfer function (ratio of output-to-input voltages) to be realizable with a network of resistances and capacitances, the following conditions must be met:

1. The magnitude of the transfer function at any value of ω must be finite.
2. The poles of the transfer function must be negative, real, and simple.
3. The zeros of the transfer function must lie in the left half of the complex-frequency plane. They may be real, or may occur in complex conjugate pairs.

Methods of synthesizing networks that satisfy the above conditions may be found in the literature.[1-3] However, the method to be presented here is an improvement on those given previously for the case where the transfer function contains a pair of complex zeros, because it yields a network that

1. maintains the level of transmission as high as possible,
2. contains the smallest number of elements, and
3. minimizes the number of elements whose values must be duplicated with small tolerances.

The last of these requirements is quite important if any of the complex zeros of the transfer function lie near the ω-axis. In general, the complex zeros are produced by means of bridge-type structures, such as the bridged-T, lattice, or twin-T, or by paralleled ladder networks as in footnote references 1 and 3. In all such networks where more than one current path exists between the input and output terminals, a null or minimum in the transfer ratio (at real frequencies) is produced by a com-

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[1] E. A. Guillemin, "Synthesis of RC-networks," *Jour. Math. Phys.* vol. 28, no. 1, pp. 22–42; April, 1949.
[2] J. L. Bower and P. F. Ordung, "The synthesis of resistor-capacitor networks," PROC. I.R.E., vol. 38, pp. 263–269; March, 1950.
[3] P. F. Ordung, H. L. Krauss, G. S. Axelby, and W. P. Yetter, "Synthesis of paralleled three-terminal RC networks to provide complex zeros in the transfer function," *Trans. AIEE*, vol. 70; 1951.

plete or partial cancellation of the currents arriving at the output terminals by parallel paths. A null produced by a lattice section, for example, requires that the phasor sum of the currents arriving by two different paths must be exactly zero at the null frequency. Obviously, a slight change in the value of one of the elements in the lattice will produce a correspondingly small change in the current that flows through it, but it may produce a very large percentage change in the net current flowing into the output terminals of the lattice. From the standpoint of practical construction, therefore, as few elements as possible should be contained in the various parallel current paths between the input and output terminals of such a network, because these are the elements that have the most severe tolerance requirements. The design procedures employed in this paper keep the lattice networks as simple as possible.

The method of synthesis to be presented here will realize the general minimum phase type of transfer function of an RC network by means of three-terminal structures connected in cascade. A pair of complex zeros in the transfer function is produced by means of a parallel-T or bridged-T network, and real zeros are realized with L-sections.

$$H(p) = \frac{(p+\alpha_1+j\beta_1)(p+\alpha_1-j\beta_1)(p+\alpha_2)}{(p+\gamma_1)(p+\gamma_2)(p+\gamma_3)} \tag{1}$$

that contains two complex conjugate zeros and one real zero will be used to illustrate the synthesis process. The network configuration that will realize the transfer function given by (1) is shown in Fig. 1.

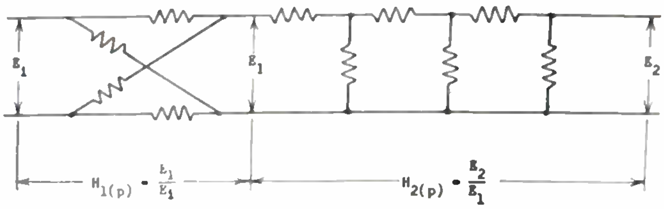


Fig. 1—The network configuration that will realize the transfer function of (1).

Outline of the Synthesis Procedure

Step 1

Express the over-all transfer function $H(p)$ as the product of the transfer functions of the lattice and ladder sections as shown in Fig. 1. Choose the transfer functions

$$H_1(p) = \frac{f(p)}{F(p)} = \frac{(p+\alpha_1+j\beta_1)(p+\alpha_1-j\beta_1)(p+\lambda_1)(p+\lambda_2)(p+\lambda_3)}{(p+\gamma_1)(p+\gamma_2)(p+\gamma_3)(p+\delta_1)(p+\delta_2)} \tag{2}$$

$$H_2(p) = \frac{(p+\alpha_2)(p+\delta_1)(p+\delta_2)}{(p+\lambda_1)(p+\lambda_2)(p+\lambda_3)}. \tag{3}$$

The synthesis procedure will be given for the restricted case of a transfer function that contains one pair of complex zeros,[4] plus one or more real zeros, and an example will follow. The basic idea of the synthesis procedure is as follows:

1. The desired transfer function is represented as the product of two functions, where one contains the real zeros and the other contains the complex zeros.
2. The transfer function that contains the complex zeros is synthesized as a loaded lattice in which the load consists of the L-sections that produce the real zeros of the desired transfer function. The transfer function for the lattice section is chosen in such a way that its transmission level will be unity at zero or infinite frequency or both, so that it is always reducible to three-terminal form.
3. The transfer function that contains the real zeros is synthesized in the form of a ladder network whose input admittance provides the necessary load for the preceding lattice section.

In the material to follow the detailed steps in the synthesis will be presented first, and a discussion of the reasons for each step will follow. A simple transfer function

[4] The case of a transfer function with more than one pair of complex zeros will be treated in another paper.

The pair of complex zeros is assigned to $H_1(p)$, and for reasons to be outlined in the following section, all of the poles of $H(p)$ are assigned to $H_1(p)$, together with two additional poles at $p=-\delta_1$ and $p=-\delta_2$ which may or may not be added. The location of these additional poles is given by (A-5). If $H(p)$ has poles at $p=-\delta_1$ and $-\delta_2$, they need not be added; but if $H(p)$ does not have poles at these points, they should be added. The three extra zeros at $p=-\lambda_1$, $-\lambda_2$, and $-\lambda_3$ are then added in order that the total number of zeros in $H_1(p)$ is *exactly* equal to the total number of poles. The function $H_2(p)$ is then chosen in such a way that the product $H_1(p)H_2(p) = H(p)$. Thus the over-all transfer function remains unchanged.

Step 2

Identify the transfer function of loaded lattice as[5]

$$H_1(p) = \frac{f(p)}{F(p)} = \frac{Y_{12}}{Y_{22}+Y_L}. \tag{4}$$

where Y_{12} is the short-circuit transfer admittance, Y_{22} is the short-circuit driving-point admittance at the output terminals and Y_L is the load admittance presented

[5] See J. L. Bower and P. F. Ordung, *loc. cit.*, for a more detailed discussion of the synthesis of the loaded lattice RC network.

to the lattice by the following network. Multiply numerator and denominator of (2) by a rational function

$$G(p) = \frac{1}{(p + \lambda_1)(p + \lambda_2)(p + \lambda_3)(p + \lambda_a)} \tag{5}$$

in which the poles occur at negative real values of p.

$$H_1(p) = \frac{f(p)G(p)}{F(p)G(p)}$$

$$= \frac{\dfrac{(p + \alpha_1 + j\beta_1)(p + \alpha_1 - j\beta_1)}{p + \lambda_a}}{\dfrac{(p + \gamma_1)(p + \gamma_2)(p + \gamma_3)(p + \delta_1)(p + \delta_2)}{(p + \lambda_1)(p + \lambda_2)(p + \lambda_3)(p + \lambda_a)}} \cdot \tag{6}$$

Since the product $F(p)G(p) = Y_{22} + Y_L$ must be identifiable as a driving-point admittance function, the poles at $p = -\lambda_1, -\lambda_2, -\lambda_3$, and $-\lambda_a$ must be chosen so as to alternate[6] with the zeros at $p = -\gamma_1, -\gamma_2, -\gamma_3, -\delta_1$, and $-\delta_2$. The value of λ_a should be within the interval given by (A-3). The numerator and the denominator of (6) may be written as

$$Y_{12} = \frac{(p + \alpha_1 + j\beta_1)(p + \alpha_1 - j\beta_1)}{p + \lambda_a} \tag{7}$$

$$Y_{22} + Y_L = \frac{(p + \gamma_1)(p + \gamma_2)(p + \gamma_3)(p + \delta_1)(p + \delta_2)}{(p + \lambda_1)(p + \lambda_2)(p + \lambda_3)(p + \lambda_a)} \cdot \tag{8}$$

Note that Y_{12} has only one pole (at $p = -\lambda_a$).

Step 3

Obtain partial fraction expansions of (7) and (8) to yield

$$Y_{12} = \frac{pk_a^{(n)}}{p + \lambda_a} + p + k_0^{(n)} \tag{9}$$

$$Y_{22} + Y_L = \frac{pk_a^{(d)}}{p + \lambda_a} + p + k_0^{(d)} + \frac{pk_1^{(d)}}{p + \lambda_1} + \frac{pk_2^{(d)}}{p + \lambda_2} + \frac{pk_3^{(d)}}{p + \lambda_3}, \tag{10}$$

where the k's are the residues at the poles and where the superscripts (n) and (d) denote, respectively, the numerator and denominator of (6).[7]

Step 4

Use (9) and (10) to synthesize the symmetrical loaded lattice shown in Fig. 2. The elements in the lattice are related to Y_{12} and Y_{22} by the expressions

$$Y_A = Y_{22} + Y_{12} \text{ and } Y_B = Y_{22} - Y_{12}. \tag{11}$$

In the synthesis, Y_L is allotted all of the expansion of $Y_{22} + Y_L$ that is not required for realizability of the lattice (i.e., the residues of Y_A and Y_B must be positive). Thus the load admittance is chosen as

$$Y_L = k_0^{(d)} - k_0^{(n)} + \frac{pk_1^{(d)}}{p + \lambda_1} + \frac{pk_2^{(d)}}{p + \lambda_2} + \frac{pk_3^{(d)}}{p + \lambda_3} + \frac{p}{p + \lambda_a}(k_a^{(d)} + k_a^{(n)}) \tag{12}$$

and lattice elements are obtained by means of (11) as

$$Y_A = 2k_0^{(n)} + 2p \tag{13}$$

$$Y_B = \frac{-2pk_a^{(n)}}{p + \lambda_a} \cdot \tag{14}$$

Once the expressions (13) and (14) have been obtained, the network configuration and element values may be found by conventional methods. Note that the lattice branches Y_A and Y_B are simple networks because Y_{12} was chosen to have only one pole, and therefore only one pole is required in Y_{22}.[8]

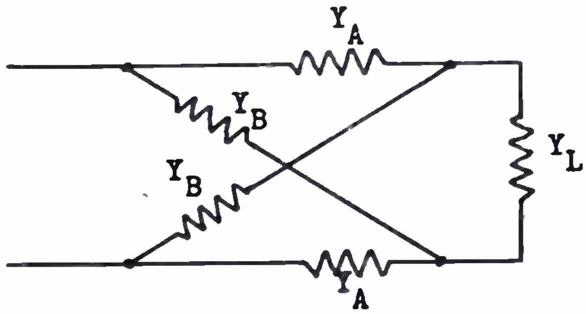


Fig. 2—Symmetrical loaded lattice.

Step 5

Reduce the lattice to three-terminal form. This reduction is always possible for the minimum phase lattices designed in this paper. The proof has been omitted in interest of brevity.

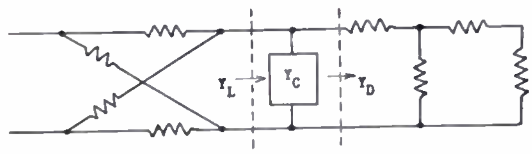


Fig. 3—The loaded admittance Y_L of the lattice is the sum of the ladder input admittance Y_D and the compensating network admittance Y_C.

Step 6

Obtain the ladder network that has $H_2(p)$ as its transfer function. It is desirable that the input admittance Y_D to the ladder network should provide the load Y_L required on the output terminals of the lattice. In the realization of $H_2(p)$ it may not be possible to design a ladder that will provide all of Y_L as its input admittance. The amount of Y_L that is not provided by the input admittance of the ladder must be assigned to an RC compensating network Y_C that must be connected in parallel with the input terminals of the ladder and the output terminals of the lattice as shown in Fig. 3. In

[6] E. A. Guillemin, "Communication Networks," John Wiley and Sons, New York, N. Y., vol. 2, pp. 211–216; 1935.

[7] The form given in (9) and (10) is characteristic for a lattice designed for unity transmission at infinity. For the case of unity transmission at zero frequency, $H(p)$ is usually multiplied by a constant $h<1$, and the result yields $k_0^{(d)} = k_0^{(n)}$ and the p terms become unequal. See Bower and Ordung, (3) and (10).

[8] E. A. Guillemin, "Communication networks," *Jour. Math. Phys.*, vol. 2, pp. 216–219. Guillemin's proof may readily be extended to the RC case.

fact, the pole at λ_a in Y_L cannot be provided in the input admittance Y_D of the ladder, and therefore this pole must be wholly assigned to Y_C. The compensating network Y_C and the input admittance Y_D to the ladder must satisfy the relation

$$Y_L = Y_C + Y_D. \tag{15}$$

The synthesis of a ladder network that will realize the desired transfer function has been described in detail elsewhere;[3,9] hence, a brief description of the process will suffice at this point. A set of L-sections that may be connected in cascade to approximate the desired $H_2(p)$ is selected from a catalog of RC networks.[3] The types of sections chosen should introduce the desired zeros of $H_2(p)$, and they should also be of such a form as to make the input admittance Y_D of the ladder equal to Y_L or as large a portion thereof as possible.

Discussion of the Synthesis Process

The method by which the functions $H_1(p)$ and $H_2(p)$ are chosen is very important; it is quite subtle since it involves many interrelated factors. Certain requirements must be met by the function $H_1(p)$ and they determine its form. With $H_1(p)$ established $H_2(p)$ is also determined because the product of the two must be equal to the original $H(p)$. However, the form of $H_1(p)$ cannot be chosen without regard to the resulting form of $H_2(p)$ because certain factors are common to both of these functions. The requirements to be met may be enumerated as follows:

1. The transfer admittance Y_{12} (see (4) and (7)) should contain only one internal pole. Since Y_{22} must have the same poles as Y_{12}, this restriction guarantees that the branches of the resulting lattice will have a simple configuration.

2. The function $H_1(p)$ should *approximate* the form

$$H_1(p) = \frac{h(p+\alpha_1+j\beta_1)(p+\alpha_1-j\beta_1)}{(p+\delta_1)(p+\delta_2)} \tag{16}$$

for frequencies on the ω-axis. The appendix shows that an unloaded lattice that has the transfer function given by (16) can have unity transmission level ($h=1$) at zero and infinite frequency if the poles δ_1 and δ_2 are chosen in the manner specified by expressions (A-5) and (A-6). If δ_1 does not have the exact value specified by (A-6), the transmission level will be unity at *either* zero ($h=\delta_1\delta_2/\alpha_1^2+\beta_1^2$) or infinite frequency ($h=1$), but not both. The additional factors that appear in H_1 according to (2) are due to the load imposed on the lattice by the following ladder section, and they are not accounted for in the development in the appendix.

However, the behavior of the actual function, (2), at frequencies $p=j\omega$ may be made to approximate very closely the behavior of the ideal function (16). When each of the zeros λ_1, λ_2, and so on in $H_1(p)$, (2), is placed near each of the poles γ_1, γ_2, and so on, the zero-pole diagram shows that for frequencies on the ω-axis the contribution of a pole to the value of $H_1(p)$ is nearly canceled by the contribution of the nearby zero. The degree of cancellation is controlled by the separation of the zero from the pole relative to their mean distance from the ω-axis. As the zero-pole separation is made smaller, the zero and pole more nearly cancel each other.[9] When $H_1(p)$ is made to approximate the ideal function, (16), it will be found that the load admittance Y_L will be small compared to Y_{22} and the level of transmission will not be reduced appreciably below that for the unloaded lattice.[10]

3. The pole λ_a of Y_{12} is one of the poles of $G_{(p)}$, and should be chosen within the interval defined by (A-3), in the appendix. This restriction on the range of λ_a is necessary to insure that the transmission level of the lattice will not have to be reduced in order to yield positive residues for Y_A and Y_B.[2] Furthermore, if the value of λ_a is picked so that the value of $H_1(p)$ given by (2) is equal to -1 at $p=-\lambda_a$, a simpler network will result because the pole λ_a will then not appear in Y_L.[11]

4. The poles of $G(p)$ are the poles of $Y_{22}+Y_L$. The pole λ_a is the pole of Y_{22}, and it may also appear in Y_L and Y_C. The other poles (λ_1, λ_2, and so on) are the poles of Y_D. Since Y_D is the input admittance of the ladder network, the poles of Y_D are identical with the poles of the transfer function $H_2(p)$. (See (3), (8), and (12)). The relationship just stated indicates why all of the poles γ of $H(p)$ (see (1)) are placed in $H_1(p)$. Had they been assigned to $H_2(p)$, they would also have to appear in $G(p)$ in place of the λ's. Then they would appear as poles of Y_{12}, and a less desirable and more complicated lattice configuration with less than unity transmission level would result.

5. Poles λ_1, λ_2, and so on of $H_2(p)$ must be introduced as zeros of $H_1(p)$ so that $H(p)$ will not be altered.

6. The poles λ_a, λ_1, λ_2, and so on of $G(p)$ must alternate with the poles δ_1, δ_2, and γ_1, γ_2, and so on of $H_1(p)$ so that the product $F(p)G(p)$ will satisfy the requirements for an RC driving-point admittance function.

[9] J. T. Fleck and P. F. Ordung, "The realization of a transfer ratio by means of a resistor-capacitor ladder network," Proc. I.R.E., vol. 39, pp. 1069–74; September, 1951.

[10] In a cascaded RC network the driving-point admittance of each successive section of the network should not excessively load the output of the preceding section, otherwise the level of transmission is severely penalized. This can be readily appreciated from (4) by means of the following argument. The transmission through the lattice depends upon Y_{12}, Y_{22}, and Y_L. Suppose that Y_{12} and Y_{22} are specified quantities and that the magnitude of Y_L can be varied. The admittance Y_L has a phase angle within the same quadrant as the phase angle of Y_{22}. Since Y_{22} and Y_L are both nonvanishing for frequencies on the ω-axis, it follows that

$$|Y_L + Y_{22}|_{p=j\omega} > |Y_{22}|_{p=j\omega}.$$

The largest ratio of output-to-input voltage that a given lattice can produce occurs, therefore, when the load is removed from its output terminals. When $Y_L = Y_{22}$, the ratio of output-to-input voltage is reduced to one half that which occurs when Y_L is negligible compared to Y_{22}. In order, therefore, for the level of transmission through the lattice not to be severely penalized, it is necessary that

$$|Y_{22}|_{p=j\omega} > |Y_L|_{p=j\omega}.$$

[11] C. Belove, "A note on the synthesis of resistor-capacitor networks," Proc. I.R.E., vol. 38, pp. 1453–1454; December, 1950.

Example

The method of synthesis will be demonstrated by means of the following example:

$$H(p) = \frac{(p+3+j3)(p+3-j3)(p+2)(p+3)}{(p+8)(p+9)(p+10)(p+11)}. \quad (17)$$

Step 1

The solutions of (A-5) and (A-6) show that the component function $H_1(p)$ should have poles located as follows:

$$0 < \delta_1 < 2.02$$
$$9 < \delta_2 < \infty.$$

$H(p)$ contains poles within the permitted range for δ_2; hence, one of these poles in $H(p)$ can be assigned as δ_2. $H(p)$ does not contain a pole within the range of δ_1; hence, one must be added to $H_1(p)$ in order that the transfer function can have a high level of transmission. Since $H(p)$ has unity transmission at infinity and less than unity at zero, the values selected for δ_1 and δ_2 are 2 and 11, respectively. An unloaded lattice having this pair of holes and the pair of complex zeros will have unity transmission at infinite frequency and less than unity at zero. There is considerable freedom of choice in the location of these poles, and this can be exploited to the fullest only after sufficient familiarity with the process has been gained. Now $H_1(p)$ and $H_2(p)$ can be chosen as follows:

$$H_1(p) = \frac{(p+3+j3)(p+3-j3)(p+\lambda_1)(p+\lambda_2)(p+\lambda_3)}{(p+2)(p+8)(p+9)(p+10)(p+11)}$$

$$H_2(p) = \frac{(p+2)^2(p+3)}{(p+\lambda_1)(p+\lambda_2)(p+\lambda_3)}.$$

Step 2

The function $G(p)$ is now chosen as

$$G(p) = \frac{1}{(p+\lambda_a)(p+\lambda_1)(p+\lambda_2)(p+\lambda_3)}.$$

The pole λ_a associated with Y_{12} of the lattice structure is chosen by means of expression (A-3) as

$$\lambda_a = 5.$$

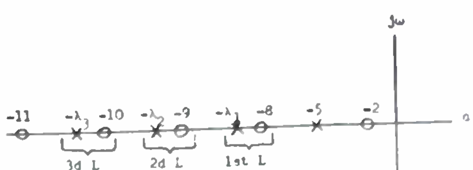


Fig. 4—The zeros and poles of $Y_{22}+Y_L$.

The remaining poles of $G(p)$, λ_1, λ_2, and λ_3, should be chosen to cancel approximately the poles at -8, -9, and -10 in $H_1(p)$ because these are the poles in $H_1(p)$ that are due to the load Y_L. Of course, all of the poles of $G(p)$ must be chosen so that they separate the poles of $H_1(p)$. This requires that the poles of $G(p)$ be chosen as indicated in Fig. 4.

In accordance with the theory of the synthesis of the RC ladder network,[3,9] the poles and zeros of $Y_{22}+Y_L$ shown in Fig. 4 are grouped and the groups are numbered to correspond with the order in which the L-sections will occur in the ladder network that is used to realize $H_2(p)$. The loading theory developed in connection with the synthesis of an RC ladder may now be applied to the determination of the values of λ_1, λ_2, and λ_3 in the following way. The loading factor K_n expressed in per cent is defined for a single zero-pole pair in Fig. 5 as

$$K_n = \frac{b_n}{d_n} \times 100.$$

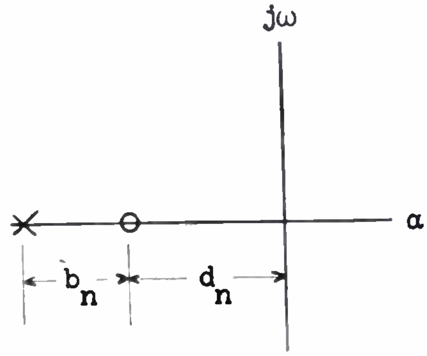


Fig. 5—The percentage loading factor for a zero-pole pair is K_n per cent $= b_n/d_n \times 100$.

The loading factors are arbitrarily selected. The first L-section is assigned a loading factor of 5 per cent, the second a loading factor of 2 per cent, and the third 1 per cent. By the application of the loading factor equation, the λ's are found to be

$$\lambda_1 = 8.4$$
$$\lambda_2 = 9.2$$
$$\lambda_5 = 10.1.$$

Thus, the values of $G(p)$, $H_1(p)$ and $H_2(p)$ are obtained as

$$G(p) = \frac{1}{(p+5)(p+8.4)(p+9.2)(p+10.1)}$$

$$H_1(p) = \frac{(p+3+j3)(p+3-j3)(p+8.4)(p+9.2)(p+10.1)}{(p+2)(p+8)(p+9)(p+10)(p+11)}$$

$$H_2(p) = \frac{(p+2)^2(p+3)}{(p+8.4)(p+9.2)(p+10.1)}.$$

Step 3

When the numerator and the denominator of $H_1(p)$ are multiplied by $G(p)$ and when the resultant numerator and denominator are separately expressed in partial fraction form, the values of Y_{12} and $Y_{22}+Y_L$ are obtained as

$$Y_{12} = \frac{-2.6p}{p+5} + p + 3.6$$

$$Y_{22} + Y_L = \frac{2.96589p}{p+5} + p + 4.05879 + \frac{0.16448p}{p+8.4} + \frac{0.08943p}{p+9.2} + \frac{0.02136p}{p+10.1}.$$

Step 4

All of $Y_{22}+Y_L$ not required for realizability of the lattice is assigned to Y_L. Then the elements Y_A and Y_B can then be obtained. This yields

$$Y_L = 0.45879 + \frac{0.36589p}{p+5} + \frac{0.16448p}{p+8.4} + \frac{0.08943p}{p+9.2} + \frac{0.02136p}{p+10.1}$$

$$Y_A = 2p + 7.2$$

$$Y_B = \frac{5.2p}{p+5}.$$

The elements of the lattice may now be obtained from Y_A and Y_B as shown in Fig. 6.

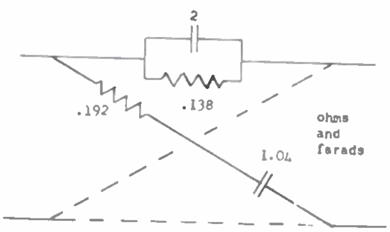


Fig. 6—Lattice network.

Step 5

The lattice shown in Fig. 6 will reduce to several forms. The one selected is shown in Fig. 7.

Step 6

The pole at -5 in Y_L does not appear in $H_2(p)$; it is wholly assigned to Y_C, the remainder of Y_L to Y_D, yielding.

$$Y_C = \frac{0.36589p}{p+5}$$

$$Y_D = 0.45879 + \frac{0.16448p}{p+8.4} + \frac{0.08943p}{p+9.2} + \frac{0.02136p}{p+10.1}.$$

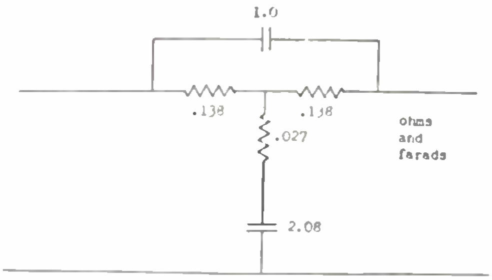


Fig. 7—Bridged-T equivalent to the lattice.

The input admittance Y_D of the ladder is synthesized according to the methods for the synthesis of the RC ladder network to yield $H_2(p)$. The complete network and its transfer function are shown in Fig. 8.

Conclusions

The method of synthesis developed in this paper yields, as a final result, a three-terminal network that consists of a set of cascaded sections. The number of elements used in this network is less than that obtained by any of the previously advanced methods of synthesis. For example, the $H(p)$ that was worked out in the example involves four poles. The network contains a total of six capacitors. There are, therefore, only two capacitors in addition to the four that are required as a basic minimum for any RC network with four poles. One of these capacitors was introduced in the compensating network, and this compensating network could have been avoided had the value of λ_a been chosen at the point where $H_1(p) = -1$. Thus the final network would have had one less capacitor and one less resistor than the circuit shown in Fig. 8.

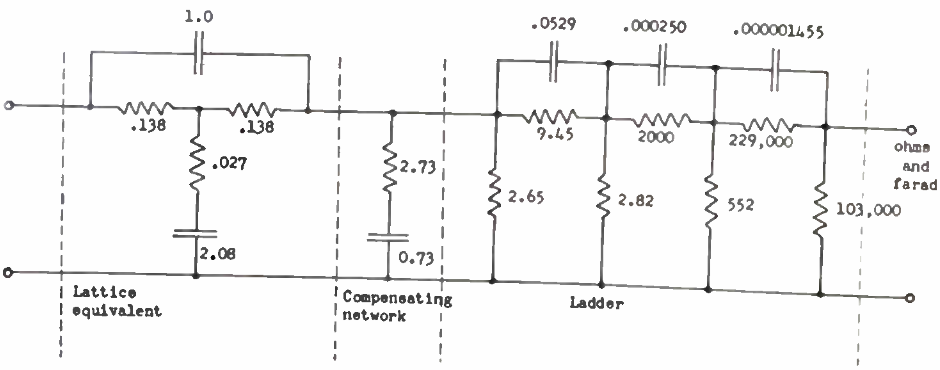


Fig. 8—A network that has the transfer function given in (17).

The range of values in this example is excessive. That is not a fault of the process, but is due to the close grouping of the poles at a considerable distance from zero frequency. Because of this grouping, the loading factors had to be taken very small, and a very wide range of element values results from small loading factors.

The lattice equivalent, which contains the elements that must be chosen with small tolerances, contains very few elements. This is an important advantage of this network as compared to the other networks that have been advanced. It should be observed, furthermore, that the level of transmission through the network in Fig. 8 is unity, the theoretical maximum for this particular $H(p)$.

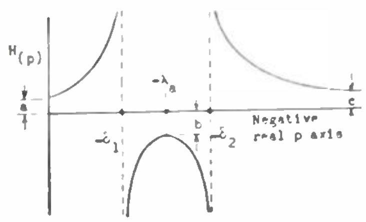
Appendix

Location of the Poles of H(p) for a Lattice to Have a Unity Transmission Level

The simplest transfer function of an RC network that can have a pair of complex zeros is

$$H(p) = \frac{h(p+\alpha+j\beta)(p+\alpha-j\beta)}{(p+\delta_1)(p+\delta_2)}. \qquad \text{(A-1)}$$

If a lattice structure is to realize (A-1) with a transmission level of unity ($h=1$), the zeros and poles of (A-1) must be located so as to satisfy the requirements shown



(I) For $|H(p)|=1$ at $p=\infty$ and 0
$a=1$
$c=1$
$b\leqq 1$.
(II) For $|H(p)|=1$ at $p=\infty$ and $|H(p)|<1$ at $p=0$
$a<1$
$b\leqq 1$
$c=1$.
(III) For $|H(p)|=1$ at $p=0$ and $|H(p)|<1$ at $p=\infty$
$a=1$
$b\leqq 1$
$c<1$.

Fig. 9—Plot of $H(p)$ for negative real values of p.

in Fig. 9.[12] Corresponding to the cases shown in Fig. 9, the following necessary conditions on the location of the zeros and poles can be stated:

[12] See J. L. Bower and P. F. Ordung, *loc. cit.*, for the justification of Fig. 9.

$$\left.\begin{array}{l}
|H(p)| \begin{Bmatrix} =1 \text{ at } p=\infty \\ =1 \text{ at } p=0 \end{Bmatrix}, \text{ and } h=1 \\
\qquad \alpha^2+\beta^2=\delta_1\delta_2 \\
|H(p)| \begin{Bmatrix} =1 \text{ at } p=\infty \\ <1 \text{ at } p=0 \end{Bmatrix}, \text{ and } h=1 \\
\qquad \alpha^2+\beta^2<\delta_1\delta_2 \\
|H(p)| \begin{Bmatrix} <1 \text{ at } p=\infty \\ =1 \text{ at } p=0 \end{Bmatrix}, \text{ and } h=\dfrac{\delta_1\delta_2}{\alpha^2+\beta^2} \\
\qquad \alpha^2+\beta^2>\delta_1\delta_2.
\end{array}\right\} \qquad \text{(A-2)}$$

These conditions are not sufficient for they do not guarantee that the distance $b\leqq 1$ as required in Fig. 9.

In order to determine the conditions necessary for $b\leqq 1$ at some point $p=-\lambda_a$, substitute $-\lambda_a$ for p in (A-1), let $H(p)=-1$ and $h=1$, and solve for λ_a. This yields a range of values of λ_a within which $b\leqq 1$;

$$p \leqq \lambda_a \leqq q,$$

where

$$\begin{aligned} p &= \frac{2\alpha+\delta_1+\delta_2-\sqrt{(2\alpha+\delta_1+\delta_2)^2-8(\alpha^2+\beta^2+\delta_1\delta_2)}}{4} \\ q &= \frac{2\alpha+\delta_1+\delta_2+\sqrt{(2\alpha+\delta_1+\delta_2)^2-8(\alpha^2+\beta^2+\delta_1\delta_2)}}{4}. \end{aligned} \qquad \text{(A-3)}$$

The two limiting values given for λ_a in expression (A-3) are the values where $H(p)=-1$. For values of λ_a between these values, $|H(p)|<1$. The interval for λ_a must, of course, be real. This requires that the quantity under the radical shall be equal to or greater than zero. Thus

$$(2\alpha+\delta_1+\delta_2)^2-8(\alpha^2+\beta^2+\delta_1\delta_2)\geqq 0. \qquad \text{(A-4)}$$

Evidently, the lattice can have unity transmission only if one of the conditions in (A-2) is satisfied and if (A-4) is also satisfied.

With the zeros specified, ranges of p can be identified in which the poles must be located in order for the network to have unity transmission. With the substitution of the condition for unity transmission at both $p=0$ and infinity into (A-4) and with some algebraic manipulation, the permitted ranges for δ_1 and δ_2 are obtained as follows:

$$0\leqq\delta_2\leqq 2\sqrt{\alpha^2+\beta^2}-\alpha-\sqrt{(2\sqrt{\alpha^2+\beta^2}-\alpha)^2-(\alpha^2+\beta^2)} \qquad \text{(A-5)}$$

$$\delta_1=\frac{\alpha^2+\beta^2}{\delta_2}. \qquad \text{(A-6)}$$

The ranges defined in (A-5) and (A-6) pertain to the case of unity transmission at both zero and infinite frequency. These ranges can of course be modified in accordance with the requirements in (A-2) and (A-4) to admit the cases of unity transmission at only zero or infinite frequency.

On the Approximation Problem in Network Synthesis*

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Summary—A procedure is presented for the synthesis of a network to yield a prescribed magnitude versus frequency characteristic. The given characteristic is replaced by a sequence of straight line segments of arbitrary slope. Each line segment is associated with a zero-pole pair properly placed on the real p axis, where p is the complex frequency variable. In this manner a real, rational network function is obtained whose magnitude variation approximates the given one. Methods for predicting the realizability of the approximating function are discussed in the application to the design of two terminal and two-terminal pair networks. To illustrate the methods outlined in the paper, a complete procedure is given for the design of attenuation equalizers using constant-resistance ladder sections.

I. Introduction

The synthesis problem is that of finding a physical network which will reproduce a given network property. It is assumed that the network property is given as a magnitude (of impedance, or transfer loss, and the like) versus frequency characteristic and that it is to be realized by the synthesis of a passive, linear, lumped parameter structure. A physical network of this class is characterized by a network function which is a real, rational function of the complex frequency variable p. As such, the function is analytic except for a finite number of poles. The problem is to choose an appropriate rational function of p which not only has the required magnitude variation at real frequency but is also realizable. Once the function has been chosen, any convenient synthesis procedure can be employed to yield the network.

The selection of an approximating function may be achieved by properly locating the zeros and poles of the function in the complex p plane. By virtue of the analogy between the two-dimensional potential problem and the logarithm of a rational function,[1] it is evident that the superposition principle may be applied to achieve a desired characteristic by employing combinations of simple configurations. In this paper the procedure is to use straight line segments as building blocks.

II. Straight Line Segments of Arbitrary Slope

Let Z denote a possible network function. Letting $p=jw$, define the magnitude characteristic $A(w)$ as the log modulus of $Z(w)$. For example, if $Z(p)$ has only a single pole on the negative real p axis then $A(w)$ is given by

$$A(w) = -20 \log \sigma_p - 10 \log [1 + (f/f_0)^2] \text{ db}, \quad (1)$$

where $\sigma_p = 2\pi f_0$ defines the pole location and $w = 2\pi f$. This function is plotted versus $\log(f/f_0)$ in Fig. 1, where it is noted that $A(f_0)$ is 3 db below $A(0)$ and that for $f>f_0$ $A(w)$ approaches a straight line with 6 db/octave slope. If the multiplicity of the pole is increased, the shape of the curve is essentially the same except that the terminal slope becomes $6n$ db/octave and the difference between $A(0)$ and $A(f_0)$ becomes $3n$ db where n is the multiplicity of the pole. If the pole is replaced by a zero, the curve becomes concave up instead of down.

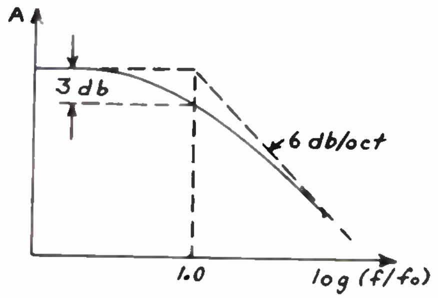

Fig. 1—$A(w)$ for a simple pole.

Noting that the transition from zero db/octave to 6 db/octave slope is achieved by a smooth curve rather than a sharp break at the critical frequency f_0, it is logical to investigate closely the magnitude characteristic which results from a zero-pole pair on the real p axis. The zero and pole locations to be considered are shown in Fig. 2. Interchanging the zero and pole would merely change the sign of $\log Z$; attention may therefore be confined to the arrangement shown in Fig. 2. The zeros and poles will be confined to the negative real p axis.[2]

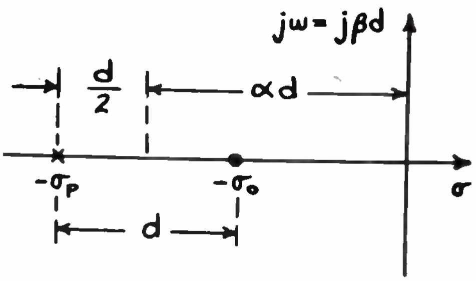

Fig. 2—Zero-pole pair on the real p axis.

In terms of the parameters α, β, and d (defined in Fig. 2), the function $Z(p) = (p+\sigma_0)/(p+\sigma_p)$ is, at $p=jw$, given by

$$Z(\beta) = \frac{(\alpha - \frac{1}{2}) + j\beta}{(\alpha + \frac{1}{2}) + j\beta}. \quad (2)$$

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[1] W. W. Hansen and O. C. Lundstrom: "Experimental determination of impedance functions by use of an electrolytic tank," Proc. I.R.E., vol. 33, pp. 528–534; August, 1945.

[2] This restriction eliminates transfer impedance functions of the nonminimum phase type. For a pole on the positive real p axis, $A(w)$ can be computed from (3) by taking the pole at its image position about the origin.

and then

$$A(\beta) = 10 \log \frac{\beta^2 + (\alpha - \frac{1}{2})^2}{\beta^2 + (\alpha + \frac{1}{2})^2} \text{ db.} \qquad (3)$$

In Fig. 3 $A(\beta)$ is plotted as a function of $\log \beta$. The straight line segment is tangent to $A(\beta)$ at its midpoint.

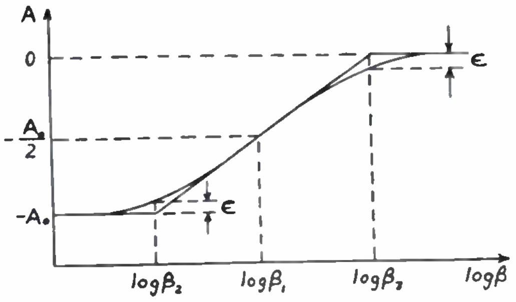


Fig. 3—Definition of line-segment parameters.

At this point the slope of $A(\beta)$ is a maximum and is given by

$$S = 3.01/\alpha \text{ db/octave.} \qquad (4)$$

The remaining parameters noted in Fig. 3 are given by

$$A_0 = 20 \log (\alpha + \tfrac{1}{2})/(\alpha - \tfrac{1}{2}) \text{ db} \qquad (5)$$

$$\beta_1^2 = \beta_2\beta_3 = (\alpha^2 - \tfrac{1}{4}) \quad \frac{\beta_3}{\beta_2} = \left[\frac{\alpha + \frac{1}{2}}{\alpha - \frac{1}{2}}\right]^{2\alpha}. \qquad (6)$$

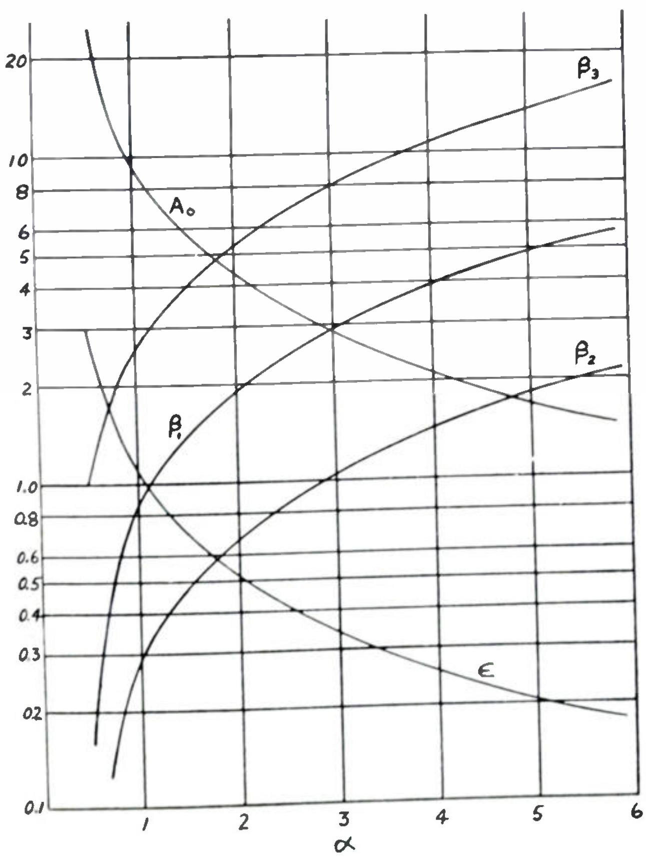


Fig. 4—Line-segment parameters.

These parameters have been computed and are shown as functions of α in Fig. 4. The deviation error, ϵ, which is also shown in Fig. 4, is given by

$$\epsilon = 10 \log \frac{\beta_3^2 + (\alpha + \frac{1}{2})^2}{\beta_3^2 + (\alpha - \frac{1}{2})^2} \text{ db.} \qquad (7)$$

III. The Associated Phase Functions

The phase angle, $\phi(w)$, of $Z(p)$ at $p = jw$ is given by

$$\phi(\beta) = \tan^{-1} \frac{\beta}{(\alpha - \frac{1}{2})} - \tan^{-1} \frac{\beta}{(\alpha + \frac{1}{2})}. \qquad (8)$$

A typical $\phi(\beta)$ curve is illustrated in Fig. 5. The maximum occurs at the frequency corresponding to β_1; its value is

$$\phi_m = \tfrac{1}{2}\pi - 2 \tan^{-1} \left[\frac{\alpha - \frac{1}{2}}{\alpha + \frac{1}{2}}\right]^{1/2}. \qquad (9)$$

To facilitate sketching of phase function associated with a given line segment, ϕ_m and $\phi_2 = \phi(\beta_2) = \phi(\beta_3)$ have been computed and are shown as functions of α in Fig. 5.

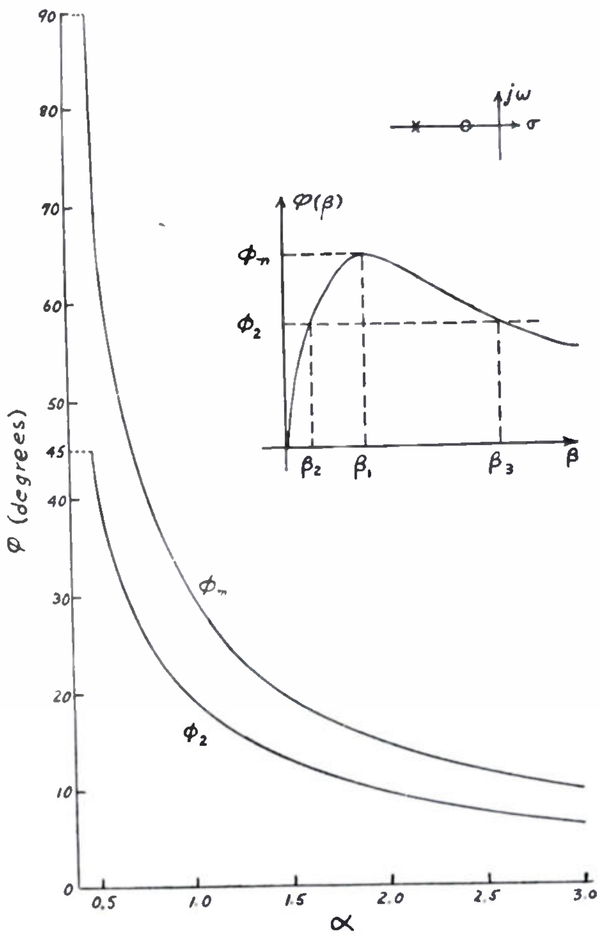


Fig. 5—Phase function data for the indicated zero-pole configuration.

IV. Zero-Pole Pairs of Multiplicity Greater Than One

If a zero and pole, each of order n, are associated as a "zero-pole pair of multiplicity n", then the formulas given above are still applicable provided the slope, S, the simulation error, ϵ, the zero frequency decrement, A_0, and all phase function values are multiplied by n. The critical frequency points, β_1, β_2, and β_3, remain unchanged.

V. Application to Design of Driving-Point Impedances

Let $Z(p)$ be a driving-point impedance function. $A(w)$ is then the log modulus of $Z(w)$ in db. If a given $A(w)$ characteristic is approximated by the straight-line segments described above, the approximating function is automatically a real, rational function of p with none of its zeros or poles in the right half p plane. (Any zeros or poles on $p=jw$ must be simple.) An additional restriction which the approximating function must satisfy is that $|\phi(w)| \leqq 90$ degrees for all w. If $Z(p)$ is a rational function having n_0 zeros and n_p poles, this last condition requires that $|n_0 - n_p|$ equal either zero or one. This difference in degree is a necessary condition which will always be satisfied by a design consisting of any number of line segments (and, where necessary, one added line segment corresponding to a simple zero or pole), but is not sufficient to insure the realizability of the approximating function. Consider the case of a single zero-pole pair. If $n=1$, the corresponding $Z(p)$ is realizable for any $\alpha \geqq \frac{1}{2}$. For $n>1$, $Z(p)$ is realizable only for $\alpha \leqq \alpha_n$ where α_n is that value of α for which $\phi_m = 90°/n$. A maximum permissible slope, S_m, corresponds to each α_n, and this may be shown to be

$$S_m = 3.01n/\alpha_n = 3.01\pi\left[\frac{\sin(\pi/2n)}{\pi/2n}\right] \text{db/oct.} \qquad (10)$$

For large n, S_m approaches the limiting value of 9.45 db/octave. It appears, therefore, that this represents the approximate upper limit to the slope which it is possible to achieve for a driving-point impedance function using the line segments described here.

Of course, it is not sufficient to consider only an isolated line segment, since the phase contributions of successive line segments are additive. Inspection of Fig. 4 reveals that the midpoints of successive line segments (the points of maximum phase contribution) are separated by about three octaves. Since this separation is, to a first approximation, independent of the slopes of the segments, it can be shown that an estimate of the total phase angle at the midpoint of a particular line segment may be obtained by adding to the ϕ_m of that segment about 25 per cent of the value of ϕ_m for each of the two immediately adjoining segments. When this estimate reveals that ϕ is close to 90 degrees at some value of w, then a more careful check of the phase function must be made in the neighborhood of that frequency.

VI. Simulation of Transfer Impedance Functions

The transfer impedance function chosen for discussion is the complex insertion loss, $\theta = A + j\phi$, of a two-terminal pair network. Since the rational functions which result from the use of the straight-line segments described above have all their zeros and poles on the real p axis, then the synthesis of these approximating functions is most conveniently accomplished on an image-parameter basis using constant-resistance sections.[3] The insertion loss of a constant-resistance section is the ratio of its input to output voltage with the section properly terminated in its characteristic resistance, R, and is given by[4,5]

$$e^\theta = Z_t/R, \qquad (11)$$

where Z_t is the short-circuit transfer impedance of the section (including its terminating resistor). Since the insertion of a constant-resistance section into a network does not change the loading of the source, e^θ must be restricted as follows:

$$|e^\theta| \geqq 1 \quad (\text{at } p = jw). \qquad (12)$$

In addition, since the restrictions on e^θ are essentially those on Z_t, the zeros of e^θ must lie in the left-half p plane (or if they occur on $p=jw$ they must be simple) while its poles are restricted only by the conjugacy condition. If, however, all the poles of e^θ lie in the left-half p plane, then the corresponding network is a minimum-phase shift structure. Since any passive ladder network is a minimum-phase shift structure,[5] then, while a constant-resistance section can be realized in either a lattice or ladder configuration, discussion is limited to the more useful ladder sections.

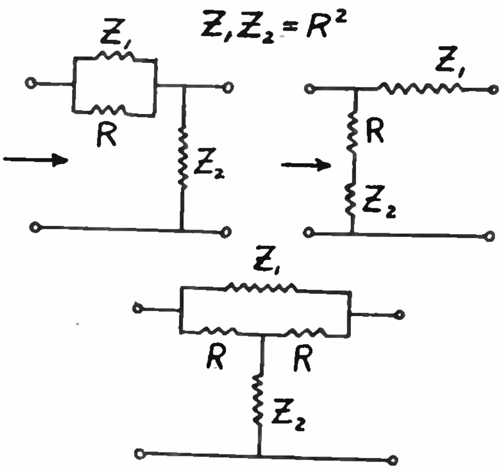


Fig. 6—Constant-resistance ladder sections.

Some typical constant-resistance ladder structures are given in Fig. 6. Two of the circuits of Fig. 6 are L sections and exhibit the constant-resistance property in one direction only. This direction is indicated by the arrows on the diagram. As noted in Fig. 6, the impedances Z_1 and Z_2 are inverse. The insertion loss of these ladder sections is

$$e^\theta = 1 + Z_1/R. \qquad (13)$$

[3] E. A. Guillemin, "Summary of Modern Methods of Network Synthesis," Advances in Electronics Vol. III (Academic Press), pp. 283–290; 1951. This reference includes a discussion of alternate synthesis procedures.

[4] O. J. Zobel, "Distortion correction in electrical circuits," *Bell Sys. Tech. Jour.*, vol. 7, p. 3; July, 1928.

[5] H. W. Bode, "Network Analysis and Feedback Amplifier Design," D. Van Nostrand Co., New York, N. Y., chaps 11 and 12.

Then,

$$Z_1/R = R/Z_2 = e^\theta - 1. \tag{14}$$

From (14) the Z_1 and Z_2 networks corresponding to the basic zero-pole configurations are readily obtained and are shown in Fig. 7. Any more complicated transfer function which is realizable in the ladder configuration

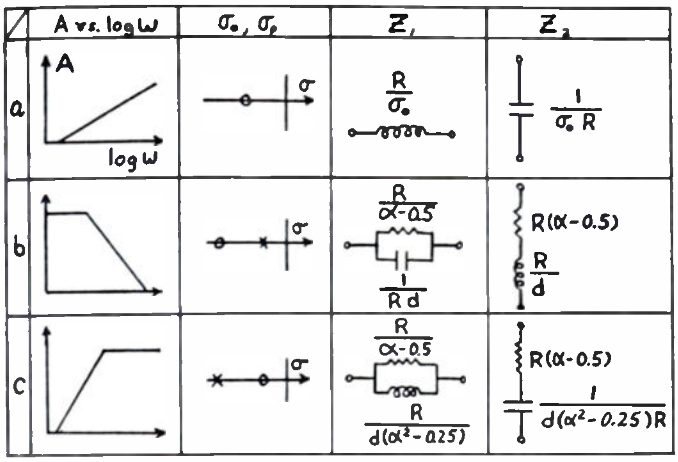


Fig. 7—Ladder-network elements corresponding to the basic zero-pole configurations.

can always be synthesized with a number of these sections in tandem, plus, if necessary, a resistance pad to attain the proper level of attenuation. However, it is often more desirable to include in a single ladder section the transfer characteristics of a number of zero-pole pairs. It is therefore of interest to investigate the conditions which insure the physical realizability of a constant-resistance ladder section.

In order that a constant-resistance ladder network be realizable, it is necessary and sufficient that Z_1 be a physical driving-point impedance. It is evident, therefore, that not only must e^θ satisfy all the restrictions previously imposed but e^θ must satisfy the additional restriction

$$Re\{e^\theta\} \geq 1 \quad (\text{at } p = jw). \tag{15}$$

A necessary, but not sufficient, condition for the realizability of an insertion-loss function in a constant-resistance ladder configuration is then that $|\phi| < 90°$ at $p = jw$. For example, where a zero-pole pair with $n > 1$ is required, it is necessary that $\alpha > \alpha_n$ where α_n is again that value of α for which $\phi_m = 90°/n$. In other words, for $\alpha > \alpha_n$, with α_n given by

$$1/\alpha_n = 2 \sin (\pi/2n), \tag{16}$$

a constant multiplier, k, can always be found such that the real part of the function

$$e^\theta = k\left[\frac{p + \sigma_0}{p + \sigma_p}\right]^n_{\alpha > \alpha_n} \tag{17}$$

is never less than one at $p = jw$. With this value of k, the prescribed insertion loss can be provided by a constant-resistance ladder section.

VII. Example of Synthesis of an Attenuation Equalizer

The problem considered is that of providing an attenuation equalizer for the cable whose insertion-loss data is specified in Fig. 8. The nominal characteristic impedance of the line is 600 ohms. The equalization is to be effective up to 20 kc. The procedure to be followed in obtaining the required network is outlined below.

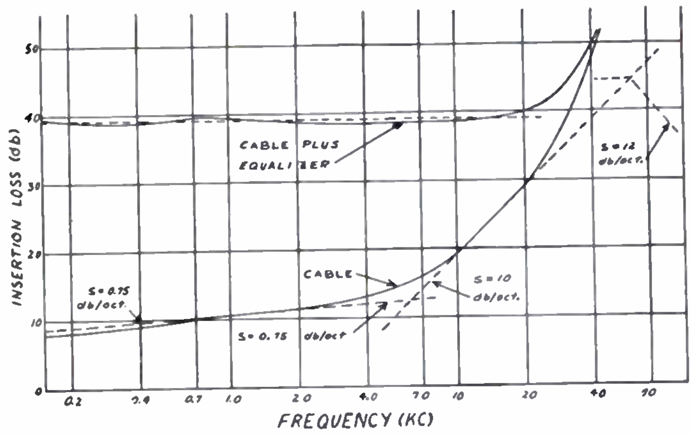


Fig. 8—Illustrating the procedure for design of an attenuation equalizer.

The slope, S_1, of the cable characteristic in the vicinity of 20 kc is approximately 10 db/octave. To achieve this slope with the simplest network will require the use of $n_1 = 2$ and $\alpha_1 = 0.6$. This choice yields a simulation error, ϵ_1, of 4.15 db and approximately 42 db over-all attenuation (A_0). If the lower terminus of the S_1 segment is set at 6.2 kc where it is followed by a segment of slope $S_2 = 0.75$ db/octave, then the error in simulation at 6.2 kc will be about 0.7 db. This value is predicted by noting that the cable attenuation is about 3.2 db greater than the attenuation at the intersection of the two line segments. The actual deviation of the equalizer attenuation curve is $(\epsilon_1 - \epsilon_2) = (4.15 - 0.25)$, or 3.90 db, where ϵ_2 is the simulation error corresponding to $S_2 = 0.75$ db/octave. Thus, the equalizer attenuation will be 0.7 db too low. It is assumed that this error is acceptable. The S_2 segment has its lower critical-frequency terminus at 830 cps. The "blocking in" of the attenuation curve is completed by the addition of a third segment of slope $S_3 = 0.75$ db/octave with its upper critical frequency terminus at 830 cps. Recapitulating, the pertinent parameters are collected in Table I.

TABLE I

	S	n	α	β_2	f_2	d
	db/oct				cps	$2\pi f_2/\beta_2$
1.	10.0	2	0.6	0.079	6,200	$1.57\pi \times 10^4$
2.	0.75	1	4.0	1.45	830	$1.15\pi \times 10^3$
3.	0.76	1	4.0	1.45	110	$1.52\pi \times 10^2$

The two low-frequency sections, corresponding to S_2 and S_3 may be synthesized directly from the data in Table I with the aid of the formulas in Fig. 7(b).

In order to decrease the over-all attenuation level of the equalizer, a double zero is added to the insertion-loss function as indicated in Fig. 8. As the critical frequency of the line segment corresponding to this double zero approaches 20 kc the over-all attenuation is decreased. At the same time, however, the error in simulation at 20 kc is increased. If a compromise value of 60 kc is chosen for this critical frequency, the simulation error will be about one db and the added attenuation at 20 kc due to the equalizer will be about 10 db. The insertion-loss function for the high-frequency section is then

$$e^{\theta} = \left[\frac{p + 12\pi \times 10^4}{12k\pi \times 10^4} \times \frac{p + 17.3\pi \times 10^4}{p + 1.57\pi \times 10^4}\right]^2, \qquad (18)$$

where k is to be given its maximum value consistent with physical realizability. Suppose it is desired to synthesize the high-frequency section as two identical L sections in tandem. For each section

$$\frac{Z_1}{R} = \frac{p^2 + \pi(29.3 - 12k)10^4 p + \pi^2(107.6 - 18.8k)10^8}{12k\pi \times 10^4\,(p + 1.57\pi \times 10^4)}, \qquad (19)$$

from which it is clear that the maximum value of k which will yield a physical network is $k_{max} = (29.3 - 1.57)/12 = 2.31$. For this value of k, (19) reduces to

$$\frac{Z_1}{R} = \frac{1}{27.7\pi \times 10^4}\left[p + \frac{64.1\pi^2 \times 10^8}{p + 1.57\pi \times 10^4}\right], \qquad (20)$$

from which Z_1 is readily synthesized. Choosing Z_2 inverse to Z_1 will then yield the required L section. The complete equalizer is shown in Fig. 9. Once k has been specified as 2.31, the equalizer attenuation at zero frequency is readily found to be 31.4 db. The cable plus equalizer attenuation can then be plotted as in Fig. 8. The maximum deviation from a flat characteristic in the range from 0.15 to 20 kc is about 0.8 db.

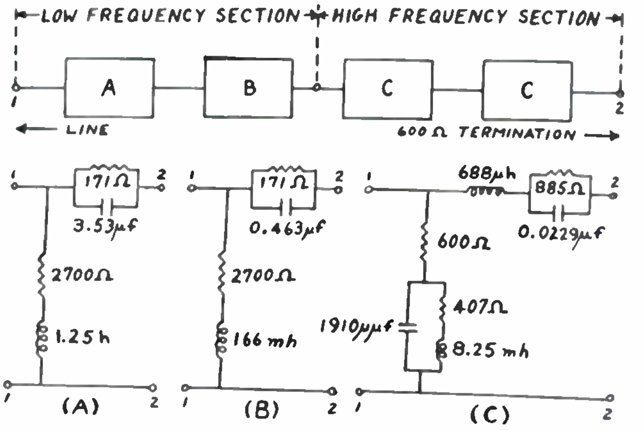


Fig. 9—Complete attenuation equalizer for the cable of Fig. 8.

VIII. Conclusions

The use of the line segments described in this paper provides a rapid and convenient method for approximating a prescribed magnitude characteristic. The basic limitation of this method is that a given line segment extends over a definite frequency interval of about three octaves. Therefore, this method is not suitable for simulation of rapid magnitude changes over a short frequency interval. The advantages of this method may be summarized as: (a) the line segments used are of arbitrary slope, (b) the use of straight line segments greatly simplifies the problem of superimposing the effects of groups of zero-pole pairs, and (c) confining the zeros and poles of approximating function to the real p axis simplifies the problem of predetermining its realizability.

Contributors to Proceedings of the I.R.E.

For a photograph and biography of F. Assadourian, see page 235 of the February, 1952 issue of the Proceedings of the I.R.E.

❖

Elizabeth H. Alexander was born in Petersburg, Va. on April 21, 1920. She received the A.B. degree from Bryn Mawr College in 1941 and the M.A. degree in 1948. She was assistant to the Director of Admissions and Dean of Freshmen at Bryn Mawr from 1944 to 1948. During 1949 and 1950 she was an assistant on admissions at Teachers College, Columbia University, in charge of the admission of foreign students.

E. H. Alexander

In the fall of 1950 Mrs. Alexander joined the RCA Laboratories Division, Princeton, N. J., where she is now engaged in personnel and editorial work.

R. J. F. Boyer was born on August 24, 1891 in Taree, N.S.W., Australia. He was educated at Newington College, Sydney, N.S.W., and received the M.A. degree from the University of Sydney in 1913. He was a Lieutenant in the 1st Battalion, A.I.F. during World War I.

R. J. F. Boyer

Although Mr. Boyer has broadcast a series of talks on international affairs through the B.B.C., London, his first association with the administrative side of broadcasting came with his appointment as a member of the Australian Broadcasting Commission on January 1, 1940. He has been abroad three times since, to the Pacific Relations Conferences at Montreal and Hot Springs and to the Commonwealth Relation Conference in London.

In 1945 Mr. Boyer was appointed chairman of the Australian Broadcasting Commission, and has since been reappointed twice.

Arthur M. Braaten (A'27–M'38–SM'43) was born at St. Paul, Minn., on November 30, 1901. He received the B.E.E. degree in 1928 and the professional E.E. degree in 1950 at the University of Minnesota. He has been an amateur radio experimenter and operator since 1916.

A. M. Braaten

Since 1928 Mr. Braaten has been an engineer with the Radio Corporation of America, in the communications research and development laboratory at Riverhead, L. I. He has been engaged chiefly in the development of precision frequency standards and methods of frequency measurement, and investigations of propagation phenomena, both ionospheric and tropospheric.

Mr. Braaten held a commission in the Signal Corps Reserve, U. S. Army, from 1928 to 1938. He is a member of Tau Beta Pi, Eta Kappa Nu, the American Association for the Advancement of Science, the

Contributors to Proceedings of the I.R.E.

American Radio Relay League, and the Radio Society of Great Britain.

❖

Aaron D. Bresler (S'43–A'46) was born in New York City on June 20, 1924. He graduated from the School of Technology of the City College of New York in 1944 with the BEE degree. Enrolled in the Electronics Trainings Group of the U. S. Army Reserve, he was then called to active duty in the U. S. Army Signal Corps and served for three years. In Vienna, Austria, he took employment with the War Department as a telephone engineer.

A. D. Bresler

In 1948 Mr. Bresler became an instructor in the electrical engineering department of the City College of New York. He received the MEE degree from the Polytechnic Institute of Brooklyn in 1951 and is continuing his post-graduate studies there. In 1951 he joined the staff of their Microwave Research Institute where he is engaged in development work in the microwave network field.

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

❖

J. F. Cline (A'43–SM'47) was born in Cadillac, Mich. on June 19, 1917. He received the B.S., M.S., and Ph.D. degrees in electrical engineering from the University of Michigan in 1938, 1941, and 1950, respectively. He has been engaged in both teaching and research at that institution since 1939, and in 1950 was appointed assistant professor of electrical engineering. In addition to teaching, he is employed in the Electronics Defense Group of the University of Michigan Engineering Research Institute, working on the design of special electronic measuring instruments.

J. F. Cline

Dr. Cline is a member of Eta Kappa Nu, Sigma XI, and A.I.E.E.

❖

Laurence G. Cowles (A'31–M'46–SM'52) received the degree of B.S. in electrical engineering from the University of Vermont in 1929 and a M.A. in physics from Columbia in 1932.

From 1929 to 1932 Mr. Cowles was engaged in studies of feedback amplifiers and modulation in vacuum tubes at the Bell Telephone Laboratories. From 1934 to 1946 he was engaged in development work in the Geophysical Laboratory of the Texas Company, Houston, Texas. Since 1946 he has been research geophysicist for the Superior Oil Company, Texas.

L. G. Cowles

Mr. Cowles is a member of the AIEE and the Society of Exploration Geophysicists.

❖

Robert C. Ellenwood was born in Wooster, Ohio on July 13, 1917. He received the B.S. degree from Ohio University in February, 1942. After graduation, he was employed by the Crosley Radio Corporation as development engineer. During World War II he served as radio technician in the U. S. Navy. From 1945 until 1950, he was employed by the National Bureau of Standards as research engineer to work on uhf standards and associated problems.

R. C. Ellenwood

At present, Mr. Ellenwood is in charge of the Advanced Base Radar Section, Bureau of Ships, Navy Department in Washington, D. C. He is a registered professional engineer of the District of Columbia.

❖

Herbert F. Engelmann (SM'52) was born on June 21, 1918 in Wilmington, Del. He received the B.S. degree in engineering physics from Lehigh University in 1940. During the following year, he did graduate work in the Physics Department of Cornell University.

H. F. Engelmann

From 1941 through 1944, Mr. Engelmann worked at the Naval Research Laboratory as a member of the radio-consultant division. Since 1944, he has served as a research engineer at Federal Telecommunication Laboratories, and at the present time is a department head. He is the author of several technical papers that have been published.

❖

D. D. Grieg (A'41–SM'44) was born on February 26, 1915 in London, England. He received his early schooling in England and the B.S. degree in electrical engineering from the College of the City of New York. He has done graduate work at Columbia and New York University.

D. D. Grieg

From 1936 to 1940, Mr. Grieg was in charge of the television department of the Davega Radio Company, and in early 1941 taught radio in Brooklyn Technical High School. Since 1941, he has been a research engineer for Federal Telecommunication Laboratories, and is now director of the special projects laboratory.

Mr. Grieg is a member of the A.I.E.E. He has served on several technical committees, including that on television of the Radio Technical Planning Board and on television relays and studio-transmitter links of the Radio-Television Manufacturers Association. He has published several technical papers and holds many radio patents.

❖

Elmer W. Engstrom (A'25–M'38–F'40) was born in Minneapolis, Minn., August 25, 1901. He received the B.S. degree from the University of Minnesota in 1923.

E. W. Engstrom

After graduation he became associated with the General Electric Company. When the radio engineering and manufacturing activities were transferred to the Radio Corporation of America in 1930, Dr. Engstrom continued as division engineer in charge of photophone or sound motion picture apparatus development and design at Camden, N. J., and assumed engineering responsibilities for RCA's broadcast receivers and radio-tube research.

In 1942 when research activities of RCA were concentrated at Princeton, N. J., he became director of general research and in 1943 director of research of RCA Laboratories. In 1945 he was elected vice president in charge of research of the RCA Laboratories Division, and in 1951 vice president in charge of the Division.

In 1949 Dr. Engstrom received the honorary degree of D.Sc. from New York University. In 1949 he received a silver plaquette from the Royal Swedish Academy of Engineering Research, and in 1950 was awarded the Outstanding Achievement Award gold medal from the University of Minnesota for "pioneering in television research."

He is a member of Sigma Xi, and a fellow of the A.I.E.E.

Contributors to Proceedings of the I.R.E.

William L. Hartsfield was born in Mississippi in 1907. He received the B.S. degree in electrical engineering from Mississippi State College in 1930.

W. L. Hartsfield

Mr. Hartsfield was a radio engineer in the office of the Chief Signal Officer during the early part of World War II. In 1942 he accepted a commission in the Signal Corps and was assigned to the Air Force Operational Testing Laboratory in Orlando, Fla.

Since 1946, Mr. Hartsfield has been employed by the National Bureau of Standards was project leader in various phases of experimental radio propagation research.

❖

Frank Hopkins, Jr. was born in Holly Springs, Miss. on January 12, 1927. He received the B.E. degree from Vanderbilt University in 1950 and the M.E. degree from Yale University in 1951. During the year 1945–1946 he served in the Signal Corps as a telephone operator in Occupation Forces, Tokyo. Since July, 1951 he has been an assistant project engineer at Sperry Gyroscope Company.

F. Hopkins, Jr.

While at Vanderbilt University Mr. Hopkins was a member of Sigma Nu and Tau Beta Pi.

❖

Everett H. Hurlburt (A'44) was born in Cleveland, Ohio on May 6, 1910. He received the B.A. degree from Western Reserve University in 1933, the M.A. degree from Harvard University in 1934, and the Ph.D. degree in physics from Ohio State University in 1940. He taught at Fenn College in Cleveland until 1942.

E. H. Hurlburt

In 1942 Dr. Hurlburt went to the Naval Research Laboratory as a member of the vacuum-tube section, where he remained until 1947. At this time he joined the staff of the Microwave Standards Section of the National Bureau of Standards. Since 1951 Dr. Hurlburt has been at the Naval Ordnance Laboratory, where he is chief of the high-frequency fields branch.

Dr. Hurlburt is a member of the IRE subcommittee 7.6 on small high-vacuum tubes, also of the A.P.S., Phi Beta Kappa, Sigma Xi, and Sigma Pi Sigma.

❖

C. W. Johnstone (SM'49) was born on August 22, 1916 in Alamosa, Col. He received the B.A. degree in physics-mathematics from Colorado College in 1938 and the M.A. degree in physics from Dartmouth College in 1940. He then spent a year as graduate assistant in the Physics Department at Pennsylvania State College.

C. W. Johnstone

In 1941 Mr. Johnstone joined the Sperry Gyroscope Company, where he was engaged in the development of indicator circuits for Navy night-fighter radar and doppler radar. He was assigned to the Combined Research Group at the Naval Research Laboratory in 1944, where he was responsible for the design of radar-I.F.F. interconnections. Returning to Sperry in 1945, he was made project engineer for marine radar development.

In 1947 Mr. Johnstone became affiliated with the Electronics Group of the Los Alamos Scientific Laboratory, where he is Section Leader for electronics research and Assistant Group Leader.

Mr. Johnstone is a member of Phi Beta Kappa and Sigma Pi Sigma.

❖

John F. Kalbach (SM'51) was born in Seattle, Wash. on January 2, 1914. After receiving the B.S. degree from the University of Washington in 1937, he joined the General Electric Company. After participating in the Test and Advanced Engineering program, he worked as design engineer in Lynn, Mass. on high-speed ac turbine generators, specializing in their testing and instrumentation.

J. F. Kalbach

In 1947, he joined the staff of the University of California at Berkeley, Calif., where he was a lecturer in electrical engineering. He moved to the University's Los Alamos Scientific Laboratory to assist with the engineering design and construction of a 12 million-volt electrostatic particle accelerator.

In 1951, after the accelerator had been put into operation, Mr. Kalbach joined the William Miller Corporation, Pasadena, Calif., where he is senior development engineer.

Mr. Kalbach is a member of A.I.E.E., Tau Beta Pi, Sigma Xi, and American Society of Professional Engineers.

❖

J. A. Kostriza (M'47) was born in Staten Island, New York on October 10, 1912. He received the B.S. degree in electrical engineering from Cooper Union Institute of Technology in 1936 and the M.E.E. degree from the Polytechnic Institute of Brooklyn in 1949. From 1938 to 1944, he taught applied mathematics and science in the New York City school system.

J. A. Kostriza

In 1944, Mr. Kostriza did research work on glass-vane attenuators for microwaves and taught undergraduate electrical engineering at the Polytechnic Institute of Brooklyn. Starting in 1945, he is now project engineer in charge of the microwave components group in the special project laboratory of the Federal Telecommunication Laboratories.

Mr. Kostriza is an associate of the A.I.E.E. and associate member of Sigma Xi.

❖

Herbert L. Krauss (S'40–A'42–M'46–SM'50) was born in Topeka, Kan. on August 24, 1916. He received the B.S. degree in electrical engineering from the University of Kansas in 1939 and the M.E. degree from Yale University in 1941. The summer of 1941 he worked in the research laboratories of the Sperry Gyroscope Company, then returned to Yale to teach in the department of electrical engineering.

H. L. Krauss

Mr. Krauss is now an associate professor at Yale, teaching communication networks and systems. He also is codirector of a research project on pulse-code modulation, sponsored by the U. S. Signal Corps.

Mr. Krauss is a member of the executive committee of the Connecticut Valley Section of the IRE, in which he has held the offices of chairman, vice-chairman, and secretary-treasurer. He is a member of the Circuits Committee of the IRE, and formerly served on the Electron Tubes Committee. Mr. Krauss also belongs to the A.I.E.E., Sigma Xi, Tau Beta Pi, and the Yale Engineering Association.

Contributors to Proceedings of the I.R.E.

Harold J. Lang (A'46) was born on April 9, 1923 in Buffalo, N. Y. He attended Rensselaer Polytechnic Institute for three years and Virginia Polytechnic Institute for one year, as an electronics student. He then joined the U. S. Army, and for three years served in the electronics group at the Los Alamos Scientific Laboratory, Los Alamos, N. M.

HAROLD J. LANG

After being discharged he returned to Los Alamos Scientific Laboratory as a staff member in the Physics Division, working on instrumentation for the 12-mev Van de Graaff generator.

❖

The following photograph and biography of Dr. Miller were omitted inadvertently from the September issue.

Kenneth S. Miller (A'47–M'52) was born on June 4, 1922 in New York, N. Y. He received the B.S. degree in chemical engineering from Columbia University in 1943.

K. S. MILLER

During World War II Dr. Miller served as a radar officer in the U. S. Navy. After a brief association with the Otis Elevator Company, he resumed his studies at Columbia University, receiving the A.M. degree in 1947 and the Ph.D. degree in 1950, both in mathematics. His post-doctoral work was done at the Institute for Advanced Study, Princeton, N. J. At present he is an assistant professor of mathematics at New York University.

Dr. Miller is a member of the American Mathematical Society, Sigma Xi, Tau Beta Pi, and Pi Mu Epsilon.

❖

Douglas E. Mode (SM'46) was born on April 4, 1911 in Brandon, Manitoba, Canada. In his youth he operated radio W9BCZ, and was in charge of service repairs for National Radio in Chicago. He received the B.S., M.S., and Ph.D. degrees from the University of Pennsylvania in 1935, 1937, and 1947, respectively.

DOUGLAS E. MODE

From 1936 to 1940 Dr. Mode was a research and development engineer with the General Electric Company. In 1940 he became an instructor at Lehigh University, then assistant professor until 1944. He then joined the electronic-design group at the Underwater Sound Laboratory in New London, Conn., where he was engaged in the development of specialty electronic devices for the Navy. In March, 1945 Dr. Mode transferred to the Radiation Laboratory at the Massachusetts Institute of Technology, where he was in charge of uhf filter designs for project Cadillac.

Returning to Lehigh in 1945, Dr. Mode became associate professor of radio communication. Since that time he has also been the director of the uhf filter research program sponsored by the Air Force.

Dr. Mode is a member of Eta Kappa Nu, Tau Beta Pi, Sigma Xi, and the A.S.E.E.

❖

Philip F. Ordung (S'40–A'43–M'48–SM'49) was born at Luverne, Minn. on August 12, 1919. He received the B.S. degree in electrical engineering at South Dakota State College of Agriculture and Mechanic Arts in 1940; the M.E. degree in 1942, and the Eng. degree in 1949 from Yale University.

P. F. ORDUNG

Dr. Ordung came to Yale as a laboratory assistant in 1940 and remained on the staff of electrical engineering until 1944. From 1944 to 1945 he was employed by the Naval Research Laboratory in connection with the development of radar modulators. In 1945 he returned to the staff of electrical engineering at Yale, where he is currently an associate professor.

He has served on the Networks Committee of the IRE and the A.I.E.E. He is an associate of the A.I.E.E. and a member of Sigma Xi.

❖

For a photograph and biography of DR. J. R. PIERCE see page 1128 of the September, 1952 issue of THE PROCEEDINGS OF THE I.R.E.

❖

E. Rimai was born in New York City on September 24, 1911. He attended the College of the City of New York, from which he received the B.S. degree in 1932 and the M.S. degree in 1933 in education.

E. RIMAI

From 1933 to 1940, Mr. Rimai was employed in several miscellaneous jobs. He served as a laboratory assistant in the Brooklyn Technical High School from 1940 to 1942 and as a junior engineer in the U.S.A. Signal Corps for a year.

Since 1943, Mr. Rimai has been employed at the Federal Telecommunication Laboratories, where he is now a senior engineer in the microwave components group of the special projects laboratory. He has worked on pulse and video circuits and on the theoretical analysis of various problems in electronics.

❖

For a photograph and biography of RICHARD SILBERSTEIN, see page 1000 of the August, 1952 issue of the PROCEEDINGS OF THE I.R.E.

❖

Edward L. Sparrow (A'51) was born on June 1, 1920 in Portland, Maine. He received the B.S. degree in electrical engineering from the University of New Hampshire in 1950 and the M.E. degree in electrical engineering from Yale University in 1951.

E. L. SPARROW

Mr. Sparrow attended General Motors Institute for a year, then he joined the U.S.A. Signal Corps in 1942, attended radar school and later served in Italy. He is now employed at the National Bureau of Standards in the Ordnance Electronics Division.

Mr. Sparrow is a member of Tau Beta Pi.

❖

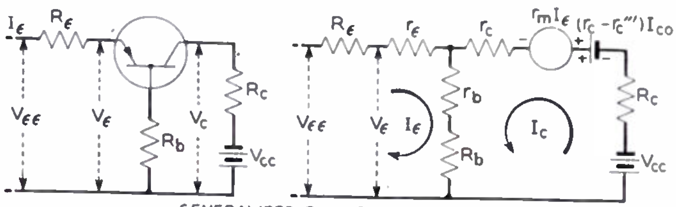
Gilbert S. Wickizer (A'28–SM'46) was born in Warren, Pa., on August 20, 1904. He received the B.S. degree in electrical engineering from the Pennsylvania State College in 1926, and after graduation he was employed by the Radio Corporation of America, in the operating division at Rocky Point, N. Y. Since 1927, he has been with RCA at Riverhead, N. Y., engaged in communications research on problems of reception, including propagation studies in the vhf and uhf regions and development work on direction-finding, frequency measurement, receiving antennas, and field strength measurement.

G. S. Wickizer

Mr. Wickizer is a member of Eta Kappa Nu, the American Geophysical Union, and the American Meteorological Society.

Correction

The synopses given below were omitted from Figs. 17, 18, and 19 of the paper, "Transistors in Switching Circuits," by A. Eugene Anderson, which appeared on pages 1541–1558 of the November, 1952 issue of the PROCEEDINGS OF THE I.R.E. The synopses summarize the approximate analytical relationships for the three regions of the negative resistance characteristics. Where the indicated approximations apply, the relationships may be employed directly in the computation of quiescent circuit behavior. Where the approximations do not apply, regional equations should be derived from the general voltage-current relation given at the beginning of each synopsis.

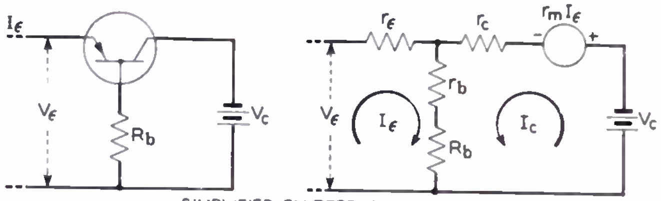


GENERALIZED EMITTER CIRCUIT

Synopsis

General

$$V_{\epsilon\epsilon} = I_\epsilon\left[(r_\epsilon + r_b + R_b + R_\epsilon) - \frac{(r_b + R_b)(r_b + R_b + r_m)}{r_b + R_b + r_c + R_c}\right] - \frac{(V_{cc} + I_{co}(r_c - r_c'''))}{r_b + R_b + r_c + R_c}(r_b + R_b).$$



SIMPLIFIED EMITTER CIRCUIT

Approximate Short Circuit Case
where

$$r_b \ll R_b;\quad r_\epsilon,\ r_\epsilon''' \ll R_b;\quad R_b \ll r_c,\ r_m;\quad R_\epsilon = R_c = 0;$$
$$I_{co}(r_c - r_c''') \ll V_c$$

Region I

$$V_\epsilon \approx I_\epsilon r_\epsilon' + \frac{V_c R_b}{R_b + r_c}$$

Region II

$$V_\epsilon \approx I_\epsilon R_b(r - \alpha) + \frac{V_c R_b}{R_b + r_c}$$

Region III

$$V_\epsilon \approx I_\epsilon(r_\epsilon''' + r_c''' - r_m''') + V_c$$

$$I_{\epsilon p} \approx 0;\quad V_{\epsilon p} \approx \frac{V_c R_b}{R_b + r_c}$$

$$I_{\epsilon t} \approx \frac{V_c}{R_b(1 - \alpha)};\quad V_{\epsilon t} = V_c\left[1 + \frac{r_\epsilon''' + r_c''' - r_m'''}{R_b(1 - \alpha)}\right]$$

$$\frac{V_{\epsilon v}}{V_{\epsilon p}} \approx \frac{R_b + r_c}{R_b}.$$

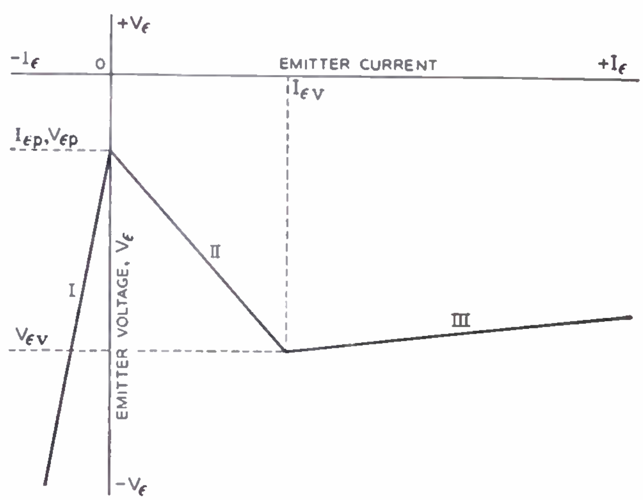
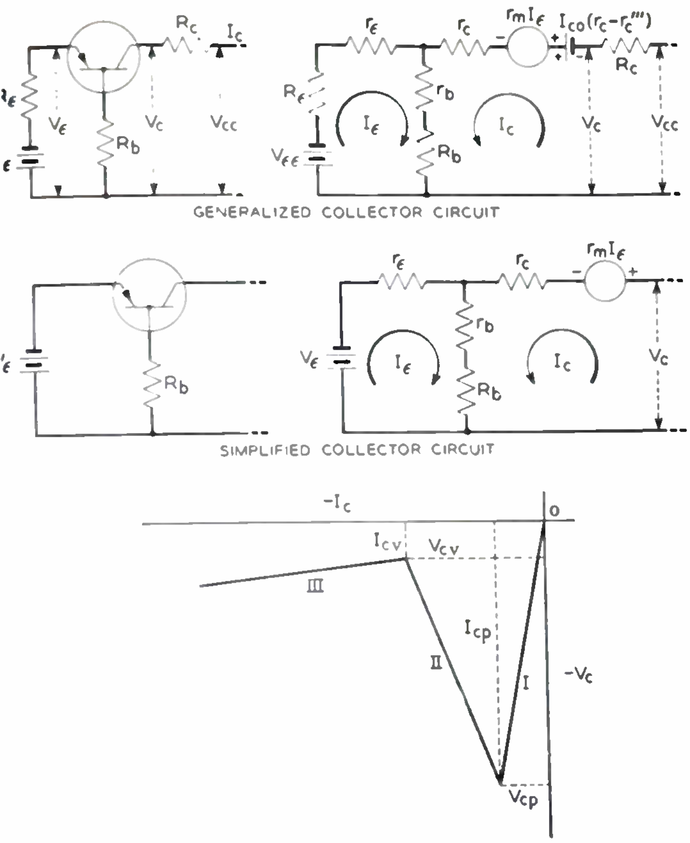


Fig. 17—Synopsis of emitter negative resistance characteristic and properties.



Synopsis

General

$$V_{cc} + I_{co}(r_c - r_c''')$$
$$= I_c\left[r_c + R_c + r_b + R_b - \frac{(r_b + R_b)(r_b + R_b + r_m)}{r_e + R_e + r_b + R_b}\right] + \frac{V_{ee}(r_b + R_b + r_m)}{r_e + R_e + r_b + R_b}.$$

Approximate Short Circuit Case
where

$$R_e = R_c = 0;\quad r_b \ll R_b;\quad I_{co}(r_c - r_c''') \ll V_{cc},\ R_b \ll r_m,\ r_c$$

Region I

$$V_c \approx I_c(r_c + R_b) + V_e \frac{R_b}{r_e'}$$

Region II

$$V_c \approx I_c[r_c(1 - \alpha)] + \frac{V_e(r_m + R_b)}{R_b}$$

Region III

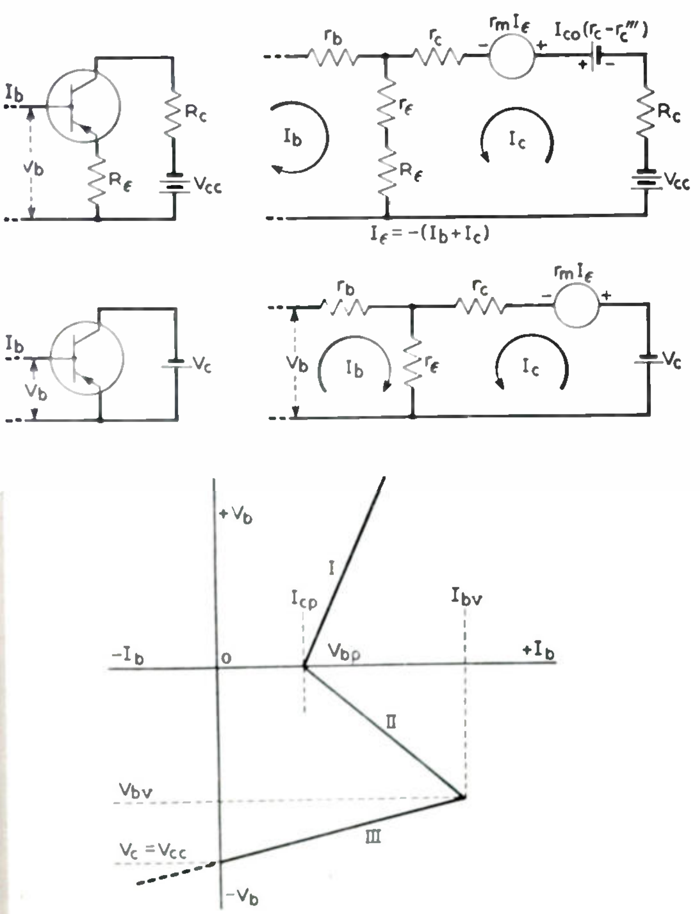
$$V_c \approx I_c(r_e''' + r_c''' - r_m''') + V_e$$

$$V_{cp} \approx V_e\left(\frac{r_c + R_b}{R_b}\right) \qquad I_{cv} \approx \frac{V_e}{R_b}\left(\frac{\alpha}{\alpha - 1}\right)$$

$$I_{cp} \approx \frac{V_e}{R_b} \qquad \frac{V_{cp}}{V_{cv}} \approx \frac{r_c + R_b}{R_b}$$

$$V_{cp} \approx V_e\left[1 + \frac{\alpha(r_e''' + r_c''' - r_m''')}{R_b(\alpha - 1)}\right]$$

Fig. 18—Synopsis of collector negative resistance characteristic and properties.



Synopsis

General

$$V_b = I_b(r_b + R_b + r_e + R_e) + I_c(r_e + R_e)$$

$$V_{cc} + I_{co}(r_c - r_c''') = I_b(r_e + R_e - r_m) + I_c(r_e + R_e + R_c - r_m)$$

$$V_b = I_b\left[r_b + R_b + R_e + r_e - \frac{(r_e + R_e)(r_e + R_e - r_m)}{r_e + R_e + r_c + R_c - r_m}\right] + \frac{[V_{cc} + I_{co}(r_c - r_c''')](r_e + R_e)}{r_e + R_e + r_c + R_c - r_m}.$$

Approximate Short Circuit Case

$$R_e = R_c = 0;\qquad I_{co}(r_c - r_c''') \ll V_c;\qquad r_e \ll r_c(1 - \alpha)$$

Region I

$$V_b \approx I_b\left(\frac{r_e' r_c}{r_c + r_e'}\right) + \frac{V_c r_e'}{r_e' + r_c}.$$

Region II

$$V_b \approx I_b\left(\frac{r_b + r_e}{1 - \alpha}\right) + \frac{V_c r_e}{r_c(1 - \alpha)}$$

Region III

$$V_b \approx I_b r_b''' + V_c$$

$$I_{bp} \approx \frac{V_c}{r_c};\qquad V_{bp} = 0$$

$$I_{bv} \approx V_c\left[\frac{1 - \alpha}{r_e}\right];\qquad V_{bv} \approx V_c\left(1 - \frac{(\alpha - 1)r_b'''}{r_e}\right).$$

Fig. 19—Synopsis of base negative resistance characteristic and properties.

Correspondence

Engineering Unity

In the interests of real unity in the engineering profession may I be allowed to submit the following thoughts for consideration?

I have been a member through all grades, and continuously since college, of one of our larger technical societies. I have also been a state section president and contributed to committees and publications. It should be evident then that I am not interested in sabotaging the value of our technical societies.

However, to many of us the crying need of engineers today is the establishment of one paramount society that will truly represent all qualified engineers, both professionally and technically, at local, national, and international levels. It should be an integrated society, and not merely a banding together of existing societies into a federation which neither represents all qualified engineers nor permits direct and democratic election of officers and directors by the individual members.

Many of us in the grass roots are disappointed in the four unity plans (A, B, C, D) so far proposed and would like to see at least one other plan considered. We are also disappointed that the individual members have had little or no opportunity to study all plans, compromises, or worthy minority ideas.

Apparently, the Exploratory Group, in its report of December, 1950, expected individual members to have ample opportunity to express their ideas on unity. This does not seem to have been done generally, and many of us feel that we are being forced to consider plans that could be improved for the benefit of engineers. I have written the Exploratory Group on this, and suggested that each individual member of at least the 15 national societies that make up the Exploratory Group be polled to learn his wishes after he has had ample opportunity to study all plans, compromises, and worthy minority ideas. Among the latter there is an admirable plan (called Plan E) that has been submitted by the Florida Section of A.S.C.E. Unless engineers can be sure of what they want, there will always be dissatisfaction and disunity.

At a very recent regional meeting of the American Society for Engineering Education, at which I spoke on the Unity situation, I was surprised to learn of the vital interest this large group of engineering educators had in the subject; of their almost unanimous dissatisfaction with the Plans A, B, C, and D; and their desire for more information and a better integrated plan to consider. A resolution was passed unanimously to that effect and forwarded to the national A.S.E.E. secretary. It turned out that only 5 out of the group had seen or heard much about the four plans before my talk. They were also keenly interested in having a plan that would be a real integration of technical and professional interests and one in which the individual could vote directly for its officers and directors.

I am interested in real unity and not further disunity. I intend to support wholeheartedly a plan that the majority of engineers favor. Some of us want to be sure, however, that engineers have adequate opportunity to express their wishes on the plan they want. Such can hardly be done without a poll, or if they are told, it must be one of the four plans or nothing.

T. H. Evans
Dean of Engineering
Colorado Agricultural and
Mechanical College
Fort Collins, Col.

Telepathy and the Quantum*

The suggestion by Hammond in his recent communication[1] that the neutrino possesses physical attributes which may permit it to serve as a carrier for telepathic communication does not take into consideration the important nonphysical attributes necessarily concomitant with any telepathic modus operandi. For instance, experiments in extrasensory perception show no correlation with distance or mass, while Rhine points out[2] that the telepathic properties are closely related to the higher properties of the mind. If it is assumed that Hammond's neutrino is an inert agent directed by some propelling mechanism within the brain, then this mechanism must have remarkable directive powers. For telephathic communication between two individuals on opposite sides of the earth, for example, the neutrino must be directed with an accuracy of approximately one part in 10^{16}, assuming the brain as target. This is an extremely stringent requirement, even neglecting the interference effects of the intervening matter or the necessity of transmitting an enormous range of information[3] via the particle.

On the other hand, Hammond's suggestion becomes attractive if the neutrino is delegated an active part in the postulated telephathic process, i.e., if the particle contains the necessary information and the means to choose and "home" on its target. These properties are, however, deterministic in nature, a characteristic not associated with inert forms of matter. It demands the existence of noninert forms of matter within the neutrino—forms of matter which have the ability to control, direct, and utilize energy. These properties, which are commonly grouped under the term "will," are associated only with biological forms of matter as far as is known at present. It therefore poses the following question: Do there exist subelectronic forms of matter possessing deterministic properties akin to those of biological matter?

It would be difficult for modern science to give a rigorous denial to this question. In fact there are suggestions of an affirmative answer as the following remarks intend to show.

Planck's quantum of action, h, which has been termed the most important constant in atomic physics and the key to the microcosm, has been identified by some philosophers and physicists with the existence of a microcosmic "will." This may be shown to result from the nature of action. Action is defined as the time integral of energy, or $\int_{t_0}^{t_1} U dt$, where U is energy and t_0 and t_1 define an interval of time. For closed systems, i.e., those having constant energy, the action is of no significance since any choice of interval is arbitrary and meaningless. However, any transfer or transformation of energy, such as a collision, chemical reaction, meteorological phenomenon, existence of a sun, and so on, is associated with a definite energy and interval, hence a finite action. But a quantum of action requires that the magnitude of an action recurs in nature with a probability of one. This in turn demands the existence of a chanceless process, hence the association with a "will." (The physicist normally stresses the converse, i.e., that the magnitudes of the components of the quantum of action, energy, and time interval are mutually indeterminate.)

Inert phenomena do not satisfy the chanceless or determinant requirements for the production of a quantum. For instance, the probability that the actions of two collisions or of two suns are the same is small, while the probability that all collisions or suns have identical action is nil. Although there is a direct cause and effect relationship in inert phenomena, the probability that all the causes, hence effects, be quantitatively identical is almost zero.

Contrarily, biological phenomena do satisfy this chanceless requirement. The probability that humans reproduce humans and not some other form of matter, as an illustration, is very nearly one. This reproductive process, one of the most chanceless in the universe, is responsible for the similar metabolic and mortality characteristics of all members of a species, and should consequently produce a similar value of action corresponding to the existence of each individual. This has been quantitatively verified by the author.[4] The results indicate that the members of each living species may be associated with a finite value of action within narrow limits.

This biological quantum of action is the only type found in nature in addition to the enigmatic h. Its existence reinforces the argument that a quantum of action is associated with determinant forms of matter, and consequently implies that one of the manifestations of h is telepathy.

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* Original manuscript received by the Institute, July 28, 1952.

[1] A. L. Hammond, "A note of telepathic communication," Proc. I.R.E., vol. 40, p. 605; May, 1952.

[2] J. B. Rhine, "The Reach of the Mind," W. Sloane Assoc., Inc., New York, N. Y.; 1947.

[3] R. J. Bibbero, "Telepathic communication," Proc. I.R.E., vol. 39, pp. 290–291; March, 1951

[4] M. Ruderfer, "The concept of action as a measure of living phenomena," *Science*, vol. 110, pp. 245–252; 1949

Institute News and Radio Notes

Calendar of COMING EVENTS

IRE-AIEE ACM Computers Conference, Park Sheraton Hotel, New York, N. Y., December 10–12

Conference on High-Energy Nuclear Physics, University of Rochester, Rochester, N. Y., December 18–20

IRE-AIEE Meeting on High-Frequency Measurements, Washington, D. C., January 14–16

IAS-IRE-RTCA-ION Symposium on Electronics in Aviation, New York, N. Y., January 26–30

IRE-AIEE Western Computer Conference, Hotel Statler, Los Angeles, Calif., February 4–6

IRE Southwestern Conference and Electronics Show, Plaza Hotel, San Antonio, Tex., February 5–7

IEE Symposium on Insulating Materials, London, Eng., March 16–18

1953 IRE National Convention, Waldorf-Astoria Hotel and Grand Central Palace, New York, N. Y., March 23–26

IRE New England Radio Engineering Meeting, Storrs, Conn., April 11

9th Joint Conference of RTMA of United States and Canada, Ambassador Hotel, Los Angeles, Calif., April 16–17

IRE Seventh Annual Spring Technical Conference, Cincinnati, Ohio, April 18

1953 National Conference on Airborne Electronics, Dayton, Ohio, May 11–14

1953 IRE-RTMA Radio Fall Meeting, Toronto, Ont., October 26–28

Supplement to Standard 51 IRE 17 S1

A supplement to the "Standards on Radio Receivers: Open-Field Methods of Measurement of Spurious Radiation from Frequency Modulation and Television Broadcast Receivers, 1951," has been prepared by the Spurious Radiation Subcommittee of the Committee on Receivers. This supplement contains practical suggestions on the choice of calibrating site, location and setup of equipment, and most expeditious use of auxiliary services. It also contains a section on site calibration, describing means for checking the over-all performance of the setup by means of a standard signal generator. By this method greater uniformity of sites and agreement between measurements taken at different sites should be achieved.

Further information may be obtained by writing to the Institute of Radio Engineers, 1 E. 79 Street, New York 21, N. Y.

Annual IRE Awards for 1953 Announced

Dr. John M. Miller, superintendent of Radio Division 1 of the Naval Research Laboratory, Washington, D. C., has been named the recipient of the IRE Medal of Honor for 1953, the Institute's highest award. The award was given "in recognition of his pioneering contributions to our basic knowledge of electron tube theory, of radio instruments and measurements, and of crystal oscillators."

The presentation of the award will be made by the President of the Institute at the IRE Annual Banquet, Waldorf-Astoria Hotel, New York, N. Y., on March 25, 1953, during the IRE National Convention.

The recipients of other annual awards have been announced as follows: Morris Liebmann Memorial Prize, to John A. Pierce, Harvard University; Vladimir K. Zworykin Television Prize Award, to Frank Gray, Bell Telephone Laboratories; Harry Diamond Memorial Award, to R. M. Page, Naval Research Laboratory; Browder J. Thompson Memorial Prize to R. C. Boonton, Massachusetts Institute of Technology; Editor's Award, to E. O. Johnson and W. M. Webster, RCA Laboratories Division.

In addition, the following were awarded the grade of Fellow, effective January 1, 1953:

E. W. Allen, Jr.	E. C. Jordon
J. P. Arnaud	F. G. Kear
B. B. Bauer	R. W. P. King
J. W. Bell	R. G. Kloeffler
L. J. Black	E. A. LaPort
H. G. Booker	R. R. Law
W. E. Bradley	W. A. MacDonald
J. L. Callahan	J. A. McCullough
K. A. Chittick	J. A. Morton
A. A. Collins	A. B. Oxley
E. U. Condon	Albert Preisman
W. W. Eitel	J. C. R. Punchard
Harry Faulkner	J. A. Rajchman
E. B. Ferrell	J. A. Ratcliffe
W. R. Ferris	S. O. Rice
L. R. Fink	Walther Richter
L. R. Hafstad	A. A. Roetken
F. Hamburger, Jr.	W. M. Rust, Jr.
L. B. Headrick	Jorgen Rybner
P. J. Herbst	Daniel Silverman
John Hessel	A. W. Straiton
H. E. Hollmann	Irven Travis
T. A. Hunter	Bertram Trevor
E. J. Isbister	H. W. Wells

C. J. Young

Technical Committee Notes

On October 8, the **Antennas and Waveguides** Committee met under the Chairmanship of D. C. Ports. The members reviewed the criticisms, comments, and the resultant action on document 51 IRE 2. PS1, Definitions of Wave Guide Terms.

Under the Chairmanship of G. D. O'Neill, the **Electron Devices** Committee met on September 12. L. S. Nergaard reported on the status of the "noise definitions." Dr. Nergaard remarked that the Committee on Receivers had presented definitions for noise factor, spot noise factor, and average noise factor approximately the same time as Committee 7 had presented its proposed definitions, but that as far as he knows, the Standards Committee has approved only the material from this Committee. The American Standards Association has requested noise standards from the IRE, and it is assumed that they will follow past practices of using what is supplied, verbatim. Dr. Nergaard believes there should be joint sponsorship with the Receivers Committee on these standards. The Definitions for Phototubes (52 IRE 7.2 C) were revised and approved by the Committee as were the proposed Definitions of Terms Related to Storage Tubes.

The **Navigation Aids** Committee met on September 16, under the Chairmanship of P. C. Sandretto. Further consideration was given to a list of terms presented by Harry Davis.

On September 12, the **Symbols** Committee met under the Chairmanship of A. G. Clavier. C. D. Mitchell, Chairman of Task Group 21.2 on Graphical Symbols for Semiconductors, gave a report on the status of work in his group. W. B. Callaway, Chairman of the Task Group on Symbols for Functional Operation of Control, Computing and Switchboard Equipment, introduced F. J. Roehm and A. C. Reynolds, Jr. of IBM, Endicott, N. Y. At Mr. Callaway's request, the chairmanship was transferred from him to Mr. Reynolds. A. F. Pomeroy made a report on the status of graphical symbols standardization in the industry and the Armed Services. The report pointed out that it is believed MIL-STD-15A will be proposed in December of this year and will be essentially in agreement with the latest ASA Y32/2 draft. Subcommittee 2 of ASA Committee Y32 has completed its draft of the ASA Standard on Graphical Symbols and has given it to a task group to edit. Discussion ensued as to whether IRE would adopt the ASA Standard containing the power and control symbols, in addition to those pertaining to electronics, or whether it was the consensus of opinion that power and control symbols be omitted from the IRE Standard. It was voted unanimously that the Symbols Committee adopt the proposal of the ASA Y32/2 Task Group on Graphical Symbols for Electrical Diagrams as an IRE Standard, with an introductory paragraph explaining that it includes power symbols originating outside of IRE. Mr. Clavier remarked that some interest has been expressed in a standard for graphical symbols for computers and asked whether any new symbols are required for computer work or if the components used in this work are adequately covered by existing symbols. It was agreed that Mr. Reynolds will furnish Mr. Clavier with a report covering his preliminary study of the scope of this job. Reporting on the need for symbols on feedback control systems, Mr. Clavier called attention to an AIEE subcommittee report on terminology and nomenclature of the Feedback Control Systems Committee of May 18, 1951. Discussion ensued on this report. The Chairman reported that C. R. Muller has provided him with the results of an informal survey, made during the 1952 IRE Convention, of present practice in regard to a schematic symbol for Geiger-Mueller counter tubes. A rather wide diversity is indicated and it was agreed that this Committee should take steps to establish a standard. Copies of Mr. Muller's report will be circulated to committee members for comment and the results will be submitted to the Chairman of the Electron Devices Committee for further comments. An attempt will be made to complete this survey in time to propose a standard symbol for inclusion in the ASA and MIL Standards on Graphical Symbols.

The Video Techniques Committee met on October 2, under the Chairmanship of W. J. Poch. The first item on the agenda was the Annual Review. A. J. Baracket has agreed to edit the material in the field of video techniques and requested suggestions, especially from the other subcommittee chairmen, for subjects which should be included in the report. A request from L. G. Cumming, regarding the status of two lists of definitions compiled several years ago, was discussed. It was agreed that these incomplete lists should be replaced by more up-to-date information. In order to expedite the work on definitions, it was decided that the immediate effort should be directed towards obtaining a satisfactory list of definitions concerned with the characteristics and measurement of the signal output from a television studio facility. After this work is completed, the remaining definitions can be considered as a second group. The Committee next reviewed its accomplishments within the last few years which include the following: (1) Standard on Measurement of Television Signal Levels, (2) Standard on Measurement of Pulses, (3) Standard on Measurement of Resolution, (4) Standards on Measurement of Electronically Regulated Power Supplies, (5) Standards on Measurement of Timing of Video Switching Systems, (6) Introduction and two tutorial papers on video recording. Also reviewed were the projects that are now active in subcommittees. A. J. Baracket, Chairman of the Subcommittee on Video Systems and Components, reported that a proposed Standard on the Measurement of Geometric Distortion is very nearly ready for submission to the Video Techniques Committee. Active work is underway on a system for measuring the transfer characteristic of an amplifier designed to compensate for pickup device characteristics. Reports are being prepared on pickup tube interlacing and dc insertion. Progress is being made on a method for measuring the rate of change of frequency of synchronizing signals. A report was made concerning the Subcommittee on Video Transmission Systems on which work is underway to develop a satisfactory method for evaluating nonlinear distortion of amplifiers expected to have a linear characteristic. Several approaches to the problem are being studied making use of special waveforms. Since R. L. Garman was unable to attend the meeting, S. W. Athey reported on the recent activities of the Subcommittee on Video Utilization. There appears to be some confusion regarding an article submitted by L. D. Grignon for Committee consideration. As this article was prepared sometime ago, a few revisions may be necessary to bring it up to date. Dr. Athey agreed to obtain additional copies of this report for circulation to members of the Video Techniques Committee in order that a decision regarding submission for publication could be made at the next meeting. Chairman Poch then submitted a list of terms used in the description and measurement of composite picture signals. This list includes terms for which definitions already are available as well as those which require new definitions. A preliminary discussion of some of the terms took place with emphasis on those for which definitions are not available. J. Battison offered to be of assistance in the definitions work and some of this activity will be referred to him. It was suggested that a closer relationship be established with the West Coast in regard to standards proposals so that such information would be made available to West Coast areas in sufficient time to receive comments before final decisions. The Video Techniques Committee now has two members from the West Coast on its Committee, and it was proposed that the subcommittees also include in their membership individuals to represent the West Coast.

Over 6,100 Attend National Electronics Conference

The eighth annual National Electronics Conference September 29–October 1, 1952, at the Hotel Sherman, Chicago, Ill., totaled a 6,165 attendance in comparison to 4,033 of the previous year.

The theme of the conference "Electronics for Defense and Industry" featured a program of 97 technical papers, covering a broad field of electronic research, development, and practical application, and were presented by prominent scientists and engineers from all sections of the country. The technical program was supplemented by 120 booths of exhibits by manufacturers and institutions foremost in the electronics field.

Highlighting the three luncheons of the conference were addresses given by E. W. Engstrom, vice president in charge of RCA Laboratories; Major General G. I. Back, Chief Signal Officer of the United States Army; and, Harner Selvidge, director of special products development, Bendix Aviation Corporation.

All technical papers presented at the conference will be published in volume 8 of the "Proceedings of the National Electronic Conference." This book will be available for five dollars after January 15, 1953, and may be ordered from the National Electronics Conference, Inc., Karl Kramer, Executive Secretary, 852 East 83 Street, Chicago Ill.

ASEE Sponsoring Literature Survey

The American Society for Engineering Education is sponsoring an "engineering literature project" to investigate the literature use and searching of practicing engineers. Taking into consideration that many engineers do not extract full value from engineering literature in the libraries, the Society is trying to discover why this may or may not be true and what remedy, if needed, may be found for it.

The survey questionnaire, directed to practicing engineers, contains these points: (a) what value they place on library or literature "know-how"; (b) what training they have had in this direction; (c) whether they think such training is desirable or even essential for prospective engineers; (d) what ideas they have on the sort of training, if any, that should be given.

The questionnaire, completed by using checkmarks, was sent on November 24, 1952, to 1,000 engineers selected at random from society and association directories.

A copy of the questionnaire is available upon request by addressing: Engineering Literature Project, ASEE, E. A. Chapman, Rensselaer Polytechnic Institute, Troy, N. Y.

Southwestern Conference Set for February

The annual Southwestern IRE Conference and Electronics Show, to be held February 5–7, 1953, at the Plaza Hotel, San Antonio, Texas, will feature a wide technical program including a session for student prize papers.

Eleven sessions of technical papers will cover the general subjects of: television, radio broadcasting, medical electronics, new components, audio, electronics in the petroleum industry, microwave communications, instrumentation, and servomechanisms. This program will be supplemented with a variety of exhibitions from radio engineering companies and a social program for the engineers and the ladies. Also, a committee will operate a placement service for the benefit of industrial firms seeking engineers and for engineers seeking positions.

Undergraduate and graduate students, with the exception of teaching staff members of the rank of instructor or higher, are eligible for the student papers prize of a session devoted to "education for radio engineers." Papers submitted should not exceed 3,000 words, should be in the general fields covered by the Proceedings of the I.R.E., and may represent original research, new application of existing theory or practive or a critical survey radio theory, new equipment, components, or radio practices.

The papers should be given to the IRE Representative in colleges or to the head of the engineering or physics division where no student IRE group exists. The representative or department head will select the two best papers and send them, by January 5, 1953, to: Box IRE, St. Mary's University, San Antonio, Texas. The first prize will be $75.00, the second will be $25.00.

For further information concerning the Conference write to: W. J. Hamm, Committee Chairman, Box IRE, St. Mary's University, San Antonio, Texas.

Professional Group News

Airborne Electronics

The Dayton Chapter of the Airborne Electronics Group has been officially approved. The appointed Chairman of the chapter is Major Maurice Jacobs, Chief ECM Unit, Aircraft Radiation Laboratory, Wright-Patterson, AFB, Dayton, Ohio.

A Philadelphia Chapter also has been approved. The new Chairman is C. K. Black, Technical Advisor, Naval Air Development Center, Johnsville, Pa.

Audio

A large interest has been shown in the Houston IRE Section for an Audio Group Chapter. For purposes of forming a chapter, a meeting was held recently at the Halliburton Laboratory, Houston, Tex. Demonstrations were given of small speaker enclosures, among them the Baruch MIT speaker (four- to five-inch speakers), the Hartley-Turner speaker and "boffle," the Permaflux eight-inch corner speaker, and a small exponential horn (not for corner).

At a Chicago Chapter meeting held recently, the topic, "Electrical Mechanical Equivalent Circuits," was presented by B. B. Bauer, of Shure Brothers, Inc., and Robert Adler of the Zenith Radio Company. This meeting was held jointly with the Circuit Theory Group Chapter.

The San Diego Chapter of the Audio Group met in November at the San Diego State College. The meeting featured the topic, "Subjective Factors in Evaluating Audio Systems," during which R. S. Gales and J. C. Webster, of the Navy Electronics Laboratory, conducted the discussion. The discussion covered the auditory capacities of the normal human observer and relationships to the evaluation of the audio system. Methods of quantitatively measuring ear activity were discussed, and a new method of conducting hearing tests was demonstrated.

Broadcast and Television Receivers

Chairman Stephen Bushman presided at the Chicago Chapter meeting of the Broadcast and Television Receivers Group, held at the Western Society of Engineers Auditorium, September 25. Albert Cotsworth and J. F. White, of the Zenith Radio Corporation, spoke on "A UHF-VHF Turret Tuner for Television Receivers."

Broadcast Transmission Systems

Two-hundred-and-fifty-one members of the Boston IRE Section attended the first meeting of the Boston Chapter on Broadcast Transmission Systems. C. J. Hirsch, of the Hazeltine Corporation, spoke on color TV. The second chapter meeting was held recently at Huntington Hall, Massachusetts Institute of Technology. A paper entitled, "TVI—Interference to Television Reception and its Elimination," was presented by Philip Rand of the Remington Rand Laboratory of Advanced Research. The paper was demonstrated with equipment furnished by the American Radio Relay League, under the supervision of George Grammer of that organization. Bimonthly meetings will be held by this Group under the Chairmanship of P. K. Baldwin.

(Broadcast Transmission Systems Cont'd)

Gerald Chinski, technical supervisor of Station KXYZ is promoting a chapter of the Group in the Houston IRE Section.

Communications

The Group on Communications held a symposium on November 21, 1952, at the Coles Signal Laboratory, Red Bank. N. J.

Electronic Computers

The Professional Group on Electronic Computers is formulating its plans for the Joint IRE/AIEE/ACM Computer Conference, February 4–6, 1953, Statler Hotel, Los Angeles, Calif.

Plans for chapters of the Electronic Computers Group are being organized in the New York, Boston, and Washington IRE Sections.

The Los Angeles Chapter held meetings recently at the Institute of Numerical Analysis, University of California, Los Angeles. At one meeting, R. Douthitt, of the Computer Research Corporation, spoke on "The CADAC-102A Computer. Mr. Douthitt discussed the operation of this computer, including features that would be of speci-l interest to coders. He gave examples of using interpretive subroutines and listed advantages and disadvantages of the device. Also, as speaker at the meeting was G. Brown of the International Telemeter Corporation. Mr. Brown described the advantages and requirements of a subscription television system and some of the International Telemeter's plans to meet the requirements. Another meeting of the Chapter featured F. M. McCormack who spoke on "A Logical Computer for Playing Tic-Tac-Toe," and J. Mendelson who spoke on "The Quac, the Quadratic Arc Computer."

Industrial Electronics

The Chicago Chapter of the Group on Industrial Electronics held a meeting at the Western Society of Engineers. A symposium on transducers, with speakers D. L. Elam and J. S. Stanley, was presented. Also presented, was a paper on sonometer, by Gordon Kennett.

NOTICE! MEMBERS

The IRE Professional Group on Communications Systems announces that members who have not previously indicated interest can obtain application forms from the Group Secretary, J. L. Callahan, Radio Corporation of America, 66 Broad Street, New York 4, N. Y.

The field of interest of this Group lies in methods and equipment employed in transmitting and receiving intelligence wire and radio telephone, telegraph, and facsimile.

Vehicular Communications

Two new local chapters of the Vehicular Communications Group have been approved recently by the IRE Executive Committee. They are: the Los Angeles Chapter, Chairman, Maurice Kennedy, Flood Control District Office, 751 S. Figueroa, Los Angeles, Calif.; and the Washington Chapter, Chairman, W. A. Shipman, Virginia Gas Transmission Corporation, Box 215, 109 E. Broad St., Falls Church, Va. Other officers elected to the Chapter are: Vice Chairman, E. L. White, and Secretary, M. E. Floegel.

The Chicago Chapter held a meeting recently at the Western Society of Engineers. E. H. Wavering, of Motorola, Inc., presented a paper on, "Mechanized Radio Production through the Use of Printed Circuits."

Music and Reproduction Lectures Scheduled

The Basic Science Division of the American Institute of Electrical Engineers is sponsoring a Symposium on the Science of Music and Its Reproduction by a group of experts who will present a series of lectures on modern thinking in this field.

The lectures, which began November 7, will be approximately one hour and a half in length followed by a period of discussion. The tuition fee for the complete Symposium is \$3.50 for members of AIEE, ASME, ASCE, AIME, IRE, AMS, AES, and AIP, and \$5.00 for nonmembers. Single lectures are \$1.00 for members of the forementioned societies and \$1.25 for nonmembers.

Applications should be directed to: J. J. Anderson, AIEE Headquarters, 33 West 39 Street, New York 18, N. Y. Checks may be payable to: Basic Science Division New York Section, AIEE.

The lectures are as follows:

November 7 (1952)—"Recordings from the Nineteenth Century to the Present," a history and demonstration of recorded music old and new, E. T. Canby, record critic, *Audio Engineering;* P. Miller, music director, New York Public Library.

December 11—"The Physics of Music and Hearing," W. E. Kock, Bell Telephone Labs.

January (1953)—"Performance Criteria of Loudspeakers," F. H. Slaymaker, Stromberg-Carlson Co.

February 20—"Some Notes on Modern Techniques of Recording and Reproducing," C. J. LeBel, Audio Devices Inc.

March 12—"The Relation Between Frequency Response and Transients in the Reproduction of Music," M. S. Corrington, RCA.

April 16—"Component Integration of Sound Systems," H. H. Scott, Hermon Hosmer Scott Inc.

Nuclear Physics Conference Slated in December

The National Science Foundation and the University of Rochester are sponsoring an international conference on High Energy Nuclear Physics, December 18–20, 1952, at Rochester, N. Y.

The meeting will bring together about 70 nuclear physicists of the United States, Canada, and Mexico. Discussions will concern recent findings on high-energy particles and plans for future studies in this field.

IRE People

Henry Ladner (A'31), president of Ballantine Laboratories, Inc., in Boonton, N. J., died recently. He was 51 years old.

One of the first to be licensed an amateur radio operator, Mr. Ladner started in the field of radio and electronics in 1916, as a radio telegraph operator. He graduated as an electrical engineer in 1922 from Brooklyn Polytechnic Institute, and then was employed as a research engineer by the American Telephone and Telegraph Company.

In 1935, Mr. Ladner graduated from the New York University Law School and joined the legal staff of the National Broadcasting Company. In 1940 he became the assistant to the administrative vice president of that department, and in 1949, he resigned from the company to open his own law offices in New York. He had been president of Ballantine Laboratories since 1950.

Arthur C. Omberg (M'43–SM'43) has been appointed director of engineering and research for the radio division of Bendix Aviation Corporation. He has been assistant director of this division for two years.

Mr. Omberg was born on November 4, 1909, at Memphis, Tenn. He received the B.S. and M.A. degrees in 1932 and 1934, and the E.E. degree in 1935, from Vanderbilt University.

From 1932–1942 Mr. Omberg was a transmitter supervisor for radio station WSM in Nashville, at the same time acting as consulting physicist for Vanderbilt University. In 1942–1944, he was the assistant director, Operational Research Group for the United States Army Signal Corps, and then became associated with the Bendix Radio Division as chief research engineer.

Mr. Omberg is the author of several articles on aviation navigation equipment as well as technical papers on the maximum range of radar and earth-moon radio circuits.

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Harold S. Osborne (A'14–M'29–SM'43–F'45–L'52), formerly chief engineer of the American Telephone and Telegraph Company, has been elected president of the International Electrotechnical Commission (IEC). The IEC held Council and technical committee meetings this fall in Scheveningen, Netherlands, at which time Dr. Osborne was elected to his new post.

Dr. Osborne is president of the United States IEC National Committee, an affiliate of the Electrical Standards Committee of the ASA. He has been active in ASA work for many years, serving as vice president of the Association from 1949–1951, and chairman of the ASA Standards Council from 1942–1945. He is past president of the American Institute of Electrical Engineers and has been active in the American Society for Engineering Education. Dr. Osborne holds directorship in several companies, including the Research Corporation, and recently retired from the American Telephone and Telegraph Company after 42 years of continuous service.

Dr. Osborne was born August 1, 1887, in Fayetteville, N. Y. He received the B.S. degree in 1908 and D.Eng in 1910, at the Massachusetts Institute of Technology.

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Leonard R. Kahn (S'46–M'51) has opened an electronics and communications consulting office in Freeport, L. I., N. Y. Previous to this Mr. Kahn was associated with the Crosby Laboratories in Mineola, N. Y., where he specialized in communications studies.

L. R. Kahn

Mr. Kahn was born in New York City in 1926, and received the B.E.E. degree from the Polytechnic Institute of Brooklyn in 1951. He attended Syracuse University under the Army Specialized Training Program from 1943–1944, and served in the United States Army Signal Corps from 1944–1946.

After working on various recording methods for the United Nations, Mr. Kahn joined RCA and worked with receiving and transmitting communication systems. During this he was on part-time loan to the RCA Laboratories.

Mr. Kahn has a number of inventions in the communications field including frequency shift transmission systems, single-sideband transmitters, and diversity receivers. He recently has been a contributor to the Proceedings and is serving on the IRE Subcommittee on Single-Sideband Transmitters. Mr. Kahn is a member of the American Institute of Electrical Engineers, Tau Beta Pi, and Eta Kappa Nu.

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Armand F. Knoblaugh (A'33–M'44) has been named associate professor of physics in the College of Liberal Arts of the University of Cincinnati.

Dr. Knoblaugh is a native of Cincinnati and received the B.S. degree in chemical engineering in 1925, the M.A. degree in 1927, and the Ph.D. Degree in physics in 1929.

From 1925–1932, Dr. Knoblaugh participated in research work in acoustics and then joined the Baldwin Company as a research physicist. He carried out important developments in electronic musical instruments, analysis of piano tones, acoustics and acoustic measurements. Dr. Knoblaugh holds various patents in his field.

Urner Liddel (SM'49) has joined the central office staff of Bendix Aviation Corporation in Detroit, Mich. He will be the director of product development and will be concerned with that company's activities in applied physics.

Urner Liddel

Dr. Liddel was born September 3, 1905, in Butler, Mo., and received the B.A. degree from Central College in 1926. He did graduate work at the University of Chicago in chemistry and physics and received the Ph.D. degree, in 1941, from George Washington University.

Prior to World War II, Dr. Liddel was associated with the Fixed-Nitrogen Research Laboratory of the Department of Agriculture and later was in charge of optics and spectroscopy for the American Cyanamid Research Laboratories. In 1942 he entered the United States Navy where he became a commander and served with the Bureau of Ordnance, Bureau of Ships Service Forces Pacific Fleet, and the Office of Research and Inventions.

Returning to civilian life, Dr. Liddel worked with the Office of Naval Research, where he was head of the physics and nuclear physics branches, and then director of the physical sciences division. Since 1952, he has been chief of the physics branch of the Atomic Energy Commission.

Dr. Liddel has been active in the IRE Professional Group on Nuclear Science and served as a member of its Administrative Committee. He is a fellow of the American Physical Society and the New York Academy of Sciences, a member of the Optical Society of America, the Philosophical Society of Washington, and Sigma Xi.

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C. A. Maynard (SM'51) has been appointed Vice President of the Indiana Steel Products Company, Valparaiso, Ind. He has been the company's director of research and engineering.

Mr. Maynard was born on May 4, 1901, in Missouri. He studied electrical engineering at the University of Kansas from 1919–1923, and received the B.A. degree from Taylor University in 1925.

After working for a number of years in the sales and service of radios and appliances, Mr. Maynard joined the Indiana Steel Products Company. Starting as an engineer, he worked in the design and applications of permanent magnets to loudspeakers, instruments, generators, and other adaptations. In 1939 he became the company's chief engineer, and in 1947, he received his appointment as director of research and engineering.

Mr. Maynard is considered one of the country's leading authorities in the field of permanent magnets.

Books

Musical Engineering by Harry F. Olson

Published (1952) by McGraw-Hill Book Company, Inc., 330 West 42 St., New York 36, N. Y. 357 pages +11-page index +ix pages 303 figures 5¾×9 $6.50.

Harry F. Olson is the director of the acoustical laboratory, RCA Laboratories, Princeton, N. J.

This interesting volume bridges the gap existing today between the technology of audio and the technology of music; a task of sufficient magnitude to justify the title of the work. The book will give the acousticians and musicologists a good foundation to understand and deal intelligently with the problems of each other.

The first chapter which is concerned with the generation and propagation of sound waves begins with elementary concepts by progressive steps and excellent illustrations. The reader is led to visualize the generation and propagation of sound, refraction, diffraction, reflection, absorption, transmission, and standing waves.

A review of musical notation is presented in the second chapter. Such definitions as the staff, the clef, sharp and flat, rest, dot, rhythm, meters, key, and loudness notation are explained. The third chapter deals with musical scales and chords.

Chapter 4 discusses resonators and radiators, electro-acousto-mechanical analogies, resonance of strings, bars, membranes and plates, vibration of air in pipes, acoustical behavior of horns, pistons, pipes, directional characteristics of sound sources.

Following is a brief description of each of a great variety of musical instruments from the automobile horn to the zither with comprehensive definitions. This chapter is followed by a section on acoustical characteristics, such as, frequency range, the timbre, and the acoustical spectrum of various musical instruments. Directional characteristics of musical instruments and human voice are discussed.

The next chapter deals with the structure and properties of human hearing mechanism, the psychological characteristics of music including pitch, loudness, timbre, duration, growth and decay, vibrato, beats, consonance and dissonance, volume, presence, measurement of musical aptitudes, hearing loss.

The book then continues on to theatres, studio and room acoustics, sound-reproducing system in the home, and the power requirements in sound systems. A description is made of broadcast studios, recording studios, vocal studios, sound-pickup arrangement for orchestras, motion pictures, and television. Specialized equipment is described including a means for synthetic reverberation, volume limiters, noise-meters.

The final chapters treat sound reproducing systems, microphones, loudspeakers, amplifiers, disk recording and reproduction, sound motion pictures, television sound-reproducing systems, magnetic sound-reproducing systems, and hearing aids. The effects of frequency discrimination upon the articulation of reproduced speech-frequency ranges of sound-reproducing systems, distortion upon quality, and the frequency-range preference for reproduced speech and music are described. The book ends with indications regarding future trends in the development of music and instruments.

While the extent of the field covered permits only a brief treatment of each subject, the author has ably extracted the wheat from the chaff and has presented a comprehensive survey of the subject matter. The book should serve well the needs of students majoring in physics and acoustics and advanced students in musical colleges. It will be of great value to the sound director and to the musical director. This book will be a convenient reference text for everyone interested in music and acoustics.

B. B. Bauer
Shure Brothers, Inc.
Chicago, Ill

Correction

The review of "The Oxide-Coated Cathode," by G. Herrmann and S. Wagener, which appeared on page 880, of the July, 1952 issue of the Proceedings, stated that "pore conduction" was not mentioned in the book. The views and results of this subject are summarized in the chapter, "The Mechanism of the Emission from An Activated Oxide Coating in Equilibrium," of the text.

Imperfections in Nearly Perfect Crystals, Symposium Edited by W. Shockley, J. H. Hollomon, R. Maurer, and F. Seitz

Published (1952) by John Wiley and Sons, Inc., 440 Fourth Ave., New York 16 N. Y. 475 pages+14 page index+xii pages. 177 figures 5½×8¼. $7.50.

W. Shockley is a member of Bell Telephone Laboratories, Inc.; J. H. Hollomon is a member of the General Electric Research Laboratories, and R. Maurer and F. Seitz are associated with the University of Illinois.

In October, 1950, a symposium on imperfect crystals was held at Pocono Manor, Pennsylvania. The symposium was arranged by the above named editorial committee and sponsored by the National Research Council. The important parts of the papers and discussions presented at Pocono Manor are summarized in 17 chapters.

The book is divided into four sections and contains the following individual papers. **Section I: On the Nature of Imperfections in Nearly Perfect Crystals.** "Imperfections in Nearly Perfect Crystals, A Synthesis," by Frederick Seitz. "On the Geometry of Dislocations," by W. T. Read, Jr., and W. Shockley. **Section II: The Role of Imperfections in Deformation.** "Imperfections from Transformation and Deformation," by C. S. Barrett. "Experimental Information on Slip Lines," by W. T. Read, Jr. "X-Ray Diffraction Studies of Cold Work in Metals," by B. E. Warren and B. L. Averbach. "Mechanical Strength and Creep in Metals," by N. F. Mott. "The Influence of Dislocations and Impurities on the Damping and the Elastic Constants of Metal Single Crystals," by J. S. Koehler. **Section III: Diffusion and Related Phenomena.** "Relaxation Effects in Ionic Crystals," by R. G. Breckenridge. "Studies of Alkali Halides by Photoelectric Methods," by L. Apker and E. Taft. "Diffusion in Alloys and the Kirkendall Effect," by J. Bardeen and C. Herring. "Theory of Diffusion," by Clarence Zener. **Section IV: On the Properties and Effects of External and Internal Surfaces of Crystals.** "Surface and Interfacial Tensions of Single-Phase Solids," by J. C. Fisher and C. G. Dunn. "Dislocation Models of Grain Boundaries," by W. T. Read, Jr., and W. Shockley. "Interphase Interfaces," by Cyril Stanley Smith. "Substructures in Crystals," by A. Guinier. "The Properties and Effects of Grain Boundaries," by Bruce Chalmers. "Movement and Diffusion Phenomena in Grain Boundaries," by R. Smoluchowski.

Seitz's paper is concerned with basic concepts. It is pointed out that there are six primary types of crystal imperfections, namely, phonons, electrons and holes, excitons, vacant lattice sites and interstitial atoms, foreign atoms in either interstitial or substitutional position, and dislocations.

The remaining papers discuss imperfect crystals from both experimental and theoretical viewpoints, with an emphasis upon the dislocations and mechanical properties. Only a small amount of space is devoted to imperfections and their effect upon electrical properties of crystals.

Although the book is planned for specialists in physical metallurgy and solid state physics, the contributors are among the outstanding leaders in their fields and present a clear picture of the status of this subject.

The work of compiling and editing the manuscripts has been an important and worthwhile task; the result of which is a valuable contribution to physics and physical metallurgy.

Edward N. Clarke
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Electronics for Communications Engineers by John Markus and Vin Zeluff

Published (1952) by McGraw-Hill Book Company, Inc., 330 West 42 St., New York 36 N. Y. 601 pages +8-page index+xi pages. Illustrated throughout with nomograms, equations, figures, charts, tables. 10¾×8¼ $10.00.

John Markus and Vin Zeluff are associate editors of *Electronics*, McGraw-Hill Book Company, Inc., New York, N. Y.

This book brings to engineers, in an easy-to-use form, the important radio communication, radio broadcasting, television, and radar design articles that have appeared in *Electronics* during the past five years. The book is a sequel to "Electronics for Engineers" and "Electronics Manual for Engineers." The material has been carefully selected and condensed by the authors for maximum reference value. A design engineer can quickly check the prior art by scanning the table of contents and save himself many hours of searching through technical literature. Each chapter contains a list of further references.

The book should be well received, particularly by new members to the engineering fraternity who wish to cover a lot of ground in a short period of time. It might well be described as a "Readers Digest" of the radar and communications field.

J. Ernest Smith
Raytheon Mfg. Co.
Newton, Mass.

(Books Cont'd)

Antennas: Theory and Practice by Sergei A. Schelkunoff and Harald T. Friis

Published (1952) by John Wiley & Sons, Inc., 440 Fourth Avenue, New York 16, N. Y. 593 pages+31-page index+15-page appendix+xxii pages. 344 figures. 5¼×9. $10.00.

Sergei A. Schelkunoff and Harald T. Friis are staff members of the Bell Telephone Laboratories, Inc., Murray Hill, N. J.

Here is a complete text on antenna theory and the practical implications of its theory. The book is designed for undergraduate and graduate college students, for radio engineers, and for applied mathematicians and physicists. Advanced material has been reserved for the companion volume, "Advanced Antenna Theory," by S. A. Schelkunoff, and the mathematical techniques of the present volume are limited to those of the calculus.

The book might be classed as a text of intermediate level although unlike many such books, it is not a simple survey text. The authors inform us that their concern is with understanding of the principles of radiation in which careful study and thought are required for this process. The authors have shown a great deal of ingenuity in providing derivations for all essentials with the mathematical tools selected. Therefore, an extensive physical understanding is given a new student, and the antenna expert is offered a new point of view.

The book begins with a chapter surveying the place of antennas in modern radio engineering, the basic field and wave concepts needed in the understanding of antennas, and some of the important problems. Maxwell's equations and several aspects of wave propagation are presented along with some introduction to waves over imperfect ground. Also included are chapters on directive radiation, antenna current, and antenna impedance. The remainder of the book is then concerned with special topics such as arrays, small antennas, horns, slot antennas, reflectors, and lenses.

Although the purpose of the book is not to introduce new material, the "sweeping off" process for analysis of dipole antennas is presented for the first time. The chapter on "antenna current" is the most complete and enlightening treatment of this subject known to the reviewer. The remaining material reflects the authors original contributions to the antenna theory and art of the past few years. The inclusion of many physical pictures and simple derivations aid in making this a genuinely original work.

The book is complete, and the authors who are among the most important original contributors to this field have presented their material carefully and skillfully. This reviewer feels it is the definitive book on antennas theory at an intermediate level.

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Electronic Analog Computers by Granino A. Korn and Theresa M. Korn

Published (1952) by McGraw-Hill Book Company, Inc., 330 West 42 St., New York 36, N. Y. 363 pages +6-page index+4-page appendix+4-page bibliography+xv pages. 213 figures. 6×9¼. $7.00.

Granino A. Korn is a staff engineer at Lockheed Aircraft Corporation, Burbank Calif. Theresa M. Korn is a graduate of electrical engineering.

This new volume of analog computers and techniques is intended as a textbook in the field. The text has been kept relatively simple and is quite readable.

For an adequate understanding of the material, a knowledge of elementary electronics and of mathematics up through elementary differential equations is required. A brief summary of the chapters follows.

In chapter one, a general view is given of the field of dc analog computers plus the applications of these devices, the mathematical relations involved, and some of the methods used.

A following chapter covers the procedures for setting up a dc analog computer to solve a set of equations. Scale factors, choice of time scales machine equations, and block diagrams are included.

Applications of dc analog computers to industrial problems are given in chapter three. The performance of a dynamic vibration absorber, analysis and synthesis of a servomechanisms problem, a trajectory computation, and the solution of aircraft flight equations are presented in some detail.

The next section describes the design of networks used to perform addition, multiplication by constants, differentiation, and integration, and chapter five covers the design of dc amplifiers and circuits used for analog computers. A discussion of stabilization of high-gain feedback amplifiers and automatic drift balancing circuits includes numerous design examples.

In the next chapter multiplication and division by variables and function generation are treated in detail. A number of previously unpublished systems are described. This is followed by a chapter on methods of inserting initial conditions, control circuits, power supplies, recording systems, and solution checking.

Chapter eight is concerned with examples of dc analog computers manufactured by various organizations.

To the reviewers knowledge, this is the first adequate discussion of scale factors, errors in computer elements, and initial conditions. In general, the text covers the entire field of electronic dc analog computers; mechanical systems are only briefly mentioned, and ac analog computers are not covered at all. Also, comparison with digital computers is very brief and sketchy.

It is regrettable that ac and dc calculating boards and "parametric computers" are not discussed. The former have very real utility and might find even wider use if they were covered compactly in a text. The "parametric computer" which has been covered in IRE papers might have been discussed in the section on repetitive computers.

While frequent references are given to the work of others, it is regrettable that very few page references are given. The two and one-fourth page appendix could very well have been included in chapter 4 without destroying the continuity of the material.

O. M. SALATI
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Printed Circuit Techniques: An Adhesive Tape Resistor System, NBS Circular 530, by B. L. Davis

Published (1952) by the Government Printing Office, Washington 25, D. C. 83 pages including appendices with 35 figures and one table. 32 illustrations. 10×7¾. Paper bound. $0.30, with additional ¼ of publication cost for foreign mailing orders.

B. L. Davis is a member of the electronic division of the National Bureau of Standards.

This is a detailed report on one phase of the Bureau's work on printed circuit techniques; the development of adhesive tape resistors. Reports which have previously appeared are Circular 468, a general survey of printed circuits, issued November, 1947; and, Miscellaneous Publication 192, covering later developments, issued November, 1948. The program has been supported by the Navy Bureau of Aeronautics.

Adhesive tape resistors were developed to give closer tolerances, greater power-handling capacity, and better aging characteristics than have been obtained with resistive paints applied to the base plate.

The tape is made by coating an asbestos paper base with resistive fluid composed of carbon in one of several forms, silicone resin, and solvent. The partially polymerized resin adheres well to the printed circuit base plate so that no additional adhesive is required and good electrical connection is assured. After application, all resistors in the assembly are cured together for several hours at 300°C. Units 0.13 by 0.30 inch produced by this method will operate for 500 hours at one-fourth watt load in an ambient temperature of 200°C with less than six per cent change in resistance, and can be used at higher wattage ratings in lower ambients. For a 500-hour life, the rating is one watt at 30°C and one-half watt at 130°C. Much longer life is obtained at reduced ratings.

This excellent performance is partly offset by the necessity for high-temperature curing, which restricts the base-plate material to glass or ceramic. Fully satisfactory formulations for operation at 200°C, also, have not yet been developed for resistors less than 100 ohms or greater than about 0.5 megohm in value.

No estimate is given of the tolerance in resistance which can be obtained in practice. The resistance of the tape is made very uniform by spraying on the resistive fluid in a large number of layers, each being partially dried before the next is applied. Each piece of material is tested before slitting and the width varied by adjustment of the slitting machine to keep the resistance per unit length within five or ten per cent of the desired value. Accuracy of the finished resistor depends also on accurate placing of the silver terminals on the base plate, particularly since the length of the conducting path between them is only 0.30 inch. One would like to see statistics included on the distribution of resistance values obtained in the production of a reasonable quantity of resistors of the same nominal value.

With this exception the reporting of the work is full and complete. A large number of formulations were tested and full information is given on the raw materials used and the commercial sources of supply. Production and test equipment, also, are described in sufficient detail to enable others to make these resistors with a minimum of duplication of the NBS experimental work.

W. N. TUTTLE
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Abstracts and References

Compiled by the Radio Research Organization of the Department of Scientific and Industrial Research, London, England, and Published by Arrangement with that Department and the *Wireless Engineer*, London, England

NOTE: The Institute of Radio Engineers does not have available copies of the publications mentioned in these pages, nor does it have reprints of the articles abstracted, Correspondence regarding these articles and requests for their procurement should be addressed to the individual publications, not to the I.R.E.

The Annual Index to these Abstracts and References, covering those published in the PROC. I.R.E. from February, 1951, through January, 1952, may be obtained for 2s.8d. postage included from the *Wireless Engineer*, Dorset House, Stanford St., London S.E., England. This index includes a list of the journals abstracted together with the addresses of their publishers.

The number in heavy type at the upper left of each Abstract is its Universal Decimal Classification number and is not to be confused with the Decimal Classification used by the United States National Bureau of Standards. The number in heavy type at the top right is the serial number of the Abstract. DC numbers marked with a dagger (†) must be regarded as provisional.

ACOUSTICS AND AUDIO FREQUENCIES

534.22-16:539.217.1 **2962**
Velocity of Sound in Porous Media—H. Labhart. (*Z. angew. Math. Phys.*, vol. 3, pp. 205–211; May 15, 1952.) Measurements show a very close relation between sound velocity and pore volume in a Ni-Zn ferrite. A theoretical expression for the velocity in a porous medium is derived that gives a good fit with the experimental curve.

534.2.31-13/-14 **2963**
Second-Order Acoustic Fields: Relations between Density and Pressure—J. J. Markham. (*Phys. Rev.*, vol. 86, pp. 719–711; June, 1952.) A general relation is derived connecting pressure and density, taking account of the flow of the medium. A nonabsorbing ideal fluid is considered, and general thermodynamic principles are applied. The results justify the neglect of the flow terms which is usual in considering more complex media.

534.231-13/-14 **2964**
Second-Order Acoustic Fields: Energy Relations—J. J. Markham. (*Phys. Rev.*, vol. 86, pp. 712–714; June 1, 1952.) The expression for the energy stored in an acoustic field is examined. Two corrections to the usually accepted formula are found to be required; these are small for a liquid, but of major importance for a gas. Their physical significance is explained, using thermodynamic theory.

534.232.003:534.321.9 **2965**
The Economical Generation of Ultrasonic Oscillations for Industrial Purposes by means of Electroacoustic Transducers—H. H. Rust. (*Elektrotech. Z.*, vol. 73, pp. 261–262; April 15, 1952.) As an alternative to tube-driven ultrasonic generators, which are not considered economical, it is proposed to use a simple type of quenched-spark generator with either a magnetostriction or a capacitive type of oscillator, a rectifier being used in the latter case to furnish a dc charging current.

534.26 **2966**
On the Diffraction of an Acoustic Pulse by a Wedge—J. W. Miles. (*Proc. Roy. Soc. A*, vol. 212, pp. 543–547; May 22, 1952.) The pressure in the pulse is assumed to be a homogeneous function of r/ct, where r is the distance from the edge, c the velocity of sound and t the time. The scattered wave is determined by reducing the original wave equation to Laplace's equation with the aid of a Tschplygin transformation, and applying Poisson's formula to the sectoral domain cut out of the circle $r \leqq ct$ by the wedge. The result appears in a form simpler than that previously obtained by Sommerfeld.

534.321.9-14:534.6 **2967**
Ultrasonic Measurement Technique in Fluids—J. Koppelmann. (*Acustica*, vol. 2, no. 2, pp. 92–95; 1952. In German.) A description is given of a microphone for probing fields at frequencies above 100 kc. Oscillations are picked up on the exposed tip of a screened steel wire 20 cm long and transferred to a quartz crystal attached to the other end of the wire. The work of Hertz and Mende (1092 of 1940) on application of Langevin's formula for acoustic radiation pressure is extended. Operation of the ultrasonic generator increases the density of the liquid in the ultrasonic beam. owing to the transport of liquid towards the axis.

534.6 **2968**
Design and Analysis of Subjective Acoustical Experiments which Involve a Quantal Response—D. L. Richards. (*Acustica*, vol. 2, no. 2, pp. 83–91; 1952.) Certain statistical methods that have been found useful in biological investigations are shown to be well adapted to subjective acoustic measurements. Examples are given of their use in analysis of the quality of telephony circuits.

534.6 **2969**
Modern Methods for Noise Measurement. Use of the Octave-Band Analyser—(*Radio. Tech. Dig., Édn franç.*, vol. 6, nos. 2 and 3, pp. 109–117 and 135–138; 1952.) Survey of methods and apparatus for acoustic measurements with 25 references.

534.76 **2970**
The Stereophonic Reproduction of Speech and Music—J. Moir and J. A. Leslie. (*Jour. Brit. IRE*, vol. 12, pp. 360–366; June, 1952.) The fundamentals of stereophony are discussed; previously proposed methods for obtaining true or pseudo stereophonic effects are described, and various theories of stereophonic perception are compared. Tests have been made to determine the influence on stereophonic auditon of acoustical conditions in existing theaters; the loudness difference between the two ears makes no significant contribution to the accuracy of source location.

534.78 **2971**
The Analysis and Automatic Recognition of Speech Sounds—C. P. Smith. (*Electronic Eng.*, vol. 24, pp. 368–372; August, 1952.)

534.84 **2972**
Radiation Problems in the Acoustics of Buildings—J. Brillouin. (*Acustica*, vol. 2, no. 2, pp. 65–76; 1952. In French.) Both theory and experiment show that the amount of external energy radiated into a room cannot be deduced from the mean amplitude of vibration of the walls. Flexural waves in a partition do not radiate unless their velocity is greater than that of sound in air; the radiation index of a partition can thus be widely different for forced and for free vibrations. A tentative theory of the suspended ceiling is presented and some observations are explained. Transient phenomena may exhibit effects not found in the steady state; some relevant experiments are discussed.

534.843 **2973**
The Correlation Coefficient as a Criterion of the Acoustic Quality of a Closed Room—S. G. Gershman. (*Zh. Tekh. Fiz.*, vol. 21, pp. 1492–1496; December, 1951.) The correlation coefficient for the oscillations at two points of the field gives a much fuller indication of the acoustic properties of a closed room than the reverberation time. The theory of the coefficient is discussed and measurements of it are described.

534.843 **2974**
Notes on Geometrical Room Acoustics—E. Meyer and W. Kuhl. (*Acustica*, vol. 2, pp. 77–83; 1952. In German.) Discussion of the effects of reflected sounds reaching a listener shortly after the sounds transmitted directly. If the delay due to the first reflections is <50 ms, reinforcement occurs. Formulas are given relating this effect to the energy density in the diffuse sound field. Practical applications of multiple reflectors to increase speech intelligibility in the rebuilt opera house, Hamburg, the large hall in the students' hostel, Bonn, and the theater, Hanover, are described.

534.843 **2975**
Standing-Wave Patterns in Studio Acoustics—C. G. Mayo. (*Acustica*, vol. 2, no. 2, pp. 49–64; 1952.) An approximate analysis is made of the sound field in a rectangular room excited by a spherical source. Two different kinds of characteristic frequencies are observed, one of which is the set of eigentones. A general picture is obtained of the relative importance of the various modes. High-frequency eigentones are relatively unimportant.

534.851+681.85 2976

Microgroove Recording and Reproduction—E. D. Parchment. (*Jour. Brit. IRE*, vol. 12, pp. 271–276; May, 1952.) A survey of basic problems, under the headings (*a*) mechanical considerations, (*b*) recording characteristics, (*c*) cutting problems, (*d*) tracing distortion, (*e*) pickups.

621.395.61:546.431.824 2977

Producing Barium-Titanate Transducers—J. M. C. (*Electronics*, vol. 25, pp. 162–174; August, 1952.) Processes described include the production of the $BaTiO_3$ cylinders from the raw powder, forming to produce the required piezoelectric properties, and calibration of the transducers.

621.396.615.029.3:621.385.5 2978

Simultaneous Generation of Several Audio-Frequency Oscillations by means of Electron Coupling in a Multi-Electrode Valve—Spengler and Rust. (See 3044.)

621.395.623.7 2979

The Loudspeaker with Phase Reversal—H. Gemperle. (*Elektrotech. Z.*, vol. 73, pp. 339–342; vol. 73.) Theory of the action of loudspeakers with phase reversal is based on the equivalent circuit for the mechanical system. The theory is applied to the design of the resonator for a concert loudspeaker with a natural frequency of 38 cps and diaphragm diameter of 35 cm, in order to obtain a two-to three-fold enhancement of the low frequencies over a bandwidth of at least 30 cps.

621.395.625.3 2980

Magnetic Print-Through. Its Measurement and Reduction—L. J. Wiggin. (*Jour. Soc. Mot. Pic. Telev. Eng.*, vol. 58, pp. 410–414; May, 1952.) A simple dynamic method of measurement is described. Application of an ultrasonic erasing bias during playback reduces the effect below the audibility limit.

621.395.625.3 2981

Some Aspects of Magnetic Recording—O. K. Kolb. (*Jour. Brit. IRE*, vol. 12, pp. 307–316; May, 1952.) The history of the development of sound recording by magnetizing wire or tape is reviewed, and a description is given of modern sound-film equipment using the process. Various explanations of the improvement produced by hf biasing are discussed. Comparison is made between signal-erasing methods using mains-frequency and hf currents, and the effect of erasing at reduced film speed is investigated.

621.395.625.3:168.2 2982

Classification of Magnetic-Recording Tapes—F. Grammelsdorff and W. Guckenburg. (*Funk u. Ton.*, vol. 6, pp. 247–257 and 311–323; May and June, 1952.) Detailed discussion of a proposed classification based on a characteristic parameter of the tape material.

621.395.92 2983

Trends in Hearing-Aid Design and Technique—R. F. Burton. (*Proc. IRE* (Australia), vol. 13, pp. 253–262; June, 1952.) Various types of hearing defect are discussed and recent progress in the design of hearing aids is reviewed.

ANTENNAS AND TRANSMISSION LINES

621.315.2:621.397.5 2984

An Improved Television Camera Cable System—(*Engineer* (London), vol. 193, p. p. 699; May 23, 1952.) A brief description of the "Polypole III" coupler, which is smaller and lighter than earlier types. Up to 36 circuits are provided for. The over-all diameter is 0.82 inch; unit lengths can be combined as required.

621.315.212 2985

Calculation of the Transmission Characteristics of Rotationally Symmetrical Connecting Units for Coaxial Cables from the Properties of Plane Electrostatic Fields—H. H. Meinke and A. Scheuber. (*Arch. elekt. Übertragung*, vol. 6, pp. 221–227; June, 1952.) Analysis shows that every rotationally symmetrical unit has an analogous plane representation which has nearly the same transmission characteristics and admits of relatively simple calculation. This principle is applied to the design of a reflection-free junction for coaxial cables with both inner and outer conductors of different diameters. See also 2429 of October.

621.315.212:621.317.34 2986

Measurement of the Attenuation and Characteristic Impedance of Transmission Lines. Tests on Coaxial Cables—Hontoy. (See 3169.)

621.392.017.13:621.3.011.2 2987

The Radiation Resistance of Resonant Transmission Lines—R. A. Chipman, E. F. Carr, N. A. Hoy and M. Yurko. (*Jour. Appl. Phys.*, vol. 23, pp. 613–620; June, 1952.) Measurements of input admittance as a function of line length were made on a line comprising parallel vertical silver rods above a metal ground plane, over the frequency range 300–1400 mc; the experimental procedure is described. The radiation resistance is obtained as the difference between the resistance values found for the same resonant section unshielded and shielded; it is independent of line length and top termination, and its value is approximately $120\ \pi^2 (d/\lambda)^2$, where d is the separation of the rods.

621.392+621.315.212].018.44 2988

Experimental Verification of the Theory of Laminated Conductors—H. S. Black, C. O. Mallinckrodt and S. P. Morgan, Jr. (Proc. I.R.E., vol. 40, pp. 902–905; August, 1952.) To test Clogston's theory (2908 of 1951), an experimental coaxial line was constructed with a laminated inner conductor. The phase velocity of the transmitted wave was varied by introducing TiO_2 cylinders or disks into the interconductor space. Critical dependence of attenuation on phase velocity was observed. At the optimum setting the attenuation, though greater than predicted by theory, was less than that of the corresponding conventional coaxial line.

621.392.2 2989

Steady-State Waves on Transmission Lines—D. L. Waidelich. (*Trans. Amer. IEE*, vol. 69, part II, pp. 1521–1524; 1950.) Various methods of determining the steady-state response of transmission lines to nonsinusoidal voltage inputs are considered. Experimental results are in good agreement with theory.

621.392.2:621.396.611.39 2990

Superdirectivity with Directional-Coupler Arrays—H. J. Riblet. (Proc. I.R.E., vol. 40, pp. 994–995; August, 1952.) Discussion on 562, 2099 and 2909 of 1951 (Bolinder).

621.392.26 2991

Symmetrically Placed Inductive Posts in Rectangular Waveguide—H. Gruenberg. (*Canad. Jour. Phys.*, vol. 30, pp. 211–217; May, 1952.) An expression is derived for the susceptance of two symmetrically placed posts in a rectangular waveguide. Curves are drawn that are valid for all rectangular guides in their normal operating range, for different post diameters and offsets from the guide walls. Satisfactory agreement was obtained between calculated values and measurements at wavelengths of 10.7, 4.74 and 3.2 cm.

621.392.26 2992

Dominant-Wave Transmission Characteristics of a Multimode Round Waveguide—A. P. King. (Proc. I.R.E., vol. 40, pp. 966–969; August, 1952.) In the 4-kmc frequency band transmission losses are lower with oversize round waveguide than with rectangular waveguide. Mode conversion effects in the round guide have been examined experimentally and found to be small; hence cross-polarized dominant modes can be used to provide two reasonably independent channels at the same frequency in the same guide. Experimental results are given for a straight guide of internal diameter 2.812 inches and length 150 feet; the effect of bending the guide is indicated.

621.392.26 2993

Field Expandability in Normal Modes for a Multi-layered Rectangular or Circular Waveguide—J. van Bladel. (*Jour. Frank. Inst.*, vol. 253, pp. 313–321; April, 1952.) Proof is given that the field can be expressed as a linear sum of normal modes, and a method of determining the field excited by a given current distribution in a multilayered waveguide is explained.

621.392.26:621.315.611 2994

Dielectric Image Line—D. D. King. (*Jour. Appl. Phys.*, vol. 23, pp. 699–700; June, 1952.) A modification of the dielectric-rod waveguide investigated by Chandler (1079 of 1950) and Elsasser (1080 of 1950) is discussed; it consists of a rod with half-round section lying on a conducting image plane. The influence of rod diameter on the field is indicated. Values determined by experiment and by calculation are given for the attenuation of a polystyrene line of diameter 0.42 cm on an image plane of width 20 cm, for use at 1.23-cm wavelength.

621.396.67 2995

Radiation Characteristics of Helical Antennas of Few Turns—O. C. Haycock and J. S. Ajioka. (Proc. I.R.E., vol. 40, pp. 989–991; August, 1952.) Square helices suitable for ionosphere measurements at 3–8 mc are considered. An investigation is made of the resistance loading required to obtain circularly polarized axial radiation from a single-turn antenna.

621.396.67 2996

Radiation Characteristics of a Turnstile Antenna Shielded by a Section of a Metallic Tube Closed at One End—A. Baños, Jr., D. S. Saxon and L. L. Bailin. (*Jour. Appl. Phys.*, vol. 23, pp. 688–696; June, 1952.) The system examined comprises a pair of crossed wires arranged transversely within a circular waveguide, the two wires being excited by voltages with a 90° phase difference. The waveguide is first considered to be infinitely long, and the conditions are determined under which only the dominant (TE_{11}) mode is important. The case is then considered of the semi-infinite waveguide, excited in the TE_{11} mode, radiating into free space. Using a solution found by Levine and Schwinger (1845 of 1948 and an unpublished paper), values of reflection coefficient and gain function were calculated at the N.B.S. Institution for Numerical Analysis. These results are compared with values found experimentally and by the Kirchhoff method.

621.396.67 2997

The Radiation Resistance of a Dipole near an Ellipsoid of Revolution with Good Conductivity—R. G. Mirimanov. (*Compt. Rend. Acad. Sci.* (U.R.S.S.), vol. 80, pp. 189–192; September 11, 1951. In Russian.) A formula (29) is derived expressing the radiated power of a dipole arranged along the axis of revolution of the ellipsoid. The case where the dipole is arranged perpendicular to the axis can be treated in a similar manner.

621.396.67:621.396.933.1 2998

Cage-Type Very-High Frequency Phase-Comparison Omnidirectional Radio Range Antenna—Lundberg and Bucher. (See 3097.)

621.396.67.011.21 2999

Self and Mutual Impedances of Parallel Identical Antennas—R. King. (Proc. I.R.E., vol. 40, pp. 981–988; August, 1952.) A method is presented in which the impedance of an isolated antenna is determined with second-order accuracy while the mutual impedance due to the coupled antenna is determined with first-order accuracy. The values obtained are shown in numerous curves.

621.396.67.012.71 3000

Universal Method of Calculating the Radiation Distribution of Electric and Magnetic Dipoles, as well as Slot and Reflector Aerials, by means of Kirchhoff's Formula—H. Kleinwächter. (*Arch. elekt. Übertragung*, vol. 6, pp. 247–253; June, 1952.) Many different methods have hitherto been used for determining the radiation characteristics of different types of antenna. It is here shown that Kirchhoff's formula is applicable in general; its use for the different types of antenna mentioned is outlined and suitable formulas are derived.

621.396.67.029.63 3001

Some Types of Omnidirectional High-Gain Antennas for Use at Ultra-High Frequencies—J. Epstein, D. W. Peterson and O. M. Woodward, Jr. (*RCA Rev.*, vol. 13, pp. 137–162; June, 1952.) A description is given of the construction and operation of the following three uhf transmitting antennas for operation in the frequency band 500–900 mc: (*a*) a cylindrical multi-slot antenna, (*b*) an inverted turnstile antenna, (*c*) a disk-loop antenna. The elements of (*a*) and (*b*) are fed in quadrature and those of (*c*) in phase. The primary disadvantages of all three systems are their frequency sensitivity and the multiplicity of feed points. The use of quadrature feed facilitates the matching of input transmission lines, the maintenance of equal division of power in the radiating elements, and the diplexing of two signals into a common antenna.

621.396.677 3002

A Method for Calculating the Current Distribution of Tschebyscheff Arrays—D. Barbiere. (PROC. I.R.E., vol. 40, p. 991; August, 1952.) Corrections to paper noted in 1211 of June.

621.396.677 3003

Relay Aerials for the Decimetre Waveband—G. Voigt. (*Nachr Tech.*, vol. 2, pp. 108–112; April, 1952.) An estimate is made of the efficiency of a pair of directive dm-wave antennas used at a relay station, and possible substitutes consisting of refracting prisms are described. One of these consists essentially of an assemblage of square-section waveguides whose lengths change gradually from the base to the vertex of the prism. The other prism is of the Venetian-blind type producing double reflections of the incident wave. Theory of the action of such prisms is given and design parameters are determined for prescribed deviation of an em wave. A model prism of height 3 m and width 2 m, designed for wavelengths of 20–25 m, gave results in good agreement with theory. Application possibilities are briefly discussed.

621.396.677 3004

Lattice Lenses for Centimetre Waves—J. Moussiegt. (*Compt. Rend. Acad. Sci.* (Paris), vol. 234, pp. 2178–2179; May 26, 1952.) Discussion of the principles of lenses based on diffraction by metal particles arranged at the nodes of a lattice such that the divergent waves issuing from a point source are rendered parallel. For this to be possible, the nodes must be located on paraboloids of revolution having the direction of the diffracted beam as common axis, the nodes being on the intersections of these paraboloids with a set of equidistant planes normal to the axis. The total number of diffracting particles required is much less than the number used in a lens of the artificial-dielectric type. Resonant $\lambda/2$ dipoles consisting of narrow thin metal strips may be used instead of metal particles, the strips being parallel to one another and lying in the nodal planes, thus fixing the polarization of the emergent wave.

621.396.677 3005

General Theory of Electromagnetic Horns—A. F. Stevenson. (*Jour. Appl. Phys.*, vol. 23, pp. 599–600; May, 1952.) Corrections to paper abstracted in 1841 of August.

621.396.677.012 3006

The Radiation Pattern of an Antenna over a Circular Ground Screen—J. E. Storer. (*Jour. Appl. Phys.*, vol. 23, pp. 588–593; May, 1952.) Using previously developed formulas for the input impedance of an antenna over a finite ground screen, an expression is obtained for the entire radiation pattern. Simple formulas are derived for the number of lobes, their angular position, and the angle within which they occur.

CIRCUITS AND CIRCUIT ELEMENTS

621.3.0157 3007

A Note on the Reproduction of Pulses—D. K. Cheng. (PROC. I.R.E., vol. 40, pp.962–965; August, 1952.) A discussion of the relative significance of rise time and percentage energy content of rectangular pulse. For a single pulse the value of rise time is different from that for a train of periodic pulses.

621.3.015.7:621.317.755 3008

A Single-Channel Pulse-Height Discriminator of High Speed and Stability—G. T. Wright. (*Jour. Sci. Instr.*, vol. 29, pp. 157–160; May, 1952.) Each pulse and its differential are applied to the *z* and *y* plates respectively of a cro whose screen is scanned in the *x* direction with a narrow optical slit and photomultiplier. The pulse-height distribution is displayed on a second cro. The equipment is free from zero drift, and from drift of channel width.

621.3.015.7:621.387.4 3009

A Fast Amplitude Discriminator and Scale-of-Ten Counting Unit for Nuclear Work—F. H. Wells. (*Jour. Sci. Instr.*, vol. 29, pp. 111–115; April, 1952.) Description of an instrument which can accept randomly spaced pulses at a rate of 10^6/second; the dead time after each recorded pulse is 0.25 ± 0.05 μs. The scaling circuit uses the technique of step charging a capacitor by the discriminator output pulses. A new clamping circuit is used to eliminate the effects of capacitor charge leakage.

621.3.015.7:621.387.422 3010

Pulse-Amplitude Analyzers for Spectrometry—G. G. Kelley. (*Nucleonics*, vol. 10, pp. 34–37; April, 1952.) The design of multichannel analyzers for counting rates of 10^4+2+10^4 per second is discussed.

621.314.22.015.7 3011

New Pulse Transformer gives Faster Response—(*Tech. Bull. Nat. Bur. Stand.*, vol. 36, pp. 78–79; May, 1952.) The anode, grid and output windings of the transformer consist respectively of 13, 12, and 6 turns of 24-gauge enamelled Cu wire on a toroidal ferrite core of diameter <1 inch. The anode and grid windings are wound together to obtain very tight inductive coupling. Used in a conventional blocking-oscillator circuit with a 500-Ω load, the measured pulse width was <0.06 μs, the rise time from 0 to 90 v was <0.02 μs, output impedance about 100 Ω, and peak pulse power about 20 w.

621.314.3† 3012

Predicting Magnetic-Amplifier Control Curves—H. Lehmann. (*Elec. Eng.* (N. Y.), vol. 71, p. 311; April, 1952.) Digest of paper to be published in *Trans. Amer. IEE*, vol. 70, part II; 1952.

621.314.3† 3013

Response Time of Magnetic Amplifiers—E. L. Harder and W. F. Horton. (*Trans. Amer. IEE*, vol. 69, part II, pp. 1130–1138; 1950. Discussion, pp. 1138–1141.) Theoretical and experimental information on response time is presented, the various factors involved are reviewed, and proposals are made for the treatment of response time in definitions and standards.

621.314.3† 3014

A Mathematical Analysis of Parallel-Connected Magnetic Amplifiers with Resistive Loads—L. A. Pipes. (*Jour. Appl. Phys.*, vol. 23, pp. 625–629; June, 1952.)

621.314.3† 3015

Series-Connected Saturable Reactor with Control Source of Comparatively High Impedance—H. F. Storm. (*Trans. Amer. IEE*, vol. 69, part II, pp. 1299–1309; 1950.) The results of mathematical analysis are presented in normalized graphs which enable the effect of any circuit parameter to be readily determined. A numerical example illustrates the use of the graphs.

621.314.3† 3016

Determination of Steady-State Performance of Self-Saturating Magnetic Amplifiers—E. J. Smith. (*Trans. Amer. IEE*, vol. 69, part II, pp. 1309–1317; 1950.) Analysis for the half-wave circuit is extended to full-wave and doubler circuits. Effects of rectifier leakage and control-circuit impedance are computed for each type of circuit and transfer curves are determined for practical conditions. Numerical results are given for amplifiers with orthonik and hypersil cores.

621.314.634:621.318.57 3017

Miniature Rectifier Computing and Controlling Circuits—An Wang. (PROC. I.R.E., vol. 40, pp. 931–936; August, 1952.) Circuits are described incorporating Se-rectifier elements and capable of operating at very high speed. Highly compact constructions have been developed.

621.316.86:537.312.6 3018

The Pressure Coefficient of Resistance of Thermistors—A. D. Misener and L. G. D. Thompson. (*Canad. Jour. Tech.*, vol. 30, pp. 89–94; April, 1952.) The pressure coefficient of resistance of one type of thermistor used for underground temperature measurements was determined experimentally at pressures up to 2,000 lb/in² at temperatures of 0°, 25° and 50°C. The coefficient appears to be independent of temperature, but decreases with increase of pressure. For temperature measurements to be accurate to within ±0.1°C a pressure correction is necessary even under moderate pressures.

621.316.935.1 3019

The Design of Reactors for Radio-Interference Filters—L. I. Knudson. (*Trans. Amer. IEE*, vol. 69, part II, pp. 1294–1298; 1950.) Discussion of various useful types of inductor, with graphical presentation of data for available core materials. Composite cores are shown to be particularly useful in certain cases, both for toroids and straight inductors.

621.319.4 3020

Pyralene-Impregnated-Paper Capacitors for Alternating Current. Factors affecting Capacitance and Losses—J. Coquillion. (*Rev. gén. Élect.*, vol. 61, pp. 205–213; May, 1952.) The discussion is confined to capacitors using kraft paper. Losses are greater at very low voltage than at nominal voltage, and their value is an indication of the ionic purity of the impregnant. At nominal voltage losses depend only on paper characteristics and on the permittivity of the impregnant.

621.392 3021
RC Coupling Networks—G. Bowers. (*Radio & Telev. News. Radio-Electronic Eng. Section*, vol. 47, p. 32; June, 1952.) Nomogram for finding phase-shift and attenuation.

621.392 3022
An Optimization Theory for Time-Varying Linear Systems with Nonstationary Statistical Inputs—R. C. Booton, Jr. (Proc. I.R.E., vol. 40, pp. 977–981; August, 1952.)

621.392 3023
Circuits with Frequency-Dependent Resistance and Frequency-Independent Reactance—H. Fricke. (*Funk u. Ton*, vol. 6, pp. 225–234; May, 1952.) By connecting between the voltage divider and the tube grid in a normal reactance circuit a device producing a grid-voltage phase shift of ±90°, the frequency-dependence characteristics of the resistive and reactive components of the impedance are interchanged, so that between the reactance-tube terminals a series arrangement of a frequency-dependent resistance and a frequency-independent reactance is obtained, whose magnitudes can be varied by altering the slope of the tube characteristic. The magnitudes and frequency dependence of the resistive and reactive components are calculated for various possible arrangements, and the design of the phase shifter is considered, with discussion of the effects produced by departure of the phase shift from its nominal value.

621.392 3024
Network Synthesis by the Use of Potential Analogs—R. E. Scott. (Proc. I.R.E., vol. 40, pp. 970–973; August, 1952.)

621.392.4 3025
Two-Terminal Networks Consisting of Reactively Connected Valves—F. Broch-Toniolo. (*Poste e Telecommunicazioni*, vol. 20, pp. 215–220; May, 1952.) The equivalent circuit is determined for a tube whose grid voltage is derived by means of a potential divider from the anode voltage. Operation as generator, reactance, or variable resistance is considered. Reactance-tube arrangements with high values of inductance and very low values of capacitance are attainable.

621.392.4 3026
Equivalence for the Analysis of Circuits with Small Nonlinearities—W. J. Cunningham. (*Jour. Appl. Phys.*, vol. 23, pp. 653–657; June, 1952.) When the amount of nonlinearity is not too large, the nonlinear element can be replaced by a linear resistance together with voltage or current generators. The analysis can be applied to a highly nonlinear element if a suitable linear resistance is connected in parallel with it. Calculations for a type-1N34 crystal diode in parallel with a 50-Ω resistor are reported.

621.392.43.018.424 3027
Wide-Band Transformation at High Frequencies—(*Fernmeldetch. Z.*, vol. 5, pp. 252–255; June, 1952.) The design and performance of band-pass coupling circuits discussed previously (1613 of 1950), and developments of these, are reviewed. Curves show the relative error likely to occur in practice as a function of bandwidth for different circuit arrangements giving transformation ratios of 2, 3 and 4.

621.392.5 3028
A General Theory of Linear Signal-Transmission Systems—L. A. Zadeh. (*Jour. Frank. Inst.*, vol. 253, pp. 293–312; April, 1952.) Full treatment of the analytical method outlined in 1225 of June. Detailed discussions of various aspects of the theory and its practical applications are to be given in subsequent papers.

621.392.5 3029
A New Approach in the Design of Equalized Filters and Delay Lines—M. E. Levy. (*Jour. Brit. IRE*, vol. 12, pp. 317–320; May, 1952.) The phase characteristics of filter networks and delay lines can be equalized by bridging mutual-inductance sections with capacitors. The corresponding *n*th-order equations are difficult to solve, but an approach which considers the transient response yields a simple solution. See also British Patent No. 614720 and Abstract 1746 of 1948 (Espley).

621.392.5 3030
Quadripole Theory, a Fresh Approach—M. Skalicky. (*Elektrotech. u. Maschinenb.*, vol. 69, pp. 239–242; May 15, 1952.) The network equations of Wilberforce [see 1536 of 1944 (Skalicky)] are developed for a quadripole in a simple form involving only three parameters: (*a*) the voltage step-up ratio with output terminals on open circuit, (*b*) the input impedance with open-circuited output, (*c*) the output impedance with input terminals short-circuited. A simple expression is derived for the current in any branch of a network fed with a single terminal voltage.

621.392.5 3031
Equivalent Circuits of the Nonreversible Quadripole—W. Klein. (*Arch. elekt. Übertragung*, vol. 6, pp. 205–208; May, 1952. Corrections, *ibid.*, vol. 6, p. 351; August, 1952.) Schulz's network-matrix analysis (68 of February) is extended to obtain generalized theory for quadripoles violating the reciprocity relation. The equivalent circuit of the nonreversible quadripole is derived as a generalized L, T or Π circuit by introducing a coupling element termed a "dual converter" ("Dualübersetzer") comprising three ideal tubes and a complex impedance. This circuit element is also useful in designing transformers with complex transformation ratio. The admittance matrix of the quadripole can also be used for deriving an equivalent circuit.

621.392.5:[621.396.645+621.317.733 3032
Particular Applications of Single-T and Double-T Networks—B. Lavagnino. (*Alta Frequenza*. vol. 21, pp. 116–129; June, 1952.) Description of (*a*) a 3-stage RC-coupled amplifier in which high selectivity is achieved by application of feedback through a T network either to input grids or cathodes, (*b*) a bridge of T-network type for the measurement of capacitance and losses at audio and ultrasonic frequencies, and suitable for tests on capacitors with a guard electrode.

621.392.52 3033
Design of Channel Filters using Quartz Crystals—N. Valentini. (*Post e Telecommunicazioni*, vol. 20, pp. 221–228; May, 1952.) A new quick method of designing lattice filters is described in detail and illustrated with examples.

621.392.52:534.113 3034
Study of a Narrow-Band Electromechanical Filter—A. Marro. (*Tech. Mitt. schweiz. Telegr.-Teleph Verw.*, vol. 30, pp. 41–50; February 1, 1952. In French.) The type of filter considered consists of one or more units formed of parallel pairs of steel rods supported so as to be capable of lateral vibration, electromechanical transformers being used at the ends for conversion from electrical to mechanical oscillations and vice versa. Theory is based on purely mechanical considerations, and design formulas are derived which involve the dimensions and physical constants of the rods Comparison is made with equivalent electrical-network filters. The action of the transformers is explained and a description is given of a complete 3-unit filter using rods of Swedish steel, with details of the methods of adjustment of frequency and bandwidth. Practical applications in carrier-frequency telephony and frequency-shift telegraphy are discussed briefly.

621.392.52:621.396.611.21 3035
A Mode of Operation of a Simple Quartz Filter—J. Marique. (*HF (Brussels)*, vol. 2, no. 2, pp. 29–33; 1952.) Analysis is presented for a simple bridge-type crystal filter in which the impedance constituting the median arm of the bridge is a very high resistance (R). This type of filter is often used in superheterodyne receivers. The analysis shows that the selectivity of such a filter approaches that of the crystal itself, and that the gain can be greater than unity, which is not the case if R is small.

621.392.52:621.396.67.029.63 3036
Separating Networks for the Operation of Several Decimetre-Wave Radio Sets on One Aerial—G. Pusch. (*Fernmeldetech. Z.*, vol. 5, pp. 262–268; June, 1952.) Tuned-cavity couplings are described. Practical designs for both series- and parallel-connected networks for transmitter-transmitter and transmitter-receiver operation are illustrated. These operate satisfactorily when the frequency separation is >7 mc.

621.392.52.025.4 3037
Synthesis of Polyphase RC Filters—G. B. Madella. (*Alta Frequenza*, vol. 21, pp. 130–136; June, 1952.) A method for the synthesis of polyphase filters with prescribed transfer characteristics is described and applied to a practical example. A particular feature of polyphase filters is their ability to discriminate positive from negative frequencies.

621.392.52.072.6 3038
Alignment and Adjustment of Synchronously Tuned Multiple-Resonant-Circuit Filters—M. Dishal. (*Elec. Commun.*, vol. 29, pp. 154–164; June, 1952.) Reprint. See 627 of April.

621.396.6 3039
Nonlinear Elements and Applications in A.F. and R.F. Circuits—H. E. Hollmann. (*Tele-Tech*, vol. 11, pp. 46–47, 127 and 56–57, 128; April and May, 1952; *Proc. Nat. Electronics Conf.* (Chicago), vol. 7, pp. 130–140; 1951.) Discussion of the properties and applications of saturable reactors, ferroelectric capacitors, and varistors, including the "polaristor." See also 2538 of October.

621.396.611.1+534.01 3040
[Oscillations in] Delayed-Action Systems—N. Minorsky. (*Compt. Rend. Acad. Sci.* (Paris), vol. 234, pp. 1945–1947; May 12, 1952.) Treatment of the differential equations for self-maintained oscillations in dynamic (mechanical or electrical) systems is simplified by use of what is termed a "stroboscopic" method, an account of which has previously been given (2591 of 1951).

621.396.611.1 3041
The Response of RLC Resonant Circuits to E.M.F. of Sawtooth Varying Frequency—J. Marique. (Proc. I.R.E., vol. 40, pp. 945–950; August, 1952.) Analysis previously given by Hok (671 of 1949) for the case of a single frequency sweep is extended to the case where the frequency sweep is repeated as, e.g., in frequency analyzers. The response is composed of two terms, one related to the instantaneous conditions and the other resulting from the preceding frequency sweeps. Response curves obtained by graphical integration are compared with curves computed by other authors. The influence of the limits of exploration is discussed.

621.396.611.4.017.21 3042
Surface Losses in Electromagnetic Cavity Resonators—I. Paghis. (*Canad. Jour. Phys.*, vol. 30, pp. 174–184; May, 1952.) The effective

skin resistance of brass was determined at microwave frequencies by means of Q measurements. The results are in essential agreement with theory, provided the surface treatment is confined to polishing by hand. The effect of surface scratches was found to be small compared with the effect of distortion of the crystal lattice due to surface working.

621.396.615 3043
The Frequency Spectrum of a Pulled Oscillator—T. J. Buchanan. (PROC. I.R.E., vol. 40, pp. 958–961; August, 1952.) Experiments are described in which a signal from a Type-CV87 reflex klystron is injected into the circuit of the oscillator tube under test, the two generators being mounted at opposite ends of a waveguide. A loosely coupled probe feeds part of the output to a cro spectrometer, the effect of varying the klystron wavelength around the center value of 3.2 cm. being studied. The results are discussed on the basis of theory previously worked out by Adler (2522 of 1946).

621.396.615.029.3:621.385.5 3044
Simultaneous Generation of Several Audio-Frequency Oscillations by means of Electron Coupling in a Multi-electrode Valve—W. Spengler and H. H. Rust. (*Arch. elekt. Übertragung*, vol. 6, pp. 254–261; June, 1952.) A frequency multiplier is described which produces four frequencies simultaneously. The fundamental frequency is generated in a feedback circuit using grids 1 and 2 of a hexode, the higher frequencies being produced by shock excitation of oscillatory circuits connected to the other electrodes and tuned to required harmonics. Nearly sinusoidal oscillations can be obtained by use of loosely coupled filters to minimize modulation of the harmonics by the fundamental. Design of circuit components to obtain optimum results is discussed.

621.396.615.12 3045
A High-Frequency Generator with Uniform RC-Line as Feedback Element determining the Frequency—F. W. Gundlach. (*Funk u. Ton*, vol. 6, pp. 298–304; June, 1952.) Description, with full circuit details, of a generator with a continuous range of 0.1–1.5 mc. The output of 3 v into 200 Ω, is constant to within 10 per cent over the whole range. Frequency variation is effected by varying the capacitance of the RC-line, which is of simple mechanical construction.

621.396.615.14:621.385.3 3046
Ultra-High Frequency Triode Oscillators using a Series-Tuned Circuit—J. M. Pettit. *Proc. IRE* (Australia), vol. 13, pp. 132–135; May, 1952.) Reprint. See 2452 of 1950.

621.396.615.141.2:621.316.729 3047
An Analysis of the Injection Locking of Magnetrons used in Amplitude-Modulated Transmitters—J. S. Donal, Jr., and K. K. N. Chang. *RCA Rev.*, vol. 13, pp. 239–257; June, 1952.) Analysis is presented for an anode-modulation single-loop magnetron, with load matched to the transmission line and the synchronizing current injected at a plane distant $\lambda/2$ from the magnetron. The rf phase modulation during the AM cycle is calculated and the power output required from the locking oscillator is determined. For a particular magnetron, using a locking amplifier capable of a power output of 10 per cent of the peak system output, the expected rf phm is about $\pm 20°$ for an AM factor of 0.74.

621.396.615.17.029.63 3048
Tetrodes improve Harmonic Generation at V.H.F. and U.H.F.—D. H. Preist. (*Tele-Tech.* vol. 11, pp. 60–61, 123; April, 1952.) Description of the performance of tetrodes such as Type 4X150A and Type 4X150G with positive feedback, for frequency multiplication at high power levels.

621.396.619.13:621.392.5 3049
Contribution to the Theory of Frequency-Modulated Signals in Linear Networks—L. Kosten. (*Tijdschr. ned. Radiogenoot.*, vol. 17, pp. 117–133; May, 1952.) By using the concepts of negative resistance and inductance, any linear network can be transformed into one containing no capacitances, whose operation can then be expressed by first-order differential equations. Matrix theory is used in combination with this transformation to determine the output current of a linear quadripole fed with a frequency-modulated wave. The formula derived is a series differing from those of Carson and Fry (464 of 1938) and Stumpers (2221 of 1947) in that it is convergent and contains finite differences rather than derivatives of the transadmittance.

621.396.645 3050
Effective Bandwidth of Video Amplifiers—F. J. Tischer. (*Arch. elekt. Übertragung*, vol. 6, pp. 241–246; June, 1952.) An expression for the effective bandwidth is derived directly from the complex amplification function for steady-state oscillations, taking account of phase shift and phase errors. The effective bandwidths for theoretical standard amplifier functions give a good idea as to the bandwidth to be expected in practical amplifiers and what improvement can result from compensation of the phase errors.

621.396.645.371 3051
Negative Feedback—W. O. Baldwin. (*Proc. Radio Club Amer.*, vol. 29, pp. 3–11; 1952.) The use of negative feedback for amplifier gain stabilization, distortion reduction, and improvement of frequency response and phase characteristics is considered, frequency and phase characteristics being especially dealt with, since if they are known the gain and distortion characteristics can be quickly calculated. A particular feature of the treatment is the use of curves showing the reciprocal of the gain plotted against frequency. This has the advantage of eliminating the addition and division of vectors necessary when gain/frequency curves are used.

GENERAL PHYSICS

530.162:519.21 3052
A Generalization of the Classical Random-Walk Problem, and a Simple Model of Brownian Motion based thereon—G. Klein. (*Proc. Roy. Soc. Edinb. A*, vol. 63, part 3, pp. 268–279; 1950/1951.) A precise mathematical model of Brownian motion is derived by introducing a "persistence" factor in analysis of the random-walk problem. This is equivalent to the assumption of a discrete velocity distribution of three variates instead of the continuous probability distribution formerly assumed. General results concerning averages are obtained and applied to special cases of conservative and dissipative systems.

535.223 3053
The Velocity of Light determined by the Band Spectrum Method—D. H. Rank, R. P. Ruth and K. L. Vander Sluis. (*Phys. Rev.*, vol. 86, p. 799; June 1, 1952.) Preliminary account of a determination based on observations of the 103 and 004 bands of HCN; the value of c obtained is 299776±7 km.

535.37+535.215 3054
The Physics of Crystal Phosphors—F. Stöckmann. (*Naturwissenschaften*, vol. 39, pp. 226–233 and 246–254. May and June, 1952.) A comprehensive study with 63 references.

535.376 3055
Electroluminescence observed in the Anodic Polishing of Zinc—M. Krieg and E. Lane. (*Naturwissenschaften*, vol. 39, p. 208; May, 1952.)

535.42:538.56 3056
On the Diffraction of an Electromagnetic Pulse by a Wedge—J. W. Miles (*Proc. Roy. Soc. A*, vol. 212, pp. 547–551; May 22, 1952.) The vector problem of the diffraction of a plane wave discontinuity with arbitrary polarization and direction of propagation is reduced to a pair of two-dimensional scalar problems. The solution of one of these is identical with that previously obtained for the analogous acoustical problem (2966 above); the second problem is treated in a similar manner, using a Tschplygin transformation to reduce the boundary-value problem to one in potential theory, which is then solved by classical methods.

535.421:538.566 3057
Electromagnetic Reflection and Transmission by Gratings of Resistive Wires—E. A. Lewis and J. P. Casey, Jr. (*Jour. Appl. Phys.*, vol. 23, pp. 605–608; June, 1952.) Honerjäger's theory (1754 of 1949) is extended to take account of the finite conductivity of the wires. Formulas and charts are given to facilitate calculations, and a practical example is worked out.

537.11:537.226 3058
The Physical Mechanism of Charge in Solid Dielectrics—H. Bonifas. (*Rev. gén. Élect.*, vol. 61, pp. 223–231; May, 1952.)

537.122 3059
A New Classical Theory of Electrons: Part 2—P. A. M. Dirac. (*Proc. Roy. Soc. A*, vol. 212, pp. 330–339; May 1, 1952.) Analysis of the motion of a stream of electrons obeying Lorentz's equations of motion leads to a more general action principle than that of an earlier paper (1574 of July), two new field variables being introduced. The theory allows vorticity in the electron stream, while still involving e and m only in the ratio e/m. A Hamiltonian formulation of the equations is deduced.

537.311.31+537.312.62 3060
The High-Frequency Resistance of Metals in the Normal and Superconducting State—C. J. Grebenkemper and J. P. Hagen. (*Phys. Rev.*, vol. 86, pp. 673–679; June 1, 1952.) Measurements were made on Pb, In and Sn at frequencies of about 9 kmc and on Sn at 24 kmc, using resonant-cavity techniques which are described. The influence of surface finish is investigated. Results for the metals in the normal state support the Reuter-Sondheimer theory of the anomalous skin effect; for the superconducting state the hf resistance varied with frequency according to a 3/2-power law rather than the theoretically predicted square law.

537.311.001.11 3061
Carrier Concentrations and Fermi Levels in Semiconductors—J. S. Blakemore. (*Elec. Commun.*, vol. 29, pp. 131–153; June, 1952.) Review of present-day semiconductor theory. 23 references.

537.312.6:621.315.592 3062
Tentative Explanation of the Law giving the Resistance of Thermistors as a Function of the Temperature—Y. Doucet and J. P. Guignard. (*Compt Rend. Acad. Sci.* (Paris), vol. 234, pp. 1856–1858; May 5, 1952.)

537.525:538.56 3063
A Nonlinear Theory of Oscillations in an Electron Plasma—A. I. Akhiezer and G. Ya. Lyubarski. (*Compt. Rend. Acad. Sci.* (U.R.S.S.) vol. 80, pp. 193–195; September 11, 1951. In Russian.)

537.525:621.396.822 3064
Observations on Radio-Frequency Oscillations in Low-Pressure Electrical Discharges—N. R. Labrum and E. K. Bigg. (*Proc. Phys. Soc.* (London), vol. 65, pp. 356–368; May 1,

1952.) Random noise of high intensity was observed at frequencies near 200 mc and also below 2 mc, in several types of discharge tube, and was found to be associated with a field reversal in the discharge. Coherent oscillations were also found at low radio frequencies, and these are apparently related to the striations of the positive column.

537.525.001.11 3065

The Initiation of Electrical Breakdown in Vacuum—L. Cranberg. (*Jour. Appl. Phys.*, vol. 23, pp. 518–522; May, 1952.) The hypothesis is suggested that initiation of high-voltage breakdown in vacuum is due to traversal of the high-voltage gap by a clump of loosely adhering material. A summary of published results which support this conclusion is presented.

537.525.5 3066

The Theory of Gaseous Arcs: Part 1—The Fundamental Relations for the Positive Columns—K. S. W. Champion. (*Proc. Phys. Soc.* (London), vol. 65, pp. 329–344; May 1, 1952.) Theory is developed for low-pressure arcs with high electron densities in which ionization by stages is important. By taking account of recombination, this theory can be applied to medium- and high-pressure arcs with high degree of ionization. The theory includes the effect of a longitudinal magnetic field.

537.525.5 3067

The Theory of Gaseous Arcs: Part 2—The Energy-Balance Equation for the Positive Columns—K. S. W. Champion. (*Proc. Phys. Soc.* (London), vol. 65, pp. 345–356; May 1, 1952.) The energy-balance equation proposed by Suits is considered and modifications of his theory are suggested which result in better agreement between theory and experiment. Radiation losses are neglected, since in most cases measurement shows them to be small. Theory of the effect of a longitudinal magnetic field on a high-pressure arc predicts that the effect will tend to a limit with sufficiently strong fields. Part 1: 3066 above.

537.525.5:621.385.132 3068

Studies of Externally Heated Hot-Cathode Arcs: Part 2—The Anode-Glow Mode—W. M. Webster, E. O. Johnson and L. Malter. (*RCA Rev.*, vol. 13, pp. 163–182; June, 1952.) In this mode all ionization and excitation occur in a thin electron sheath close to the anode surface. Theory indicates that the electron current should vary as the fourth power of the difference between the applied potential and the ionization potential of the gas in the discharge tube. Experiment confirms this. Evidence is presented to show that the plasma density distribution is one in which the lowest diffusion mode predominates. Part 1: 959 of May.

537.533.8 3069

Theory of the Production of Secondary Electrons in Solids—A. J. Dekker and A. van der Ziel (*Phys. Rev.*, vol. 86, pp. 775–760; June 1, 1952.) The problem is formulated on the assumption of a simple Coulomb interaction between primary electrons and lattice electrons; the energy losses of the bombarding primaries are examined. The basic features of previously presented theories are discussed as approximations to the present formulation. The numbers of secondaries emitted according to Wooldridge's theory (147 of 1940) and Baroody's theory (107 of February) are compared, and the range of applicability of their approximations is discussed.

537.58:538.221 3070

Thermionic Emission from Ferromagnetic Materials—A. V. Sokolov and A. Z. Veksler. (*Compt. Rend. Acad. Sci.* (U.R.S.S.), vol. 81, pp. 27–30; November 1, 1951. In Russian.) The anomalous variation with temperature of the thermionic emission from ferromagnetic materials may be due to disappearance of spontaneous magnetization when passing through the Curie point. On this assumption, and using the model of the exchange interaction between the valence and inner electrons proposed by Vonsovski (2074 of 1947), a formula (15) is derived showing the temperature dependence of the saturation current and its deviation from the normal temperature dependence (16).

538.122+537.212 3071

The Two-Dimensional Magnetic or Electric Field inside a Semi-infinite Slot terminated by a Semicircular Cylinder—N. Davy and N. H. Langton. (*Brit. Jour. Appl. Phys.*, vol. 3, pp. 156–158; May, 1952.) Exact calculations, with tables and graph of results.

538.249 3072

Theory of Magnetic Diffusion After-Effect—L. Néel. (*Jour. Phys. Radium*, vol. 13, pp. 249–264; May, 1952.)

621.3.011.4 3073

Calculation of the Electrostatic Capacitance of a Conductor—W. Gross. (*R.C. Acad. naz. Lincei*, vol. 12, pp. 495–506; May, 1952.)

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.72+523.8]:621.396.822 3074

Radio Astronomy—(*Engineer* (London), vol. 193, pp. 640–641; May 9, 1952. A brief survey including a note about the 265-foot steerable radio telescope planned to be installed at Lodrell Bank for Manchester University.

523.72:621.396.822 3075

Solar Radio-Noise—(*Tech. Bull. Nat. Bur. Stand.*, vol. 36, pp. 65–67; May, 1952.) Radio-astronomy methods were used for observation of the radio-noise bursts, which are considered to originate in the many high-velocity streams of ionized plasma in the corona, being the result of the direct conversion of the kinetic energy in the plasma to em energy. Some evidence indicates correlation of the noise bursts with sudden ionosphere disturbances, and they also tend to accompany, precede or follow flurries of solar activity.

523.72:621.396.822.029.65 3076

Detection of Millimeter Wave Solar Radiation—W. M. Sinton. (*Phys. Rev.*, vol. 86, p. 424; May 1, 1952.) Solar radiation over a band with an average wavelength of 1.4 mm was detected by allowing the sun to drift across the field of a mm-wave telescope, a Golay infrared detector being used at the focus of a modified 24-inch searchlight. Typical records are shown.

523.78 3077

Observations of the Solar Eclipse of 25th February 1952 in the Sudan—H. von Klüber. (*Naturwissenschaften*, vol. 39, pp. 199–206; May, 1952.) Illustrated account of the equipment of different research groups and their program of observations.

550.38"1952.04/.06" 3078

Indices of Geomagnetic Activity of the Observatories Abinger, Esdalemuir and Lerwick, April to June 1952—(*Jour. Atmos. Terr. Phys.*, vol. 2, pp. 306–308; 1952.)

551.510.535 3079

A Search for Radio Echoes of Long Delay—K. G. Budden and G. G. Yates. (*Jour. Atmos. Terr. Phys.*, vol. 2, pp. 272–281; 1952.) An account of attempts to detect long-delay echoes of the of the type reported by Størmer (1929 Abstracts, pp. 38, 565 and 623) and others. High-power transmitters operating on frequencies of approximately 13.5 and 20.7 mc were used, but no long-delay echoes were observed. Possible explanations of this failure are suggested.

551.510.535 3080

A Method for studying Sporadic-E Clouds at a Distance—O. G. Villard, Jr., A. M. Peterson and L. A. Manning. (Proc. I.R.E., vol. 40, pp. 992–994; August, 1952.) A pulsed transmitter is used in conjunction with a rotatable Yagi antenna to track moving clouds of sporadic E by means of the back-scattered echoes, which are displayed on a plan position indicator. PPI photographs obtained at Stanford University on 15th December 1951 are shown together with the corresponding $h'f$ records.

551.510.535 3081

The Graphical Representation of the Longitude Effect in F_2 Region—C. M. Minnis. (*Jour. Atmos. Terr. Phys.*, vol. 2, pp. 261–265; 1952.) Discussion leads to the conclusion that for commercial use the best solution of the problem would be a set of hourly charts each showing the fF_2 distribution at a fixed universal time.

551.510.535:551.557 3082

A Radio-Astronomical Investigation of Winds in the Upper Atmosphere—A. Maxwell and C. G. Little. (*Nature* (London), vol. 169, pp. 746–747; May 3, 1952.) Results of observations using three receivers at the corners of a triangle (spacing about 4 km) indicate that F-region irregularities have a steady translational movement, which is usually maintained in the same direction for many hours. During May-June and September-October 1951 the most favored direction was towards the west, the variation in direction during a 4-hour period being generally $<25°$ and the average velocity about 350 km/hr.

551.510.535:551.557 3083

A Radio Echo Method for the Investigation of Atmcspheric Winds at Altitudes of 80 to 100 km—J. S. Greenhow. (*Jour. Atmos. Terr. Phys.*, vol. 2, pp. 282–291; 1952.) The variations of wind velocity with height between altitudes of 80 and 100 km can be determined from the fluctuations in amplitude and the changes in width of the recorded radio echoes from meteor trails. Results of observations are presented, with typical records, and discussed.

551.510.535:621.3.087.4 3084

Study and Design of an Ionospheric Radar Sounder—M. Geffroy. (*Radio franç.*, pp. 16–24; May, 1952.) Full circuit details are given of a vertical-incidence recorder with transmitter peak power of 2 kw, frequency range 5–10 mc, pulse width 100 μs and repetition frequency 50/second. The control circuits are shown and the derivation of pulses of different waveform for cro calibration and transmitter switching is described stage by stage. The construction of a pulse transformer for anode modulation is illustrated. A complete circuit diagram of the receiver is given.

551.594.22 3085

The Relation between Point Discharge Current and Field—J. A. Chalmers. (*Jour. Atmos. Terr. Phys.*, vol. 2, pp. 292–300; 1952.)

551.594.22 3086

Point Discharge Currents—J. A. Chalmers. (*Jour. Atmos. Terr. Phys.*, vol. 2, pp. 301–305; 1952.)

551.594.221 3087

Lightning and Buildings. Statistical Study of Lightning Strokes occurring in Switzerland from 1925 to 1947.—(*Bull. schweiz. elektrotech. Ver.*, vol. 43, pp. 428–432; May 17, 1952. In French.)

551.594.221:001.891 3088

Experimental Lightning Research—H. Norinder. *Jour. Frank. Inst.*, vol. 253, pp. 471–504; May, 1952.) Historical account of methods of investigation from Franklin's time to the present-day. 51 references.

LOCATION AND AIDS TO NAVIGATION

621.396.9 3089
Some Modern Developments in Radar Equipment for Shipboard Use—C. B. Broersma (*Tijdschr. med. Radiogenoot.*, vol. 17, pp. 139–145; May, 1952. Discussion, pp. 145–146.) Postwar development of radar for merchant ships is reviewed. Current trends are toward greatest possible simplicity and toward the use of large cro screens. The relation between the desirable size of screen and the duration of the radar pulse is discussed. A description is given of a modern 38-tube equipment using a 16-inch tube and a magnetron producing 0.2-μs pulses with a peak power of 7 kw. The supply is ac at 2 kc.

621.396.9:621.396.825 3090
Echo and Noise in a Radar System subjected to Deliberate Interference—U. Tiberio. (*Alta Frequenza*, vol. 21, pp. 137–151; June, 1952.) When a radar system is jammed by transmissions from the target, the echo/noise ratio has a value dependent on the range. This dependence is analyzed for practical applications, mainly naval ones. Formulas are derived for the maximum detection range possible for a given ratio of jammer to radar power.

621.396.9.002.2 3091
The Engineering of Radar Equipments designed for the R.A.F.—G. W. A. Dummer. (*Electronic Eng.*, vol. 24, pp. 348–355; August, 1952.) Discussion of factors affecting design, including sealing, pressurizing, heat dissipation, weight reduction, accessibility for servicing, simplicity of controls, corrosion, packaging, and transport risks.

621.396.93 3092
The Measurement of Angles by Direction-Finding Technique—W. Messerschmidt. (*Arch. tech. Messen*, no. 195, pp. 73–80; April, 1952.) Discussion of the principles of various methods and review of applications in air, marine and ground radiolocation systems, with indication of the limitations imposed by the antenna characteristics.

621.396.932 3093
Conference of the Committee for Radio Navigation—Kronjäger. (*Fernmeldetech. Z.*, vol. 5, pp. 287–289; June, 1952.) Summaries of nine papers read in Hamburg, March 1952, on marine navigation systems.

621.396.932 3094
Microwave Lighthouse—A. Roberts. *Radio & Telev. News, Radio-Electronic Eng. Section*, vol. 47, pp. 6–7, 31; 1952.) Description of a cheap and simple navigation aid for small ships. The 7-kw shore transmitter uses a 3-cm magnetron modulated at 500 pulses per second by a rotary spark gap, and a twin-beam antenna keyed in one of the usual interlocking codes. The ship-borne receiver is integral with a parabolic-cylinder antenna, and has a crystal detector; its sensitivity is such that a signal of duration 1μs and power 10^{-8}w can be heard above receiver noise. An accurate fix on the shore station can be obtained.

621.396.932/.933 (43–15) 3095
Integration of the Recently Installed Air-Navigation Safety System of the Federal German Republic with the Existing West European Network—F. C. Saic. (*Elektrotech. u. Maschinenb.*, vol. 69, pp. 203–207; May 1, 1952.) The principles of the Decca system are outlined and the two-frequency Decca-Telefunken system due to O'Brien and Schwarz is described. In this system, signals from two transmitters, with frequencies which are different multiples of a common frequency, are picked up on separate receivers in a ship or aircraft and multiplied in frequency so as to derive two signals of identical frequency, whose phase difference is measured by a phase bridge enabling location in the hyperbola system to be determined to within about 4 m. The master transmitter at Madfeld, Westphalia, operates on a frequency 6 f_2, from which are derived, by frequency division and subsequent multiplication, the frequencies $8f_0$, $9f_0$ and $5f_0$ of the three slave transmitters, which are symmetrically located round the master transmitter at a distance from it of 200 km. Three combinations give frequencies of $24f_0$, $18f_0$ and $30f_0$ for use in the phase-measurement bridge. The signals for the "coarse" location, with frequencies interchanged, are transmitted during short breaks in the "fine" location transmissions. The transmitter power is 2.4 kw and vertical wire-cage antennas are used. Standby Diesel generators are provided in case of mains failure, with battery feed during the starting-up period. See also 1923 of August.

621.396.933:657.7 3096
The Application of Telecommunications to Civil "Airways"—D. P. Taylor. (*Jour. Brit. I.R.E.*, vol. 12, pp. 341–359; June, 1952.) An account of the development of facilities for promoting safety and regularity in civil aviation operation in the U.K. in accordance with decisions taken by the Ministry of Civil Aviation in 1948. The airways system is described and a list is given of communication facilities and navigation aids essential for its operation. Descriptions are given of the vhf air-to-ground R/T system, using area-coverage networks, and of the mf radio ranges and beacons and vhf fan markers. References are included to more detailed accounts of individual features of the system.

621.396.933.1:621.396.67 3097
Cage-Type Very-High-Frequency Phase-Comparison Omnidirectional Radio Range Antenna—F. J. Lundburg and F. X. Bucher. (*Elec. Commun.*, vol. 29, pp. 108–116; June, 1952.) Description of an antenna system consisting of a dipole rotating within a cage of vertical metal rods, together with an upper cage extension serving to suppress vertical polarization. Tests carried out on the system show that it has good azimuth accuracy, a small cone of silence, and vertical polarization 50 db below horizontal polarization for an upper-cage length of 12 feet, the whole system being mounted on a circular metal counterpoise 35 feet in diameter and 15 feet above the ground. Details are given of the tone wheel and magnetic pickup that provide the fixed-phase reference signal.

621.396.933.23+621.317.79 3098
Airborne Receivers and Test Gear for Instrument Landing Systems—F. G. Overbury. (*Elec. Commun.*, vol. 29, pp. 122–130; June, 1952.) A description has previously been given of the ILS-2 ground equipment [2513 of 1950 (Hampshire and Thompson)]. Details are now given of the operation of the SR.14 and SR.15 airborne receivers which derive suitable course indications from comparison of the modulation depths of the transmitted 90- and 150-cps tones. Sources of error and means adopted for reducing them are discussed. In the SR. 14 localizer receiver, avc is derived at the detector, delay being determined by a neon reference tube. In the SR.15 glide-slope receiver an audio type of avc is used. An outline description is given of portable field test equipment which enables accurate checking of audio, filter and rectifier circuits on one crystal-controlled channel in the localizer and glide-slope frequencies. Rf circuits are checked by functional tests.

621.396.93 3099
Radio Research Special Report No. 22. The Siting of Direction-Finding Stations. [Book Review]—W. Ross and F. Horner. Publishers: H. M. Stationery Office, London, Eng., 1952, 38 pp., 1s. 6d. (*Nature* (London), vol. 169, p. 875; May 24, 1952.) "The main conclusions of the report are summarized in tables showing the minimum tolerable distances for different objects when it is desired to achieve specified accuracies."

621.396.933 3100
Radio Research Special Report No. 21. Radio Direction-Finding and Navigational Aids; some Reports on German Work issued in 1944–45. [Book Review]—Publishers: H. M. Stationery Office, London, Eng., 1951, 92 pp., 3s. 6d. (*Nature* (London), vol. 169, p. 875; May 24, 1952.) Translations of nine hitherto unpublished papers by German experts.

MATERIALS AND SUBSIDIARY TECHNIQUES

531.788.13 3101
Knudsen Gauges—W. Steckelmacher. (*Vacuum*, vol. 1, pp. 266–282; October, 1951.) The design of improved forms of suspended-vane metal and glass instruments is discussed. Gauges can be constructed for the pressure range 10^{-2}–10^{-8} mm Hg with phosphorbronze taut-strip suspension and eddy-current damping. The inherently narrow range of the instrument is extended by means of an alternating magnetic field acting inductively on the vane system. The thoery of the Knudsen gauge is developed. 48 references.

531.788.7 3102
Use of Penning's Gauge. Experimental Comparison with the Ionization Gauge.—J. Vermande. *Le Vide*, vol. 7, pp. 1145–1150; March, 1952. Discussion pp. 1150–1152.) Calibration and operation of the vacuum gauge [1423 of 1950 (Penning and Nienhuis)] are described; its advantages are summarized.

531.788.7 3103
Thermocouple Micromanometer. Theoretical and Experimental Study—D. Degras. (*Le Vide*, vol. 7, pp. 1153–1171; March, 1952.) Description and theory of the instrument, and discussion of factors affecting sensitivity and the aging of the thermocouple.

535.215:537.311.33:546.23 3104
Photoconductivity in Vacuum Coated Selenium Films—P. H. Keck. *Jour. Opt. Soc. Amer.*, vol. 42, pp. 221–225; April, 1952.) The influence of base-plate temperature and process timetable on the growth of crystals in evaporated Se coatings was investigated. The presence of a small amount of crystalline Se increases red sensitivity, but high insulation is maintained only if the crystals are well separated by the vitreous matrix. The effect on the spectral response of Te additions is considered. See also 1925 of 1951.

535.215:546.482.21 3105
Note on Quenching of Photoconductivity in Cadmium Sulfide—E. A. Taft and M. H. Hebb. (*Jour. Opt. Soc. Amer.*, vol. 42, pp. 249–251; April, 1952.) Experiments were made on a single crystal 1×1×4 mm in size, subjected to a small unidirectional field and simultaneously irradiated with two monochromatic beams, one of constant and the other of variable intensity. There appear to be two independent but similar quenching processes, with peaks at variable-beam energies of 0.9 and 1.5 ev respectively. An interpretation based on Frerich's theory (450 of 1948) is proposed.

535.215:549.328.1 3106
Antimony Content and Photoelectric Effect of Different Samples of Galena—J. E. Hiller and H. G. Smolczyk. (*Naturwissenschaften*, vol. 39, p. 208; May, 1952.) Results of tests on 57 samples indicate that a Sb content of <0.03 per cent, a negatively directed photo-

electric effect (current from contact point to galena) and a positive thermoelectric effect are characteristic of samples which are good detectors.

535.343:[546.817.221+546.817.231 +546.817.241 3107
The Absorption Spectra of Single Crystals of Lead Sulphide, Selenide and Telluride—A. F. Gibson. (*Proc. Phys. Soc.* (London) vol. 65, pp. 378–388; May 1, 1952. Correction, *ibid.*, vol. 65, p. 555; July 1, 1952.) The spectra were examined over the temperature range 20–600°K; they are characterized by a sharp absorption "edge" coincident with the long-wave limit of the photoconductivity of each material.

535.37 3108
The Third All-Union Conference on Luminescence and the Applications of Luminescent Materials—P. Feofilov. (*Uspekhi fiz. Nauk*, vol. 45, pp. 445–457; November, 1951.) Report on a conference held in Moscow, June 15–21, 1951. Summaries of 45 papers are given.

535.37:546.412.84 3109
Optical Properties of Calcium-Silicate Phosphors—G. R. Fonda and F. J. Studer. (*Jour. Opt. Soc. Amer.*, vol. 42, p. 360; May, 1952.) Further investigations indicate that the optical properties of these phosphors are dependent on structure and not on lead content. See also 107 of 1950.

535.372 3110
Luminescence of Alkali Sulphides and Sulphates—H. Gobrecht and D. Hahn. (*Z. Phys.*, vol. 132, pp. 111–128; April 10, 1952.) By reduction of the alkali sulphates, materials are obtained giving red or blue luminescence when excited by Hg radiation of wavelength 366 mμ or 254 mμ. The red luminescence is due to the production of polysulphides, the blue to alkali atoms in the sulphate lattice. Investigations of the luminescence spectra at different temperatures are described and discussed.

537.226:546.311.88 3111
Ferroelectric Properties of Tantalates and Niobates of Alkali Metals—N. V. Kozhevnikova and A. I. Medovoi. (*Zh. Tekh. Fiz.*, vol. 21, pp. 1383–1387; November, 1951.) The temperature dependence of the dielectric constant and coefficient of linear expansion was investigated for certain tantalates and niobates of alkali metals, and their lattice parameters were determined. Over the temperature range 20°C–500°C these materials did not show any ferroelectric properties. These results are contrary to those obtained by Matthias (*Phys. Rev.*, vol. 75, p. 1771; 1949) and by Matthias and Remeika (3023 of 1951).

537.226.2 3112
Theory of the Dielectric Constant of Mixtures—G. Eckart. (*Z. angew. Phys.*, vol. 4, pp. 134–136; April, 1952.) A formula based on calculations of Darwin and Hartree is derived for the dielectric constant of a material containing globular particles of a second material embedded in it. Curves are drawn to simplify calculations. Application of the formula to the case of water drops or vapor in air is illustrated. Experimental evidence indicates that the formula is only useful if the dielectric constants of the two materials differ by a factor <10.

537.226.31 3113
The Effect of Orientation on the Dielectric Losses in Polar Polymers—G. P. Mikhailov. (*Zh. Tekh. Fiz.*, vol. 21, pp. 1395–1401; November, 1951.)

537.312 3114
Measurement of the Resistance of Thin Insulating Layers between Gold Contacts with the Range of the Tunnel Effect—I. Dietrich. (*Z. Phys.*, vol. 132, pp. 231–238; May 14, 1952.) Results of measurements on TiO_2 layers show that for layer thicknesses <100 Å, contact resistance is governed by the tunnel effect, being independent of the specific resistance of the layer material and, for layer thicknesses <80 A, independent of temperature between $+160°$ and $+20°$C.

538.221 3115
Minute Eddy Currents due to Displacement of Domain Boundaries—N. S. Akulov and G. S. Krinchik. (*Compt. Rend. Acad. Sci.* (U.R.S.S.), vol. 81, pp. 171–174; November 11, 1951. In Russian.)

538.221 3116
Theory of the Coercive Force and Magnetic Susceptibility of Ferromagnetic Powders (Dependence on the Density of Packing)—E. Kondorski. (*Compt. Rend. Acad. Sci.* (U.R.S.S.), vol. 80, pp. 197–200; September 11, 1951. In Russian.)

538.221 3117
The Magnetization of Highly Coercive Ferromagnetic Materials in Weak Fields—D. I. Volkov. (*Compt. Rend. Acad. Sci.* (U.R.S.S.), vol. 80, pp. 349–351; September 21, 1951. In Russian.)

538.221 3118
New Ferromagnetic Materials with High Coercivity, High Permeability and Low Losses—C. Guillurd. (*Onde élect.*, vol. 32, pp. 238–253; June, 1952.) The domain theory of ferromagnetism is outlined and the properties of recently developed permanent-magnet and magnetically soft materials are described, including both solid materials and those produced by powder-metallurgy technique, ferites being particularly considered. Applications of the new materials for filter-coil cores, wideband transformers, magnetostriction devices, magnetic amplifiers, etc., are briefly discussed. 27 references.

538.221 3119
Calculation of the Magnetic Skin-Effect in Sheet Permalloy and Determination of its Characteristic Parameters—A. A. Shvarts. (*Zh. Tekh. Fiz.*, vol. 21, pp. 1293–1310; Novemver, 1952.) The usual equation (1) of the hysteresis loop is valid only for the case of a quasistatic field and ceases to be accurate if the field varies with a finite frequency. A generalized equation (14) is derived for investigating the behavior of ferromagnetic materials in weak alternating fields both with and without taking account of their domain structure. A new method is proposed for separating the losses in sheet matcrials, and an experimental determination of the parameters of sheet permalloy is reported.

538.221 3120
The Spontaneous Magnetization of Magnesium Ferrite and Magnesium Ferrite-Aluminate Powders at Low Temperatures—G. O. Jones and F. F. Roberts. (*Proc. Phys. Soc.* (London), vol. 65, pp. 390–391; May 1, 1952.)

538.221:061.3 3121
Soft Magnetic Materials in Telecommunications—(*Nature* (London), vol. 169, pp. 905–906; May 31, 1952.) Report of discussions at the Post Engineering Research Station, London, April 1952, at which 34 papers were presented.

538.221:538.541 3122
Eddy Currents in Solid Cylindrical Cores having Nonuniform Permeability—H. Aspden. (*Jour. Appl. Phys.*, vol. 23, pp. 523–528; May, 1952.) A method of estimating magnetization losses due to eddy currents in inhomogeneous ferromagnetic materials is given. A case in which the permeability changes across the core section is considered and the solution is extended to a homogeneous core whose permeability changes with the degree of magnetization.

538.221:669.15.24-198 3123
Study of a Ferronickel Alloy of Very Low Strain Energy in Steady and Alternating Magnetic Fields—I. Épelboin and G. Gilardin. (*Compt. Rend. Acad. Sci.* (Paris), vol. 234, pp. 1860–1862; May 5, 1952.) Discussion of measurements on very thin mumetal strip, the thickness of which was successively reduced electrolytically, with subsequent annealing in an atmosphere of H_2.

538.221.001.8 3124
Some Applications of Ferroxcube—W. Six. (*Philips Tech. Rev.*, vol. 13, pp. 301–311; May, 1952.) Review of the properties of ferroxcube and of applications for filter coils, loading coils for telephone circuits, wideband hf transformers, "palisade" screening, uhf modulation, and in television line-scan circuits.

538.221.096:546.726-3 3125
Thermomagnetic Study of a Single Crystal of $Fe_2O_3\alpha$—L. Néel and R. Pauthenet. (*Compt. Rend. Acad. Sci.* (Paris), vol. 234, pp. 2172–2174; May 26, 1952.) Measurements of the magnetization of a natural single crystal of $Fe_2O_3\alpha$ are shown graphically for the temperature range 20–950°K. A discontinuity occurs at about 250°K.

539.234:537.311.31:546.92 3126
Electrical Conductivity of Thin Deposits of Platinum on Dielectric Layers evaporated in Vacuo—C. Feldman. (*Compt. Rend. Acad. Sci.* (Paris), vol. 234, pp. 1858–1860; May 5, 1952.) Measurements show that the resistivity of Pt films deposited on evaporated layers of KBr or CaF_2 is much higher than that of Pt films on glass. The difference is not so great for films on layers of SiO_2. An explanation is suggested.

546.217:621.317.335.3.029.64 3127
The Dielectric Constant of Dry Air—J. V. Hughes and H. L. Armstrong. (*Jour. Appl. Phys.*, vol. 23, pp. 501–504; May, 1952.) Measurements by a two-cavity method similar in some respects to that of Birnbaum et al. (1426 of 1951) give a value of 1.000569 for the dielectric constant of dry air at N.T.P., for a frequency of 3 kmc. The value previously reported by Hughes and Lavrench (3047 of 1951) was found to be too high because of insufficient drying of the air.

546.23:[535.323+535.343 3128
Properties of Amorphous Selenium and its Use as an Optical Material—H. A. Gebbie and C. G. Cannon. (*Jour. Opt. Soc. Amer.*, vol. 42, p. 277; April, 1952.) Measurements were made of the transmission over the wavelength range 1–25μ. Results are discussed in relation to values of optical constants previously reported by Gebbie and Saker (*Proc. Phys. Soc.* (London), vol. 64, pp. 360–361; April 1, 1951), and by Dowd (1013 of May).

546.24:[537.311.33+538.632 3129
The Hall Effect and Electrical Resistivity of Tellurium—V. E. Bottom. (*Science*, vol. 115, pp. 570–571; May 23, 1952.)

546.24:538.632 3130
Interpretation of the Double Reversal of the Hall Effect in Tellurium—H. Fritzsche. (*Science*, vol. 115, pp. 571–572; May 23, 1952.)

546.24:621.314.632 3131
Contact Rectification with Tellurium—J. Lagrenaudie. (*Jour. Phys. Radium*, vol. 13, p. 308; May, 1952.) Systematic measurements have been made of mean rectified current and upper-limit value of reverse voltage for single-crystal and polycrystalline specimens of Te

with metal point contacts. Rectification is obtained with contact metals having low work function and coated with oxide. A theoretical explanation is advanced for the different results observed with different contact metals. Measurements made with unidirectional voltages are also reported.

546.28:537.323 3132

The Sign of the Thermal E.M.F. of Silicon—J. Savornin and F. Fourrier-Savornin. (*Compt. Rend. Acad. Sci.*, (Paris), vol. 234, pp. 2165–2167; May 26, 1952.) Experiments carried out on small bars of Si (98 per cent Si, 1.4 per cent Al, 0.6 per cent Fe), with Cu and constantan contacts at the ends, show that the thermal emf of Si with respect to Cu is positive, not negative, as given in tables of physical constants. For a Si-Pb couple the thermal emf is 408μV/1°C, as against 80μV/1°C for a Pb-Si couple.

546.281.26:537.311.4 3133

Contribution to the Theory of the Silicon Carbide Contact—E. Holm. (*Jour. Appl. Phys.*, vol. 23, pp. 509–517; May, 1952.) The high limiting contact voltage of 40–50 v between SiC single crystals of the black-green variety is explained on the basis of the known temperature-voltage relation. The electrical properties of the surface layer on the crystals are investigated with special reference to the "tunnel" effect, which affords an explanation of the resistance at low voltages.

546.289:537.311.33 3134

***p-n* Junction Method for Measuring Diffusion in Germanium**—W. C. Dunlap, Jr. and D. E. Brown. (*Phys. Rev.*, vol. 86, pp. 417–418; May 1, 1952.) Diffusion of an *n*-type impurity into a *p*-type semiconductor creates a *p-n* junction which can be detected electrically by means of a probe. Measurements of the rate of diffusion by this method and by a radio-active-tracer method gave results in good agreement.

546.289:[621.314.63+621.314.7+621.383.5 3135

Single-Crystal Germanium—G. K. Teal, M. Sparks and E. Buehler. (PROC. I.R.E., vol. 40, pp. 906–909; August, 1952.) When single crystals of Ge are used, the properties of the barriers between *p*-type and *n*-type specimens can be predicted from measurements on the separate specimens. The long life of carriers injected into single crystals and the good chemical controllability are particularly useful characteristics from the point of view of developing rectifiers, transistors and photocells. The range of properties of available Ge crystals is indicated.

546.289:669.054.83 3136

Germanium from Coal—R. C. Chirnside and H. J. Cluley. (*GEC Jour.*, vol. 19, pp. 94–100; April, 1952.) An account of the methods developed for the production of high-purity Ge from flue dusts, with some details of the treatment of $GeCl_4$ with Cu turnings to remove traces of As.

546.431.824-31:537.226 3137

The Effective Fields in Barium Titanate—V. Kh. Kozlovski. (*Zh. Tekh. Fiz.*, vol. 21, pp. 1388–1394; November, 1951.)

546.72-3:537.311.33 3138

Semiconducting Properties of Oxides of Iron—J. Martinet. (*Compt. Rend. Acad. Sci.* (Paris), vol. 234, pp. 2167–2169; May 26, 1952.) Results of measurements on Fe_3O_4, $Fe_2O_3\alpha$, $Fe_2O_3\gamma$ and intermediate mixtures from $-190°$ to $+100°C$ are presented and discussed.

546.722.21:538.22 3139

Paramegnetism of Sulphides of Iron—R. Benoît. (*Compt. Rend. Acad. Sci.* (Paris), vol. 234, pp. 2174–2175; May 26, 1952.) Graphical presentation and discussion of measurements on various sulphides in the temperature range 0–1,000°C.

546.817.221+546.817.231+546.817.241]
:537.311.33 3140

Electrical Conductivity in the Compounds PbS, PbSe, PbTe—E. H. Putley. (*Proc. Phys. Soc.* (London), vol. 65, pp. 388–389; May 1, 1952.) Measurements on single crystals give electron and hole mobilities two or three times those reported for multicrystal specimens.

548.0:537.228.1:539.32 3141

The Elastic Constants of Piezoelectric Crystals—R. F. S. Hearmon. (*Brit. Jour. Appl. Phys.*, vol, 3, pp. 120–124; April, 1952.) Published values of the elastic constants of Rochelle salt, KH_2PO_4 (KDP), $(NH_4)H_2PO_4$(ADP), quartz, $NaClO_3$ and $NaBrO_3$ crystals are assembled and discussed. 23 references.

548.0:537.228.1:539.4 3142

Mechanical Strength of Piezoelectric Crystals—R. Bechmann and P. L. Parsons. (*Brit. Jour. Appl. Phys.*, vol. 3, pp. 147–150; May, 1952.) A direct mechanical method and an electrical method have been used to determine the breaking strength of crystals of $NaClO_3$, $NaBrO_3$, ADP, EDT and Li_2SO_4. Results are tabulated. New measurements on quartz crystals were used to check the methods. A formula for the current due to the piezoelectric polarization is given which covers the longitudinal flexural, contour, and thickness modes of vibration considered. The calculated maximum safe currents are tabulated for resonators of various materials and cuts.

549.211:621.317.335.3 3143

The Dielectric Constant of Diamond—F. P. Pietermaat, W. van Dyck and F. de Keuster. (*HF* (Brussels), vol. 2, no. 2, pp. 47–51; 1952.) Bridge measurements on pure diamonds at frequencies from 100 cps to 1 mc gave a permittivity value of 5.6, independent of frequency. The value for industrial diamonds at frequencies <5 kc was slightly higher.

549.514.51:621.396.611.21 3144

Heat Treatment and Internal Friction of Piezoelectric Quartz Resonators—G. Frigerio. (*Alta Frequenza*, vol. 21, pp. 102–104; April, 1952.) Brief account of an experimental investigation of the effect of heat treatment on crystal structure and *Q*-value.

620.197:621.396.6 3145

A Colonial talks about Tropicalization—E. Dawance. (*Toute la Radio*, no. 166, pp. 177–182; June, 1952.) Discussion of the various mechanical and electrical faults commonly found in radio equipment used in the tropics, with detailed suggestions as to the treatment of components, assemblies and complete units, necessary to ensure reliable operation under difficult conditions.

621.3.066.6 3146

Materials for Electrical Contacts—H. Gagel and H. Dittler. (*Elektrotech. Z.*, vol. 73, pp. 292–294; May 1, 1952.) Review of the special characteristics of the metals and alloys commonly used, with a summary of their relative advantages and disadvantages.

621.314.632:[549.325.2+546.784.221 3147

Rectification Effects with Molybdenite and Tungstenite—J. Lagrenaudie. (*Jour. Phys. Radium*, vol. 13, pp. 311–312; May, 1952.) Results are reported of measurements on sheets of natural molybdenite (MoS_2) soldered to a large-contact base, and on artificial tungstenite (WS_2). For MoS_2 the results are not affected by the particular contact metal used, for WS_2 the nature of the contact metal has some influence. The forward resistance of the MoS_2 rectifier is high, due to the laminated nature of the material. Modifications of the characteristics obtained by lightly firing the contact are described.

621.315.613.1 3148

Processing Mica Paper for Electrical Insulation—R. L. Griffeth and E. R. Younglove. (*Elec. Eng.* (N.Y.), vol. 71, no. 5, pp. 463–465; May, 1952.) A.I.E.E. Winter General Meeting paper, January, 1952. An account of the production and properties of the type of mica paper developed in France by Bardet. See also 1407 of 1951 (George and Metzger).

621.315.613.1 3149

Synthesis of Mica—A. Van Valkenburg and R. G. Pike. (*Bur. Stand. Jour. Res.*, vol. 48, pp. 360–369; May, 1952.) An account of the preparation and properties of a phlogopite-type mica in which the (OH) ions present in natural mica are replaced by fluorine.

621.316.87:541.18:537.311.35 3150

The Electrical Properties of Colloidal Suspensions and Mixtures and their Use in the Manufacture of Nonlinear Resistors—H. E. Hollmann. (*Arch. elekt. Übertragung*, vol. 6, pp. 178–186; May, 1952.) See 2538 of October.

621.318.2:669.1-492.2 3151

Permanent Magnets from Ultrafine Iron Powder—B. Kopelman. (*Elec. Eng.* (N.Y.), vol. 71, pp. 447–451; May, 1952.) A.I.E.E. Winter General Meeting paper, January 1952. The salient points of the domain theory pertaining to such magnets are reviewed and the properties of magnets at present available are described. Theoretically it is possible to produce magnets with coercive forces of 2,500 oersted or more, saturation magnetization of the order of 11,000 gauss, and remanence of 5,000 gauss, but actual figures are considerably below these values. BH_{max} values are of the same order as for alnico-3, but the iron powder magnets are much lighter, containing only about 50 per cent Fe. Possible methods for obtaining improved magnetic properties in this type of magnet are discussed.

621.318.23 3152

Modern Permanent Magnets and their Application—F. Latscher. (*Elektrotech. u. Maschinenb.*, vol. 69, pp. 188–192; April 15, 1952.)

MATHEMATICS

517.946:517.949.8:518.12 3153

Numerical Solution of Boundary-Value Problems in Elliptic Partial Differential Equations—E. Batschlet. (*Z. angew. Math. Phys.*, vol. 3, pp. 165–193; May 15, 1952.) Partial differential equations of the elliptic type are solved by finite-difference approximation. If the boundary conditions involve derivatives, such approximation may be difficult. It is shown how the normal derivative may be approximated for a curved boundary without any corner. The finite-difference solutions converge to the exact solution of the differential equation as the mesh side tends to zero; this is proved, under certain conditions by a method similar to that given by Gerschgorin. Relaxation technique is considered and it is proved that the residuals for inner and for boundary points converge to zero. 24 references.

517.946:518.12 3154

Numerical Determination of Periodic Solutions for Nonlinear Oscillations—L. Collatz. (*Z. angew. Math. Phys.*, vol. 3, pp. 193–205; May 15, 1952.) Description of a relatively simple multipoint method, with worked-out examples.

681.142:512.3 3155

The Solution of Algebraic Equations on the EDSAC—R. A. Brooker. (*Proc. Camb. Phil. Soc.*, vol. 48, part 2, pp. 255–270; April, 1952.) Three iterative methods are examined: Bernoulli's method, the root-squaring method and the Newton-Raphson method. Quadratically convergent methods are found preferable to those less rapidly convergent. Examples are given.

681.142:621.3.042.143 3156
Static Magnetic Matrix Memory and Switching Circuits—J. A. Rajchman. (*RCA Rev.*, vol. 13, pp. 183–201; June, 1952.) Description of recent developments in this type of memory device. See also 2258 of September (Papian).

MEASUREMENTS AND TEST GEAR

531.76:621.3.015.7 3157
The Use of a Pulse-Height Analyzer for Time-Interval Measurements—G. Jenssen and A. Sunde. (*Physica*, vol. 18, pp. 265–269; April, 1952.) Description of an instrument adapted from the pulse-height analyzer of Elmore and Sands (2007 of 1950).

531.764.5 3158
Development of a Clock whose Rate is Accurately the Arithmetic Mean of the Rates of Several Clocks—B. Decaux, J. Lucas and V. Yanouchevsky. (*Compt. Rend. Acad. Sci.*, (Paris), vol. 234, pp. 2164–2165; May 26, 1952.) Description of a method particularly applicable to quartz clocks. By a process of simple frequency mixing and division, a frequency is derived which is the exact arithmetic mean of the fundamental 100-kc nominal frequencies of several clocks, or of nominal frequencies of 1 kc derived by frequency division. In the latter case a synchronous motor can then be used to drive mechanism for recording the mean time or operating seconds contacts.

621.317.2(44):621.317.361 3159
Recent Developments in the Frequency-Measurement Department of the Laboratoire National de Radioélectricité—B. Decaux. (*Onde élect.*, vol. 32, pp. 219–231; June, 1952.) An outline is given of the organization of the department and of its functions, with descriptions of the measurement equipment, including the standard oscillators (installed underground), frequency meters up to 4 kmc, synchronous recording drums, beat-frequency counters, etc. A new microwave meter is to range up to 12 kmc.

621.317.3:621.396.611.21 3160
Measurement of the Parameters of a Quartz Crystal. Use of the Two-Circle Abac—J. Coulon. (*Compt. Rend. Acad. Sci.*, (Paris), vol. 234, pp. 1965–1968; May 12, 1952.) Discussion of the application of an orthogonal system of circles to the determination of crystal parameters. See also 2549 and 2550 of October.

621.317.3:621.396.822 3161
Characteristics of Noises and Noise Voltages—H. Bittel. (*Z. angew. Phys.*, vol. 4, pp. 137–146; April, 1952.) The frequency spectrum of a noise voltage often gives insufficient data on the character of the noise; a knowledge of the statistical amplitude distribution is required. In many practical cases this distribution is Gaussian. Deviations are due to non-overlapping of the voltage pulses; the frequency characteristic of the transmission system may contribute to this. The effect of the amplitude distribution on the rectification process is analyzed and measurement apparatus is described. For resistance and tube noise a Gaussian distribution is confirmed experimentally.

621.317.3.017.143:621.396.611.4 3162
An Approximate Theory of the Cavity-Resonator Method of Determining the Dielectric Loss of Solids at Microwave Frequencies—S. K. Chatterjee. (*Jour. Indian Inst. Sci.*, vol. 34, pp. 43–49; April, 1952.) The field equations for a cylindrical cavity resonator and the perturbation formula due to Bethe and Schwinger are applied to the calculation of the real and imaginary parts of the generalized dielectric constant of a small sample of solid dielectric rod introduced into the resonator. The loaded Q of the cavity is determined from the field equations and the Poynting vector.

621.317.3.029.5/.6 3163
High-Frequency Measurement Technique—W. Druey. (*Tech. Mitt. schweiz. Telegr.-TelephVerw.*, vol. 30, pp. 50–56; February 1, 1952. In German.) Reprint. See 1954 of August.

621.317.32:537.221 3164
Measurement of the Volta Effect—R. Bourion. (*Ann. Phys.*, (Paris), vol. 7, pp. 360–395; May/June, 1952.) Investigation of the sources of error in contact-potential measurements resulted in the development of a reliable method, a detailed account of which is given, including a description of the technique for obtaining the very high vacuum necessary to obtain consistent results. Values obtained for the contact emf for a layer of Cu condensed on a W wire are discussed in relation to results published by other investigators. See also 1885 of August.

621.317.331.029.51:621.316.993 3165
The Value of H.F. Measurements on Lightning-Protection Earths—W. Bulla. (*Elektrotech. u. Maschinenb.*, vol. 69, pp. 140–146; March 15, 1952.) Discussion indicates that hf measurements on earthing systems supply little additional information to that furnished by measurements with a lf bridge.

621.317.335.3:518.4 3166
The Computation of Dielectric Constants—R. M. Redhefter, R. C. Wildman and V. O'Gorman. (*Jour. Appl. Phys.*, vol. 23, pp. 505–508; May, 1952.) Charts are provided which enable the complex dielectric constant to be determined for any type of sample from measurements by the shorted-line method.

621.317.335.3:621.316.726 3167
A Frequency Stabilization System for Microwave Gas Dielectric Measurements—W. F. Gabriel. (Proc. I.R.E., vol. 40, pp. 940–945; August, 1952.) In a method based on observing the shift of resonance frequency of a cavity when filled with the gas, the frequency of the klystron oscillator used is automatically controlled by means of a double-loop servo system. One loop is of the type described by Pound (1311 of 1948) and the other of the type described by Rideout (276 of 1948). The value of $(n-1)$, where n is the refractive index, can be obtained accurate to three or four significant figures.

621.317.336:621.315.212 3168
The Sweep-Frequency Response of RG-6U [cable]—W. T. Blackband. (Proc. I.R.E., vol. 40, pp. 995–996; August, 1952.) A discussion of the causes of frequency dependence and irregularity of the measured characteristic impedance noted by Alsberg (728 of April).

621.317.34:621.315.212 3169
Measurement of the Attenuation and Characteristic Impedance of Transmission Lines. Tests on Coaxial Cables—P. Hontoy. (*HF*, (Brussels), vol. 2, no. 2, pp. 35–46; 1952.) A method of measurement applicable to all uniform line is described. If a line has a variable purely reactive termination, the locus, in the complex plane, of its input impedance is a circle whose position and radius are functions of the attenuation and characteristic impedance. The mathematical theory of the method makes use of the properties of certain transformations in the complex plane. The necessary formulas are established for the representation in cartesian coordinates and in Smith's diagram. Tests on coaxial cables for a very large range of frequencies gave attenuation values in good agreement with wattmeter measurements.

621.317.35.029.3 3170
Gated Amplifier Wave Analyzer—V. R. Nelson. (*Electronics*, vol. 24, pp. 136–139; August, 1952.) Description of an instrument giving a direct-reading quantitative indication of the spectral components of complex af waveforms. The waveform under test and gating pulses from a variable-frequency multivibrator are fed to an amplifier having in its output circuit a meter whose deflection varies as a function of the phase difference between the two inputs.

621.317.351:534.442.2 3171
Some Problems in Audio-Frequency Spectrum Analysis—S. V. Soanes. (*Electronic Eng.*, vol. 24, pp. 268–270 and 312–318; June and July, 1952.) Theory is presented for analyzers of the type using a fixed-frequency filter and a swept-frequency heterodyne oscillator. A description is given of a double-heterodyne analyzer for general laboratory use covering the working range 20 cps–20 kc; the useful range of input voltage is 1 mv–300 v, the sweep frequency is variable between 0.1 cps and 30 cps and the filter bandwidth is variable between 10 cps and 500 cps. The response is displayed on a long-persistence cr tube.

621.317.361 3172
A Recording Frequency Comparator—R. Walter and H. Voigt. (*Tech. Hausmitt. NordwDtsch. Rdfunks*, vol. 4, pp. 111–114; May/June, 1952.) A special heterodyne method is described in which a sawtooth oscillation of the one frequency is multiplicatively mixed in a pentode with pulses repeated at the other frequency; the resulting beat has a sawtooth form, enabling the direction of frequency deviation to be recognized immediately. A practical arrangement is illustrated in which several oscillators can be compared simultaneously with the same reference oscillator, the results being recorded on a single paper-strip chart.

621.317.361.029.6 3173
Frequency Measurement in the Microwave Range—B. Koch. (*Arch. tech. Messen*, no. 196, pp. 111–116; May, 1952.) Review of different methods and apparatus, including wavemeter methods, direct heterodyne methods and others involving frequency multiplication. A list of 64 NH_3 absorption lines between 19 and 40 kmc is given. 47 references.

621.317.444.087 3174
A Recording Fluxmeter of High Accuracy and Sensitivity—P. P. Cioffi. (*Bell Lab. Rec.*, vol. 30, pp. 247–251; June, 1952.) Description of an instrument which plots magnetization curves and major and minor hysteresis loops of ring and bar samples on standard coordinate paper.

621.317.7:537.311.33:621.315.592 3175
Apparatus for Electrical Measurements on Semi-conductors—H. K. Henisch and J. Ewels. (*Research* (London), vol. 5, pp. 235–237; May, 1952.) Description of apparatus facilitating measurements over a wide temperature range and in controlled gas atmospheres; it is intended mainly for dc operation. Experiments have been made on Se, Ge and TiO_2; typical results are given.

621.317.715 3176
Integrating and Other Galvanometers—A. H. Bebb. (*Jour. Sci. Instr.*, vol. 29, pp. 105–111; April, 1952.) The theory, design and construction are discussed of an integrating galvanometer with a free period of 80 seconds. The damping/control ratio is large enough to enable measurement of the change of flux through an exploring coil of considerable resistance connected in series, even though the

ux change may take several minutes. The nall degree of control is achieved by attaching magnetized needle to the upper end of a lass tube whose lower end is secured to the ıoving-coil system, the needle being located in n auxiliary field of opposite polarity to that f the needle. The effect of shunting the in- egrating galvanometer is examined and the ıeory confirmed experimentally.

21.317.723 — 3177

A Mechanically Astatized Leaf Electrometer—H. W. Lücking. (*Z. angew. Phys.*, vol. 4, p. 169–173; May, 1952.) The instrument described is some hundreds of times more sensitive than earlier types of leaf electrometer, as result of (*a*) the astatization, and (*b*) arranging the direction of electric force to coincide with the gravitational force. Both direct and f voltages can be measured.

21.317.725:621.318.572 — 3178

Anodige: a Discrete-Digit Voltage-Indicating Device—(*Tech. Bull. Nat. Bur. Stand.*, vol. 36, pp. 70–71; May, 1952.) Description of equipment which measures continuously variable voltages and indicates their values on a digital panel or records them on a strip of electro-sensitive paper. Essentially the instrument consists of an electronic counter which counts the number of equal increments of charge required to raise the terminal voltage of a capacitor up to the value of the unknown voltage. 400 readings per second are possible with the present model, but this can easily be increased.

621.317.729 — 3179

Electrolyte Tank with Automatic Recording of Equipotential Lines—H. Schmidl. (*Electrotech. u. Maschinenb.*, vol. 69, pp. 155–161; April 1, 1952.

621.317.733:621.316.8.011.6 — 3180

A Precision Bridge for Determination of Time Constants of Resistors for Measurement Apparatus—E. Blechschmidt. (*Elektrotechnik* (Berlin), vol. 6, pp. 199–202; May, 1952.) Description of a bridge, developed by G. Zickner at the German Office of Weights and Measures, for measurement of the time constants of resistors in the range 1Ω–100kΩ. The phase shift due to the time constant of the resistor under test is compensated by means of a special capacitor in parallel with one arm. The actual evaluation of the time constant is effected by a substitution method, stretched twin wires, screened or unscreened, serving as time-constant standards for resistance values up to 10kΩ, and screened carbon-film resistors for values from 10kΩ to 100kΩ.

621.317.75.029.4 — 3181

Applications of the Muirhead-Pametrada Wave Analyser Type D-489: Part 1—Aircraft-Engine Research—B. D. Banks. (*Muirhead Technique*, vol. 6, pp. 11–14; April, 1952.) An instrument of the tuned-filter type for measuring amplitude and frequency of any component of a complex wave. Frequency range is 19 cps–21 kc. Percentage frequency accuracy is high and constant at all frequencies. In vibration measurements described, a resistance strain gauge or moving-coil pickup is used.

621.317.75.029.42 — 3182

Adapting the Wave Analyser for Very-Low-Frequency Measurements—(*Muirhead Technique*, vol. 6, pp. 15–16; April, 1952.) Description of a mains-operated ring-modulator unit extending the range of the Type D-489 analyzer (3181 above) down to 2 cps. A RC filter in a selective feedback circuit provides 40-db attenuation above 100 cps for suppressing unwanted frequencies.

621.317.755:531.765 — 3183

Circular-Sweep Chronograph for Single Millisecond Time Intervals—A. Linz, Jr. (*Rev. Sci. Instr.*, vol. 23, pp. 199–203; May, 1952.) Description, with circuit details, of equipment comprising (*a*) a scaling-circuit interval timer driven by a 100-kc frequency standard, and (*b*) a cro with a 10-μs circular sweep driven from the same standard. The scaling circuit measures the interval between two electrical signals to within 10 μs, readings on the cro being used for interpolation to within 10 mμs. Suitable pulse-sharpening circuits and a high-speed gate circuit are also described.

621.317.755:621.314.7.012 — 3184

Display of Transistor Characteristics on the Cathode-Ray Oscillograph—G. B. B. Chaplin. (*Jour. Sci. Instr.*, vol. 29, pp. 142–145; May, 1952.) Pulse and step waves are generated and applied to the grids of two cathode-follower circuits, the outputs from which are fed to the appropriate transistor electrodes. Any of the following families of characteristics can then be displayed: (*a*) I_e against V_c or V_e, with I_c as parameter; (*b*) I_c against V_c or V_e, with I_e as parameter, where *e* and *c* denote emitter and collector respectively. The equipment is designed for testing *n*-type transistors; the modifications necessary for *p*-type transistors are indicated.

621.317.78.029.64 — 3185

Arrangement for the Measurement of High Powers at Microwave Frequencies—S. Giustini and R. Tozzi. (*Alta Frequenza*, vol. 21, pp. 67–76; April, 1952.) Description of a calorimetric arrangement which has practically no energy losses and has a measurement range up to some hundreds of watts with an error <6 per cent.

621.317.79+621.396.933.23 — 3186

Airborne Receivers and Test Gear for Instrument Landing Systems—Overbury. (See 3098.)

621.317 — 3187

Electrical Measurements. [Book Review]—F. K. Harris. Publishers: J. Wiley & Sons, New York, 784 pp., $8.00. (*Tech. Bull. Nat. Bur. Stand.*, vol. 36, p. 79; May, 1952.) Basic instrument theory is thoroughly discussed, and direct-current and low-frequency measurements are covered in detail."

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

531.719.33 — 3188

The F.R.B. Servo-Gauge—Bonhomme and Droin. (*Électronique* (Paris), no. 66, pp. 30–35; May, 1952.) Equipment is described for measuring the depth of liquids and signaling the result to a remote point. The principle of operation is to arrange just above and just below the surface of the liquid a pair of "feelers" attached to a vertical metal strip which is driven up or down by a servomechanism according as the liquid level rises or falls.

534.321.9:539.32 — 3189

A Simple Method for Measurement of Elastic Constants, using Ultrasonic Pulses—A. Lutsch. (*Z. angew. Phys.*, vol. 4, pp. 166–168; May, 1952.) The velocities of waves propagated longitudinally and transversely in a medium are determined in a single operation. The piezoelectric generator/detector is of the type used for nondestructive testing, and the cro display is self-calibrated.

534.321.9:672.8 — 3190

Cleaning Work with the Aid of Ultrasonic Vibration—C. R. Fay. (*Machinery*, London), vol. 80, pp. 853–855; May 15, 1952.) Description of a machine in which small metal parts are cleaned by ultrasonic agitation of a solution in which they are immersed. A quartz resonator with a natural frequency of 750 kc is used.

621-57:621.318 — 3191

Magnetic-Powder Clutch—O. Grebe. (*Electrotech. Z.*, vol. 73, pp. 281–284; May 1, 1952.) Discussion of operating torque characteristics and description of typical equipment made by Elektro-Mechanik G.m.b.H.

621.316.7 — 3192

Control Technique—(*Elektrotech. Z.*, vol. 73, pp. 181–251; April 1, 1952.) A symposium of papers dealing with numerous aspects and applications of electrical control equipment.

621.365.54† — 3193

Equipment for Inductive Surface Hardening—K. Kegel. (*Z. Ver. dtsch. Ing.*, vol. 94, pp. 331–338; April 21, 1952.) Review of general-purpose and special-purpose equipment and discussion of power requirements for specified hardening depths.

621.365.54/.55† — 3194

Radio-Frequency Heating—(*Brown Boveri Rev.*, vol. 38, pp. 315–371; November, 1951.) A collection of papers describing equipment for, and methods and applications of rf heating.

621.38:529.78 — 3195

Applications of Electronics to the Control of the Rate of Watches and Clockwork Movements—J. Dusailly. (*Électronique* (Paris), no. 67, pp. 10–15; June, 1952.) Description of equipment giving a record on a paper band of the rate of a watch or clock movement relative to a standard frequency derived from a quartz-crystal oscillator. Each tick of the watch serves to initiate a hv spark which perforates and blackens the paper.

621.383.001.8 — 3196

Amplification of Light-Intensity Fluctuations by means of Photoconductive Cells—M. Ploke. (*Funk u. Ton*, vol. 6, pp. 305–310; June, 1952.) Discussion of the use of PbS and CdS photocells, which have definite advantages over Se and Tl cells as regards sensitivity.

621.384.611.2† — 3197

Synchrotron—Please note that 621.364.612 will be used in future for synchrotrons in place of 621.384.611.2† used hitherto.

621.384.612:621.311.6 — 3198

The Bevatron Power Plant—J. V. Kresser. (*Elec. Eng.* (N. Y.), vol. 71, pp. 338–343; April, 1952.) Description of the power-supply arrangements for the bevatron at the University of California.

621.384.62 — 3199

Expression for the Electromagnetic Field in Linear Ion Accelerators—M. Bernard. (*Compt. Rend. Acad. Sci.* (Paris), vol. 234, pp. 1862–1865; May 5, 1952.) A solution of Maxwell's equations is obtained for a semi-infinite cylinder excited by application of a difference of potential between the cylinder and a metal diaphragm across its end.

621.384.62 — 3200

Numerical Calculation of the Electromagnetic Field in Linear Ion Accelerators—M. Bernard. (*Compt. Rend. Acad. Sci.* (Paris), vol. 234, pp. 2175–2178; May 26, 1952.) The series previously given for the field are in general difficult to evaluate numerically. Simple approximate formulas for the field on the axis are derived.

621.384.62 — 3201

Application of the W.B.K. Method to the Dynamics of Linear Accelerators—M. Hoyaux. (*Rev. Sci. Instr.*, vol. 23, pp. 173–175; April, 1952.) The dynamics of "small motions" in a linear accelerator is studied for conditions as general as possible. It is concluded that heavy particles cannot be accelerated up to the 10^9-ev range by any practical combination of TM and/or TE traveling and/or stationary waves. Several methods are, however, possible for electrons.

621.385.833 — 3202

An Approximation Method for the Sinuous Trajectories of Highly Convergent [electron]

Lenses—F. Bertein. (*Jour. Phys. Radium*, vol. 13, p. 309; May, 1952.)

621.385.833 3203
Study of an Electron Lens by the W.K.B. Method—C. Muscia. (*R.C. Accad. naz. Lincei*, vol. 12, pp. 575–582; May, 1952.)

621.385.833 3204
Electronoptical Velocity Filters—M. Schiekel. (*Optik*, vol. 9, no. 4, pp. 145–153; 1952.) Chromatic aberration in the electron microscope can be reduced by use of a unipotential lens with a negative middle electrode as a velocity filter for the electrons scattered inelastically at the object. The image-forming properties of such filters are calculated for different potential distributions. The optimum resolving power is 110Å.

621.385.833:061.3 3205
The Fourth Annual Convention of the German Association for Electron Microscopy, Tübingen, 6th–8th June 1952—(*Optik*, vol. 9, no. 4, pp. 189–192; 1952.) Titles are given of all the papers presented.

621.385.833:061.3 3206
Report of Conferences on Electron Microscopy, Washington and Philadelphia 1951—V. E. Cosslett. (*Brit. Jour. Appl. Phys.*, vol. 3, pp. 137–139; May, 1952.)

621.387.4(083.72) 3207
Standards on Gas-Filled Radiation Counter Tubes: Definitions of Terms, 1952—(Proc. I.R.E., vol. 40, pp. 924–926; August, 1952.)

621.387.4(083.74) 3208
Standards on Gas-Filled Radiation Counter Tubes: Methods of Testing, 1952—(Proc. I.R.E., vol. 40, pp. 926–930; August, 1952.)

621.387.422:621.385.2 3209
Performance of Pulsed Photomultipliers—R. F. Post. (*Nucleonics*, vol. 10, pp. 46–50; May, 1952.) Report of investigations on selected type 931A and type 1P21 tubes fed with pulses of duration up to 3μs, the applied voltages corresponding to peak secondary emission with total amplification up to 10^9. Short resolving times are obtained. Time dispersion effects are estimated.

621.387.424 3210
Geiger-Müller Counters—N. Warmoltz. (*Philips Tech. Rev.*, vol. 13, pp. 282–292; April, 1952.) The different possible ways of operating gas-filled tubes as counters of ionizing particles are discussed, and descriptions are given of recently developed types of G-M counter, the importance of the quenching gas being emphasized.

621.387.462:549.211 3211
The Texture of Diamonds used for Counting α, β or γ Particles as found from Divergent-Beam X-Ray Photographs—H. J. Grenville-Wells. (*Proc. Phys. Soc.* (London), vol. 65, pp. 313–320; May 1, 1952.)

PROPAGATION OF WAVES

621.396.11:523.4 3212
Planetary Position Effect on Short-Wave Signal Quality—J. H. Nelson. (*Elec. Eng.*, (N. Y.), vol. 71, pp. 421–424; May, 1952.) A.I.E.E. Winter General Meeting paper, January, 1952. Investigations extending over seven years indicate distinct correlation between the fading of sw transatlantic radio signals and certain planetary configurations in which the heliocentric angles differ by multiples of 90°. Typical configurations which were accompanied by severe fading are shown. A forecasting system based on planetary indications, solar observations and day-to-day signal analysis has given good service throughout 1950 and 1951. See also of 1997 of 1951.

621.396.11:550.38 3213
Some Aspects of the Average Monthly Radio Propagation Conditions of the Circuit New York-Amsterdam during the Last Three Years, and their Relation with the Average Monthly Geomagnetic Activity and the Maximum Usable Frequency—B. van Dijl and D. van Sabben. (*Tijdschr. ned. Radiogenoot.*, vol. 17, pp. 135–137; May, 1952.) Correlation is sought between graphs showing the mean monthly values from October 1949 to April 1952 of (*a*) the percentage of hours lost, (*b*) the percentage of hours during which the *K* index (at Witteveen) had a value of 4 or more, and (*c*) the lowest daily value of muf. According as the muf value is low or high, the number of hours lost is higher or lower than would be expected from the geomagnetic activity. It is noted that magnetic activity increased throughout the period, though the sunspot maximum occurred 4–5 years before.

621.396.11:621.317.353.3 3214
Resonance in Gyro-interaction of Radio Waves—V. A. Bailey, R. A. Smith, K. Landecker, A. J. Higgs and F. H. Hibberd. (*Nature* (London) vol. 169, pp. 911–913; May 31, 1952.) Experiments carried out in Australia during the past two years are described which have completely confirmed Bailey's theoretical predictions (2437 of 1937 and 9 of 1939). The gyro-wave *A* was radiated vertically from a horizontal antenna at Armidale, New South Wales, and the wanted wave *B* was radiated from Brisbane, Queensland, on 590 kcs with a power of 10 kw. The principal observations of *B* were made at Katoomba, New South Wales, Armidale being very nearly at the mid-point of the 740-km path from Brisbane to Katoomba. The pulse power of *A* was about 36 kw, frequencies from 1255 to 1880 kc being used, the estimated gyro-frequency being about 1530 kc. The results show that a notable degree of resonance occurs as the frequency of the disturbing wave *A* passes through the gyro-frequency. Both double-humped and single-humped resonance curves were obtained. A detailed report of the investigations is to be published elsewhere.

621.396.11.029.55 3215
New Propagation Forecasts from WWV—(*QST*, vol. 36, p. 19; June, 1952.) From 1st July 1952, forecasts of sw radio disturbances will be broadcast from WWV on the standard frequencies 2.5, 5, 10, 15, 20 and 25 mc). The forecasts are prepared four times daily, and are transmitted in code at 19.5 and 49.5 minutes past each hour. The letters N, V, W denote respectively the existing normal, unsettled, or disturbed conditions. The following number indicates on the N.B.S. scale the expected quality of future reception, 1 representing "impossible" and 9 "excellent." The forecasts refer only to North Atlantic paths, such as Washington to London or New York to Berlin.

621.396.11.029.62/.64 3216
Transmission beyond the Horizon at Frequencies between 40 and 4000 Mc/s—(*Bell Lab. Rec.*, vol. 30, pp. 245–246; June, 1952.) A short account of experimental results which show that the power received at points beyond the horizon is substantially independent of frequency, antenna height, and weather effects, and that the signal strength decreases much more slowly with increase of distance than the rapid decrease predicted from the classical smooth-earth theory. A fuller report is to be published.

621.396.11.029.62 3217
The Propagation of Ultrashort Waves beyond the Horizon, with Particular Reference to the Meteorological Influences—B. Abild, H. Wensien, E. Arnold and W. Schikorski. (*Tech. Hausmitt. NordwDtsch. Rdfunks*, vol. 4, pp. 85–100; May/June, 1952.) A study is made of the meteorological conditions in western Germany causing ultrashort waves to be propagated to abnormally great distances; both mean values and detailed variation of field strength are examined. Predictions from theory are compared with results of measurements recorded at a number of receiving stations. Previous investigations, e.g. 2580 of October (Abild), have indicated that field-strength fluctuations depend mainly on vapor pressure and temperature in the lower troposphere. Probable secondary influences are turbulence in the lower atmosphere and variations of the state of the ground.

621.396.11.029.64(442.6/.8) 3218
Study of the Propagation of Centimetre Waves in Northern France—P. Chavance. (*Ann. Télécommun.*, vol. 7, pp. 254–261; June, 1952.) An account of investigations on wavelengths of 9.5 and 3.2 cm, using equipment described previously [3115 of 1951 (Maillard, Voge and Chavance)]. The aim was to obtain statistical information on propagation over a 76-km path with insufficient ground clearance. Seasonal and diurnal effects on signal strength and fading are shown graphically and discussed and records of typical fading effects are displayed and analyzed.

621.396.81 3219
Interpretation of High-Frequency C.W. Field-Intensity Records with the Aid of Simultaneous Pulse Data—R. Silberstein. Proc. I.R.E., vol. 40, pp. 974–976; August, 1952.)

RECEPTION

621.396.62:061.4 3220
Radio at the Paris Fair—(*TSF et TV*, vol. 28, pp. 187–189; June, 1952.) Comment on the exhibits and classification of 133 receivers shown.

621.396.621(083.74)(44) 3221
French Standard C92-120 on Battery-Operated Receivers—Radionyme. (*Toute la Radio*, pp. 193–195; June, 1952.) Analysis of the specifications for receivers of different types, with an outline of test methods for sensitivity, selectivity, distortion, etc.

621.396.8+621.396.1 3222
Reception of Broadcasting from all over the World—Lhombreaud. (See 3228.)

621.396.97:621.396.823:351.819 (44) 3223
The New French Regulations for the Protection of Broadcasting against Interference of Industrial Origin—M. Adam. (*Rev. gén. Élect.*, vol. 36, pp. 197–200; April, 1952.) Maximum permissible interfering voltages are specified for the long-, medium- and short-wave bands respectively. Methods of measuring such voltages are indicated. Apparatus must be fitted with suppressor devices before being offered for sale.

STATIONS AND COMMUNICATION SYSTEMS

621.39.001.11 3224
Basic Communication Theory—L. S. Schwartz. (*Radio & Telev. News, Radio-Electronic Eng. Section*, vol. 47, pp. 3–5, 28–30 and 11–13; June and July, 1952.) A non-mathematical presentation of the theory developed by Shannon, Wiener and others.

621.39.001.11:519.21 3225
Convexity and Information—R. Féron. *Compt. Rend. Acad. Sci.* (Paris), vol. 234, pp. 1840–1841; May 5, 1952.) Proof is given that the necessary and sufficient condition that the gain of information should not be negative for any pair *XY* of aleatory variables is that a certain function of the distribution function of *Y* should be a concave function.

621.396.029.6 3226
Radio Communication on Short Waves—H. Köppen. (*NachrTech.*, vol. 2, pp. 136–139; May, 1952.) A short review of present-day

technical developments in communication on m, dm and cm waves, and of recent investigations of the practicability of using wavelengths in the range 25–100 m for communication in mines.

621.396.1 3227
Wavelength Problems in Telephony and Television Broadcasting—G. Pedersen. (*Teleteknik, Copenhagen*, vol. 3, pp. 49–60; May, 1952.) An outline is given of the principles governing the international allocation of wavelengths. The heavy bandwidth demands of television are discussed with special reference to the plans for television in Denmark.

621.396.1:621.396.8 3228
Reception of Broadcasting from all over the World—C. Lhombreaud. (*TSF et TV*, vol. 28, pp. *Doc. tech.* 1–3; April, 1952.) Report of a survey made in the light of the Copenhagen frequency allocation. This article is the first of a series giving station operating details and an indication of the quality of reception near Bordeaux, starting with European stations.

621.396.4.029.53 3229
Microwave Systems for 960 and 2000 Mc/s—R. V. Rector and W. E. Sutter. *Trans. Amer. IEE*, vol. 69, part II, pp. 1100–1108; 1950. Discussion, pp. 1108–1109.) In the 2-kmc transmitter, 2–5 w output is obtained from a type-SRL-7c klystron rated at 10 w. Good frequency stability is obtained by accurate voltage and temperature control. Pulse-duration modulation is used and 24 channels are provided, each of which can give 18 two-way control channels. The 960-mc transmitter provides 7 channels, each giving either two-way voice communication or 18 two-way control channels. Block diagrams of both equipments are given, with description and illustrations.

621.396.619.16 3230
A System of Pulse-Code Modulation using Circulated Pulses—S. Fedida. (*Electronic Eng.*, vol. 24, pp. 356–361; August, 1952.) A method is described for converting sample pulses into sequences of up to five on/off pulses which, when interpreted as digits in a binary system of units, reproduce the original information represented by the sample pulses. Two possible methods of decoding to derive the original within a prescribed tolerance are outlined.

621.396.619.16:621.396.4 3231
Nonsynchronous Pulse Multiplex System—A. L. Hopper. (*Electronics*, vol. 25, pp. 116–120; August, 1952.) An experimental time-sharing multiplex system is described in which the inputs to the different transmitters are converted to pam by sampling with random pulses, these AM pulses being converted to equal and opposite pulse pairs separated by a constant delay whose value is selected by means of a switch. This delay constitutes the identifying characteristic at the receiver. The system can be used for rural radiotelephony and for communication between moving vehicles. It has the disadvantage that it is not economical of channel capacity, and would probably be useful for the transmission of intelligence rather than high-quality speech.

621.396.619.16:621.396.41 3232
Electronic Pulse Systems for Telegraphy—G. Montessori. (*Alta Frequenza*, vol. 21, pp. 77–101; April, 1952.) Synchronization, regeneration and channel separation are provided electronically in a time-division multiplex telegraphy system using ring distributors controlled by a frequency-stabilized pulse generator, the synchronizing signal being produced by modifying the regular pulse rhythm. The system has been used by the Italcable Co. for high-speed telegraphy.

621.396.651:621.396.43 3233
Multiple-Channel Telephony on U.H.F. Radio Links—B. R. Tupper and P. B. Patton. (Proc. I.R.E., vol. 40, pp. 913–916; August, 1952.)

621.396.65:621.396.43 3234
Design Fundamentals for Beam Radio Systems—H. Werrmann. (*Funk u. Ton*, vol. 6, pp. 281–297; June, 1952. Correction, *ibid.*, vol. 6, p. 380; July, 1952.) Discussion of the various factors which must be taken into account, including effects of normal attenuation, ground proximity and operation beyond the optical range, antenna aperture and gain, interference and system noise, and the type of modulation to be used.

621.396.65.029.6:621.316.925:621.311.1 3235
Protective Relaying Systems using Microwave Channels—H. W. Lensner. (*Elec. Eng.* (N. Y.), vol. 71, pp. 400–405; May, 1952.) A.I.E.E. Winter General Meeting paper, January, 1952. Several practical applications in power systems are outlined.

621.396.65.029.63:[621.396.5+621.317.083.7 3236
Microwave Radio Links of Bonneville Power Administration—S. Metzger, N. H. Gottfried and R. W. Hughes. (*Elec. Commun.*, vol. 29, pp. 87–92; June, 1952.) Description of the FTL-10B 23-channel system now in operation. See also 1777 of 1951 (Stevens and Stringfield).

621.396.72.029.62 3237
The Inauguration of F8 REF—J. Ferré. (*Radio franç.*, no. 5, p. 15; May, 1952.) Note of sw R/T transmissions to be made twice weekly from a central station for the benefit of French amateurs.

621.396.8.029.53 3238
Medium-Wave Broadcasting Coverage in the NWDR Area—G. Paulsen. (*Tech. Hausmitt. NordwDtsch. Rdfunks*, vol. 4, pp. 101–110; May/June, 1952. Correction, *ibid.*, vol. 4, p. 141; July/August, 1952.) A résumé is given of the theory of radio wave propagation and of transmission requirements for a satisfactory broadcasting service. Interference between transmissions on (*a*) common channels and (*b*) adjacent channels is discussed and the limiting values adopted by the NWDR for the ratio between wanted and unwanted signals in various cases are shown graphically. The principles of system planning to cover the greatest possible fraction of the population are discussed in relation to the area; about 70 per cent of the population is adequately served. The complementary uses of medium-wave and usw services are indicated.

621.39.001.11 3239
La Cybernétique-Théorie du Signal et de l'Information. [Book Review]—L. de Broglie (Ed.). Publishers: Editions de la Revue d'Optique Théorique et Instrumentale, 1951, 318 pp., 1600 fr. (*Brit. Jour. Appl. Phys.*, vol. 3, p. 133; April, 1952.) Papers presented at a conference at the Henri Poincaré Institute, Paris, 1950.

SUBSIDIARY APPARATUS

621-526:621.313.281 3240
Amplifying Dynamos: their Use in Servomechanisms—G. Lehmann. (*Bull. Soc. franç. Élect.*, vol. 2, pp. 198–209; April, 1952.)

621.314.632:546.289 3241
The New G-10 Germanium Dot Rectifier—T. J. Ferguson. (*Radio & Telev. News*, vol. 47, pp. 42–43; June, 1952.) Description and some performance figures of a rectifier unit suitable for supplying power to radio and television equipment. The G-10 is a series combination of two "button" rectifiers each consisting of a pellet of spectroscopically pure Ge, $\frac{1}{8}$-inch square, placed at the center of a metal dish sealed with butyl rubber and mounted on a 2-inch-diameter metal cooling fin. Units are selected to ensure equal division of peak back voltage across the two associated rectifiers.

621.314.634.012 3242
Static and Dynamic Characteristic Curves for Selenium Rectifiers—I. Somos. (*Elektrotechnika* (Budapest), vol. 45, pp. 154–159; May, 1952.) Methods of measurement are described which give reproducible results.

621.316.722.1:621.326 3243
Incandescent Lamp Bulbs in Voltage Stabilizers—W. J. Cunningham. (*Jour. Appl. Phys.*, vol. 23, pp. 658–662; June, 1952.) An approximate analysis is made of the operation of lamps used as sources of reference voltage in ac stabilizers. The equivalent-circuit theory developed in 3026 above is used to determine the distortion due to the nonlinearity of the lamp I/V characteristic. The effects of changes of frequency and current are demonstrated.

621.316.93 3244
Lightning Protection since Franklin's Day—K. B. McEachron. (*Jour. Frank. Inst.*, vol. 253, pp. 441–470; May, 1952.) Historical account of the development of the various types of protective device in use today. 46 references.

TELEVISION AND PHOTOTELEGRAPHY

621.397.5 3245
Optimum Number of Lines and Screen Dimensions—P. Stroobants. (*Télévision*, no. 23, pp. 113–117; May, 1952.) The lowest number of scanning lines N consistent with invisibility of line structure in the television image is expressed in terms of the angular resolution of the eye and the ratio between the viewing distance (as selected naturally by average viewers) and the screen height h. Based on subjective judgments, curves are plotted showing the variation of N with h for 95 per cent and for 100 per cent observer satisfaction. By reference to these curves line standards of 625, 819 and >819 are shown to be appropriate respectively for receivers with screen diameters up to 22 cm, between 22 and 40 cm, and over 40 cm.

621.397.5:061.3(431.55) 3246
Berlin Television Conference—(*Funk u. Ton*, vol. 6, pp. 258–264; May, 1952.) Summaries are given of papers presented at the conference arranged by the Berlin-Charlottenburg Technical University, March 1952.

621.397.5:535.623 3247
Requisite Color Bandwidth for Simultaneous Color-Television Systems—K. McIlwain. (Proc. I.R.E., vol. 40, pp. 909–912; August, 1952.) Report of subjective tests, using both skilled and lay observers, to determine how far bandwidth can be reduced before picture reproduction becomes unsatisfactory. Under the particular test conditions described a band about 1 mc wide is sufficient for most color transmissions, provided a further band 4 mc wide is available for transmitting the brightness detail.

621.397.5:535.88:791.45 3248
A Direct-Projection System for Theater Television—F. N. Gillette. (*Jour. Soc. Mot. Pic. Telev. Eng.*, vol. 58, pp. 385–396; May, 1952.) General description of the Simplex Model PB-600 for projecting a full-size television picture on a theatre screen. The system combines simplicity in installation, convenience in maintenance and reliability in operation.

621.397.5:621.396.712 3249
The Lime Grove Television Studios of the British Broadcasting Corporation—(*Engineer-*

noulli's method, the root-squaring method and the Newton-Raphson method. Quadratically convergent methods are found preferable to those less rapidly convergent. Examples are given.

681.142:621.3.042.143 3156
Static Magnetic Matrix Memory and Switching Circuits—J. A. Rajchman. (*RCA Rev.*, vol. 13, pp. 183–201; June, 1952.) Description of recent developments in this type of memory device. See also 2258 of September (Papian).

MEASUREMENTS AND TEST GEAR

531.76:621.3.015.7 3157
The Use of a Pulse-Height Analyzer for Time-Interval Measurements—G. Jenssen and A. Sunde. (*Physica*, vol. 18, pp. 265–269; April, 1952.) Description of an instrument adapted from the pulse-height analyzer of Elmore and Sands (2007 of 1950).

531.764.5 3158
Development of a Clock whose Rate is Accurately the Arithmetic Mean of the Rates of Several Clocks—B. Decaux, J. Lucas and V. Yanouchevsky. (*Compt. Rend. Acad. Sci.*, (Paris), vol. 234, pp. 2164–2165; May 26, 1952.) Description of a method particularly applicable to quartz clocks. By a process of simple frequency mixing and division, a frequency is derived which is the exact arithmetic mean of the fundamental 100-kc nominal frequencies of several clocks, or of nominal frequencies of 1 kc derived by frequency division. In the latter case a synchronous motor can then be used to drive mechanism for recording the mean time or operating seconds contacts.

621.317.2(44):621.317.361 3159
Recent Developments in the Frequency-Measurement Department of the Laboratoire National de Radioélectricité—B. Decaux. (*Onde élect.*, vol. 32, pp. 219–231; June, 1952.) An outline is given of the organization of the department and of its functions, with descriptions of the measurement equipment, including the standard oscillators (installed underground), frequency meters up to 4 kmc, synchronous recording drums, beat-frequency counters, etc. A new microwave meter is to range up to 12 kmc.

621.317.3:621.396.611.21 3160
Measurement of the Parameters of a Quartz Crystal. Use of the Two-Circle Abac—J. Coulon. (*Compt. Rend. Acad. Sci.*, (Paris), vol. 234, pp. 1965–1968; May 12, 1952.) Discussion of the application of an orthogonal system of circles to the determination of crystal parameters. See also 2549 and 2550 of October.

621.317.3:621.396.822 3161
Characteristics of Noises and Noise Voltages—H. Bittel. (*Z. angew. Phys.*, vol. 4, pp. 137–146; April, 1952.) The frequency spectrum of a noise voltage often gives insufficient data on the character of the noise; a knowledge of the statistical amplitude distribution is required. In many practical cases this distribution is Gaussian. Deviations are due to non-overlapping of the voltage pulses; the frequency characteristic of the transmission system may contribute to this. The effect of the amplitude distribution on the rectification process is analyzed and measurement apparatus is described. For resistance and tube noise a Gaussian distribution is confirmed experimentally.

621.317.3.017.143:621.396.611.4 3162
An Approximate Theory of the Cavity-Resonator Method of Determining the Dielectric Loss of Solids at Microwave Frequencies—S. K. Chatterjee. (*Jour. Indian Inst. Sci.*, vol. 34, pp. 43–49; April, 1952.) The field equations for a cylindrical cavity resonator and the perturbation formula due to Bethe and Schwinger are applied to the calculation of the real and imaginary parts of the generalized dielectric constant of a small sample of solid dielectric rod introduced into the resonator. The loaded Q of the cavity is determined from the field equations and the Poynting vector.

621.317.3.029.5/.6 3163
High-Frequency Measurement Technique—W. Druey. (*Tech. Mitt. schweiz. Telegr.-Teleph Verw.*, vol. 30, pp. 50–56; February 1, 1952. In German.) Reprint. See 1954 of August.

621.317.32:537.221 3164
Measurement of the Volta Effect—R. Boution. (*Ann. Phys.*, (Paris), vol. 7, pp. 360–395; May/June, 1952.) Investigation of the sources of error in contact-potential measurements resulted in the development of a reliable method, a detailed account of which is given, including a description of the technique for obtaining the very high vacuum necessary to obtain consistent results. Values obtained for the contact emf for a layer of Cu condensed on a W wire are discussed in relation to results published by other investigators. See also 1885 of August.

621.317.331.029.51:621.316.993 3165
The Value of H.F. Measurements on Lightning-Protection Earths—W. Bulla. (*Elektrotech. u. Maschinenb.*, vol. 69, pp. 140–146; March 15, 1952.) Discussion indicates that hf measurements on earthing systems supply little additional information to that furnished by measurements with a lf bridge.

621.317.335.3:518.4 3166
The Computation of Dielectric Constants—R. M. Redheffer, R. C. Wildman and V. O'Gorman. (*Jour. Appl. Phys.*, vol. 23, pp. 505–508; May, 1952.) Charts are provided which enable the complex dielectric constant to be determined for any type of sample from measurements by the shorted-line method.

621.317.335.3:621.316.726 3167
A Frequency Stabilization System for Microwave Gas Dielectric Measurements—W. F. Gabriel. (PROC. I.R.E., vol. 40, pp. 940–945; August, 1952.) In a method based on observing the shift of resonance frequency of a cavity when filled with the gas, the frequency of the klystron oscillator used is automatically controlled by means of a double-loop servo system. One loop is of the type described by Pound (1311 of 1948) and the other of the type described by Rideout (276 of 1948). The value of $(n-1)$, where n is the refractive index, can be obtained accurate to three or four significant figures.

621.317.336:621.315.212 3168
The Sweep-Frequency Response of RG-6U [cable]—W. T. Blackband. (PROC. I.R.E., vol. 40, pp. 995–996; August, 1952.) A discussion of the causes of frequency dependence and irregularity of the measured characteristic impedance noted by Alsberg (728 of April).

621.317.34:621.315.212 3169
Measurement of the Attenuation and Characteristic Impedance of Transmission Lines. Tests on Coaxial Cables—P. Hontoy. (*HF*, (Brussels), vol. 2, no. 2, pp. 35–46; 1952.) A method of measurement applicable to all uniform line is described. If a line has a variable purely reactive termination, the locus, in the complex plane, of its input impedance is a circle whose position and radius are functions of the attenuation and characteristic impedance. The mathematical theory of the method makes use of the properties of certain transformations in the complex plane. The necessary formulas are established for the representation in cartesian coordinates and in Smith's diagram. Tests on coaxial cables for a very large range of frequencies gave attenuation values in good agreement with wattmeter measurements.

621.317.35.029.3 3170
Gated Amplifier Wave Analyzer—V. R. Nelson. (*Electronics*, vol. 24, pp. 136–139; August, 1952.) Description of an instrument giving a direct-reading quantitative indication of the spectral components of complex af waveforms. The waveform under test and gating pulses from a variable-frequency multivibrator are fed to an amplifier having in its output circuit a meter whose deflection varies as a function of the phase difference between the two inputs.

621.317.351:534.442.2 3171
Some Problems in Audio-Frequency Spectrum Analysis—S. V. Soanes. (*Electronic Eng.*, vol. 24, pp. 268–270 and 312–318; June and July, 1952.) Theory is presented for analyzers of the type using a fixed-frequency filter and a swept-frequency heterodyne oscillator. A description is given of a double-heterodyne analyzer for general laboratory use covering the working range 20 cps–20 kc; the useful range of input voltage is 1 mv–300 v, the sweep frequency is variable between 0.1 cps and 30 cps and the filter bandwidth is variable between 10 cps and 500 cps. The response is displayed on a long-persistence cr tube.

621.317.361 3172
A Recording Frequency Comparator—R. Walter and H. Voigt. (*Tech. Hausmitt. NordwDtsch. Rdfunks*, vol. 4, pp. 111–114; May/June, 1952.) A special heterodyne method is described in which a sawtooth oscillation of the one frequency is multiplicatively mixed in a pentode with pulses repeated at the other frequency; the resulting beat has a sawtooth form, enabling the direction of frequency deviation to be recognized immediately. A practical arrangement is illustrated in which several oscillators can be compared simultaneously with the same reference oscillator, the results being recorded on a single paper-strip chart.

621.317.361.029.6 3173
Frequency Measurement in the Microwave Range—B. Koch. (*Arch. tech. Messen*, no. 196, pp. 111–116; May, 1952.) Review of different methods and apparatus, including wavemeter methods, direct heterodyne methods and others involving frequency multiplication. A list of 64 NH_3 absorption lines between 19 and 40 kmc is given. 47 references.

621.317.444.087 3174
A Recording Fluxmeter of High Accuracy and Sensitivity—P. P. Cioffi. (*Bell Lab. Rec.*, vol. 30, pp. 247–251; June, 1952.) Description of an instrument which plots magnetization curves and major and minor hysteresis loops of ring and bar samples on standard coordinate paper.

621.317.7:537.311.33:621.315.592 3175
Apparatus for Electrical Measurements on Semi-conductors—H. K. Henisch and J. Ewels. (*Research* (London), vol. 5, pp. 235–237; May, 1952.) Description of apparatus facilitating measurements over a wide temperature range and in controlled gas atmospheres; it is intended mainly for dc operation. Experiments have been made on Se, Ge and TiO_2; typical results are given.

621.317.715 3176
Integrating and Other Galvanometers—A. H. Bebb. (*Jour. Sci. Instr.*, vol. 29, pp. 105–111; April, 1952.) The theory, design and construction are discussed of an integrating galvanometer with a free period of 80 seconds. The damping/control ratio is large enough to enable measurement of the change of flux through an exploring coil of considerable resistance connected in series, even though the

flux change may take several minutes. The small degree of control is achieved by attaching a magnetized needle to the upper end of a glass tube whose lower end is secured to the moving-coil system, the needle being located in an auxiliary field of opposite polarity to that of the needle. The effect of shunting the integrating galvanometer is examined and the theory confirmed experimentally.

621.317.723 3177
A Mechanically Astatized Leaf Electrometer—H. W. Lücking. (*Z. angew. Phys.*, vol. 4, pp. 169–173; May, 1952.) The instrument described is some hundreds of times more sensitive than earlier types of leaf electrometer, as a result of (*a*) the astatization, and (*b*) arranging the direction of electric force to coincide with the gravitational force. Both direct and hf voltages can be measured.

621.317.725:621.318.572 3178
Anodige: a Discrete-Digit Voltage-Indicating Device—(*Tech. Bull. Nat. Bur. Stand.*, vol. 36, pp. 70–71; May, 1952.) Description of equipment which measures continuously variable voltages and indicates their values on a digital panel or records them on a strip of electro-sensitive paper. Essentially the instrument consists of an electronic counter which counts the number of equal increments of charge required to raise the terminal voltage of a capacitor up to the value of the unknown voltage. 400 readings per second are possible with the present model, but this can easily be increased.

621.317.729 3179
Electrolyte Tank with Automatic Recording of Equipotential Lines—H. Schmidl. (*Electrotech. u. Maschinenb.*, vol. 69, pp. 155–161; April 1, 1952.

621.317.733:621.316.8.011.6 3180
A Precision Bridge for Determination of Time Constants of Resistors for Measurement Apparatus—E. Blechschmidt. (*Elektrotechnik* (Berlin), vol. 6, pp. 199–202; May, 1952.) Description of a bridge, developed by G. Zickner at the German Office of Weights and Measures, for measurement of the time constants of resistors in the range 1Ω–100kΩ. The phase shift due to the time constant of the resistor under test is compensated by means of a special capacitor in parallel with one arm. The actual evaluation of the time constant is effected by a substitution method, stretched twin wires, screened or unscreened, serving as time-constant standards for resistance values up to 10kΩ, and screened carbon-film resistors for values from 10kΩ to 100kΩ.

621.317.75.029.4 3181
Applications of the Muirhead-Pametrada Wave Analyser Type D-489: Part 1—Aircraft-Engine Research—B. D. Banks. (*Muirhead Technique*, vol. 6, pp. 11–14; April, 1952.) An instrument of the tuned-filter type for measuring amplitude and frequency of any component of a complex wave. Frequency range is 19 cps–21 kc. Percentage frequency accuracy is high and constant at all frequencies. In vibration measurements described, a resistance strain gauge or moving-coil pickup is used.

621.317.75.029.42 3182
Adapting the Wave Analyser for Very-Low-Frequency Measurements—(*Muirhead Technique*, vol. 6, pp. 15–16; April, 1952.) Description of a mains-operated ring-modulator unit extending the range of the Type D-489 analyzer (3181 above) down to 2 cps. A RC filter in a selective feedback circuit provides 40-db attenuation above 100 cps for suppressing unwanted frequencies.

621.317.755:531.765 3183
Circular-Sweep Chronograph for Single Millisecond Time Intervals—A. Linz, Jr. (*Rev. Sci. Instr.*, vol. 23, pp. 199–203; May, 1952.) Description, with circuit details, of equipment comprising (*a*) a scaling-circuit interval timer driven by a 100-kc frequency standard, and (*b*) a cro with a 10-μs circular sweep driven from the same standard. The scaling circuit measures the interval between two electrical signals to within 10 μs, readings on the cro being used for interpolation to within 10 mμs. Suitable pulse-sharpening circuits and a high-speed gate circuit are also described.

621.317.755:621.314.7.012 3184
Display of Transistor Characteristics on the Cathode-Ray Oscillograph—G. B. B. Chaplin. (*Jour. Sci. Instr.*, vol. 29, pp. 142–145; May, 1952.) Pulse and step waves are generated and applied to the grids of two cathode-follower circuits, the outputs from which are fed to the appropriate transistor electrodes. Any of the following families of characteristics can then be displayed: (*a*) I_e against V_c or V_e, with I_c as parameter; (*b*) I_c against V_c or V_e, with I_e as parameter, where *e* and *c* denote emitter and collector respectively. The equipment is designed for testing *n*-type transistors; the modifications necessary for *p*-type transistors are indicated.

621.317.78.029.64 3185
Arrangement for the Measurement of High Powers at Microwave Frequencies—S. Giustini and R. Tozzi. (*Alta Frequenza*, vol. 21, pp. 67–76; April, 1952.) Description of a calorimetric arrangement which has practically no energy losses and has a measurement range up to some hundreds of watts with an error <6 per cent.

621.317.79+621.396.933.23 3186
Airborne Receivers and Test Gear for Instrument Landing Systems—Overbury. (See 3098.)

621.317 3187
Electrical Measurements. [Book Review]—F. K. Harris. Publishers: J. Wiley & Sons, New York, 784 pp., $8.00. (*Tech. Bull. Nat. Bur. Stand.*, vol. 36, p. 79; May, 1952.) Basic instrument theory is thoroughly discussed, and direct-current and low-frequency measurements are covered in detail."

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

531.719.33 3188
The F.R.B. Servo-Gauge—Bonhomme and Droin. (*Électronique* (Paris), no. 66, pp. 30–35; May, 1952.) Equipment is described for measuring the depth of liquids and signaling the result to a remote point. The principle of operation is to arrange just above and just below the surface of the liquid a pair of "feelers" attached to a vertical metal strip which is driven up or down by a servomechanism according as the liquid level rises or falls.

534.321.9:539.32 3189
A Simple Method for Measurement of Elastic Constants, using Ultrasonic Pulses—A. Lutsch. (*Z. angew. Phys.*, vol. 4, pp. 166–168; May, 1952.) The velocities of waves propagated longitudinally and transversely in a medium are determined in a single operation. The piezoelectric generator/detector is of the type used for nondestructive testing, and the cro display is self-calibrated.

534.321.9:672.8 3190
Cleaning Work with the Aid of Ultrasonic Vibration—C. R. Fay. (*Machinery*, London), vol. 80, pp. 853–855; May 15, 1952.) Description of a machine in which small metal parts are cleaned by ultrasonic agitation of a solution in which they are immersed. A quartz resonator with a natural frequency of 750 kc is used.

621-57:621.318 3191
Magnetic-Powder Clutch—O. Grebe. (*Elektrotech. Z.*, vol. 73, pp. 281–284; May 1, 1952.) Discussion of operating torque characteristics and description of typical equipment made by Elektro-Mechanik G.m.b.H.

621.316.7 3192
Control Technique—(*Elektrotech. Z.*, vol. 73, pp. 181–251; April 1, 1952.) A symposium of papers dealing with numerous aspects and applications of electrical control equipment.

621.365.54† 3193
Equipment for Inductive Surface Hardening—K. Kegel. (*Z. Ver. dtsch. Ing.*, vol. 94, pp. 331–338; April 21, 1952.) Review of general-purpose and special-purpose equipment and discussion of power requirements for specified hardening depths.

621.365.54/.55† 3194
Radio-Frequency Heating—(*Brown Boveri Rev.*, vol. 38, pp. 315–371; November, 1951.) A collection of papers describing equipment for, and methods and applications of rf heating.

621.38:529.78 3195
Applications of Electronics to the Control of the Rate of Watches and Clockwork Movements—J. Dusailly. (*Électronique* (Paris), no. 67, pp. 10–15; June, 1952.) Description of equipment giving a record on a paper band of the rate of a watch or clock movement relative to a standard frequency derived from a quartz-crystal oscillator. Each tick of the watch serves to initiate a hv spark which perforates and blackens the paper.

621.383.001.8 3196
Amplification of Light-Intensity Fluctuations by means of Photoconductive Cells—M. Ploke. (*Funk u. Ton*, vol. 6, pp. 305–310; June, 1952.) Discussion of the use of PbS and CdS photocells, which have definite advantages over Se and Tl cells as regards sensitivity.

621.384.611.2† 3197
Synchrotron—Please note that 621.364.612 will be used in future for synchrotrons in place of 621.384.611.2† used hitherto.

621.384.612:621.311.6 3198
The Bevatron Power Plant—J. V. Kresser. (*Elec. Eng.* (N. Y.), vol. 71, pp. 338–343; April, 1952.) Description of the power-supply arrangements for the bevatron at the University of California.

621.384.62 3199
Expression for the Electromagnetic Field in Linear Ion Accelerators—M. Bernard. (*Compt. Rend. Acad. Sci.* (Paris), vol. 234, pp. 1862–1865; May 5, 1952.) A solution of Maxwell's equations is obtained for a semi-infinite cylinder excited by application of a difference of potential between the cylinder and a metal diaphragm across its end.

621.384.62 3200
Numerical Calculation of the Electromagnetic Field in Linear Ion Accelerators—M. Bernard. (*Compt. Rend. Acad. Sci.* (Paris), vol. 234, pp. 2175–2178; May 26, 1952.) The series previously given for the field are in general difficult to evaluate numerically. Simple approximate formulas for the field on the axis are derived.

621.384.62 3201
Application of the W.B.K. Method to the Dynamics of Linear Accelerators—M. Hoyaux. (*Rev. Sci. Instr.*, vol. 23, pp. 173–175; April, 1952.) The dynamics of "small motions" in a linear accelerator is studied for conditions as general as possible. It is concluded that heavy particles cannot be accelerated up to the 10^9-ev range by any practical combination of TM and/or TE traveling and/or stationary waves. Several methods are, however, possible for electrons.

621.385.833 3202
An Approximation Method for the Sinuous Trajectories of Highly Convergent [electron]

Lenses—F. Bertein. (*Jour. Phys. Radium*, vol. 13, p. 309; May, 1952.)

621.385.833 3203
Study of an Electron Lens by the W.K.B. Method—C. Muscia. (*R.C. Accad. naz. Lincei*, vol. 12, pp. 575–582; May, 1952.)

621.385.833 3204
Electronoptical Velocity Filters—M. Schiekel. (*Optik*, vol. 9, no. 4, pp. 145–153; 1952.) Chromatic aberration in the electron microscope can be reduced by use of a unipotential lens with a negative middle electrode as a velocity filter for the electrons scattered inelastically at the object. The image-forming properties of such filters are calculated for different potential distributions. The optimum resolving power is 110Å.

621.385.833:061.3 3205
The Fourth Annual Convention of the German Association for Electron Microscopy, Tübingen, 6th–8th June 1952—(*Optik*, vol. 9, no. 4, pp. 189–192; 1952.) Titles are given of all the papers presented.

621.385.833:061.3 3206
Report of Conferences on Electron Microscopy, Washington and Philadelphia 1951—V. E. Cosslett. (*Brit. Jour. Appl. Phys.*, vol. 3, pp. 137–139; May, 1952.)

621.387.4(083.72) 3207
Standards on Gas-Filled Radiation Counter Tubes: Definitions of Terms, 1952—(Proc. I.R.E., vol. 40, pp. 924–926; August, 1952.)

621.387.4(083.74) 3208
Standards on Gas-Filled Radiation Counter Tubes: Methods of Testing, 1952—(Proc. I.R.E., vol. 40, pp. 926–930; August, 1952.)

621.387.422:621.385.2 3209
Performance of Pulsed Photomultipliers—R. F. Post. (*Nucleonics*, vol. 10, pp. 46–50; May, 1952.) Report of investigations on selected type 931A and type 1P21 tubes fed with pulses of duration up to 3μs, the applied voltages corresponding to peak secondary emission with total amplification up to 10^9. Short resolving times are obtained. Time dispersion effects are estimated.

621.387.424 3210
Geiger-Müller Counters—N. Warmoltz. (*Philips Tech. Rev.*, vol. 13, pp. 282–292; April, 1952.) The different possible ways of operating gas-filled tubes as counters of ionizing particles are discussed, and descriptions are given of recently developed types of G-M counter, the importance of the quenching gas being emphasized.

621.387.462:549.211 3211
The Texture of Diamonds used for Counting α, β or γ Particles as found from Divergent-Beam X-Ray Photographs—H. J. Grenville-Wells. (*Proc. Phys. Soc.* (London), vol. 65, pp. 313–320; May 1, 1952.)

PROPAGATION OF WAVES

621.396.11:523.4 3212
Planetary Position Effect on Short-Wave Signal Quality—J. H. Nelson. (*Elec. Eng.*, (N. Y.), vol. 71, pp. 421–424; May, 1952.) A.I.E.E. Winter General Meeting paper, January, 1952. Investigations extending over seven years indicate distinct correlation between the fading of sw transatlantic radio signals and certain planetary configurations in which the heliocentric angles differ by multiples of 90°. Typical configurations which were accompanied by severe fading are shown. A forecasting system based on planetary indications, solar observations and day-to-day signal analysis has given good service throughout 1950 and 1951. See also of 1997 of 1951.

621.396.11:550.38 3213
Some Aspects of the Average Monthly Radio Propagation Conditions of the Circuit New York-Amsterdam during the Last Three Years, and their Relation with the Average Monthly Geomagnetic Activity and the Maximum Usable Frequency—B. van Dijl and D. van Sabben. (*Tijdschr. ned. Radiogenoot.*, vol. 17, pp. 135–137; May, 1952.) Correlation is sought between graphs showing the mean monthly values from October 1949 to April 1952 of (*a*) the percentage of hours lost, (*b*) the percentage of hours during which the *K* index (at Witteveen) had a value of 4 or more, and (*c*) the lowest daily value of muf. According as the muf value is low or high, the number of hours lost is higher or lower than would be expected from the geomagnetic activity. It is noted that magnetic activity increased throughout the period, though the sunspot maximum occurred 4–5 years before.

621.396.11:621.317.353.3 3214
Resonance in Gyro-interaction of Radio Waves—V. A. Bailey, R. A. Smith, K. Landecker, A. J. Higgs and F. H. Hibberd. (*Nature* (London) vol. 169, pp. 911–913; May 31, 1952.) Experiments carried out in Australia during the past two years are described which have completely confirmed Bailey's theoretical predictions (2437 of 1937 and 9 of 1939). The gyro-wave *A* was radiated vertically from a horizontal antenna at Armidale, New South Wales, and the wanted wave *B* was radiated from Brisbane, Queensland, on 590 kcs with a power of 10 kw. The principal observations of *B* were made at Katoomba, New South Wales, Armidale being very nearly at the mid-point of the 740-km path from Brisbane to Katoomba. The pulse power of *A* was about 36 kw, frequencies from 1255 to 1880 kc being used, the estimated gyro-frequency being about 1530 kc. The results show that a notable degree of resonance occurs as the frequency of the disturbing wave *A* passes through the gyro-frequency. Both double-humped and single-humped resonance curves were obtained. A detailed report of the investigations is to be published elsewhere.

621.396.11.029.55 3215
New Propagation Forecasts from WWV—(*QST*, vol. 36, p. 19; June, 1952.) From 1st July 1952, forecasts of sw radio disturbances will be broadcast from WWV on the standard frequencies 2.5, 5, 10, 15, 20 and 25 mc). The forecasts are prepared four times daily, and are transmitted in code at 19.5 and 49.5 minutes past each hour. The letters N, V, W denote respectively the existing normal, unsettled, or disturbed conditions. The following number indicates on the N.B.S. scale the expected quality of future reception, 1 representing "impossible" and 9 "excellent." The forecasts refer only to North Atlantic paths, such as Washington to London or New York to Berlin.

621.396.11.029.62/.64 3216
Transmission beyond the Horizon at Frequencies between 40 and 4000 Mc/s—(*Bell Lab. Rec.*, vol. 30, pp. 245–246; June, 1952.) A short account of experimental results which show that the power received at points beyond the horizon is substantially independent of frequency, antenna height, and weather effects, and that the signal strength decreases much more slowly with increase of distance than the rapid decrease predicted from the classical smooth-earth theory. A fuller report is to be published.

621.396.11.029.62 3217
The Propagation of Ultrashort Waves beyond the Horizon, with Particular Reference to the Meteorological Influences—B. Abild, H. Wensien, E. Arnold and W. Schikorski. (*Tech. Hausmitt. NordwDtsch. Rdfunks*, vol. 4, pp. 85–100; May/June, 1952.) A study is made of the meteorological conditions in western Germany causing ultrashort waves to be propagated to abnormally great distances; both mean values and detailed variation of field strength are examined. Predictions from theory are compared with results of measurements recorded at a number of receiving stations. Previous investigations, e.g. 2580 of October (Abild), have indicated that field-strength fluctuations depend mainly on vapor pressure and temperature in the lower troposphere. Probable secondary influences are turbulence in the lower atmosphere and variations of the state of the ground.

621.396.11.029.64(442.6/.8) 3218
Study of the Propagation of Centimetre Waves in Northern France—P. Chavance. (*Ann. Télécommun.*, vol. 7, pp. 254–261; June, 1952.) An account of investigations on wavelengths of 9.5 and 3.2 cm, using equipment described previously [3115 of 1951 (Maillard, Voge and Chavance)]. The aim was to obtain statistical information on propagation over a 76-km path with insufficient ground clearance. Seasonal and diurnal effects on signal strength and fading are shown graphically and discussed and records of typical fading effects are displayed and analyzed.

621.396.81 3219
Interpretation of High-Frequency C.W. Field-Intensity Records with the Aid of Simultaneous Pulse Data—R. Silberstein. Proc. I.R.E., vol. 40, pp. 974–976; August, 1952.)

RECEPTION

621.396.62:061.4 3220
Radio at the Paris Fair—(*TSF et TV*, vol. 28, pp. 187–189; June, 1952.) Comment on the exhibits and classification of 133 receivers shown.

621.396.621(083.74)(44) 3221
French Standard C92-120 on Battery-Operated Receivers—Radionyme. (*Toute la Radio*, pp. 193–195; June, 1952.) Analysis of the specifications for receivers of different types, with an outline of test methods for sensitivity, selectivity, distortion, etc.

621.396.8+621.396.1 3222
Reception of Broadcasting from all over the World—Lhombreaud. (See 3228.)

621.396.97:621.396.823:351.819 (44) 3223
The New French Regulations for the Protection of Broadcasting against Interference of Industrial Origin—M. Adam. (*Rev. gén. Élect.*, vol. 36, pp. 197–200; April, 1952.) Maximum permissible interfering voltages are specified for the long-, medium- and short-wave bands respectively. Methods of measuring such voltages are indicated. Apparatus must be fitted with suppressor devices before being offered for sale.

STATIONS AND COMMUNICATION SYSTEMS

621.39.001.11 3224
Basic Communication Theory—L. S. Schwartz. (*Radio & Telev. News, Radio-Electronic Eng. Section*, vol. 47, pp. 3–5, 28–30 and 11–13; June and July, 1952.) A nonmathematical presentation of the theory developed by Shannon, Wiener and others.

621.39.001.11:519.21 3225
Convexity and Information—R. Féron. *Compt. Rend. Acad. Sci.* (Paris), vol. 234, pp. 1840–1841; May 5, 1952.) Proof is given that the necessary and sufficient condition that the gain of information should not be negative for any pair *XY* of aleatory variables is that a certain function of the distribution function of *Y* should be a concave function.

621.396.029.6 3226
Radio Communication on Short Waves—H. Köppen. (*NachrTech.*, vol. 2, pp. 136–139; May, 1952.) A short review of present-day

technical developments in communication on m, dm and cm waves, and of recent investigations of the practicability of using wavelengths in the range 25–100 m for communication in mines.

621.396.1 3227
Wavelength Problems in Telephony and Television Broadcasting—G. Pedersen. (*Teleteknik, Copenhagen*, vol. 3, pp. 49–60; May, 1952.) An outline is given of the principles governing the international allocation of wavelengths. The heavy bandwidth demands of television are discussed with special reference to the plans for television in Denmark.

621.396.1:621.396.8 3228
Reception of Broadcasting from all over the World—C. Lhombreaud. (*TSF et TV*, vol. 28, pp. *Doc. tech.* 1–3; April, 1952.) Report of a survey made in the light of the Copenhagen frequency allocation. This article is the first of a series giving station operating details and an indication of the quality of reception near Bordeaux, starting with European stations.

621.396.4.029.53 3229
Microwave Systems for 960 and 2000 Mc/s—R. V. Rector and W. E. Sutter. *Trans. Amer. IEE*, vol. 69, part II, pp. 1100–1108; 1950. Discussion, pp. 1108–1109.) In the 2-kmc transmitter, 2–5 w output is obtained from a type-SRL-7c klystron rated at 10 w. Good frequency stability is obtained by accurate voltage and temperature control. Pulse-duration modulation is used and 24 channels are provided, each of which can give 18 two-way control channels. The 960-mc transmitter provides 7 channels, each giving either two-way voice communication or 18 two-way control channels. Block diagrams of both equipments are given, with description and illustrations.

621.396.619.16 3230
A System of Pulse-Code Modulation using Circulated Pulses—S. Fedida. (*Electronic Eng.*, vol. 24, pp. 356–361; August, 1952.) A method is described for converting sample pulses into sequences of up to five on/off pulses which, when interpreted as digits in a binary system of units, reproduce the original information represented by the sample pulses. Two possible methods of decoding to derive the original within a prescribed tolerance are outlined.

621.396.619.16:621.396.4 3231
Nonsynchronous Pulse Multiplex System—A. L. Hopper. (*Electronics*, vol. 25, pp. 116–120; August, 1952.) An experimental time-sharing multiplex system is described in which the inputs to the different transmitters are converted to pam by sampling with random pulses, these AM pulses being converted to equal and opposite pulse pairs separated by a constant delay whose value is selected by means of a switch. This delay constitutes the identifying characteristic at the receiver. The system can be used for rural radiotelephony and for communication between moving vehicles. It has the disadvantage that it is not economical of channel capacity, and would probably be useful for the transmission of intelligence rather than high-quality speech.

621.396.619.16:621.396.41 3232
Electronic Pulse Systems for Telegraphy—G. Montessori. (*Alta Frequenza*, vol. 21, pp. 77–101; April, 1952.) Synchronization, regeneration and channel separation are provided electronically in a time-division multiplex telegraphy system using ring distributors controlled by a frequency-stabilized pulse generator, the synchronizing signal being produced by modifying the regular pulse rhythm. The system has been used by the Italcable Co. for high-speed telegraphy.

621.396.651:621.396.43 3233
Multiple-Channel Telephony on U.H.F. Radio Links—B. R. Tupper and P. B. Patton. (Proc. I.R.E., vol. 40, pp. 913–916; August, 1952.)

621.396.65:621.396.43 3234
Design Fundamentals for Beam Radio Systems—H. Werrmann. (*Funk u. Ton*, vol. 6, pp. 281–297; June, 1952. Correction, *ibid.*, vol. 6, p. 380; July, 1952.) Discussion of the various factors which must be taken into account, including effects of normal attenuation, ground proximity and operation beyond the optical range, antenna aperture and gain, interference and system noise, and the type of modulation to be used.

621.396.65.029.6:621.316.925:621.311.1 3235
Protective Relaying Systems using Microwave Channels—H. W. Lensner. (*Elec. Eng.* (N. Y.), vol. 71, pp. 400–405; May, 1952.) A.I.E.E. Winter General Meeting paper, January, 1952. Several practical applications in power systems are outlined.

621.396.65.029.63:[621.396.5+621.317.083.7 3236
Microwave Radio Links of Bonneville Power Administration—S. Metzger, N. H. Gottfried and R. W. Hughes. (*Elec. Commun.*, vol. 29, pp. 87–92; June, 1952.) Description of the FTL-10B 23-channel system now in operation. See also 1777 of 1951 (Stevens and Stringfield).

621.396.72.029.62 3237
The Inauguration of F8 REF—J. Ferré. (*Radio franç.*, no. 5, p. 15; May, 1952.) Note of sw R/T transmissions to be made twice weekly from a central station for the benefit of French amateurs.

621.396.8.029.53 3238
Medium-Wave Broadcasting Coverage in the NWDR Area—G. Paulsen. (*Tech. Hausmitt. NordwDtsch. Rdfunks*, vol. 4, pp. 101–110; May/June, 1952. Correction, *ibid.*, vol. 4, p. 141; July/August, 1952.) A résumé is given of the theory of radio wave propagation and of transmission requirements for a satisfactory broadcasting service. Interference between transmissions on (*a*) common channels and (*b*) adjacent channels is discussed and the limiting values adopted by the NWDR for the ratio between wanted and unwanted signals in various cases are shown graphically. The principles of system planning to cover the greatest possible fraction of the population are discussed in relation to the area; about 70 per cent of the population is adequately served. The complementary uses of medium-wave and usw services are indicated.

621.39.001.11 3239
La Cybernétique-Théorie du Signal et de l'Information. [Book Review]—L. de Broglie (Ed.). Publishers: Editions de la Revue d'Optique Théorique et Instrumentale, 1951, 318 pp., 1600 fr. (*Brit. Jour. Appl. Phys.*, vol. 3, p. 133; April, 1952.) Papers presented at a conference at the Henri Poincaré Institute, Paris, 1950.

SUBSIDIARY APPARATUS

621-526:621.313.281 3240
Amplifying Dynamos: their Use in Servomechanisms—G. Lehmann. (*Bull. Soc. franç. Élect.*, vol. 2, pp. 198–209; April, 1952.)

621.314.632:546.289 3241
The New G-10 Germanium Dot Rectifier—T. J. Ferguson. (*Radio & Telev. News*, vol. 47, pp. 42–43; June, 1952.) Description and some performance figures of a rectifier unit suitable for supplying power to radio and television equipment. The G-10 is a series combination of two "button" rectifiers each consisting of a pellet of spectroscopically pure Ge, ⅛-inch square, placed at the center of a metal dish sealed with butyl rubber and mounted on a 2-inch-diameter metal cooling fin. Units are selected to ensure equal division of peak back voltage across the two associated rectifiers.

621.314.634.012 3242
Static and Dynamic Characteristic Curves for Selenium Rectifiers—I. Somos. (*Elektrotechnika* (Budapest), vol. 45, pp. 154–159; May, 1952.) Methods of measurement are described which give reproducible results.

621.316.722.1:621.326 3243
Incandescent Lamp Bulbs in Voltage Stabilizers—W. J. Cunningham. (*Jour. Appl. Phys.*, vol. 23, pp. 658–662; June, 1952.) An approximate analysis is made of the operation of lamps used as sources of reference voltage in ac stabilizers. The equivalent-circuit theory developed in 3026 above is used to determine the distortion due to the nonlinearity of the lamp I/V characteristic. The effects of changes of frequency and current are demonstrated.

621.316.93 3244
Lightning Protection since Franklin's Day—K. B. McEachron. (*Jour. Frank. Inst.*, vol. 253, pp. 441–470; May, 1952.) Historical account of the development of the various types of protective device in use today. 46 references.

TELEVISION AND PHOTOTELEGRAPHY

621.397.5 3245
Optimum Number of Lines and Screen Dimensions—P. Stroobants. (*Télévision*, no. 23, pp. 113–117; May, 1952.) The lowest number of scanning lines N consistent with invisibility of line structure in the television image is expressed in terms of the angular resolution of the eye and the ratio between the viewing distance (as selected naturally by average viewers) and the screen height h. Based on subjective judgments, curves are plotted showing the variation of N with h for 95 per cent and for 100 per cent observer satisfaction. By reference to these curves line standards of 625, 819 and >819 are shown to be appropriate respectively for receivers with screen diameters up to 22 cm, between 22 and 40 cm, and over 40 cm.

621.397.5:061.3(431.55) 3246
Berlin Television Conference—(*Funk u. Ton*, vol. 6, pp. 258–264; May, 1952.) Summaries are given of papers presented at the conference arranged by the Berlin-Charlottenburg Technical University, March 1952.

621.397.5:535.623 3247
Requisite Color Bandwidth for Simultaneous Color-Television Systems—K. McIlwain. (Proc. I.R.E., vol. 40, pp. 909–912; August, 1952.) Report of subjective tests, using both skilled and lay observers, to determine how far bandwidth can be reduced before picture reproduction becomes unsatisfactory. Under the particular test conditions described a band about 1 mc wide is sufficient for most color transmissions, provided a further band 4 mc wide is available for transmitting the brightness detail.

621.397.5:535.88:791.45 3248
A Direct-Projection System for Theater Television—F. N. Gillette. (*Jour. Soc. Mot. Pic. Telev. Eng.*, vol. 58, pp. 385–396; May, 1952.) General description of the Simplex Model PB-600 for projecting a full-size television picture on a theatre screen. The system combines simplicity in installation, convenience in maintenance and reliability in operation.

621.397.5:621.396.712 3249
The Lime Grove Television Studios of the British Broadcasting Corporation—(*Engineer-*

ing (London), vol. 173, pp. 518–519; April 25, 1952.) Details are given of studio arrangements and camera equipment in use. See also 753 of 1951.

621.397.5(204.1) 3250
Underwater Television—(*Engineer* (London), vol. 193, pp. 642–643; May 9, 1952.) Description, based on an Admiralty bulletin, of remotely controlled television camera equipment developed by Pye, Ltd. for operation at depths up to 1,000 feet; sea trials have been made in the diving vessel "Reclaim." Using a plane window, a 75° viewing angle has been obtained by simple devices.

621.397.5(204.1) 3251
Underwater Television—(*Engineer.* (London), vol. 193, p. 565; April 25, 1952.; *Engineering* (London), vol. 173, p. 531; April 25, 1952.) Account of a laboratory demonstration of progress made since the first use of underwater television (2053 of August). Camera mounting and lighting arrangements are described. The image-orthicon equipment is modified to permit remote control of focusing and aperture, with remote indication on the parent ship permitting deductions to be made as to size of object and distance from camera; the brand of a packet of cigarettes could be identified at 6–12 feet. A 625-line picture is used.

621.397.5.001.8 3252
Television Technique as an Aid to Observation—J. D. McGee. (*Jour. R. Soc. Arts*, vol. 100, pp. 329–345; March 21, 1952. Discussion, pp. 346–349.) A survey of applications covering (*a*) the extension of vision in respect of either distance or wavelength range, (*b*) television memory devices.

621.397.6 3253
Improving TV System Transient Response—J. Ruston. (*Electronics*, vol. 25, pp. 110–113; August, 1952.) A television transmitter/receiver system having the over-all frequency characteristic specified by the F.C.C. and R.T.M.A. has unacceptably high transient distortion. This distortion can be reduced by modifying the over-all response curve to produce a stepped characteristic with a region of symmetry about the carrier frequency. A network suitable for producing such a modification in the receiver video circuit is illustrated.

621.397.61(494) 3254
The Uetliberg as a Site for a Television Transmitter—H. Laett. (*Tech. Mitt. schweiz. Telegr.-Teleph Verw.*, vol. 30, pp. 59–69; February 1, 1952. In French and German.) An account is given of field-strength and picture-quality measurements in the district within about 40 km of Zürich, which is the most densely populated part of Switzerland. A double-turnstile antenna mounted on a tower at the summit of the Uetliberg, which dominates the district, was fed by a transmitter operating on 62.25 mc with a peak power of 400 w. Field strengths are shown on a map. The results as a whole show clearly the primary importance of operation within the optical range, though diffraction effects rendered reception satisfactory over a considerable part of the region not visible from the transmitter.

621.397.611.2 3255
The Application of Negative Feedback to Flying-Spot Scanners—R. Theile and H. McGhee. (*Jour. Brit. IRE*, vol. 12, pp. 325–339; June, 1952.) Negative feedback between the output of the amplifier following the photomultiplier and the control electrode of the scanning tube affords a convenient means of controlling contrast. Problems introduced by the time delay round the feedback loop are discussed. The influence of feedback on the appearance of screen afterglow is analyzed, and the effect on signal/noise ratio is considered.

621.397.611.2:621.385.2 3256
A Simple Electrostatic Electron-Optical System with Only One Voltage—Schagen, Bruining and Francken. (See 3284.)

621.397.62 3257
The Simplification of Television Receivers—W. B. Whalley. (*Proc. IRE* (Australia), vol. 13, pp. 99–103; April, 1952.) Reprint. See 1271 of 1950.

621.397.621.2 3258
The Focusing of Cathode-Ray Tubes for Television Receivers—J. A. Hutton. (*Jour. Brit. IRE*, vol. 12, pp. 295–304; May, 1952.) The problem is examined from the point of view of receiver design rather than tube design. Deflection defocusing and resulting aberrations are discussed and remedies indicated. The influence on focus control of the configuration and position of the focusing field is investigated, and the effect of supply-voltage variation considered.

621.397.621.2 3259
Cathode-Ray Picture Tube with Low Focusing Voltage—C. S. Szegho. (PROC. I.R.E., vol. 40, pp. 937–939; August, 1952.) Focusing is performed by means of a univoltage es lens with the low-voltage electrode at 0–5 per cent of anode voltage. A description and operating characteristics are given for a particular design incorporating an ion trap. Methods of avoiding breakdown due to high voltage gradients are discussed.

621.397.621.2:535.241.48 3260
A Graphical Treatment of the Tone-Reproduction Problem in Television Systems—R. B. Mackenzie. (*Brit. Jour. Appl. Phys.*, vol. 3, pp. 141–147; May, 1952.) "The impracticability of analyzing the tone reproduction properties of a television system in terms of simple mathematical laws is discussed. A construction for a tone reproduction chart is presented which enables a realistic assessment of the over-all performance of a system to be made, subjective effects being taken into account. The use of the chart is demonstrated by examining the effects of altering certain parameters of the system."

621.3.69721.2:535.623 3261
Elimination of Moiré Effects in Tricolor Kinescopes—E. G. Ramberg. (PROC. I.R.E., vol. 40, pp. 916–923; August, 1952.) The influence of scanning-line width, mask-aperture size, aperture spacing, line separation, orientation of scanning pattern relative to mask, and picture content on moiré effects arising in tubes of the type described by Law (844 of April) is discussed.

621.397.621.2:621.397.335 3262
Flywheel Synchronization of Sawtooth Generators in Television Receivers—P. A. Neeteson. (*Philips Tech. Rev.*, vol. 13, pp. 312–322; May, 1952.) The sensitivity of different systems of synchronization to interference is discussed and a detailed description is given of the "flywheel" method of line synchronization which minimizes the effect of interference. The principles of aphc., particularly important in this system, are fully explained, and two circuits are described in which the functions of phase discriminator and sawtooth-voltage generator are combined in an ordinary pentode.

621.397.74 3263
Maximum Coverage for V.H.F.-U.H.F. TV—F. W. Smith. (*Electronics*, vol. 25, pp. 146–150; July, 1952.) A series of charts are presented relating transmitter power, antenna height and service area for the two grades of service specified in the F.C.C. report of April 1952 revising the frequency-allocation system.

621.397.82 3264
Reducing TV Receiver Oscillator Radiation—E. W. Chapin and W. K. Roberts. (*Electronics*, vol. 25, pp. 116–120; July, 1952.) Measurements of the radiation from typical receivers are described and the results are tabulated. Methods of screening the oscillator unit efficiently, and circuit modifications which reduce interference with other receivers, are detailed.

TRANSMISSION

621.396.61:621.396.931 3265
F.M. Transmitter for 42 Mc/s—H. G. Stratman. (*Radio & Telev. News, Radio-Electronic Eng. Section*, vol. 47, pp. 10–13, 31; June, 1952.) Design and performance details are given of a 3-kw transmitter for police communications.

621.396.619.13 3266
Improved Reactance-Valve Circuit—J. Wobst. (*NachrTech.*, vol. 2, pp. 177–179; June, 1952.) A circuit is described which gives the same maximum frequency swing as can be obtained with the normal reactance-tube modulator, but which suppresses completely the AM which usually accompanies the FM. On account of the frequency dependence of the phase shifter used, the new arrangement is only suitable for a frequency range of about 11.3. Design formulas are given and applied to the determination of circuit parameters for a FM oscillator covering the range 10–12 mc.

621.396.619.23 3267
Study of the Serrasoid Modulator—F. W. Grundlach, (*Fernmeldetech. Z.*, vol. 5, pp. 256–262; June, 1952.) The merits of three ways of operating the modulator [342 of 1949 (Day)] are examined by analyzing the frequency spectrum of the pulse trains. The only method providing complete freedom from AM is that in which the pulses are of constant height, a form of PWM being applied. The effect of slight AM on the frequency multiplier performance is studied. The multiplier should operate in class C with automatic bias.

TUBES AND THERMIONICS

621.314.7 3268
Crystal Triodes—E. G. James and G. M. Wells. (*Jour. Brit. IRE*, vol. 12, pp. 285–292; May, 1952. Discussion, pp. 293–294.) A brief account is given of developments leading to the production of the Ge triode and some applications and limitations are indicated.

621.314.7 3269
New Transistors Give Improved Performance—J. A. Morton. (*Electronics*, vol. 25, pp. 100–103; August, 1952.) Design developments leading to improved reliability, reproducibility and frequency response are described briefly. For a fuller account see 2651 of October.

621.383:621.385.15:535.51 3270
Polarization Effects in Photomultiplier Tubes—E. P. Clancy. (*Jour. Opt. Soc. Amer.*, vol. 42, p. 357; May, 1952.) Measurements were made of the response of a photomultiplier tube as a function of the angle θ between the direction of the electric vector of the plane-polarized incident light and the longitudinal axis of the tube. Type 931-A tubes gave the highest value of the ratio of the responses at $\theta=90°$ and $\theta=0°$.

621.383.2 3271
Production Testing of Multiplier Phototubes—R. W. Engstrom, R. G. Stoudenheimer and A. M. Glover. (*Nucleonics*, vol. 10, pp. 58–62; April, 1952.) Account of tests applied in the manufacture of the R.C.A. 5819 photomultiplier, with emphasis on cathode sensitivity.

621.383.27 3272
Non-Linear Amplification in E.M.I. Photomultipliers—J. F. Raffle and E. J. Robbins. (*Proc. Phys. Soc.* (London), vol. 65, pp. 320–324; May 1, 1952.) The heights of the output pulses obtained from E.M.I. photomultipliers are not always proportional to the quantity of light incident on the photo cathode, the linear relation failing when the charge density in the multiplier becomes too great.

621.383.5 3273
Response of Barrier-Layer Photocells. Theory permitting the Prediction of the Variations of Output Voltage as a Function of the Illumination and the Load Resistance of a Selenium Photocell—G. Blet. (*Compt. Rend. Acad. Sci.* (Paris), vol. 234, pp. 2187–2189; May 26, 1952.) A single curve is derived which gives results in good agreement with experiment for any value of load resistance and for a very wide range of intensity of illumination.

621.384.5:621.318.572 3274
The Cold-Cathode Gaseous Discharge as a Switching Device—N. L. Harris. (*Engineer* (London), vol. 193, pp. 460–462; April 4, 1952.) Applications are described of cold-cathode tubes of various types in over-voltage protection and in radar switching devices.

621.385.029.6:621.392.22 3275
A Broad-Band Interdigital Circuit for Use in Traveling-Wave-Type Amplifiers—R.C. Fletcher. (PROC. I.R.E., vol. 40, pp. 951–955; August, 1952.) Analysis indicates that the interdigital type of structure, which is capable of handling high power, can be designed to have a wide frequency band. Phase-velocity/frequency curves plotted from measurements made on a model operating at 300 mc are of the same general shape as curves derived from the theory.

621.385.029.6:621.396.822 3276
Calculation of the Noise Figure of the Travelling-Wave: Part 1—W. Kleen and W. Ruppel. (*Arch. elekt. Übertragung*, vol. 6, pp. 187–194; May, 1952.) Recent investigations indicate that fluctuations of density and velocity have a periodic distribution along the electron beam, while the energy fluctuations are uniformly distributed. Because of the periodicity, there is an optimum value of the distance between accelerator electrode and entrance to delay line. The noise figure is approximately proportional to the ratio between the phase constant and the attenuation constant for transmission through the tube, and under optimum conditions is equal to this ratio. The variation of noise figure with dimensions and operating conditions is shown for a tube with helical delay line; in this case the optimum value varies approximately exponentially with frequency, being about equal at 3 kmc to the noise figure of a crystal detector in a mixing circuit.

621.385.032.216 3277
Thermionic Emission and Electrical Conductivity of Oxide-Coated Cathodes—S. I. Narita. (*Jour. Appl. Phys.*, vol. 23, p. 599; May, 1952.) Measurements on both sintered and ordinary oxide-coated cathodes are described and direct comparisons made. The variations of emission and conductivity with temperature and with degree of activation are shown. The sintered cathode was prepared by converting $BaCO_3$ to BaO under conditions of slow speed of exhaust and at very high cathode temperature. The activities of both types of cathode were varied by evaporating Ba on to the surfaces. Three mechanisms of electron conduction in the oxide coating are considered possible, all operating simultaneously in the most general case.

621.385.032.216 3278
Activation of High-Vacuum Oxide-Cathode Valves—G. H. Metson. (*Vacuum*, vol. 1, pp. 283–293; October, 1951.) Discussion, based on laboratory experience, of three current theories of activation: chemical reduction, electrolysis and thermodynamic action. None of these gives an adequate explanation of the high initial activation commonly achieved.

621.385.032.216 3279
Chemical Reactions in Barium-Oxide-on-Tungsten Emitters—R. C. Hughes, P. P. Coppola and H. T. Evans. (*Jour. Appl. Phys.*, vol. 23, pp. 635–641; June, 1952.) Alternative theories are examined regarding the reactions responsible for the Ba_3WO_6 interface formed when a BaO-on-W cathode is prepared by applying $BaCO_3$ to W and processing normally. Two possibilities are considered: (*a*) formation of Ba_3WO_6 from BaO and W, and (*b*) formation of Ba_3WO_6 from $BaCO_3$ and W. Experiments made to test these theories are described. A series of four reactions occur at progressively higher temperatures. Prolonged heating at over 1,000°C may convert the whole of the oxide layer into Ba_3WO_6. The interface can probably be eliminated by applying BaO to oxide-free W and adding the necessary Ba for activation from an outside source.

621.385.032.216 3280
Physical Processes in the L Cathode—D. L. Schaefer and J. E. White. (*Jour. Appl. Phys.*, vol. 23, pp. 669–674; June, 1952.) Experiments on the L-type cathode [773 of 1951 (Lemmens, Jansen and Loosjes)] are described; degree of coverage of the *W* surface with Ba, and rate of evaporation of the Ba were investigated. The evaporation rate is found to be controlled by the surface diffusion of the Ba over the *W*. Despite incomplete coverage of the emitting surface with Ba, and almost complete absence of streaming of active material out through pores in the surface material, evaporation is sufficient to cause concern in certain applications.

621.385+621.326].032.7:666.17 3281
Making Glass Bulbs—(*Elec. Rev.* (London), vol. 150, pp. 1124–1128; May 23, 1952.) Description of the plant and operation of a new factory at Harworth, Notts., manufacturing 1,500,000 bulbs daily from the basic raw materials by a highly mechanized system of "flow production." The smaller of two glass-moulding bulb-blowing machines operating on a continuous glass ribbon produces the complete range of tube bulbs of diameter up to 44.5 mm, including all the miniature types. Its output is approximately one million bulbs in 24 hours. The larger machine has a daily output of half a million lamp bulbs of diameter up to 8 cm. For similar descriptions see *Elec. Times*, vol. 121, pp. 937–940; May 22, 1952; and *Electrician*, vol. 148, pp. 1693–1696; May 23, 1952.

621.385.2:546.289 3282
The Time Lag of the Forward Conductance of Germanium Diodes—T. Einsele. (*Z. angew. Phys.*, vol. 4, pp. 183–185; May, 1952.) Measurements were made of Ge-diode current with a pulsed input voltage of low duty factor; the forward characteristics obtained at different instants are plotted for a specimen in which the conductance took nearly 1μs to reach its static value. With Si diodes no lag was observed; with Ge diodes the lag was longer when large reverse bias was applied. In contrast to the results obtained by Meacham and Michaels (1817 of 1950), no lag was observed in the backward conductance.

621.385.2:546.289:621.317 3283
Germanium Diodes for Indicating Instruments and Relays—F. J. Lingel. (*Tele-Tech*, vol. 11, pp. 42–43, 104; April, 1952.) A series of circuit diagrams illustrates the various applications of Ge rectifiers. A table and graphs show the operating characteristics of different available types.

621.385.2:621.397.611.2 3284
A Simple Electrostatic Electron-Optical System with only One Voltage—P. Schagen, H. Bruining and J. C. Francken. (*Philips Res. Rep.*, vol. 7, pp. 119–130; April, 1952.) Analysis of a system for use in television camera tubes or image converters, in which the cathode and anode are concentric spheres, the anode being the smaller. The effect of providing an aperture in the anode for the passage of the electrons is investigated. The formulas derived from theory were applied to an experimental arrangement with a cathode in part spherical and in part cylindrical; pictures of good definition and freedom from distortion were obtained.

621.385.3/.5 3285
Determination of Penetration Factor for Amplifier Valves—H. Köppen. (*NachrTech.*, vol. 2, pp. 112–116; April, 1952.) Charts are provided which enable penetration factors to be readily determined from the physical dimensions of tube electrode systems; their use is illustrated for a directly heated pentode.

621.385.3/.4].029.63 3286
Some New Ultra-High-Frequency Power Tubes—P. T. Smith. (*RCA Rev.*, vol. 13, pp. 224–238; June, 1952.) Experimental grounded-grid triodes and grounded-cathode tetrodes with close grid-cathode spacing are described. The output of the triodes is 5–10 kw at 900 mc, about the same as at lower frequencies. The tetrodes have lower power gain, but have certain advantages when high-level modulation is required.

621.385.3.029.64 3287
Amplification Constant for Microwave Triodes—Y. Koike and S. Yamanaka. *Technol. Rep. Tohoku Univ.*, vol. 15, pp. 14–25; 1951.) Published results of various workers for microwave tubes with parallel-wire grids are reviewed and suitable formulas for calculating the amplification factor are quoted for the two cases where island formation is appreciable or negligible. Formulas for the screening effect of wire-mesh grids are based on experimental results.

621.385.5.018.424 3288
New Valve for Wide-Band Amplifiers—P Meunier. (*Onde élect.*, vol. 32, pp. 232–237; June, 1952.) Detailed description of the construction and characteristics of two pentodes, Type PTT216 with noval base and Type PTT214P with standard PTT type-P base. Cathode-current density is 50 ma/cm², grid-cathode distance 0.06 mm, grid pitch 0.065 mm and diameter of grid wires only 8 μ. Seven Type-PTT216 tubes were used in an amplifier with 75-Ω input and output impedance, gain 70 db and pass band of 25 mc centered on 70 mc. An equivalent amplifier using Type-6AK5 tubes would have required 13 tubes.

621.385.83 3289
The Effect of Velocity Distribution in a Modulated Electron Stream—D. A. Watkins. (*Jour. Appl. Phys.*, vol. 23, pp. 568–573; May, 1952.) A method of solving electron-beam problems is described which takes account of the thermal spread of velocity. The method is based on Liouville's theorem. The effect of the thermal spread on signal and noise in a drifting stream is calculated by means of a power series (*a*) for small-signal vm of the stream, (*b*) with the stream initially possessing full shot noise.

621.385.832 3290
Internal Electrostatic Deflection Yokes—K. Schlesinger. (*Electronics*, vol. 25, pp. 105–109; July, 1952.) Description of the "deflectron" electrode design. For deflection in two directions at right angles, composite electrodes with triangular boundaries are used which

form the sides of a box. This provides simultaneous horizontal and vertical deflection, equal sensitivites and a common center of deflection, giving greater freedom from scan distortion and defocusing than a conventional crossed-plate structure. Cylindrical and conical modifications of the design are illustrated; their application and production techniques are described.

621.396.615.14+621.396.645].029.64 3291

Generation and Amplification of Oscillations in the Ultra-High-Frequency Region—F.W. Gundlach. (*Z. angew. Phys.*, vol. 4, pp. 147–157; April, 1952.) The mode of operation and practical constructions of microwave triode, klystron and travelling-wave tubes, including multi-segment magnetrons, are described. Sectional drawings of selected types are shown. 70 references.

621.396.615.141.2:621.365.55† 3292

Industrial Magnetrons for Dielectric Heating—R. B. Nelson. (*Electronics*, vol. 25, pp. 104–109; August, 1952.) Magnetrons and associated circuits for operation at 915 mc and 2.450 kmc are described. A 5-kw oscillator is available for the 915-mc band, and experimental 50-kw models have been produced. A 2-kw model is available for the 2.450-kmc band. See also 556 of March.

621.396.615.141.2.016.352 3293

Instabilities in the Smooth-Anode Cylindrical Magnetron—L. A. Harris. (*Jour. Appl. Phys.*, vol. 23, pp. 562–567; May, 1952.) A magnetically focused space-charge cloud of the type found in the smooth-anode magnetron is examined to determine whether a perturbation of the equilibrium condition will grow. A field analysis is carried out in which radial admittances are matched at the edge of the cloud. The solutions for the characteristic frequencies are complex, indicating that the disturbance grows with time.

621.396.615.141.2.029.63:621.396.619.13 3294

Frequency Modulation of Magnetron in the Decimetre Wave Range—F. Fricke. (*Arch. elekt. Übertragung*, vol. 6, pp. 228–240 and 281–287; June and July, 1952. Corrections, *ibid.*, vol. 6, p. 351; August, 1952.) Magnetron characteristics are deduced from circle-diagram analysis of the equivalent circuit for the apparent conductance between two adjacent segments of a multisegment magnetron. This shows that with the usual method of modulation by variation of the anode voltage, amplitude variation is superposed on the frequency modulation. A new method is proposed which results in wide-band FM without accompanying AM. The method consists in varying a capacitive reactance connected in parallel with the oscillatory system. An experimental verification was carried out using the grid-anode path of a retarding-field tube as the variable reactance.

621.396.615.141.2.029.64:621.396.619.13 3295

A 7000-Mc/s Developmental Magnetron for Frequency Modulation—H. K. Jenny. (*RCA Rev.*, vol. 13, pp. 202–223; June, 1952.) Description of a 24-vane double-strapped tube operated at the relatively low voltage of 550v and cathode-current density of 150 ma/cm² to ensure long life. The frequency range is 6.575–6.875 kmc, output power 10 w, and efficiency 30–40 per cent; frequency swings up to 16 mc can be handled without AM. Tuning and modulation curves are derived from consideration of equivalent circuits.

621.396.622.63 3296

An Analysis of Crystal Diodes in the Millivolt Region—W. B. Whalley and C. Masucci. (*Tele-Tech*, vol. 11, pp. 40–42, 131; May, 1952.) The resistance characteristics of different diodes were determined using a balanced ac source, a high-gain band-pass RC amplifier and a cro. The over-all characteristic is expanded to show the mid-region constant-resistance portion below about 1 mv. This is correlated experimentally with the threshold rf detection voltage. Traces obtained with a selector circuit using two diodes are analyzed.

MISCELLANEOUS

621.3:061.4 3297

26th Brussels International Fair, 26th April to 11th May 1952—(*Radio Revue TV*, vol. 4, pp. 173, 207; May, 1952.) Note on acoustic and radio apparatus exhibited by certain firms.

PROCEEDINGS OF THE I.R.E.

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TABLE OF CONTENTS

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Contents of Volume 40—1952

Volume 40, Number 1, January, 1952
PROCEEDINGS OF THE I.R.E.

Volume 40, Number 2, February, 1952
PROCEEDINGS OF THE I.R.E.

Volume 40, Number 3, March, 1952
PROCEEDINGS OF THE I.R.E.

Volume 40, Number 3, March, 1952 (Cont'd.)

Volume 40, Number 4, April, 1952
Proceedings of the I.R.E.

Volume 40, Number 5, May, 1952
Proceedings of the I.R.E.

Volume 40, Number 8, August, 1952 (Cont'd.)

Volume 40, Number 9, September, 1952

Proceedings of the I.R.E.

Volume 40, Number 9, September, 1952 (Cont'd.)

Volume 40, Number 10, October, 1952

Proceedings of the I.R.E.

Volume 40, Number 10, October, 1952 (Cont'd.)

Volume 40, Number 11, November, 1952

PROCEEDINGS OF THE I.R.E.

Volume 40, Number 11, November, 1952 (Cont'd.)

INDEX TO AUTHORS

Numbers refer to the chronological list. Light-face type indicates papers, **bold-face type indicates discussions and correspondence,** and *italics refer to books and book reviews.*

INDEX TO BOOK REVIEWS

INDEX TO SUBJECTS

This listing includes technical, sociological, economic, and general papers. Numbers refer to chronological list.

B

C

D

E

N

O

P

Q

R

S

T

NONTECHNICAL INDEX

Editorials

Front Covers

Frontispieces

IRE People

IRE Professional Groups

Miscellaneous

Notices

Obituaries

Report of the Secretary

Representatives in Colleges

Representatives on Other Bodies

Sections

Standards

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1946	Vol. 34	January, February, April to December, inc.
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THE INSTITUTE OF RADIO ENGINEERS, INC.

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TRANSACTIONS OF THE I.R.E.

Published by
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The Institute of Radio Engineers, Inc.

1951-1952 INDEX

Airborne Electronics
Antennas and Propagation
Audio
Broadcast and Television Receivers
Circuit Theory
Electron Devices
Instrumentation
Quality Control
Vehicular Communications

Editorial Department
Alfred N. Goldsmith, Editor

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Technical Editor

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Assistant Editor

The Institute of Radio Engineers, Inc.
1 East 79 Street
New York 21, N.Y.

TABLE OF CONTENTS

GENERAL INFORMATION

The Institute

The Institute of Radio Engineers serves those interested in radio and allied electronics and electrical-communication fields through the presentation and publication of technical material.

Membership has grown from a few dozen in 1912 to more than 30,000. There are several grades of membership, depending on the qualifications of the applicant, with dues ranging from $5.00 per year for Students to $15.00 per year for Members, Senior Members, Fellows, and Associates of more than five years' standing.

To serve more fully the many special fields of interest, Professional Groups have been formed in each of 19 technical fields on an Institute-wide basis, with membership open only to IRE members. Group activities include the sponsoring of symposia and conferences, and the publication of technical material of special interest to their members. To support these activities, assessment fees may be levied by the Groups on their members. The Professional Groups and their assessment fees are listed on Cover IV of this index.

The PROCEEDINGS OF THE I.R.E., issued monthly by the Institute, is sent free to all IRE members of record on the date of publication. The TRANSACTIONS, issued at intervals by several of the Professional Groups, are sent free to paid members of the respective Groups. IRE Standards, as listed on Cover IV of the index to the PROCEEDINGS, are available for those who wish to buy them at the prices indicated.

The PROCEEDINGS

The PROCEEDINGS has been published without interruption from 1913, when the first issue appeared. Over 4,400 technical contributions have been included in its pages, portraying a currently written history of developments in both theory and practice. The contents of papers are the responsibility of the authors and are not binding on the Institute or its members. The annual contents of the PROCEEDINGS are in a separate index.

Annual subscription rates for the United States of America, its possessions, and Canada, $18.00; to college and public libraries when ordering direct, $13.50; other countries, $1.00 additional for postage.

The TRANSACTIONS

TRANSACTIONS have been published by several Professional Groups since December, 1951, when the first issue appeared. A total of nearly 200 specialized technical papers have thus been made promptly available to Group members during the first year of publication. All papers published in the TRANSACTIONS are procured and reviewed by the respective Professional Group. The contents of papers are the responsibility of the authors and are not binding on the Institute, the Groups, or their members. The annual contents of the TRANSACTIONS are published in a separate index.

Subscription rates covering all issues of TRANSACTIONS published during the twelve-month period starting July 1, 1952, for the United States, its possessions, and Canada, $70; to college and public libraries, $50; other countries, $1.00 additional for postage.

Combined Index to Authors

Code numbers refer to papers as given in the contents list for each Professional Group. The letters in the code number designate the particular Professional Group, as follows:

AE	Airborne Electronics	CT	Circuit Theory
AP	Antennas and Propagation	ED	Electron Devices
A	Audio	I	Instrumentation
BTR	Broadcast and Television Receivers	QC	Quality Control
		VC	Vehicular Communications

Professional Group on Airborne Electronics

Contents

PGAE-1, December, 1951

TRANSACTIONS OF THE I.R.E.

(*Paper 51PG1101*)

PGAE-2, December, 1951

TRANSACTIONS OF THE I.R.E.

(*Paper 51PG1102*)

PGAE-3, April, 1952

TRANSACTIONS OF THE I.R.E.

(*Symposium on the Integration of Electronic Equipment with Air-Frame Design, 1952 IRE National Convention, New York, N. Y., March 6, 1951*)

PGAE-3, April, 1952 (Cont'd.)

PGAE-4, September, 1952

TRANSACTIONS OF THE I.R.E.

PGAE-5, October, 1952

TRANSACTIONS OF THE I.R.E.

PGAE-6, December, 1952

TRANSACTIONS OF THE I.R.E.

PGAE-6, December, 1952 (Cont'd.)

Index to Subjects

Professional Group on Antennas and Propagation

Contents

PGAP-1, February, 1952

TRANSACTIONS OF THE I.R.E.

(*IRE Western Convention, San Francisco, Calif., August 22–24, 1951*)

Editorial

PGAP-1, February, 1952 (Cont'd.)

PGAP-4, December, 1952

TRANSACTIONS OF THE I.R.E.

(IRE Western Convention, Long Beach, Calif., August 26–29, 1952)

Index to Subjects

Nontechnical Index

Professional Group on Audio

Contents

PGA-1, December, 1951

Transactions of the I.R.E.

PGA-2, December, 1951

Transactions of the I.R.E.

PGA-3, December, 1951

Transactions of the I.R.E.

PGA-4, December, 1951

Transactions of the I.R.E.

PGA-5, February, 1952

Transactions of the I.R.E.

PGA-6, March, 1952

Transactions of the I.R.E.

PGA-7, May, 1952

Transactions of the I.R.E.

PGA-7, May, 1952 (Cont'd.)

PGA-8, July, 1952

Transactions of the I.R.E.

PGA-9, September–October, 1952

Transactions of the I.R.E.

PGA-9, September–October, 1952 (Cont'd.)

PGA-10, November–December, 1952

Transactions of the I.R.E.

Index to Subjects

Nontechnical Index

Committees

Editorials

Meetings

Miscellaneous

PGA Chapters

PGA People

Professional Group on Broadcast and Television Receivers

Contents

PGBTR-1, July, 1952

TRANSACTIONS OF THE I.R.E.

Index to Subjects

Professional Group on Circuit Theory

Contents

PGCT-1, December, 1952

TRANSACTIONS OF THE I.R.E.

PGCT (Cont'd.)

Index to Subjects

Nontechnical Index

Professional Group on Electron Devices

Contents

PGED-1, November, 1952

TRANSACTIONS OF THE I.R.E.

PGED-1, November, 1952 (Cont'd.)

Index to Subjects

Professional Group on Instrumentation

Contents

PGI-1, May, 1952

TRANSACTIONS OF THE I.R.E.

PGI-1, May, 1952 (Cont'd.)

Index to Subjects

Professional Group on Quality Control

Contents

PGQC-1, August, 1952

TRANSACTIONS OF THE I.R.E.

PGQC-1, August, 1952 (Cont'd.)

Index to Subjects

Professional Group on Vehicular Communications

Contents

PGVC-1, February, 1952

TRANSACTIONS OF THE I.R.E.

PGVC-1, February, 1952 (Cont'd.)

PGVC-2, August, 1952

TRANSACTIONS OF THE I.R.E.

(Symposium on What's New in Mobile Radio, 1952 IRE National Convention, New York, N. Y., March 6, 1952)

Index to Subjects

Professional Groups of the I.R.E.

Listed below are the Professional Groups of the I.R.E. and their corresponding assessment fees. If no amount is indicated, no assessment has yet been levied.

Group	*Assessment*
Airborne Electronics	$2.00
Antennas and Propagation	4.00
Audio	2.00
Broadcast and Television Receivers	2.00
Broadcast Transmission Systems	2.00
Circuit Theory	2.00
Communications Systems	
Electron Devices	2.00
Electronic Computers	2.00
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Whenever circuits call for precision and high resolution in compact space . . .

There's a 10-turn Helipot to meet your requirements

With the development of the original HELIPOT— the *first* multi-turn potentiometer—an entirely new principle of potentiometer design was introduced to the electronic industry. It made possible variable resistors combining high resolution and high precision in panel space no greater than that required for conventional single-turn potentiometers.

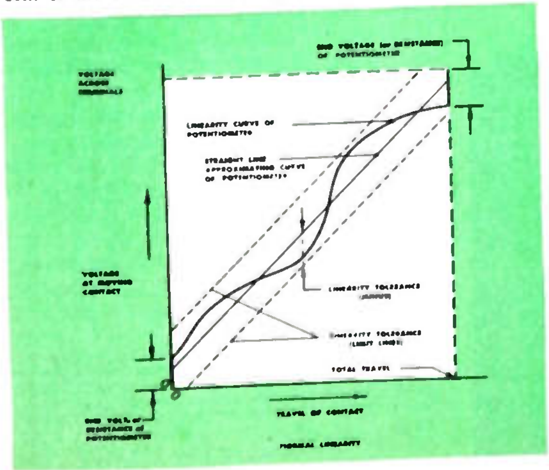
The Helipot Principle . . . *High resolution and precision settings require a long slide wire. But by coiling a resistance element into a helix, it is possible to gain desired resolution and precision without wasting panel space. This principle is applied in various Helipot models with slide wires ranging from 3 to 40 helical turns.*

Advantages are immediately apparent. In the case of the widely-used 10-turn Model A Helipot, for example, a 45" long slide wire—coiled into ten helical turns—is fitted into a case 1¾" in diameter, and 2" in length. Another advantage of the 10-turn pot is that, when equipped with a turns-indicating RA Precision DUODIAL, slider position can be read directly as a decimal, or percentage, of total coil length traversed.

10-TURN HELIPOT MODELS—CONDENSED SPECIFICATIONS

	Model A	Model AN	Model AJ
No. of turns	10	10	10
Resistance Range	10 ohms to 300,000 ohms	100 ohms to 250,000 ohms	100 ohms to 50,000 ohms
Resistance Tolerance: Standard	±5%	±5%	±5%
Best	±1%	±1%	±3%
*Linearity Tolerance: Standard	±0.5%	±0.5%	±0.5%
Best	±0.05% (1K ohms and above)	±0.025% (5K ohms and above)	±0.1% (above 5K ohms)
Power rating @ 40°C	5 watts	5 watts	2 watts
Mechanical Rotation	3600° +4° −0°	3600° +1° −0°	3600° +12° −0°
Electrical Rotation	3600° +4° −0°	3600° +1° −0°	3600° +12° −0°
Starting Torque	2 oz. in.	1.0±.3 oz. in.	.75 oz. in.
Running Torque	1.5 oz. in.	0.6±.3 oz. in.	.60 oz. in.
Net Weight	4 oz.	4 oz.	1 oz.

*i.e. INDEPENDENT LINEARITY. The above linearity tolerances are based on the following definition recently proposed to clarify and standardize nomenclature related to precision variable resistors. . . . "Independent linearity is the maximum deviation in per cent of the total electrical output of the actual electrical output at any point from the best straight line drawn through the output versus rotation curve. (This line shall be measured through the extent of the effective electrical angle.) The slope and position of the straight line from which the linearity deviations are measured must be so adjusted as to minimize these deviations."



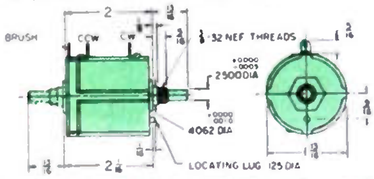
10-Turn Helipot Highlights

From the basic Helipot principle, model variations have been developed to meet new requirements:

Model A Helipot

the original 10-turn Helipot—provides a resolution from 12 to 14 times that of conventional single-turn potentiometers of same diameter (1¾"), linearities as close as ±0.05% in resistances as low as 1K ohms.

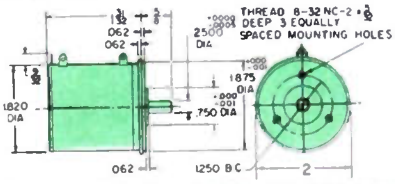
The same multi-turn principle is also available in 3 turn units (Model C), and larger-diameter units of 15 turns (Model B), 25 turns (Model D), and 40 turns (Model E)—a type for every application from 5 ohms to 1 megohm.



Model AN Helipot

an ultra-precision version of the basic 10-turn Helipot. Produced in volume to extremely close electrical and mechanical tolerances, this unit features precision ball bearings (Class 5), servo mounting lid, plus linearity tolerance as close as ±0.025% as low as 5K. A 3-turn unit (Model CN) is also available.

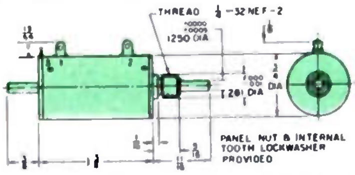
Models AN and CN are particularly recommended for precise servo-mechanism applications and represent the most advanced design and highest quality available today in the field of precision potentiometers.



Model AJ Helipot

a 10-turn *miniature* Helipot only ¾" in diameter, weighs 1 oz., has slide wire 18" long. Also available with servo mounting (Model AJS) and servo mounting with *ball* bearings (Model AJSP). Linearities as close as ±0.1% as low as 5K.

Designed for long life under severe operating conditions, the AJ Series is widely used where small size and weight are vital.



Design details on above units are subject to change without notice. Certified drawings available upon request.

Only Helipot is able to supply—in volume—multi-turn helical potentiometers *with special features to meet your particular needs* . . . Special Shafts, Extra Spot Welded Taps at any position, Ganged Assemblies (except AJ), Special Temperature Coefficients, etc. Send us your requirements!

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Industrial Engineering Notes[1]

MOBILIZATION NEWS

Current demand for antennas is much greater than during the first seven months of this year and only part of the upsurge is attributable to the usual season increase, the Antenna Manufacturers Industry Advisory Committee told the NPA. The opening of new TV stations, together with channel changes by existing stations and improvements in sensitivity of receiving sets is increasing the demand for large units as well as home-type antennas. The committee also reported that antenna replacements have more than doubled and further increases may be expected. The larger units require about twice the amount of aluminum and considerable more steel and copper than the smaller units being replaced. . . . Defense Mobilizer H. H. Fowler has reported to the President that **the output of electronic equipment for the military now is running at a rate more than double that of a year ago. . . . Brigadier General David Sarnoff, chairman of the board of the Radio Corporation of America, has been named by Defense Secretary Robert Lovett, to head an investigation of the utilization of manpower in the armed forces.** The group, known as the Citizens Advisory Commission on Manpower Utilization in the Armed Forces, will comprise 10 other prominent citizens—six civilians and four retired military officers. The study was proposed by the Senate Preparedness Subcommittee which recently has accused the military of dragging its feet in setting up the group. General Sarnoff estimated that the study would take a year or two, but he promised to make recommendations as the investigation progresses.

INDUSTRY STATISTICS

Production of television receivers in August, 1952 increased by 171 per cent over the corresponding month of 1951, as the radio output dropped three per cent, according to reports to RTMA. RTMA estimated the industry's output at 397,769 TV sets compared with 146,705 units in August, 1952. The August radio production was estimated at 543,802 units compared with 563,407 sets manufactured in the same 1951 month. . . . **Sixty-eight per cent of the television picture tubes sold to receiver manufacturers in August, 1952 were 18 inches and larger in size,** according to reports to RTMA. Sales to set manufacturers in August totaled 394,605 units valued at \$8,913,358 compared with 239,625 tubes valued at \$5,165,256 in July, 1952. Ninety-nine per cent of the cathode-ray tubes sold to receiver manufacturers in the month were rectangular in form and 16 inches and larger in size. . . .

[1] The data on which these NOTES are based were selected by permission from *Industry Reports*, issues of October 3, October 10, and October 24, 1952, published by the Radio-Television Manufacturers Association, whose co-operation is gratefully acknowledged.

(Continued on page 67A)

Industrial Engineering Notes

(Continued from page 66A)

The FCC has released the final financial data covering the 1951 operations of the AM-FM radio broadcasting industry. The final figures supplant the preliminary statistics issued earlier this year. In the main, the report showed: 1. Total radio (AM-FM) revenues of seven networks and 2,241 radio stations reached a record high of $450.4 million in 1951, an increase of 1.3 per cent over 1950. Radio income (before Federal income tax) declined, however, to $57.5 million or 15.7 per cent in the earnings of the networks from radio operations coupled with a slight decline of about 4 per cent in the earnings of individual radio stations. 2. Twenty-four per cent (519) of the almost 2,200 AM stations reported losses from 1951 operations—the smallest proportion of AM losers since 1946. The bulk of the losers, 77 per cent (400), started operation since World War II. However, this number represented only 29 per cent of the 1,384 stations that went on the air since that date. Of the 800 odd prewar AM stations, 15 per cent reported losses. Of the 66 FM-only stations, 60 reported losses from 1951 operations. 3. The year 1951 marked the first time that the proportion of AM losers was greater in TV markets than in non-TV markets. Almost 31 per cent of the former lost money as compared to 21 per cent of the latter. The proportion of losers appeared to be greatest among non-network affiliates in the TV markets with 36.5 per cent of such stations reporting losses. 4. The average prewar AM station received almost $300,000 in total revenues from which it earned a profit (before Federal income tax) of slightly above $50,000. The average postwar AM station (eliminating those in operation less than two years) received almost $100,000 in revenues from which it earned a profit of approximately $7,500. . . . **Production of television receiver in September, 1952 increased 124 per cent over the industry output in the corresponding month of 1951,** according to RTMA's estimates. However, the radio receiver output dropped considerably under last year. The RTMA report for September, a five-week period, showed the manufacture of 755,665 television sets as against 337,341 units in the same month of last year. The radio output was estimated at 865,654 sets compared with 1,100,246 units in September, 1951.

New Receiver Being Produced

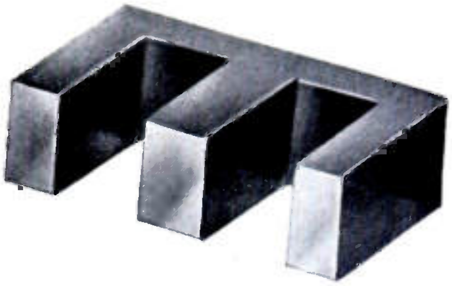
A new general utility radio receiver, developed by the Rauland Corporation, is being produced for the army by the Emerson Radio and Phonograph Corporation, the Signal Corps announced recently. The new unit is designed for use in all types of armored and personnel vehicles, gun carriages, and field and fixed installations.

Designated the AN/GRR-5, the receiver is designed to achieve maximum ruggedness and reliability under all operating conditions. It is immersion proof and concussion proof and is capable of operation from dry battery, storage or mobile-type battery, or ac power line.

(Continued on page 70A)

• HP • C • J •

Iron Powders...



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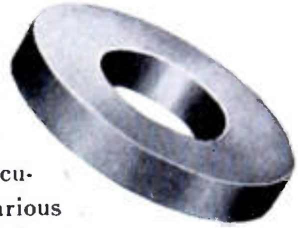
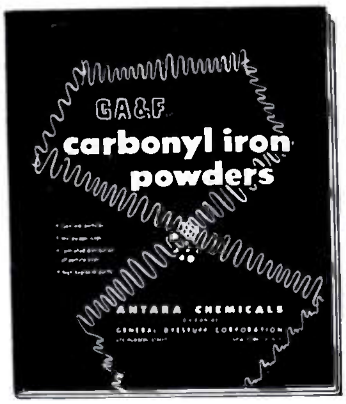
L



We invite you to write for your copy of the book pictured below — which will give you a far more detailed and documented description of the various types of G A & F Carbonyl Iron Powders.

Even more important, if you are one of the few whose requirements call for still greater stability, density, permeability, etc.—than are normally offered by any of our standard types—we invite your inquiry. Our sales engineers and sales service men will welcome the opportunity to supply samples or to work with you—in either laboratory or application tests—to help you find the answer to any problem that is logically within our province.

This wholly new 32-page book offers you the most comprehensive treatment yet given to the characteristics and applications of G A & F Carbonyl Iron Powders. 80% of the story is told with photomicrographs, diagrams, performance charts and tables. For your copy—without obligation — kindly address Department MJ.



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Industrial Engineering Notes

(Continued from page 67A)

Television News

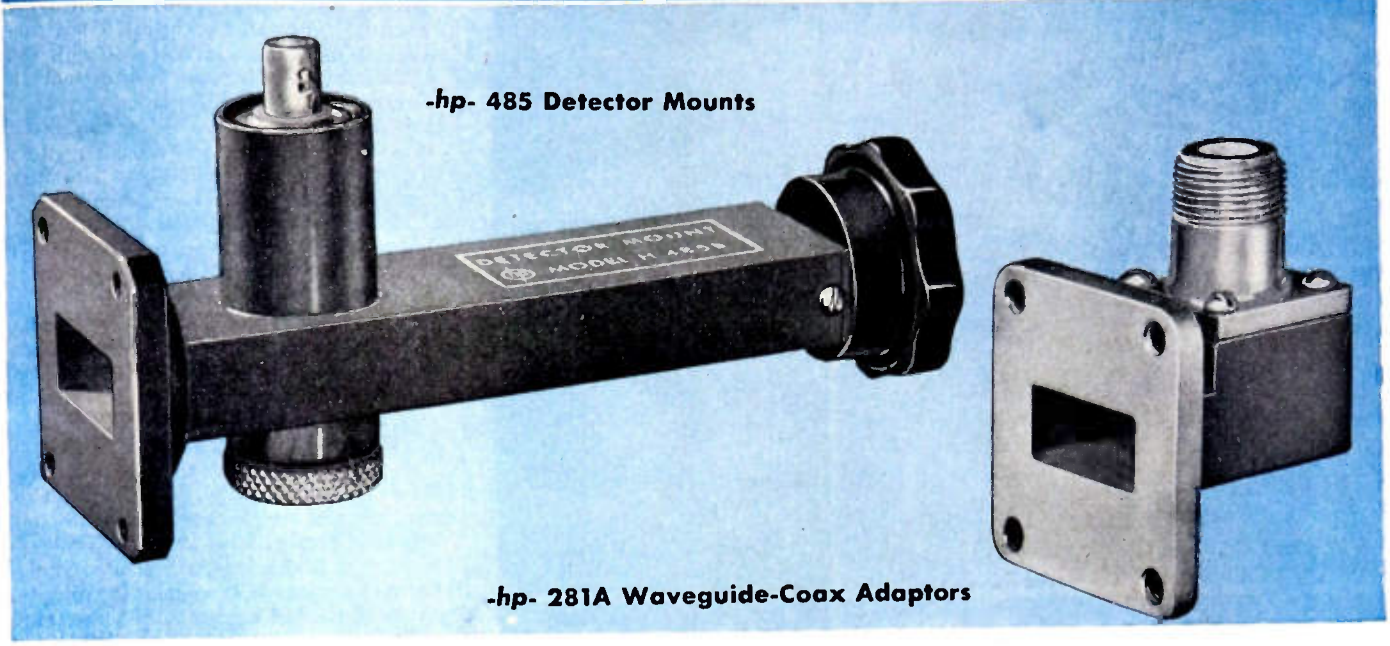
The authorizations for 72 new TV stations have been granted, as of October 16, since the FCC lifted its "freeze" on new construction. The Commission also has approved a special temporary authorization for KBTV (TV), Denver, Colo., the nation's third post-freeze station to get on the air. The STA was effective September 29, 1952, and authorizes the outlet to operate with 12.5 kw visual and 6.3 kw aural on channel 9. . . . **The National Broadcasting Company will test a radio-type microphone in the studios of KNBH(TV),** Hollywood, Calif., the Federal Communications ComWission announced recently. A special temporary authorization was granted by FCC for the device which will operate in the frequency band 49.48 to 49.52 mc. Tests will be conducted during a 30-day period to determine the usefulness of the microphone in the production of television programs, it was reported. . . . **Frequency space totaling 420 mc was requested recently by representatives of motion picture companies** during the opening sessions of an FCC hearing on the question of theatre television. During the hearings, it was pointed out that the case is not one of licensing facilities, as its scope is limited to the allocation of frequencies. Included among the Commission's issues in the case in the event it decides to establish a theatre-TV service, is whether the new service should be operated on a common carrier or some other basis. The motion picture witnesses emphasized that they were not asking for any frequencies used by or allocated to home television broadcasting, including those for pickup and relay purposes. All the theatre spokesmen indicated that any allocation of frequencies would be taken away from services other than TV which currently are not using their allocated space. The proposed theatre-TV frequencies now are allocated to the common carrier service, land mobile, and the fixed services. Theatre spokesmen declared that they wanted a TV service comparable in quality to 35 millimeter motion pictures. They are proposing a 735-line system with a 10 mc video band and a total channel width of 30 mc. Plans of the theatre group involve six separate intercity systems each with two channels but with no city having more than 3 channels available to it.

FCC Actions

E. H. Merrill has been named a member of the Federal Communications Commission by President Truman. He will fill the vacancy created by the resignation of Robert F. Jones. The appointment is for two years to fill Mr. Jones' unexpired term of office. Most recently, Mr. Merrill has been Director of Materials in the Office of Programs and Requirements of the Defense Production Administration. He joined the National Production Authority

(Continued on page 72A)

ELECTRONIC TEST INSTRUMENTS



New broad band Adaptors and Detector Mounts offer high accuracy, easy operation, low cost

Model 485 Detector Mounts and 281A Adaptors typify the new *-hp-* line of precision waveguide test instruments. Each has the simplest possible construction consistent with its basic function. Each covers the complete frequency range of its waveguide size and is wholly integrated with other equipment for the same band. Novel circuitry plus simple mechanical design insure highest accuracy and stability, provide utmost operating ease and permit quantity production at low cost.

-hp- 485 Detector Mounts

These mounts offer new convenience in measuring microwave power with a bolometer, or detecting rf energy with a crystal. A single tuning control adjusts match easily and quickly. (See Figure 1.) For optimum match, mounts may be preceded by a slide-screw tuner such as *-hp-* 870A. Detected output appears at a BNC jack, and may be measured with an *-hp-* 430B Microwave Power Meter or an *-hp-* 415A Standing Wave Indicator.

-hp- 485B Mounts are tunable and available in waveguide sizes 2″ x 1″, 1½″ x ¾″, 1¼″ x ⅝″, and 1″ x ½″. Maximum VSWR when used with a Sperry 821 barretter is 1.25. These mounts also accommodate 1N21 and 1N23 crystals.

-hp- S485A Mount is for use with 3″ x 1½″ waveguide, and employs only a Sperry 821 barretter. It requires no tuning, and maximum VSWR is 1.25 at any point in the frequency band.

-hp- 281A Adaptors

These adaptors provide a convenient means of transmission between waveguide and coaxial systems. Power may be fed in either direction, and each unit covers the full frequency range of its waveguide size with VSWR less than 1.25. (See Figure 2.) Coaxial connections are made to a standard Type N plug, and waveguide connections to a plain AN flange. *-hp-* 281A Adaptors are offered in all waveguide sizes covering the frequency range from 2.6 to 12.4 kmc.

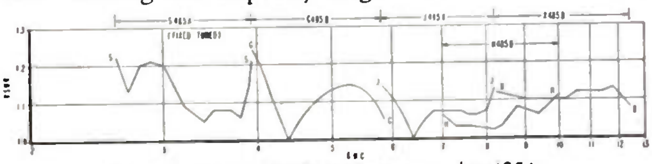


Figure 1. Typical VSWR vs. Frequency, -hp- 485A, when used with barretter.

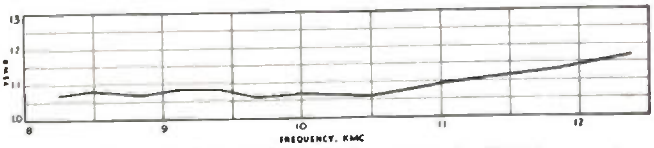


Figure 2. Typical VSWR vs. Frequency, -hp- X281A.

For complete details, see your -hp- field representative or write direct

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Instruments for Complete Coverage

Industrial Engineering Notes

(Continued from page 70A)

early in its formation and moved to DPA when it was created early in 1951. From 1945 to 1950, Mr. Merrill was with the United States Military Government in Germany as Chief of Communications. In this post he was responsible for the allocation of frequencies for the occupation forces and German civilian population for broadcasting, radio telecommunications, and other uses. During World War II, Mr. Merrill was with the War Production Board, handling the allocation of materials to the telephone industry. He also has served with the Public Service Commission of Utah, his home state. . . . **The FCC has finalized its proposal to add 540 kc to the standard broadcast band.** The AM broadcast band for use in the United States is now specified 535 to 1,605 kc, in lieu of 550 to 1,600 kc. Use of the additional channel (540 kc), the FCC said, will be subject to the "harmful interference" provisions contained in Section 2.104(a) of the Table of Frequency Allocations rules. United States Class II stations will recognize the priority of use on the 540 kc channel given to Canada under provisions of the pending North American Regional Broadcasting Agreement (NARBA).

700 Attend RTMA Meeting

Registration at the 1952 Radio Fall Meeting held in Syracuse, October 20–22 totaled 700 and approximately 350 persons attended the annual dinner, according to V. M. Graham, chairman of the Fall Meeting committee. The event is sponsored annually by the RTMA engineering department.

Dr. E. W. Engstrom, of RCA, was presented a plaque at the dinner on October 21, for his "contributions in the field of tricolor picture tubes." J. W. McRae, of the Bell Telephone Laboratories, was toastmaster.

Dr. W. R. G. Baker, director of the RTMA engineering department, showed movies of his recent trip to the Korean battlefields. The next Radio Fall Meeting will be held at Toronto, Canada, on October 26–28, 1953.

Research News

A constant-amplitude oscillator which provides an RF voltage that remains reasonably stable regardless of changes in tube parameters, supply voltage, heater voltage, or load impedance has been developed by the National Bureau of Standards. The device is reported to consist essentially of a conventional oscillator with a diode connected across the terminals. Output stability is provided by a biased control clamper tube sharing the same plate-dropping resistor with the oscillator. Full information on the constant-amplitude oscillator appeared in the November, 1952, issue of the NBS *Technical News Bulletin.*

(Continued on page 74A)

If you

want to **get tough**

in your assemblies,

In the heavy-weight division — fixed and adjustable Greenohms — up to 200 watt.

specify

greenohm*

power resistors

* The green-colored power resistors so conspicuous these days in dependable radio-electronic and electrical assemblies, are GREENOHMS. *No tougher resistors made.* That statement is sustained by laboratory tests. Likewise by countless case histories out in the field.

Unimpaired wire winding firmly imbedded in exclusive cold-setting inorganic cement. Exceptional heat conduction and surface radiation. Heavy overloads handled without damage. Severe heat-shock resistance permits extreme on-off operation without flinching. And Greenohms last and last.

Choice of standard types. Also in virtually unlimited special types. Wide selection of resistance values, wattages, taps, terminals, mountings. And remember, *Greenohms cost less* though they offer you more!

Greenohm Jr. — point-to-point wired power resistor sealed in ceramic tubular casing. 4, 7 and 8 watt.

Flat Greenohms for flat mounting individually, or for stacked arrays. 30 to 75 watt.

In the bantam-weight division — 5 and 10 watt fixed Greenohms.

Standees — convenient above-chassis mounting Greenohms in ceramic casings. 10 to 25 watt.

What is the ideal resistance value? That's easy. With the Clarostat Power Resistor Decade Box inserted in actual circuit, handling actual load, you try the six knobs for anything from 1 to 999,999 ohms. When right operating conditions are attained, read resistance directly off dials. Quick, simple, positive, economical.

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Engineering data on request. Send us your resistance or control requirements for engineering aid and quotations. Try Greenohms!

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Controls and Resistors

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In Canada: Canadian Marconi Co., Ltd., Toronto, Ontario

Industrial Engineering Notes

(Continued from page 72A)

... A number of **new manufacturing techniques and materials of interest to the electronics industry are reported in the September, 1952 issue of the** *Bibliography of Technical Reports*, by the Office of Technical Services, Department of Commerce. The "Bibliography" review reports on scientific and technical research done under or with the financial aid of the government. It is available for 50 cents per copy or $5.00 a year through the Office of Technical Services, Department of Commerce, Washington 25, D. C. ... The National Bureau of Standards has reported that it is **investigating the feasibility of detecting incipient failures of electronic equipment long before they perceptibly affect the over-all performance.** The study is designed to help insure higher reliability in electronic equipment. Quick and easy failure-prediction checks by unskilled personnel reportedly are the goal of the NBS work, which is being sponsored by the Office of Naval Research. NBS has evolved a technique experimentally in which a maintenance man simply plugs a failure-prediction unit into the slightly-modified equipment to be checked and turns a multipoint selector switch. A red light then flashes on to identify stages or components that have deteriorated below safe levels and have become prospective causes of equipment failure. In accelerated-aging experiments on a military radio receiver, the Bureau reports that it has been able to predict most failures many hours before they occur. Details of the work in the prediction of electronic failures will appear in the December issue of the NBS *Technical News Bulletin*.

STUDENT BRANCH MEETINGS

Agricultural and Mechanical College of Texas IRE-AIEE Branch

"Activities of Joint AIEE-IRE Student Branch This Year," by N. F. Rode and H. C. Dillingham, September 30, 1952.

University of Alberta, IRE-AIEE Branch

"History of IRE" by J. W. Porteous, Faculty University of Alberta, October 8, 1952.

Brown University IRE-AIEE Branch

"Proceedings of an Engineering Instructors Institute," by M. F. Gordon and "Observations of Recent Engineering Graduates in Research," by J. Ruins, Faculty, Brown University, October 8, 1952.

Bucknell University IRE-AIEE Branch

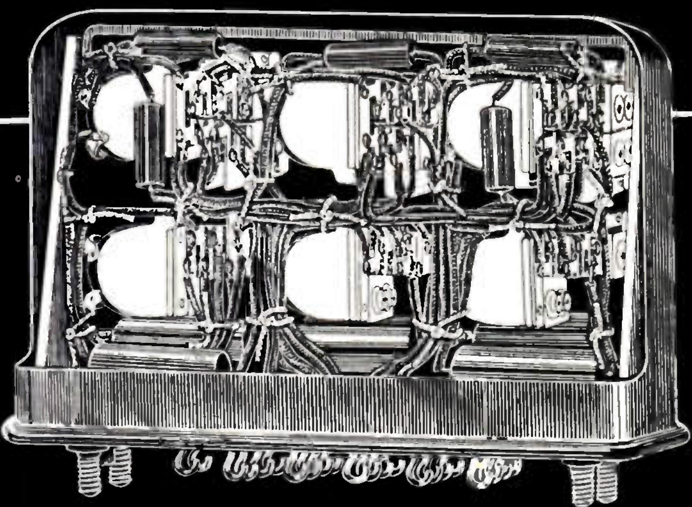
General Business Meeting; September 25, 1952.

General Business Meeting; October 8, 1952.

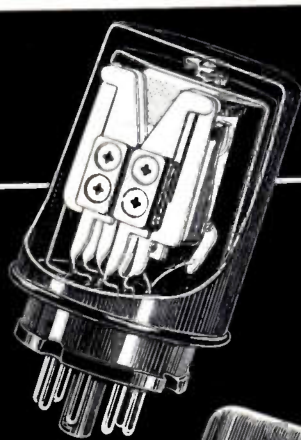
Inspection tour of IBM plant; October 15, 1952.

(Continued on page 76A)

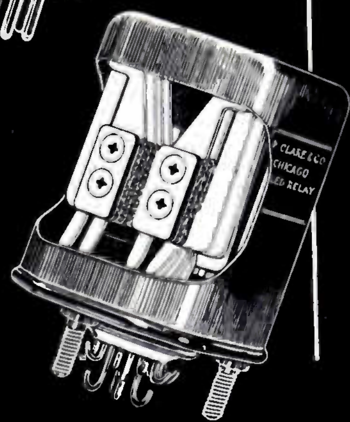
CLARE offers the widest variety of HERMETICALLY SEALED RELAYS for most exacting design requirements!



Considerable cost and space can often be saved by sealing more than one relay in an enclosure. Illustration shows six CLARE Type "K" relays, associated resistors and capacitors, wired and mounted in a common enclosure.



Here is one of over 300 plug-in relays in the CLARE SK-5000 series.



CLARE Type "N" relay in a Series SN-41000 container.

What CLARE Hermetic Sealing Means:

After assembly in the container, the enclosure is attached to a high vacuum pump and pumped down to a few microns pressure to remove all traces of moisture and gases, then flushed with dry nitrogen, and again pumped down.

While under this extreme vacuum, the enclosure and seals are tested for leaks by means of a Mass Spectrometer—a device so sensitive that it can detect a leak so tiny that more than thirty-one years would be required for one cubic centimeter of air to pass through it. This highly refined method of leak testing causes rejection of many enclosures which could pass the usual immersion tests without detection.

For most applications, the enclosure is then filled with dry nitrogen, which has a relatively high arcing potential.

IN THE fourteen years since CLARE first began the development of hermetically sealed relays for airborne, military and industrial use, CLARE has developed over 50 different series of hermetically sealed relays.

Each series varies in the size of the container, the number and kind of terminals, mounting facilities and the type or types of relays which can be sealed in it. Within each series, innumerable variations of relay coil and contact specifications are possible.

Two things, however, never vary: the high quality of the CLARE relay which goes into each enclosure and the completely airtight sealing which permits no gas or spirit to escape from the enclosure or enter it.

If your product requires the use of hermetically sealed relays, CLARE can supply you just the relay you need from this wide variety, or will develop and seal for you a special, "custom-built" relay to meet your most exacting requirements.

Send for CLARE BULLETIN NO. 114 on Hermetically Sealed Relays or contact the nearest CLARE sales engineer for complete information. Address: C. P. Clare & Co., 4719 West Sunnyside Avenue, Chicago 30, Illinois. In Canada: Canadian Line Materials Co., Ltd., Toronto 13. Cable address: CLARELAY.

CLARE RELAYS

...First in the Industrial Field

STUDENT BRANCH MEETINGS

(Continued from page 74A)

CALIFORNIA STATE POLYTECHNIC COLLEGE, IRE BRANCH

"The Engineer and the Army," by Col. James Foster, Operations & Training Officer, U. S. Army Signal Corps; October 2, 1952.

UNIVERSITY OF COLORADO, IRE-AIEE BRANCH

"Reason for Sudan expedition to observe eclipse," by Dr. Billings and Mr. Cooper, Scientists; September 24, 1952.

"The Instrument Story," by Mr. Henry Berring, Educational Director, Weston Electrical Instrument Corp.; October 8, 1952.

UNIVERSITY OF DENVER, IRE-AIEE BRANCH

"Instrument Construction and Their Application," by Mr. Berrings, Weston Instrument Co.; October 6, 1952.

UNIVERSITY OF DETROIT, IRE-AIEE BRANCH

General Business Meeting; September 30, 1952.

UNIVERSITY OF FLORIDA, IRE-AIEE BRANCH

General Business Meeting; September 30, 1952.

GEORGE WASHINGTON UNIVERSITY, IRE BRANCH

Engineers Mixer, sponsored by the Engineers Council of the School of Engineering; October 1, 1952.

MANHATTAN COLLEGE, IRE-AIEE BRANCH

"Transformers, Principles & Applications," by Thomas Keene, General Electric Co.; October 22, 1952.

MICHIGAN COLLEGE OF MINING & TECHNOLOGY, IRE-AIEE BRANCH

"Amateur Radio Station of MCMT," by J. Bremer, Student Member, IRE; September 23, 1952.

"Experience and the Young Engineer," by George Roman, Faculty, Mich. Tech.; October 7, 1952.

MISSISSIPPI STATE COLLEGE, IRE BRANCH

Election of Officers; October 2, 1952.

"Future For Engineers," by G. Reits, Educational Director, General Electric; October 16, 1952.

MISSOURI SCHOOL OF MINES & METALLURGY, IRE-AIEE BRANCH

General Meeting; September 18, 1952.

UNIVERSITY OF NEBRASKA, IRE-AIEE BRANCH

General Business Meeting; September 23, 1952.

COLLEGE OF THE CITY OF NEW YORK, IRE BRANCH

General Meeting; September 15, 1952.

NEW YORK UNIVERSITY (Evening Division) IRE-AIEE BRANCH

General Meeting; October 10, 1952.

NORTH DAKOTA AGRICULTURAL COLLEGE, IRE-AIEE BRANCH

"Membership in the Student Branch of AIEE and IRE," by E. M. Anderson, Faculty, N. Dakota Agricultural College; October 1, 1952.

OKLAHOMA AGRICULTURAL & MECHANICAL COLLEGE, IRE-AIEE BRANCH

"Microwave Radio Relay," by C. C. Flora, Southwestern Bell Tel. Co.; September 22, 1952.

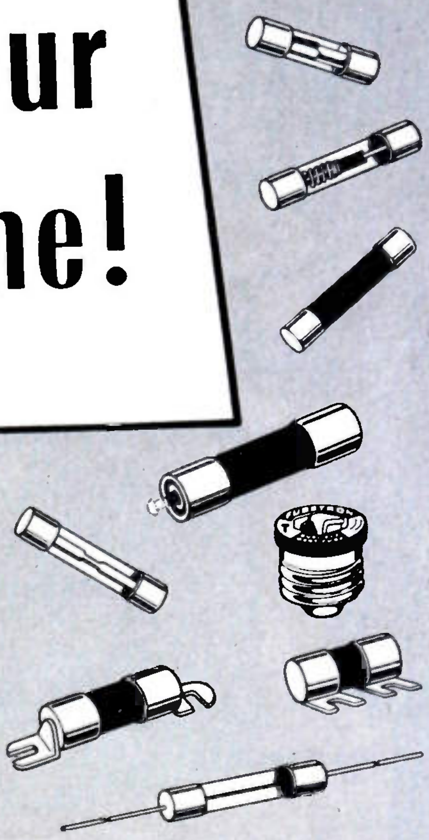
General Meeting; October 13, 1952.

OREGON STATE COLLEGE, IRE BRANCH

"25 KV Under the Sea," by John Mather, Electrical Engineer, B.P.A.; September 30, 1952.

(Continued on page 78A)

Guard Your Good Name!



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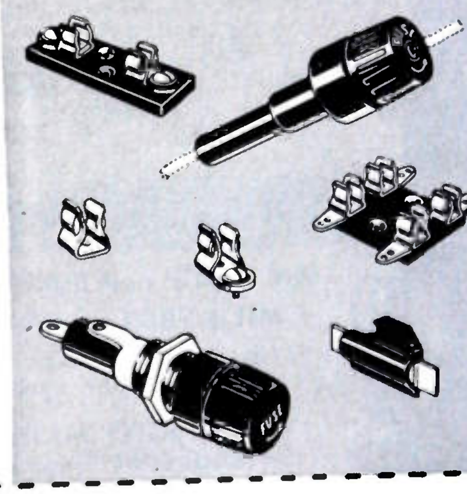
***Plus* a companion line of Fuse Clips, Blocks and Fuse holders**



The cost of a fuse is small, compared to the value of the product it protects, — but the *customer influence* of a BUSS Fuse can be many times greater. The name BUSS is recognized as meaning fuses of unquestioned high quality. What better "silent salesmanship" could you ask for to complement your product?

To maintain this high standard each and every BUSS fuse is tested in a highly sensitive electronic device that rejects any fuse that is not correctly calibrated — properly constructed and right in physical dimensions.

When your problem is electrical protection, call in a BUSS Fuseman. He is at your service and can make available to you the World's largest fuse research laboratory and the World's largest fuse production capacity.

This Coupon will bring you — facts on BUSS small dimension fuses, fuse clips, blocks and fuse holders.

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Please send me bulletin SFB containing facts on BUSS small dimension fuses and fuse holders.

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BUSSMANN MFG. CO. Division of McGraw Electric Company
University at Jefferson St. Louis 7, Mo.

STUDENT BRANCH MEETINGS

(Continued from page 76A)

Pennsylvania State College, IRE-AIEE Branch

General Meeting; September 25, 1952.

University of Pittsburgh, IRE Branch

"Underwriters' Laboratories," by Mr. L. F. Lauer, Inspector, Underwriters' Laboratories Inc.; October 16, 1952.

Rensselaer Polytechnic Institute, IRE-AIEE Branch

"The Instrument Story," by H. Berring, Weston Electrical Instrument Corp.; September 30, 1952.

Stanford University, IRE-AIEE Branch

"Radio Astronomy," by Dr. Oswald Garrison Villard, Jr., Faculty, Stanford Univ.; October 8, 1952.

University of Texas, IRE-AIEE Branch

General Business Meeting; October 6, 1952.

Tufts College, IRE-AIEE Branch

Films: "Shining Rails," "Sightseeing at Home," "Thunderbolt Hunters"; October 15, 1952.

Virginia Polytechnic Institute, IRE-AIEE Branch

General Meeting and Election of Officers; October 7, 1952.

General Meeting; October 14, 1952.

Wayne University, IRE-AIEE Branch

Business Meeting; September 23, 1952.

Worcester Polytechnic Institute, IRE-AIEE Branch

General Business Meeting; September 29, 1952

SECTION MEETINGS

Akron

"Exploitation of Message Statistics," by R. E. Graham, Bell Telephone Laboratories; September 23, 1952.

Atlanta

"Electronics at Work in the Petroleum Industry," by Dr. W. M. Rust, Jr., Director, Region 6; September 12, 1952.

Baltimore

"Concepts and Components in Modern Miniature Deisgn," by Y. Jacobs, Electronics Research and Development Laboratories, WADC; October 8, 1952.

Beaumont-Port Arthur

Discussion of Section Affairs; July 19, 1952.

"High Fidelity Audio and Acoustical Equipment," by H. A. Keep and Hoyt Hughes, Gulf Coast Electronics Corporation; September 23, 1952.

Binghamton

"Application and Theory of Thyratrons," by D. E. Marshall, Westinghouse Electric Corporation; September 26, 1952.

Buffalo-Niagara

"Telemetry and its Application to Pilotless Aircraft," by G. S. Hartloff, Bell Aircraft Corporation; September 17, 1952.

(Continued on page 80A)

NEW! UHF TELEVISION
Standard Signal Generator

MODEL 84-TV

Model 84-TV Standard Signal Generator has been developed to meet the need for a reliable signal source for the UHF Television band. Research requirements as well as production testing needs are met with accuracy, stability and ease of operation.

Important features extend the usefullness of this versatile new instrument to many applications within its frequency range. Model 84 TV's combination of high output and low VSWR assures the owner of an instrument that will make a wide range of measurements with the reliability expected from Measurements Laboratory Standards. This instrument is useful for driving slotted lines and other impedance measuring devices, as well as making direct gain measurements of RF amplifiers.

Because of its low harmonic content, the characteristics of UHF filters, traps, antennas, matching networks and other circuits may be accurately measured.

SPECIFICATIONS

FREQUENCY RANGE: 300-1,000 megacycles.

OUTPUT: .1 Microvolt to 1 Volt, across 50 Ohms.

OUTPUT IMPEDANCE: 50 Ohms coaxial.

MODULATION: Internal 400 cycle, continuously variable from 0 to 30%. Provision for external modulation of 50 to 20,000 cycles.

LEAKAGE: Negligable.

SIZE: Overall dimensions: 11¾ inches high, 19 inches wide, 11 inches deep.

WEIGHT: Approximately 40 pounds.

POWER: 115 volts, 60 cycles, 120 watts.

Descriptive circular upon request

MEASUREMENTS CORPORATION
BOONTON NEW JERSEY

SECTION MEETINGS

(Continued from page 78A)

Cedar Rapids

Conference on Communications; September 19-20, 1952.

Chicago

"Your Institute, a Million Dollar Business," by Dr. D. B. Sinclair, General Radio Company and President of IRE; September 26, 1952.

Cleveland

"This I Saw," by R. M. Pierce, WDOK; September 25, 1952.

Columbus

"Junction Transistor Physics," by Dr. James Ebers, Bell Telephone Laboratories; October 15, 1952.

Dayton

"Recent Development on Television Camera Design," by N. M. Marshall, and E. J. Manzo, General Precision Laboratory; October 9, 1952.

Denver

"Electronics in Strain Analysis," by James Carson, Hathaway Instrument Company; October 17, 1952.

Des Moines-Ames

"Spectrum Analyzers and Their Uses," by Bruce Wholey, Hewlett-Packard; October 7, 1952.

El Paso

Two Technical Films and Social Meeting; September 26, 1952.

Emporium

"Manufacture and Application of Carbon and Graphite," by M. S. May, Speer Carbon Company; September 23, 1952.

"Television and the Bell System," by R. G. Fithian, Bell Telephone Company of Pennsylvania; October 14, 1952.

Fort Wayne

"Engineers, Inventions, Employers," by A. W. Graf, Patent Lawyer; October 2, 1952.

Hamilton

"Electronic Applications in Mining Operations," by R. L. Adams, McPhar Engineering; September 29, 1952.

Hawaii

Short talks by: G. Reber, G. Stagner of RCA, E. Sawyer of CAA, J. Erdman of IBM, Capt. Colmar, USCG, and L. H. Gilbert of State Department; July 9, 1952.

"Magnetic Recorders, Their Design and Operational Considerations," by Danny Dashiell, Pearl Harbor Naval Shipyard; August 13, 1952.

"Design Considerations and Performance of High Fidelity Amplifiers," by F. McIntosh, Frank McIntosh Company, and Description of 1952 Western Electronic Show and Convention at Long Beach, California, by E. A. Piety; September 10, 1952.

Inyokern

"Applications of Analogue Computer Techniques to Loud Speaker Design," by B. N. Locanthi, Jim Lansing Sound, Inc.; September 18, 1952.

"Measurement of Wow and Flutter in Magnetic Tape Recording," by John Mullin, Crosby Enterprises; October 13, 1952.

Kansas City

"Servomechanisms as Applied to Analog Computers," by Dr. A. C. Hall, Bendix Aviation Corporation; October 14, 1952.

Little Rock

"Electronic Generation of Musical Tones," by J. F. Jordan, Baldwin Piano Company; September 24, 1952.

(Continued on page 82A)

Engineered today for your needs tomorrow!

MYCALEX®

PRECISION-MOLDED MYCALEX 410

TRANSISTOR SOCKETS

Mycalex 410 Transistor Socket shown actual size

Mycalex 410 Transistor Socket enlarged to show detail

—now in the pilot production stage
—engineered in advance of actual need

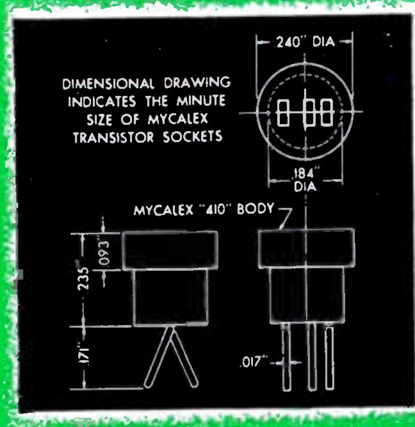
In keeping with the MYCALEX policy of progressive design in advance of needs, these Transistor Sockets were engineered months ago and are now in small scale pilot production. They'll be available in quantity in advance of actual needs.

Achievement in PRECISION MOLDING!

The production of Mycalex Transistor Sockets is a real accomplishment of precision molding in miniature. The holes for the leads are the smallest ever molded. All tolerances are exceedingly close. Mycalex production engineers are proud of their achievement . . . particularly because low-cost, mass production techniques can be adhered to.

The body is precision-molded of MYCALEX 410, glass-bonded mica insulation for lasting dimensional stability, low dielectric loss, immunity to high temperature and humidity exposure combined with maximum mechanical strength. The loss factor is only 0.014 at 1 MC and dielectric strength is 400 volts/mil.

Contacts can be supplied in brass or beryllium copper. The sockets are readily solderable. The socket bodies will not warp or crack when subjected to high soldering temperature. They function in ambient temperatures up to 700° F.



Mycalex Low-loss Tube Sockets and Multiple Headers

A complete line of tube sockets including sub-miniature types is available in Mycalex 410 and Mycalex 410X glass-bonded mica insulation. Comparative in cost to ordinary phenolic sockets they are far superior in every respect. Dimensional accuracy is unexcelled. For complete information on standard and custom Tube Sockets or Multiple Headers, call, wire or write . . . there is no obligation, of course.

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SECTION MEETINGS

(Continued from page 80A)

LONDON

"The Production of Plastics for the Radio and Electronic Industry," by Paul Scott, Dow Chemical Company; September 27, 1952.

LOS ANGELES

"Earthquakes," by Dr. G. H. Benioff, Faculty, California Institute of Technology, "Statistical Concepts for Research, Development and Engineering Design," by Dr. E. P. Coleman, Hughes Aircraft Company and "How Not to be a Poor Technical Editor," by Dr. Duane Roller (Dinner Speaker); October 7, 1952.

NEW MEXICO

"Dielectric Amplifiers," by E. G. Miller, Jr., Sandia Corporation; August 21, 1952.

"Electrographic Recording," by Dr. C. A. Heiland, Heiland-Denver; September 18, 1952.

NEW YORK

"The Collection of Information in Human Networks," by L. S. Christie, Massachusetts Institute of Technology; September 10, 1952.

PHILADELPHIA

"Electronic Computers," by Dr. Aiken, Harvard Computation Lab.; October 2, 1952.

PITTSBURGH

"Germanium Power Rectifiers," by Addison Sheckler, General Electric Company; October 13 1952.

PRINCETON

"Information Theory Applied to the Human Being," by Dr. J. C. R. Licklider, Massachusetts Institute of Technology; October 9, 1952.

SACRAMENTO

"The C-1 Alarm and Control System for Use with Microwave Radio Relay," by H. M. Pruden and "Practical Applications of Information Theory to Transmission Problems," by W. R. Bennett, both of Bell Telephone Laboratories; September 5, 1952.

SAN FRANCISCO

"Microwave Radio Relay Alarm," by H. M. Pruden and "Information Theory," by W. R. Bennett, both of Bell Telephone Laboratories; September 3, 1952.

"Applications of Pulse Counting Techniques in Measurement and Control," by J. L. Corl, Berkeley Scientific Company; October 8, 1952.

TOLEDO

"Television and Communications Microwave Relay Systems," by W. H. Forster, Philco Corporation; October 9, 1952.

TORONTO

"Television Synchronizing Circuit," by V. J. Byers, Ryerson Institute of Technology; September 29, 1952.

TULSA

"Electronic Generation of Musical Tones," by J. F. Jordan, Baldwin Company; September 23, 1952.

"Permanent Magnet Materials and Their Applications," by C. A. Maynard, Indiana Steel Products Company; October 15, 1952.

TWIN CITIES

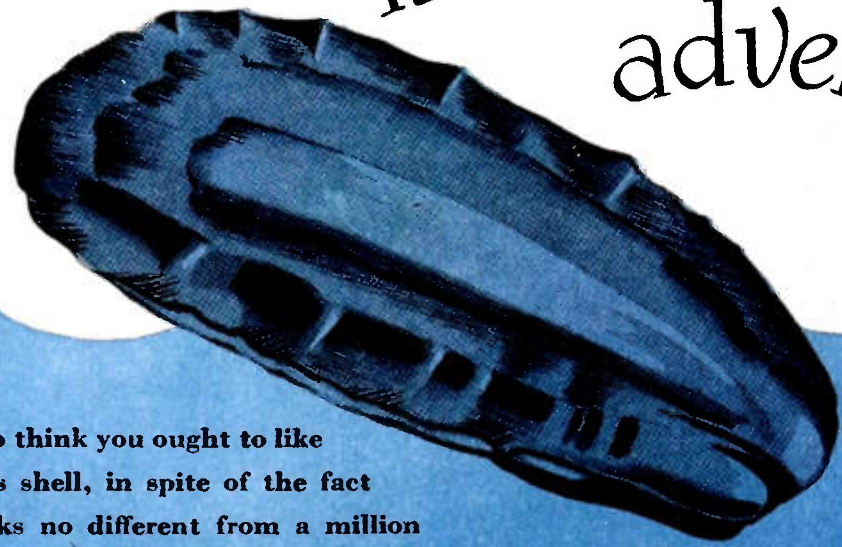
"The Emerging Science of Echography," by J. J. Wild, University of Minnesota; October 2, 1952.

VANCOUVER

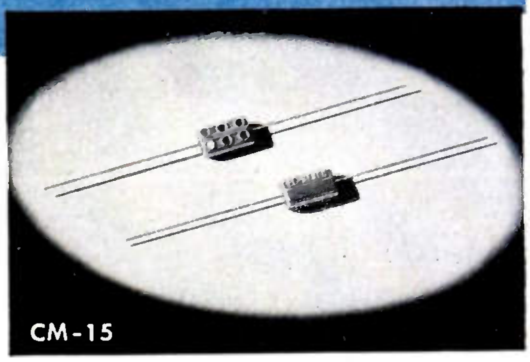
"Television and Television Relay," by Dr. M. E. Strieby, American Telephone and Telegraph Company; October 6, 1952.

(Continued on page 86A)

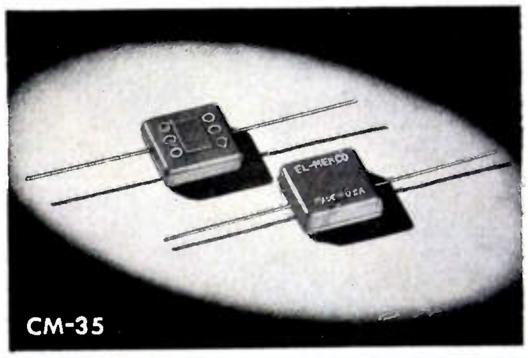
an oyster never advertises



He seems to think you ought to like him for his shell, in spite of the fact that it looks no different from a million other oyster shells. If he's got a pearl inside, why doesn't he say so.



CM-15



CM-35

CAPACITORS LOOK PRETTY MUCH ALIKE FROM THE OUTSIDE, BUT EL-MENCO'S HAVE SOMETHING IN THEM *and we want the world to know it.*

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Jobbers and Distributors: For information write to Arco Electronics, Inc., 103 Lafayette St., New York, N. Y.—Sole Agent for Jobbers and Distributors in U.S. and Canada.

Write on business letterhead for catalog and samples.

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Radio and Television Manufacturers, Domestic and Foreign, Communicate Direct With Factory—

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A Complete Lin

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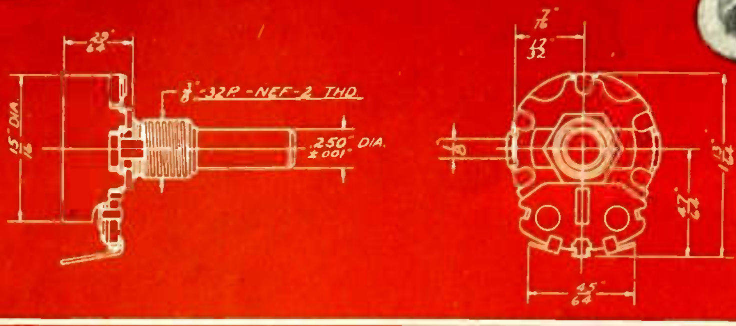
TYPE 45

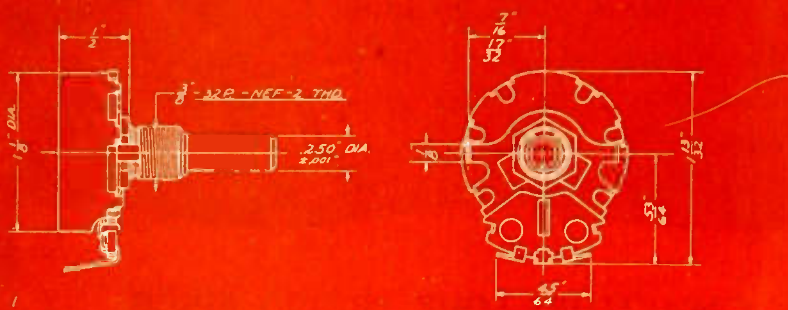
(JAN-R-94, Type RV3)



¼ watt, 15/16" diameter variable composition resistor.
Also available with other special military features not covered by JAN-R-94. Attached Switch can be supplied.

TYPE 35

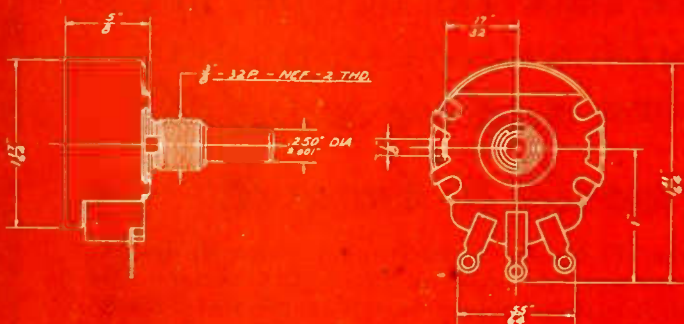
(JAN-R-94, Type RV3)



½ watt, 1⅛" diameter variable composition resistor.
Also available with other special military features not covered by JAN-R-94. Attached Switch can be supplied.

TYPE 252

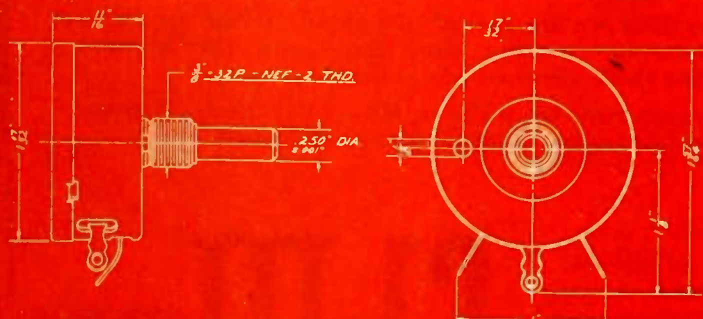
(JAN-R-19, Type RA20)



2 watt, 1 11/64" diameter variable wirewound resistor. Also available with other special military features not covered by JAN-R-19. Attached Switch can be supplied.

TYPE 25

(JAN-R-19, Type RA30)



4 watt, 1 17/32" diameter variable wirewound resistor. Also available with other special military features not covered by JAN-R-19. Attached Switch can be supplied.

For additional information on these 7 controls, write for Data Sheet No. 160

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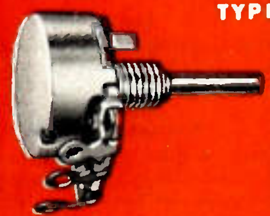
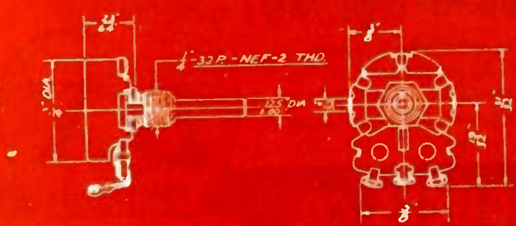
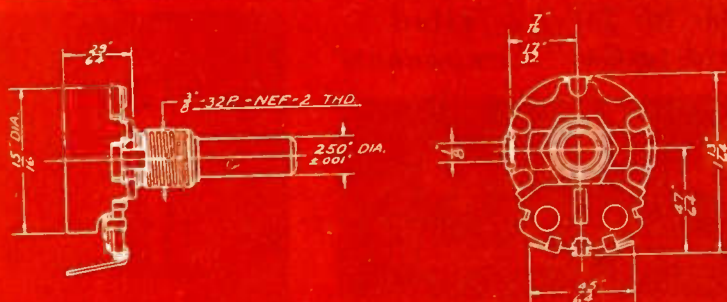
TYPE 65





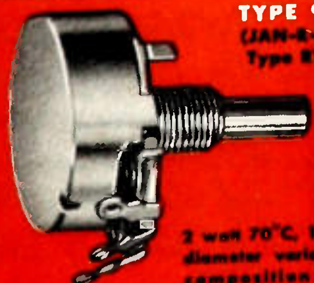
½ watt 70°C, ¾" diameter miniaturized variable composition resistor.

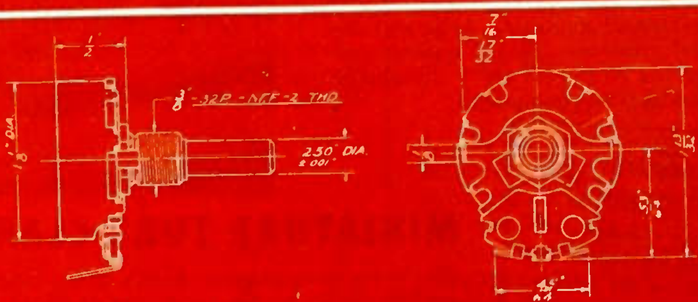
TYPE 90



1 watt 70°C, ¹⁵⁄₁₆" diameter variable composition resistor. Attached Switch can be supplied.

TYPE 95
(JAN-R-94, Type RV4)





2 watt 70°C, 1⅛" diameter variable composition resistor. Also available with other special military features not covered by JAN-R-94. Attached Switch can be supplied.

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OTHER EXPORT

Sylvan Ginsbury
8 West 40th Street
New York 18, N. Y.

SECTION MEETINGS

(*Continued from page 82A*)

WASHINGTON, D. C.

"Loudspeakers and Transmission of Sound," by F. H. McIntosh, McIntosh Engineering Laboratory, Inc.; October 13, 1952.

WILLIAMSPORT

"Distributed High Frequency Transformers," by H. G. Rudenberg, Transitron Electronic Corporation; September 17, 1952.

SUBSECTIONS

LANCASTER

"Applications of the Traveling Wave Principle to Microwave Electronics," by Dr. R. Kompfner, Bell Telephone Laboratories; October 8, 1952.

LONG ISLAND

"Theseus—a Maze Solving Machine," by Dr. C. E. Shannon, Bell Telephone Laboratories; September 9, 1952.

MID-HUDSON

"The Low Frequency Oscillograph, Accessories and Application," by Robert Dolbear, Allen B. Dumont Labs.; September 23, 1952.

NORTHERN NEW JERSEY

"Micro-Strip Printed Circuits for the Kilomegacycle Range," by Dr. Fred Assadourian, Federal Telecommunication Laboratories, Inc.; September 17, 1952.

ROME

"Some Ancient Propagation Discoveries—(Their Lessons)," by Dr. E. H. Armstrong; October 13, 1952.

MEMBERSHIP

The following transfers and admissions were approved to be effective as of December 1, 1952:

Transfer to Senior Member

Angelakos, D. J., 1320 LaLoma Ave., Berkeley 8, Calif.
Brainerd, H. B., 10 Upland Rd., Wellesley 81, Mass.
Bremer, F. V., 1020 Broad St., Newark 1, N. J.
Clark, T. C., Jr., 5381 Village Green, Los Angeles 16, Calif.
Cronin, W. M., 1403 Chadwick Dr., Dayton 6, Ohio
Downs, J. W., 7 Redwood Path, Glen Cove, L. I., N.Y.
Glaser, J. L., 168 Park Ave., Madison, N. J.
Gokarn, G. D., "Red Lands," 53 New Marine Lines, Fort Bombay, India
Koppl, W. J., 31C Dunvale St., Towson 4, Md.
Levy, M., 39 Henderson Ave., Ottawa, Ontario, Canada
Markell, J. H., 121 Raleigh St., S.E., Washington 20, D. C.
Martin, E. T., 108 Old Farm Rd., N., New Hyde Park, L. I., N. Y.
Ollendorff, F., P.O.B. 910, Hebrew Institute of Technology, Haifa, Israel
Preston, G. W., 1000 Pheasant La., Oreland, Pa.
Rothammer, W. H., 1203 Salem Ave., Dayton 6, Ohio
Rothstein, M., 71-59—163 St., Flushing 65, L. I., N. Y.
Shelley, E. F., 120 Cabrini Blvd., New York 33, N. Y.

(*Continued on page 88A*)

MEMBERSHIP

(*Continued from page 86A*)

Watson, R. P., Pinewood Dr., R.F.D. 6, Schenectady, N. Y.
Welch, H. W., Jr., Engineering Research Institute, University of Michigan, Ann Arbor, Mich.
Zelazo, N. K., Braddock Acres, Box 524A7, R.F.D. 3, Alexandria, Va.

Admission to Senior Member

Booth, C. F., 8, Durham Rd., North Harrow, Middx., England
Buechner, R. H., 3538 Blodgett, Apt. 1, Houston, Tex.
Burke, A. L., Signal Division, Hq. SHAPE, APO 55, c/o Postmaster, New York, N. Y.
DeVoll, R. L., Main Blvd., Timonium, Md.
Fouse, G. T., 106 Lewiston Rd., Dayton 9, Ohio
Goldup, T. E., Century House, Shaftesbury Ave., London W.C. 2, England
Jarrette, V., 2335 S. Home Ave., Berwyn 50, Ill.
Lynch, D. S., 427 Woodbine Ave., Towson 4, Md.
Mumford, A. H., 27 Grendon Gardens, Wembly Park, Middx., England
Parker, W. H., Jr., 14812½ Sylvan St., Van Nuys, Calif.
Parmet, B. S., 2658 W. Altgeld St., Chicago 47, Ill.
Reiskind, H. I., Engineering Section, Record Department, RCA Victor Division, 501 N. LaSalle St., Indianapolis 1, Ind.
Story, V. V., 4 Woodford Rd., Rockville, Md.
Stout, H. L., 4049 Pennsylvania, Kansas City 2, Mo.
Young, V. J., Hazeltine Corp., 58-25 Little Neck Pkwy., Little Neck, L. I., N. Y.

Transfer to Member

Bangs, P. C., 323 Walton Bldg., Atlanta 3, Ga.
Crane, R., Sperry Gyroscope Co., Mail Station L-37, Great Neck, L. I., N. Y.
Daugherty, C. F., WSB, Biltmore Hotel, Atlanta, Ga.
Dominick, J. B., c/o DC&E, Hq. ADC, Ent AFB, Colorado Springs, Colo.
Erwood, R. G., 5117 South Francis, Oklahoma City 9, Okla.
Gourrich, G. E., 12830 Parkyns St., Los Angeles 49, Calif.
Haimowitz, B., 1726 N. Paxon St., Philadelphia 31, Pa.
Holbrook, J. G., Box 111, Hawthorne, Calif.
Hunter, J. B., 360 Laird Dr., Toronto 17, Ont., Canada
Jones, W. C., NAS Annex, Solomons, Md.
Kwast, V. B., Weston Electrical Instrument Corp., A.C. Development, Box 318, 617 Frelinghuysen Ave., Newark 5, N. J.
LaRose, A. P., 4915 N. Damen Ave., Chicago 25, Ill.
Martin, R. L., 1326 S. West St., Arlington, Tex.
Miller, W. B., 1618 Rockwood St., Los Angeles 26, Calif.
Norkis, B. S., 3106 S. Llewellyn Ave., Dallas 8, Tex.
Sher, N., 1215 Unruh Ave., Philadelphia 11, Pa.
Southall, T. W., Chief Division Engineer, American Forces Network APO 227 c/o Postmaster, New York, N. Y.
Thompson, L. V., 3247 Winter Dr., Oklahoma City 12, Okla.
Welliver, C. L., 15 S. Marengo Ave., Alhambra, Calif.
Wilson, T. A., Hughes Aircraft Co., Florence Ave. at Teale St., Culver City, Calif.

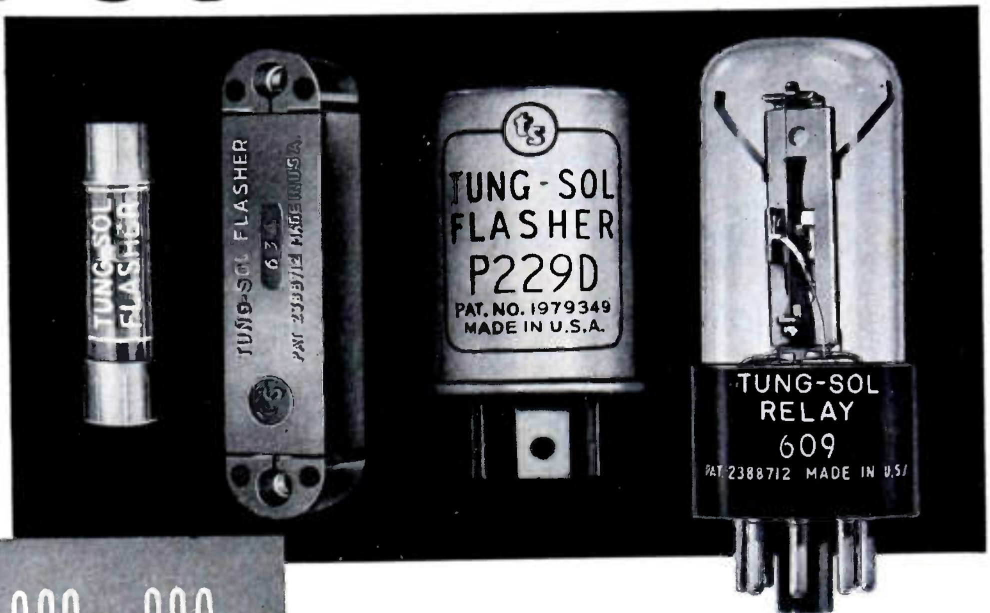
Admission to Member

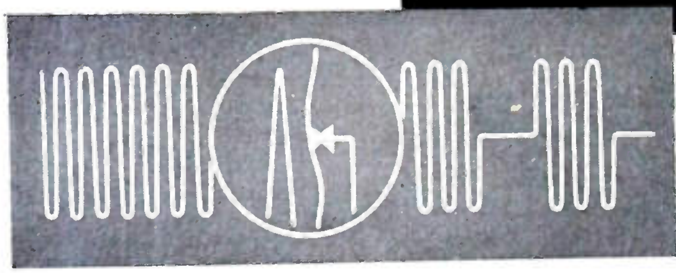
Ayers, J. L., 9 Third Ave., Garston, Watford, Herts., England
Bacon, F. S., Jr., 16 Fullerbrook Rd., Wellesley, Mass.
Brainin, S. M., 5862 Hardwick, Long Beach, Calif.
Bund,a F. E., Apt. 3, 210 Devargas, El Paso, Tex.
Buuck, W. P., 77 Thorndike St., Arlington 74, Mass.

(*Continued on page 90A*)

TUNG-SOL® flashers

new low-cost circuit control devices for electronic equipment





"Flasher" is the automotive name for this Tung-Sol product. Actually, it is the most simplified, most reliable thermal-operated relay ever developed.

If you own an automobile made since 1939 and it has directional signals, then you have already witnessed first-hand the virtually unfailing performance of the Tung-Sol Flasher. Tucked away under the instrument panel, this tube-size mechanism makes the turn signal lights blink on and off.

After 13 years, the 13 million flashers in automotive use have demonstrated that this device usually outlasts the car it is on, and the average life of a car is 7 years! Tung-Sol Flashers not only are more reliable than conventional types of relays—they are more compact and they cost less.

Now then, where can you use a "circuit breaker" or "fuse" or "relay" in your electronic equipment?

As a circuit breaker? For this type of application, Tung-Sol Flashers are built with normally closed contacts. Under the effect of a short or overload, there is an almost instantaneous response and the contacts are opened. With equal rapidity the device cools and the contacts close. As long as the disturbance within the circuit exists the Flasher will continue automatically to sample the condition of the equipment, thus providing absolute safety against costly, damaging burn-out.

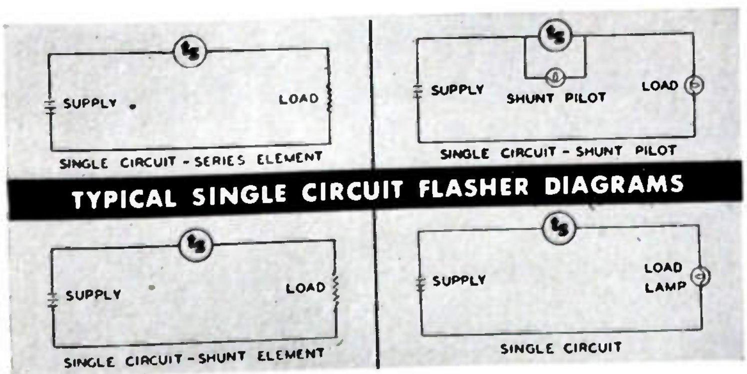
As a voltage limiter? When an overload surge raises voltage to a damaging level, the Tung-Sol Flasher will throw in a protective resistance. When the voltage returns to normal, the resistance is shorted out.

As a cycling control? Where it is desirable that equipment operate intermittently, the Flasher will cycle on and off at a pre-determined rate.

As a time delay relay? This type is non-operative until a given voltage or current is reached, when the Flasher will make contact and activate a switch.

As a warning device? Tung-Sol Flashers provide for visual or audible warning, as well as mechanical protection through use of a pilot light, horn, or siren which may be installed on the equipment or at a remote point.

The circuit protection, freedom from service interruptions and lower maintenance which you could offer your customers by installing Tung-Sol Flashers in the equipment you make, will certainly warrant your obtaining complete information. Our staff will be glad to work with your engineers. Write today.



TYPICAL SINGLE CIRCUIT FLASHER DIAGRAMS

FLASHERS FOR APPLICATIONS WITH VOLTAGES BETWEEN 3 and 32 VOLTS AC or DC.

LOAD	CARTRIDGE	PLASTIC CASE
150 ma.		627
175 ma.	606	
175 ma.		625
200 ma.		617
220 ma.		634
250 ma.		633
300 ma.		623
400 ma.		619
600 ma.		624
.05 amp 110V (6W lamp)	608	
.2 amp 110V (25W lamp)	607	
Switching relay		609

TUNG-SOL FLASHERS

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(Continued from page 88A)

Cancellari, N. J., 411 St. George St., Biloxi, Miss.
Coker, V. A., AA & GM Branch, TAS, Box No. 72, Fort Bliss, Tex.
Collins, Z. L., 403 S. Hammonds Ferry Rd., Linthicum Heights, Md
Conesa, R., St. Xavier's College Technical Institute, Cruickshank Rd., Bombay 1, India
Crowley, K. L., Henry L. Crowley & Co., Inc., One Central Ave., West Orange, N. J.
Daniels, C. L., 1614 Reding, Oklahoma City, Okla.
DeLutis, T., 531 Turin St., Rome, N. Y.
Fisher, C. D., 232A Princeton Rd., Haddonfield, N. J.
Goode, R. M., R.F.D. 2, New Carlisle, Ohio
Glover, B. W., 1623 Johnston Dr., Oklahoma City, Okla.
Gracie, J. A., I.F.R.B., International Telecommunications Union, Palais-Wilson, Geneva, Switzerland
Guerrero, E. S., 115 Witmer St., Los Angeles 26, Calif.
Hall, G. L., 557 Passaic Ave., Clifton, N. J.
Krishnamurti, T., Professor of Physics, Presidency College, Madras, India
Landsberg, S. S., 51 Bar-Giora St., Haifa, Israel
Larson, R. G., Westinghouse Manufacturing Co., Bloomfield, N. J.
Little, C. W., Jr., Allis Chalmers Manufacturing Co., Research Division, Box 512, Milwaukee 1, Wis.
Little, F. A., 3905 E. Anderson Ave., Albuquerque, N. Mex.
Lofgren, L. E., Forsvarets Forskningsanstalt, Avd. 3, Stockholm 61, Sweden
Merritt, H. J., Canadian Westinghouse Co., 239 Argyle Ave., Ottawa, Ont., Canada
Moore, E. B., 33 Mawal Dr., Cedar Grove, N. J.
Pritchard, D. H., R.F.D. 3, Varsity Ave., Princeton, N. J.
Reed, R. D., 30 Curve, Waltham 54, Mass.
Rohrer, G. W., 624 Fourth St., N.W., Canton 3, Ohio
Rota, L., Apartado 414, Quito, Ecuador
Rowley, R. A., 22 Edgecomb Rd., Binghamton, N. Y.
Royko, W., 92A Nairn Rd., Transcona, Man., Canada
Russell, G. A., 920 S. Longbeach Ave., Freeport, L. I., N. Y.
Saling, D. M., 2 Baker St., Poughkeepsie, N. Y.
Seelig, G., 2154—45 St., Astoria, L. I., N. Y.
Tlapa, J. A., 1919 Wabansia Ave., Chicago 22, Ill.
van Marle, J. C., 159 Stinson St., Hamilton, Ont., Canada
Wallach, C., 312 Arnold Dr., Midwest City, Okla.
White, D. R. J., Code 3496 DW, RFR, Naval Research Laboratory, Washington, D. C.
Wishnefsky, W., 40 Holiday St., Dorchester 22, Mass.

The following elections to the Associate grade were approved to be effective as of November 1, 1952:

Acosta, A. T., 4523 N Huntington Dr., Los Angeles, Calif.
Alexanoff, E., 4236 N. Troy St., Chicago 18, Ill.
Arsenault, W. R., 708 Pine St., Apt C, Santa Monica, Calif.
Asen, R., 166 W. 58 St., New York, N. Y.
Baldauf, D. R., 423 E. Main St., Endicott, N. Y.
Balfour, L. S., 600 W 111 St., New York, N. Y.
Ball, L. G., 1808 Elm Ave., Manhattan Beach, Calif.
Ballin, H. M., 113 Moore St., New Hyde Park, L. I., N. Y.
Bennett, A. O., Box 598, Corbin, Ky.
Bereman, E. W., 1837 S. Estelle, Wichita 16, Kan.
Berg, C. H., 424 Sylvan Ave., San Mateo, Calif.
Birch, R. S., 1312 W. Orange Grove Ave., Pomona, Calif.

(Continued on page 92A)

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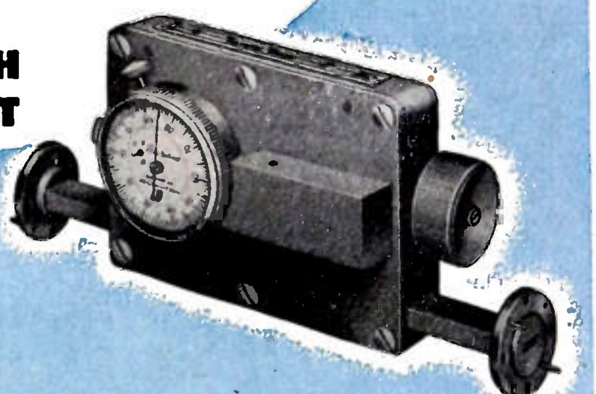
PRD

precision variable attenuators

- METALLIZED GLASS ATTENUATING ELEMENTS
- PRECISE, PERMANENT CALIBRATION
- BROADBAND CHARACTERISTICS
- NEGLIGIBLE INSERTION LOSS
- BACKLASH-FREE
- LOW REFLECTION
- WELL SHIELDED CASING

The use of metallic-film-on-glass techniques to provide attenuation at microwave frequencies is no longer new. This type of PRD attenuator is now well recognized for its constancy of attenuation with time as well as for its insensitivity to variations of humidity and temperature. PRD has now augmented this line of attenuators with units employing metallized mica elements to provide broader-band characteristics for the millimeter region of the microwave spectrum. As a consequence, it is now possible to offer complete coverage of the range from 2,600 to 40,000 megacycles per second in designs varying from a simple level set attenuator to a precisely calibrated secondary standard. Write today for our complete new catalog of microwave test equipment—address Dept. R-12. Are you on our list to regularly receive "PRD Reports"?

Polytechnic RESEARCH & DEVELOPMENT COMPANY, Inc.



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MEMBERSHIP

(Continued from page 90A)

Blair, L. R., 108 Chestnut St., Wadsworth, Ohio
Blancher, D. W., 6208 Gentry Ave., North Hollywood, Calif.
Bolstridge, L. J., 6920 Security Groupe, APO 994, c/o Postmaster, San Francisco, Calif.
Bower, H. W., 218 S. Front St., Sunbury, Pa.
Boyce, W. E. L., 1824—17 St., Cuyahoga Falls, Ohio
Bradley, L. W., c/o International Business Machines Corp., 590 Madison Ave., New York 22, N. Y.
Brady, D. J., Box 463, Arnold, Md.
Brosch, H. T., 9575 Stoepel, Detroit, Mich.
Carlson, G. R., 967 Vernon Ave., Glencoe, Ill.
Carttar, G. L., 853 N. Lorraine, Wichita 6, Kan.
Cassedy, E. S., Jr., 8702 Barron St., Takoma Park, Md.
Cherry, M. V., c/o W.L.Y.C., 331 Pine St., Williamsport, Pa.
Clifton, J. L., Box 138, R.F.D. 4, Oklahoma City, Okla.
Conroy, R. J., 505 E. Garden St., Rome, N. Y.
Cook, J. G., Colonial Terrace, 1413 Montana St., El Paso, Tex.
Corns, R. B., 517 Cole St., Raleigh, N. C.
Coulombe, J. N., 124 Emery St., Berlin, N. H.
Courtney, I. E., 1951 N. Hydraulic, Wichita, Kan.
Cox, S. M., Box 7164, Wright-Patterson Air Force Base, Dayton, Ohio
Crystal, D. G., 11330 Weddington St., North Hollywood, Calif.
Culbertson, J. T., Math. Division, Rand Corp., Santa Monica, Calif.
Dayton, W. P., 4406 Classen Blvd., Oklahoma City, Okla.
Dobkowski, J. T., 5117 Walker Way, El Paso, Tex.
Duncan, D. B., 111 Encanto Dr., Arcadia, Calif.
Edwards, R. L., 110 Fairway Dr., Huntsville, Ala.
Evans, J. T., Jr., 2024 Morrow Ave., Schenectady, N. Y.
Fayman, D. L., 5845 Elmonte Dr., Mission, Kan.
Feigus, J. I., 775 Aircraft Control and Warning Sq., Cambria, Calif.
Finneran, W. J., Somerset Hotel, 5009 N. Sheridan Rd., Chicago 40, Ill.
Fischer, J. J., 602 N. Magnolia, Whittier, Calif.
Fisher, E. J., 3824 Terrace St., Philadelphia, Pa.
Flowers, C. R., 561 Schiller Ave., Akron 10, Ohio
Freedman, L. M., 2064 Ocean Pkwy., Brooklyn, N. Y.
Fullen, R. E., 2001 Carroll Dr., Raleigh, N. C.
Gallwey, K. L., 12139 Highwater Rd., Granada Hills, Calif.
Garman, D. F., Box 233, Enon, Ohio
George, P. H., 2446 Pensacola Ave., Chicago 18, Ill.
Gerdes, J. W., 131 S. Main St., Natick, Mass.
Goetze, A. J., 100 Irvington St., S.W., Apt. 1-A, Washington 20, D. C.
Gold, A. R., 8203 Blackburn Ave., Los Angeles, Calif.
Gosley, A. W., 605-A Anacapa Dr., Oxnard, Calif.
Gracey, T. G., 275 Arlington Ave., Toronto, Ont., Canada
Grosse, R. H., 5434 Hillside Ave., Cincinnati 38, Ohio
Guthrie, D., 1115 W. Berry St., Fort Wayne, Ind.
Haerer, W. A., 117 Second St., Apt. F-1, Garden City, L. I., N. Y.
Hagelgans, E., Jr., 1620 Roundhill Rd., Baltimore 18, Md.
Hegler, R. E., Burroughs Rd., North Reading Mass.
Henry, J. R., 2133—19 St., Cuyahoga Falls, Ohio
Herbert, H. W., Box 11, Rixford, Pa.
Hertz, M., 2003 August Dr., Silver Spring, Md.
Hirsch, A., 2961 W. 97 St., Evergreen Park 42, Ill.
Hirshfield, J. L., 1821½ Catalpa Dr., Dayton 6, Ohio
Hodge, M. H., Jr., 503 Valley Ave., Washington, D. C.
Horner, G. F., 1125—59 St., S., St. Petersburg, Fla.

(Continued on page 94A)


keeping communications ON THE BEAM
JK
PRODUCTS
JK STABILIZED
H-4 CRYSTAL
JK
CRYSTALS
TYPE H4
SER. NO. NR409
FREQ 3000 KC
THE JAMES KNIGHTS CO
SANDWICH ILL. U.S.A.
Her Ship-to-Shore is Ship Shape
Her decks may be awash but there's fair weather in the radio shack. Despite wind and waves the Captain's message will reach the home port. In fair weather or foul, you'll find JK Crystals rate a Navy "E" for their part in keeping marine communications "ship shape."
CRYSTALS FOR THE CRITICAL
A versatile crystal the JK H-4 is widely used as a replacement crystal in marine and other communications systems. Pressure mounted, dust and water proof, stainless steel electrodes. Frequency range 1800 kc to 15 mc. Military type holder. Another of the many JK Crystals available to serve every need.
the JK
FD-12
FREQUENCY & MODULATION MONITOR
Monitors any four frequencies anywhere between 25 mc and 175 mc, checking both frequency deviation and amount of modulation. Keeps the "beam" on allocation; guarantees more solid coverage, too!
THE JAMES KNIGHTS COMPANY
SANDWICH ILLINOIS

MEMBERSHIP

(Continued from page 92A)

Howe, E. R., Jr., Hqs. Sq. 1804 AACS Group, APO 942, c/o Postmaster, Seattle, Wash.
Hulett, H. R., Detroit Lubricator, 806 Chestnut St., Redwood City, Calif.
Intrator, A. M., 575 E. Kamala St., Oxnard, Calif.
Johnson, R. F., 4815 N.E. Campaign St., Portland 13, Ore.
Jones, D., 2522 Raymond Ave., Los Angeles, Calif.
Kelner, R. C., 32 Heath Bridle Rd., Concord, Mass.
King, J. D., 303 Lee Ave., R.F.D. 2, Johnson City, N. Y.
Kono, T., 511 Izumi-Cho, Suginami-Ku, Tokyo, Japan
Korman, M. M., 612—31 Ave., San Mateo, Calif.
Krill, C. K., Librascope, Inc., 1607 Flower St., Glendale, Calif.
Krumhardt, C., 7447 N. Olcott Ave., Chicago 31, Ill.
Lancaster, A. W., 117 Georgetown Rd., Raleigh, N. C.
Lanzinger, D. J., 1642 N. 28 St., Phoenix, Ariz.
Lehtone, L. L., 1615 West 38 Pl., Los Angeles, Calif.
Leitner, R. T., Box 667, Sherburne, N. Y.
Lian, K. T., 6 Surrey La., Great Neck, L. I., N. Y.
Liekens, A. F., 19 Beerselhock, Putte, Mechelen, Belgium
Lindeman, R. J., 61-33—171 St., Flushing, L. I., N. Y.
Loizzo, V. J., 2735 N. Ashland Ave., Chicago, Ill.
Magers, T. M., 1706 E. 22 St., Anderson, Ind.
Margol, L., 1625 S. LaBrea St., Los Angeles 19, Calif.
Margulies, I., 5800 N. Fares Ave., Evansville, Ind.
McClure, R. E., Sperry Gyroscope Co., Mail Station C-39, Great Neck, L. I., N. Y.
McGhee, G. L., 1013 Lodge Ave., Evansville, Ind.
McIlroy, C. R., 181 Jackson St., W., Hamilton, Ont., Canada
McSweeney, G. M., Civil Aviation Dept., Talkatora Rd., New Delhi 1, India
Meyers, M. L., 125 W. 16 St., New York 11, N. Y.
Miglicco, P. S., 878 Storer Ave., Akron, Ohio
Nag, D. S., Mundtsvej 10-A, Copenhagen, Lyngby, Denmark
Nelson, G. A., 2552 Napier St., Vancouver, B. C., Canada
Nevin, M. E., 638—16 St., North Chicago, Ill.
Noorland, M., 126½ N. Flores St., Los Angeles, Calif.
Orr, L. W., 605 Argo Dr., Ann Arbor, Mich.
Parker, B. G., 2208 Dunham, Toledo 9, Ohio
Perrin, B. J., 26 N. Bates, Apt. 8, Akron 3, Ohio
Phares, D. P., 169 Marvin Ave., Akron 2, Ohio
Pooms, A. L., 2614 Grand Ave., Waukegan, Ill.
Powell, J. M., 6040 Ingleside Ave., Chicago, Ill.
Rask, O. N., 2904 Guilford Ave., Baltimore 18, Md.
Rector, J. D., 1297—30 St., N.E., Cedar Rapids, Iowa
Robinson, B. H., Jr., 5900 Northwest Highway, Chicago, Ill.
Robinson, M., 45 Elm St., Staten Island 10, N. Y.
Romano, V., 685—18 St., Brooklyn 18, N. Y.
Rowley, B. G. H., 23 Beaver St., New York, N. Y.
Ruthenberg, W. G., 34 Flagship Rd., Baltimore 22, Md.
Schneider, R. F., 2979 E. 65 St., Cleveland, Ohio
Schwartz, J. H., 71 Wilbury Pl., Buffalo, N. Y.
Scott, D. W., Box 155, Oak Ridge, Tenn.
Sebald, L. E., 334 Oakview Dr., San Carlos, Calif.
Sharf, W. A., 2 Rosemount Ave., Toronto, Ont., Canada
Sharpe, L. E., 8531 Clifton Way, Beverly Hills, Calif.
Shaw, H. F., 2125 S. Columbus St., Arlington 6, Va.
Shepherd, H. F., Jr., 127 S. Citrus Ave., Los Angeles, Calif.
Simmons, D. J., 4305 Fairfax, Fort Worth, Tex.
Sloop, W. B., 704 Grove St., Raleigh, N. C.
Smith, B. M., 713 Montauk Ave., New London, Conn.

(Continued on page 96A)

Membership

(Continued from page 94A)

Sprinz, E., Box 1327, Haselton Branch, Rome, N. Y.
Starr, I. M., 2027 W. 73 St., Los Angeles 47, Calif.
Sutton, A. T., 3913 Cross Creek Rd., Nashville, Tenn.
Swinney, R. W., 1128 N.W. 28 St., Oklahoma City, Okla.
Taschler, E. J., 505 E. Garden St., Rome, N. Y.
Terkanian, H., Johnson Court, R.F.D. 2, New London, Conn.
Terleckyi, J., 2210 W. Huron, Chicago 12, Ill.
Tosspon, A. E., 7307 S. Atlantic, Bell, Calif.
Toth, P. A., Electronic Research Laboratory, Box 1, Kiriat Motzkin, Israel
Ullrich, D. P., 700 Washington Ave., Alton, Ill.
Voltaggio, F., Jr., 4513 Eichelberger Ave., Dayton 6, Ohio
Weiss, H., 595 Hafelerstr., Nussbaumen A-G, Switzerland
Weyrick, R. C., 2560 Ogden Ave., Akron 12, Ohio
Wilensky, E., 1002 Darlington Apts., Charleston, S. C.
Zuranski, R. C., 775 A.C.& W. Squadron, Cambria, Calif.

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 12A)

Static Converter

Mercury Electronic Co., Box 450, Red Bank, N. J., has designed a new static converter, Model E-1.

The input is 110–120 volts, 380 to 420 cps, single phase. The output is 300 volts dc, adjustable over a range of ±5 per cent. Output current is 0 to 400 ma dc. Regulation is within 0.3 per cent from no load to full load at 300 volts, and within 0.3 per cent for line voltage variations from 105 to 125 volts. Ripple is less than 80 mv at any line voltage or load within ratings. This equipment is designed to operate at altitudes of up to 65,000 feet.

Nuclear Catalog

A new complete catalog of nuclear instruments, accessories and services can be secured by addressing inquiries on a business letterhead to **Nucleonic Company of America**, 497 Union St., Brooklyn 31, N. Y. The catalog includes the following instruments: basic radioactivity laboratory instrumentation—scalers and accessories; survey instruments and replacement parts; detectors, Geiger-Müller tubes and accessories, lead shields, flow counters; sample handling equipment, safety equipment, special electronics devices; and miscellaneous products and services.

(Continued on page 98A)

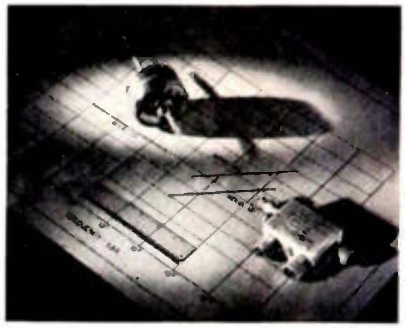
News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 96A)

Wide-Band Directional Couplers

Widely applicable tools for measuring numerous parameters relating to transmission lines are available from **Sierra Electronic Corp.**, 811 Brittain Ave., San Carlos, Calif. Sierra Wideband Directional Couplers are available in three models, 137 and 138 for the frequency range 30 to 1500 mc and 139 for the frequency range 10 kc to 1 mc.



As the response curves show, the model 137 operates over the entire frequency range from 30 to 1500 mc with a sensitivity rising from −70 to −35 db. The model 138 covers the same frequency range, but has a sensitivity ranging from −55 to −20 db. Operating in a 5.5-ohm coaxial line, these couplers are usable from 0.1 watts up. Reflection coefficient is indicated with an error no greater than 0.02, while directivity over the range is greater than 46 db. Precision fabricated from solid dural blocks with coupling between primary and secondary lines accomplished through a small hole in the common wall of two precision lines, the models 137 and 138 couplers are provided with standard coaxial-line fittings.

Frequency independent at a sensitivity of −50 db over the 30-kc to 1-mc range, the model 139 coupler is applied to balanced two-wire lines at power levels ranging up to 15 kw. Directivity and sensitivity are constant from 10 kc to 1 mc. Based on a series element consisting of an extremely wide-band, ferrite-core toroidal current transformer and a specially compensated capacitor shunt element, the entire coupler is cast in plastic with the primary line carried through the axis in the form of a ¼-inch diameter conductor.

Radioactive Light Source

Tracerlab, Inc., 130 High St., Boston 10, Mass., is using tritium, a product of the Oak Ridge atomic reactor, to make a substantially constant light source.

A quantity of radioactive tritium is incorporated into stilbene, a crystalline substance, and processed chemically to form a solid crystal.

The tritium constantly gives off beta rays which cause the stilbene to fluoresce.

(Continued on page 100A)

Now . . . with G-E 5-Star Tubes . . .

DESIGN TRANSMITTERS TO HAVE MINIMUM OFF-THE-AIR TIME!

Help your customers *save* thousands of dollars now being lost from downtime! Install G-E high-reliability types that make your equipment far more dependable!

STANDARD TYPES	REPLACE WITH THESE 5-STAR TYPES
2C51	*GL-5670—h-f medium-mu twin triode.
2D21	GL-5727—thyratron.
5Y3-GT	GL-6087—full-wave rectifier.
6AK5	GL-5654—sharp-cutoff r-f pentode.
6AL5	GL-5726—twin diode.
6AQ5	GL-6005—beam power amplifier.
6AS6	GL-5725—dual-control sharp-cutoff r-f pentode.
6AU6	GL-6136—sharp-cutoff pentode.
6BA6	GL-5749—remote-cutoff r-f pentode.
6BE6	GL-5750—pentagrid converter.
6C4	*GL-6135—medium-mu triode.
6SK7	GL-6137—remote-cutoff r-f pentode.
12AT7	GL-6201—high-Gm medium-mu twin triode.
12AU7	*GL-5814—medium-mu twin triode.
12AX7	*GL-5751—high-mu twin triode.
12AY7	*GL-6072—low-noise medium-mu twin triode.
. . . . . .	GL-5686—beam power amplifier.

Slight electrical difference

$200 A MINUTE THROWN AWAY! Even a small radio-TV station may have to write off a sum that large, when transmission failure interrupts a commercial. Commonest cause of off-the-air incidents, is receiving-tube trouble in studio or transmitting equipment.

HELP YOUR BROADCAST-TELECAST CUSTOMERS STAY ON THE AIR by installing 5-Star Tubes in equipment you build! Design . . . from the start . . . high reliability into hundreds of sockets where, if a receiving type fails, the station may lose part of its program audience, and often important revenue as well.

FIVE-STAR TUBES ARE UNIFORMLY OPERABLE when you install them in your transmitters! And because they are specially designed and built for reliability, 5-Star Tubes will continue to serve your customers by doing full rated jobs over a long period.

MAINTENANCE NEEDS ARE LOWER with 5-Star Tubes. Here's another "plus" that reflects itself favorably in your customers' cost sheets! *Less time* is required to keep transmitting equipment operating—far *fewer tube replacements* are needed.

CHECK THE 17 5-STAR TYPES ABOVE against your circuit needs! If you wish to explore your requirements further, a G-E tube engineer will be glad to call on you. *Tube Department, General Electric Company, Schenectady 5, New York.*

● **SUB-MINIATURE G-E 5-STAR TUBES,** as well as regular 5-Star types, are listed in new Booklet ETD-548-A, which contains a cross-reference table of ratings and characteristics for application use. Wire or write for it!

GENERAL ELECTRIC

163-183

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 100A)

Transistor Sockets

Mycalex Tube Socket Corp., 60 Clifton Blvd., Clifton, N. J., has started pilot production on a line of transistor sockets. The body is precision-molded of Mycalex 410, a glass-bonded mica insulation for lasting dimensional stability, low dielectric loss, immunity to high temperature and humidity exposure combined with maximum mechanical strength. The loss factor is 0.014 at 1 mc and dielectric strength is 400 volts/mil.

Contacts can be supplied in brass or beryllium copper. The sockets are readily solderable. The socket bodies will not warp or crack when subjected to high soldering temperatures. They function in ambient temperatures to 700°F.

(Continued on page 103A)

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 102A)

New Plant

Measurements Corporation, Boonton, N. J., manufacturers of precision electronic instruments, has announced the purchase of an additional plant.

The newly acquired property is located in Randolph Township, N. J., 12 miles from their main location and consists of a modern building, with 15,000 square feet of manufacturing space. The Randolph plant is situated on a 72-acre tract, 5 acres of which are in an industrial zone, providing for future expansion.

Complete alterations are now under way, and it is expected that the new plant will soon be in operation. Approximately 125 people will be employed in the manufacture of the company's well-known laboratory standards.

(Continued on page 104A)

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 103A)

Crystal Test Set

The T104A Crystal Test, portable, self-contained equipment for the field testing and selection of 1N23B matched crystal pairs for X-band balanced mixer applications in the frequency range of 8500–9500 mc. has been developed by **Microwave Associates, Inc.**, 22 Cummington St., Boston 15, Mass. Provision is made for testing pairs for crystal current balance, IF impedance balance, and leakage power (an indication of rf impedance balance), the three characteristics for which test limits have been defined in the proposed JAN specification for 1N23B matched pairs. Specifically, the requirements are as follows: (1) crystal current balance within 10 per cent of the lower of the two readings; (2) IF impedance balance within 15 ohms; (3) leakage power less than 10 per cent.

The equipment consists of a 2K25 oscillator, a power-set attenuator, a frequency meter, a directional coupler for determining the leakage power test limit, two matched single-ended mixers for measuring leakage power, a balanced test mixer, and the required power supply and switching circuitry. A vacuum-tube voltmeter is included for the measurement of IF impedance. Suitable switching permits the two indicators, a 0–1-ma meter and a null indicator, to serve multiple purposes. Critical circuit constants, however, are independent of switch position.

Teflon Paint

E. I. Du Pont de Nemours and Co., Wilmington, Del., announces that the paint plant at Philadelphia is meeting production schedules for "Teflon" polytetrafluoroethylene finish, which is selling for $75.00 a gallon.

According to Du Pont "Teflon" finish is worth its high cost for several reasons, foremost of which is that practically nothing will stick to it.

(Continued on page 106A)

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 104A)

Engineers, particularly in the packaging industry or wherever adhesives are used, have long been occupied with the problem of glue sticking to machine parts preventing accurate and efficient operation.

A similar headache exists elsewhere in industry where sticky substances such as powdered soap, rubber, candy, and frozen foods are apt to cling to the smoothest metal surfaces. "Teflon" finishes seem to be the cure to these costly troubles, cheap even at 29 cents per tablespoonful.

The finish is a water suspension of a Du Pont-invented plastic which has such a high chemical, heat, and moisture resistance it is also used to prevent corroison of equipment, and as electrical-wire insulation.

It is an inherently expensive material to produce and will probably never reach a price level that would qualify it as a consumer product. Moreover, the finish must be fused at about 750°F in special equipment.

Solderless Terminal

A new solderless terminal developed especially for control-panel wiring has just been announced by **Aircraft-Marine Products, Inc.**, 2100 Paxton St., Harrisburg, Pa.

The reinforced AMPLI-BOND terminal's new design assures that no underlying conducting surface will be exposed even if the insulating sheath is pierced. This is accomplished by means of an insulated metal ring near the base of the insulation support sleeve. The ring gives all necessary strength to combat vibration and sharp bending, but does not communicate with the electrical connection farther up the barrel.

The terminals are now available in the 12-10 and 16-14 HD sizes, but in the near furture they will be available in smaller wire sizes. They are color coded for identification, inspection, and quality control. Requests for complete information will receive prompt attention.

(Continued on page 108A)

Announcing

A NEW SPOT-RATING SERVICE ON G-E THYRATRONS!

Equipment designers can now call on General Electric to investigate and approve applications of thyratrons which are not covered by published ratings

- **PUBLISHED RATINGS ARE MAXIMUM LIMITS FOR A SPECIFIC SET OF CONDITIONS.** The published ratings of a G-E thyratron apply to a set of pre-established conditions. In actual practice, your new circuit may call for a control tube with higher average current capacity than, say, the GL-3C23's 1.5 amp—yet peak voltage requirement may be less than the tube's rated 1,250 v. At your lower voltage, Type GL-3C23 may well carry the additional current! General Electric always is glad to suggest such possibilities.

- **START WITH WIDEST CHOICE OF TYPES!** When you buy an overcoat, a camera, or an outboard motor, you are best served at the store that offers a large selection of types and sizes. The same holds true with electronic tubes. G.E. builds more thyratrons than any other manufacturer—34 types in all. You are more apt to find the exact control tube you need!

- **THYRATRON IS A G-E "FIRST"!** General Electric pioneered the thyratron, which means longer experience with the tube, greater know-how—more opportunity to cross check design against performance in all types of applications.

- **DISCUSS YOUR PROBLEM WITH G.E.!** A staff of experienced tube engineers will be glad to analyze your control-tube needs. You may wish to describe these by letter, or ask a G-E engineer to call. There are *more* G-E thyratrons . . . they will *do more* for you! General Electric's new spot-rating service pinpoints both advantages to your benefit! *Tube Department, General Electric Company, Schenectady 5, N. Y.*

GL-3C23
1.5 amp

GL-5545
6.4 amp

GL-5855
12.5 amp

CHECK G.E.'S 34 TYPES *FIRST!*

What are your thyratron needs? G. E. offers you the widest choice in the industry—34 types. They range, in average current, from 0.1 amp up to 12.5 amp; in peak inverse voltage, from 200 v up to 15,000 v. Chances are, the ratings of one or more of these G-E tubes will closely approximate your requirements.

GENERAL ELECTRIC

163-1A4

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 106A)

Events-Per-Unit-Time Meter

Berkeley Scientific Div. Beckman Instruments, Inc., 2200 Wright Ave., Richmond, Calif., has a new Events-Per-Unit-Time Meter (EPUT) Model 556, a high-speed electronic counter combined with a time base which is used to control the interval of counting. The counting rate of this unit is from 20 to 100,000 events per second and the counting interval is 1 second.

The instrument therefore reads the unknown repetition rate directly in events per second. The events whose rate is to be determined may be any optical, physical, or electrical occurrences. These can be translated into changing voltages and defined directly. The unit automatically counts and displays the number of events that occur during the 1-second interval.

Specifications: Count indication is by direct decimal presentation by means of 4 counting units. At frequencies above 9999 cps only the last 4 digits will be indicated. Accuracy is ±1 event with suitable time base. Using normal power line, the accuracy of the instrument is ±0.2 per cent. Power requirements are 117 volts ±10 per cent, 60 cps. There are approximately 100 watts input requirements. Sensitivity of 0.2 volt rms over the range of 20 to 100,000 kc. Pulses of positive polarity are required. Price: $560.00 fob factory.

Booklet on X-Ray Analysis

A new eight-page booklet, entitled "Facts and Figures on Three Powerful X-Ray Tools for Non-Destructive Analysis," is available from C. J. Woods, **Research and Control Instruments Div. North American Philips Co., Inc.,** 750 S. Fulton Ave., Mount Vernon, N. Y.

Diagrams are used to show the principles of operation for the three instruments, data is given on recommended fields of application, and results to be obtained are explained.

In addition, the booklet illustrates how the simplest film diffraction unit consisting of the basic X-ray generator plus a camera, can be converted to spectrometer and spectrograph use through the addition of these components.

(Continued on page 110A)

potentiometers

Syncromount

Linear and functional output, rugged construction, ball bearings, small size, low torque, syncro-type mount.

Rectipot

Push-pull motion, linear and functional output, high resolution, rectilinear potentiometer.

Gangpot

Functional and linear outputs, coils independently adjustable, variety of flexible assemblies.

Microtorque

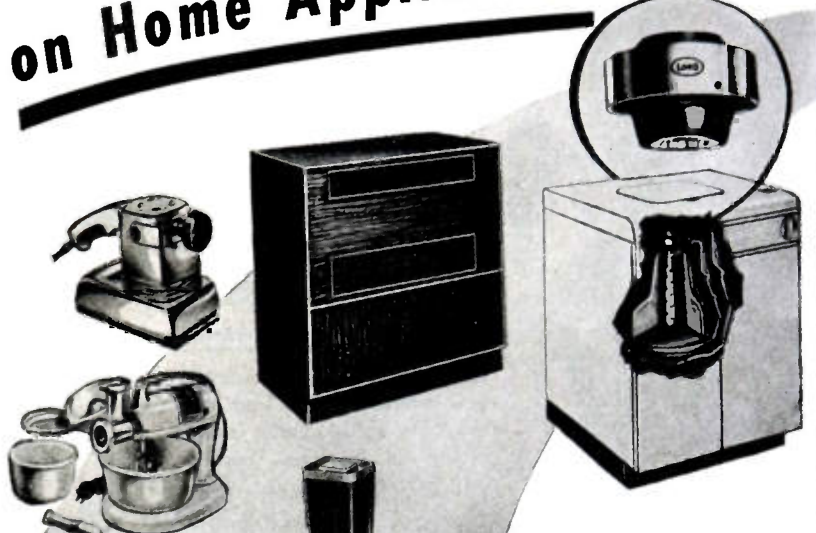
Linear output, minimum torque, potentiometer and selsyn outputs, most ultra sensitive of them all.

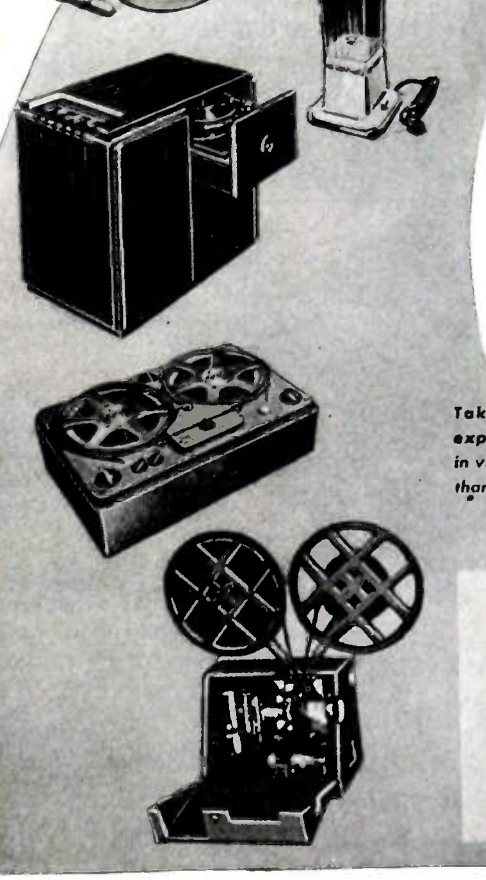
These potentiometers are available in a variety of resistance values and circuits. For details on these and other fine instruments, write:

G. M. GIANNINI & CO., INC.
Pasadena 1, Calif.

Giannini

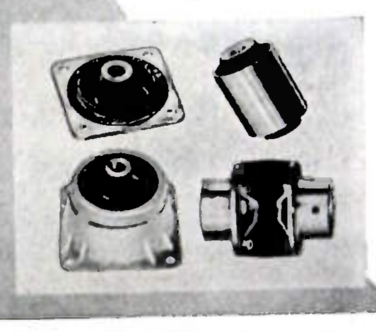
LORD MOUNTINGS Widely Used on Home Appliances





EVERY ONE of these electrical appliances incorporates Lord Mountings to isolate and control vibration and shock . . . thus to improve the operation of the appliance . . . In addition to regular bonded-rubber mountings, Lord Manufacturing Company designs and makes precision bonded-silicone mountings to maintain normal performance where extremes of temperature are encountered.

Take advantage of Lord experience . . . specialists in vibration control for more than a quarter century.

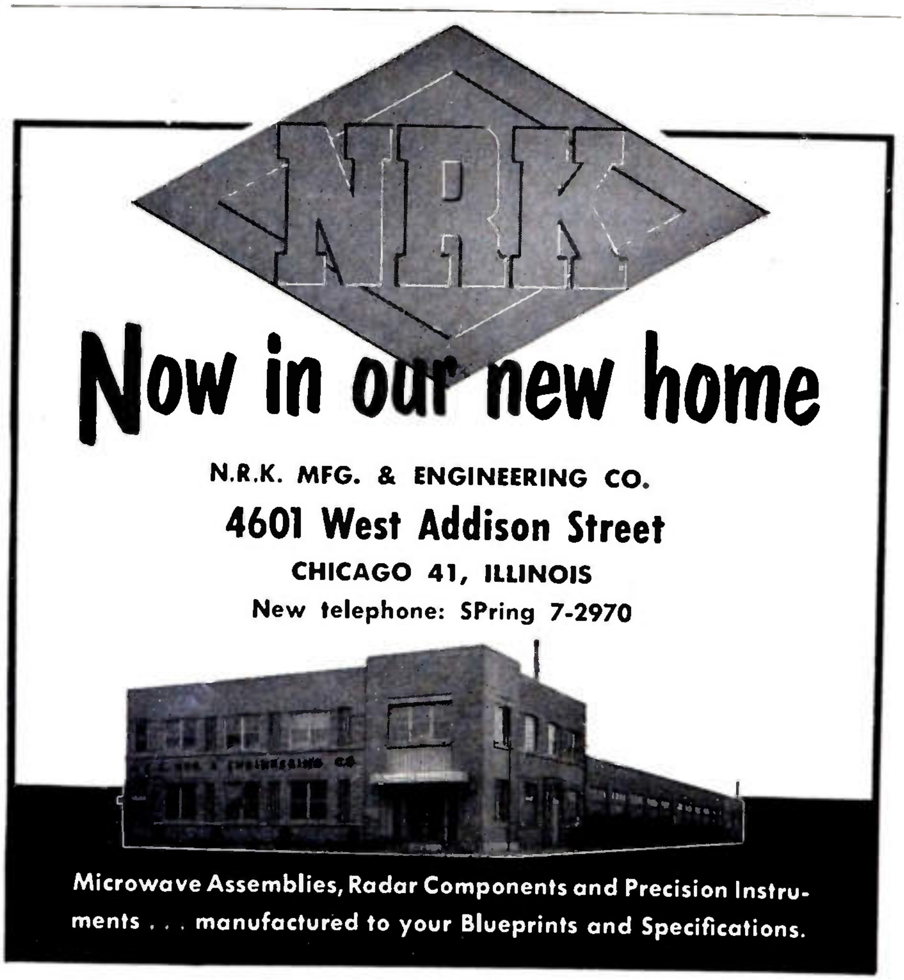


BURBANK, CALIFORNIA 233 South Third Street	**DALLAS, TEXAS** 413 Fidelity Union Life Building	**PHILADELPHIA 7, PENNSYLVANIA** 725 Widener Building	**DAYTON 2, OHIO** 410 West First Street
DETROIT 2, MICHIGAN 7310 Woodward Ave.	**NEW YORK 16, NEW YORK** 280 Madison Avenue	**CHICAGO 11, ILLINOIS** 520 N. Michigan Ave.	**ERIE, PENNSYLVANIA** 1635 West 12th Street

LORD MANUFACTURING COMPANY • ERIE, PA.

LORD BONDED RUBBER

Headquarters for **VIBRATION CONTROL**



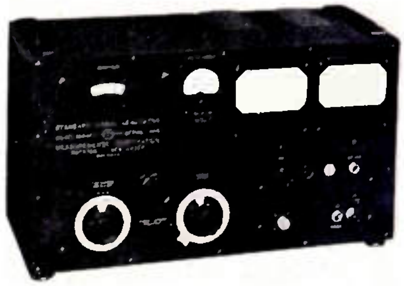
News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 108A)

UHF Signal Generator

A new standard signal generator, with frequency range of 300 to 1,000 mc has been announced by **Measurements Corp.**, Boonton, N. J. The new instrument, Model 84-TV, is useful for determining the characteristics of television receivers for the uhf band, and other equipment operating within that range.



Output voltage is continuously variable from 0.1 μv to 1 volt across a 50-ohm load. The output impedance is 50 ohms and the vswr is 1.3 to 1 or better. Provision is made for operating the filament of the oscillator tube from an external direct-current supply to remove residual hum.

Modulation, continuously variable from 0 to 30 per cent may be obtained from an internal 400-cps oscillator. Provision is also made for applying external modulation within the range of 50 to 20,000 cps. Percentage modulation is indicated by a panel meter.

This instrument is suited for making direct-gain measurements of rf amplifiers and testing mobile communications receivers in the uhf range. Because of its high output, this new signal generator may also be used to drive slotted lines or other impedance measuring devices, as well as aiding in the measurement of Q. Because of Model 84-TV's low harmonic content, the characteristics of uhf filters, traps, antennas, matching networks, and other circuits may be accurately made, without the use of selective detectors.

Precision Pulser

Radiation Counter Laboratories, Inc., 5122 Grove St., Skokie, Ill., have a new precision pulser, Mark 15 Model 47, a pulse generator with an extremely short rise-time pulse, and a precise control of pulse amplitude.

The pulser is of value in testing linear amplifiers and pulse circuits where a low-level signal is required. The pulse rise time is less than 10^{-8} seconds, fall time 350 μsec. The instrument has ranges of 1-mv, 3-mv, 10-mv, 30-mv, and 100-mv-pulse amplitude with 10-turn linear potentiometer control over these ranges. The pulse height is standardized against a standard cell in the instrument. Repetition rate is 3,600 pps. The instrument is similar to Oak Ridge National Laboratory Model Q-1066.

(Continued on page 113A)

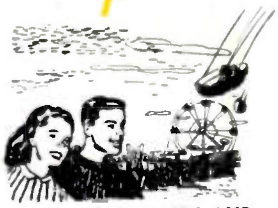
SKATING RINKS

FUNERAL PARLORS

DANCE STUDIOS

strikes a **NEW NOTE** in continuous performance playback music

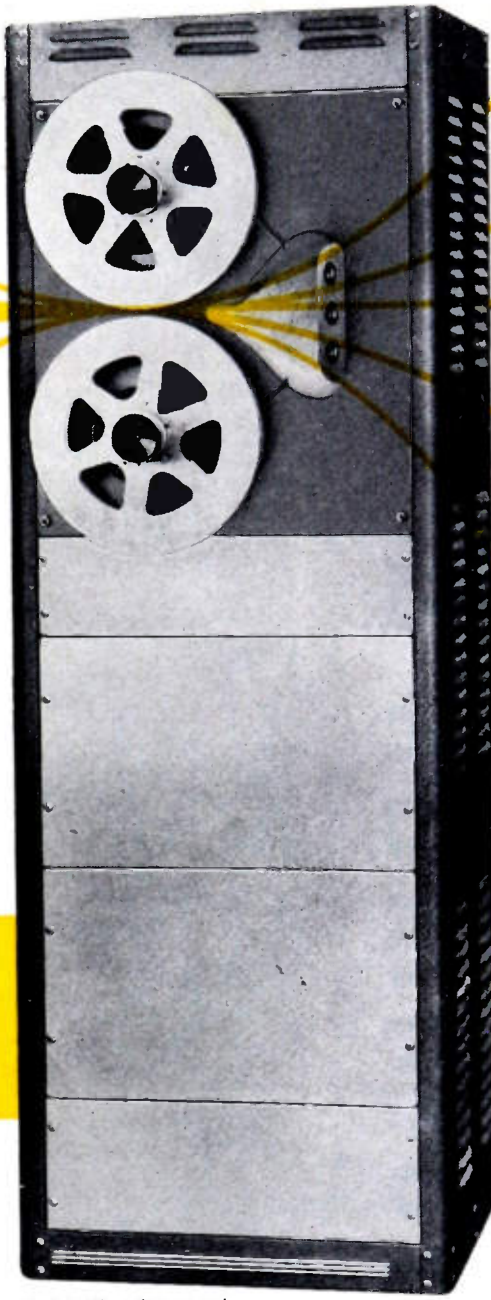
STEAMSHIPS



AMUSEMENT PARKS AND RECREATION CENTERS

INTRODUCING THE

AMPEX 450



Model 450 rack-mounted.
Also available in portable or console mount.

- ***Up to eight hours of uninterrupted performance — day after day, year after year***
- ***Requires no attention during operation***
- ***Lowest cost per hour***

The new AMPEX 450 gives you hours of high-quality background music delivered at *lowest cost per hour* of any musical reproduction system. With the AMPEX there are no interruptions, no records to change and no attendants since it *needs no attention* during operation. It plays at the touch of a button and keeps on playing for as long as eight hours without repetition. Because tape doesn't lose quality with repeated playings, music is always scratch-free and pleasant, with less background noise and distortion.

The Model 450 is engineered to rigid AMPEX standards and is capable of delivering thousands of hours of service with no breakdowns and minimum maintenance.

For further information, write to Dept. G

FEATURES

- 50 to 7500-cycle frequency response at 3¾ inch tape speed
- Standard NARTB reels up to 14 inches
- Pushbutton controls
- Automatic reverse control available as an accessory permits full eight hour program without interruption.

IF YOU PLAN FOR TOMORROW, BUY AN AMPEX TODAY

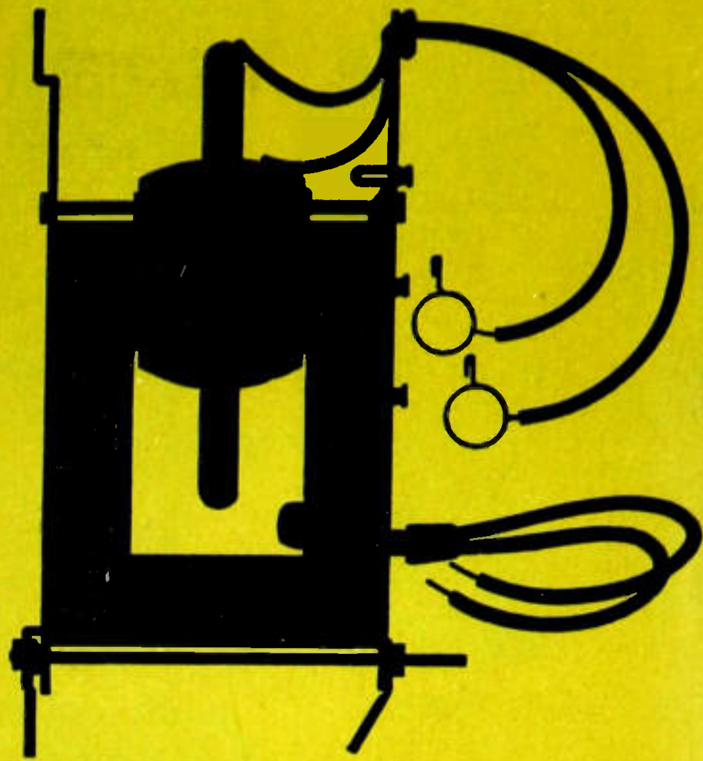
AMPEX

MAGNETIC RECORDERS

AMPEX ELECTRIC CORPORATION
934 CHARTER STREET • REDWOOD CITY, CALIF.

edwin i. guthman & co., inc.

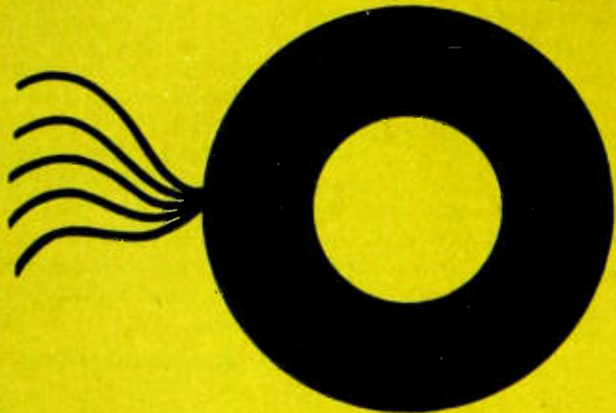
15 s. throop st. chicago 7, CH 3-1600 • also attica, indiana



flyback transformers

For reliability in high voltage specify Guthman Flybacks—they wont break down even under the most severe voltage requirements. Wire used in Guthman Flybacks is fabricated in our own plant and is quality controlled from raw material to finished product guaranteeing a superior uniformity of performance. The excellent linearity and voltage regulation characteristics of Guthman Flybacks aids in preserving picture quality.

Coils used in Guthman Yokes are form wound. Complete isolation between vertical and horizontal coils achieved by a molded nylon piece permits a yoke rating of 5,000 volts pulse maximum. Anti-magnetic core retainer band and brass mounting nut assures no magnetism in Guthman Yokes.



DELAY LINES
SHIELD CANS
ANTENNA COILS
OSCILLATOR COILS
COMPRESSION TYPE MICA TRIMMERS
I.F. TRANSFORMERS
LOOP ANTENNAS
R.F. TUNERS

yokes

BURTON BROWNE ADVERTISING

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 110A)

Smog Problem Eliminated

Production-line operators at the CBS-Columbia, Inc., Television Plant, 170 53rd St., Brooklyn 32, N. Y., have overcome a "smog" problem by ingenuity. A fan running in reverse, as shown in picture, pulls the soldering fumes away from the operator's nose. Suction action is accomplished by reversing the fan on a motor shaft, or by rebending the fan blades. Simple hardware cloth gives more protection than an ordinary fan guard.

(Continued on page 114A)

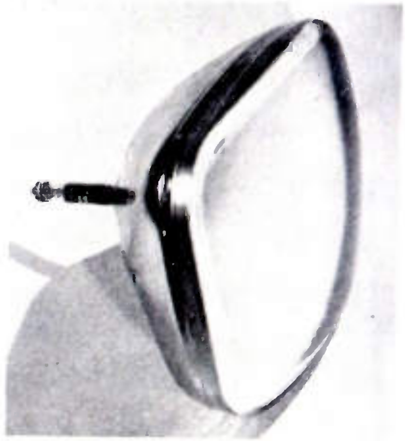
News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 113A)

27-Inch TV Picture Tube

The General Electric Co., Tube Dept., 1 River Road, Schnectady, N. Y., today announced the development of a 27-inch rectangular television picture tube.



The tube is a magnetic-focus, magnetic-deflection, all-glass tube which features an aluminized backing on the screen which reflects light emitted from the back surface of the screen, providing a picture which is up to 100 per cent brighter than a nonaluminized 27-inch tube at the same voltage; consequently, it has greatly increased black and white contrast.

The tube, type number 27EP4, provides a 24 by 18½-inch picture.

Recommended operating conditions for the 27EP4: anode voltage, 16,000 of volts grid #2 voltage, 300 volts grid #1 voltage, −33 to −77 volts; and ion-trap field intensity, 38 gausses.

Transformers and IF-RF Coils

Six new transformers are now available from **Merit Coil and Transformer Corp.,** 4427 N. Clark St., Chicago 40, Ill.

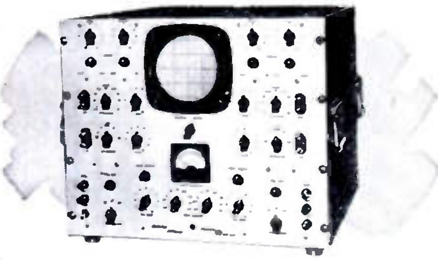
Types P3076 and P3078 are units for the new low-voltage, high-current TV set designs and P3079 is an isolation power transformer for sets such as Philco Model 50T201 and RCA 17T151, which use selenium rectifiers. Model P3097 is a damper isolation filament transformer. Rating is primary 6.3, secondary 12.6 at 1 ampere or 6.3 at 1.2 amperes. TV auto transformer Model P3098 is a picture-tube voltage booster with rating of primary 6.3, output 12.6 at 1 ampere with taps at 9.45 and 6.3 volts.

Merit has also announced six new IF-RF coils. Three 4.5-mc coils are for TV sound amplifier, sound discriminator, and sound detector use. They have ¾-inch clip-type mounting. Two 262-kc and one 455-kc filter-type IF coils are for late model auto radio sets.

(Continued on page 116A)

ETC

MULTI-CHANNEL OSCILLOSCOPES



***...for more accurate farther-reaching* TEST, RESEARCH *and* CONTROL**

By facilitating simultaneous observation or strip-film recording of 2, 4 or more transients, ETC multi-channel oscilloscopes pave the way to more accurate research, test and visual control along many lines. Available types cover a broad range of requirements in laboratory research, production testing, electroencephalography, neurophysiology, seismology, explosives, strain and vibration analysis and other fields. Catalog on request to **Electronic Tube Corporation, 1200 E. Mermaid Lane, Philadelphia 18, Pa.**

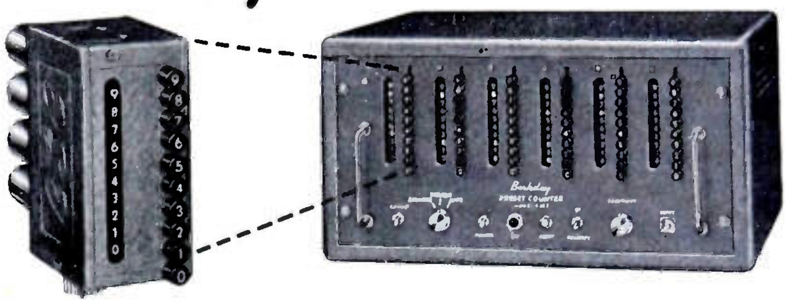
MULTI-GUN C-R TUBES

Now...

COUNTING PLUS CONTROL

AT RATES TO **40,000 CPS** WITH

Berkeley PRESET COUNTERS



DESCRIPTION—The Berkeley Preset Counter is an electronic decade with provisions for producing an output signal or pulse at any desired preset count within the unit's capacity. Any physical, electrical, mechanical or optical events that can be converted into changing voltages can be counted, at rates from 1 to 40,000 counts per second. Total count is displayed in direct-reading digital form. Presetting is accomplished by depressing pushbuttons corresponding to the desired digit in each column. Model 730 Preset Decimal Counting Units are used. These are completely interchangeable plug-in units designed for simplicity of maintenance and replacement.

APPLICATIONS—Flexibility and simplicity of operation make the Berkeley Preset Counter suitable for both production line and laboratory use. It has practical applications wherever signalling or control, based on occurrence of a predetermined number of events or increments of time is desired. Output signals from the unit can be used to actuate virtually any type of process control device, or to provide aural or visual signals.

SPECIFICATIONS	Model				
	422	423	424	425	426
MAX. COUNT CAPACITY	100	1000	10,000	100,000	1,000,000
INPUT SENSITIVITY (MIN.)	± 1 v. to ground, peak; at least 2 μ sec. wide				
OUTPUT	Choice of pos. pulse and relay closure, or pos. pulse. SPST relay closure approx. 1/30 sec; pulse output is + 125 v. with 3 μ sec. rise time and 15 μ sec. duration.				
PANEL DIMENSIONS	15⅝" x 8¾"		19" x 8¾"		
OVERALL DIMENSIONS	16⅝" x 10¼" x 13"		20¾" x 10½" x 15"		
POWER REQUIREMENTS	117 v. ± 10% @ 90w.		117 v. ± 10% @ 180 w.		
PRICE (F.O.B. FACTORY)	$375	$450	$595	$695	$795

M3

For complete information, please request Bulletin 2012

Berkeley Scientific

division of BECKMAN INSTRUMENTS INC.
2200 WRIGHT AVENUE • RICHMOND, CALIFORNIA

"DIRECT READING DIGITAL PRESENTATION OF INFORMATION"

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 114A)

Synchronous Motor

The **A. W. Haydon Co.**, 240 N. Elm St., Waterbury, Conn., has developed a practical 400-cycle synchronous ac timing motor for use where light weight, accuracy, and dependability are required.

The 400-cycle motor features almost instantaneous starting and stopping. Use of a single-pole double-throw switch accomplishes effective reversing. One winding 90° out of phase assures rapid starting, smooth operating, and absolute ease of reversal.

Mounting dimensions are identical, providing convenient interchangeability in all timers manufactured by Haydon. Weight 8 ounces.

The motor operates on 115 volts ± 10 per cent with frequency of 400 cps ± 20 per cent. The torque is 0.025 ounce-inch at 3,000 rpm starting and running. The motor operates with a power of 6 watts, including the phase shift network (4.5 watts motor winding). The rotor speed is 3,000 rpm at 4,000 cps with output speeds available from 3,000 rpm to $1\frac{2}{3}$ rph.

The new 400 motor meets the temperature, altitude and vibrations requirements of MIL-E-5272.

Manual on Circuit Breakers

A new manual explaining operating principles of basic circuit breaker designs and providing engineering data on factors of application has just been published by the **Heinemann Electric Co., 306 Plum St.**, Trenton 2, N. J.

Included in the new manual are simplified diagrams, with brief descriptions, showing the three basic types of circuit breakers in general use today. Explanations of temperature factors, inrush current effects, tripping and reset time, and time delay curves are provided. Also discussed are the questions of quick or slow make-and-break, and wire deterioration rates at various ampere values.

Copies of Manual 101 are available upon request.

(Continued on page 118A)

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 116A)

Capacitors

Industrial Condenser Corp., 3243 N. California Ave., Chicago 18, Ill., has a new line of capacitors possessing stable characteristics over a wide range of temperatures. Known as the "Stabelex D" series, these capacitors are particularly adapted for use in equipment subjected to extreme altitude and climatic changes or similarly difficult operational variables.

"Stabelex D" capacitors have an unusually low temperature coefficient of capacity, as is evidenced by only an 0.8 per cent change in capacitance from +20° C to −80° C. This is a highly important factor in circuits where the constants depend on unvarying capacity. Power factor is 0.00025 at 1 kc. Insulation resistance at 20° C is said to be approximately 500 times that of ordinary commercial oil capacitors. It is claimed that "Stabelex D" capacitors have time constants in excess of 4,800 hours.

Contact Cleaner

Quietone Div., R. & L. Radio-Television, 1704 Hudson Boulevard, Jersey City 5, N. J., has announced the development of a new contact cleaner and lubricant. Trade named Quietone, it is a highly effective cleaner, non-inflammable, non-corrosive, and non-solvent to metals or plastics. Oscillator frequency characteristics are not affected by it. Most important of all, lubrication action is non-greasy but useful in preventing future oxidation. Quietone has been field tested by service organizations in television, electronics, communication, telephone, test equipment, automotive fields, and other allied electrical uses.

Quietone is marketed in 2 ounce dropper bottles, 2 ounce plastic spray squeeze bottles, 8 ounce and quart sizes.

Exclusive wholesale distributor; Fischer Dist. Co., 118 Duane St., New York, N. Y.

Voltage Stabilizer Bulletin

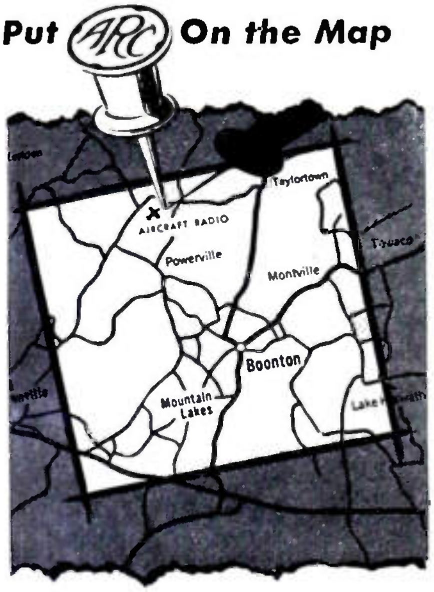
A new 12-page, two-color bulletin on automatic voltage stabilizers ranging from 15 to 5,000 volt amperes has been announced as available from the **General Electric Co.**, Schenectady 5, N. Y.

The booklet (GEA 5745) contains photographs and diagrams of the equipment, explains operation principles and construction, and gives complete specifications. It also describes the causes and effects of voltage variations and lists typical applications for stabilizers.

(Continued on page 120A)

Consistent QUALITY...

Put ARC On the Map



On air map or road map of New Jersey, you will see the name "Aircraft Radio" marking our location just N.N.W. of Boonton.

Names don't appear on the map overnight. It takes stability and reputation. And as we approach our 25th anniversary, it is gratifying to know that A.R.C. has been "put on the map" in another sense, too. All over the world, A.R.C. is known and our communications and navigational instruments are widely used and trusted.

A.R.C. has become a standard of excellence in its field because it is quality-built for precision rather than price. Into each unit go the finest of components—plus 24 years of specialized engineering experience.

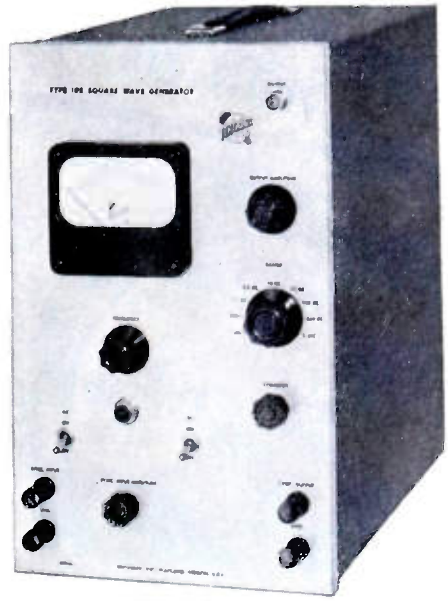
VHF NAVIGATIONAL RECEIVERS
MARKER BEACON RECEIVERS
ISOLATION AMPLIFIERS
LF RANGE RECEIVER WITH LOOP
VOR TEST EQUIPMENT
MICROWAVE TEST EQUIPMENT

Dependable Electronic Equipment Since 1928

Aircraft Radio Corporation
BOONTON NEW JERSEY

SQUARE WAVE GENERATORS

Use a Type 105 for response checks and adjustments of wide-band equipment



TYPE 105

With a Type 105 you can quickly and accurately test equipment having a pass-band of a few cycles per second to 20 mc. The square wave generated has flat horizontal portions for low frequency checks, and a risetime of 0.02 μsec into a load of 100 ohms or less for high frequency work. Frequency range of the square wave is continuously variable from 25 cps to 1 mc. The direct reading frequency meter is accurate within 3% of full scale.

The Type 105 can be easily synchronized with a frequency standard if desired. A sync output of about 5 v is available for external use. Square wave output amplitude is continuously variable from 0 to 100 v peak to peak across an internal 600 ohm load. Current available for external load—0 to 160 ma. All dc voltages electronically regulated.

Type 105 — $395 f.o.b. Portland, Oregon

PRODUCTION TESTING

TYPE 104A

Here is a low cost square wave generator for production line testing of amplifiers, filter networks and attenuator circuits. The Type 104A generates four fixed frequencies—50 cps, 1 kc, 100 kc, and 1 mc. Risetime of the two high frequencies is 0.02 μsec without overshoot. Amplitude of both low frequency outputs is continuously variable from 0 to 50 v and accurate within 3%. Selected frequencies will be supplied on special order.

Type 104A — $195 f.o.b. Portland, Oregon

TEKTRONIX, Inc.

P. O. Box 831B, Portland 7, Oregon   Cable: TEKTRONIX

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 118A)

Capacitors

The Johanson Manufacturing Corp., Boonton, N. J., announces development of a new concentric high-ratio capacitor with a maximum capacity of 35 $\mu\mu$f, and a minimum capacity of 1 $\mu\mu$f. The new item is now being produced in quantity.

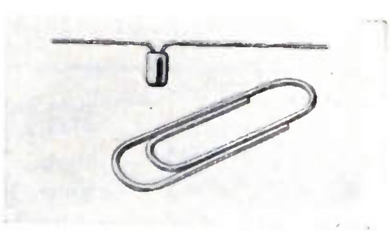
The capacitor is recommended for applications requiring a low minimum capacity, high Q, and stability. Because its ratio of capacity is 35 to 1, it has many uses in electronic equipment where capacitive adjustments need to be made over a wide range with great accuracy.

The new capacitor is being used in ten-channel transceivers with outstanding results. Because of its construction of silver-plated brass and Pyrex glass, it has excellent performance characteristics at the higher frequencies. It is high Q capacitor at and above 200 mc.

A friction spring that locks the rotor assures its stable characteristics and permanency in instrument calibration is guaranteed.

Selenium Diodes

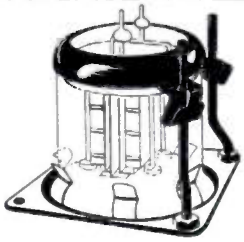
Two new sub-miniature selenium diodes, Type 1S1 and Type 5U1, have been developed by **International Rectifier Corp.**, 1521 Grand Ave., El Segundo, Calif.



The type 1S1 is rated for a maximum of 26 volts rms at 100-μa output, while the Type 5U1 is rated for 130 volts maximum at 1.5 ma. These new diodes augment the line of eight types currently being produced for operation in an ambient temperature range of 50 to 100° dc. The units are encapsulated within a thermosetting plastic. These diodes are being used to provide bias for tubes in diversified military and commercial electronic equipment. The output voltages available are 20 to 100 volts at currents of 100 μa to 1.5 mamps. The Type 1S1 is 0.10 inch wide by 0.21 inch long. The Type 5U1 measures 0.30 inch wide by 0.25 inch long.

(Continued on page 136A)

TOP HAT RETAINERS



Securely holds tubes and other plug-in components in position.

They will not loosen under the most extreme conditions of shock or vibrations.

Made in a variety of sizes to fit almost any type tube.

Recommended for use in Army, Navy and Air Force equipment.

- **EASY TO APPLY**
- **INSTANTLY RELEASED**
- **POSITIVE LOCKING ACTION**

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Use the ALL NYLON "NyLoc" CABLE CLIPS

for tough conditions and unusual heat, etc.

NEW!

Use the ETHYL CELLULOSE "EthoLoc" CABLE CLIPS

for average conditions and maximum economy

Send for details and FREE samples.

WECKESSER COMPANY
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"It's SONODYNE
MULTI-IMPEDANCE DYNAMIC MICROPHONE
at recording time!"

—say actual users* in the field and here are a few reasons why...

"This microphone has been used for a variety of purposes—but mostly for tape recording fifteen-minute shows for future airing on a nearby radio station. We like it fine, and it does take a beating."
Speech and Drama Director
Indiana

"A wonderful little mike. Plenty of gain and normal voice."
Director of Radio Activities
Texas

"We are using this microphone with good results on our recorder."
Audio-Visual Librarian

"Wonderful for wire recording purposes and P.A. use. I use it mainly for recording."
Sound Service Massachusetts

"Used for recording organ music. Performance is very satisfactory: especially good on highs."
Recording Professional
Colorado

"Very good output and fidelity. Used for recording for broadcast purposes."
Producer and Director
Canada

"Excellent results in recording and for comments in the showing of motion pictures."
Amateur
New York

* Individual names available on request.

SHURE

SHURE BROTHERS, Inc. — Microphones and Acoustic Devices
225 West Huron Street, Chicago 10, Illinois • Cable Address: SHUREMICRO

POSITIONS OPEN

The following positions of interest to I.R.E. members have been reported as open. Apply in writing, addressing reply to company mentioned or to Box No. ....

The Institute reserves the right to refuse any announcement without giving a reason for the refusal.

PROCEEDINGS of the I.R.E.
I East 79th St., New York 21, N.Y.

ELECTRONIC ENGINEER

An established business organization engaged in development and manufacture of products for VHF and UHF television. Application requires an individual qualified to work independently, to organize, and to supervise development projects. This position is to be permanent and will offer the opportunity for unlimited advancement to a successful career. Stimulating and congenial surroundings in a newly acquired plant. Attractive salary. Write stating qualifications to Blonder-Tongue Laboratories, 526-536 North Ave., Westfield, New Jersey.

ELECTRONIC ENGINEERS

Electronic engineers meeting civil service requirements are needed by the Mare Island Naval Shipyard in connection with the installation, maintenance, and major repair of electronic equipment in the Pacific area or at shore activities in the Twelfth Naval District and on board ships at the shipyard. Address inquiries to the Employment Dept., Mare Island Shipyard, Vallejo, Calif.

ENGINEER

An engineer with a degree in communications or electronics to work with a growing sales engineering organization in the southwest, selling complete line of component parts and test equipment. Production engineering experience desirable. Live in Dallas, Texas, and travel to Oklahoma, Arkansas, Louisiana and Texas. Please sumbit a complete application stating educational background and past work experience. John A. Green Co., 6815 Oriole Drive, Dallas 9, Texas.

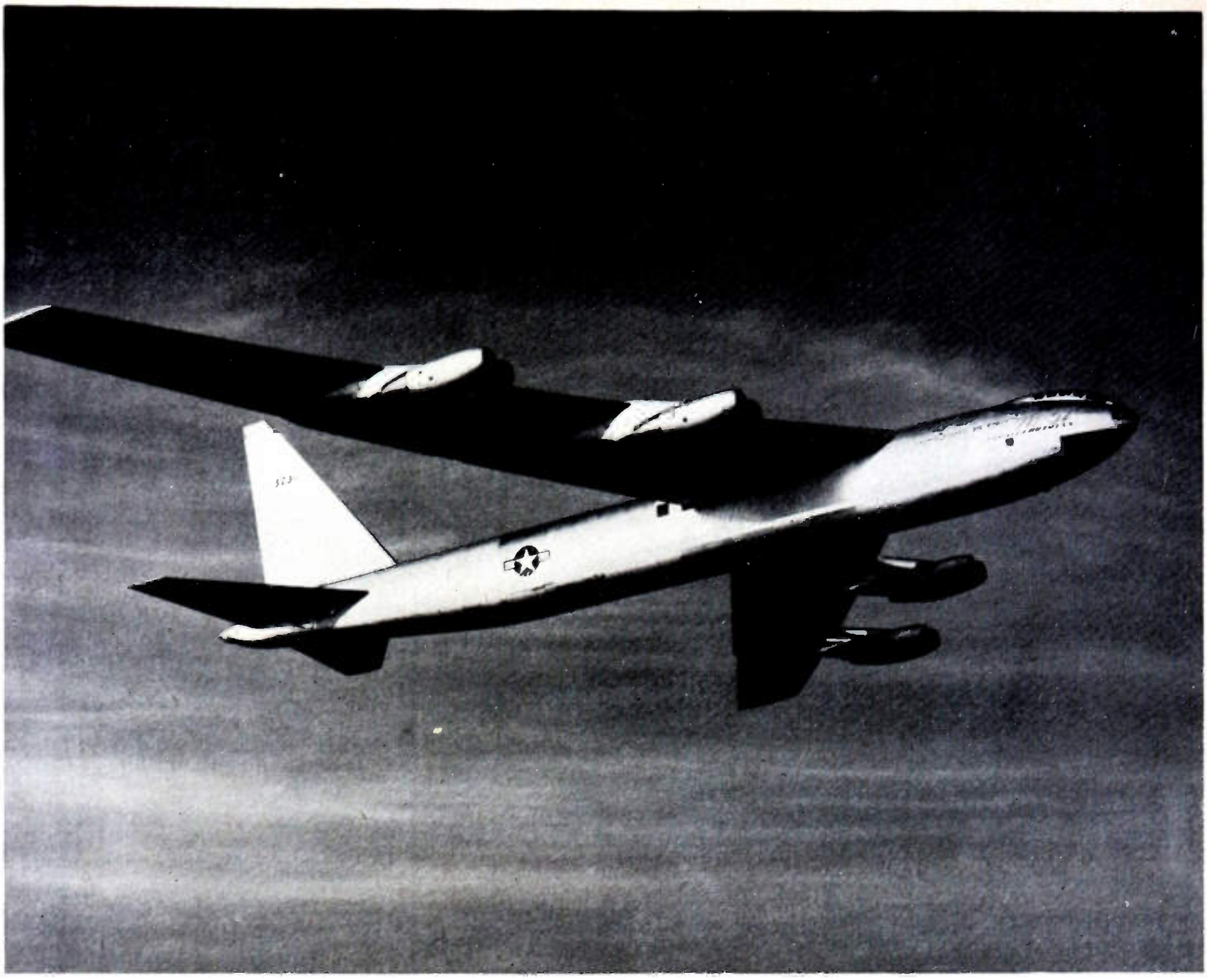
TRANSFORMER ENGINEER

We are seeking a man experienced in design, development and manufacturing; to head progressive, growing electronic type transformer company. Salary $7000 to $8500. Metropolitan New York area. Box 710.

ENGINEERS

MIT's Digital Computer Laboratory has opportunities in the development of high-speed electronic digital equipment (including work on vacuum-tube circuitry, ferromagnetic and ferroelectric memory cells and computer elements, and magnetic drum usage). There is also work on use of high-speed digital computers to control large physical systems, involving study of the control requirements of the whole system and reduction of these to a simple pattern of coded instructions. Position requires appreciation of physical systems, ingenuity, and imagination. Candidates experienced in computer principles will be trained. Persons from other fields are encouraged to apply and may come on leave. Opportunity for academic study. Salary appropriate to candidate's experience and training. Further information on request. Apply: MIT Digital Laboratory, 211 Massachusetts Ave., Cambridge 39, Mass.

(Continued on page 124A)



Positions Open

(Continued from page 122A)

ELECTRONIC ENGINEER

Electronic engineer, specializing in measurement and calibration. Ability to set up and direct all phases of electronic measurement and calibration required, involving supervision of several specialists. Advanced degree and 6 to 8 years of applicable experience preferred. Salary open, commensurate with ability. Please mail complete resume of education and experience to Mr. Robert E. McQuiston, Dept. EPD-1, Radio Corporation of America, RCA Victor Div., Camden 2, New Jersey.

ENGINEERS

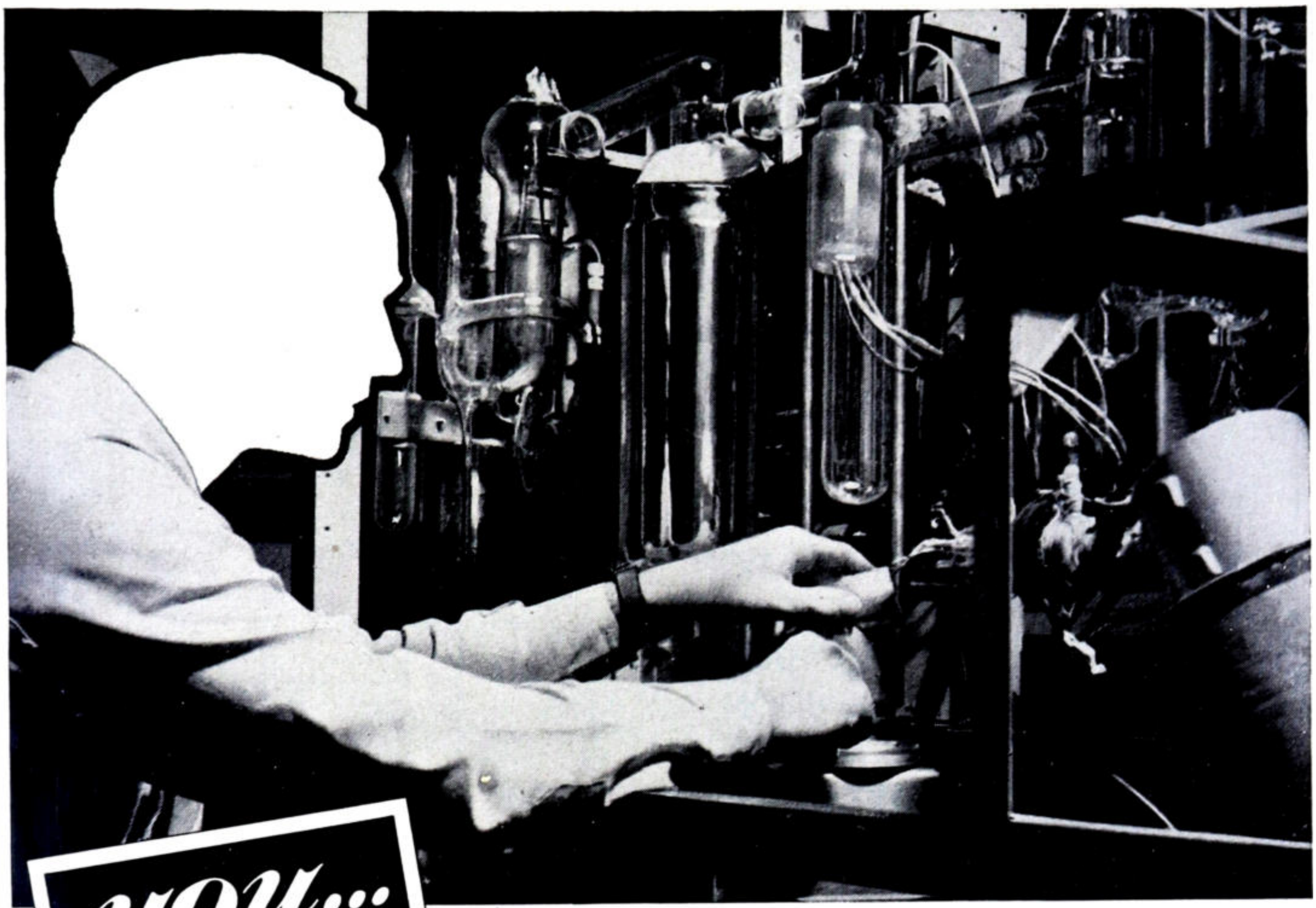
The manufactures of the UNIVAC—the first electronic, general-purpose digital computer system to be sold commercially—have interesting and important positions with challenging futures. Engineers and physicists are needed for work at all levels in many fields.

Our rapidly expanding engineering and production programs have created many permanent positions paying excellent salaries. These positions offer outstanding opportunities for professional development. The possibilities for graduate study in this locale are excellent and the Company's plan for reinbursement of tuition expenses is extremely liberal. Interviews arranged at our expense. Replies strictly confidential. Remington Rand Inc. Eckert-Mauchly Division, 2300 W. Allegheny Ave., Phila. 29, Pa.

ELECTRONICS ENGINEER

Group leader required to take charge of an electronics laboratory engaged in analytical instrument development. Design ability in conventional circuitry as applied to a.c. and d.c. amplifiers, power supplies, light detection

(Continued on page 126A)



you...

... are headed for a better future —when you come to RCA

If you want to work where you enjoy the highest professional recognition among your colleagues, come to RCA. Here your accomplishments are recognized and rewarded. Here your future is brighter, through challenging assignments that lead to better opportunities, better positions. Here you set goals for future attainment at advanced levels.

If your talent and skill are not being used in a way for which your education and experience has equipped you, come to RCA. Here you will find unusual opportunities to work in close association with distinguished scientists and engineers in research . . . development . . . design . . . and application of specialized electronic equipment for military projects as well as for an ever-increasing line of diversified commercial products.

Positions open are lifelong *career* opportunities. They are not "temporary" jobs. Unlike "feast or famine" industries, RCA has forged ahead regardless of war or depression. You can continue advanced study at recognized universities under RCA's modern tuition refund plan. You and your family enjoy outstanding Company benefits. Yes, your future is better at RCA.

LIFETIME OPPORTUNITIES FOR

ENGINEERS—Electronic . . . Electrical . . . Communication . . . Mechanical . . . Computer . . . METALLURGISTS and PHYSICISTS

In Research—Development—Design—Application: in the following fields:

RADAR • MISSILE GUIDANCE • SERVO MECHANISMS • COMPUTERS • TRANSFORMERS AND COILS • NAVIGATION AIDS • TELEVISION • ELECTRON TUBES • COMMUNICATIONS TECHNICAL SALES • ELECTRONIC EQUIPMENT FIELD SERVICE

Send a complete résumé of your education and experience.

Personal interviews arranged in your city.

Send résumé to:
Mr. ROBERT E. McQUISTON, Manager
Specialized Employment Division,
Dept. 94L
Radio Corporation of America
30 Rockefeller Plaza, New York 20, N. Y.

RADIO CORPORATION of AMERICA

ELECTRONIC ENGINEERS & PHYSICISTS

OUR STEADILY EXPANDING LABORATORY OPERATIONS ASSURE PERMANENT POSITIONS AND UNEXCELLED OPPORTUNITY FOR PROFESSIONAL GROWTH IN

RESEARCH & DEVELOPMENT

GUIDED MISSILES
RADAR
ELECTRONIC NAVIGATION
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CAPEHART FARNSWORTH CORP.
FORT WAYNE, IND.

Electronic Designers

For design and layout of UHF equipment, Microwave components and systems.

Radio Engineers

Minimum 5 years' experience. For research and development in radio and radar systems and components.

Engineers

Experienced in the design and development of components for the magnetic deflection of Cathode Ray Tubes.

What can Kollsman mean to you?

OPPORTUNITY

The progressive, growing Kollsman organization offers continuing opportunities in the design and development of America's finest aircraft instruments.

CONVENIENCE

An easy-to-reach modern plant, located in a quiet, residential section of New York.

SATISFACTION

The finest facilities at your disposal . . . friendly, cooperative co-workers . . . many liberal benefits including completely paid life, hospitalization, surgical, accident and health insurance.

Find Out For Yourself—Contact Kollsman Today!

KOLLSMAN INSTRUMENT CORP.
80-08 45th Avenue, Elmhurst, Long Island, N.Y.

Positions Open

(Continued from page 124A)

devices, thyratron circuits, discriminators, magnetic circuitry and fractional horse-power motors desirable. 5 years experience or advanced degrees in lieu of part of this experience required. Send resume with salary requirements to Personnel Mgr. Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Pa.

ENGINEER

A national employee-owned electrical distributing company offers permanent position to graduate electrical engineer for electronics sales work. Experience in broadcast, sound, radio communication, and industrial electronics desired, but not necessary. Opportunity for advancement; liberal employee benefits and security. Man 22 to 28 preferred. Send complete resume of training and experience, including salary desired to R. W. Griffiths, Graybar Electric Co., 21-15 Bridge Plaza North, Long Island City 1, N.Y.

ELECTRONIC ENGINEERS, ELECTRICAL ENGINEERS & PHYSICISTS

The Rome Air Development Center has positions in electronic research and development available at salaries from $3400.00 per annum to $9600.00 per annum. Write: Professional & Scientific Requiter, Civilian Personnel Div. Griffiss Air Force Base, Rome New York.

ENGINEER—TEACHING

The University of Nebraska has one full-time teaching position open now in the Electrical Engineering Dept. Salary range $3200 to $4600 depending upon education and experience. One interested in electronics preferred. For details write to Prof. Ferris W. Norris, Chairman, Dept. of Electrical Engineering, University of Nebraska, Lincoln, Nebraska.

ELECTRONIC ENGINEERS

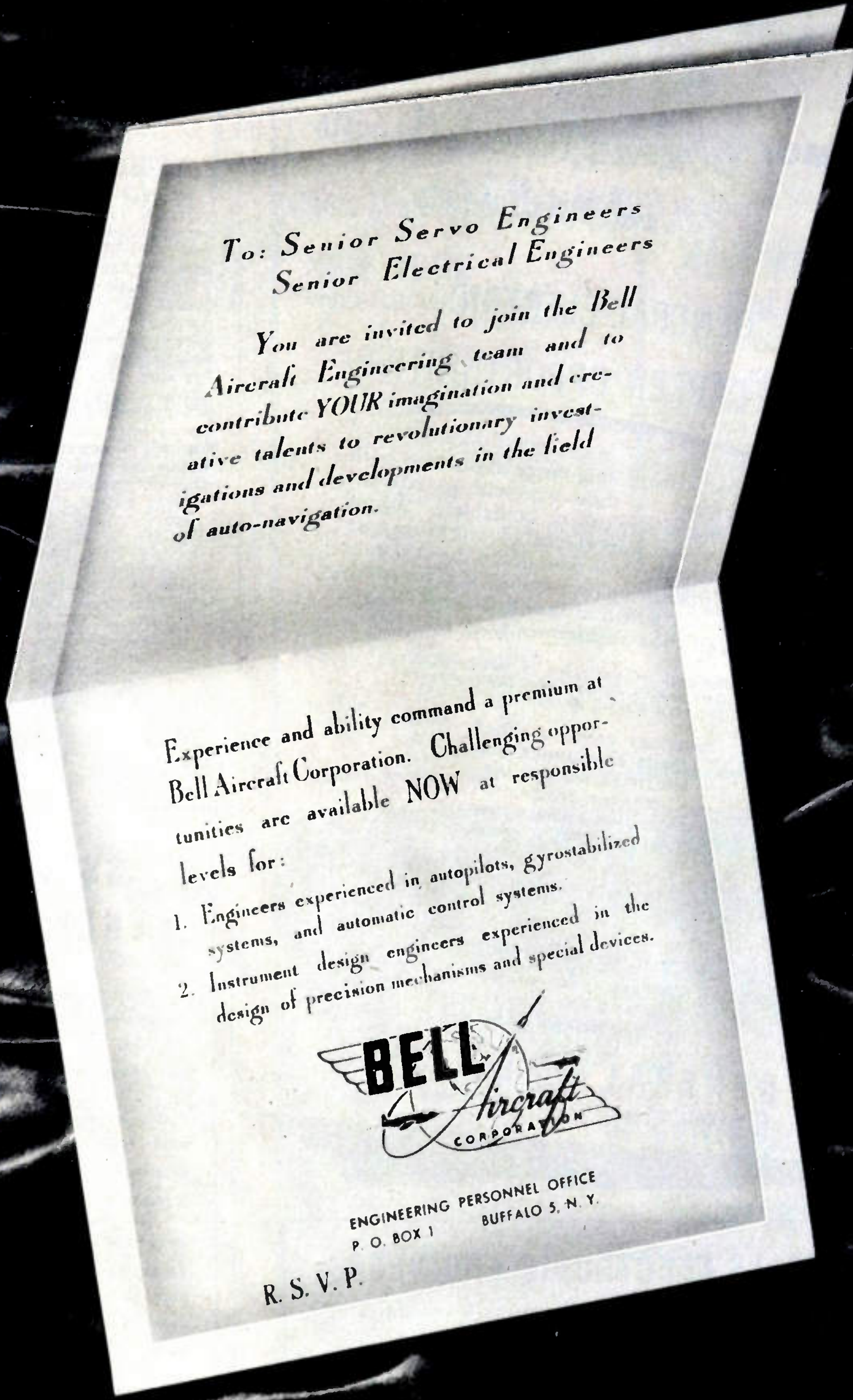
•

We are looking for Electronic Engineers, with experience in the development of electronic digital computers, to work in the development of business machines. Plenty of opportunities for advancement.

Write, giving full details, including education and experience.

•

THE NATIONAL CASH REGISTER COMPANY
South Main and "K" Streets
Dayton 9, Ohio



INERTIAL GUIDANCE SYSTEM DEVELOPMENT IS A LONG-RANGE PROGRAM AT BELL AIRCRAFT

Positions Wanted By Armed Forces Veterans

In order to give a reasonably equal opportunity to all applicants and to avoid overcrowding of the corresponding column, the following rules have been adopted:

The Institute publishes free of charge notices of positions wanted by I.R.E. members who are now in the Service or have received an honorable discharge. Such notices should not have more than five lines. They may be inserted only after a lapse of one month or more following a previous insertion and the maximum number of insertions is three per year. The Institute necessarily reserves the right to decline any announcement without assignment of reason.

SALES ENGINEER

22 years in radio. Age 38. Hard worker, desires challenging position. Experienced in various phases of radio, including publications, commercial operating, sales, mobile radio, microwave, carrier. Interested in position that will allow me to earn $10,000 per year or better. Will relocate for proper position. Married, 1 child. Box 582 W.

ELECTRONIC ENGINEER

BEE, June 1950, New York University. 2 years electronic design experience. Desires position as electronic sales representative in New York area. Box 583 W.

(Continued on page 130A)

ENGINEER!

IS YOUR WORK STIMULATING?

•

ARE YOU CHALLENGED BY YOUR JOB?

•

ARE YOU RECEIVING PROFESSIONAL RECOGNITION?

SYLVANIA

believes in building men

The company, now in its 51st year, is expanding rapidly. Net sales this year exceed 1938 by 16 times. Additional high caliber men are needed with training and experience in all phases of electronics, physics and mechanics.

Write us about yourself, if your experience and future plans fit into this picture.

JOHN WELD
Department F

SYLVANIA ELECTRIC PRODUCTS INC.
Radio and Television Division
254 Rano Street
Buffalo 7, New York

BELL Aircraft CORPORATION

Offers Challenging Opportunities in Guided Missile Programs

NEW YORK

****SERVOMECHANISMS ENGINEERS**

for research, design, development and test assignments on:

- Servomechanisms
  - Gyroscopes
  - Computors
  - Autopilots
- Electronic Guidance Systems
  - Antennas
  - Radomes
  - Wave Guides
  - Telemetering
  - Radar
- Missile Systems
  - Electrical
  - Mechanical
- Production Test Equipment
  - Automatic Go-No Go types
- Missile Test Equipment
  - Systems testing
  - Components testing

****ELECTRONICS FLIGHT TEST ENGINEERS**

to install, test and operate electronic guidance equipment in high speed bombers.

NEW MEXICO and CALIFORNIA

****ELECTRONICS ENGINEERS**

****ROCKET ENGINEERS**

****ELECTRONICS TECHNICIANS**

for field testing of

- Servomechanisms
- Guidance Systems
- Telemetering
- Rocket Power Plants

These are permanent positions which provide top pay, opportunities for advancement as well as numerous liberal benefits including special insurance and retirement plan.

WRITE: Mgr., Engineering Personnel
Bell Aircraft Corporation
P.O. Box 1, Buffalo 5, New York

POSITIONS OPEN

Location
Kansas City, Mo.

Electronic & Mechanical Engineers

ELECTRONIC ENGINEERS: Must have considerable development experience in radio transmitting and receiving equipment. Ability to fill position of Senior Project Engineer a requisite.

MECHANICAL ENGINEER: Must have development experience in mechanical design of electronic or similar precise equipment. Practical and theoretical knowledge of materials, finishes, sheet metal, and machine shop design are basic requirements. Position is one of considerable responsibility.

SALARY: Open

These positions are permanent.

Write stating educational and professional history direct to:

JAY V. WILCOX, *President*

WILCOX ELECTRIC COMPANY, INC.
1400 Chestnut St., Kansas City 1, Mo.

Dependable communications since 1931

ENGINEERS

USE YOUR EXPERIENCE TO BUILD A SOUND FUTURE AT SPERRY

Choose your desired field of work! Project and product engineering work exists for graduate engineers with design, development and product experience in:

VACUUM TUBE TECHNIQUES • ANALOGUE COMPUTERS • RADAR • HYDRAULICS • COMMUNICATION EQUIPMENT • ELECTRONIC PACKAGING • PULSE TRANSFORMERS • SERVO MECHANISMS • ELECTRONIC CIRCUITS • AIRCRAFT CONTROLS • INSTRUMENTATION • PRINTED CIRCUITS • FRACTIONAL H.P. MOTORS • MAGNETIC AMPLIFIERS • RADIO FREQUENCY & MICROWAVE MEASUREMENT

ALSO PUBLICATIONS ENGINEERS To write manuals and engineering reports.

ENJOY MANY ADVANTAGES

• Interesting, diversified work plus • Association with top engineering men on unusual engineering problems • Cost of Living Adjustment • Adequate Housing • Liberal Employee Benefits • Top Rates

SUBMIT RESUME TO EMPLOYMENT OFFICE

SPERRY GYROSCOPE CO. DIVISION OF THE SPERRY CORP. GREAT NECK, L. I., N.Y.

Southern California Calling

SENIOR ELECTRONIC SYSTEMS ENGINEERS:

A better job, a better life, a better future can be yours in Southern California—at Lockheed Aircraft Corporation.

On the job, you enjoy increased pay; fine, modern working conditions; association with top men in your profession—men who have helped build Lockheed's reputation for leadership.

Off the job, you live in a climate beyond compare — where outdoor living can be enjoyed the year around.

In addition, Lockheed's production rate and backlog of orders—for commercial as well as military aircraft—insures your future.

REQUIREMENTS:

1. An M.S. or Ph.D. in Electrical Engineering or Physics.
2. A minimum of three years' experience in advanced electronic systems development, including radar microwave techniques, servo-mechanisms, computers and fire control.
3. Familiarity with airborne electronics equipment requirements.

NOTE TO ENGINEERS WITH FAMILIES:

Housing conditions are excellent in the Los Angeles area. More than 50,000 rental units are available. Thousands of homes have been built since the war; huge tracts are under construction now. You will find the school system as good—from kindergarten to college.

Send today for free, illustrated brochure describing life and work at Lockheed in Southern California. Use handy coupon below.

M. V. Mattson, Employment Manager, Dept. IRE-12

LOCKHEED

AIRCRAFT CORPORATION, Burbank, California

Dear Sir: Please send me your brochure describing life and work at Lockheed.

My name ____________________

My occupation ____________________

My address ____________________

My city and state ____________________

Positions Wanted

(Continued from page 128A)

ELECTRONIC ENGINEER

Age 37. Seeks position requiring initiative and broad experience. BSEE 1937. 4 years electrical construction and maintenance, steel mill; 5 years officer, Corps of Engineers; 6 years electronic design and development, radio and TV. Box 584 W.

INDUSTRIAL ELECTRONIC ENGINEER

BS, working toward MEE. Age 34. 5 years experience electronic control systems. 6 years electronics instructor, including top administrative work. New York or Los Angeles metropolitan area. Box 585 W.

ENGINEER

BEE, electronics option, University of Dayton, Feb. 1951. Age 27, married. Desires design or development position in a field such as radar or communications. Interested in advanced degrees. Box 590 W.

ELECTRONICS ENGINEER

MS in mathematics, minor in communications-electronics. 5 years technical director TV Institute. 2 years instructor Pratt Institute. 4 years experience radar and electronics. Age 40. Will relocate. Box 591 W.

ENGINEER

SBEE., M.I.T., 1939. Varied development, design, and standards experience. Most recently, product design for 3½ years. Familiar with Government specifications. Signal Corps Inspector Agency for 3 years. Desires responsible position in design and development. Box 592 W.

(Continued on page 131A)

STAVID ENGINEERING, INC.

has openings for

GRADUATE ELECTRONIC and MECHANICAL ENGINEERS

Experience in Design and Development of Radar and Sonar necessary.

Broad knowledge of Search and Fire Control Systems; Servo Mechanisms, Special Weapons, Microwave, Antennas and Antenna Mounts, etc.

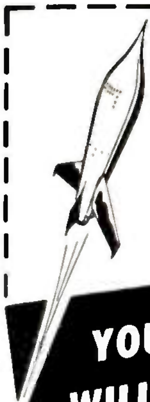
Mechanical Engineer should also have experience in packaging of Electrical Equipment to Gov't specifications including design of complex cabinets, shock mounts and sway brace structures.

FIELD ENGINEERS

Qualified to instruct in the operation and supervise installation, maintenance and repair of Radar, Sonar and allied electronic equipments in the Field.

A chance to grow with a young and progressive company; salary and advancement commensurate with ability; liberal vacation, sick leave, 9 paid holidays, group life, sickness and accident insurance plans, and a worthwhile pension system.

Personnel Office, 200 W. Seventh St.
Plainfield, N.J.—Tel. Pl. 6-4806



Aerophysicists, Designers, Engineers

YOUR IDEAS WILL COUNT AT NORTH AMERICAN

North American encourages advanced thinking, because they know looking ahead is the only way to maintain leadership in the aviation industry. That's why North American needs men of vision. If you like hard thinking and would like to work for a company that will make the most of your ideas, you'll find real career opportunities at North American. North American offers you many extra benefits, too.

North American Extras—

Salaries commensurate with ability and experience • Paid vacations • A growing organization • Complete employee service program • Cost of living bonuses • Six paid holidays a year • Finest facilities and equipment • Group opportunities for advancement • Group insurance including family plan • Paid sick leave • Transportation and moving allowances • Educational refund program • Low-cost group health (including family) and accident and life insurance • A company 24 years young.

Write Today

Please write us for complete information on career opportunities at North American. Include a summary of your education, background and experience.

IS YOUR FIELD LISTED HERE?

- Airborne Electronic Equipment
- Equipment Flight Tests
- Precision Instruments
- Automatic Controls
- Propulsion Systems
- Servo-Mechanisms
- Airframe Studies
- Radar Devices
- Instrumentation
- Micro Wave Techniques
- Metallurgical
- Electroplating
- Engineering Planning

NORTH AMERICAN AVIATION, INC.

Aerophysics, Electro-Mechanical Research Division

Dept. 7, Personnel Section,

12214 Lakewood Blvd., Downey, California

North American Has Built More Airplanes Than Any Other Company In The World

Positions Wanted

(Continued from page 130A)

TV BROADCAST ENGINEER

Desires responsible position with new TV station. 5 years AM broadcasting, 2 years TV. Last 2 years, Technical Supervisor, 50,000 watt AFRS broadcast station overseas. Considerable construction experience. Box 593. W.

ENGINEER—INSTRUCTOR

BEE electronics major, 1950. Age 30. Married. Electrician experience, AAF radio instructor. Presently employed by Civil Service as Educational Consultant and Technical Advisor. GS-11. Prefer employment in industrial sales or technical teaching. Box 594 W.

ENGINEER

BSEE., 1951, power and communications majors. Age 24. Single. Desires position in design and development of electronic equipment. 16 months Navy Electronic Technician. Eta Kappa Nu, Tau Beta Pi. Available November 1952. Box 595 W.

JUNIOR ELECTRONIC ENGINEER

Age 29. USN-ETM 1/c, completed 4 years, evenings at New York University toward BEE. Experience: 4 years TV, 1½ years research assistant in electronics for metropolitan university. Box 596 W.

ENGINEER

Senior communications engineer (supervisory) desires to locate in Canada. Thoroughly experienced hi-power international, relay, and medium wave broadcasting; aviation radar-radio; teaching; administration and liaison. Degree in physics (electronics-magna cum laude). Phi Beta Kappa, Sigma Pi Sigma, IRE, AAPT, ASA. Speak French, Spanish and English. Available December. Brochure on request. Box 597 W.

(Continued on page 132A)

Positions Wanted

(Continued from page 131A)

ENGINEER

BSEE, electronics 1949. 2 years electronic design and development. 1 year development microwave components. Presently project engineer on radar plumbing systems. Desire sales or application engineering in New York City, Connecticut or Massachusetts. Age 27. Married. Box 598 W.

ELECTRONIC ENGINEER

BEE., MS., age 28. 2 years Navy electronic Technician; 3 years college teaching; 3½ years circuit design experience. Seeks position with supervisory and/or customer relation responsibilities. Box 599 W.

ENGINEER

BSEE., communications option, Iowa State College. Age 27, married, 2 children. 10 months experience research testing of servo-amplifiers, computers. 1 year experience as groond radar officer, USAF. Desires research and development position. Box 601 W.

ENGINEER—PRACTICAL SALES

Outstanding electronic, mechanical skills knowledge. 4 years supervisory military communications. 6 years shop and theory instructor AM, FM, TV communications. Marine radio, motors and generators, pulse circoitry, visual aids. 2 years broadcast engineer. 3 years sales engineer. Former trades editor. FCC licensed, 1st phone, 2nd telegraph, amateur W2JZB (mobile) Single. Age 29. Prefer sales engineering. Box 602 W.

ENGINEER

BE. communications, 1949. MSEE. upon completion of thesis. Tau Beta Pi. Currently employed in TV research and development at

(Continued on page 135A)

ENGINEERS

Electronic

RADAR

SERVO

COMPUTER

Make Your Move In The Right Direction

MAXSON

N W E S

POSITIONS THAT POINT TO A SUCCESSFUL FUTURE!

Heavy experience in system analysis, circuit and component design. Engineering leadership and management ability desirable.

TOP SALARIES

If your skills are now being fully utilized in a vital defense industry, please do not apply.

Kindly send resume and salary requirements to:

The W. L. MAXSON CORPORATION
460 W. 34th ST.
NEW YORK 1, N.Y.

ENGINEERS

FOR ATOMIC WEAPONS INSTALLATION

Mechanical Engineers, Electronics and Electrical Engineers, Physicists, Aerodynamicists, and Mathematicians. A variety of positions in research and development open for men with Bachelors or advanced degrees with or without applicable experience.

These are permanent positions with Sandia Corporation, a subsidiary of the Western Electric Company, which operates the Laboratory under contract with the Atomic Energy Commission. The Laboratory offers excellent working conditions and liberal employee benefits, including paid vacations, sickness benefits, group life insurance and a contributory retirement plan.

LOCATE IN THE *Healthful Southwest*

Albuquerque, center of a metropolitan area of 150,000, is located in the Rio Grande Valley, one mile above sea level. Albuquerque lies at the foot of the Sandia Mountains which rise to 11,000 feet. Cosmopolitan shopping centers, scenic beauty, historic interest, year 'round sports, and sunny, mild, dry climate make Albuquerque an ideal home. New residents experience little difficulty in obtaining adequate housing in the Albuquerque area.

THIS IS NOT A CIVIL SERVICE APPOINTMENT

Make Application to the
PROFESSIONAL EMPLOYMENT DIVISION

SANDIA *Corporation*

SANDIA BASE
ALBUQUERQUE, N. M.

Positions Wanted

(Continued from page 132A)

project engineer level. 4 years military radar-radio maintenance. 10 years experience designing and building amateur communications, receivers and transmitters. Desires employment in development or design of electronic or communications equipment. Box 605 W.

ENGINEER

Soon at liberty. CAA engineer in full charge of airway aids. Considerable experience in field work and handling men. Ex-AAF radar officer, Harvard-M.I.T. Radar School, ex-radar instructor. Young adaptable, not afraid of hard work. Degree in mathematics and 10 years experience in electronics and radar. Salary requirements modest for interesting and challenging work. Box 616 W.

ENGINEER

BEE. 1951. Ex-Navy ETM (Naval Research Lab.) 1 year design and development work in radio interference suppression. Age 24, married. Desires non-military work with a future in New York metropolitan area. Box 617 W.

ENGINEER

Electronics engineer, 5 years post-war design, production and administrative experience. U. S. citizen, Navy veteran. Knowledge of several foreign languages. Interested in a position in a large city in western Europe. Box 618 W.

ELECTRONIC ENGINEER

USAF Guided Missile Officer. Age 25, married. BSEE., communications option witb honors. BS in commerce. Graduate of USAF Airborne Electronics, Guided Missile Guid-

(Continued on page 136A)

Positions Wanted

(Continued from page 135A)

ance, and Control schools. Guided missile and radar field experience. 1 year industrial experience. Interested in production, administration and development. Available March 1953. Box 619 W.

ENGINEER

Age 27. B.S. in physics 1951. Graduate student in psychology at University of Maryland. Wartime Navy Radio Technician. Scattered experience since 1942 in AM and TV broadcasting, teaching, defense work in circuit development and engineering psychology. Amateur W3KNP. Interested in audio-visual arts. Box 620 W.

ENGINEER

BS. Industrial Arts. 10 years teaching and administration in radio and allied arts, 2 years Air Force radio. Age 30, married, 1 child. Willing to locate anywhere. Available within 30 days. Box 621 W.

ELECTRONIC ENGINEER

Navy electronics officer to be released in Feb. 1953 desires position in management or sales. Age 25, single. BSEE. Radiotelephone 1st class license; 3 years practical electronics experience. Will relocate. Box 622 W.

ELECTRONIC ENGINEER

Electronic engineer graduate Queen's University post graduate work McGill University Canadian Civil Servant with 12 years experience in systems engineering, project engineering, radar and pulse technique and fully conversant with implementation of Canadian Government defense contracts, desires suitable position in industry. Available 2 or 3 months after submitting resignation. Box 623 W.

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 120A)

New Firm

Hugo Woerdemann and Associates have announced the formation of the **Magnetic Research Corp.**, 318 Kansas St., El Segundo, Calif.

The organization is devoted to research, development and production of magnetic devices, including the following: magnetic amplifiers, magnetic voltage regulators, magnetic frequency regulators, ferro-resonant circuits, magnetic pulse generators, magnetic frequency changers, low level signal converters.

Associated with Woerdemann are W. F. DeBoice and K. L. Sanders, both magnetic amplifier specialists.

Woerdemann and his associates have recently applied for over 15 patents on magnetic amplifiers and saturable core devices. These patents include a basic magnetic-amplifier circuit having one cycle time delay for phase reversible ac output, another with polarity reversible dc output, which is up to 50 per cent efficient. Other patents pertain to magnetic amplifier controlled alternators, magnetic voltage references and high powered magnetic radar modulators.

(Continued on page 137A)

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 136A)

Slip Ring

The Electro Tec Corp., South Hackensack, N. J., manufacturers of miniature slip ring and commutator assemblies, has developed an extremely short slip ring assembly providing 46 independent circuits.

Shaft dimensions of the assembly are held to highest accuracy to allow for direct bearing mounting.

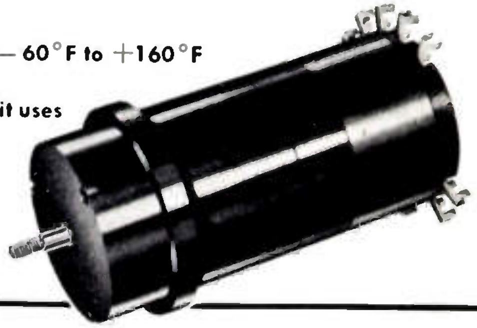
Individual rings are 0.023 inches wide and barriers between rings 0.020 inches in width. Each ring is located within 0.002 inches of its nominal dimension over the 1.935 inches of active length. Gold finish is provided to maintain a constant low voltage drop between the wire brushes and the rings.

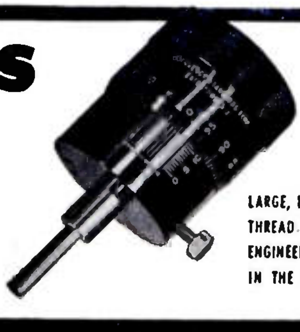
Audio Isolation Amplifier

Flite-tronics, Inc., 3303 Burton Ave., Burbank, Calif., has a new light weight 7-channel audio-isolation system amplifier in full production. General features include use of one type of amplifier in any size aircraft and isolated input circuits to eliminate any need for matching to various makes of receivers. Provision is made for reception of single or mixed simultaneous voice, marker, range, or other audio signals on either one or more loud speakers or earphones. The CA-1 operates with equal efficiency in system with either high or low power dynamotor supply. It is recommended for use with high power dynamotor for high noise-level cockpits and can be used with low-power dynamotor supply in low noise-level instances.

Audio output maintains balanced volume regardless of number of channels put in use. The CA-1 audio amplifier has the same case dimensions, shock mounting and basic appearance of the Flite-Tronics MB-3 Marker Beacon Receiver and is designed as matched equipment to the MB-3. Complete cockpit isolation between pilot and co-pilot is accomplished by using two CA-1 amplifiers.

(Continued on page 138A)





News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 137A)

Carrier Telephone System

Up to 24 broad-band voice channels can be transmitted over a wide-band radio channel with a new Type 33C carrier telephone system manufactured by **Lenkurt Electric Co.,** 1129 County Rd., San Carlos, Calif.

Designed specifically for application to radio links, this frequency division multiplex system is comprised of three eight-channel groups. A single group or less can be installed initially and expanded to the maximum capacity in the future as traffic increases.

A full 24 channel Type 33C system can be used with any radio system which has adequate power levels and is capable of transmitting signals up to 135 kc. Less than 24 channels can be used with radio systems which have less usable bandwidth. The frequency division, single sideband method of operation lends itself readily to dropping or inserting channels at intermediate repeater points on the radio system.

Two frequency allocations are available; one uses frequencies up to 135 kc, and the other uses frequencies up to 150 kc. Each channel includes a broad speech band of approximately 300 to 3,400 cps with provision for out-of-band signaling at 3.9 kc.

With the exception of a group positioning panel, each eight-channel group uses identical channel equipment. Unitized construction is used throughout to conserve space and simplify production.

These and other features provide a high quality carrier system at a lower cost than otherwise possible.

Complete information about the new type 33C telephone carrier system can be obtained from the Lenkurt Electric Company.

Rectifier Unit

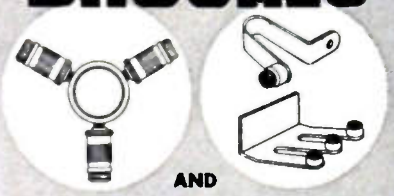
A new type of high-performance ac-to-dc regulated rectifier has been announced by **Inet, Inc.,** 8655 S. Main St., Los Angeles 3, Calif. Named the "MagniVolt," it combines ruggedness and close regulation of low voltage in a highly dependable, low cost unit.

Regulation by the "MagniVolt" is better than 1 per cent from no load to full load with ±10 per cent ac line variation. Response is faster than 0.2 second even under extreme contrast of load conditions. RMS ripple is less than 1 per cent.

(Continued on page 140A)

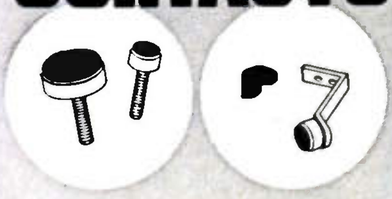
SILVER GRAPHALLOY

BRUSHES



AND

CONTACTS



. . . for applications requiring low electrical noise, low and constant contact drop, high current density and minimum wear.

GRAPHALLOY
TRADE MARK REG. U. S. PAT. OFF.

EXTENSIVELY USED IN

SELSYNS
ROTATING THERMOCOUPLE and STRAIN-GAGE CIRCUITS
ROTATING JOINTS
GUN-FIRE CONTROLS
DYNAMOTORS etc.

Wide range of grades available for standard and special applications.

Brush holders and coin silver slip rings available for use with Silver Graphalloy Brushes.

OTHER GRAPHALLOY PRODUCTS:

Oil-free self-lubricating Bushings and Bearings, Oil-free Piston Rings, Seal Rings, Thrust and Friction Washers, Pump Vanes.

Write us for Data Sheets and further information. Outline your problem and we will apply our years of accumulated experience toward its solution.

GRAPHITE METALLIZING CORPORATION
1001 NEPPERHAN AVENUE • YONKERS, N. Y.

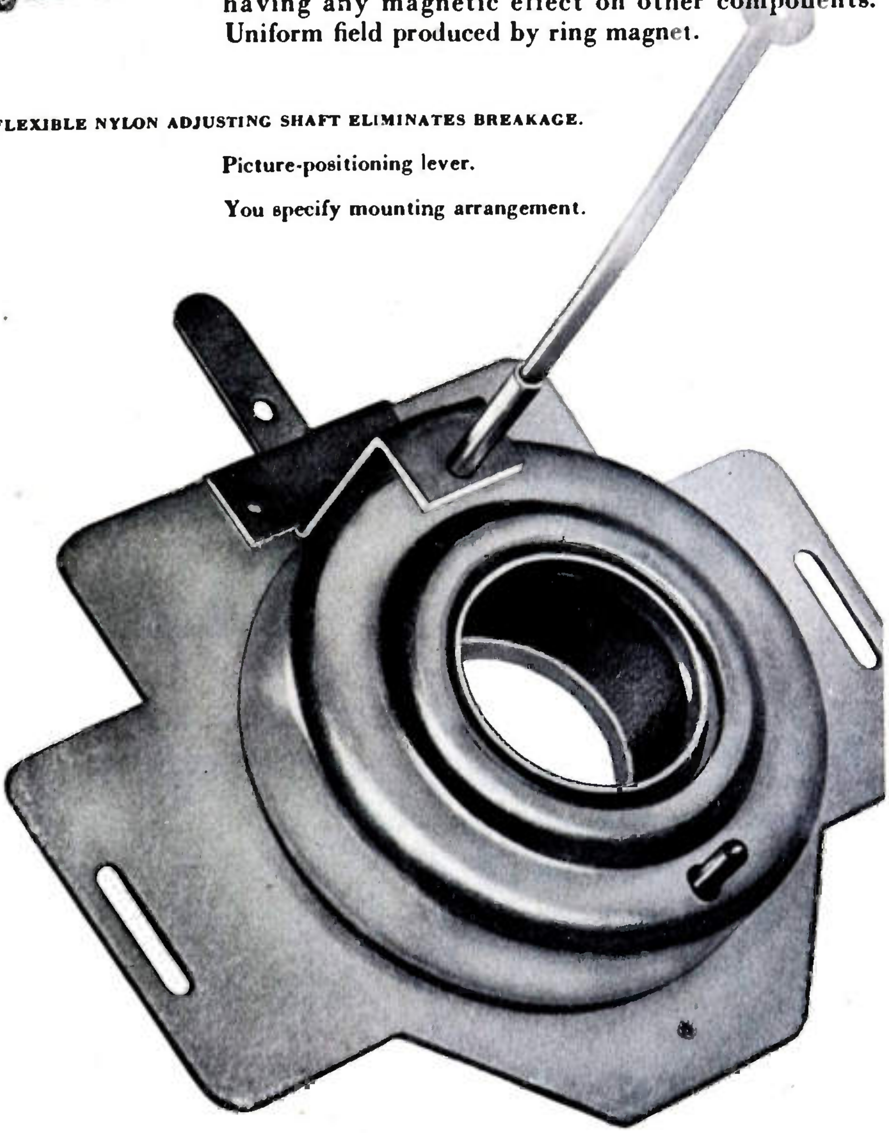
NEWLY REDESIGNED FOR 21″ and 27″ TUBES AT NO PRICE INCREASE. Also perfectly focuses all smaller tubes. Highly efficient ring magnet uses only 4-oz. Alnico P. M.

NO HARMFUL EXTERNAL FIELD. Ring magnet is completely enclosed by the external shunt (an original Heppner design). This prevents the leakage field from having any magnetic effect on other components. Uniform field produced by ring magnet.

FLEXIBLE NYLON ADJUSTING SHAFT ELIMINATES BREAKAGE.

Picture-positioning lever.

You specify mounting arrangement.



Write today for information on lowering your set costs with this Focomag.

HEPPNER
MANUFACTURING COMPANY
Round Lake, Illinois (50 Miles Northwest of Chicago)
Phone: 6-2161
SPECIALISTS IN ELECTRO-MAGNETIC DEVICES

Representatives: **John J. Kopple**, 60 E. 42nd St., New York 17, N.Y.
James C. Muggleworth, 506 Richey Ave., W., Collingswood, N. J.
Ralph Haffey, 2417 Kenwood Ave., Ft. Wayne 3, Indiana
Irv. M. Cochrane Co., 408 So. Alvarado St., Los Angeles, Calif.

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 138A)

The "MagniVolt" is designed to operate on 115 volt, single phase, 60 cps current. It is built in standard models ranging from 1.2 volts to 28.0 volts, and from 2.5 amperes to 30.0 amperes.

The firm claims that the equipment's ruggedness is achieved through a magnetic amplifier which contains no moving parts or vacuum tubes.

In addition to resistance to shock and wear, the "MagniVolt" is also insensitive to frequency and temperature changes. Because of its compact design, it is expected to be used in a wide variety of applications where space and weight are at a premium. The unit is designed for rack mounting with standard cabinets specified as an extra.

Oscillograph Tube

Radio Corp. of America, Tube Dept., Harrison, N. J., has a new, 7-inch, cathode-ray tube (7VP1) utilizing electrostatic focus and electrostatic deflection.

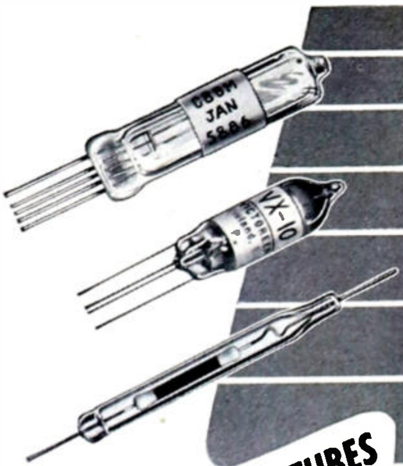
Although having the same appearance as the older type 7JP1 which it supersedes, the 7VP1 gives superior resolution of a line trace compared with the 7J-types which were designed for high brightness in a television raster. As a result of the 7VP1 gun design, the spot can be more sharply focused and its intensity is adequate for a bright oscillograph trace.

Having the same shape, dimensions, basing, and deflection factors as the 7JP1, the 7VP1 can be used in place of the 7JP1 to give superior performance in all oscilloscope equipment having a high-voltage supply up to 4,000 volts.

Recorder Booklet

A new booklet that explains the advantages of using Sanborn equipment for the study and recording of a wide variety of electrical and mechanical phenomena has just been released. It contains sixteen pages of illustrations and pertinent text that describes Sanborn Direct Recording Equipment for industrial users. Entitled, "7 Advantages of Sanborn Direct-Writing Recorders for Industrial Users," it may be obtained without obligation by writing to **Sanborn Co.,** 38 Osborne St., Cambridge, Mass.

(Continued on page 142A)



for ELECTROMETER TUBES it's **Victoreen**

Specialists in the measurement of small currents and electrostatic voltages.

An electrometer tube is a special purpose vacuum tube designed to present a minimum load to the signal voltage or current applied to the input. It has extremely small grid currents, high inter-electrode resistance and stable D.C. characteristics.

Originally developed for laboratory use, the electrometer tube has come of age with the development of atomic energy. It now finds many new applications in other fields, e.g., electrostatic voltmeters, computors, photometers, p.h. meters, etc.

5886

Electrometer Pentode—For use with high gain amplifiers having feedback to degenerate the input signal. When triode connected, it is interchangeable with the 5803 for many applications. $I_c = 2 \times 10^{-13}$.

5800

Electrometer Tetrode—The ultimate in low grid currents. G_2 is the control element. G_1 is an accelerator grid which may also serve as the plate in the inverted triode connection. $I_c = 3 \times 10^{-15}$.

5803

Electrometer Triode—For single tube circuits it is a compromise to produce higher transconductance at the expense of slightly higher grid currents. It is also used as an inverted trianode. $I_c = 5 \times 10^{-14}$.

5799

Electrometer Diode—Used as a clipper wherever high insulation is important. As an electrometer, it requires a high gain feedback amplifier circuit. $R = 10^{14}$ Ohms.

VX-10

Electrometer Switch—For switching in high impedance circuits or remote locations. $R = 10^{15}$ Ohms.

HI-MEG

Resistors—"Calibrated Insulators" for electrometer input circuits. $R = 10^{6}$ to 10^{14} Ohms.

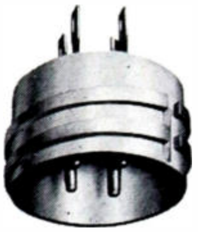
BETTER COMPONENTS MAKE BETTER INSTRUMENTS

COMPONENTS DIVISION

Victoreen Instrument

3800 PERKINS • CLEVELAND 14, O.

CANNON PLUGS *for hermetic sealed applications*



KH

RKH

HERMETIC SEALED Type RKH Plugs and KH Receptacles mate with their corresponding Cannon RK and K standard fittings. The basic construction of fused vitreous insulation around the contacts is same as GS type. Shell materials and finish are likewise similar. Various types of flange or hex-bulkhead styles may be made to order.

Refer to KH-1 Section in K Bulletin.

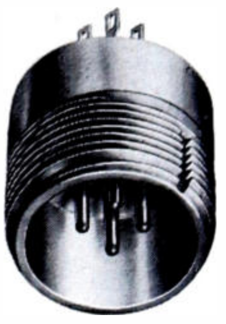
SUB-MINIATURE receptacles of the new Cannon "U" Series are used on miniature switches, relays, transformers, amplifiers, and other sealed components, requiring a true hermetic seal or a connector of sub-miniature size with performance superiority.

"U" plugs have a steel shell and "SILCAN*" insulator, cable relief and moisture resistant sleeve.

Bayonet-type locking means prevents vibration failure. Rated 1700v. d.c.; 5a. Available in 3, 6, and 12 contact arrangements with one plug style and two receptacles.

**Cannon Electric's special silicone resilient material.*

Refer to U-2 Bulletin



GS02

GS06

GS Types mate with standard AN(MIL) types. These highly successful hermetically sealed plugs (GS06) and receptacles (GS02) pioneered this field and are top quality fittings. Fused vitreous insulation provides a true hermetic seal for relays, position indicators, etc. Shells are steel, finished in cadmium plate and bleached Iridite; coupling nut on plug is natural finish Dural. Eyelet or solder pot terminals.

Built to resist thermal shock, –300°F. to +600°F., surpassing MIL Spec. GS02 Types will withstand operation temperatures 400°F. to 600°F., and pressures as high as 200 to 900 psi; specials to 7500 psi. GS Types approximate AN voltage and current ratings. Wide range of AN layouts available.

See GS-3 section in AN-8 Bulletin for details.

COMING: TYPE "DH" HERMETIC SEALED CONNECTORS SIMILAR TO PRESENT DA-15P

CANNON ELECTRIC

Since 1915

Factories in Los Angeles, Toronto, New Haven, Benton Harbor. Representatives in principal cities. Address inquiries to Cannon Electric Co., Dept. I. 377, P.O. Box 75, Lincoln Heights Station, Los Angeles 31, Calif.

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 140A)

Illuminated Panel Meter

International Instruments, Inc., P. O. Box 2954, New Haven 15, Conn., announces the production of a new 1½-inch illuminated panel meter. They are available in Model 150, Round Case and Model 153, Square Case, and have an external lamp housing.

A small compact D'Arsonval movement designed by International Instruments, permits light admitted through a window in the rear of case to pass over the movement and be diffused through a translucent plastic scale. The source of illumination is a miniature aircraft lamp mounted in a specially designed housing attached to the back of the instrument case. A lamp is supplied for 6, 14, and 28 volts.

(Continued on page 143A)

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 142A)

Miniature Attenuator

The Daven Co., Dept. A, 191 Central Ave., Newark, N. J., announces the availability of its new miniature attenuator, Series 120, 1 3/8 inches in diameter ×1 29/32 inches deep. This unit was developed primarily for government and commercial applications requiring a smaller step-type attenuator. Its reduced size and weight make it particularly suitable for use in portable equipment as well as stationary equipment where space is at a premium.

This miniature attenuator is available in 20 steps having a ladder or potentiometer network. All standard decibel steps and various impedances up to 500,000 ohms are available.

The resistor accuracy is ± 5 per cent and the power dissipation is 0.6 watt.

(Continued on page 144A)

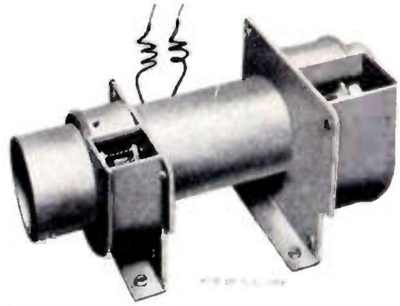
News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 143A)

Motor Blowers

Now available from EMC and Cyclohm Divisions of **Howard Industries, Inc.,** 1760 State St., Racine, Wisc., are two fractional-hp motor blowers. Currently being used for cooling aircraft electronic equipment and micro-wave relay equipment, these motor blowers are manufactured in a wide range of motor types and hp ratings as well as blower heads.



Model 100 dc motor is rated 1/50 hp hp at $27\frac{1}{2}$ volts. Designed for aircraft, this model operates at 4,500 rpm at sea level, 6,500 rpm at 50,000 feet with a relatively constant air delivery of 40 cfm. Ambient temperature range is −65°C to +70°C. Approved and tested for aircraft applications.

Model 2914, an induction motor rated from 1/100 to 1/15 hp, currently is used for micro-wave relay equipment and other electronic applications. This motor operates at 1,650 rpm with an input voltage of 90–120 v. Motor is self-ventilated and is available with ball or sleeve bearings. Air delivery of double blower is 37 cfm each head at 95 volts ac.

Resistors

Gorman Mfg. Corp., 2240 Sepulveda Blvd., Los Angeles, Calif., has a new line of "encapsulated" Tru-Mite wire-wound precision resistors. The component features extremely low thermal expansion, rugged construction, and the ability to withstand salt water immersion and extreme humidity. The resistors can be supplied to tolerances of 1.0, 0.50, 0.25, and 0.10, per cent and operate in a temperature range of from −65° to +125°C. On special order they can be had up to +150°C.

These resistors are supplied to meet MIL specifications, and good production schedules are in effect.

(Continued on page 146A)

COMMUNICATIONS EQUIPMENT CO.

PULSE TRANSFORMERS

0-166173: Video, Ratio = 50:900 Ohms 10KC—2MC $12.50
G.E.K.-2745 ..... $39.50
G.E.K.-2744-A. 11.5 KV High voltage, 3.2 KV Low voltage @ 200 KW oper. (270 KW max.) 1 microsec. or 1/2 microsec. @ 600 PPS $39.50
W.E. D169271 Hi Volt input pulse Transformer $27.50
G.E. K2450A. Will receive 13KV, 4 micro-second pulse on pri. secondary delivers 14KV. Peak power out 100 KW G. E. $34.50
G. E. K2748A. Pulse Input line to magnetron $36.00
Ray UX 7896—Pulse Output Pri. 5v, sec. 41v $7.50
Ray UX 8442—Pulse Inversion—40v + 40v $7.50
Ray UX 7361 ..... $5.00
PHILCO 352-7250, 352-7251, 352-7287
UTAH 9332, 9278, 9341,
RAYTHEON: UX8693, UX5986 ..... $5 ea.
W.E.: 0-166310, 0-16638, KS 9800, KS9948

PULSE EQUIPMENT

APQ-13 PULSE MODULATOR. Pulse Width .5 to 1.1 Micro Sec. Rep. rate 624 to 1348 Pps. Pk. Pwr. out 35 KW Energy 0.018 Joules $49.00

TPS-3 PULSE MODULATOR. Pk. power 50 amp. 24 KV (1200 KW pk); pulse rate 200 PPS, 1.5 microsec. pulse line impedance 50 ohms. Circuit series charging version of DC Resonance type. Uses two 705-A's as rectifiers. 115 v. 400 cycle input. New with all tubes $49.50

DELAY LINES

D-168184: 0.5 microsec. up to 2000 PPS 1800 ohm term $4.00
D-170499: 25/.50/.75 microsec. 8 KV 50 ohms imp. $16.50
D-165997: 1¼ microsec. $7.50
RCA 255686-502. 2.2μ sec. 1400 ohms $2.00

PULSE NETWORKS

G.E. 36E3-5-2000-50P2T. 6KV "E" circuit, 3 sections .5 microsecond, 2000 PPS 50 ohms impedance $6.50
15A-1-400-50: 15 KV, "A" CKT, 1 microsec. 400 PPS 50 ohms imp. $37.50
G.E. 3E (3-84-810) 8-2.24-405) 50P4T; 3KV "E" CKT Dual Unit: Unit 1, 3 sections, 0.84 Microsec. 810 PPS, 50 ohms imp.; Unit 2, 8 Sections, 2.24 microsec. 405 PPS. 50 ohms imp. $6.50
7-5E3-1-200-67P. 7.5 KV "E" Circuit, 1 microsec 200 PPS, 67 ohms impedance 3 sections $7.50
7.5E4-16-60. 67P. 7.5 KV. "E" Circuit, 4 sections 16 microsec. 60 PPS, 67 ohms impedance $15.00
7.5E3-3-200-6FT. 7.5 KV, "E" Circuit, 3 microsec. 200 PPS, 6 ohms imp. 3 sections $12.50
2755: 10KV, 2.2usec., 375 PPS, 50 ohms imp. $27.50
2754: 10KV, 0.85usec., 750 PPS, 50 ohms imp. $27.50

400 CYCLE TRANSFORMERS

(All Primaries 115V, 400 Cycles)

Stock	Ratings	Price
352-7039	640VCT @ 250MA, 6.3V/.9A, 6.3V/6A, 5V 6A	$5.49
702724	9800 8600 @ 32MA	8.95
12033	4540V 250MA	17.50
KS9584	5000V 290MA, 5V 10A	22.50
52J652	13,500V/3.5MA	14.65
KS9607	734VCT .177A, 1710VCT .177A	6.79
352-7273	700VCT 350MA, 6.3V 0.9A, 6.3V 2.5A 6.3V .06A, 5V/CA	6.95
352-7070	2X2.5V/2.5A (2KV TEST) 6.3V/2.25A, 1200/1000/75 OV @ .035A	7.45
352-7196	1140V 1.25MA, 2.5V/1.75A, 2.5V 1.75A —5KV Test	3.95
352-7176	320VCT 50MA, 4.5V 3A, 6.3VCT 20A, 2X6.3VCT/6A	4.75
RA6400-1	2.5V/1.75A, 6.3V/2A—5KV Test	2.39
901692	13V 9A	2.49
901699-501	2.77V @ 4.25A	3.45
901698-501	900V 75MA, 100V/.01A	4.29
UX8855C	900VCT .067A, 5V 3A	3.79
RA6405-1	800VCT 65MA, 5VCT 3A	3.69
T-48852	700VCT 80MA, 5V 3A, 6V 1.75A	4.25
352-7098	2500V 6MA, 300 VCT, 135MA	5.95
KS 9336	1100V 50MA TAPPED 625V 2.5V/5A	3.95
M-7474319	6.3V 2.7A, 6.3V .66A, 6.3VCT 21A	4.25
KS 8984	27V 1.3A, 6.3 2.9A, 1.25V .02A	2.95
52C080	526VCT 50MA, 6.3VCT/2A, 5VCT/2A	3.75
32332	400VCT 35MA, 6.4V 2.5A, 6.4V/.15A	3.85
68G631	1150-0-1150V	2.75
80G198	6VCT .00006 KVA	1.75
302433A	6.3V 9.1A, 6.3VCT/6.5A, 2.5V/3.5A, 2.5V 3.5A	4.85
KS 9445	592VCT 118MA, 6.3V 8.1A, 5V/2A	5.39
KS 9685	6.4 7.5A, 6.4V 3.8A, 6.4V 2.5A ALL CT	4.79
70G30G1	800VCT 36MA	2.65
M-7474318	2100V/.027A	4.95
95-G-45	2000V .002A, 465V .6A, 44V/10A, 6.3V 23.5A, 6.3V/1.8A, 5V/9A, 2X2.5V/1.75	17.95
TRANSTAT	IN: 115V, 400 CY. OUT: 75-120V, 6.0 Amps.	12.95

MICROWAVE COMPONENTS

S BAND—3" x 1½" WAVEGUIDE

DIRECTIONAL COUPLER. Broadband type "N" Coupling, 20 db. with std. flanges. Navy 3CABV 47AAN-2. As shown $37.50
WAVEMETER, 2700-3400 MC, Reaction type with counter Dial—Mfg., W.E. $92.50
REACTION WAVEMETER, Mfg. G.E. 3000-3700 MC, Mic Head $125.00
LHTR. LIGHTHOUSE ASSEMBLY. Part of RT39 APG 5 & APG 15. Receiver and Trans. Cavities w/assoc. Tr. Cavity and Type N CPLG. To Recvr. Uses 2C40, 2C43, 1B27. Tunable APX 2400-2700 MCS. Silver Plated $49.50
BEACON LIGHTHOUSE cavity 10 cm. Mfg. Bernard Rice, each $47.50
MAGNETRON TO WAVEGUIDE Coupler with 721A Duplexer Cavity, gold plated $45.00
RT-39 APG-5 10 cm. lighthouse RF head c/o Xmtr.-Recvr-TR, cavity compl. recvr. & 30 MC IF strip using 60K5 (2C40, 2C43, 1B27 lineup) w/Tubes.
721A TR BOX complete with tube and tuning plungers $12.50
McNALLY KLYSTRON CAVITIES for 707B or 2K28 ..... $4.00
F 29 SPR-2 FILTERS, type "N" input and output $12.50
WAVEGUIDE TO ⅞" RIGID COAX "DOOR-KNOB" ADAPTER CHOKE FLANGE, SILVER PLATED BROAD BAND $32.50
AS14A AP-10 CM Pick up Dipole with "N" Cables $4.50
OAJ ECHO BOX, 10 CM TUNABLE $22.50
HOMERELL-TO-TYPE "N" Male Adapters. W.E. 2D167284 ..... $2.75
I. F. AMP. STRIP: 30 MC, 120 d.b. gain, 2 MC Bandwidth, uses 6AC7's—with video detector. Less tubes $24.50
POLYROD ANTENNA, AS31/APN-7 in Lucite Ball, Type "N" feed $22.50
ANTENNA, AT49A/APR: Broadband Conical, 300-3300 MC Type "N" Feed $12.50
"E" or "H" PLANE BENDS. 90 Deg. less flanges $7.50

⅞" RIGID COAX—⅜" I.C.

RIGHT ANGLE BEND, with flexible coax output pickup loop $8.00
SHORT RIGHT ANGLE BEND, with pressurizing nipple $3.00
RIGID COAX to flex coax connector $3.50
STUB-SUPPORTED RIGID COAX, gold plated 5' lengths. Per length $5.00
RT. ANGLES for above $2.50
RT. ANGLE BEND 15" L. OA $3.50
FLEXIBLE SECTION. 15" L. Male to female $4.25
⅞" RIGID COAX. BULKHEAD FEED-THRU $14.00

IMMEDIATE DELIVERY -- FULLY GUARANTEED

X BAND—1" x ½" WAVEGUIDE

1" x ½" waveguide in 5' lengths, UG 39 flange to UG40 cover ..... per length $7.50
Rotating joints supplied either with or without deck mounting. With UG40 flanges ..... each, $17.50
Bulkhead Feed-thru Assembly $15.00
Pressure Gauge Section 15 lb. gauge and press nipple $10.00
Pressure Gauge, 15 lbs. $2.50
Dual Oscillator, Mount. (Back to back) with crystal mount, tunable termination attenuating slugs $18.50
Directional Coupler, UG-40/U Take off 20 db. $17.50
TR-ATR Duplexor section for above $8.50
723AB Mixer—Beacon dual Osc. Mnt. w/xtal holder $12.00
Waveguide Section 12" long choke to cover 45 deg. twist & 2½" radius 90 deg. bend $4.50
Twist 90 deg. 5" choke to cover w/pres nipple $6.50
Waveguide Section 2½ ft. long silver plated with choke flange $5.75
Rotary joint choke to choke with deck mounting $17.50
3 cm. mitered elbow "E" plane $12.00
UG 39 Flanges ..... $ .85
90 degree elbows, "E" or "H" plane 2½" radius $12.50
90 degree twist 6" long $8.00
45 degree twist $8.00
APS-4 Under Belly Assembly, less tubes $375.00

1¼" x ⅝" WAVEGUIDE

X Band Wave GD 1¼" x ⅝" O.D. 1/16" wall aluminum ..... per ft. 75c
Slug Tuner Attenuator W.E. guide, Gold plated $6.50
Bi-Directional Coupler, Type "N" Takeoff 25 db. coupling $27.95

POWER TRANSFORMERS

Comb. Transformers—115V/50-60 cps Input

CTJ5-2-600VCT/.2A, 5V/CA $5.95
CT-15A 550VCT .085A 6.3V/.6A, 6.3V/1.8A 2.85
CT-164 4200V,.002A/12KV Test, 5VCT/3A/12KV Test, 6.3V 0.6A 5400 V Test 12.95
CT-341 1050V/10MA,—625V @ 5 MA, 26V @ 4.5A 2x2.5V/3A, 6.3V @ 3A 16.95

CT-825	360VCT	.340A	6.3VCT/3.6, 6.3VCT 3A	3.95
CT-626	1500V	.160A	2.5 12, 30/.100	9.95
CT-071	110V	.200A	33/.200, 5V/10, 2.5/10	4.95
CT-367	580VCT	.050A	5VCT/3A	2.25
CT-99A	2x110VCT	.010A	6.3/1A, 2.5VCT/7A.	3.25
CT-403	350VCT	.026A	5V/3A	2.75
CT-931	585VCT	.086A	5V 3A, 6.3V/6A	4.25
CT-610	1250	.002A	2.5V 2.1A, 2.5V/1.75A	4.95
CT-456	390VCT	80MA	6.3V 1.3A, 5V/3A	3.45
CT-160	800VCT	100MA	6.3V 1.2A, 5V/3A.	4.95
CT-931	585VCT	86MA	5V 3A, 6.3V/6A	4.95
CT-442	525VCT	75MA	5V 2A, 10VCT/2A, 50V 200MA	3.85

CT-720 550-0-550V/250MA, 6.3V 1.8A 8.95
CT-43A 600-0-600V/.08A, 2.5VCT 6A, 6.3VCT/1A 6.49
CT7-501 650VCT 200MA, 6.3V 5A 6.49
CT-444 230-0-230V/.085A, 5V 3A, 6V/2.5A 3.49

Filament Transformers—115V 50-60 cps input

Item	Rating	Each
FT-674	8.1V/1.5A	$ 1.10
FT-157	1V/16A,2.5V/1.75A	2.95
FT-101	6V/.25A	.79
FT-924	5.25V/21A, 2x7.75V/6.5A	11.95
FT-824	2x26V/2.5A, 16V/1A, 7.2V/7A, 6.4V/10A, 6.4V/2A	8.95
FT-463	6.3VCT 1A, 5VCT 3A, 5VCT/3A	5.49
FT-55-2	7.2V 21.5A, 6.5V/6.85A, 5V/6A, 5V/3A	8.95
FT-986	16V @ 4.5A or 12V @ 4.5A	3.75
FT-38A	6.3/2.5A, 2x2.5V/7A	4.19
FT-A27	2.5V/2.5A, 7V/7A, TAP 2.5V/2.5A, 16KV TEST	18.95
FT-608	6.3V 3A/750V Test	1.79
FT-873	4.5V/.5A, 7V/7A	2.19
FT-899	2x5V @ 5A, 29KV Test	24.50

Plate Trans.—115V, 60 cps

Item	Rating	Price
PT-446	18.5V3.5A	$4.59
PT-699	300/150V/.05A, 300/150V .05A	2.79
PT-302	120-0-120V/350MA	4.69
PT-671	62V/3.5A	7.95

Special Fil. Transformers—60 cps

Item	Pri. Volts	Secondaries	Price
STF-370	220/440	3x2.5V 5A, 3KV Test 2.5V 15A	$ 6.95
STF-11A	220V	2x40V/.05A, 2x5V/6A 12.6V 1A	4.49
STF-608	220V	24V 0.6A, 5V/3A, 6.3V/1A, 6.3V/1A	3.45
STF-968	230V	2.5V 6.5A	3.50
STF-631	230V	2x5V/27A, 2x5V/9A	17.59

THERMISTORS VARISTORS

D167018	$1.50	D171812	$1.50
D167332	1.50	D172155	1.50
D167613	1.50	D167176	1.50
D166228	1.50	D168687	1.50
D164699	2.50	D167208E, D171858	1.50
D163903	1.95	308A, 3A, 27-B	1.50
D166792	2.15	D168403	2.15

DYNAMOTORS

Type	Input Volts	Input Amps	Output Volts	Output Amps	Radio Set
PE86	28	1.25	250	.060	RC 36
DM416	14	6.2	330	.170	RU 19
DM33A	28	7	540	.250	BC 456
PE101C	13/26	12.6 6.3	400 800	.135 .020	SCR 515
BO AR 93	28	3.25	375	.150	
23350	27	1.75	285	.075	APN-1
ZA0515	12/24	4/2	500	.050	
B-19 pack	12	9.4	275 500	.110 .050	MARK II
D104	12		225 440	.100 .200	
DA-3A	28	10	300 150 14.5	.060 .010 .5	SCR 522
5053	28	1.4	250	.060	APN-1
PE73CM	28	19	1000	.350	BC 375
CW21AAX	13 26	12.6 6.3	400 800 9	.135 .020 1.12	
PE94	28	10	300 150 14.5	.200 .101 .5	SCR 522

INVERTERS

PE-218-H: Input: 25 28 vdc, 92 amp. Output: 115 v. 350 500 cy 1500 volt-amperes, New $44.50
PE-206: Input: 28vdc, 38 amps. Output: 80 v 800-cy. 500 volt-amps. Dim: 13" × 5½". New $22.50
LELAND No. 10536: IN: 28 VDC, 12A. OUT: 115V, 115VA, 400 CY 3 PHASE, EXC. COND. $70.00

MAGNETRONS

Tube	Tube	Tube
2J27	2J49	718DY
2J31	2J56	720BY
2J21	2J61	725-A
2J22	700	730-A
2J26	706	QK 62
2J32	2J62	QK 61
2J38	3131	QK 60
2J39	5J30	

MAIL ORDERS PROMPTLY FILLED. ALL PRICES F.O.B. NEW YORK CITY. SEND M.O. OR CHECK. ONLY SHIPPING SENT C.O.D. RATED CONCERNS SEND P.O. ALL MDSE. SUBJECT TO PRIOR SALE, AND PRICES SUBJECT TO CHANGE WITHOUT NOTICE. PARCELS IN EXCESS OF 20 POUNDS WILL BE SHIPPED VIA CHEAPEST TRUCK OR RAILEX.

131 Liberty St., New York 7, N. Y. Dept I-12 Chas. Rosen Phone: Digby 9-4124

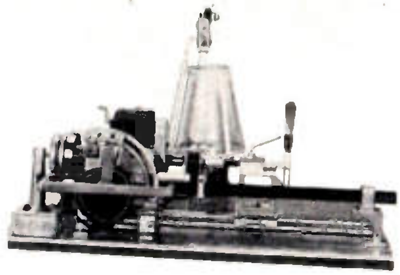
News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 144A)

Bobbin Winder

A new calibrated 2-inch economy box-type cam which provides any winding traverse from 0 to 2 inches is the outstanding feature on the new Model 119-A bobbin winder offered by **George Stevens Mfg. Co., Inc.,** Pulaski Rd., at Peterson, Chicago 30, Ill. Calibrations allow instant adjustment of winding traverse to the desired winding width. An infinite range between 0 and 2 inches is available for any winding needed. There are no cams to change when changing winding widths.



Model 119-A winds all types of random-wound bobbin coils, solenoids, repeater coils, and resistors up to 2 inches wide and up to 3 inches outside diameter. One Model 92-6 De-Reeler tension is furnished for handling wire gauges 24 to 44 and spools up to 6 inches in diameter. Model 92-6D tension may be specified for wire gauges 18 to 24. Winding speed is up to 7,000 rpm. One winding setup is furnished. Compound idlers are available for additional gear ratios.

Veeder-Root predetermined counter is used for registering number of turns wound up to 99,999 in conjunction with the extra economy precision automatic stop feature. This stop eliminates the main cause of coil rejection by winding accurately to the specified number of turns and then stopping automatically.

Printed Circuits Brochure

Printed circuits, their function, fabrication, and application, are comprehensively outlined and described in a new 8-page brochure prepared by **Photocircuits Corp.,** Glen Cove, L. I., N. Y.

Lower wiring costs, reduced assembly time, circuit reproducibility, improved reliability, and miniaturization are the advantages advanced by this modern method of "wiring"—with applications extending to microwave plumbing, radio, and television chassis, IF strips, antenna filters, terminal boards, wiping switches, flush commutators, and the like.

The brochure includes information on methods of application, materials, electrical characteristics with tables of values, components such as capacitors, resistors, tube sockets, switches, and so on. Assembly methods are described and costs are suggested.

(Continued on page 148A)

CONTINENTAL

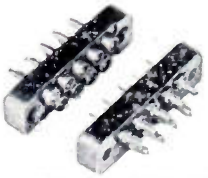
MINIATURE

Power CONNECTORS

SERIES 14

RACK TO PANEL TYPE

7-9-10-15 CONTACTS



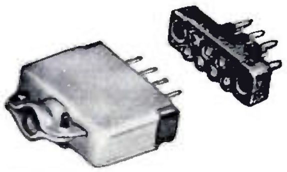
SERIES 14 FOR #14 AWG WIRE

These precision power connectors were developed to employ the same electrical and mechanical properties as our series 16 but were reduced by 25% in height with a larger solder cup for #14 AWG wire.

The disengagement force is also considerably reduced.

CABLE TO PANEL TYPE

7-9-10-15 CONTACTS



SPECIFICATIONS

MAXIMUM WIRE SIZE....#14 AWG

Creepage between contacts 7/32" MIN.

Air Space between contacts 3/32" MIN.

Breakdown voltage between contacts wih connector engaged at sea level, normal conditions......5500 V.R.M.S.

CABLE TO PANEL TYPE

7-9-10-15 CONTACTS

ALUMINUM HOOD AND CABLE CLAMP IS AVAILABLE FOR ALL TYPES DESIGNATED BY ADDING "H" TO TYPE DESIRED, i.e.: 7-14 PH, Plug with Hood, 7-14 SH, Receptacle with Hood, 7-14 H. Hood only.

CATALOG WITH COMPLETE DETAILS — AVAILABLE ON REQUEST. TO DEPT. E-12-P

ELECTRONIC DeJUR U.S.A. INSTRUMENTS

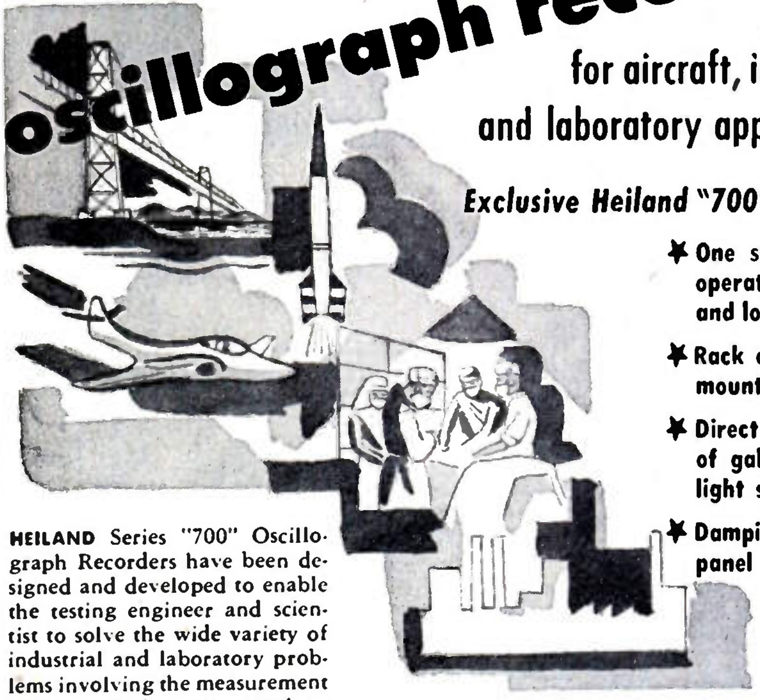
DeJUR AMSCO CORPORATION

45-01 NORTHERN BOULEVARD, L. I. C. 1, N. Y.

Heiland DENVER

oscillograph recorders

for aircraft, industrial and laboratory applications



Exclusive Heiland "700" Features

- One surface operation, control and loading
- Rack or table mounting
- Direct monitoring of galvanometer light spots
- Damping resistor panel

HEILAND Series "700" Oscillograph Recorders have been designed and developed to enable the testing engineer and scientist to solve the wide variety of industrial and laboratory problems involving the measurement of physical phenomena such as strains, stresses, vibrations, pressures, temperatures, accelerations, impact, etc. Accurate and dependable oscillograph records permit the study of various recorded data comparatively, individually and collectively making for better product design and performance.

HEILAND Series "700" Oscillograph Recorders are being widely used today for the analysis of static and dynamic strains, vibrations, etc. in aircraft and guided missile flight testing; structural tests; performance tests; riding quality evaluation; voltage and current measurements; medical research; general industrial problem analysis.

A708 24-channel Oscillograph Recorders

Other "700" models up to 60 channels are available. Write today for a complete catalog of Heiland "700" oscillograph recorders.

The Heiland Research Corporation

130 East Fifth Avenue, Denver 9, Calarado

dependable instruments

Heiland DENVER

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 146A)

RF Tuner Plate

A high frequency contact plate, providing precision tuning of five rf channels, is in production at **Mycalex Corp. of America,** Clifton Blvd., Clifton, N. J. Although the circuits tuned operate at high frequency, permanently accurate tuning is attained.

The part described is of MYCALEX 410 glass-bonded mica dielectric, injection-molded to close tolerances and incorporating a series of coin silver contacts, stainless steel distributing rings, and an integral center hub.

The use of MYCALEX insulation results in extremely low dielectric loss, long-term dimensional stability, and permits precision molding with resultant dimensional uniformity of all pieces. This process also reduces the unit cost considerably as compared to other materials and methods of fabrication. In this application moisture is also an important factor. MYCALEX, being non-hygroscopic, solves this problem completely.

Meter Calibrator

Bruck Industries, Inc., Syosset, L. I., N. Y., has developed a new instrument designed specifically for the rapid calibration of dc volt and milliammeters, and for testing and adjustment of dc type analog computers.

The calibrator is completely self contained. It consists of 4 major components: two regulated power supplies, a normalizer, and the calibrator proper. The normalizer is referenced to a built in standard cell. The output can be preset on 4 decade dials, and is maintained automatically constant and accurate to within 0.1 per cent over 90 per cent of its range, independent of load, input voltage or ambient conditions.

Both the normalizer and the calibrator are controlled and compensated by electro mechanical transducers in conjunction with high gain 60 cps amplifiers, and all manual operations such as checking of meters, zeroing of galvanometers or adjustment of rheostats are completely eliminated. Prices and technical literature available upon request.

(Continued on page 150A)

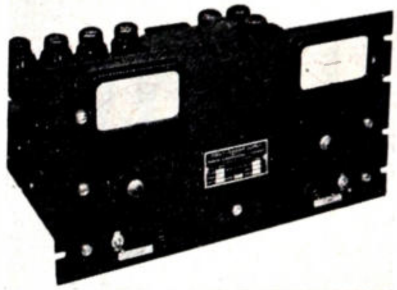
PROFESSIONAL CARDS

News—New Products

(Continued from page 148A)

Power Supply

The Perkin Engineering Corp., 345 Kansas St., El Segundo, Calif., has a new Model No. M-900 regulated dc power supply to give an output of 300 volts, and is automatically and electronically regulated to within 0.15 per cent at any current load from 0 to 500 ma. Inherent ripple is below 0.004 RMS volts. The unit is also equipped with a time-delay relay to withhold the dc output for a period of 40 seconds after initial energization to provide for thermal stabilization and for the protection, during their warm-up period, of circuits powered by the supply.



A dc bias output of minus 105 volts is also provided. This voltage is regulated to within 1 per cent at any load from 0 to 5. The entire unit is treated for resistance to extremes of humidity and its pre-set voltage calibration obviates the necessity for time-consuming adjustment in the hands of semi-skilled operators.

Model M-900 is also available in a special series to provide for other voltage or current requirements.

INDEX AND DISPLAY ADVERTISERS

DISPLAY ADVERTISERS

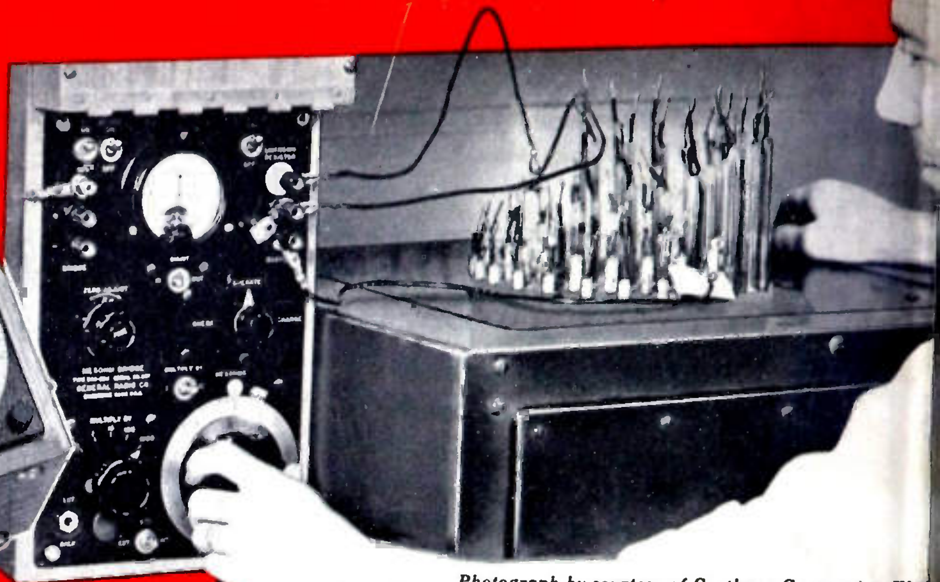
(Continued on page 152A)

DISPLAY ADVERTISERS

(Continued from page 151A)

Resistance Tests

0.1 megohm to 1,000,000 megohms



Photograph by courtesy of Synthane Corporation. With aid of Type 544 Megohm Bridge, engineer determines resistance to leakage across and through insulating materials, under constant temperature and humidity conditions.

The GR Type 544-B Megohm Bridge is an accurate, simple-to-operate, portable test instrument for measuring resistances in the megohm ranges. Among its many uses are the testing of cartridge type resistors — insulation resistance measurements on electrical machinery, generators, motors, and transformers — insulation study of single conductors, cables, and long sections of high voltage cables — measurements on capacitors and slabs of insulating materials.

The instrument is basically a Wheatstone bridge with special adaptations for insulation resistance testing.

Type 544-BA Megohm Bridge with A-C Power Supply $340

Type 544-BB Megohm Bridge with Batteries $250

Sensitivity: A very sensitive vacuum-tube voltmeter, used as the null detector, permits measurement of resistances as high as 1,000,000 megohms. Resistance values are read directly from a dial and five-position multiplier switch for rapid and convenient measurements. The scale is approximately logarithmic with an effective length of 38 inches.

Accuracy: ±3% from 0.1 megohm to 100 megohms, ±4% from 100 to 10,000 megohms. Above 10,000 megohms, accuracy is essentially that with which scale can be read.

Simplicity of Operation: The CHECK position is for adjusting galvanometer zero. The OPERATE position is for measurements. In the CHARGE position either 100 or 500 volts is supplied directly to the unknown for any desired length of time.

Power Supply: The bridge operates directly from a completely self-contained a-c or d-c power supply. A-c unit delivers d-c test voltages of 500, the ASTM standard, or 100 volts for testing insulation of low dielectric strength. This voltage is held constant regardless of the value of the unknown. Battery power supplies 90 volts for the test voltage. All high-voltage terminals are insulated for operators' protection.

Guard Terminal: This third terminal is very useful when three terminal networks such as multi-wire cables and multi-circuit transformers are being measured.

Accessories Supplied: Seven-foot line cord with a-c supply, spare fuses, test probe and spare neon ballast tube.

Dimensions: 8½" (width) x 22½" (length) x 8" (height) overall.

Net Weight: 26⅜ pounds with a-c supply; 29½ pounds with batteries.

GENERAL RADIO Company

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Admittance Meters ☆ Coaxial Elements ☆ Decade Capacitors
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Frequency Meters ☆ Frequency Standards ☆ Geiger Counters
Impedance Bridges ☆ Modulation Meters ☆ Oscillators
Variacs ☆ Light Meters ☆ Megohmmeters ☆ Motor Controls
Noise Meters ☆ Null Detectors ☆ Precision Capacitors
Pulse Generators ☆ Signal Generators ☆ Vibration Meters ☆ Stroboscopes ☆ Wave Filters
U-H-F Measuring Equipment ☆ V-T Voltmeters ☆ Wave Analyzers ☆ Polariscopes