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.

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

THE ULTIMATE IN QUALITY. . .

UTC Linear Standard Audio Transformers represent the closest approach to the ideal component from the standpoint of uniform frequency response, low wave form distortion, high efficiency, thorough shielding and utmost dependability.

UTC Linear Standard Transformers feature . . .

- True Num Balancing Coil Structure . . . maximum neutralization of stray fields.
- Balanced Variable Impedance Line . . . permits highest fidelity on every tap of a universal unit without reflections or transverse coupling.
- Reversible Mounting . . . permits above chassis or sub-chassis wiring.
- Alloy Shields . . . maximum shielding from inductive pickup.
- Hiper-Imp-Ng . . . a stable, high permeability nickel-iron core material.
- Semi-Teroidal Multiple Coil Structure . . . minimum distributed capacity and leakage resistance.
- Precision Winding . . . accuracy of winding .1%, perfect balance of inductance and capacity, exact impedance reflection.
- High Fidelity . . . UTC Linear Standard Transformers are the only audio units with a guaranteed uniform response of ±1 DB from 20,20,000 cycles.

TYPICAL LS LOW LEVEL TRANSFORMERS

<table>
<thead>
<tr>
<th>Type No.</th>
<th>Application</th>
<th>Primary Impedance</th>
<th>Secondary Impedance</th>
<th>+1 dB From</th>
<th>Max. Level</th>
<th>Max. Unbalanced DC</th>
<th>List Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>LS-10</td>
<td>Low-impedance mike, pickup, or multiple line to grid</td>
<td>50. 125, 250, 500, 1000/600 ohms</td>
<td>20-20,000</td>
<td>+15 DB</td>
<td>-14 DB</td>
<td>5 MA</td>
<td>$25.00</td>
</tr>
<tr>
<td>LS-10X</td>
<td>As Above</td>
<td>At above</td>
<td>50,000 ohms</td>
<td>20-20,000</td>
<td>+11 DB</td>
<td>-12 DB</td>
<td>5 MA</td>
</tr>
<tr>
<td>LS-12</td>
<td>Low-impedance mike, pickup, or multiple line to push pull grids</td>
<td>50, 125, 250, 500, 600 ohms</td>
<td>20-20,000</td>
<td>+15 DB</td>
<td>-12 DB</td>
<td>5 MA</td>
<td>$20.00</td>
</tr>
<tr>
<td>LS-12X</td>
<td>As above</td>
<td>At above</td>
<td>80,000 ohms overall, in two sections</td>
<td>20-20,000</td>
<td>+14 DB</td>
<td>-12 DB</td>
<td>5 MA</td>
</tr>
<tr>
<td>LS-26</td>
<td>Bridging line to single or push pull grids</td>
<td>5,000 ohms</td>
<td>20-20,000</td>
<td>+20 DB</td>
<td>-14 DB</td>
<td>0 MA</td>
<td></td>
</tr>
<tr>
<td>LS-19</td>
<td>Single plate to push pull grids</td>
<td>like 234 4LA, 200A. Split secondary.</td>
<td>20-20,000</td>
<td>+17 DB</td>
<td>-16 DB</td>
<td>0 MA</td>
<td></td>
</tr>
<tr>
<td>LS-21</td>
<td>Single plate to push pull grids, split primary and secondary</td>
<td>20,000 ohms</td>
<td>20-20,000</td>
<td>+11 DB</td>
<td>-12 DB</td>
<td>0 MA</td>
<td></td>
</tr>
<tr>
<td>LS-22</td>
<td>Push pull plates to push pull grids, split primary and secondary</td>
<td>20,000 ohms</td>
<td>20-20,000</td>
<td>+17 DB</td>
<td>-14 DB</td>
<td>0 MA</td>
<td></td>
</tr>
<tr>
<td>LS-30</td>
<td>Mixed Impedance mike, pickup or multi-line to multi-line</td>
<td>50, 125, 250, 500, 600, 1000 ohms</td>
<td>20-20,000</td>
<td>+17 DB</td>
<td>-14 DB</td>
<td>5 MA</td>
<td></td>
</tr>
<tr>
<td>LS-30X</td>
<td>As Above</td>
<td>As above</td>
<td>50,000 ohms</td>
<td>20-20,000</td>
<td>+15 DB</td>
<td>-12 DB</td>
<td>5 MA</td>
</tr>
<tr>
<td>LS-27</td>
<td>Single plate to multiple grids</td>
<td>150,000 ohms</td>
<td>20-20,000</td>
<td>+17 DB</td>
<td>-14 DB</td>
<td>0 MA</td>
<td></td>
</tr>
<tr>
<td>LS-50</td>
<td>Single plate to multiple grids</td>
<td>150,000 ohms</td>
<td>20-20,000</td>
<td>+17 DB</td>
<td>-14 DB</td>
<td>0 MA</td>
<td></td>
</tr>
<tr>
<td>LS-51</td>
<td>Push pull low level plates to multiple lines</td>
<td>50, 125, 250, 500, 600 ohms</td>
<td>20-20,000</td>
<td>+20 DB</td>
<td>-17 DB</td>
<td>3 MA</td>
<td></td>
</tr>
<tr>
<td>LS-141</td>
<td>Three sets of Balanced winding for hybrid sets</td>
<td>500,000 ohms</td>
<td>30-12,000</td>
<td>+10 DB</td>
<td>-14 DB</td>
<td>0 MA</td>
<td></td>
</tr>
</tbody>
</table>

TYPICAL LS OUTPUT TRANSFORMERS

<table>
<thead>
<tr>
<th>Type No.</th>
<th>Primary will match following typical tubes</th>
<th>Primary Impedance</th>
<th>Secondary Impedance</th>
<th>+1 dB From</th>
<th>Max. Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>LS-32</td>
<td>25A A prime, 250, 650, 42 or 25A A prime</td>
<td>8000 ohms</td>
<td>50, 332, 256, 700, 125, 56, 38, 20, 15, 10, 7.5, 5, 1.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LS-55</td>
<td>Push pull 26A's, 6A5, 300A, 120A. 75A x 2, 6564</td>
<td>5000 ohms plate to plate and 3000 ohms plate to plate</td>
<td>50, 332, 256, 700, 125, 56, 38, 20, 15, 10, 7.5, 5, 1.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LS-57</td>
<td>Same as above</td>
<td>5000 ohms plate to plate and 3000 ohms plate to plate</td>
<td>50, 332, 256, 700, 125, 56, 38, 20, 15, 10, 7.5, 5, 1.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LS-58</td>
<td>Push pull parallel 26A's, 6A5, 300A, 120A. 26A x 2, 6564</td>
<td>2500 ohms plate to plate and 1500 ohms plate to plate</td>
<td>50, 332, 256, 700, 125, 56, 38, 20, 15, 10, 7.5, 5, 1.2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>LS-61</td>
<td>Push pull 6AS's self bias</td>
<td>8000 ohms plate to plate</td>
<td>50, 332, 256, 700, 125, 56, 38, 20, 15, 10, 7.5, 5, 1.2</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Write for our Catalog PS-520
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
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Radio Industry Products Show

FIFTH Southwestern IRE Conference

IRE Meetings and Exhibits Promote Electronic Progress!

Table of Contents will be found following page 84A
How to tell Quality in **TEFLON**

You'll have all these properties with **FLUOROFLEX-T**®

- "Teflon" powder is converted into Fluoroflex-T rod, sheet and tube under rigid control, on specially designed equipment, to develop optimum inerterness and stability in this material. Fluoroflex-T assures the ideal, low loss insulation and stability in this material. Fluoroflex-T rods feed properly in automatic screw machines without the costly time and material waste of centerless grinding. Tubes are concentric — permitting easier boring and reaming. Parts are free from internal strain, cracks, or porosity.

For maximum quality in Teflon, be sure to specify Fluoroflex-T.

*DuPont trade mark for its tetrafluoroethylene resin.

"Fluoroflex" means the best in Fluorocarbons

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.

December 10, 11 & 12, 1952
Joint IRE-AIEE Computers Conference Park Sheraton Hotel
Exhibits: Perry Crawford, 373 Fourth Avenue, New York City.

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.

February 5, 6 & 7, 1953
Southwestern IRE Conference Plaza Hotel, San Antonio, Tex.
Exhibits: M. B. Lamp, Box IRE, St. Mary's University, San Antonio, Texas

March 23, 24, 25 & 26, 1953
Radio Engineering Show Grand Central Palace, New York City
Exhibits Manager: Wm. C. Copp, 303 W. 42nd Street, New York 36, N. Y.

April 11, 1953

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

May 11, 12 & 13, 1953
National Conference on Airborne Electronics Hotel Billmore, Dayton, Ohio.
Exhibits: Paul D. Hauser, 1430 Gascho Drive, Dayton 3.
Printed circuits like those shown here offer important advantages in radio and TV production—fewer parts to purchase, inspect, handle, and stock; fewer soldering operations and quicker assembly with minimal wiring errors; faster and easier inspection; greater compactness; and lighter weight. And usually they cost less than the individual capacitors and resistors they replace!

BULPLATE Printed Circuits are a logical outgrowth of Sprague-Herlec BULPLATE Multiple Ceramic Capacitors, first to use the active dielectric as a supporting medium for printed wiring. The printed resistor elements of these plates have proved to be highly stable, another important Sprague contribution.

Thousands of BULPLATES are now in use in radio, television, and military electronics. Are you overlooking a winning bet for your production?

And remember—if you have a special problem on a network which must perform a certain circuit function, Sprague will design it for you.


Typical Radio and TV BULPLATE Circuits

Diode Filter
Triode Coupling
Vertical Integrator
Pentode Coupling
I-F Filter
Audio Output

Sprague
World's Largest Capacitor Manufacturer

PROCEEDINGS OF THE I.R.E. December, 1952
In a split second, relays, which are high-speed switches, set up dial telephone connections. Then they are off to direct the next call. Yet even this speed is too slow for Bell Laboratories scientists in quest of still faster switching.

Scientists and engineers devised a new relay — the wire spring relay — and worked out the production problem with Western Electric, manufacturing unit of the Bell System. This is twice as fast, uses less power and costs less to make and maintain.

With speedier relays, switching can be done with less equipment . . . and calls go through faster. The wire spring relay is a practical example of how Bell Telephone Laboratories and Western Electric pool their skills to improve telephone service while keeping its cost down.

New wire spring relay. Older relays had flat metal springs and 70 parts to be handled, compared with 12 in the new model. Relays operate by means of an electromagnet which responds to high-speed pulses.

New relays must be able to operate one billion times—equal to once-a-second for 30 years. Employing a sound recorder as a precision vibrator, Bell scientists learned to evaluate the effect of sideways motion on relay life. Such rubbing motion is limited to one-thousandth of an inch in the new relays.

Dynamic Fluxmeter, developed by Bell Laboratories, indicates flux build-up in intervals of 25 millionths of a second. Precise information like this was essential to higher speed operation.

Relay springs as they come from Western Electric molding machine, before being cut apart for use. Molding technique saves time and money . . . makes possible the maintenance of precise adjustment.

Bell Telephone Laboratories

Improving telephone service for America provides careers for creative men in scientific and technical fields
Here, again, is another HERMETIC exclusive... another remarkable engineering feat in sub-miniaturization... to permit the greatest number of terminals in smaller-than-ever, minimal space.

By means of HERMETIC's new, Sub-Miniature, 4-Terminal, Relay Header, emphasis is placed on minimum dimensional requirements for the mounting surface as well as the space above and below it. And, despite its miniaturized size, this header offers mechanically secure connections in smallest possible areas... for use with relays, rectifiers, choke coils, etc.

No. 1333... terminals with double-turret top and straight-cut or flattened and pierced bottom
No. 1539... terminals with hooked top and straight-cut or flattened and pierced bottom
No. 1385... with tubing suitable for feed-through attachment

Because the solution of this problem is characteristic of HERMETIC's ability to serve you, contact the one and only dependable source of supply, and be sure that your problems will be solved, too.
The Type 211-A Signal Generator was designed by Boonton Radio Corporation in cooperation with the CAA and leading manufacturers of aircraft navigation and landing receivers. It was designed for specific application to the calibration of these receivers to the high accuracy characteristics required. The CAA system requiring these receivers guides aircraft from one location to another and assists in landing under marginal weather conditions. The Signal Generator is also useful in testing accurately tuned communications receivers.

**SPECIFICATIONS**

**RF SECTION**
- **Frequency Range:** 88 to 140 mc.
- **Output Frequency:** Monitored
- **Modulation Frequency:** 0-100% with internal or external oscillator
- **Output Level:** 1 to 200,000 microvolts across 53 ohms unbalanced
- **Modulation Fidelity:** 0.5 db
- **Phase Distortion:** Less than 0.25 degrees at 30 cps and 10 degrees at 11 Kc.
- **Spurious FM:** Less than 1 Kc at 60% FM.
- **Crystal Calibrating Frequencies:** 110.100 and 114.900 mc. ± 0.0035%.
- **Modulation:** Amplitude (up to 30%) using internal or external source.
- **Price:** $1800.00 FOB Boonton, N. J. (Relay Rock not included)
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.

HUDSON TOOL AND DIE COMPANY • INC
PRODUCERS OF CASES, COVERS AND CUSTOM METAL STAMPINGS FOR ELECTRICAL, ELECTRONIC AND NUCLEAR INDUSTRIES
118-122 SO. FOURTEENTH STREET, NEWARK 7, NEW JERSEY
Built for the toughest service.....

Mallory Q Series
Wire Wound Controls

If you need a wire wound control that will stand up under the most severe conditions, here's the answer to your problem—Mallory Series Q controls. These new features make the Q series your best choice for military and other exacting applications:

**IMPERVIOUS TO MOISTURE AND FUNGUS:** all insulation used in this control is made of high resistance material which has exceptionally low moisture absorption...treated to prevent fungus growth.

**WEATHERPROOF FINISH:** nickel plated case, stainless steel shaft, and all other metal parts will pass a 100-hour salt spray test.

**LONGER LIFE:** hard nickel-silver contacts withstand the wear of thousands of rotations.

**SELECTION OF TAPERS:** all standard JAN tapers are available.

In addition to these standard features, Q series controls can be supplied in a number of special variations invaluable in applications requiring complete waterproofing or extreme resistance to vibration:

**WATERPROOF SHAFT BUSHING:** a waterproof gasket between shaft and bushing, sealed with silicone grease, prevents leakage along the shaft.

**WATERPROOF PANEL SEAL:** gasketed seal prevents leaks at the point of panel mounting.

**BUSHING LOCK:** a split bushing, when tightened, prevents shaft rotation even under severe shock and vibration.

New Technical Bulletin Number 76-3 includes complete details on Mallory wire wound controls. Write for your copy.

<table>
<thead>
<tr>
<th>Series</th>
<th>Watts</th>
<th>Diameter</th>
<th>Similar JAN Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>QC</td>
<td>2</td>
<td>1 1/8&quot;</td>
<td>RA15</td>
</tr>
<tr>
<td>OR</td>
<td>2</td>
<td>1 1/4&quot;</td>
<td>RA20</td>
</tr>
<tr>
<td>QM</td>
<td>4</td>
<td>1 3/8&quot;</td>
<td>RA25 &amp; RA30</td>
</tr>
</tbody>
</table>

SERVING INDUSTRY WITH THESE PRODUCTS:
- Electromechanical—Resistors • Switches • Television Tuners • Vibrators
- Electrochemical—Capacitors • Rectifiers • Mercury Dry Batteries
- Metallurgical—Contacts • Special Metals and Ceramics • Welding Materials
In the field of Guided Missiles an engineering team which can carry a program forward from the very conception of the idea to the completion of a missiles weapon system is essential. Such a team is at work in Fairchild's Guided Missiles Division. Supporting this experienced engineering team is a production organization which has produced complete missile weapon systems for all three branches of the Armed Services. Recently Fairchild completed this country's first privately built plant devoted exclusively to missile design, development and production.

ENGINE AND AIRPLANE CORPORATION
FAIRCHILD
Guided Missiles Division
Wyondanch, L.I., N.Y.

Other Divisions: Aircraft Division, Hagerstown, Md.
Engine Division, Farmingdale, N.Y.
Stratos Division, Bay Shore, L.I., N.Y.
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.

C A M B R I D G E  T H E R M I O N I C  C O R P O R A T I O N

custom or standard...the guaranteed components
Wilko, the first licensee under Western Electric patents to produce carbon deposited precision resistors, takes another step forward. Wilko now offers hermetically-sealed Carbofilm Resistors, the first fully-protected precision resistors available on a production basis.

Primarily intended for circuits calling for the accuracy and stability of wire-wound resistors, yet with the compactness of carbon or composition-element resistors. Excellent for measuring-instrument applications; in test and lab equipment; in oscillography and other critical electronic circuits; in electronic computers and allied techniques; and now, in the encased, hermetically-sealed construction, particularly in applications where resistance values must be critically maintained over long service life, regardless of climatic conditions.

**SPECIFICATIONS**


2. Temperature Coefficient not exceeding .0003 ohm per ohm per °C, over temperature range of -40°C to +60°C. Up to 15 megohms. Not exceeding .0005 ohm per ohm per °C, up to 100 megohms.

3. Voltage Coefficient does not exceed .002% per volt.

4. Overloads up to 200% of rated voltage, without showing permanent change in resistance.

5. Accuracy guaranteed tolerance of plus/minus 1% at 20°C (68°F).

6. Aging Changes negligible. Average change in resistance for self-aging, approximately 0.2% in a year.

7. Noise: Silver-to-silver contacts insure very high stability and correspondingly low noise levels.

8. In Four Sizes: Two 1/2 watt, 1 watt and 2 watt. Cased or uncased.
**New Capacitor Firm**

A new firm in the field is Plastic Capacitors, Inc., 2511 West Moffat St., Chicago 47, I1, Stephen Meskin, 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 photo-multivibrator 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., 501-29 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 omnibearing 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 locator 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.

The two coiled heaters used in the 5726 are internally connected in series to provide fail-safe operation in applications where there is danger of failure of any part of the device. These units are contained in a single housing and are not subject to damage from external sources of heat.

**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.

**Bandwidth Compressor**

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**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.
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.
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 unexcelled 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.
For more than 18 years, Eclipse-Pioneer has been a leader in the development and production of high precision synchros for use in automatic control circuits of aircraft, marine and other industrial applications. Today, thanks to this long experience and specialization, Eclipse-Pioneer has available a complete line of standard (1.431" dia. X 1.631" lg.) and Pygmy (0.937" dia. X 1.278" lg.) Autosyn synchros of unmatched precision. Furthermore, current production quantities and techniques have reduced cost to a new low. For either present or future requirements, it will pay you to investigate Eclipse-Pioneer high precision at the new low cost.

### AVERAGE ELECTRICAL CHARACTERISTICS—AY-200 SERIES**

<table>
<thead>
<tr>
<th>Type</th>
<th>Voltage</th>
<th>Milliamperes</th>
<th>Watts</th>
<th>Ohms</th>
<th>Ohms</th>
<th>Minimum Error Spreading Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmitters</td>
<td>AY201-2</td>
<td>26V, 400-1 ph</td>
<td>100</td>
<td>0.45</td>
<td>45-6-225</td>
<td>11.8</td>
</tr>
<tr>
<td>Receivers</td>
<td>AY201-2</td>
<td>26V, 400-1 ph</td>
<td>100</td>
<td>0.45</td>
<td>45-6-225</td>
<td>11.8</td>
</tr>
<tr>
<td>Central Transformers</td>
<td>AY201-5</td>
<td>From Trans. Autosyn</td>
<td>Depend upon Circuit Design</td>
<td></td>
<td></td>
<td>250.0</td>
</tr>
<tr>
<td>Resolvers</td>
<td>AY221-3</td>
<td>26V, 400-1 ph</td>
<td>60</td>
<td>0.25</td>
<td>308-2425</td>
<td>11.8</td>
</tr>
<tr>
<td></td>
<td>AY243-5</td>
<td>1V, 30-1 ph</td>
<td>3.7</td>
<td>—</td>
<td>240-1300</td>
<td>0.34</td>
</tr>
<tr>
<td>Differentials</td>
<td>AY231-3</td>
<td>From Trans. Autosyn</td>
<td>Depend upon Circuit Design</td>
<td></td>
<td></td>
<td>14.0</td>
</tr>
</tbody>
</table>

**Also includes high frequency Resolvers designed for use up to 100K (AY251-24)

### AY-500 (PYGMY) SERIES

<table>
<thead>
<tr>
<th>Type</th>
<th>Voltage</th>
<th>Milliamperes</th>
<th>Watts</th>
<th>Ohms</th>
<th>Ohms</th>
<th>Minimum Error Spreading Minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmitters</td>
<td>AY503-4</td>
<td>26V, 400-1 ph</td>
<td>235</td>
<td>2.2</td>
<td>45-9-300</td>
<td>15.8</td>
</tr>
<tr>
<td>Receivers</td>
<td>AY503-2</td>
<td>26V, 400-1 ph</td>
<td>235</td>
<td>2.2</td>
<td>45-9-300</td>
<td>15.8</td>
</tr>
<tr>
<td>Central Transformers</td>
<td>AY503-3</td>
<td>From Trans. Autosyn</td>
<td>Depend upon Circuit Design</td>
<td></td>
<td></td>
<td>170.0</td>
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<tr>
<td></td>
<td>AY503-5</td>
<td>From Trans. Autosyn</td>
<td>Depend upon Circuit Design</td>
<td></td>
<td></td>
<td>550.0</td>
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<tr>
<td>Resolvers</td>
<td>AY523-3</td>
<td>26V, 400-1 ph</td>
<td>45</td>
<td>0.5</td>
<td>290-4925</td>
<td>11.8</td>
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<tr>
<td></td>
<td>AY543-5</td>
<td>26V, 400-1 ph</td>
<td>9</td>
<td>0.1</td>
<td>900-32200</td>
<td>11.8</td>
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<tr>
<td>Differentials</td>
<td>AY533-3</td>
<td>From Trans. Autosyn</td>
<td>Depend upon Circuit Design</td>
<td></td>
<td></td>
<td>45.0</td>
</tr>
</tbody>
</table>

For detailed information, write to Dept. G.

---

**ECLEPSE-PIONEER DIVISION of BENDIX AVIATION CORPORATION**

Export Sales: Bendix International Division, 72 Fifth Avenue, New York 11, N. Y.

---

**SOUTHWESTERN INDUSTRIAL ELECTRONICS COMPANY**

2831 East Oak Road • Houston 19, Texas
G-E Diffused Junction

NOW RATED

Old Style
G10 SERIES

New Style
JA1A SERIES

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.
**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.
**SI ELECTRON C-CORES...BIG or LITTLE**

...any quantity and any size

For users operating on government schedules, Arnold is now producing C-Cores wound from \( \frac{1}{4}, \frac{1}{2}, 1, 2, 4 \) and 12-mil Silectron strip. The ultra-thin oriented silicon steel strip is rolled to exacting tolerances in our own plant on precision cold-reducing equipment of the most modern type. Winding of cores, processing of butt joints, etc. are carefully controlled, assuring the lowest possible core losses, and freedom from short-circuiting of the laminations.

We can offer prompt delivery in production quantities—and size is no object, from a fraction of an ounce to C-Cores of 200 pounds or more. Rigid standard tests—and special electrical tests where required—give you assurance of the highest quality in all gauges. • Your inquiries are invited.

**THE ARNOLD ENGINEERING COMPANY**

SUBSIDIARY OF ALLEGHENY LUDLUM STEEL CORPORATION

General Office & Plant: Marengo, Illinois

PROCEEDINGS OF THE I.R.E. December, 1952
wilcox
Type 429 A
GLIDESLOPE
RECEIVER

wilcox
ELECTRIC COMPANY, INC.
Fourteenth and Chestnut
Kansas City 27, Missouri, U.S.A.

- 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!

Available Now...
For Immediate Delivery

Write today for complete specifications.
Truscon knows towers—is staffed and equipped to engineer your next tower assembly to meet all your requirements.

That's because Truscon has an unexcelled background of tower information and skill. Truscon engineers have designed and built radio towers for all types of duty throughout the world... towers to function dependably in all kinds of topography and weather conditions... towers with the strength to meet all contingencies.

And, this experience is at your call now. Whether your current or future plans call for new or enlarged AM, FM, TV, or Microwave facilities, take your tower troubles to Truscon.

Your phone call or letter to your nearest Truscon district office—or to our home office in Youngstown—gets tower problems off your hands and into ours. Phone or write today. Truscon® Steel Division, Republic Steel Corporation, 1072 Albert St., Youngstown 1, Ohio.

TRUSCON a name you can build on

PROCEEDINGS OF THE I.R.E. December, 1952
Here's what makes REELABLE SUBMINIATURE TUBES

RAYTHEON

RELIABLE

SUBMINIATURE
TUBES

CK5702WA
RF Amplifier Pentode
CK5703WA
High Frequency Triode
CK5744WA
High Mu Triode
CK5783WA
Voltage Reference
CK5784WA
RF Mixer Pentode
CK5787WA
Voltage Regulator
CK5829WA
Dual Diode
CK6021
Medium Mu Dual Triode
CK6111
Low Mu Dual Triode
CK6112
High Mu Dual Triode
CK6152
Low Mu Triode

✓ EXPERIENCE Raytheon has been in constant, large scale production of subminiatures for fourteen years — has made millions of them.

✓ ENGINEERING Many Raytheon engineers have worked exclusively on the development and improvement of Subminiature tubes. Raytheon designs have proved themselves in the field.

✓ EQUIPMENT Raytheon's production, testing and inspection facilities are custom built. Improved welding, sealing and exhaust procedures are among the many exclusive Raytheon advances.

✓ EXCLUSIVE SUBMINIATURE TECHNIQUES Include closer production tolerances for all parts; separate production and inspection personnel free of production-incentive pressure; grid inspection with high optical magnification; microscopic inspection of each assembly; longer, more complete electrical aging; rigid tests for shock, vibration, acceleration and all other factors affecting performance and life.

RAYTHEON MANUFACTURING COMPANY

PROCEEDINGS OF THE I.R.E. December, 1952
Designed for dependability

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

KOLLMAN 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.
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.
Whether your particular requirements are for standard or special application, choose LENZ for the finest in precision-manufactured electronic wire and cable.

**GOVERNMENT PURPOSE RADIO AND INSTRUMENT HOOK-UP WIRE,**
plastic or braided type, conforming to Government Specification JAN-C-16, etc., for radio and instruments. Solid or flexible conductors, in a variety of sizes and colors.

**RADIO AND INSTRUMENT HOOK-UP WIRE,**
Underwriters Approved, for 80° C., 90° C. and 105° C. temperature requirements. Plastic insulated, with or without braids.

**RF CIRCUIT HOOK-UP AND LEAD WIRE**
for VHF and UHF, AM, FM and TV high frequency circuits. LENZ Low-Loss RF wire, solid or stranded tinned copper conductors, braided, with color-coded insulation, waxed impregnation.

**SPECIAL HARNESSSES,**
cords and cables, conforming to Government and civilian requirements.

**SHELDED JACKETED MICROPHONE CABLE**
Conductors: Multiple—2 to 7 or more conductors of stranded tinned copper. Insulation: extruded color-coded plastic. Closely braided tinned copper shield. Tough, durable jacket overall.

**JACKETED MICROPHONE CABLE**
Conductors: Extra-flexible tinned copper. Polyethylene insulation. Shield: 136 tinned copper, closely braided, with tough durable jacket overall. Capacity per foot: 29MMF.

**TINNED COPPER SHIELING AND BONDING BRAIDS**
Construction: #34 tinned copper braid, flattened to various widths. Bonding Braids conforming to Federal Spec. QQ-B-775 or Air Force Spec. 94-4022.

**PA AND INTERCOMMUNICATION CABLE**
Conductors: #2 stranded tinned copper, insulation: textile or plastic Insulated conductors. Cable formed of Twisted Pairs, color-coded. Cotton braid or plastic jacket overall. Furnished in 2, 5, 7, 13 and 25 paired, or to specific requirements.

**SHELDED COTTON BRAIDED CABLES**
Conductors: Multiple—2 to 7 or more of flexible tinned copper. Insulation: extruded color-coded plastic. Cable concentrically formed. Closely braided tinned copper shield plus brown overall cotton braid.

**SHELDED MULTIPLE CONDUCTOR CABLES**
Conductors: Multiple—2 to 7 or more of flexible tinned copper. Insulation: extruded color-coded plastic. Closely braided tinned copper shield. For: Auto radio, indoor PA systems and sound recording equipment.

**CHECK LENZ FIRST!**

**Lenz Electric Manufacturing Co.**
1751 N. Western Ave., Chicago 47, Illinois
Our 49th Year in Business

cords, cable and wire for radio • p. a. • test instruments • component parts

PROCEDINGS OF THE I.R.E. December, 1952
Yuletide joys of '52 will again include many Xmas electrical gifts controlled by Guardian Relays. Despite circumstances that enlist more Guardian Relays for jobs in war planes, tanks, communications, bomb releases and gun controls, Guardian Relays are still available in quantity for improved control of peacetime products. The Guardian Series 335 D.C. Relay is a typical unit. It has been furnished to both MIL-R-5757 and MIL-R-6106 in open and sealed versions and is manufactured under MIL-Q-5923A standards.

Generous coil winding area permits single windings up to 15,000 ohms. Power: Normal 3 1/2 watts. Bakelite insulated tested at 900 V., 60 Cyc. Built-in delay with copper head for delayed attract up to .06 second and copper heel for delayed release up to 0.1 second. Contacts 1/4" dia. silver, 12 amps at 24 V., D.C. Maximum combination up to 4 PDT (with 12 amp contacts). Open type mounting, metal cover, or hermetically sealed with leads or screw terminals. Special brackets to order.
"SEAL ED- IN" DESIGN eliminates need for metal enclosures and fungus-proof coating.

New G-E cast-permafil transformers are 20% smaller, "sealed for life"

Meet MIL-T-27 (Grade 1) performance requirements

Greater flexibility in many electronic designs is made possible by General Electric's new line of cast-permafil transformers, thanks to their light weight and small size.

These solventless-resin-type transformers are completely moisture-proof. They have fewer machined and punched parts. Tough, solid, shatter-resistant cast permafil ends the necessity for fungus-proof protective coatings.

At 130C ultimate, these transformers have an expected life of 1000 hours or more. The complete line of 11 sizes, available in various terminal arrangements, averages about 20 per cent smaller than previous metal-encased transformer models.

For further information, write to Section 667-23, General Electric Company, Schenectady 5, New York.

TRANSPARENT MODEL shows simple construction of new transformer. Terminals are anchored directly in mixture to cut size and weight.
Permafil d-c capacitors have 80% less weight, bulk

They operate in ambient up to 125°C 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 150°C.

Permafil capacitors average about 1/5 the size and weight of liquid-filled capacitors properly derated to operate at 125°C. Because of their small size and excellent electrical characteristics they are ideal for most high-ambient blocking, bypass, filtering, coupling and timing applications. They are available in ratings of 0.05 to 1.0 mF, 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.
**TYPE 1U1**

Output 20V - 200 μA
Specifications at 45°C
Max. Reverse Current ... 6.0 μA at 26V
Rated Forward Current ... 200 μA
Shunt Capacitance at 200 KC ... 0.00007 μf

Maximum Ratings
Peak Inverse Voltage ... 60 volts
Max. Average Rectified Current ... 200 μA
Peak Rectified Current ... 2.6 mA
Max. Surge Current (1 sec) ... 10 mA
Ambient Temp. Range ... −50 to 100°C
Max. RMS Applied Voltage ... 26 volts
Max. RMS Input Current ... 500 μA
Max. DC Output Voltage ... 20 volts
Voltage Drop at Full Load ... 1 volt
Reverse Current at 10 V RMS ... 0.6 μA
Frequency, Max. ... 200 Kc

Also available in 2U1, 3U1, 4U1

**TYPE T SERIES**

WRITE FOR BULLETIN SD-1

---

**INTERNATIONAL RECTIFIER CORPORATION**

General Offices: 1521 E. Grand Ave., El Segundo, Calif. • Phone: El Segundo 1890
Chicago Branch Office: 205 West Wacker Drive • Phone: Franklin 2-3889
New York Branch Office: 12 West 32nd Street, N. Y. 1 • Phone: Chickering 4-0017

PROCEEDINGS OF THE I.R.E. December, 1952
Selenium Rectifiers

**POWER RECTIFIERS**

- **CELL SIZES**: From 1" x 1" to 6 1/4" x 7 1/4"
- **CURRENT RATINGS**, per cell:
  - 0.125 amperes to 7 amperes
- **VOLTAGE RATINGS**, inverse per cell:
  - 22 volts rms to 40 volts rms
- **Efficiency** to 87%. **Power factor** 95%
- Suitable for oil immersion.
- **Ratings to 250 KW. Send for Bulletin C-349**

---

**SELENIUM DIODES**

- **DIAMETER**: From 1/8" to 13/32"
- **LENGTH**: From 1/4" to 1/2"
- **RMS applied voltage**:
  - From 26 volts to 104 volts
- **RMS input current**:
  - max. 500 microamperes
- **DC output voltage**:
  - From 20 volts to 80 volts
- **DC output current**: avg. from 200 microamperes to 5 milliamperes
- **Reverse Leakage at 10 volts RMS**:
  - 0.6 microamperes to 2.4 microamperes
- Potted in thermosetting compound
- **Temperature Range**:
  - From -60° C to 100° C
- Available in 1, 2, 3 and 4 cell Diodes
  - Send for Bulletin SD-1

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**INTERNATIONAL RECTIFIER CORPORATION**

**General Offices**: 1521 E. Grand Ave., El Segundo, Calif. • Phone: El Segundo 1890
**Chicago Branch Office**: 205 West Wacker Drive • Phone: Franklin 2-3889
**New York Branch Office**: 12 West 32nd Street, N.Y. 1 • Phone: Chickering 4-0017

PROCEEDINGS OF THE I.R.E. December, 1952
CLOSE-UP OF SERVO PANEL

The above panel contains 110 Allen-Bradley Type J potentiometers, each of which may be adjusted to meet transmitter operating requirements.

Type J Bradleyometers can be supplied in single, dual, or triple unit construction, with or without line switch.

OVERSEAS TRANSMITTER

has 110

Type J Bradleyometers

The Bradleyometers used in this Western Electric panel board assure stability of transmitter performance because the solid molded resistor elements of these Bradleyometers are not affected by heat, cold, moisture, or age. The contact brush, which actually improves with age, is always noiseless in operation.

Bradleyometers can be built to produce any resistance - rotation curve. During manufacture, the materials entering into the molded resistor can be varied in resistance throughout the circumference of the ring to meet your special electronic circuit requirements.

If you have a critical rheostat or potentiometer problem, be sure to investigate the Type J Bradleyometer.

Allen-Bradley Co., 114 W. Greenfield Ave., Milwaukee 4, Wis.

ALLEN-BRADLEY

FIXED & ADJUSTABLE RADIO RESISTORS

Sold exclusively to manufacturers of radio and electronic equipment
DEPENDABLE
1/8 MICRO-SECOND TIMING
WHEN YOU CAN'T
AFFORD TO MISS

IN MEASURING:
• VELOCITY
• ACCELERATION
• DETONATION
• DOPPLER
• PULSE

8 MEGACYCLE
COUNTER-
CHRONOGRAPH

GREATER ACCURACY
The use of an 8 megacycle crystal time base provides the highest resolution of time measurement available in direct reading instruments.

COMPLETE DEPENDABILITY
To assure the highest degree of dependability, a straightforward 3-stage binary counter is used at the 8 megacycle frequency, permitting the conservative use of decade counters at the lower frequencies.

DIRECT READING
Digital registration is used to indicate time from 1 microsecond to 1 second by means of 8 Potter decades. Fractional parts of a microsecond are read from a 3-stage binary counter which indicates, in steps of 1/8 microsecond.

PROVED PERFORMANCE
Ten years of service in proving grounds and research centers give conclusive evidence that the simplified circuitry inherent in the Potter Counter-Chronographs provides the maximum reliability for critical timing applications.

WIDE APPLICATION
There is a Potter Counter-Chronograph made for your specific application. High-speed digital recorders are available for permanent recording of measurements at rates up to 150 per second.

WRITE FOR INFORMATION AND ENGINEERING DATA

POTTER INSTRUMENT COMPANY
INCORPORATED
109 CUTTER MILL ROAD, GREAT NECK, NEW YORK

MANUFACTURERS OF
PREDETERMINED ELECTRONIC COUNTERS • FREQUENCY TIME COUNTERS • PRESET INTERVAL GENERATORS
HIGH SPEED PRINTING AND RECORDING, SHIFT REGISTERS, AND DATA HANDLING EQUIPMENT

Do you need
A RELIABLE AND
CONVENIENT MEANS
FOR CHECKING BOTH LEAKAGE AND CONTINUITY OF ELECTRICAL COMPONENTS?

MODEL C-3 RESISTANCE METER IS YOUR ANSWER

The Model C-3 Resistance Meter is designed for use by manufacturers in checking both leakage and continuity of electrical components. It is particularly valuable for making rapid checks of the insulation resistance of transformer windings, condensers, and electrical wiring, as well as measuring the ohmic value of resistors and windings.

ELECTRICAL SPECIFICATIONS

ACCURACY: Plus or minus 3% of full scale deflection plus 1 ohm on the OHMS ranges.

Plus or minus 3% of full scale deflection (approximately 3 degrees) on the MEGOHMS ranges except 10' range.

Plus or minus 5% of full scale deflection on 10' megohm range.

RANGES: 1 ohm to 1 million megohms

The ohmmeter applies a maximum of 1½ volts to the resistor under test. It has a scale of from 0 to 500 ohms and a selector switch for selecting scale multipliers of x 1, x 10, x 100, and x 1000.

The leakage tester applies a maximum of 105 volts to the unit under test. Its scale reads from 1 to 100 megohms and has multipliers of x 1, x 10, x 100, x 1000, and x 10000.

SOUTHWESTERN INDUSTRIAL ELECTRONICS COMPANY
2831 Post Oak Road, Houston 19, Texas

MODERN ELECTRONICS
MAGAZINE
APRIL 1954

POTTER INSTRUMENT COMPANY
INCORPORATED
109 CUTTER MILL ROAD, GREAT NECK, NEW YORK

MANUFACTURERS OF
PREDETERMINED ELECTRONIC COUNTERS • FREQUENCY TIME COUNTERS • PRESET INTERVAL GENERATORS
HIGH SPEED PRINTING AND RECORDING, SHIFT REGISTERS, AND DATA HANDLING EQUIPMENT
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.


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
NEW Styroflex COAXIAL

provides high-power, low-loss communication links

**Cut-away Section of Styroflex Coaxial Cable**

- **Inner Copper Conductor**
- **Styroflex Tape Helix**
  - Keeps inner conductor absolutely and permanently centered, even at sharp bends.
  - Provides a uniform combination of solid and air dielectrics at every cross-section of cable.
- **Outer Belt of Styroflex Tape**
  - Increases leakage path between inner conductor and outer aluminum sheath.
- **Outer Aluminum Sheath**
  - Consists of continuous aluminum tube without joints.
  - Acts as outer conductor.

Typical TV antenna installation of Styroflex coaxial cable as a power line from station transmitter to antenna.
Reflections Reduced to Absolute Minimum
in AM, FM, TV and Microwave Applications

Phelps Dodge Copper Products Corporation's new semi-flexible, aluminum sheathed Styrolflex 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 Felt & Guillaume 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 Styrolflex film to form a helix. This helix, built up of hundreds of precision-wound Styrolflex 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 Styrolflex tape is obtained by special manufacturing techniques.

- In test of strength and ruggedness of Styrolflex coaxial cable, heavy truck drives over several samples without damaging them.
- Perfect centering of inner conductor is maintained by Styrolflex tape helix, regardless of bending or load cycling both during installation and in service.
MINIATURE IN SIZE - GIGANTIC IN PERFORMANCE

FUSITE GLASS-TO-METAL HERMETIC TERMINALS

These Miniatures . . . . Now Available in these Electrode Treatments

1000 V
Flange Diameter .200
Mounting Hole 3/16"
Illustrated #104 THFP

1500 V
Flange Diameter .250
Mounting Hole 5/16"
Illustrated #105 THSW

1500 V
Flange Diameter 1\(\frac{3}{16}\)
Mounting Hole 3/16"
Illustrated #106 FP

2000 V
Flange Diameter 3/8"
Mounting Hole 1\(\frac{3}{16}\)"
Illustrated #107 BLHT

104 SERIES

104 SW
104 L
104 THSW
104 THFP
104 FP

105 SERIES

105 SW
105 L
105 THSW
105 THFP
105 FP

107 SERIES

107 TH
107 HT
107 FP
107 HT (Short)

THE FUSITE CORPORATION
6000 FERNVIEW AVENUE - CINCINNATI 13, OHIO

GENERAL SPECIFICATIONS

MATERIALS—C. R. Steel disc and steel electrodes. Interfused with glass.

INSULATION TEST—10,000 megohms after salt water immersion.

PRESSURE TEST—12 pounds gauge.

SUDDEN THERMAL SHOCK TEST—dry ice to boiling water.
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. 13 "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.

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

PROCEEDINGS OF THE I.R.E. December, 1952
EAI’s Dataplotter...

An Electronic System That Converts Digital Data To An Analog Plot...

Here is a system that will save countless man-hours and costs, and will inscribe accurate and clear presentation of data.

This new Dataplotter, designed and developed by Electronic Associates Inc., will automatically plot a cartesian curve composed of incremental points or symbols from IBM card data at maximum machine reading speed.

It will accept data from other inputs — Magnetic tape, keyboards, digital computers, etc.

It will retain at all times the basic accuracy of the digital system.

Here’s what the Dataplotter system consists of:

- Variplot Model 205G
- Digital-to-analog converter, Model 417
- Data input keyboard

For further information, clip out and mail the coupon below. No obligation.

Electronic Associates Inc.
Long Branch
New Jersey

Gentlemen: Would you be kind enough to send me detailed information on your Dataplotter.

Name ........................................ Title ........................................

Company ......................................... Address ........................................

City ........................................... Zone .......... State ..................
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

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Frequency</td>
<td>455 kc</td>
</tr>
<tr>
<td>Nominal Band Width</td>
<td>3 kc</td>
</tr>
<tr>
<td>Peak to Valley Ratio</td>
<td>1.5 db</td>
</tr>
<tr>
<td>Insertion Loss</td>
<td>26 db</td>
</tr>
<tr>
<td>Overload Input Power Level (without temperature compensation)</td>
<td>0.035 watt</td>
</tr>
<tr>
<td>Operating Temperature Range</td>
<td>15°C to 80°C</td>
</tr>
<tr>
<td>Vibration</td>
<td>Satisfies Requirements of Army Navy Specification AN-E-19</td>
</tr>
<tr>
<td>Case Size (Filter Shown with Hermetically Sealed Shield Removed)</td>
<td>1&quot; x 15/16&quot; x 2-13/16&quot;</td>
</tr>
<tr>
<td>Input and Output Impedance</td>
<td>6,500 ohms</td>
</tr>
</tbody>
</table>

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...
Q-MAX is widely accepted as the standard for R-F circuit components because it is chemically engineered for this sole purpose.

Q-MAX provides a clear, practically loss-free covering, penetrates deeply, seals out moisture, imparts rigidity and promotes electrical stability.

Q-MAX is easy to apply, dries quickly and adheres to practically all materials. It is useful over a wide temperature range and serves as a mild flux on tinned surfaces.

Q-MAX is an ideal impregnant for high "Q" coils. Coil "Q" remains nearly constant from wet application to dry finish.

Q-MAX is supplied in 1, 5, and 55 gallon containers.

WRITE FOR ILLUSTRATED LITERATURE
The CP Catalog contains detailed information including recommended applications and typical uses. Illustrated literature is also available on SEAL-O-FLANGE TRANSMISSION LINE, TOWER HARDWARE, COAXIAL DIPOLE ANTENNAS, AND AUTO-DRYaire DEHYDRATORS. Request your copies today.
What Rauland means by "Perfection Through Research"

Rauland is one of the few companies devoting so much top engineering talent full time to picture tube improvement and perfection.

The result has been to give you more picture tube advancements since the war than any other manufacturer... first chance at the latest developments for companies using Rauland tubes as original equipment... and a real selling edge at the retail level because of the extra satisfaction which Rauland advantages offer.

That's why so many alert manufacturers look to Rauland for the best in picture tubes.

Rubber model for studying electron optical designing—basis for Rauland's exclusive Indicator Ion Trap.

Alignment of the screen and parallax mask of tri-color tube containing approximately a million fluorescent dots.

All-electronic tri-color tube in electronic receiver system (left) in comparison with mechanical system (right).

Inspection and checking of perforations .0075" in diameter in masks of tri-color picture tubes.

Rauland large-screen projectors using three different optical systems, all of which give theater-size pictures.

Careful study of the formation of thin metallic films in a vacuum... basis for the aluminizing of tubes.

Examination with polarimeter permits careful control of strains for superior glass-to-metal sealing.

A physicist using a Rauland-developed radiation meter in checking X-ray radiations from cathode ray apparatus.

THE RAULAND CORPORATION

Perfection Through Research

77-urnertyk Rd., Lenexa, Kansas

4245 N. Knox Avenue • Chicago 41, Illinois

PROCEEDINGS OF THE I.R.E. December, 1952
Electronic Computer gets the answers... 
BRUSH PUTS THEM IN WRITING!

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.

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
DEVELOPMENT COMPANY

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

PROCEEDINGS OF THE I.R.E. December, 1952
THE addition of a new complete line of ERIE Button Silver-Mica Condensers, designed for operation at 150°C, is important news to manufacturers of military electronic equipment and specialized commercial applications. The new line greatly extends the range of applications for the popular ERIE Button Micas. The new line is available in the eight standard terminal and mounting styles, and in other styles on special order. Write for samples and literature.

SPECIFICATIONS

Maximum Operating Temperature: 150°C.
Voltage Rating: 500 DC.
Capacitance Values: All standard decade values from 10 mmf to 1000 mmf.
Capacitance Tolerance: ± 20%, ± 10%, ± 5%, ± 2%, or ± 1 mmf, whichever is greater.
Q: 1000 minimum for values above 30 mmf.
Insulation Resistance: 10,000 megohms minimum.
Life Test: 750 volts DC for 1000 hours at 150°C.
Seal Test: Moisture resistance conditioning in accordance with MIL M745. After this the following shall be met:
Insulation Resistance: 500 megohms minimum.
Q: 500 minimum for values above 30 mmf.
Capacitance Change Limit: 3% or 0.5 mmf, whichever is greater.
Temperature and Immersion Cycling: In accordance with ASES Project 114. After this the following shall be met:
Dielectric Strength: 600 volts DC.
Insulation Resistance: 3000 megohms minimum.
Q: 750 minimum for values above 100 mmf.
Capacitance Change Limit: 3% or 0.5 mmf, whichever is greater.
NEW

To AM Broadcasting

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

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.
Two Special Purpose Connectors by BREEZE MARK

Battery Connectors

8-pin type for both A and B batteries used in all types of field communication equipment. "RUGGEDIZED" for extra security and long service life: polarizing stud is ALL METAL and all metal parts are cadmium plated and sealed with an iridite sealer.

Cable may be brought out at any desired side position and locked. Handy bail makes removal from inaccessible places easy.

Quick Disconnect

Simply push male and female members together and lock. To disconnect with minimum resistance, pull back sleeve on plug shell and disconnect. Exceptionally low disengaging force required (less than 6 lbs., excepting pin friction).

Vibration proof, moisture-proofed with synthetic rubber insert. Meets AN pin pattern and voltage requirements, in accordance with MIL C-5015.

Plug shell and coupling sleeve are aluminum alloy, cadmium plated and iridite-sealed.

(Federal Spec. QQP – 416, Type 2.)

Receptacle Types:
Round flange single hole panel-mounted, square flange for 4 bolts, or specially flanged to specification. All contacts silver plated.

We invite your inquiries on any problems concerning connectors. Our wealth of engineering experience in this specialty is at your service.
With its six crystal-controlled fixed-frequencies, the "SP-600" is the perfect receiver for point-to-point and network applications. Pre-arrange day and night fixed-frequencies. With crystal control you can select your desired channels immediately without searching. You'll always be on the nose because of crystal control.

The "SP-600-JX," built to JAN specs and specially ruggedized to provide years of day-in-day-out competent performance, is the most carefully engineered receiver available anywhere for selective channel operation.

But whether you want to operate on a fixed-frequency for contact with an individual station or network, or roam the entire receiver range from 540 Kc to 54 Mc in search of other contacts, you just can't operate a finer receiver than the "SP-600-JX."

Write to the Hammarlund Manufacturing Company for further details.
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 thoriated tungsten core filament for high electron emissivity.
2. Exclusive UNITED graphite anode for maximum thermal dissipation.
3. Exclusive UNITED isolated getter cups 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.

<table>
<thead>
<tr>
<th>Kilovolts</th>
<th>Amperes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inverse Peak</td>
<td>Peak Plate Current as shunt diode</td>
</tr>
<tr>
<td>40</td>
<td>80</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>800 mADC (average) as a rectifier</th>
</tr>
</thead>
<tbody>
<tr>
<td>11 Volts Nominal</td>
</tr>
<tr>
<td>15.5 Amperes</td>
</tr>
</tbody>
</table>

TYPE X-80
(actual size)

UNITED ELECTRONICS, 42 Spring Street, Newark 2, N.J.
(TRANSMITTING TUBES EXCLUSIVELY Since 1934)
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/sec.
- 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
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 piezoelectric 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 $-35^\circ\text{C}$ and $+85^\circ\text{C}$. For example, a 1000 microsecond delay line will change less than $\pm 2$ 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) attenuation 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™

You can be sure... if it's

Westinghouse
When you need die-pressed ceramics, American Lava Corporation has (1) BIG CAPACITY (2) BETTER QUALITY (3) LOW COST (4) DEPENDABLE DELIVERY. Here are a few pictures of our presses, from small tabletting presses and high speed rotaries to 100 ton hydraulics. This equipment, unmatched in the industry, is ready to serve you.

AMERICAN LAVA CORPORATION
51ST YEAR OF CERAMIC LEADERSHIP
CHATTANOOGA 5, TENNESSEE
How much can you expect an oscilloscope camera to do?

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 adapter and motor, universal mount for camera and periscope, binocular split-beam view find.

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 3½ x 4½ and each records two traces exactly one-half life size. Write today for details.
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 2½" x 15" |
| Mounting: Standard relay rock cabinet |
| Weight: 150 pounds |
| Power: 775 watts at full power output, 100 watts standby. The entire unit is rigidly assembled and mounted to prevent overheating 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.
Ohmite offers an unusually complete line of resistors that meet the most rigid requirements (characteristics “G,” “J,” and “F”) of Joint Army-Navy Specification JAN-R-26A. To meet these requirements, resistors must pass severe moisture resistance and thermal shock tests. They are required to withstand strenuous vibration applied for five continuous hours, and satisfy the requirements of many other tests.

Of the 38 different resistor styles listed in JAN-R-26A, Ohmite offers 33 styles that meet these specifications, in a complete range of resistance values.
This New, 12-Page Microwave Components Data Book

Send for Your Copy

Contains diagrams and tables of sizes and types—detailed Government specifications for rigid and flexible waveguides—manufacturing and testing operations.

If you’re working on electronic contracts, this Handbook belongs on your desk. The coupon brings you as many copies as you need.

TITEFLEX, INC.
511 Frelinghuysen Avenue
Newark 5, N. J.

Please send me without cost copies of your new Microwave Components Data Book.

NAME ____________________________
TITLE ____________________________
FIRM ____________________________
ADDRESS ____________________________
CITY __________  ZONE __________ STATE ____________________________
SYLVANIA TUBE SOCKETS
for Rugged Military Service

HIGH QUALITY SYLVANIA SOCKETS IMMEDIATELY AVAILABLE

JAN OCTAL TUBE SOCKETS
Saddles of these sockets are nickel plated brass, either top or bottom mounted, with or without ground lugs. Body and contacts are of the same materials as the JAN miniature tube sockets. Contact tabs and saddle ground lugs are hot tin dipped.

JAN 7- AND 9-PIN MINIATURE TUBE SOCKETS
These sockets are available in grade L-4B or better ceramic, or type MFE low loss plastic. The contacts are either phosphor bronze or beryllium copper, silver plated. Contacts and center shield tab are hot tin dipped. Nickel plated brass shields equipped with sturdy springs are available for all 7- and 9-pin sockets.

BUTTON TYPE SUBMINIATURE (T3) TUBE SOCKETS
These sockets are available for round 8-pin subminiature tube types. Insulation is type MFE low loss plastic and contacts are beryllium copper silver plated with gold flash covering. Contacts especially designed for positive connection and high pin retention even after many insertions. Sockets are of rugged construction for long life.

When you order Sylvania Tube Sockets you get the extra value of Sylvania's experience and know-how at no extra cost. Designed for maximum strength and optimum electrical properties, Sylvania Sockets assure high tube retention and tube pin contact even under severe vibration.

Highest quality is guaranteed by Sylvania's own exacting quality control.

...to Engineers and Scientists

You can now fill vital positions in our guided missile projects

Chance Vought Aircraft, a supplier of high performance Navy aircraft for 35 years, is presently engaged in highly classified work on guided missiles under Navy contract. These missiles are in restricted production for intensive experimental use. They are flying and their performance has been excellent.

Engineering and scientific personnel with backgrounds in Aerodynamics or Electronics will find exceptional opportunities for employment on these interesting projects. Openings are available to personnel with Ph.D. and M.S. degrees, or B.S. degrees with related missile experience.

For further information write Engineering Personnel Section, Chance Vought Aircraft, P. O. Box 5907, Dallas, Texas.
Write today for your
New
ACE SCREEN ROOM GUIDE

This helpful booklet brings you the latest data on shielded enclosure construction, selection and use. Prepared by Ace screen room specialists, it includes latest Ace design features, an analysis of the factors influencing measurements of attenuation versus frequency, and suggestions for assuring maximum shielded enclosure efficiency. Ask for Ace Bulletin No. 3.

ELIMINATE RADIO INTERFERENCE INFLUENCE

in meeting JAN-I-225, MIL-I-6181, 16E4 (SHIPS)
and other stringent specification requirements

As long-time leaders in modern shielded enclosure development, Ace offers a complete range of "cell type" screen room shapes and sizes. Ace rooms are guaranteed to produce a minimum attenuation of 100 db from 0.15 to 1000 mc, and to closely approach this attenuation at 10,000 mc. Supplied in pre-built sectional form, they incorporate the latest developments in door design, line filters and service entrances. The list of Ace users includes top-ranking military and civilian equipment producers and laboratories throughout the world.

KENYON TRANSFORMERS
FOR STANDARD AND SPECIAL APPLICATIONS

For more than 25 years, Kenyon has led the field in producing premium quality transformers. These rugged units are (1) engineered to specific requirements (2) manufactured for long, trouble-free operation (3) meet all Army-Navy specifications.

KENYON TRANSFORMERS FOR
• JAN Applications
• Radar
• Broadcast
• Atomic Energy Equipment
• Special Machinery
• Automatic Controls
• Experimental Laboratories

PROCEEDINGS OF THE I.R.E. December, 1952
WHEN HEWLETT-PACKARD engineers designed the new -hp- Model 624A SHF Test Set they sought a signal source of dependable uniformity, high stability under shock and temperature changes, and smooth, chatter-free tuning. To meet these needs, they selected the Varian V-50 reflex klystron.

WHEREVER these characteristics are required in an x-band oscillator, the V-50 merits your consideration. For applications involving still greater shock and vibration, where single shaft tuning is not required, the extremely rugged V-51 may be more suitable.

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RADIO CORPORATION of AMERICA
ELECTRON TUBES
HARRISON, N. J.

PROCEEDINGS OF THE I.R.E. December, 1952
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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 worldwide 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 have 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. BOYERT

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—the 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: 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? I put it to you 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 mischiefs than to promote self-government.

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 mistakes 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, very good and bad. If rightly used, it is perhaps the chief hope on the material side for the future of mankind.

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 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 scientists 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 manufacturers 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 present a view 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 character 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. Our plea is to 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 too poor or daring to go to public taste. He simply has to make the decision in the last resort. Nevertheless, public reactions
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, 1953.
† 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 task-master 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

I. 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 re-
search 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 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 instrumentality 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 tech-
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 prod-
transmission systems, "vol. 40, the received October by the Institute, May 22, 1952; revised manuscript received October 8, 1952. Presented at the National Convention of the Institute of Radio Engineers in New York, N. Y., March 5, 1952.

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Ideal, 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 rigidly 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 Kilomacycle 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 non-critical 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
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 electrostatic 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).

If the upper conductor is disturbed by moving it upward, the image obligingly 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 correspond to the TEM mode. This has been confirmed approximately by theoretical work and by measurements performed on practical systems comprising composite dielectrics and finite conductor dimensions.

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.

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 1

<table>
<thead>
<tr>
<th>Frequency in mc</th>
<th>Rectangular waveguide</th>
<th>Coaxial line</th>
<th>Wire above ground</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000</td>
<td>Air 0.021, Poly. 0.18</td>
<td>0.041, 0.085</td>
<td>0.018, 0.047</td>
</tr>
<tr>
<td>5,000</td>
<td>Air 0.076, Poly. 0.48</td>
<td>0.099, 0.120</td>
<td>0.058, 0.270</td>
</tr>
<tr>
<td>10,000</td>
<td>Air 0.021, Poly. 0.18</td>
<td>0.041, 0.085</td>
<td>0.018, 0.047</td>
</tr>
</tbody>
</table>

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 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:

\[
Pr = 160 \left( \frac{\pi D}{\lambda} \right)^3 \text{ watts per ampere},
\]

where \( P_r \) is the radiated power, \( D/\lambda \) 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

\[
P_r = \frac{320}{\pi} \left( \frac{\pi h}{\lambda} \right)^2 P \quad Z_0 = \frac{R_0}{2} \frac{Z_0}{\lambda}.
\]

where \( P \) is the power in the line and \( \lambda \) 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 \( h/\lambda \).

### 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. 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

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* A. Alford, U. S. Patent 2,159,648; May 23, 1940.
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**

<table>
<thead>
<tr>
<th>Characteristic impedance</th>
<th>Strip line</th>
<th>Wire above ground</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductor dimensions</td>
<td>50 ohms</td>
<td>0.220 by 0.002 inch</td>
</tr>
<tr>
<td>Copper</td>
<td>0.125-inch diameter</td>
<td></td>
</tr>
<tr>
<td>Ground-plane width</td>
<td>Copper</td>
<td>3 times conductor width</td>
</tr>
<tr>
<td>0.064 polystyrene sheet</td>
<td>Copper</td>
<td>3 times conductor diameter</td>
</tr>
<tr>
<td>Conductor support</td>
<td>Polystyrene bead</td>
<td></td>
</tr>
<tr>
<td>Height above ground plane</td>
<td>0.064 inch</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.024 inch</td>
<td></td>
</tr>
</tbody>
</table>

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**

<table>
<thead>
<tr>
<th>Characteristic impedance of air line in ohms</th>
</tr>
</thead>
<tbody>
<tr>
<td>k/b</td>
</tr>
<tr>
<td>Maximum voltage between conductors</td>
</tr>
<tr>
<td>Maximum power transfer</td>
</tr>
<tr>
<td>Minimum attenuation</td>
</tr>
<tr>
<td>Minimum resonant impedance</td>
</tr>
<tr>
<td>Maximum resonant impedance</td>
</tr>
</tbody>
</table>

For the particular wire-above-ground dimensions given, an estimation of the radiation can be made using (2). For h = 0.025 inch, Z₀ = 50, and λ = 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 circuitry 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. 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.](image)
configuration 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.](image)

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 1/4 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, $4 \times 10^6$ 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, photo-engraving, 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 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, 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 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 sloting 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:

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 chassis 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. RIMA†

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. If the electric field is writ-

ten as \( E(x, y) \) multiplied by factors involving time and the direction of propagation \( \xi \), then \( E(x, y) \) is an electrostatic field.

One may write \( E = -\nabla \phi \), where the scalar potential \( \phi \) satisfies \( \nabla^2 \phi = 0 \) and takes specific values, for example \( \phi_1 \) and \( \phi_2 \), 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

\[
C = q/(\phi_2 - \phi_1)
\]

and

\[
Z_0 = (\mu \epsilon)^{1/2}/C.
\]

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

\[
P = \frac{1}{2} (\frac{q}{\mu \epsilon})^{1/2} \iiint |E|^2 dS = (\phi_2 - \phi_1)^2/2Z_0,
\]

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 from the previously found field for the lossless case.

One may write

\[
\alpha = \frac{P_{c1} + P_{c2} + P_d}{2P} = \alpha_{c1} + \alpha_{c2} + \alpha_d = \alpha_e + \alpha_d,
\]

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

\[
P_e = \frac{\eta}{2} \frac{\epsilon}{\mu} \int |E|^2 ds, \quad \eta = (\pi \mu \sigma_{\xi})^{1/2},
\]

where \( ds \) is an element of length along the conductor boundary, \( f \) is frequency, and \( \sigma_{\xi} \) is conductivity.

The power loss \( P_d \) in the dielectric per unit length along \( \xi \) is given by

\[
P_d = \frac{1}{2} \sigma_d \int |E|^2 dS,
\]

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

\[
\alpha_d = \frac{\sigma_d (\mu \epsilon)^{1/2}}{2}
\]

which is independent of the geometry of the conductors.
The conductivity $\sigma_d$ is obtained from the complex dielectric constant
$$
e' = \epsilon - j\omega = \epsilon(1 - j\sigma_d/\omega), \quad \sigma_d = \omega(\epsilon_i/\epsilon),$$
where the loss ratio $\epsilon_i/\epsilon$ is assumed to be small.

3. Electrostatic Calculations in the Complex Plane

The quantities listed in the previous section require knowledge of $E$ and $\phi$. The method for their calculation followed in this paper uses functions of a complex variable.\(^3\)

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
$$F(z) = \phi(x, y) + j\psi(x, y),$$
where $\phi$ and $\psi$ satisfy the Cauchy-Riemann and Laplace equations. Curves of constant $\phi$ are equipotential lines, and the orthogonal curves of constant $\psi$ are flux lines.

The electric intensity vector $E$ can be represented in complex form by
$$E(z) = -\frac{dF}{dz},$$
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
$$E(z) = -\frac{dF}{dz}(dw/dz) = E(w)dw/dz.$$ (11)
For small elements $|dz|$ and $|dw|$, one has approximately
$$|E(z)|dz = |E(w)||dw|.$$ (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 $\epsilon$ will yield the total charge per unit length along $\xi$, this charge $q$ is found more quickly from
$$F(w) = \phi(u, v) + j\psi(u, v)$$ (13)
by taking $\epsilon$ times the change in $\psi$ 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 $ds_1$ and $ds_2$ be two orthogonal elements at a point $z$ with orthogonal images $dw_1$ and $dw_2$ at the image point $w$. Then $|ds_1| = |ds_2|$ and $|dw_1| = |dw_2|$ are areas of elementary rectangles. If now (12) is written twice for $ds_1$ and $ds_2$ and the results are multiplied, one obtains
$$|F(z)|^2ds_1 = |E(w)|^2dw.$$ (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
$$|F(z)|^2|dz| = |E(w)|^2|dw|\frac{dw}{dz}.$$ (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 $\sigma_e$ 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 shown in Fig. 1. The quantity $a$ is related to height $h$ and radius $b$ by
$$h^2 = a^2 + b^2.$$ (16)
The bilinear transformation
$$z = ja(1 + w)/(1 - w),$$ (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
$$F(w) = (\phi_2 - \phi_1)\ln w/\ln R + \phi_1 = \phi(u, v) + j\psi(u, v),$$ (18)
and leads to the well-known results,
$$\phi = \frac{\phi_2 - \phi_1}{\ln R} \ln r + \phi_1, \quad \psi = \frac{\phi_2 - \phi_1}{\ln R} \ln \theta, \quad w = re^{\theta}.$$ (19)
$$E(w) = -\frac{\phi_2 - \phi_1}{\ln R} \frac{1}{w^2}.$$ (20)
and

\[ q = 2\pi \frac{\phi_2 - \phi_1}{\ln R}, \quad C = \frac{2\pi e}{\cosh^{-1} (h/b)}, \]

\[ Z_0 = \frac{1}{2\pi} \left( \frac{\mu}{\epsilon} \right)^{1/2} \cosh^{-1} (h/b). \] (21)

The radial flux lines are images of

\[(x + a \cot \theta)^2 + y^2 = a^2 \csc^2 \theta. \] (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

\[ k = (\pi - \theta_1)/\pi. \] (23)

It should be noted again that \( k \) is the same in either plane. The choice of several values for \( \theta_1 \) 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 \( \theta \) plane yields

\[ \alpha_e = \frac{1}{2a} \left( \frac{\pi e}{\sigma_e} \right)^{1/2} \frac{1 + \frac{h}{b}}{\cosh^{-1} (h/b)}, \]

\[ \left( \frac{\pi e}{\sigma_e} \right)^{1/2} = \eta \left( \frac{\epsilon}{\mu} \right)^{1/2}. \] (24)

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

\[ \alpha_e = \frac{4.34}{\sigma_0} \eta \left( \frac{\epsilon}{\mu} \right)^{1/2} \frac{1 + \frac{h}{b}}{\cosh^{-1} h/b} \]

in db per unit length.

\[ \eta = \left( \frac{\pi e}{\sigma_e} \right)^{1/2}. \]

\[ h/b = 2.447, \]

\[ (\alpha_e)_{\text{min}} = \frac{1.117}{\sigma_0} \left( \frac{\pi e}{\sigma_e} \right)^{1/2} \text{nepers/meter}. \] (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 \( 4 \times 10^{-4} \) (polystyrene), one obtains

\[ a = 0.0576 \text{ inch}, \quad (\pi e/\sigma_e)^{1/2} = 7.80 \times 10^{-6}, \]

\[ \alpha_e = 0.20 \text{ db/ft}, \quad \alpha_d = 0.09 \text{ db/ft}, \]

\[ \alpha = \alpha_e + \alpha_d = 0.29 \text{ db/ft}, \quad Z_0 = 31 \text{ ohms}. \]

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.

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

\[ \theta_2 \gg \phi_1 \]

\[ \theta_2 \]

\[ \phi_1 \]

\[ \phi_2 \]

\[ \phi \]

\[ \theta \]

\[ \eta \]

\[ \sigma_0 \]

\[ \sigma_e \]

\[ h/b = 2.447, \]

\[ (\alpha_e)_{\text{min}} = \frac{1.117}{\sigma_0} \left( \frac{\pi e}{\sigma_e} \right)^{1/2} \text{nepers/meter}. \] (25)

known 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 total charge on the actual strip is given by
\[
d \text{distribution for the right half of the configuration by assuming that the strip extends to infinity at the left. The field to the left of the line of symmetry through } A \text{ then follows by symmetry.}
\]

The conformal mapping given by
\[
\pi z/h = 1 + w + \ln w \quad (26)
\]
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 \( x \) 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 inexactness of the mapping. The worst inaccuracy is in the region of lowest field intensity.

The complex potential in the image plane is
\[
F(w) = -j \frac{\phi_2 - \phi_1}{\pi} \ln w + \phi_1
\]
\[
= -j \frac{j E_0}{\pi} \ln w + \phi_1 = \phi + j \psi, \quad (27)
\]
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
\[
\pi z/h = 1 + r \cos \theta + \ln r, \quad \pi y/h = \theta + r \sin \theta. \quad (28)
\]
From (27) one obtains for the electric fields
\[
E(w) = -j \frac{E_0}{\pi w}, \quad E(z) = -j E_0 / w + 1. \quad (29)
\]
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
\[
-\pi b/2h = 1 - r + \ln r, \quad \ln r_B/r_A = r_B - r_A. \quad (30)
\]
For large \( b/h \), it is seen that
\[
\ln r_A \approx -1 - \pi b/2h, \quad r_B = \ln r_B/r_A = 1 + \pi b/2h + \ln (1 + \pi b/2h). \quad (31)
\]
The charge \( q_{AB} \) between \( A \) and \( B \) is
\[
q_{AB} = \epsilon (h E_0 / \pi) \ln r_B/r_A.
\]
The total charge on the actual strip is \( q = 2 q_{AB} \).

The characteristic impedance is
\[
Z_0 = \frac{\pi}{2} \left( \frac{\mu}{\epsilon} \right)^{1/2} \frac{1}{\ln r_B/r_A}
\]
\[
= Z_0' / \left\{ 1 + \frac{2b}{\pi b} \left[ \ln \left( 1 + \frac{\pi b}{2h} \right) + 1 \right] \right\},
\]
\[
Z_0' = \frac{b}{b} \left( \frac{\mu}{\epsilon} \right)^{1/2}, \quad (32)
\]
where \( Z_0' \) corresponds to a constant field in the absence of fringing and leakage flux. This result has been derived by Maxwell in terms of capacitance.

A rigorous mapping for the entire strip has been previously used to find the accurate electrostatic distribution and, for \( b \gg h \), gives rise to the result
\[
Z_0 = Z_0' / \left[ 1 + (2h/\pi b)(1 + \ln \pi b/h) \right]. \quad (33)
\]
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.

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
\[
\frac{P_Q}{P} = \frac{\ln r_Q/r_A}{\ln r_B/r_A}, \quad (34)
\]
where \( r_Q < r_B \) corresponds to the second pair of flux lines.

For example, \( r = 1 \) for flux lines leaving the strip edges and \( P_c/P \) is then given by
\[
\frac{P_c}{P} = \frac{-\ln r_A}{\ln r_B - \ln r_A} = \frac{1 + \pi b/2h}{1 + \pi b/2h + \ln (1 + \pi b/2h)}. \quad (35)
\]
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.

6. Wide Strip of Small Thickness Above Infinite Ground

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

\[
\frac{\pi z}{d} = \frac{p + 1}{p'^{1/2}} \tanh^{-1} R + \frac{p - 1}{p'^{1/2}} \frac{R}{1 - R^2} + \ln \frac{R^{p^{1/2}} - 1}{R^{p'^{1/2}} + 1},
\]

where \( R \) and \( p \) are defined by

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

\[
p = -1 + 2\beta^2 + 2\beta(\beta^2 - 1)^{1/2}, \quad \beta = 1 + d/h.
\]

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.

![Diagram](image)

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

\[
E(z) = -j \pi p^{1/2}/[(w + p)(w + 1)]^{1/2}.
\]

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

\[
\pi x/h = 1 + w + \ln w - (w + 1)\delta/2, \quad \delta = p - 1.
\]

The equations for the equipotential and flux lines are

\[
\pi x/h = (1 - \delta/2)r \cos \theta + 1 + \ln r - \delta/2, \quad \pi y/h = \theta + r(1 - \delta/2) \sin \theta,
\]

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

\[
-\pi b/2h = (1 - \delta/2)(1 - r) + \ln r.
\]

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

\[
r = r'(1 + \delta/2).
\]

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

\[
\alpha_1 = \eta \left( \frac{\epsilon}{\mu} \right)^{1/2} \frac{1 + \pi b/2h}{1 + \pi b/2h + \ln (1 + \pi b/2h),} \]

\[
\alpha_2 = \eta \left( \frac{\epsilon}{\mu} \right)^{1/2} \frac{\pi + 1 + \pi b/2h - 2\ln \delta/4}{2h} + \frac{\pi b/2h + \ln (1 + \pi b/2h)}{1 + \pi b/2h + \ln (1 + \pi b/2h).}
\]

![Plot](image)

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

\[
\alpha_c = 8.6859 \frac{\pi (\epsilon/\mu)^{1/2}}{h} \left( \frac{\pi b}{2h} \right)^{1/2} \frac{1 + \pi b/2h + \ln \delta/4 + \ln (1 + \pi b/2h)}{1 + \pi b/2h + \ln (1 + \pi b/2h)} \text{ in } \text{db/ft}. \]

\[
\eta = \left( \frac{\pi b}{a} \right)^{1/2}, \delta = \rho - 1. \quad \rho = -1 + 2\beta^2 + 2\beta(\beta^2 - 1)^{1/2},
\]

\[
\beta = 1 + d/h.
\]

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 \times 10^{-4}.

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

\[
r_A = 2.30 \times 10^{-3}, \quad r_B = 10.92, \quad Z_0 = 45.0 \text{ ohms},
\]

\[
\alpha_{c1} = 0.10 \text{ db/ft}, \quad \alpha_{c2} = 0.20 \text{ db/ft}, \quad \alpha_d = 0.09 \text{ db/ft},
\]

\[
\alpha = \alpha_c + \alpha_d = 0.39 \text{ db/ft}.
\]

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 approximativeness 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

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

where \( \tau \) satisfies

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

The region of the \( w \) plane that is used for final calculations corresponds to \( r_A \leq \tau \leq r_B \).

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 \( P_0/P \) are the same as in the two preceding sections. For \( E(z) \) one now has

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

The equipotential and flux lines are given by

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

Both \( r_A \) and \( r_B \) satisfy

\[
\pi rb/2h = 1/2 - \tau + r^2/2 + (\tau - 1)r - \tau \ln r, \quad (48)
\]

where \( \tau \) is first found from (45).

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

\[
z = (s + 1)/2, \quad j = A(1 + w)/(1 - w) - II, \quad (50)
\]

where

\[
B = b/2, \quad II = 2h, \quad \text{and} \quad A^2 = II^2 - B^2.
\]

The \( s \rightarrow z \) 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 \( t = j(A - II) \) goes into \( w = 0 \) and the circle \( |A| = B \) goes into the circle \( |x| = R \) 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

$$
e_D = R\exp(j\theta _1), \quad w_C = R\exp(-j\theta _1), \quad \tan \theta _1 = A/B. \quad (52)$$

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

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

$$y = -B^2 -(A+H)^2 \rho^2 + 2H\rho (A+H)\cos \theta$$

$$2(A+H) \quad (A_1 - B_1), \quad (53)$$

where $A_1$ and $B_1$ are defined by

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

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

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

$$x_{D'} = -\frac{(II+B)(II^2+HB+B^2)}{2II^3 + 2BH + B^3},$$

$$y_{D'} = -\frac{II^3(I+H)}{2II^3 + 2BH + B^2}. \quad (55)$$

For narrow strips, $II > B$ and $(55)$ reduces to

$$x_{D'} = -\frac{H}{2}, \quad y_{D'} = -\frac{H}{2}. \quad (56)$$

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

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

where $Z_0'$ corresponds to a uniform field between parallel conductors of width $b$ and separation $h$. This result has been published$^{4}$ in terms of capacitance.

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

$$x = -H\cot \theta/2, \quad y = -H/2. \quad (58)$$

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

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.

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 metal-lacquered 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 papers1-3 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, head 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.

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 G1,F 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
wavelength 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, 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. 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.

Fig. 3 shows the variation of $\lambda_0$ 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, $\lambda_0 = \lambda_0$.
2. For a given width of line conductor, $\lambda_0$ decreases as the thickness of the dielectric increases.
3. For a given thickness of dielectric, $\lambda_0$ decreases as the width of the line conductor increases.
4. For a given thickness of dielectric and line-conductor width, $\lambda_0$ decreases as the dielectric constant of the material increases.
5. The ratio of $\lambda_0/\lambda_0$ is not equal to $e^{1/2}$, where $e$ 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 $\lambda_0$. The dielectrics are polystyrene = P, XXXP22 Diclecto = D, G6 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 $\lambda_0$ to the theoretical norm or ideal, $\lambda_{TEM}$. In the case of an infinite-extent polystyrene dielectric, the phase wavelength, $\lambda_0$, 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 \((\lambda_a/\lambda_p)^2\) are \(\epsilon(\text{PL})=1.97, \epsilon(\text{PL}+1)=2.16, \epsilon(\text{PL}+2)=2.21\), and \(\epsilon(\text{PL}+3)=2.25\).

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 \((\lambda_a/\lambda_p)^2\) should approach an \(\epsilon\) 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 \(\epsilon\) (equivalent) is defined as \((\lambda_a/\lambda_p)^2\), Fig. 4 shows that it increases with increasing over-lying layers of dielectric and presumably would eventually approach \(\epsilon\) (polystyrene), a value of 2.55.

D. Dispersion

An item of interest is dispersion,\(^5\) a measure of frequency-rate-of-change of \((\lambda_a/\lambda_p)\) 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 \(\frac{1}{4}\) 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.

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 \(\frac{1}{2}\) - and \(\frac{3}{4}\)-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 \(\lambda_a/\lambda_p\) plays an important part in determining \(Z_a\), the characteristic impedance. Since \((\lambda_a/\lambda_p)\) versus frequency is a constant (over the band shown), then \(Z_a\) 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, \(\frac{1}{2}\)-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.

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 \( \frac{1}{4} \)-Inch 50-Ohm Coaxial Line
Wide-band transitions have been designed to operate in the 4400-to-5000-mc band from \( \frac{1}{4} \)-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.

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 \( \frac{1}{4} \lambda_p \) 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.

![Diagram of transition for a sandwich line and a coaxial line.](image)

**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 $\frac{1}{4}$, $\frac{1}{8}$, 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 $l$, $w$, $W$, and $\theta$, when $h = 0$. Increasing the longitudinal length of the sheet increases the attenuation.

![Diagram of variable attenuator for a wire-above-ground transmission line.](image)

**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 $\theta$. 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.

![Diagram of wide-band fixed-tuned crystal mount for a wire-above-ground transmission line.](image)

**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, $\frac{1}{4} \lambda_0$ 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.

![Diagram of crystal mount for a dielectric-sandwich line.](image)

**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 interfe-
ence 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.

\[
\begin{align*}
&\text{Fig. 14—Two-probe type of directional coupler.} \\
&\text{Fig. 15—The familiar rat race in wire-above-ground and strip forms compared with the coaxial type.}
\end{align*}
\]

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


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.
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

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.

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, varicas, 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† electrostatic accelerator at Los Alamos, N. M.,

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* Decimal classification: 621.375.616. Original manuscript received by the Institute, November 19, 1951. Presented at the IRE Seventh Region Conference of 1951 at the University of Washington. Work done under the auspices of the A.E.C.
† University of California, Los Alamos Scientific Laboratory, Los Alamos, N. M.
‡ William Miller Corp., 325 N. Halstead Ave., Pasadena 8, Calif.
†† 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.)
A Telemetering System for a Large Electrostatic Accelerator*

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

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<table>
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<tr>
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<td>L-</td>
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<tr>
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<td>PHASE (OR LOCK) ANY OF 4 FUNCTIONS</td>
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<tr>
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<tr>
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<td>L-</td>
<td>LEAK HEATER VOLTAGE</td>
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<td>L-</td>
<td>FOCUS VOLTAGE</td>
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<td>SPARE</td>
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<tr>
<td>10</td>
<td>L+</td>
<td>SPARE</td>
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Fig. 3(a)—Control link channel functions.

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<td>10</td>
<td>L+</td>
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Fig. 3(b)—Monitoring link channel functions.
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).

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

**Fig. 11** — Code and channel pulse-timing diagram.
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.](image-url)
This input voltage range causes the phantastron delay to change by a ratio of 1.5/1. Care must be taken to ensure 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.

**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.

**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.

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.

**Phototube Receiver and Amplifier**

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” extraneous...
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. 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.

Fig. 21 — Operation of flip-flops.

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).
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.

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 sig-

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

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

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

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-
frequency 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 incompletely 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.
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 the use of an AR-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. Ultrasonomics 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.
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. 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. 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 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.

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.

![Diagram](image_url)

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 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 \( v(t) + \theta(t) \), where \( \theta(t) \) is the velocity due to the ac fields produced by other charges; i.e., \( \theta(t) \) 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 \( v(t) + \theta(t) \) by adding to the response to \( v(t) \) the response due to \( \theta(t) \). 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 \( \theta(t) \) we consider the charge as smoothed out. Thus, because of this approximation the effect of \( \theta(t) \) 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, 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.

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 \( \omega \). Such an impressed current \( I \), is represented by the integral

\[
I = \frac{e^{i\omega t}}{2\pi} \int_{-\infty}^{\infty} e^{ipz} \frac{dp}{p}
\]

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 field and some convection current. Let the total convection current, including both the total impressed current \( I \), and the convection current excited in the smoothed-out flow, be \( I_c \). Let \( i \) be a component of impressed current which varies with time and distance as

\[
e^{i\omega t} e^{-i\beta z}
\]

This will give rise to some component \( i_t \) of total convection current with the same spatial and temporal variation.

\[
i_t = F(\beta)i. \tag{2}
\]

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

\[
I_t = \frac{ie^{\frac{iu}{c}}}{2\pi j} \int_c \frac{F(\frac{\omega + j\beta}{\nu})}{\beta} e^{(\nu - j(\nu)^*)} d\beta, \tag{3}
\]

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 \( \beta \) rather than \( \rho \) as a variable of integration, giving

\[
I_t = -\frac{ie^{\frac{iu}{c}}}{2\pi j} \int_c \frac{F(\beta)e^{-\frac{iu}{\nu}} d\beta}{(\beta - \omega)} \tag{4}
\]

The contour is now along the real axis of \( \beta \), 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 along frequency \( \omega \), 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 \( i \), of frequency \( \omega \) and propagation constant \( \beta \). For an average charge density of electrons \( dp \) moving with a velocity \( u \) the convection current density \( di \) produced by a field \( E \) having the spatial and temporal variation assumed is

\[
di = -j\omega \left( \frac{\epsilon}{m} \frac{dp}{\epsilon} \right) \frac{E}{(\omega - \beta u)^2}. \tag{5}
\]

Let

\[
dp = \rho_{0}f(u)du, \tag{6}
\]

\[
\int_{u_1}^{u_2} f(u)du = 1, \tag{7}
\]

\[
\omega = \frac{m}{\epsilon}. \tag{8}
\]

Then the total convection current \( i \) produced by the field \( F \) will be

\[
i = -j\omega E \int_{u_1}^{u_2} f(u)du \tag{9}
\]

It is assumed that \( f(u) \) is zero outside of the limits \( u_1 \) and \( u_2 \).

The total convection current component will be

\[
i_t = i_1 - j\omega E \int_{u_1}^{u_2} f(u)du \tag{10}
\]

The total ac charge density \( \rho_t \) will be

\[
\rho_t = \frac{\beta}{\omega} i_t. \tag{11}
\]

From Poisson's equation

\[
\rho_t = -j\epsilon E, \tag{12}
\]

and from (11), (10) and (9)

\[
\frac{i_t}{i_1} = F(\beta) = \frac{1}{1 - \omega^2 \int_{u_1}^{u_2} f(u)du}. \tag{13}
\]

We will now consider a very simple case; that in which

\[
f(u) = \frac{1}{\delta}, \tag{14}
\]

\[
\frac{u_0 - \frac{\delta}{2} < u < u_0 + \frac{\delta}{2}}{u < u_0 - \frac{\delta}{2} \ or \ u > u_0 + \frac{\delta}{2}}
\]

In this case the integral in the denominator of (12) is

\[
\frac{1}{\delta} \int_{u_0 - \frac{\delta}{2}}^{u_0 + \frac{\delta}{2}} \frac{du}{(\omega - \beta u)^2} = \frac{1}{(\omega - \beta u_0)^2 - \beta^2 \frac{\delta^2}{4}}. \tag{15}
\]

This result is certainly valid if \( \omega - \beta u \) is not zero in the range of integration. We can make this so if \( \beta \) is real by allowing \( \omega \) to have a small imaginary part. We see that no matter how we let this go to zero we obtain (15) for \( \omega \) and \( \beta \) real.

Accordingly, the transfer function of (13) will be

\[
F(\beta) = \frac{(\omega/u_0 - \beta)^2 - \beta^2 \frac{\delta^2}{4u_0^2}}{(\omega/u_0 - \beta)^2 - \beta^2 \frac{\delta^2}{4u_0^2} - \omega^2 \frac{\delta^2}{u_0^2}}. \tag{16}
\]

The function \( F(\beta) \) can be written in the form

\[
F(\beta) = \frac{(\beta - \beta_1)(\beta - \beta_2) + (\omega_p/u_0)^2}{(\beta - \beta_1)(\beta - \beta_2)} \tag{17}
\]

\[
\beta_1 = \frac{\omega}{u_0} + \frac{\omega_p}{u_0} \tag{18}
\]

\[
\beta_2 = \frac{\omega - \omega_p}{u_0} - \frac{\omega}{u_0} \tag{19}
\]

\[
\omega_p = \omega \sqrt{1 - (\delta/2u_0)^2((\omega/\omega_p)^2 - 1)}. \tag{20}
\]

From (4) the total convection current is given by
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 \((\delta/2u_0)^2\)—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

\[
\beta_1 = \frac{\omega}{u_0} + \frac{\omega_p}{u_0}, \\
\beta_2 = \frac{\omega}{u_0} - \frac{\omega_p}{u_0}.
\]

We then find that

\[
I_1 = i e^{i\omega t} \left( (\omega_p/u_0)^2 \right) \left( e^{-i\beta_1 z} + \frac{e^{-i\beta_2 z}}{(\beta_1 - \omega/v)(\beta_1 - \beta_2)} \right) + \left( 1 + \frac{(\omega_p/u_0)^2}{(\beta_2 - \omega/v)(\beta_2 - \beta_1)} \right) e^{-i(\omega/v)t}. \tag{23}
\]

We see that

\[
\beta_1 - \beta_2 = 2 \frac{\omega_p}{u_0}, \tag{24}
\]

\[
\beta_1 - \omega/v = \frac{\omega}{u_0} + \frac{\omega_p}{u_0}, \tag{25}
\]

\[
\beta_2 - \omega/v = \frac{\omega}{u_0} - \frac{\omega_p}{u_0}, \tag{26}
\]

where

\[
\epsilon = \frac{v - u_0}{v}. \tag{27}
\]

Now, since \( \delta \) is the total velocity spread among electrons, \( u_0 \) is the average velocity, and \( v \) lies within the range of electron velocities, \( \epsilon \) is of the order of \( \delta/u_0 \) and we should retain powers of \( \epsilon \) up to the first only. To this approximation we obtain

\[
I_1 = i e^{i\omega t} e^{-i(\omega_p/u_0)z} \left( \cos \left( \frac{\omega_p}{u_0} z \right) \right. \\
+ j \frac{\epsilon \omega_p}{\omega_p} \sin \left( \frac{\omega_p}{u_0} z \right). \tag{28}
\]

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 \( \epsilon u_0 \). The expression is valid to the first order in \( \epsilon \).

While (28) is valid to the first order in \( \epsilon \) and in \( \delta/u_0 \), we note that when \( \cos \left( (\omega_p/u_0)z \right) \) is not zero an expansion of the expression for the amplitude of \( I_1 \) in terms of powers of \( \epsilon \) has no term in \( \epsilon \) 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 \( \epsilon \). Thus, for any correct value of the argument which makes the cosine zero, the amplitude is given correctly to the first order in \( \epsilon \). For other values of the argument, for which the amplitude is much larger, the amplitude is not in error to the first order in \( \delta/u_0 \) or \( \epsilon \), though terms in \( \epsilon^2 \) may be in error.

We should note that the special solution has no component of amplitude to the first order in \( \epsilon \).

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 \( \epsilon \) has really been obtained by assuming the velocity distribution to be very narrow. We might infer that to the first order in \( \epsilon \) 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 \( |I_1|^2 \) be the mean square amplitude of the frequency component considered,

\[
|I_1|^2 = \epsilon^2 \left( \cos^2 \left( \frac{\omega_p}{u_0} z \right) + \epsilon^2 \left( \frac{\omega}{\omega_p} \right)^2 \sin^2 \left( \frac{\omega_p}{u_0} z \right) \right). \tag{29}
\]

This is the square of the total current due to an injected current of mean square amplitude \( \epsilon^2 \). Let \( I_s \) be the electron current carried by electrons with velocities in some narrow range about \( u_0 \), a velocity specified by a value \( \epsilon_0 \) of the parameter \( \epsilon \). The impressed noise current \( i_n^2 \) due to this current is taken as shot noise

\[
i_n^2 = 2eI_sB. \tag{30}
\]

At \( z = 0 \), total current must be equal to \( i_n^2 \), so the part of \( |I_1|^2 \) due to electrons in this velocity range must be
\[ |I^2_n| = 2eI_nB \left( \cos^2 \left( \frac{\omega_p}{u_0} \right) \right) \]
\[ + \epsilon_n^2 \left( \frac{\omega}{\omega_p} \right)^2 \sin^2 \left( \frac{\omega_p}{u_0} \right) \right). \tag{31} \]

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

\[ |I^2| = 2eIB \left( \cos^2 \left( \frac{\omega_p}{u_0} \right) \right) \]
\[ + \epsilon^2 \left( \frac{\omega}{\omega_p} \right)^2 \sin^2 \left( \frac{\omega_p}{u_0} \right) \right) \]
\[ I = \sum I_n \] \tag{32}
\[ \epsilon^2 = \frac{1}{I} \sum I_n \epsilon_n^2 = \frac{1}{u_0^2} \sum \frac{I_n}{I} (v_n - u_0)^2 \tag{34} \]

That is, \( \epsilon^2 \) 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

\[ |I^2|_{\text{min}} = \epsilon^2 \left( \frac{\omega}{\omega_p} \right)^2 2eIB. \tag{35} \]

These minima occur at

\[ \frac{\omega_p}{u_0} = \frac{\pi}{2} + n\pi. \tag{36} \]

V. TREATED BY RACK-LEWELLYN-PETERTON METHOD

According to the Rack-Llewellyn-Peterson approach, we assign to the electron convection current passing the grid both a current fluctuation \( \eta^2 \) and a velocity fluctuation \( \nu^2 \). The current fluctuation is just shot noise

\[ \eta^2 = 2eI_0B. \tag{37} \]

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.

\[ I_0 = \sum I_n. \tag{38} \]

Each current \( I_n \) is assumed to have a mean square fluctuation

\[ \eta_n^2 = 2eI_nB. \tag{39} \]

The average velocity \( u_0 \) is

\[ u_0 = \frac{1}{I_0} \sum I_n v_n. \tag{40} \]

The change in \( u_0 \) due to a change \( dI_n \) in \( I_n \) is

\[ du_0 = \left( -\frac{1}{I_0^2} \frac{dI_n}{dI_n} \sum I_n v_n + \frac{v_n}{I_0} \right) dI_n \]
\[ \tag{41} \]

\[ du_0 = \frac{1}{I_0} (v_n - u_0) dI_n. \tag{42} \]

From (42) and (39) we find total mean square fluctuation in the average velocity, which we will call \( \nu^2 \), to be

\[ \nu^2 = 2eB \left( \frac{1}{I_0^2} \sum I_n (v_n - u_0) \right) \tag{43} \]
\[ \nu^2 = \frac{2eB}{I_0^2} \epsilon^2 u_0^2. \tag{44} \]

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 velocity fluctuation initially have their convection currents in phase and the total convection current carried by the pair varies as \( \sin (\omega_p \pm u_0) \).

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 \( \sin (\omega_p\pm u_0) \).

Thus shot noise (37) will excite a noise current in the beam

\[ \eta^2 = 2eI_0B \cos^2 \left( \frac{\omega_p}{u_0} \right). \tag{45} \]

The velocity fluctuation (44) will excite a mean square convection current in the beam

\[ \nu^2 = 2eI_0B \left( \frac{\omega}{\omega_p} \right)^2 \sin^2 \left( \frac{\omega_p}{u_0} \right). \tag{46} \]

The total mean square noise current is

\[ \tilde{t}^2 = \eta^2 + \nu^2 \]
\[ \tilde{t}^2 = 2eI_0B \left( \cos^2 \left( \frac{\omega_p}{u_0} \right) \right)
\[ + \epsilon^2 \left( \frac{\omega}{\omega_p} \right)^2 \sin^2 \left( \frac{\omega_p}{u_0} \right) \right). \tag{47} \]

This has minima at

\[ \frac{\omega_p}{u_0} = \frac{\pi}{2} + n\pi, \tag{48} \]

and the noise current at the minima is

\[ \tilde{t}^2 = 2eI_0B \left( \frac{\omega}{\omega_p} \right)^2 \epsilon^2. \tag{49} \]

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
\[
\frac{\omega_p^2}{\omega_0} = \frac{\pi}{2} + n\pi, \quad (50)
\]
and the noise current at the minima is
\[
\bar{I}^2 = 2e\phi B \left( \frac{\omega}{\omega_p} \right)^2 e^2. \quad (51)
\]

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 \( \lambda \) is the number of cycles drift between a current maximum and a current minimum,
\[
\omega = 4\lambda. \quad (52)
\]

We see that the noise is proportional to the relative mean square velocity spread \( \bar{e}^2 \). Suppose that all electrons are accelerated from the cathode without interaction and by the same dc voltage \( V_0 \). For this case, if \((eV/kT)\gg1\),
\[
\bar{e}^2 = \frac{1}{4} \left( \frac{kT}{eV_0} \right)^2 = \frac{1}{4} \left( \frac{T}{11,600V_0} \right)^2. \quad (53)
\]
This is usually very small. For instance, if
\[
T = 1,160^\circ K, \quad V_0 = 1,000 \text{ volts}, \quad \bar{e}^2 = 2.5 \times 10^{-9}. \quad (54)
\]

We should note, however, that \( \bar{e}^2 \) 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
\[
\bar{e}^2 = \frac{1}{1536\pi^2 e^2(c/m)} \frac{I_0^2}{V_0^2}. \quad (55)
\]

The units are amperes and volts.

A perversity of \( 10^{-4} \), that is, \( I_0/V_0^{0.7} = 10^{-4} \), is a reasonably large perversance. For this value of perversance, from (55)
\[
\bar{e}^2 = 4.78 \times 10^{-4}.
\]

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-Petersen method, is zero.

We can say that at least for the case treated the new method gives the same result as the Rack-Llewellyn-Petersen 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.\(^7\)


\(^7\) 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.
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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 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, \( F \) and Spot Noise Factor, \( F(f) \) is

\[
F = \frac{\int_0^\infty f(f)G(f)df}{\int_0^\infty G(f)df},
\]

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 frequencies 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 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. 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.)


The unknown resistance and reactance are represented by the symbols $R$ and $X$. The two equal capacitive reactances marked $X_e$ 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.

$$B = \frac{I_5}{I_1} \quad (5)$$

and re-arranging as shown in (6) and (7):

$$\left(\frac{R+R_1}{X_e}\right)^2 + \left(\frac{X+X_1}{X_e} - \frac{1}{1-A^2}\right)^2 = \left(\frac{A}{1-A^2}\right)^2 \quad (6)$$

$$\left(\frac{R+R_1}{X_e}\right)^2 + \left(\frac{X+X_1}{X_e} - \frac{1-2B^2}{1-B^2}\right)^2 = \left(\frac{B}{1-B^2}\right)^2 \quad (7)$$

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,

$$(x - x')^2 + (y - y')^2 = r^2, \quad (8)$$

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 $(X + X_1)/X_e = 1$ 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 $(R + R_1)/X_e = 0$. From these three facts it follows that the $A$ and $B$ families of circles are images of each other with respect to the line $(X + X_1)/X_e = 1$ and that each family is the image of itself with respect to the line $(R + R_1)/X_e = 0$. 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 $I_1$, $I_5$, 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 $(R + R_1)/X_e$ and $(X + X_1)/X_e$.
3. Multiply by $X_e$ to obtain $(R + R_1)$ and $(X + X_1)$.
4. Subtract $R$, and $X_1$ to obtain $R$ and $X$. 

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 $X_e$ are the standards.
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 $K_1$ 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.

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

$$A = \frac{I_{L2}}{I_{L1}}$$

and

$$B = \frac{I_{L3}}{I_{L1}}$$

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 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.

![Image](image.png)

**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 ½-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 \( X_2 \), 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.
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.

![Graph](image)

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

$$A = \frac{I_{L2}}{I_{L1}}$$

and

$$B = \frac{I_{L3}}{I_{L1}}$$

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...
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.

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 \( R_i \) and \( X_i \), 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 \( X_i \) and \( X_s \) 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.
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 \( \lambda_c \) is equal to \( 4a \sqrt{\epsilon} \), where \( a \) is the length of each slug and \( \epsilon \) 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 Tomiyyasu.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 \( \epsilon \). 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

\[ Z = R + jX = \cot \theta \]

where \( \theta = \cot \theta \). If \( S \) is the length of transmission line from the load to a voltage minimum, transformed normal.

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malized impedance looking in at this minimum will be

\[ Z_i = R_i = \text{coth} \theta_i = \text{coth} (\rho + j\omega S + j\beta d), \]

where \( \theta_i = \alpha_0 + j\beta_0 \) is the complex propagation constant for an air-filled transmission line, either coaxial or waveguide. Now at a voltage minimum we have \( Z_i = 1/r \), where \( r = \text{VSWR} \), and the phase angle appearing in the hyperbolic cotangent must be \( \pi/2 \). Hence, we may also write \( Z_i = \text{coth} (\rho_i + j\pi/2) = 1/\text{coth} \rho_i = 1/r \). Equating the real and imaginary parts of these relations, we have \( \rho_i = \rho + \alpha_0 S \) 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 \( k = \epsilon + j\beta \) 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 \( Z \).](image)

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:

\[
Z_1 = \text{coth} \theta_1 = \text{coth} (\theta_i + k\omega d) \quad = \text{coth} [\rho_i + \alpha_0 d + j(\pi/2 + \beta_0 d)].
\]

\[
Z_1' = \text{coth} \theta_1' = \sqrt{\epsilon} Z_1 = \sqrt{\epsilon} \text{coth} \theta_i = \sqrt{\epsilon} \text{coth}(\theta_i' + k\omega d).
\]

\[
Z_2' = \text{coth} \theta_2' = \text{coth} (\theta_i' + ka).
\]

\[
Z_3 = \text{coth} \theta_3 = \frac{1}{\sqrt{\epsilon}} Z_3' = \frac{1}{\sqrt{\epsilon}} \text{coth} \theta_2'.
\]

\[
Z_4 = \text{coth} \theta_4 = \frac{1}{\sqrt{\epsilon}} Z_4' = \frac{1}{\sqrt{\epsilon}} \text{coth} \theta_i'.
\]

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 \( Z_i = 1 \).

These eight equations, together with the expression for \( Z \) given previously, may be combined to give:

\[
1 + r \text{coth} k\omega d + \sqrt{\epsilon} r \text{coth} ka + \sqrt{\epsilon} \text{coth} k\omega d \quad = \frac{1 + r \text{coth} k\omega d + \sqrt{\epsilon} r \text{coth} ka + \sqrt{\epsilon} \text{coth} k\omega d}{\sqrt{\epsilon} r + \sqrt{\epsilon} \text{coth} k\omega d + \coth ka + r \text{coth} k\omega d} \quad \text{coth} ka \text{coth} k\omega d - \epsilon \text{coth} k\omega d - \epsilon \text{coth} ka + \epsilon \sqrt{\epsilon} \sqrt{\epsilon} \text{coth} ka \text{coth} k\omega d - \epsilon \text{coth} ka \text{coth} k\omega d + 1 - \sqrt{\epsilon} \text{coth} ka, \quad (1)
\]

where all \( Z \)'s and \( \theta \)'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 \( k_0 = j\beta_0 \), \( \text{coth} k\omega d = -j \epsilon \text{coth} \beta d \), and \( \text{coth} k\omega d = -j \epsilon \text{coth} \beta d \). 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 \( ka = -j \epsilon \text{coth} \beta a \).

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 \( \text{coth} \beta d \). By eliminating \( \text{coth} \beta d \) between these equations, the following quadratic equation in \( r \) is obtained:

\[
r^2 - (b + 2)r + 1 = 0, \quad (2)
\]

where

\[
b = \left\{ \frac{1}{2} \left( \epsilon - \frac{1}{\epsilon} \right) (1 - \cos 2\beta a) \sin 2\beta d \right\}^2.
\]

Solving (2), we have

\[
r = 1 + \frac{b}{2} + \sqrt{b^2 - \frac{b^2}{2},} \quad (4)
\]

Thus the VSWR of the load can be calculated from a knowledge of \( \epsilon \), \( a \), \( \beta_0 \), \( \beta \), and the spacing \( l \) between the slugs when the matched condition is obtained. The constants of the particular slugs used are \( \epsilon \) and \( a \), and, as usual, \( \beta_0 = 2\pi \lambda_0 \) and \( \beta = 2\pi / \lambda \), where \( \lambda_0 \) is the wavelength in the air-filled line and \( \lambda \) is the wavelength in the dielectric-filled line. In the coaxial case \( \lambda_0 \) will be the free-space wavelength and \( \lambda_0' = \lambda / \epsilon \). In the waveguide case

\[
\lambda_0 = \lambda_0' \sqrt{1 - \left( \frac{\lambda}{2w} \right)^2},
\]

(the guide wavelength) and

\[
\lambda_0 = \lambda_0' \sqrt{\epsilon - \left( \frac{\lambda}{2w} \right)^2},
\]

where \( \lambda \) 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:

\[
\cot \beta_0 d = \frac{m}{n} \left( 1 + \frac{m}{n} \sqrt{\left( \frac{2}{n} \right)^2 + \left( \frac{m}{n} \right)^2} \right), \quad (5)
\]

where
The form of (5) gives $\cot \beta d l$ without any ambiguity of sign arising from the radical. Thus, $d$ can be calculated from a knowledge of the same parameters used to obtain $r$.

$$m = \frac{1 + (\epsilon^2 - 1)(1 - \cos \beta d l) \sin \beta d l - 2 \sqrt{\epsilon} (\epsilon - 1) \sin \beta d l}{\sqrt{\epsilon} (\epsilon + 1) \sin \beta d l - 2 \sqrt{\epsilon} \cos \beta d l} \cos \beta d l$$

and

$$n = \frac{1 + (\epsilon^2 - 1)(1 - \cos \beta d l) \sin \beta d l - 2 \sqrt{\epsilon} (\epsilon - 1) \sin \beta d l}{\sqrt{\epsilon} (\epsilon + 1) \sin \beta d l - 2 \sqrt{\epsilon} \cos \beta d l} \cos \beta d l$$

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. 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 $f$. This value of $l$ will be designated $L$. For example, the distance $l$ at the maximum point of the 1.1 curve of Fig. 3 is the $L$ 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

$$\tan \beta d l = \frac{\epsilon + 1}{2 \sqrt{\epsilon}} \tan \beta a,$$

where $\beta$ is dependent on $\epsilon$, being $2\pi \sqrt{\epsilon/\lambda}$ in the coaxial case and $\beta = 2\pi \sqrt{\epsilon - (\lambda/2\omega)^2}/\lambda$ for waveguides. It can be seen from Fig. 3 that there are two values of $l$, $l_1$ and $l_2$ both less than $\lambda/2$, 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-

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 $\epsilon^2$. Fig. 2 is a graph of the effect of frequency variation upon the matching capability of transformers 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 $\beta d l$ for frequencies from 0.5 $f_e$ to 1.5 $f_e$ ($f_e$ being center frequency). A graph of $\beta d l$ versus $\beta d l$ from (6) is shown in Fig. 4. Here, also, $\epsilon = 3$ and the frequency range is from 0.5 $f_e$ to 1.5 $f_e$.

Since the dielectric slugs are required to slide freely in the transformer, they cannot have a perfectly tight fit.
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 \( \beta \) in terms of \( \epsilon \). The resulting transcendental expression can be solved by successive approximations, yielding the “effective” value of \( \epsilon \) for the particular slugs used, taking into account the looseness of the fit. This “effective” value of \( \epsilon \) 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 \( \epsilon \), together with \( a = 3.95 \) cm (as measured for this instrument) were substituted into (3), giving

\[
\sqrt{b} = 1.313 \left( \frac{\pi}{1 - \cos 27.26} \right) \sin \frac{2\pi}{\lambda} \frac{l}{\lambda} \sin \frac{\pi}{\lambda} \frac{l}{\lambda} - 1.143 \sin 27.26 \frac{\lambda}{\lambda}
\]

where \( \lambda \) 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:

\[
\frac{\Delta r}{r} = \frac{\delta}{\rho} \left( \frac{r - 1}{r + 1} \right) \left( \frac{\epsilon^2 + 1}{\epsilon^2 - 1} \right)
+ \frac{\delta^2}{\rho} \left( \frac{r - 1}{r^2 - 1} - \frac{1}{r + 1} \right) \left( \frac{\epsilon^2 + 1}{\epsilon^2 - 1} \right),
\]

where \( \Delta r/r \) is the fractional error in vswr and \( \delta = \rho - 1 \), \( \rho \) 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 \( \pm 2 \) 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 \( \epsilon \) (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

<table>
<thead>
<tr>
<th>Freq mc</th>
<th>vswr by slotted line</th>
<th>vswr by Dbl-slug trans</th>
<th>vswr by slotted line</th>
<th>vswr by Dbl-slug trans</th>
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<td>700</td>
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</tr>
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</table>

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. 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.

Field Strengths Recorded on Adjacent FM Channels at 93 MC Over Distances from 40 to 150 Miles*

G. S. WICKIZER†, SENIOR MEMBER, IRE AND A. M. BRAATEN†, SENIOR MEMBER, IRE

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>
<thead>
<tr>
<th>TRANSMITTER</th>
<th>RECEIVING LOCATION</th>
<th>E₀ db above 1 µv/m</th>
</tr>
</thead>
<tbody>
<tr>
<td>KE2XCC, Alpine</td>
<td>Hauppauge, L. I.</td>
<td>87.6</td>
</tr>
<tr>
<td>KE2XCC, Alpine</td>
<td>Riverhead, L. I.</td>
<td>84.1</td>
</tr>
<tr>
<td>WBZ-FM, Boston</td>
<td>Riverhead, L. I.</td>
<td>74.7</td>
</tr>
<tr>
<td>WBZ-FM, Boston</td>
<td>Hauppauge, L. I.</td>
<td>72.2</td>
</tr>
</tbody>
</table>

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
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 \( \frac{1}{2} \) 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

installed on all except the Alpine receiver at Hauppauge at various times between June, 1949 and January, 1950. However, the Engellard 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.

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.
son 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. 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 compari-

scatterering. 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. 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.

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.

![Graph](image)

**Fig. 12—Analysis of simultaneous hourly variation.**

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.

![Graph](image)

**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.

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 mV 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. 1207, 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 because of focus effects at the edge of the skip distance. 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° and at a distance of 263 degrees from true north. The receiver was a Communications type modified for pulse reception, and a Lorcan 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

* Decimal classification: R113.242. Original manuscript received by the Institute, November 19, 1951; revised manuscript received June 4, 1952.


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
delay times in milliseconds between the transmitted pulse and the earliest peak of energy in the F₂-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-ke 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, 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. 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

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Fig. 1—Normal day record, December 4-5, 1950.

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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.
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 F2 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. 5—Simultaneous plots of field intensity of WWV. Recorded in New Mexico and Sterling, Va. Backscatter delay 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 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 for 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 m sec might be regarded as one-hop ground scatter propagated by F2, and the echoes at about 11 m sec 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 F2 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 F2 skip distance, it is necessary to distinguish, by experience, which group is the ground-scatter group propagated via F2.

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.

Fig. 6—Comparison of estimated and observed failure and recovery times.
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 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 ionospheric 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, 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 F2 layer at high latitudes. The rates of travel are similar to the velocities of irregularities in F2 noted by Munro and others. The F2 scattering regions are apparently identical with Dieminger's G-scatter, 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

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 F2-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 F2-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 of 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 F2-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 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 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 undisurbed 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.
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 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

\[
Z_{0s} = \frac{2}{\sqrt{\frac{4Y_1}{Y_2} + 1}},
\]

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. 2. The series transmission line between shunt obstacles is replaced by its equivalent pi section in which \( \phi \) 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-
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](image)

Fig. 3—The equivalent circuit of a narrower-band filter. $Z_B = -2jZ_{01} \cot \theta x$.

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 Marcuvitz¹ 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 $\theta_2$ and characteristic impedance $Z_{02}$. As the length $\theta_2$ 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 $\theta_1$, 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

$$Y_2 = j \left[ \frac{2}{Z_k} \tan \phi x + \frac{1}{Z_{02}} - \frac{1}{Z_{01}} \cot \theta_1 x \right],$$

(4)

and the image impedance becomes

$$\frac{Z_{1p}}{Z_k} = \frac{1}{B} \left[ \frac{2 \csc 2\phi x}{B} - 1 \right],$$

(5)

The effect of varying $\phi$ is indicated in Figs. 4-8. It is seen that as $\phi$ is increased the primary and first secondary pass bands begin to squeeze the upper primary attenuation band. Fig. 7 is computed for $\phi$ 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 $\theta_1$ controls the lower cutoff frequency of the filter. Beginning with Fig. 4, where $\theta_1$ is 2.2 degrees, Fig. 9 shows the filter behavior for $\theta_1$ equal to 4, 6, and 8 degrees. As $\theta_1$ 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 $\theta_2$ 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 ½ 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

Fig. 4—Calculated image-impedance behavior of a band-pass filter having $\phi = 10^\circ$.

Fig. 5—Calculated image-impedance behavior of a band-pass filter having $\phi = 14^\circ$.

Fig. 6—Calculated image-impedance behavior of a band-pass filter having $\phi = 20^\circ$.

Fig. 7—Calculated image-impedance behavior of a band-pass filter having $\phi = 25^\circ$.

Fig. 8—Calculated image-impedance behavior of a band-pass filter having $\phi = 30^\circ$.

Fig. 9—A family of image-impedance characteristics showing the effect of varying the parameter $\theta_i$. The $\theta_i$ values are $4^\circ$ for curve $a$, $6^\circ$ for curve $b$, and $8^\circ$ 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.

**Experimental Results**

The variation of the lower cutoff frequency of the wide-band filter with the parameter $Z_{41}$ has been shown 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.
- Outer conductor, I.D.
- Length ($\theta$)
- Disc O.D.
- Thickness
- 4-0.010 inch diam. shunt wire, 1/16 inch long.

The effect of the parameter $\phi$ is of interest. Figs. 10, 11, and 12 show the insertion loss versus frequency for $\phi$ 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 $Z_{41}$ and $Z_{42}$ 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 $x_2$,

\[
\frac{Z_4}{2Z_{41}} = \frac{\tan \theta_2 x_1 \left[ \tan \phi x_2 - \frac{2}{\sin 2\phi x_2} \right] - \tan \phi_1 x_1 \tan \theta_2 x_2}{\tan \theta_2 x_1 \cot \theta_1 x_2 - \cot \theta_1 x_1 \tan \theta_2 x_2}
\]

\[
\frac{Z_4}{2Z_{42}} = \frac{\cot \theta_1 x_1 \left[ \tan \phi x_2 - \frac{2}{\sin 2\phi x_2} \right] - \tan \phi_1 x_1 \cot \theta_2 x_2}{\tan \theta_2 x_1 \cot \theta_1 x_2 - \cot \theta_1 x_1 \tan \theta_2 x_2}
\]

![Fig. 10—Experimental insertion-loss characteristic for a 6-section band-pass filter, $\phi = 14^\circ$.](image1)

![Fig. 11—Experimental insertion-loss characteristic for a 6-section band-pass filter, $\phi = 20^\circ$.](image2)

![Fig. 12—Experimental insertion-loss characteristic for a 6-section band-pass filter, $\phi = 27^\circ$.](image3)

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 give a value of about 13 ohms for this parameter.

The parameter $\theta_1$ 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 de-
cided 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. 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. 13](image1.png)

![Fig. 14](image2.png)

**Fig. 13**—Experimental insertion-loss characteristic for a 6-section band-pass filter, $\theta_1 = 8^\circ$.

**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 \( Z_2 \), as shown in Fig. 1. The mesh equations for this network are

\[
\begin{align*}
&\epsilon_1 = +i_1(Z_1 + Z_2 + Z_3) - i_2Z_2 \\
&\epsilon_0 = -i_2Z_2 + i_3(Z_2 + Z_2 + Z_3) - i_3Z_3 \\
&\epsilon_0 = +i_3(Z_2 + Z_3) - i_2Z_2 \\
&\epsilon_0 = -i_2Z_2 + i_6(Z_2 + Z_3)
\end{align*}
\]

From the above it is easily shown that

\[
\Delta = Z_1Z_2(Z_2 + Z_3)(Z_2 + 2Z_2 + Z_4 + 2Z_3) + (Z_1 + Z_2)[Z_2(Z_2 + 2Z_2)(Z_4 + Z_4)] + Z_2Z_4(Z_4 + 2Z_2)(Z_4 + 2Z_3)
\]

The fourth-order determinant \( \Delta \) of the impedance coefficients is

\[
\Delta = \begin{vmatrix}
Z_1 & 0 & -Z_4 - Z_5 & Z_6 \\
0 & Z_0 & Z_6 & -Z_4 - Z_6 \\
Z_5 & Z_2 & Z_2 + Z_4 & Z_2 + Z_4 \\
-3 & Z_3 + Z_3 & -Z_3 - Z_6 Z_3 + Z_3 + Z_4 + Z_6
\end{vmatrix}
\]

The input current \( i_1 \) is, therefore,

\[
i_1 = \frac{Z_0(Z_2 + Z_3)(Z_2 + 2Z_2 + Z_4 + 2Z_3) + (Z_2 + Z_3)(Z_2 + Z_4)(Z_4 + 2Z_3)}{Z_2Z_3(Z_4 + 2Z_2) - Z_3Z_4(Z_2 + 2Z_3)} \epsilon_1
\]

The output current \( i_0 \) is

\[
i_0 = \frac{Z_2Z_3(Z_2 + 2Z_3) + Z_3Z_4(Z_4 + 2Z_6)}{\Delta} \epsilon_1
\]

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As is to be expected, (5) shows that the transfer admittance \( \frac{e_0}{e_1} \) 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 \( Z_3 \) pure resistances,

\[ Z_2 = r, \text{ and } Z_3 = \frac{p^2 r}{2}, \]

and \( Z_3 \) and \( Z_4 \) pure capacitances,

\[ Z_3 = -j\frac{r}{2p}, \text{ and } Z_4 = -jpr, \]

where \( t = \omega_0/\omega \).

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

\[
\begin{align*}
\frac{i_1}{e_1} &= \frac{Z_n}{r} \frac{1 + p^2 (1 - j\frac{r}{2}) + p^2 (2p - j1)(1 - j\frac{r}{2})}{Z_1 + Z_0} \frac{1 + p^2 (1 - j\frac{r}{2})}{1 - 2j\frac{r}{p}} + \frac{Z_n}{r} \frac{1 - 2j\frac{r}{p}}{(1 - 2j\frac{r}{p})} \\
\frac{i_0}{e_1} &= \frac{1}{(Z_1 + Z_0)} \frac{1 - 2j\frac{r}{p}}{2j\frac{r}{p}} + \frac{Z_n}{r} \frac{1 - 2j\frac{r}{p}}{(1 - 2j\frac{r}{p})} \frac{1 - 2j\frac{r}{p}}{(1 - 2j\frac{r}{p})} \\
&= \frac{1}{(Z_1 + Z_0)} \frac{1 - 2j\frac{r}{p}}{2j\frac{r}{p}} + \frac{Z_n}{r} \frac{1 - 2j\frac{r}{p}}{(1 - 2j\frac{r}{p})} \frac{1 - 2j\frac{r}{p}}{(1 - 2j\frac{r}{p})}
\end{align*}
\]

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,

\[ \text{Due to draftsman's error Fig. 2 is incorrect. Lower resistor in Fig. 2 should read } \frac{pr}{2}, \text{ instead of } \frac{2p}{r}. \]

respectively, by the loss at zero frequency,

\[
\frac{e_0}{e_1}_{t=0} = \frac{Z_0}{Z_0 + 2Z_2 + Z_1} \frac{1}{1 + \frac{2r}{p^2} + \frac{Z_1}{Z_0}}
\]

and the loss at infinite frequency,

\[
\frac{e_0}{e_1}_{t=\infty} = \frac{1}{1 + \frac{2Z_1}{r} + \frac{Z_1}{r} + \frac{Z_1}{Z_0}}.
\]

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 \( \omega_0 \), 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.

**Non-Symmetrical Response**

As an example of the nonsymmetrical response, let \( p = 1, Z_0 = z \), 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.

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

\[
Z_1 Z_0 = \frac{2Z_2^2 Z_b}{Z_b + Z_1}, \tag{10}
\]
or

\[
\frac{Z_1 Z_0}{r^2} = \frac{\rho^2}{\rho^2 + 1}. \tag{11}
\]

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 \( \rho \). For reasons given later, interest is largely in the case for which \( \rho = 1 \); 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,

\[
i_0 = \frac{1 - \rho^2}{(Z_1 + Z_0)\left(1 - \rho^2 - 2j\frac{\rho^2 + 1}{\rho}\right) + 2r(1 - \rho^2 - 2j\rho t)}, \tag{12}
\]
and hence,

\[
\frac{e_0}{e_1} = \frac{Z_0(1 - \rho^2)}{[Z_1 + Z_0 + 2r](1 - \rho^2) - 2j\left(2r\rho + [Z_1 + Z_0]\frac{\rho^2 + 1}{\rho}\right)}. \tag{13}
\]

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

\[
\frac{e_0}{e_1} = \rho e^{i\theta}, \tag{14}
\]

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

\[
\theta = \cot^{-1}\left(\frac{1}{t} - 1\right), \tag{16}
\]

where

\[
Q = \frac{Z_1 + Z_0}{r} + \frac{2}{2\frac{\rho^2}{\rho^2 + 1} + 1} + \frac{Z_1 + Z_0}{r} + \frac{4\rho}{r} \tag{17}
\]

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

$$\theta = \cos^{-1} \left( \frac{Z_1 + Z_0 + 2r}{Z_0} \right) \frac{e_0}{e_1};$$

hence,

$$\theta = \cos^{-1} \left( \frac{e_0}{e_1} \right).$$

(18)

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

$$\frac{2}{Z_1 + Z_0} \frac{r}{r} = 2 \frac{Z_1 + Z_0}{r} + 4.$$  

(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

$$Q = \frac{Z_1 + Z_0}{r} + 2 \frac{r}{r} = \frac{Z_1 + Z_0}{r} + 1,$$  

(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 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."](image)

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 = ω_0L/Q, the two circuits have identical amplitude- and phase-frequency characteristics.

![Fig. 6—Symmetrical parallel-T frequency characteristics—normalized.](image)
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.

$$r = \sqrt{\frac{Z_1}{Z_0}}.$$  

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 $\omega_0$. (b) High $Z_1$ and low $Z_0$ which result in a $Q$ of one-quarter and no loss at frequencies removed from $\omega_0$.

The null in the response characteristic falls at the frequency $\omega_0$ 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 $\beta$ 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 the phase shift approaches 90 degrees the transmission approaches a null.

Hastings 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 equation shows, there is a shift in the frequency at the null point. Bowers 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. For

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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. 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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ple 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.

\[
II(p) = \frac{(p + \alpha_1 + j\beta_1)(p + \alpha_1 - j\beta_1)(p + \alpha_2)(p + \alpha_2)}{(p + \gamma_1)(p + \gamma_2)(p + \gamma_3)}
\]

(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 \(II(p)\) as the product of the transfer functions of the lattice and ladder sections as shown in Fig. 1. Choose the transfer functions

\[
II_1(p) = \frac{f(p)}{F(p)} = \frac{(p + \alpha_1 + j\beta_1)(p + \alpha_1 - j\beta_1)(p + \lambda_1)(p + \lambda_2)(p + \lambda_3)}{(p + \gamma_1)(p + \gamma_2)(p + \gamma_3)}
\]

(2)

\[
II_2(p) = \frac{(p + \alpha_2)(p + \delta_1)(p + \delta_2)}{(p + \lambda_1)(p + \lambda_2)(p + \lambda_3)}
\]

(3)

The pair of complex zeros is assigned to \(II_1(p)\), and for reasons to be outlined in the following section, all of the poles of \(II(p)\) are assigned to \(II_1(p)\), 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 (\(\Lambda\)-5). If \(II(p)\) has poles at \(p = -\delta_1\) and \(-\delta_2\), they need not be added; but if \(II(p)\) 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 \(H(p)\) is exactly equal to the total number of poles. The function \(H_2(p)\) is then chosen in such a way that the product \(H_1(p)H_2(p) = II(p)\). Thus the over-all transfer function remains unchanged.

**Step 2**

Identify the transfer function of loaded lattice as

\[
II_1(p) = \frac{f(p)}{F(p)} = \frac{Y_{12}}{Y_{12} + Y_L}. \tag{4}
\]

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

\[^{a}\text{See J. L. Bower and P. F. Ordung, loc. cit., for a more detailed discussion of the synthesis of the loaded lattice RC network.}\]
to the lattice by the following network. Multiply numerator and denominator of (2) by a rational function

\[ G(p) = \frac{1}{(p + \alpha_1)(p + \alpha_2)(p + \lambda_2)(p + \lambda_a)} \]

(5)
in which the poles occur at negative real values of \( p \).

\[ H_1(p) = \frac{f(p)G(p)}{F(p)G(p)} \]

(6)

\[ \frac{(p + \alpha_1 + j\beta_1)(p + \alpha_2 - j\beta_1)}{p + \lambda_2} \]

(7)

\[ \frac{(p + \gamma_1)(p + \gamma_2)(p + \delta_1)(p + \delta_2)}{(p + \lambda_1)(p + \lambda_2)(p + \lambda_3)(p + \lambda_a)} \]

Since the product \( F(p)G(p) = Y_{21} + Y_L \) 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 \( \lambda_a \) should be within the interval given by (A-3). The numerator and the denominator of (6) may be written as

\[ Y_{12} = \frac{(p + \alpha_1 + j\beta_1)(p + \alpha_2 - j\beta_1)}{p + \lambda_a} \]

(7)

\[ Y_{21} + Y_L = \frac{(p + \gamma_1)(p + \gamma_2)(p + \gamma_3)(p + \delta_1)(p + \delta_2)}{(p + \lambda_1)(p + \lambda_2)(p + \lambda_3)(p + \lambda_a)} \]

(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

\[ Y_{12} = \frac{p\kappa_1^{(n)}}{p + \lambda_a} \quad Y_{21} + Y_L = \frac{p\kappa_1^{(d)}}{p + \lambda_a} \]

\[ \frac{p\kappa_2^{(d)}}{p + \lambda_1} + \frac{p\kappa_2^{(d)}}{p + \lambda_2} + \frac{p\kappa_3^{(d)}}{p + \lambda_3}, \]

(9)

where the \( \kappa \)'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 \( Y_{21} \) and \( Y_L \) by the expressions

\[ Y_A = Y_{21} + Y_{12} \quad Y_B = Y_{21} - Y_{12} \]

(11)

In the synthesis, \( Y_L \) is allotted all of the expansion of \( Y_{21} + Y_{12} \), and 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

\[ Y_L = k_0^{(d)} - k_0^{(n)} + \frac{p\kappa_1^{(d)}}{p + \lambda_1} + \frac{p\kappa_2^{(d)}}{p + \lambda_2} + \frac{p\kappa_3^{(d)}}{p + \lambda_3} \]

\[ + \frac{p}{p + \lambda_a} \]  \( k_a^{(d)} + k_a^{(n)} \)

(12)

and lattice elements are obtained by means of (11) as

\[ Y_A = 2k_0^{(n)} + 2p \]

(13)

\[ Y_B = -2p k_a^{(n)} \]

(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 \( Y_{21} \).\(^8\)

---


\(^7\) 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 \( k < 1 \), and the result yields \( k_0^{(d)} = k_0^{(n)} \) and the \( p \) terms become unequal. See Bower and Ordung, (3) and (10).

fact, the pole at \( \lambda_b \) 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

\[
Y_L = Y_c + Y_D.
\]  

(15)

The synthesis of a ladder network that will realize the desired transfer function has been described in detail elsewhere,\textsuperscript{9,10} hence, a brief description of the process will suffice at this point. A set of 1-sections that may be connected in cascade to approximate the desired \( H_1(p) \) is selected from a catalog of RC networks.\textsuperscript{9} The types of sections chosen should introduce the desired zeros of \( H_1(p) \), 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 \( H_1(p) \) 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 \( Y_{11} \) (see (4) and (7)) should contain only one internal pole. Since \( Y_{11} \) 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

\[
H_1(p) = \frac{h(p + \alpha_1 + j\beta_1)(p + \alpha_1 - j\beta_1)}{(p + \delta_1)(p + \delta_2)}
\]  

(16)

for frequencies on the \( \omega \)-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 \( \delta_1 \) and \( \delta_2 \) are chosen in the manner specified by expressions (A-5) and (A-6). If \( \delta_1 \) does not have the exact value specified by (A-6), the transmission level will be unity at either zero \( (h = \delta_2/\alpha_1^2 + \beta_1^2) \) 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 \( \lambda_1 \), \( \lambda_2 \), and so on in \( H_1(p) \), (2), is placed near each of the poles \( \gamma_1 \), \( \gamma_2 \), and so on, the zero-pole diagram shows that for frequencies on the \( \omega \)-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 \( \omega \)-axis. As the zero-pole separation is made smaller, the zero and pole more nearly cancel each other.\textsuperscript{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 \( Y_{12} \) and the level of transmission will not be reduced appreciably below that for the unloaded lattice.\textsuperscript{10}

3. The pole \( \lambda_b \) of \( Y_{12} \) is one of the poles of \( G(p) \), and should be chosen within the interval defined by (\( \lambda - 3 \)) in the appendix. This restriction on the range of \( \lambda_b \) is necessary to insure that the transmission level of the lattice will not have to be reduced in order to yield positive residues for \( Y_1 \) and \( Y_2 \).\textsuperscript{9} Furthermore, if the value of \( \lambda_b \) 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 \( \lambda_b \) will then not appear in \( Y_L \).\textsuperscript{11}

4. The poles of \( G(p) \) are the poles of \( Y_{12}^* Y_{11} \). The pole \( \lambda_a \) is the pole of \( Y_{12} \), and it may also appear in \( Y_{11} \) and \( Y_c \). The other poles \( \lambda_1, \lambda_2, \) 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 \( \gamma \) 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 \( \lambda_a \)'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 \( \lambda_1, \lambda_2 \), 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 \( \lambda_b, \lambda_1, \lambda_2, \) and so on of \( G(p) \) must alternate with the poles \( \delta_1, \delta_2, \) and \( \gamma_1, \gamma_2, \) 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.


\textsuperscript{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 \( Y_{11}, Y_{22}, \) and \( Y_{12} \). Suppose that \( Y_{12} \) and \( Y_{22} \) are specified quantities and that the magnitude of \( Y_{11} \) can be varied. The admittance \( Y_L \) has a phase angle within the same quadrant as the phase angle of \( Y_{12} \). Since \( Y_{12} \) and \( Y_{22} \) are both nonvanishing for frequencies on the \( \omega \)-axis, it follows that

\[
|Y_{12} + Y_{22}|_{|\omega| > \omega_0} > |Y_{11}|_{|\omega| > \omega_0}.
\]

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 \( Y_{12} = Y_{22} \), the ratio of output-to-input voltage is reduced to one half that which occurs when \( Y_{12} \) is negligible compared to \( Y_{22} \). In other words, for the level of transmission through the lattice not to be severely penalized, it is necessary that

\[
|Y_{12} + Y_{22}|_{|\omega| > \omega_0} > |Y_{22}|_{|\omega| > \omega_0}.
\]

Example

The method of synthesis will be demonstrated by means of the following example:

(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:

\[
\begin{align*}
0 &< \delta_1 < 2.02, \\
9 &< \delta_2 < \infty.
\end{align*}
\]

\( H(p) \) contains poles within the permitted range for \( \delta_2 \); hence, one of these poles in \( H(p) \) can be assigned as \( \delta_2 \). \( H(p) \) does not contain a pole within the range of \( \delta_1 \); 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 \( \delta_1 \) and \( \delta_2 \) 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:

\[
\begin{align*}
H_1(p) &= \frac{(p + 3 + j3)(p + 3 - j3)(p + \lambda_1)(p + \lambda_2)}{(p + 2)(p + 8)(p + 9)(p + 10)(p + 11)}, \\
H_2(p) &= \frac{(p + 2)(p + 3)}{(p + \lambda_1)(p + \lambda_2)(p + \lambda_3)}.
\end{align*}
\]

Step 2

The function \( G(p) \) is now chosen as

\[ G(p) = \frac{1}{(p + \lambda_1)(p + \lambda_2)(p + \lambda_3)(p + \lambda_4)}. \]

The pole \( \lambda_4 \) associated with \( Y_L \) of the lattice structure is chosen by means of expression (A-3) as

\[ \lambda_4 = 5. \]

The remaining poles of \( G(p) \), \( \lambda_1 \), \( \lambda_2 \), and \( \lambda_3 \), should be chosen to cancel approximately the poles at \(-8, -9, \) and \(-10\) in \( H_2(p) \) 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, the poles and zeros of \( Y_{11} + Y_L \) 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 \( \lambda_1, \lambda_2, \) and \( \lambda_3 \) 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](image)

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 \( \lambda \)'s are found to be

\[
\begin{align*}
\lambda_1 &= 8.4, \\
\lambda_2 &= 9.2, \\
\lambda_3 &= 10.1.
\end{align*}
\]

Thus, the values of \( G(p), H_1(p) \) and \( H_2(p) \) are obtained as

\[
\begin{align*}
G(p) &= \frac{1}{(p + 5)(p + 8.4)(p + 9.2)(p + 10.1)}, \\
H_2(p) &= \frac{(p + 2)(p + 3)}{(p + 8.4)(p + 9.2)(p + 10.1)}.
\end{align*}
\]

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 \( Y_{11} \) and \( Y_{11} + Y_L \) are obtained as


\[
Y_{12} = -\frac{2.6p}{\rho + 5} + p + 3.6
\]

\[
Y_{12} + Y_L = \frac{2.96589\rho}{\rho + 5} + p + 4.05879
+ \frac{0.16448\rho}{\rho + 8.4} + \frac{0.08943\rho}{\rho + 9.2} + \frac{0.02136\rho}{\rho + 10.1}.
\]

**Step 4**

All of \(Y_{12} + Y_L\) 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

\[
Y_L = \frac{0.45879\rho + 0.16448\rho + 0.08943\rho + 0.02136\rho}{\rho + 8.4} + \frac{p + 9.2}{\rho + 10.1}.
\]

\[
Y_A = 2p + 7.2
\]

\[
Y_B = \frac{5.2p}{\rho + 5}.
\]

The elements of the lattice may now be obtained from \(Y_A\) and \(Y_B\) as shown in Fig. 6.

**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.

\[
Y_c = \frac{0.36589\rho}{\rho + 5}
\]

\[
Y_D = \frac{0.45879 + 0.16448\rho + 0.08943\rho + 0.02136\rho}{\rho + 8.4} + \frac{0.02136\rho}{\rho + 10.1}.
\]

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 \(\lambda\) been chosen at the point where \(H_2(p) = -1\). Thus the final network would have had one less capacitor and one less resistor than the circuit shown in Fig. 8.

**Fig. 7**—Bridged-\(T\) equivalent to the lattice.

**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

$$H(p) = \frac{h(p + \alpha + j\beta)(p + \alpha - j\beta)}{(p + \delta_1)(p + \delta_2)}. \quad (A-1)$$

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 in Fig. 9.

The two limiting values given for $\lambda_a$ in expression (A-3) are the values where $H(p) = -1$. For values of $\lambda_a$ between these values, $|H(p)| < 1$. The interval for $\lambda_a$ must, of course, be real. This requires that the quantity under the radical shall be equal to or greater than zero. Thus

$$(2\alpha + \delta_1 + \delta_2)^2 - 8(\alpha^2 + \beta^2 + \delta_1\delta_2) \geq 0. \quad (A-4)$$

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 $\delta_1$ and $\delta_2$ are obtained as follows:

$$0 \leq \delta_2 \leq \frac{2\sqrt{\alpha^2 + \beta^2} - \alpha - \sqrt{(2\sqrt{\alpha^2 + \beta^2} + \alpha)^2 - (\alpha^2 + \beta^2)}}{\delta_1} \quad (A-5)$$

$$\delta_1 = \frac{\alpha^2 + \beta^2}{\delta_2} \quad (A-6)$$

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

AARON D. BRESLER†, ASSOCIATE, IRE

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, 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

\[
A(w) = -20 \log \sigma_p - 10 \log \left(1 + \frac{f/f_0}{2}\right)^2 \text{dB, (1)}
\]

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.](image)

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.

![Fig. 2 — Zero-pole pair on the real \( p \) axis.](image)

In terms of the parameters \( \alpha, \beta, \) and \( d \) (defined in Fig. 2), the function \( Z(p) = (p + \sigma_0)/(p + \sigma_p) \) is, at \( p = jw \), given by

\[
Z(j\beta) = \left(\alpha - \frac{1}{2}\right) + j\beta
\]

\[
Z(j\alpha) = \left(\alpha + \frac{1}{2}\right) + j\beta
\]

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
\[ A(\beta) = 10 \log \frac{\beta^2 + (\alpha - \frac{1}{2})^2}{\beta^2 + (\alpha + \frac{1}{2})^2} \text{ db.} \quad (3) \]

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.

At this point the slope of \( A(\beta) \) is a maximum and is given by
\[ S = 3.01/\alpha \text{ db/octet.} \quad (4) \]

The remaining parameters noted in Fig. 3 are given by
\[ .1_0 = 20 \log \frac{\alpha + \frac{1}{2}}{\alpha - \frac{1}{2}} \text{ db} \quad (5) \]
\[ \beta_1^2 = \beta_2 \beta_3 = (\alpha^2 - \frac{1}{4}) \frac{\beta_3}{\beta_2} = \left[ \frac{\alpha + \frac{1}{2}}{\alpha - \frac{1}{2}} \right]^{2n} \quad (6) \]

\[ \epsilon = 10 \log \frac{\beta_2^2 + (\alpha + \frac{1}{2})^2}{\beta_2^2 + (\alpha - \frac{1}{2})^2} \text{ db.} \quad (7) \]

III. The Associated Phase Functions

The phase angle, \( \phi(w) \), of \( Z(p) \) at \( p = jw \) is given by
\[ \phi(\beta) = \tan^{-1} \frac{\beta}{(\alpha - \frac{1}{2})} - \tan^{-1} \frac{\beta}{(\alpha + \frac{1}{2})} \quad (8) \]

A typical \( \phi(\beta) \) curve is illustrated in Fig. 5. The maximum occurs at the frequency corresponding to \( \beta_1 \); its value is
\[ \phi_m = \frac{1}{2} \pi - 2 \tan^{-1} \left[ \frac{\alpha - \frac{1}{2}}{\alpha + \frac{1}{2}} \right]^{1/2} \quad (9) \]

To facilitate sketching of phase function associated with a given line segment, \( \phi_m \) and \( \phi_2 = \phi(\beta_2) = \phi(\beta_3) \) have been computed and are shown as functions of \( \alpha \) in Fig. 5.

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, \( \epsilon \), the zero frequency decrement, \( A_0 \), and all phase function values are multiplied by \( n \). The critical frequency points, \( \beta_1, \beta_2, \) and \( \beta_3 \), 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 $|\phi(w)| \leq 90$ degrees for all $w$. If $Z(p)$ is a rational function having $n_z$ zeros and $n_p$ poles, this last condition requires that $|n_z - n_p|$ 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 $\alpha \geq \frac{1}{2}$. For $n > 1$, $Z(p)$ is realizable only for $\alpha \leq \alpha_n$ where $\alpha_n$ is that value of $\alpha$ for which $\phi_n = 90^\circ/\pi$. A maximum permissible slope, $S_m$, corresponds to each $\alpha_n$, and this may be shown to be

$$S_m = 3.01\pi/\alpha_n = 3.01\pi \left[ \frac{\sin (\pi/2n)}{\pi/2n} \right] \text{db/oct.} \quad (10)$$

For large $n$, $S_m$ approaches the limiting value of 9.45 db/oct. 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 $\phi_n$ of that segment about 25 per cent of the value of $\phi$, for each of the two immediately adjoining segments. When this estimate reveals that $\phi$ 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. 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

$$\varepsilon^e = Z_i/R,$$  \quad (11)

where $Z_i$ 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, $\varepsilon^e$ must be restricted as follows:

$$|\varepsilon^e| \geq 1 \quad (at \; p = jw).$$  \quad (12)

In addition, since the restrictions on $\varepsilon^e$ are essentially those on $Z_i$, the zeros of $\varepsilon^e$ 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 $\varepsilon^e$ 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, 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.

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 $Z_i$ and $Z_2$ are inverse. The insertion loss of these ladder sections is

$$\varepsilon^e = 1 + Z_i/R. \quad (13)$$

---


Then, \[ Z_1/R = R/Z_2 = \varepsilon - 1. \] (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 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 \( \varepsilon \) satisfy all the restrictions previously imposed but \( \varepsilon \) must satisfy the additional restriction

\[ \text{Re}[\varepsilon] \geq 1 \quad \text{at} \quad p = jw. \] (15)

A necessary, but not sufficient, condition for the realizability of an insertion-loss function in a constant-resistance ladder configuration is that \( \phi < 90^\circ \) at \( p = jw \). For example, where a zero-pole pair with \( n > 1 \) is required, it is necessary that \( a > a_\phi \), where \( a_\phi \) is again that value of \( \alpha \) for which \( \phi_n = 90^\circ/n \). In other words, for \( \alpha > a_\phi \), with \( a_\phi \) given by

\[ 1/a_\phi = 2 \sin \left( \pi/2n \right), \] (16)

a constant multiplier, \( k \), can always be found such that the real part of the function

\[ \varepsilon = k \left[ \frac{\rho + a_\phi}{\rho + a_\phi + a_\phi} \right]^n \] (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.

### Table I

<table>
<thead>
<tr>
<th>( S )</th>
<th>( n )</th>
<th>( \alpha )</th>
<th>( \beta_1 )</th>
<th>( f_1 )</th>
<th>( d )</th>
</tr>
</thead>
<tbody>
<tr>
<td>dB/oct</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>10.0</td>
<td>2</td>
<td>0.6</td>
<td>0.079</td>
<td>6200</td>
</tr>
<tr>
<td>2.</td>
<td>0.75</td>
<td>1</td>
<td>4.0</td>
<td>1.45</td>
<td>830</td>
</tr>
<tr>
<td>3.</td>
<td>0.76</td>
<td>1</td>
<td>4.0</td>
<td>1.45</td>
<td>110</td>
</tr>
</tbody>
</table>

The two low-frequency sections, corresponding to \( S_1 \) and \( S_2 \), 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

\[ \varphi = \left( \frac{p + 12\pi \times 10^4}{12\pi \times 10^4} \times \frac{p + 17.3 \times 10^4}{p + 1.57\pi \times 10^4} \right)^2, \quad (18) \]

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

\[ Z_1 = \frac{\rho^2 + \rho (29.3 - 12k)10^5 p + \rho^2 (107.6 - 18.8k)10^8}{12\pi \times 10^4 (p + 1.57\pi \times 10^4)}, \quad (19) \]

from which it is clear that the maximum value of \( k \) which will yield a physical network is \( k_{\text{max}} = (29.3 - 1.57)/12 = 2.31 \). For this value of \( k \), (19) reduces to

\[ Z_1 = \frac{1}{27.7\pi \times 10^4} \left[ p + \frac{64.1\pi \times 10^8}{p + 1.57\pi \times 10^4} \right], \quad (20) \]

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.

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 \( \rho \) 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.

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 Tarco, 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 1915. He was a Lieutenant in the 1st Battalion, A.I.F., during World War I.

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 Relations 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.

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

Aaron D. Bresler (S'43–M'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 Training 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. 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 postgraduate 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.

Dr. Cline is a member of Eta Kappa Nu, Sigma Xi, and A.IEEE.

Laurence G. Cowles (A'31–M'36–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.

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 ubf standards and associated problems.

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.

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.

E. 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.

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 plaque 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."}

The above is a member of Sigma Xi, and a fellow of the A.IEEE.
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. 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 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. 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. 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 a graduate assistant in the Physics Department at Pennsylvania State College.

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. 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.

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. degree from the Polytechnic Institute of Brooklyn in 1942. From 1938 to 1944, he taught applied mathematics and science in the New York City school system.

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 21, 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. 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 photographs 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. 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. From 1936 to 1940 Dr. Mode was a research and development engineer with the General Electric Company. In 1940 he became an instructor in the Electronics Laboratory at the University of Pennsylvania, 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. Ording (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.

Dr. Ording 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.

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.

Mr. Sparrow attended General Motors Institute for a year, then he joined the U.S. 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 uhf and vhf regions and development work on direction-finding, frequency measurement, receiving antennas, and field strength measurement.

Mr. Wickizer is a member of Eta Kappa Nu, the American Geophysical Union, and the American Meteorological Society.

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 Silverstein, see page 1000 of the August, 1952 issue of the PROCEEDINGS OF THE I.R.E.
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.

**General**

\[ V_{en} = I_e \left[ (r_e + r_b + R_b + R_e) \right. \frac{(r_b + R_b + R_b + r_m)}{r_b + r_e + R_b + R_e} \left. \frac{(V_{ce} + I_{ce}(r_e - r_m))}{r_b + r_e + R_b + r_m} \right] \]

Approximate Short Circuit Case

where

\[ r_b \ll R_b; \quad r_e, r_m \ll R_b; \quad R_b \ll r_e, r_m; \quad R_e = R_e = 0; \quad I_{ce}(r_e - r_m) \ll V_e \]

**Region I**

\[ V_i \approx I_e r_f' + \frac{V_e R_b}{R_b + r_e} \]

**Region II**

\[ V_i = I_e R_b (r - \alpha) + \frac{V_e R_b}{R_b + r_e} \]

**Region III**

\[ V_i = I_e (r'' + r'' - r_m'') + V_e \]

\[ I_{ip} = 0; \quad V_{rp} = \frac{V_e R_b}{R_b + r_e} \]

\[ I_{ci} = \frac{V_e}{R_b(1 - \alpha)}; \quad V_{ci} = V_e \left[ 1 + \frac{r'' + r'' - r_m''}{R_b(1 - \alpha)} \right] \]

\[ V_{ip} = \frac{R_b + r_e}{V_{ip}} \]

---

Fig. 17—Synopsis of emitter negative resistance characteristic and properties.
General

\[ V_{cc} + I_{co}(r_c - r''') = \]
\[ I_c \left[ r_e + r_c + r_b + r_b - \frac{(r_b + R_b)(r_b + R_b + r_m)}{r_e + r_i + r_b + R_b} \right] \]
\[ + \frac{1}{r_c + r_e + r_b + R_b} \]

Approximate Short Circuit Case

where \( R_e = R_i = 0; \ r_b \ll R_b; \ I_{co}(r_c - r''') \ll V_{ce}, \ R_b \ll r_m, \ r_c \)

Region I

\[ V_c = I_c (r_c + R_b) + V_e \frac{R_b}{r_e} \]

Region II

\[ V_c = I_c (r_c + R_b) + V_e \frac{r_m + R_b}{R_b} \]

Region III

\[ \frac{V_c}{I_c} = I_b (r_b + r_i + r_c + R_i) + I_c (r_c + R_c) \]
\[ V_{ce} + I_{co}(r_c - r''') = I_b (r_c + R_c - r_m) + I_c (r_c + R_c - r_m) \]
\[ V_{be} = V_b \left[ r_b + R_b + R_c + r_c - \frac{(r_c + R_c)(r_c + R_c - r_m)}{r_e + r_i + r_c + R_c - r_m} \right] \]
\[ + \frac{V_{ce} + I_{co}(r_c - r''')}{r_c + r_i + r_c + R_c - r_m} \]

Approximate Short Circuit Case

where \( R_e = R_i = 0; \ I_{co}(r_c - r''') \ll I_c; \ r_c \ll r_c(1 - \alpha) \)

Region I

\[ \frac{V_b}{I_b} = I_b \left( \frac{r_b'}{r_e + r_b'} \right) + \frac{V_i'}{r_e' + r_c} \]

Region II

\[ \frac{V_b}{I_b} = I_b \left( \frac{r_b + r_i}{r_c(1 - \alpha)} \right) + \frac{V_i'}{r_c(1 - \alpha)} \]

Region III

\[ V_b = V_i' + V_c \]
\[ I_{bp} \approx V_e \quad V_{bp} = 0 \]
\[ I_{bn} \approx V_e \left[ 1 - \frac{1}{r_c} \right]; \quad V_{bn} = V_c \left( 1 - \frac{(\alpha - 1)r_k'''}{r_c} \right) \]
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 committee 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 communication1 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 out2 that the telepathic properties are closely connected 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 telepathic 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 10^4, 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 information3 via the particle.

On the other hand, Hammond's suggestion becomes attractive if the neutrino is delegated an active part in the postulated telepathic 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

\[ \int d\psi \psi^* H \psi \]

where \( U \) is energy and \( \psi \) and \( \psi^* \) 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 magnitude that is equal and opposite to 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.

Martin Rudderfer
517 150 St.
Kew Gardens Hills
L. I., N. Y.

*Original manuscript received by the Institute, July 15, 1951.
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; Broad 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.
- J. P. Arnaud
- B. B. Bauer
- J. W. Bell
- L. J. Black
- H. G. Bookner
- W. E. Bradley
- J. L. Callahan
- K. A. Chittick
- A. A. Collins
- E. U. Condon
- W. W. Eitel
- Harry Faulkner
- E. B. Ferrell
- W. R. Ferris
- L. R. Fink
- L. R. Hafstad
- F. Hamburger, Jr.
- L. B. Heurdick
- P. J. Herbst
- John Hessell
- H. E. Hollmann
- T. A. Hunter
- E. J. Ishiber
- 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. FSI, Definitions of Wave Guide Terminology.

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 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 Grapical Symbols for Semi-conductors, 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 would be necessary to submit a report 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 or computer work or if the components used in this work are ade-
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. Atley reported on the recent activities of the Subcommittee on Video Utilization. These papers and a report on this report are a submission 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. Atley 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 are not available. J. Battersby 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 decision. The Video Techniques Committee now consists of 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 4,013 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.

A questionnaire, sent out to the rank of instructors, and engineers from all sections of the country, asked for their opinions concerning the conference. The questionnaire was completed by 1,825 of the attendees.

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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 (of small speakers), the Hartley-Turner speaker and “fofle,” the Permaphon 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 of Sound Transducers,” was presented by R. 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 car 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-YHF 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 Hazleton Corporation, spoke on color TV. The second chapter meeting was held recently at Huntington Hall, Massachusetts Institute of Technology. A paper entitled, “TV Interference—An Approach to Interference,” 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 Baldwin, of that organization. Bimonthly meetings will be held by this Group under the Chairmanship of P. K. Baldwin.


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 special 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 Telemetor Corporation. Mr. Brown described the advantages and requirements of a subscription television system and some of the international Telemetor’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 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 sonometry, by Gordon Koonett.

Notices

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 in radio and television, 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: Vice Chairman, E. L. White, and Secretary, M. E. Florogel. 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 $1.50 for members AIEE, ASME, AIEE, ASME, AIEE, ASME, AIME, AES, and AIP, and $50.00 for nonmembers. Single lectures are $1.00 for members of the aforementioned 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, by E. T. Canby, record critic, Radio Engineering; P. Miller, music director, New York Public Library.


January 5, 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 Homer 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.
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 1933, 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. Ombreg (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. Ombreg 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. Ombreg 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 Signal Corps, and then became associated with the Bendix Radio Division as chief research engineer.

Mr. Ombreg 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.

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 Schenningen, 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.

Leonard R. Kahn (SM’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.

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.

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 pianoforte tones, acoustics and acoustic measurements. Dr. Knoblaugh holds various patents in his field.

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.
Musical Engineering by Harry F. Olson
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 make the title of this book difficult to give since it 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, reflection, diffraction, sound source, and standing waves. A review of reflection notation is pre- sented in the second chapter. Such definitions as the wall, 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, electronic-thermo-electrical-analytical techniques, resonance of strings, bars, membranes, and plates, and the behavior of air in pipes, acoustic 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 musical 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, growth of time, duration, growth of decay, vibrato, beats, consonance and dissonance, volume, presence, measurement of musical aptitudes, and hearing loss.

The book then continues on to theatres, television, recording systems, 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. BATE
Stere Brothers, Inc.
Chicago, III.

Correction

The review of "The Oxide-Coated Cathode," by G. Hermann and S. Wagen, which appeared on page 880, of the July, 1952 issue of the Proceedings, stated that "pore conduction" was not mentioned in the text. The text 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 inNearly Perfect Crystals, Symposium Edited by W. Shockley, J. H. Holomon, R. Maurer, and F. Seitz
Published (1952) by John Wiley and Sons, Inc., 440 Fourth Ave., New York 16, N. Y. 809 pages + 14-page index and tables. 312 figures 31 X 9.5 cm.

W. Shockley is a member of Bell Telephone Laboratories, Inc.; J. H. Holomon 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 imperfection 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 contained in this volume.

The book is divided into four sections and contains the following individual papers:


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 the 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 provide 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
Sylvania Electric Products Inc.
Bayville, N. Y.

Electronics for Communications Engineers by John Markus and Via Zeluff


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.
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 electronic circuitry and a thorough grounding in 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 of solution. 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, and phase 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 servomechanism problem, a trajectory computation, and the solution of aircraft flight equations are presented in some detail.

The next chapter deals with 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 compensation for computer 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 computer systems; most of these systems are briefly mentioned, and a few important systems are not covered. Also, comparison with digital computer circuits 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 four without destroying the continuity of the material.

John R. Whinney
Hughes Aircraft Company
Culver City, Calif.

Electronic Analog Computers by Grano An. Korn and Thomas M. Korn

Printed Circuit Techniques: An Adhesive Tape Resistor System, NBS Circular 530, by B. L. Davis

B. L. Davis is a member of the electronic division of the National Bureau of Standards.

This is a detailed report of 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 work 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 laying 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, the 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 50 hours at one-fourth watt load in an ambient temperature of 200°C with less than one percent change in resistance, and can be used at higher wattage ratings in lower ambient temperatures. 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 may be obtained in practice. The resistance of the film is more 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 percent of the desired value. Accuracy of the finished resistor depends also on accurate placing of the silver terminals on the base plate, particularly the length of the conducting path between them. Use of 0.35 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
General Radio Company
Cambridge, Mass.
The number in heavy type at the upper left of each Abstract is its Decimal Classification number, and is not to be confused with the Dewey 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.

ACOUSTIC AND AUDIO FREQUENCY

534.22-16: 539.217.1


534.23-31-13-14

Second-Order Acoustic Fields: Relations between Density and Pressure—J. J. Markham. (Phys. Rev., vol. 86, pp. 719-721; June 1, 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

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

The Economic Generation of Ultrasonic Oscillations for Industrial Purposes by means of Electroacoustic Transducers—H. H. Rust. (Elektrochem., vol. 73, pp. 251-262; April 15, 1952.) As an alternative to a tube-driven ultrasonic generator, which is not considered economical, it is proposed to use a simple type of quenched-spark generator with either a magnetostriiction or a capacitive type of oscillator, a rectifier being used in the latter case to furnish a dc charging current.

534.520

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 \( r / \delta \), where \( r \) is the distance from the edge, \( \delta \) the velocity of sound and \( t \) the time. The scattered wave is determined by reducing the original equation to Laplace's equation, with the aid of a Tschuplyev transformation, and applying Poisson's formula to the secular domain cut out of the circle \( r < \delta \) by the wedge. The result appears in a form simpler than that previously obtained by Sommerfeld.

534.321-9-14: 534.6

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 (1902 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

Design and Analysis of Subjective Acoustic Experiments Which Involve a Quantal Response—D. L. Richard. (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 telephone circuits.

534.6


534.76

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; previous 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 audition of acoustical conditions in existing theaters; the loudness difference between the two ears makes no significant contribution to the accuracy of sound location.

534.827


534.84

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 flexural and for in-plane 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

The Correlation Coefficient as a Criterion of the Acoustic Quality of a Closed Room—S. G. Cernyeman. (Z. tech. Phys., 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

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 less than 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' hotel, Bonn, and the theater, Hanover, are described.

534.843

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 eigenfrequencies. A general picture is obtained of the relative importance of the various modes. High-frequency eigenfrequencies are relatively unimportant.
621.305.615:621.385.5

Simultaneous Generation of Several Audio-Frequency Oscillations by means of Electron Coupling in a Multi-Electrode Valve—Spengler and Rust. (See 3044.)

621.305.623.7

The Loudspeaker with Phase Reversal II. Gempeler. (Elektrotechn., vol. 73, pp. 339-342; vol. 73.) Theory of the action of loudspeakers with phase reversal is based on the evolution of the principles of the mechanical system. The theory is applied to the design of a loudspeaker 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.

621.305.625.3


621.305.625.3:108.2

Classification of Magnetic-Recording Tapes—F. Grimmelsdorff and W. Guckenberg. (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.

621.305.92

Transmission 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

621.315.2:621.379.5

An Improved Television Camera System—(Engineer) (London), vol. 19, p. 171-174; May, 1952.) A brief description of the "Polypole III" coupling, which is smaller and lighter than earlier types, up to 36 circuits are provided for. The overall diameter is 8.2 inches; unit lengths can be combined as required.

621.315.212

Calculation of the Transmission Character-istics of Rotationally Symmetrical Connecting Units for Coaxial Cables from the Properties of Plane Electrostatic Fields.—H. H. Meinke and A. Scheurer. (Arch. elektr. Übertrag., vol. 15, pp. 521-527; May, 1952.) Analysis shows that every rotationally symmetrical unit has an analogous plane representation which has nearly the same transmission characteristics and admittance. A novel calculation of this plane representation has been made, and the results are presented 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.

621.315.212:621.317.34

Measurement of the Attenuation and Characteristic Impedance of Transmission Lines. Tests on Coaxial Cables—Honto. (See 3109.)

621.317.017:621.311.02

The Radiation Resistance of Resonant Transmission Lines—R. A. Chipman, 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 was described. The radiation resistance is obtained as the difference between the radiation resistance value found for the same resonant section unshielded and shielded; it is independent of line length and top diameter, and its value is approximately 120 Ω for (d/λ), where d is the separation of the rods.

621.317.24+621.315.212.018.44

Experimental Verification of the Theory of Laminated Conductors.—H. L. Black, C. O. Mallinckrodt and S. P. Morgan, Jr. (Proc. IRE, vol. 40, pp. 902-905; August, 1952.) To test Clogston's theory (1951), an experimental coaxial line was constructed with a laminated conductor. The phase velocity of the transmitted wave was varied by introducing TiO2 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.

621.317.2

Steady-State Waves on Transmission Lines—D. L. Waldick (Traw. Amer. IRE, vol. 69, part II, pp. 1521-1524; 1952.) 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.

621.317.2:621.306.113.39


621.317.26

Symmetrically Placed Inductive Inputs in Rectangular Waveguides—H. H. Gruenberg. (Can. Jour. Phys., vol. 30, pp. 211-217; May, 1952.) An expression is derived for the susceptance of a symmetrically placed loops in a rectangular waveguide. The curves are drawn that are valid for all rectangular guides in the normal operating range, for different post diameters and offsets from the guide walls. Satisfactory agreement was obtained between calculated values and measurements at wave-lengths of 10.7, 4.74 and 3.2 cm.

621.320.26

Dominant-Wave Transmission Characteristics of a Multimode Round Waveguide—A. L. King, L. P. Field and J. W. (Proc. IRE, vol. 40, pp. 966-969; August, 1952.) In the 4-km 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.

621.320.26:621.315.61

Dielectric Image Line—D. L. King. (Jour. Appl. Phys., vol. 23, pp. 609-700; June, 1952.) A modification of the dielectric rod waveguide investigated by Chandler (1950) and Ehrenson (1950) is discussed; it consists of a rod with a dielectric medium 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 propagation of a polystyrene line of diameter 0.42 cm on an image plane of width 20 cm, for use at 1.23-cm wavelength.

621.390.67


621.390.67

Radiation Characteristics of a Turnstile Antenna Shielded by a Section of a Metallic Tube Closed at One End—A. Babo, Jr., D. D. Saxon and L. L. Hallin. (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 wires being excited by voltages with a 90° phase difference. The wave-guide is first considered to be infinitely long, and the condition is determined under which only one mode, the TE10 mode is important. The case is then considered in which the semi-infinite waveguide, excited in the TE10 mode, radiating into free space. Using a solution found by Levine and Schwinger (1943) for the problem of radiation from a line lying on the field line of a uniform magnetic field, values of radiation 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.

621.390.67

The Radiation Resistance of a Dipole near an Ellipsoid of Revolution with Good Conductivity—R. G. Mirimanov. (Compt. Rend., Acad. Sci. (U.S.S.R.), vol. 80, pp. 189-192; September 11, 1951.) In the general case 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.

621.390.67:621.390.933.1

Cage-Type Very-High-Frequency Phase-Comparison omnidirectional Radio Antennas—Lucas and Guehler. (See 3087.)

621.390.67:621.306.112.21

Self and Mutual Interferences of Parallel Identical Antennas—A. King. (Proc. IRE,}
1952

Abstracts and References

1745

vol. 40, pp. 981–988; August, 1952.) A method is presented in which the impedance of an ideal dipole 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 to be in numerous curves.

621.306.677

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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—J. Klein-werth (Zeitschrift für Telegraphie, 6. p. 247–253; June, 1952.) Many different methods have hitherto been used for determining the radiation characteristics of different types of antennas, but it has so far not been 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.

621.306.677v.029.63

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 of the following ultra high transmitting antennas for operation in the frequency band 500–900 mc; (a) a cylindrical multi-slot antenna, (b) an inverted turnstile antenna, and (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 structural problems. The use of quadrature feed facilitates the matching of input transmission lines, the maintenance of equal division of power in the radiated beam, and the complexing of two signals into a common antenna.

621.306.677


621.306.677

Relay Aerials for the Demicell Wave-band—G. Voigt. (Zachr Tech., vol. 2, pp. 108–112; April, 1952.) An estimate is made of the efficiency of a pair of mutually coupled, two-turn, toroidal relay antennas, and possible substituting consists of retracting prisms are described. One of these consists essentially of a pair of thin glass plates, the diaphragms 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.

621.306.677

Lattice Lenses for Centimetre Waves—J. Coussngue. (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 equipotential planes normal to the axis. The total number of Kirchhoff’s particles required is much less than the number used in a lens of the artificial-dioptric type. Resonant λ/2 di-
621.302


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The magnitudes can be varied by altering the slope of the frequency-dependent characteristic. The magnitude and frequency dependence of the resistive and reactive components are calculated for various possible arrangements, and the design of the phase-shifting networks with discussion on the effects produced by departure of the phase shift from its nominal value.

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621.302

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, rectance, or variable resistance is considered. Reactance-tube arrangements with high values of inductance and very low values of capacitance are attainable.

621.302

Equivalence of the Analysis of Circuits with Static 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 connected in parallel 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 i and v generators. Calculations for a type-13TH crystal diode in parallel with a 50-ohm resistor are reported.

621.302


621.302


621.302

A New Approach in the Design of Equalized Filters and Delay Lines—M. E. Levy. (Jour. Brit. Inst., vol. 12, pp. 317–320; May, 1952.) The phase characteristics of filter networks and delay lines can be equalized by the use of coupling transformers with capacitors. The corresponding 6th-order equations are difficult to solve, but an approach which considers the transient response yields a simple solution. See also British Patent No. 61720 and Abstract 1746 of 1948 (Eleyope).

621.302

Quadruple Theory, a Fresh Approach—M. Skolicky. (Elektrotech. u. Maschinenb., vol. 69, no. 202, May 15, 1952.) The network equations of Wilbertz (see 1566 of 1948 (Skolicky)) are developed for a quadruple 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.

621.302

Equivalent Circuits of the Nonreversible Quadruple—W. Klein. (Arch. elekt. Ubertragung, vol. 6, no. 6, pp. 205–208; May, 1952. Corrections, ibid., vol. 6, p. 351; August, 1952.)

621.302

Schul’s network (Wilbertz’s network, a monograph) is extended to obtain generalized theory for quadrupoles violating the reciprocity relation. The equivalent circuit of the nonreversible quadruple is derived from the equivalent diagram of a T and II circuit by introducing a coupling element termed a "dual converter" ("Duddler-setzer") comprising three ideal tubes and a complex impedance. This circuit element is also useful in designing transformers with complex ratio transformation. The admittance matrix of the quadrupole can also be used for deriving an equivalent circuit.

621.302

Equalization of Resonators—I. Paghis. (J. R.E.E., vol. 95, no. 2, pp. 279–293; May, 1952.)

621.302


621.302


621.302


621.302

The effective reactance of the transformer is the result of the transformer being used at the ends for conversion from electrical to mechanical oscillations and vice versa. Theory is based on purely mechanical considerations. The analysis is extended to include the dimensions and physical constants of the rods. Comparison is made with equivalent electrical-network filters. The advantages and disadvantages of both forms are discussed. The method is described in detail and illustrated with examples.

621.302

Study of a Narrow-Band Electromechanical Filter—A. Muro. (Tech. Mitt. Schweiz. Telegr.-Telephonw., vol. 30, no. 4, pp. 1–5; 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 sliding past one another without any of the transformers being used at the ends for conversion from electrical to mechanical oscillations and vice versa. Theory is based on purely mechanical considerations. The analysis is extended to include the dimensions and physical constants of the rods. Comparison is made with equivalent electrical-network filters. The advantages and disadvantages of both forms are discussed. The method is described in detail and illustrated with examples.

621.302


621.302

Study of the effects produced by departure of the phase shift from its nominal value.

621.302


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The effective reactance of the transformer is the result of the transformer being used at the ends for conversion from electrical to mechanical oscillations and vice versa. Theory is based on purely mechanical considerations. The analysis is extended to include the dimensions and physical constants of the rods. Comparison is made with equivalent electrical-network filters. The advantages and disadvantages of both forms are discussed. The method is described in detail and illustrated with examples.
skin resistance of brass was determined at microwave frequencies by means of Q measurement of oscillatory circuits with the 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
The Frequency Spectrum of a Pulled Oscillator—T. J. Buchanan. (Proc. I.R.E., vol. 40, pp. 938-961; August, 1952.) Experiments were described in which a signal from a Type-217678 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 is placed part of the output to a crospectrometer, the effect of varying the klystron wavelength around the center value of 3.2 cm. being studied. A frequency-multiplying circuit theory previously worked out by Aitken (2522 of 1946).

621.396.615.029.3: 621.385.5
Simultaneous Generation of Several Audio-Frequency Oscillations by Means of Electron Coupling in a Proportioned Valve System. H. H. Rust. (Arch. elektr. Übertragung, vol. 6, pp. 254-261; June, 1952.) A frequency multiplier is described which produces, at different fundamental frequencies, a higher of the reference 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
A High-Frequency Generator with Uniform RC-Line as Feedback Element determining the output power from the generator range of oscillatory circuits essential agreement with the theory generally worked out by Aitken (2522 of 1946).

621.396.615.1: 621.385.3

621.396.615.1: 621.316.729
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.) The circuits were designed for an anode modulation single-loop magnetron, with load matched to the transmission line and the synchronization current injected at a plane distance 0.1 cm. from the magnetron. The effect of phase modulation during the A1 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 effect of rp h m is about 20° for an AM factor of 0.74.

621.396.615.1: 621.029.63
5348 The Effect of Magnetic and Harmonic Generation at V.E.F. and U.E.F.—D. H. Preist. (Tele-Techn. vol. 11, pp. 60-61, 123; April, 1952.) Description of the performance of tetrodes such as Type 6146 A and Type 4X150; with positive feedback, for frequency multiplication at high power levels.

621.396.619.13: 621.392.5
Contribution to the Theory of Frequency-Motion in Microwave Liners. L. Kosten. (Tijdschr. med. Radioingen., vol. 17, pp. 117-133; May, 1952.) By using the concepts of negative resistance and inductance, a microwave circuit can be transformed into one containing no capacitances, whose operation can then be expressed by first-order differential equations. Matrix theory is used in connection with this transformation to determine the output current of a linear quadrupole fed with a frequency-modulated wave. The formula derived is a series differing from those of Lighthill (1938) and Stemmer (2221 of 1947) in that it is convergent and contains finite differences rather than derivatives of the transmittance.

621.396.645
Effective Bandwidth of Video Amplifiers—F. T. Tischer. (Arch. elektr. 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 from practical amplifiers and what improvement can result from compensation of the phase errors.

621.396.655.731
Negative Feedback—W. O. Baldwin. (Proc. Radio Club Amer., vol. 29, pp. 3-11; 1952.) The use of negative feedback for amplifier circuits is considered in the gain and improvement of frequency response and phase characteristics is considered, frequency and phase characteristics being especially dealt with, since they are known the gain and distortion characteristics can be quickly calculated. A particular feature of the treatment is the use of contour charts showing the reciprocals 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.

630.162: 519.21
A Generalization of the Classical Random-Walk Problem, and a Simple Model of Brownian Motion in a Liquid. H. J. Zehnder. (Proc. Roy. Soc. Edinb., vol. 63, part 3, pp. 268-279; 1950/1951.) A precise mathematical model of Brownian motion is described by introducing a "resistance factor" into the random walk problem. This is equivalent to the assumption of a discrete velocity distribution of three varieties 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
The Velocity of Light determined by the Balanced Electron Mach-Zehnder Interferometer, R. P. Ruth and K. L. Vander Sluys. (Phys. Rev., vol. 86, p. 799; June 1, 1952.) Preliminary account of a determination based on observations of the 103 and 004 lines of HCN; the value of c obtained is 299776 ± 7 km.

535.372+535.215

535.376
Electroluminescence observed in the Anodic Polishing of Zinc—M. Krieg and E. Lane. (Naturwissenschaften, vol. 39, p. 208; May, 1952.)

535.42-535.56
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 disturbance 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 (2660 of 1956); the second problem is treated in a similar manner, using a Tschuplygin transformation to reduce the boundary-value problem to one in potential theory, which is then solved by classical methods.

535.421: 538.566
Electromagnetic Reflection and Transmission by Graffiti of Resistive Wires—E. A. Lewis and J. P. Case, Jr. (Jour. Appl. Phys., vol. 23, pp. 605-608; June, 1952.) Homogenizer'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.

535.111-537.312.62
The Physical Mechanism of Charge in Solid Dielectrics—H. Bonifas. (Rev. gen. Elect., vol. 61, pp. 223-231; May, 1952.)

535.122
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 1957), two new field variables being introduced. The theory allows vorticity in the electron stream, while still involving e and in the relativistic formulation of the equations is deduced.

535.311.1+537.312.62
The High-Frequency Resistance of Metals in the Normal and Superconducting State—C. J. Grebenenkenper 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 interpretation of the interface resistance is investigated. Results for the metals in the normal state support the Reuter-Sondheimer theory of the anomalous skin effect for the superconducting state if the resistance varied with frequency according to a 1/2-power law rather than the theoretically predicted square law.

535.311.001.1

535.312.6: 621.315.592

535.325: 538.56

535.252: 538.63

535.525: 621.396.822
Served at and below 2 mC, in several types of siss, indicated 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.

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.

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 density in which ionization by stages is important. By taking account of recombination, this theory can be applied to neutral- and high-pressure arcs with high density ionization. The theory includes the effect of a longitudinal magnetic field.

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-balace 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 is presented. The effect will tend to a limit with sufficiently strong fields. Part I: 3066 above.

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-balace 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 is presented. The effect will tend to a limit with sufficiently strong fields. Part I: 3066 above.

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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.

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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.
Abstracts and References

1952

methods of investigation from Franklin's time to the present-day. 51 references.

LOCATION AND AIDS TO NAVIGATION

621.306.9

Some Modern Developments in Receiving Equipment for Shipboard Use—C. B. Broersma (Tijdschr. med. Radiooe. Scient., vol. 17, pp. 139-145; May, 1952. Discussion, pp. 145-146.) Postwar developments for marine receiving equipment are described. Current trends are toward greatest possible simplicity and toward the use of large crop 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 kw.

621.306.9: 621.306.825

Echo and Noise in a Radar System subjected to Deliberate Interference—T. Tiberio. (Alia Frequenza, vol. 21, pp. 137-141; 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 in the field of jammers. Formulas are developed to minimum detection range possible for a given ratio of jammer to radar power.

621.306.9: 621.306.002.2

The Engineering of Radar Equipment 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.

621.306.932

The Measurement of Angles by Direction-Finding Technique—W. M. Mersenn. (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 radio localization systems, with indication of the limitations imposed by the antenna characteristics.

621.306.322


621.306.932

Microphone Lighthouse—A. Roberts. "Naval News," Radio-Electronic Eng. Section, vol. 47, pp. 6-7, 31; (1952.) Description of a cheap and simple navigation aid for small ships. The 3-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 receiver is integral with a parabolic-cylinder antenna, and has a crystal detector; its sensitivity is such that a signal of duration 1 μs and power 10^-4 w. can be heard above receiver noise. An accurate fix on the shore station can be obtained.

621.306.932: 933 (43-15)

Integration of the Recently Installed Air Navigation Safety System of the Federal German Republic with the Existing West European Telefunker System—C. Sci. (Elektrotechn. u. Maschinenw., vol. 69, pp. 203-207; May 1, 1952.) The principles of the Deca system are outlined and the services provided. The Telefunker 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 sypropola system zone to within about 4 m. The master transmitter at Madfeld, Westphalia, operates on a frequency 6.7 from which are derived, by frequency division and multiplication, frequencies 960, 970, and 596 of the three slave transmitters, which are symmetrically located round the master transmitter at a distance of from 100 km. Detection is accomplished by frequencies of 2460, 1830, and 9600 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. Stanby Diesel generators are used, with battery feed during the starting-up period. See also 1923 of August.

621.306.033: 657.7

The Application of Telecommunications to Civil "Airways"—D. F. Taylor. (Jour. Brit. Inst. Radio Eng., vol. 29, pp. 174-176; May 1952.) An account of the development of facilities for promoting safety and regularity in civil aviation 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. Details of the requirements for a multi-channel VHF R/T system, using area-coverage networks, and of the microwave ranges and beacons and VHF fan markers. References are included to more detailed accounts of individual features of the system.

621.306.033: 621.306.67

Cage-Type Very-High-Frequency Phase-Comparison Omnidirectional Range Antenna—F. J. Lombardi 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 core 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 high and 11 feet above the ground. Details are given of the tone wheel and magnetic pickup that provide the fixed-phase reference signal.

621.306.033: 621.317.79

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 ground equipment (2513 of 1950) (Hamphire 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 modulated low-frequency signals by 90- and 150-cs tones. Sources of error and means adopted for reducing them are discussed. In the SR 14, localizer receiver, ac is derived at the output of a two-stage amplifier controlled by a neon reference tube. In the SR 15, glide-slope receiver an audio type of ac is used. An output line is given of portable field test equipment designed to test the receiver circuits, including a pickup, filter and rectifier circuits on one crystal-controlled channel in the localizer and glide-slope frequencies. RF circuits are checked by functional tests.

621.306.93

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]
530.17
530.17 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, pp. 555; July 1, 1952.) The spectra were examined over the temperature range 20°C–60°C, they are characterized by a sharp absorption "edge" coincident with the long-wave limit of the photoconductivity of each material.

535.37
530.18

535.37: 546.412.84
530.19
530.19 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 510 of 1950.

535.372
531.10
531.10 Luminescence of Alkaline Sulphides and Sulphates—I. Gobrecht and D. Hahn. (Z. Phys., vol. 132, pp. 111–128; April 10, 1952.) By reduction of the alkaline sulphates, materials are obtained giving red or blue luminescence when excited by Hg radiation of wavelength 365 mm or 254 mm. The red luminescence is due to the production of polysulphides, the blue to alkaline atoms in the sulphate lattice. Investigations of the luminescence spectra at different temperatures are described and discussed.

537.226: 546.311.88
531.11 Ferroelectric Properties of Tantulates and Niobates of Alkaline Metals—V. V. Kovzhennikova and A. I. Medovoi. (Zh. Tekh. Fiz., vol. 21, pp. 133–136; November, 1951.) The temperature dependence of the dielectric constant and coefficient of linear expansion was investigated for certain tantulates and niobates of alkaline 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 compared to those obtained by Matthews (Phys. Rev., vol. 75, p. 1771; 1949) and by Matthias and Reineka (3023 of 1951).

537.226.2
531.12
531.12 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
531.13

537.312
531.14
531.14 Measurement of the Resistance of Thin Insulating Layers between Gold Contacts with the Range of the Tunnel Effect—I.

538.221: 546.217–228
531.19
531.19 Calculation of the Magnetic Skin-Effect in Sheet Permalloy and Determination of its Characteristic Parameters—A. A. Silvarts. (Zh. Tekh. Fiz., vol. 21, pp. 1393–1310; November, 1952.) The usual equation (1) of the hysteresis loop is valid only for the case of a quasi-static 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 account taken of the structure. A new method is proposed for separating the losses in sheet materials, and an experimental determination of the parameters of sheet permalloy is reported.

538.221: 546.217–228
532.001.3

538.221: 553.841
532.11
532.11 Eddy Currents in Solid Cylindrical Cores Having Nonuniform Permeability—H. Aspden. (Jour. Appl. Phys., vol. 23, pp. 310–328; 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: 553.15.24.198
532.12
532.12 Study of a Ferronickel Alloy of Very Low Strain Energy in Steady and Alternating Magnetic Fields—J. Ebeloh and G. Gilardin. (Comp. Rend. Acad. Sci. (Paris), vol. 234, pp. 1860–1862; May, 1952.) Discussion of measurements on very thin unaligned strip, the thickness of which was successively reduced electrolytically, which is subsequent annealing in an atmosphere of Hz.

538.221: 553.01.8
532.13

538.221: 546.726.3
532.14
532.14 Thermomagnetic Study of a Single Crystal of FeOa—L. Nico and R. Poussenert. (Comp. Rend. Acad. Sci. (Paris), vol. 234, pp. 2172–2174; May 26, 1952.) Measurements of the magnetization of a natural single crystal of FeO2 are shown graphically for the temperature range 20–90K. A discontinuity is observed at about 250K.

539.234: 553.311: 546.92
532.15
532.15 Electrical Conductivity of Thin Deposits of Platinum on Dielectric Layers evaporated in Vacuo—C. Feldman. (Comp. 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 CaF2 is much higher than that of Pt films on glass. The difference is not so great for films of layers of SiO. An explanation is suggested.

546.217: 621.317.355.3.20.64
532.16
532.16 The Dielectric Constant of Dry Air—J. H. V. Hughes and H. L. Armstrong. (Jour. Appl. Phys., vol. 23, pp. 301–304; May, 1952.) Measurements by a two-cavity method similar in principle to the previous two-cavity methods of Hughes 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 1947) was found to be too high because of insufficient drying of the air.

546.23: 553.323 + 553.343
532.17
532.17 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 1–2.5µ. 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 (1031 of May).

546.24: 553.311 + 553.632
532.18
532.18 The Hall Effect and Electrical Resistivity of Tellurium—V. E. Bottom. (Science, vol. 115, pp. 570–571; May 23, 1952.)

546.24: 553.632
532.19

546.24: 621.314.632
532.20
532.20 Contact Rectification with Tellurium—J. 523. Contact Rectification with Tellurium. (Jour. Appl. Phys., vol. 13, p. 308; May, 1952.) Spectroscopic measurements have been made of mean rectified current and upper-limit value of reverse voltage for single-crystal and polycrystalline specimens of Te
Graphical presentation and discussion of measurements on various sulphides in the temperature range 0–100°C.

5.46.817.221+5.46.817.231+5.46.817.241

537.311.33

1340


5.48.0:537.221.1+5.390.32

1341

The Elastic Constants of Piezoelectric Crystals—R. F. S. Hearmon. (Brit. Jour. Appl. Phys., vol. 3, pp. 134–136; May, 1952.) A direct mechanical method and an electrical method have been used to determine the bulk-strength of crystals of NaClO₃, NaBrO₃, ADT, and LiSO₄. Results are tabulated. New measurements on quartz crystals are used to check the methods. A formula for the current due to the piezoelectric polarization is given which covers the longitudinal flexural, corner, and thickness modes of vibrations. The calculated maximum safe currents are tabulated for resonators of various materials and cuts.

5.40.211:621.375.3

1343

The Dielectric Constant of Diamond—F. P. Pietermaat, W. van Dyck and F. de Keuster. (Ulf (Brussels), vol. 3, 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.

5.40.514.51:621.396.612.21

1344

Heat Treatment and Internal Friction of Piezoelectric Quartz Resonators—G. Prieger. (Arch. Elektrot. (Berlin), vol. 21, pp. 102–104; April, 1952.) A brief account of an experimental investigation of the effect of heat treatment on crystal structure and Q-value.

6.20.107:621.396.6

1345

A Colonial talks about Tropicalization—E. Dawar and H. D. Pritchett. (E. African Jour. Vol. 21, pp. 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.

6.21.006.6

1346


6.21.346.632+5.46.784.221

1377

Recrystallization of Materials in the MoS₂, W₃O₅, and Tungsten—J. Lagrenaudie. (Jour. Phys. Radium, vol. 13, pp. 311–312; May, 1952.) Results are reported of measurements on samples of natural molybdenum (MoS₂) annealed to a large-contact-base, and on artificial tungsten (W₃O₅). For MoS₂ the results are not affected by the particular contact metal used, for W₃O₅, the tungsten base has some influence. The forward resistance of the MoS₂ rectifier is high, due to the laminated nature of the material. Modifications of the characteristics obtained by lightly firing the contacts are described.

6.31.651.3

1348


6.31.651.3

1349


6.31.687.154:18.371.315

1350


6.31.682.6:660.1–492.2

1351

Permanent Magnets from Utrafine Iron Powder—B. Kopolman. (Elec. Eng. (N.Y.), vol. 71, pp. 447–451; May, 1952.) A.I.E.E. Winter General Meeting paper, January, 1952. The point of view 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 obtain 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. BHmax 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. The methods for obtaining improved magnetic properties in this type of magnet are discussed.

6.31.828.23

1352

Modern Permanent Magnets and their Application—F. Latacker. (Elektrotech. u. Maschinena., vol. 69, pp. 188–192; April 15, 1952.)

MATHMATICS

517.946:517.949.8:518.12

1353

Numerical Solution of Boundary-Value Problems in Elliptic Partial Differential Equations—E. Batschlet. (Z. Angew. Math. Phys., vol. 5, pp. 193–205; March, 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. Relational 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

1354


681.412.523

1355

convex methods are found preferable to those less rapidly convergent. Examples are given.

601.42: 621.304.143

3150

Static Magnetic Magnetic Memory and Sightg Circuits—J. A. Rajchman, C.RA Res., 13, pp. 185-201; June, 1952. Description of recent developments in this type of memory device. See also 2258 of September (Papian).

MEASUREMENTS AND TEST GEAR

531.76: 621.303.57

3157


531.764.5

3158

Development of a Clock whose Rate is Accurately the Arithmetic Mean of the Rates of Several Clocks—R. Deccaux and V. Yanouchevsky, Compt. Rend. Acad. Sci., (Paris), vol. 234, pp. 2104-2105; 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-ke nominal frequency of the clocks whose nominal frequencies of 1 ke derived by frequency division. In the latter case a synchronous motor can then be used to drive mechanism for recording the mean time over outgoing contacts.

621.372.4(44): 621.371.381

3159

Recent Developments in the Frequency-Measurement Department of the Laboratory National de Radioélectricité—B. Deccaux. (Onde Elect., 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 km, synchronous recording drums, beat-frequency counters, etc. A new microwave meter is to range up to 12 km.

621.371.3: 621.390.011.21

3160


621.371.3: 621.390.882

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 instance and tube noise a Gaussian distribution is confirmed experimentally.

621.371.3: 621.390.143: 621.390.614

3162

An Approximate Theory of the Cavity-Resonator Method of Determining the Dielectric Constants of Microwave Frequencies—S. K. Chatterjee. (Journ. Indian Inst. Sci., vol. 34, pp. 43-49; April, 1952.) The field equations for a cylindrical cavity resonator and the perturbation formula due to Hele 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 rods placed into the resonator. The loss factor Q of the cavity is determined from the field equations and the Poynting vector.

621.371.3: 621.020.5/6

3163


621.371.3: 537.222

3164

Measurement of the Voltage Effect—R. Houorton. (Ann. Phys., (Paris), vol. 7, pp. 390-395; May/June, 1952.) Investigation of the sources of error in contact-potential measurements reported 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. Voltages across the contact end 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.

621.371.3: 621.310.993

3165

High-Frequency Measurement Technique—Lightning-Protection Earths—W. Balle. (Electric. u. Maschinenbau, vol. 69, pp. 140-144; March 15, 1952.) Discussion indicates that if measurements on earthy systems supply little additional information to that furnished by measurements with a lightning wire.

621.371.3: 518.5

3166

The Computation of Dielectric Constants—R. M. Redfield, R. C. Wildman and V. O'Gorman. (Journ. Appl. Phys., vol. 23, pp. 505-515; September, 1952.) Methods are presented which enable the complex dielectric constant to be determined for any type of sample from measurements by the shorted-line method.

621.371.35: 621.376.760

3167

A Frequency Stabilization System for Microwave Gas Dielectric Measurement—W. F. Gabriel. (Proc. I.R.E., vol. 40, pp. 949-954; August, 1952.) In a method based on observing the shift of resonance frequency of a cavity when filled with gas, the frequency of the klystron oscillator is used automatically controlled by means of a double-loop servo system. One loop is of the type described by Pound (1948) and the other of the type described by Rideout (1948). The value of (n-1), where n is the refractive index, can be calculated accurately to three or four significant figures.

621.371.36: 621.315.212

3168


621.371.34: 621.312.21

3169

Measurement of the Attenuation and Characteristic Impedance of Transmission Lines. Tests on Coaxial Cables—P. Huntley. (Phil. Mag., (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 pulse length, the characteristic impedance in the complex plane, of its input impedance is a circle whose position and radius are functions of the excitation and characteristic impedance. The mathematical theory of the method makes use of the properties of certain transformations in the complex plane. The necessary formulae are derived, and their representation in cartesian coordinates and in Smith's vector diagram. Tests on coaxial cables for a very large

601.371.35: 534.442.2

3171

Some Problems in Audio-Frequency Spectrum Analysis—S. V. Soames. (Electronic Eng., vol. 1, pp. 260-270 and 312-323; June and July, 1952.) Theory is presented for analyzers of this type using a fixed-frequency filter and a swept-frequency heterodyne oscillograph. A description is given of a double-heterodyne analyzer for general laboratory use covering the working range 20 cps to 20 ke; the useful range of input voltage is 1 mv to 300 v, the sweep frequency is varied between 20 cps and 300 cps and the filter bandwidth is variable between 10 cps and 500 cps. The response is displayed on a long-persistence CRT.

621.371.36: 621.302.9

3172

A Recording Frequency Comparator—R. Holter and E. Voigt. (Tech. Blatt dun. Nordwest., vol. 30, 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 period 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 for comparing the output of several oscillators can be compared simultaneously with the same reference oscillator, the results being recorded on a single paper strip chart.

621.371.361.29

3173

Frequency Measurement in the Microwave Range—R. Koch. (Arch. tech. Wiss., no. 196, pp. 111-116; May, 1952.) Review of different methods and apparatus, including wavemeter methods, direct heterodyne methods and others. A list of 64 NiI absorption lines between 19 and 40 km is given. 47 references.

621.371.444.087

3174

A Recording Fluorimeter of High Accuracy and Sensitivity—P. P. Cioffi. (Dell Lab. Rec., vol. 36, pp. 208-250 and 312-334; June, 1952.) Description of an instrument which plots maximum curves and major and minor hysteresis loops of ring and bar samples on standard coordinate paper.

621.377.337.311: 621.352.592

3175

Apparatus for Electrical Measurements on Semi-conductors—J. J. Fues. (Research (London), vol. 5, pp. 235-237; May, 1952.) Description of apparatus for oscillography 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 Ti; typical results are given.

621.372.715

3176

Integrating and Other Galvanometers—A. H. Bebb. (Journ. Sci. Inst., vol. 29, pp. 105-111; April, 1952.) The theory, design and construction are discussed of an integrating galvanometer with a time period of 80 seconds. The damping/contrast ratio is large enough to enable measurement of the change of flow through an exploring coil of considerable resistance connected in series, even though the

Correlation is sought between gradius showing the mean monthly values from October 1949 to April 1952 of (a) the percentage of hours lost, (b) the percentage of hours in which the K index (at Wittwezen) had a value of 4 or more, and (c) the lowest daily value of mu. According as the mu value is low or high, the number of hours of fading and the loss which could 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.

621.396.11:550.38


many causing ultrashort waves to be propagated to abnormally great distances; both mean values and detailed variations of field strength and duration are given. Predictions from theory are compared with results of measurements recorded at a number of receiving stations. Previous investigations, e.g. 3250 of October (Abild), have shown that such fluctuations do not 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.

621.396.11:020.64(442.6/8)

Study of the Propagation of Centimetre Waves in Northern France—P. Chavanne. (Ann. Télécommun., vol. 7, pp. 254–261; June, 1952.) An account of investigations on wave lengths of 9.5 and 3.2 cm, using equipment described previously [115 of 1951 (Maillard, Voge and Chavanne)]. 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


RECEPTION

621.396.62:061.4

Radio at the Paris Fair—(TSP et TV, vol. 28, pp. 187–189; June, 1952.) Containing the exhibits and classification of 133 receivers shown.

621.396.62:083.74(44)


621.396.8+621.6

Reception of Broadcasting from all over the World—L. hombrood. (See 3228.)

621.396.97:621.396.823:351.819(44)

The New French Regulations for the Protection of Broadcasting against Interference of Industrial Origin—M. Adam. (Rev. gén. Élec., vol. 36, pp. 191–195; June, 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

621.390.01.11

Basic Communication Theory—I. S. Schwarzschild. (Radio Rev., vol. 4, pp. 29–30; December, 1952.)

621.390.01.11:519.21

Convexity and Information—R. Feron. (Compt. Rend. Acad. Sci., Paris, vol. 234, pp. 1840–1841; May, 1952.) Proof is given that necessary and sufficient conditions for the gain of information should not be negative for any XY of aleatory variables is that the gain of the distribution function of Y should be a concave function.

621.390.02.6

technical developments in communication on m, mm and sub-mm waves, and of recent investigations on the practicality of using wave-lengths in the range 25-100 m for communication in mines.

621.390.1

Wavelength Problems in Telephony and Television Broadcasts. Televerner—L. W. Sutcliffe, T. E. S., vol. 3, pp. 49-60; May, 1952.) An outline is given of the principles governing the international allocation of wave-lengths. This is followed by a description of demands and telephony are discussed with special reference to the plans for television in Denmark.

621.396.1:621.396.8

Reception of Broadcasting from all over the World—C. Lhmouraud. (TST e T. W., vol. 28, pp. 48-58; Apr., 1952.) 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.

621.396.4:20.53

Microwave Systems for 900 and 1000 MHz. M. A. J. Schroeder, W. E. Sutcliffe, T. E. S., vol. 69, part II, pp. 1108-1110; May, 1952. Discussion, pp. 1108-1109.) In the 2-kmc transmitter, 2-5 w output is obtained from type-SR17-1, 5-klystron, rated at 10 w. Good frequency stability is obtained by adjusting the circuit and temperature control. Pulse-determination and modulation is used and 24 channels are provided. The 900-kmc system is designed to give 18-way control of the channels. The 900-mc-transmitter provides 7 channels, each giving either two-way voice communication or 18-way control of the in-between carrier system. The switching of equipments is discussed with given illustrations.

621.396.619.10

A System of Pulse-Code Modulation using Circulated Pulses—S. F. Fedida. (Electronic Eng., vol. 24, pp. 366-361; Aug., 1952.) A method is described for converting sampling pulses into sequences of up to five on/off pulses which, when interpreted as digits in a binary system of units, reproduce the desired information. Two different methods of decoding to derive the original within a prescribed tolerance are outlined.

621.396.619.16:621.396.4

Non synchronous Pulse Multiplex System—A. L. Hopper. (Electronics, vol. 25, pp. 110-112; Aug., 1952.) An experimental time-sharing multiplex system is described in which the inputs to the different transmitters are converted to ramp by sampling with random pulses, these AM pulses being converted to on/off and opposite pulse pairs separated by a constant interval 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

Electron Pulse Systems for Telegraphy—G. Montessori. (Alta Frequenza, vol. 21, pp. 77-101; April, 1952.) A high-frequency, single-fed, automatic channel separation is provided electronically in a time-division multiplex telegraphy system using ring distributors controlled by synchronizing pulses. The control generator, the synchronizing signal being produced by modulating the regular pulse rhythm. The system has been used by the Italice Co. for high-speed telegraphy.

Abscvis and References

621.396.651:621.396.43


621.396.65:621.396.43

Design Fundamentals for Beam Radio Systems—H. W. Wernmann. (Funk u. Ton, vol. 6, pp. 281-297; June, 1952. Correction, ibid., vol. 6, p. 380; July, 1952.) Discussion of the various factors relating to this system must be taken into account, including effects of normal attenuation, ground proximity and operation beyond the optical range, antenna aperture and gain, interference of system noise, and the type of modulation to be used.

621.396.650.209.6:621.396.925:621.311.112


621.396.650.209.63:621.396.5:621.370.083.7


621.396.720.922.06

The Inauguration of F8 REF—J. Ferré. (Radio franc., no. 5, p. 15; May, 1952.) Note of an experiment with R/T transmissions to be made twice weekly from a central station for the benefit of French amateurs.

621.396.800.53

Medium-Wave Broadcasting Coverage in the NWDR Area—G. Paulsen. (Tech. Hausmit. Nordwestd. Rfjufon/, vol. 4, pp. 101-110; May/June, 1952. Correction, ibid., vol. 4, p. 141; July/August, 1952.) A summary 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 detail. Experimental time-sharing of the 253, p. 441-470; May, 1952.) Historical account of the development of television transmitters of protective device in use today. References.

TELEVISION AND PHOTOTELEGRAPHY

621.397.5

Optimum Number of Lines and Screen Dimensions—P. Strombolls. (Televis., no. 23, pp. 112-117; May, 1952.) The curves of screening numbers N consistent with visibility of line structure in the television image is expressed in terms of the angular resolution of the eye and the ratio of the screening angle (as selected naturally by average viewers) and the screen height. Based on subjective judgments, curves are plotted showing the variation of N with k from 2 percent to 4 percent per observer preference. By reference to these curves line standards of 625, 819 and >819 are shown to be appropriate respectively for receivers with screen diameters of 22 and 40 cm, and over 40 cm.

621.397.5:061.3(413.55)

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.

621.397.5:535.023

Requisite Color Bandwidth for Simultaneous Color-Television Systems—K. McNeilain. (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 unacceptably poor. Under the particular test conditions described a band about 1 mc wide is sufficient for most color transmissions, provided a further band 2 mc wide is available for transmitting the brightness detail.

621.397.5:535.88:791.45


621.397.5:621.396.712

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 3150 Static Magnetic Matrix Memory and Switching Circuits—A. Rajchman. (ACA Rev., vol. 13, pp. 183-209; June, 1952.) Description of recent developments in this type of memory device. See also 2258 of September (Pupin).

**MEASUREMENTS AND TEST GEAR**


631.764.5 3158 Development of a Clock whose Rate is Accurately the Arithmetical Mean of the Rates of Several Clocks—B. Decaux. (J. Radioelec., vol. 6, pp. 216-216; May 26, 1952.) A 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 Hz, if nominal frequencies of several clocks, or of nominal frequencies of 1 kHz derived by frequency division. In the latter case a synchronous motor can then be used to drive the mechanism for recording the mean time or operating seconds.

621.317.24(4):621.317.361 3159 Recent Developments in the Frequency-Measurement Department of the Laboratoire National de Radiélectricité—B. Decaux. (Onde Elect., vol. 32, pp. 219-231; June, 1952.) An outline is given of the organization of that department and of its functions, with descriptions of the measurement equipment, including the standard oscillators (installed underground), frequency meters up to 4 km, synchronous recording drums, beat-frequency counters, etc. A new microwave meter is to range up to 12 km.

621.317.3:621.390.611.21 3160 Measurement of the Parameters of aQ. v. V. Yonuchevsky. (P. R. C. Acad. Sci., (Paris), vol. 234, pp. 2166-2165; May 26, 1952.) A 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 Hz, if nominal frequencies of several clocks, or of nominal frequencies of 1 kHz derived by frequency division. In the latter case a synchronous motor can then be used to drive the mechanism for recording the mean time or operating seconds.

621.317.3:621.390.611.22 3161 Characteristics of Noises and Noise Voltages—H. I. Bittel. (Z. angew. Phys., vol. 4, pp. 111-116; October, 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 particular 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 modulation amplitude on the rectification process is analyzed and measurement apparatus described. For resistance and the noise Gaussian distribution is confirmed experimentally.

621.317.017.143:621.390.611.4 3162 An Approximate Theory of the Cavity-Resonator Method of Determining the Dielectric Loss of Solid Microwaves Frequency—K. Chantler. (Jour. Sci. Inst., vol. 34, pp. 34-49; April, 1952.) The field equations for a cylindrical cavity resonator and the perturbation formula due to the electrical field are given. The resonance voltages are used to calculate the imaginary part of the dielectric constant of a small sample of solid dielectric rod introduced into the resonator. For the low-pass and high-pass forms of the cavity the field equations and the bingtony vector are determined.


621.317.3.257.221 3164 Measurement of the Volta Effect—R. Houn- tion. (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 ent for a layer of Cu conduction 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. (Elektron. u. Maschinenb., vol. 69, pp. 140-141; March 15, 1952.) Discussion indicates that measurements on earthings systems supply little additional information to that furnished by measurements with a tel bridge.

621.317.335.5.518.4 3166 The Computation of Dielectric Constants—R. M. Reddelier, R. C. Willman and V. O'Gorman. (Jour. Appl. Phys., vol. 23, pp. 1951-1952; December, 1952.) A description of a machine which can be used to determine the complex dielectric constant for any type of sample from measurements by the shorted-line method.

621.317.335.5:621.316.720 3167 A Frequency Stabilization System for Microwave Gas Dielectric Measurements—W. F. Gabriel. (Proc. I.R.E., vol. 40, pp. 940-945; August, 1952.) A method in based on observing the shift of resonance frequency of a cavity resonator when a gas is introduced into the resonator. The gas used is oxygen which can be used to control the frequency of the klystron oscillator used in a measurement system. A new microwave meter is to range up to 12 km.


621.317.34:621.316.212 3169 Measurement of the Attenuation and Characteristic Impedance of Transmission Lines. Tests on RG-6175 Cables—P. Houyot. (T.H. (Brussel), vol. 4, no. 2, pp. 33-46; April, 1952.) A method of measurement applicable to all uniform lines is described. If a line has a variable purely resistive characteristic, 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 frequency characteristic of the transmission line is a function of the frequency characteristic of the input impedance, which is determined by the method.


621.317.34:621.316.212 3169 Measurement of the Attenuation and Characteristic Impedance of Transmission Lines. Tests on RG-6175 Cables—P. Houyot. (T.H. (Brussel), vol. 4, no. 2, pp. 33-46; April, 1952.) A method of measurement applicable to all uniform lines is described. If a line has a variable purely resistive characteristic, 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 frequency characteristic of the transmission line is a function of the frequency characteristic of the input impedance, which is determined by the method.

621.317.34:621.316.212 3169 Measurement of the Attenuation and Characteristic Impedance of Transmission Lines. Tests on RG-6175 Cables—P. Houyot. (T.H. (Brussel), vol. 4, no. 2, pp. 33-46; April, 1952.) A method of measurement applicable to all uniform lines is described. If a line has a variable purely resistive characteristic, 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 frequency characteristic of the transmission line is a function of the frequency characteristic of the input impedance, which is determined by the method.

621.317.7:537.311.33:621.315.502 3175 Apparatus for Electrical Measurements on Semi-conductors—K. H. Wachtel and J. Ewels. (Research (London), vol. 6, no. 2, pp. 215-225; May, 1952.) Discussion of apparatus facilitating measurements over a wide temperature range and in controlled gas atmospheres; it is intended mainly for de operation. Experiments have been made on Se, Ge and T.A., typical results are given.

621.317.7:537.311.33:621.315.502 3175 Apparatus for Electrical Measurements on Semi-conductors—K. H. Wachtel and J. Ewels. (Research (London), vol. 6, no. 2, pp. 215-225; May, 1952.) Discussion of apparatus facilitating measurements over a wide temperature range and in controlled gas atmospheres; it is intended mainly for de operation. Experiments have been made on Se, Ge and T.A., typical results are given.

621.317.7:537.311.33:621.315.502 3175 Apparatus for Electrical Measurements on Semi-conductors—K. H. Wachtel and J. Ewels. (Research (London), vol. 6, no. 2, pp. 215-225; May, 1952.) Discussion of apparatus facilitating measurements over a wide temperature range and in controlled gas atmospheres; it is intended mainly for de operation. Experiments have been made on Se, Ge and T.A., typical results are given.
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. Stated in more detail, the ends of the moving coil system, the needle being located in an auxiliary field of opposite polarity to that of the needle. The effect of slumping the integrating, the vibrating, the instrument is examined and the theory confirmed experimentally.

3177 A Mechanically Actuated Leaf Electrometer—H. W. Lucking. (Z. angew. Phys., vol. 4, pp. 160–173; May, 1932.) The instrument described in this paper is a modified form of the field ion microscope. It consists of a thin metal foil in the moving-coil system. The foil is deflected by a potential difference of about 1000 volts. The deflection is measured with a sensitive microammeter. The instrument is suitable for measuring small charges and is particularly useful in studies of the surface properties of materials. 

3178 Anodige: a Discrete-Digit Voltmeter—Indicating Device—(Tech. Bull. Nat. Bur. Stand., vol. 36, pp. 70–71; May, 1952.) Description of equipment which registers 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 automatic register and recorder which counts the number of equal increments of charge required to raise the terminal voltage of a capacitor to the value of the unknown voltage. A voltmeter per second is possible with the present model, but this can easily be increased.

3179 Electrolyte Tank with Automatic Recording of Equipotential Lines—H. Schmied. (Elektrotech. u. Maschinenw., vol. 69, pp. 155–161; April 1, 1952.) The tank consists of a number of horizontal planes, each of which is connected to a separate battery. The voltages of these batteries are adjusted so that each plane is equipotential with respect to the previous one. The equipotential lines are recorded on the tank wall by means of a moving finger. The instrument is suitable for the study of electrochemical processes in tanks of large dimensions.

3180 A Precision Bridge for Determination of Time Constants of Resistors for Measurement Apparatus—E. Bierichsend. (Elektrotechik (Berlin), vol. 6, pp. 199–202; May, 1952.) Description of a bridge, developed by G. Zieker at the German Office for Weights and Measures, for measurement of the time constants of resistors in the range 10–10000 s. The bridge is based on the principle of a null detector and uses a transistorized detector circuit. The instrument is suitable for the determination of the time constants of resistors in the range 10–10000 s.

3181 Applications of the Muirhead-Pamela Wave Analyser Type D-489: Part I—Aircraft-Engine Research—B. D. Banks. (Muirhead Technique, vol. 6, pp. 11–14; April, 1952.) An instrument of the tunnel-filter type for measuring amplitude and frequency of any component of a complex wave. Frequency range is 19 cps to 21 kc. The instrument is a small box, designed for use in aircraft. It is suitable for the measurement of sound waves in the range 19 cps to 21 kc.

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, extending the range of the Type D-489 wave analyser to 2 cycles. A RC filter in a selective feedback circuit provides 40 db attenuation above 100 cps for suppressing unwanted frequencies.

3183 Circuitry for 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 μs. Suitable pulse-sharpening circuits and a high-speed gas switcher are also described.

3184 Display of Transistor Characteristics on the Cathode-Ray Oscillograph—G. B. H. 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 proper transistor electrodes. The following families of characteristics can then be displayed: (a) I_E against V_T or V_C, with I_E as parameter; (b) I_C against V_T or V_C, with I_E as parameter, where I_E is the collector emitter and collector collector current, respectively. The equipment is designed for testing n-type transistors; the modifications necessary for p-type transistors are indicated.

3185 Arrangement for the Measurement of High Voltages with 230 kHz—S. Giustini and R. Tozzi. (Alfa Frequenza, vol. 21, pp. 67–76; April, 1952.) Description of a calorimetric arrangement which has practical applications in energy losses and has a measurement range up to some hundreds of watts with an error of less than 0.1%.

3186 Airborne Receivers and Test Gear for Instrument Landing Systems—Overby. (See 3098.)


OTHER APPLICATIONS OF RADIO AND ELECTRONICS

3188 The F.R.R. Servo-Gauge—Bohnemone and Droin. (Electronique (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 photoelectric cells attached to a vertical metal strip which is driven up or down by a servomechanism according as the liquid level rises or falls.


3190 Cleaning Work with the Aid of Ultrasonic Vibrations—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 of detergent. A quartz resonator with a natural frequency of 750 kc is used.

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.

3192 Control Technique—(Elektrotech. Z., vol. 73, pp. 181–231; April 1, 1952.) A symposium on the control of temperature with the use of thermostats, applications of electrical control equipment.


3195 Applications of Electronics to the Control of the Rate of Watches and Clockwork Movements—J. Duasone, (Elektrotechik (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 glowing spark which perforates and blanks the paper.

3196 Amplification of Light-Intensity Fluctuations by means of Photographic Plates—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 Ti cells as regards sensitivity.

3197 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.


3199 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.

3200 Application of the W.B.K. Method to the Dynamics of Linear Ion Accelerators—M. Hoyaux. (Rev. Sci. Instr., vol. 23, pp. 173–175; April, 1952.) A dynamical analysis of "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 ion energy range by any practical combination of TM and/or TF traveling and/or stationary waves. Several methods are, however, possible for electrons.

3201 An Approximation Method for the Sinusoid Trajectories of Highly Convergent (electron)

621.385.833 3203

621.385.833 3204
Electrooptical Velocity Filters—M. Schickel. (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 in eluting the object. The image-forming properties of such filters are calculated for different potential distributions. The optimum resolving power is 1100.

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

621.3774083.72 3207

621.380.4083.74 3208

621.387.422:621.385.3 3209
Performance of Pulsed Photomultipliers—R. F. Post. (Nuclearon, vol. 10, pp. 46-50; May, 1952.) Report of investigations on selected type 931A and type 1212 tubes fed with square wave voltages corresponding to peak secondary emission up to 105. Short resolving times are obtained. Time dispersion effects are estimated.

621.387.424 3210
Ge-Müller Counters—N. Warburton. (Philips Tech. Rev., vol. 13, pp. 282-292; April, 1952.) The different possible ways of operating gas-filled tubes as counters of ionizing radiation are discussed, and descriptions are given of recently developed types of G-M counter, the importance of the quenching gas being emphasized.

621.387.402:549.211 3211
The Texture of Diamonds used for Counting a, b, or y Particles as found from Divergence—C. Letts. (Jour. Chem. Crystallography, Vol. 5, p. 1-10, May, 1952.)

PROPA GATION OF WAVES

621.391.11523.4 3212

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 comparison is made with solar observations and day-to-day signal analysis has given good service throughout 1950 and 1951. See also of 1957 of 1951.

621.390.111:550.38 3213

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 radio channels during which the K-index (at Witteweer) had a value of 4 or more, and (c) the lowest daily value of Nm. According as the Nm value is low or high, the number of hours spent at less than 100 miles is expected or can be expected from the geomagnetic activity. It is noted that magnetic activity increased through- out the period, though the sunspot maximum occurred 4-5 years before.

621.391.112:375.3 3214
Resonance in Gyro-Interaction of Radio Waves—W. A. Bailey, R. A. Smith, K. Lander, A. J. Jiggis and F. H. Hillbrad. (London, 1951, pp. 91-170; 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-velocity changes in a partially filled hydrogen from horizontal antenna at Armidale, New South Wales, and the wanted wave B was radiated from Brisbane, Queensland, on 900 kcs with a power of 10 kw. The principal observations of B were made at Kalooma, New South Wales, Amilda being very nearly at the mid-point of the 740-km path from Brisbane to Kalooma. The pulse power of B was about 36 kw; frequencies from 1255 to 1800 kcs being used, the estimated gyro-frequency being about 1530 kcs. The results show that a notable degree of resonance is found with the ray 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.

621.391.112:092.55 3215
New Frequency Propagation Formulas from WVW—(QST, vol. 36, p. 19; June, 1952.) From July 1952, the forecasts of SW radio disturbances will be broadcast from WVW on the standard frequencies 2.5, 5, 10, 15, 20, and 25 mc. The forecasts are prepared four times daily, and are transmitted at 0700, 0900, 1100, and 1500 each day past each hour. The letters N, W, V, D 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.

621.391.112:692.6/64 3216
Transmission beyond the Horizon at Frequencies between 40 and 4000 Mc/s—(Bell Lab. Rev., vol. 30, pp. 245-246; June, 1952.) A short account of the additional results which show that the power received at points beyond the horizon is substantially independent of frequency, antenna height, and weather effects, and that refractive changes are much more slow with increase of distance than the rapid decay predicted from the classical smooth-earth theory. A fuller report is to be published here.

621.391.112:092.62 3217
The Propagation of Ultrashort Waves beyond the Horizon, with Particular Reference to the Meteorological Influences—H. Abild, H. Wernert, H. Arnold and W. Schikorski. (Tech. Haushmitt, NordDusch. Rufsunks, vol. 4, p. 85-100; May/June, 1952.) A study is made of the meteorological conditions in western Ger-
1952

Abstracts and References


1952. 369.65: 296.369.43  3234  Design Fundamentals for Beam Radio Systems—H. W. 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 due to systems noise, and the type of modulation to be used.


1952. 369.72.029.62  3237  The Inauguration of F8 REF—J. Fergé. (Radio franç., no. 5, p. 15; May, 1952.) Note of the turn on of N/T transmissions to be made twice weekly from a central station for the benefit of French amateurs.

1952. 369.8.029.53  3238  Medium-Wave Broadcasting Coverage in the NWDR Area—G. Paulsen. (Tech. Hausb. Nordost. RF, funks., 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 interfering signals in various cases is shown graphically. The principles of system planning to cover the greatest possible fraction of the population are discussed in relation to giving an average of 70 percent of the population adequate coverage. The complementary uses of medium-wave and UHF services are indicated.


SUBSIDIARY APPARATUS

1952. 526: 212.313.281  3240  Analyzing Pulse Systems for Telegraphy—G. Montessori. (Alta Frequenza, vol. 21, pp. 77–101; April, 1952.) Synchronization, regeneration and channel separation are provided for in a high-speed multiplex telegraphy system using ring distributors controlled by a frequency-stabilized pulse generator, the synchronizing signal being delivered to the regular pulse rhythm. The system has been used by the Italcable Co. for high-speed telegraphy.

1952. 526: 212.313.41  3232  Electronic Pulse Systems for Telegraphy—G. Montessori. (Alta Frequenza, vol. 21, pp. 77–101; April, 1952.) Synchronization, regeneration and channel separation are provided for in a high-speed multiplex telegraphy system using ring distributors controlled by a frequency-stabilized pulse generator, the synchronizing signal being delivered to the regular pulse rhythm. The system has been used by the Italcable Co. for high-speed telegraphy.


1952. 369.65: 296.369.43  3234  Design Fundamentals for Beam Radio Systems—H. W. 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 due to systems noise, and the type of modulation to be used.


1952. 369.72.029.62  3237  The Inauguration of F8 REF—J. Fergé. (Radio franç., no. 5, p. 15; May, 1952.) Note of the turn on of N/T transmissions to be made twice weekly from a central station for the benefit of French amateurs.

1952. 369.8.029.53  3238  Medium-Wave Broadcasting Coverage in the NWDR Area—G. Paulsen. (Tech. Hausb. Nordost. RF, funks., 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 interfering signals in various cases is shown graphically. The principles of system planning to cover the greatest possible fraction of the population are discussed in relation to giving an average of 70 percent of the population adequate coverage. The complementary uses of medium-wave and UHF services are indicated.


TELEVISION AND PHOTOTELEGRAPHY

1952. 369.5  3245  Optimum Number of Lines and Screen Dimensions—P. Stroobants. (Théâtrion, no. 23, pp. 113–117; May, 1952.) The lowest number of scanning lines yielding satisfactory clarity and acceptability 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 and the image height (cassette viewer) and the screen height h. Based on subjective judgments, curves are plotted showing the variation of N with h for 95 percent and for 100 percent 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 20, 22 and 40 cm, and over 40 cm.


1952. 369.75: 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 everyday observers, to determine how far bandwidth can be reduced before picture reproduction becomes unsatisfactory. Under the particular test conditions, a bandwidth of about 1 mc is sufficient for most color transmissions, provided a further band of 4 mc is available for transmitting the brightness detail.


1952. 369.75: 536.712  3249  The Lime Grove Television Studios of the British Broadcasting Corporation—(Engineer-
PROCEEDINGS OF THE I.R.E.  December

621.397.2 (204.1)  3250
Underwater Television—(Engineer (Lon-
don), vol. 193, p. 655; April 25, 1952.) Description, based on an Admiralty bulletin, of remote-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 “Reclain.” Using a plane window, a 75° viewing angle has been obtained by simple devices.

621.397.2 (204.1)  3251
Underwater Television—(Engineer (Lon-
don), vol. 193, p. 656; April 25, 1952.) Engineer (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 bracket range of the illumination effects can be varied from 6-12 feet. A 625-line picture is used.

621.397.2 (500.118)  3252
Television Technique as an Aid to Obser-
vation—(J. D. McGee, Jour. Soc. Arts, vol. 100, pp. 329-345; March 21, 1952. Discussion, p. 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. Ku-tale." (Electronics, vol. 25, pp. 110-113; August 1952.) An attempt to improve transient response of a television system having the over-all frequency characteristic specified by the F.C.C. and R.T.A.M. has unsuccessfully high transient dis-
tortion. 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 capable of introducing such a modifica-
tion in the receiver video circuit is illustrated.

621.397.6 (494)  3254
The Uttelberg as a Site for a Television Transmitter—H. Laett. (Tech. Mitt. schweiz. Telegr. Telef. Verw., vol. 40, pp. 59-69; February 15, 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 Uttelberg, which dominates the district, was fed by a transmitter operating on 64 mc with a peak power of 400 k. Field strengths are given on a map. The results as a whole show clearly the pri-
mary importance of operation within the optimal range of 40 km. However, ordered reception satisfactory over a considerable part of the region not visible from the trans-
mitter.

621.397.611.2  3255
The Application of Negative Feedback to Focusing Problem in Television Receivers—W. H. Twibell and H. M. Gleich. (Jour. Brit. IRE, vol. 12, pp. 325-339; June, 1952.) Negative feedback between the output of the amplifier following the photo-multiplier 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 consid-
ered.

621.397.611.2:621.385.2  3250
A Simple Electrostatic Electron-Optical System with Only One Voltage—Schagen, Braining and Frankem. (See 3248.)

621.397.62  3257

621.397.621.2  3258
The Focusing of Cathode-Ray Tubes for Television Receivers—J. A. Hutton. (Jour. Brit. IRE, vol. 12, pp. 295-301; May, 1952.) The problem is examined from the point of view of receiver design rather than tube design. Defocus degrading and resulting aberrations are discussed and remedies indicated. The in-
nfluence on focus control of the configuration and position of the focusing field is investi-
gated, and the effect of supply-voltage vari-
ation considered.

621.397.621.2  3259
Cathode-Ray Picture Tube with Low Voltage—C. N. Sorensen. (Proc. IRE, vol. 40, pp. 937-939; August, 1952.) Focusing is performed by means of a univoltage e lens with the low-voltage electrode at 0-5 per cent of anode voltage. Uniformity and operation characteristics are given for a particular design incorporating an ion trap. Methods of avoiding breakdown due to high voltage gradients are discussed.

621.397.621.2:621.524.4  3260
A Graphical Treatment of the Tone-Repro-
duction Characteristic Problem in Television—(Electronics, vol. 25, pp. 110-113; August 1952.) A tone-reproduction characteristic of a television system in which a mathematical law is discussed. A construction for a tone reproduction chart is presented which enables a realistic assessment of the overall per-
formance 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.

621.397.621.2:621.5263  3261
Elimination of Moiré Effects in Tricolor Kinoscopes—E. Strugler. (Proc. IRE, vol. 40, pp. 916-923; August, 1952.) The influence of scanning-line width, mask-aperture size, aperture spacing, line separation, orientation of scan relative to mask, and picture content on moiré effects arising in tubes of the type described by Law (1944 of April) is discussed.

621.397.621.2:621.3335  3262
Flywheel Synchronization of Sawtooth Generators in Television Receivers—F. Neutze. (Philips Tech. Rev., vol. 13, pp. 312-322; May, 1952.) The sensitivity of different systems of synchronization to interference is discussed. A detailed description is given of the “flywheel” method of line synchronization which minimizes the effect of interference. The principles of apical, particularly important in this system, are explained, and the term 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.) Antennas are pro-
sented 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 Radi-
ation—W. Chapman 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 taken to mean that the oscillator should be made efficient, and circuit modifications which reduce interference with other receivers, are detailed.

TRANSMISSION

621.396.61 621.396.931  3265
F.M. Transmitter for 44 Mc s—J. G. Stratman. (Radio & Tele. News, Radio-

621.396.619.13  3266
Improved Reactance-Valve Circuit—J. W. Wolst. (Nachr. Tech., 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-valve modulator, but which suppresses completely the AM which usually accompanies the FM. On account of the frequency-dependent nature of the phase shift, the new arrangement is only suitable for a frequency range of about 11.3. Design formulas are given and applied to the determina-
tion of the frequency of a FM oscillator covering the range 10-12 mc.

621.396.619.23  3267
Study of the Serrasied Modulator—W. Grundsehler. (Ferrarneteriete, Z., vol. 5, pp. 256-262; June, 1952.) The merits of three ways of operating the modulator [342 of 1949 (July) are examined by analyzing the frequency spectrum of the pulse trains. The only method providing complete freedom from AM is that in which the phases are of constant height, a form of PWM being applied. The effect of slight AM on the AM frequency multiplier per-
formance is studied. The multiplier should operate in class C with automatic bias.

TUBES AND THERMIONICS

3268

3269
New Transistors Give Improved Performance—J. A. Morton. (Electronics, vol. 25, pp. 160-164; August, 1952.) Design developments leading to improved reliability, repro-
ducibility and frequency response are de-
scribed briefly. For a fuller account see 2651 of October.

3270
Polarization Effects in Photomultiplier Tubes—E. P. Chaffee and O. S. Inner. (Jour. Brit. IRE, vol. 42, pp. 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 plan-
epolarized incident light and the longitudinal axis of the tube. Type 931-A tubes gave the highest value of the ratio of the response at θ = 90° and θ = 90°.

3271
Production Testing of Multimeter Phototubes—R. W. Engstrom, R. G. Stoudenheimer and A. M. Glover. (Nuclonics, vol. 10, pp. 58-64; August, 1952.) An account of tests applied in the manufacture of the R.C.A. 5819 photomultiplier, with emphasis on cathode sensitiv-
ity.
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1052

621.383.27 3272 Non-Linear Amplification in E.M.I. Photo-multipliers—J. F. Raffae 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 cathode, the linear relation failing when the charge density in the multiplier becomes too great.


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 Travelling-Wave-Type Amplifiers—L. R. Ruppel. (Proc. I.R.E., vol. 41, 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 theory.

621.385.029.6:621.396.822 3276 Calculation of the Noise Figure of the Travelling-Wave: Part I—W. Kleen and W. Ruppel. (Arch. elektr. 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 this periodical fluctuation, the distance between the lower electrode and the emitter determines the attenuation constant for transmission through the tube, and under optimum conditions is equal to this ratio. The variation of noise figure with intermediate frequencies is shown for a tube with helical delay line; in this case the optimum value varies approximately exponentially with frequency, being about equal at 1 km 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. J. Narita. (Jour. Appl. Phys., vol. 24, pp. 195–201; May, 1953.) 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 coating BaCO₃ on a low temperature under conditions of slow speed of exhaust and at very high bake-out temperature. The high cathode temperature and the high cathode temperature of both types of cathode were varied by evaporating Ba on to the surfaces. Three mechanisms of electron conduction, i.e., band conduction constancy and activation energy of the two types of cathode, were studied and operating parameters were calculated, 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, electrolytic and thermodynamic action. None of these theories offers an adequate explanation of the high initial activation commonly achieved.

621.385.032.2216 3279 Chemical Reactions in Barium-Oxide-tungsten Emitter Cathodes—R. C. Lund, P. P. Copolla and H. T. Evans. (Jour. Appl. Phys., vol. 25, pp. 635–646; June, 1952.) Alternative theories are examined regarding the reactions responsible for the Ba₂O₃ initial oxide formed when a BaO-on-W cathode is prepared by applying BaCO₃ to W and processing normally. Two possibilities are considered: (a) formation of Ba₃WO₄ from Ba₂O₃ and W, and (b) formation of Ba₂WO₄ from BaCO₃ and W. Experiments made to test these theories are described. A series of four reactions occurs at progressively higher temperatures to form BaO and necessary for the Ba₂WO₄ formation.

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 type cathode [733 of 1951 (Lemmens, Jensen and Loosjes)] are described; degree of coverage of the W surface by 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 by Ba, almost complete absence of streaming of Ba through pores in the material, evaporation is sufficient to cause concern in certain applications.

621.385.032.027.066.11 3281 Making Glass-Balls—(Elect. Rev. [London], vol. 51, pp. 1124–1128; August 23, 1952.) Description of the plant and operation of a new factory at Harworth, Nottingham, manufacturing, 1,500,000 bulbs daily from the basic raw materials by a high pressure glass blowing process known as "flow production." The two smaller glass-men blowing-blowing machines operating on a continuous glass ribbon process, which completely covers the range of tube length varying from 0 to 45.5 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 high bulbs of diameter up to 8 cm. For similar descriptions see Elect. Times, vol. 121, pp. 917–940; May 22, 1952; and Elcetrician, vol. 148, pp. 1693–1696; May 23, 1952.

621.385.2:540.289 3282 The Time Lag of the Forward Conductance of Germanium Diodes—T. Einsele. (Z. angew. Phys., vol. 4, pp. 181–185; 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+error near 0 to reach its static value, the Shockley effect was noted. With Ge diodes the lag was longer when a large reverse bias was applied. In contrast to the results obtained by Meacham and Michaels (1950) there was no delay observed in the backward conductance.

621.385.2:540.289:621.317 3283 Germanium Diodes for Indicating Instruments and Relays—F. J. Lingel. (Tele-Tech, vol. 11, pp. 42–43; 104; April, 1954.) A series of germanium rectifiers with various applications are described. 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. B. Baars and C. Franssen. (Neth. 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 the 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.

621.385.3.5:420.63 3285 Determination of Penetration Factor for Amplifier Valves—II. Köppen. (NachTech., 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.

621.385.3.029.64 3287 Amplification Constant for Microwave Triodes—Y. Kolske and S. Yamakawa. Technol. Tokuh. Univ., vol. 18, pp. 14–25; 1954.) Published results of various workers for microwave tubes with parallel-grid 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.

621.385.5.011.424 3288 New Valve for Wide-Band Amplifiers—P. Meunier. (Onode. elect., vol. 32, pp. 232–237; June, 1952.) Detailed description of the construction and characteristics of two pentodes, Type TPT214 and with standard TPT type-1 base and grid-cathode spacing. The output of the triodes is 5–10 kw at 900 mc, about the same as the amorphous; have lower power gain, but have certain advantages when high-level modulation is required.

621.385.5.029.6 3289 The Effect of Velocity Distribution in a Modulated Electron Stream—D. A. Watkins. (Jour. Appl. Phys., vol. 25, pp. 568–573; 1954.) 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 drift tube stream is calculated by means of a power series (a) for small-signal-vm of the stream, (8) with the stream initially possessing full shot noise.

621.385.83 3289 Internal Electrostatic Deflection Yoke—K. Schiessinger. (Zeitschrift für Physik, vol. 105, pp. 105–109; July, 1952.) Description of the "deflection" electrode design. For deflection in two directions at right angles, composite electrode with triangular boundaries are used which...
form the sides of a box. This provides simultaneous horizontal and vertical deflection, equal sensitivities 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 2450 kmc are described. A 2-kw model is available for the 915-mc band, and experimental 50-kw models have been produced. A 2-kw model is available for the 2450-kmc band. See also 356 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.

621.396.615.141.2:020.63:621.396.619.13 3294

Frequency Modulation of Magnetron in the Decimetre Wave Range—F. Frick. (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 rotating-field tube as the variable reactance.

621.396.615.141.2:020.64:621.396.619.13 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. (Telr-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

621.3-001.4 3297

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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 the index to Transactions.

The Proceedings of the I.R.E., issued monthly by the Institute, is sent free to all members of record on the date of publication. The Proceedings, 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 this index, are available for those who wish to buy them at the prices indicated.

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1951-1952 INDEX

Airborne Electronics
Antennas and Propagation
Audio
Broadcast and Television Receivers
Vehicular Communications

Circuit Theory
Electron Devices
Instrumentation
Quality Control

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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.

<table>
<thead>
<tr>
<th>Group</th>
<th>Assessment</th>
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<tr>
<td>Airborne Electronics</td>
<td>$2.00</td>
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<tr>
<td>Antennas and Propagation</td>
<td>4.00</td>
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<tr>
<td>Audio</td>
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<tr>
<td>Broadcast and Television Receivers</td>
<td>2.00</td>
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<td>Broadcast Transmission Systems</td>
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<td>Circuit Theory</td>
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<td>Electron Devices</td>
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<td>Engineering Management</td>
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<td>Microwave Theory and Techniques</td>
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<td>Quality Control</td>
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<tr>
<td>Radio Telemetry and Remote Control</td>
<td></td>
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<tr>
<td>Vehicular Communications</td>
<td>2.00</td>
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</tbody>
</table>
**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 13/4" in diameter, and 2" in length. Another advantage of the 10-turn pot is that, when equipped with a turns-indicating RA Precision Dials, slider position can be read directly as a decimal, or percentage, of total coil length traversed.

### 10-TURN HELIPO T MODELS—CONDENSED SPECIFICATIONS

<table>
<thead>
<tr>
<th></th>
<th>Model A</th>
<th>Model AN</th>
<th>Model AJ</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of turns</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Resistance Range</td>
<td>10 ohms to 300,000 ohms</td>
<td>100 ohms to 250,000 ohms</td>
<td>100 ohms to 50,000 ohms</td>
</tr>
<tr>
<td>Resistance Tolerance Standard</td>
<td>-5%</td>
<td>+3%</td>
<td>+3%</td>
</tr>
<tr>
<td>Best</td>
<td>-1%</td>
<td>+3%</td>
<td>+3%</td>
</tr>
<tr>
<td>Linearity Tolerance Standard</td>
<td>-0.5%</td>
<td>+0.5%</td>
<td>+0.5%</td>
</tr>
<tr>
<td>Best</td>
<td>-0.05%</td>
<td>+0.025%</td>
<td>+0.1%</td>
</tr>
<tr>
<td>(1K ohms and above)</td>
<td>(5K ohms and above)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power rating @ 40°C</td>
<td>5 watts</td>
<td>5 watts</td>
<td>2 watts</td>
</tr>
<tr>
<td>Mechanical Rotation</td>
<td>360° ± 4°</td>
<td>360° ± 1°</td>
<td>360° ± 1°</td>
</tr>
<tr>
<td>Electrical Rotation</td>
<td>360° ± 4°</td>
<td>360° ± 1°</td>
<td>360° ± 1°</td>
</tr>
<tr>
<td>Starting Torque</td>
<td>2 oz in</td>
<td>1 oz to 3 oz in</td>
<td>75 oz in</td>
</tr>
<tr>
<td>Running Torque</td>
<td>1 oz in</td>
<td>0.1 oz to 3 oz in</td>
<td>60 oz in</td>
</tr>
<tr>
<td>Net Weight</td>
<td>4 oz</td>
<td>4 oz</td>
<td>1 oz</td>
</tr>
</tbody>
</table>

*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. According to this, independent linearity is the maximum deviation in percent 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 considered as 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 (1/2"), linearity as close as ±0.05% in resistances as low as 1K ohms.

The same multi-turn principle is also available in 2 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 3 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 (MS), plus linearity tolerance as close as ±0.025% as low as 1K. 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 1/4" in diameter, weighs 1 oz, has slide wire 18" long. Also available with servo mounting (Model AJSF) and servo mounting with ball bearings (Model AJW). Lineraties as close as ±0.1% as low as 1K.

Designed for long life under severe operating conditions, the AJ Series is widely used where small size and weight are vital.

**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, Gangged Assemblies (except AJ), Special Temperature Coefficients, etc. Send us your requirements!

For complete details contact your nearby Helipot representative. Or write direct.

**THE HELIPO T CORPORATION**

A subsidiary of Heekon Instruments, Inc.

SOUTH PASADENA 6, CALIFORNIA


PROCEEDINGS OF THE I.R.E. December, 1952
from Research, through Design, Development and Production...

...all working together as a unified team...that's Amphenol!

Every one of the over 9,000 electronic components in the Amphenol line has been tested and twisted, frozen and baked and in some instances simply "shocked" to death. This testing and checking occurs not only in preliminary design and development stages, actual production samples are also "tortured" in order that Amphenol engineers may know the complete strength and weakness of each design, finish and material.

One of the principle strengths of the Amphenol team is the vast accumulation of engineering experience and ability at Amphenol. Amphenol's customers recognize this fact and bring their application problems to Amphenol. As a result, over 75% of the Amphenol line has been developed to meet specific needs in the electronic industry.

Rigid quality controls have been set up to assure the equipment manufacturers that each Amphenol component will perform as specified.

The exacting nature of equipments requiring quality electronic components, as well as the continued growth in the number of manufacturers who specify Amphenol, has developed a highly specialized, highly productive, multi-plant operation.

The net result of this finely coordinated team of specialists, working with the most modern equipment in production-engineered buildings, provides a higher level of consistent quality with greater achievement in delivered efficiency.

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Industrial Engineering
Notes

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 NFA. 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 1, October 16, and October 24, 1952, published by the Radio-Television Manufacturers Association, whose co-operation is gratefully acknowledged.

(Continued on page 67A)
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 $75.3 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 ($19) 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 since 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 $5,500. 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 1,100,216 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 submersion-proof and concussion-proof and is capable of operation from dry battery, storage or mobile-type battery, or ac power line.
In the many fields using

When you seek the utmost in

I. F. Cores (TV)
Permeability Tuner Cores
I. F. Cores (BC)
FM tuning cores
Core resistivity
Low modulation and hysteresis
Low modulation, but good permeability
Stability
Density
Green Strength
Smooth machining
Sintering at low temperatures
Finest particles
Magnetic fluids, dispersibility
Permeability
Purity — for high purity alloys

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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 GA & 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 GA & 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 M1.
VERSATILITY, COMPACTNESS, QUALITY

Few instruments will prove so handy in so many ways as this versatile B&W Model 600 Dip Meter! Ideal for lab, production, service or ham shack use, it provides a quick, accurate means for measuring resonant circuit frequencies, spurious emissions and many other tuned circuit characteristics. Shaped for easy use in today's compact electronic assemblies, highly sensitive and accurately calibrated, it incorporates many features previously found only in higher-priced instruments. You'll find dozens of uses for it as . . .

A Grid Dip Oscillator for determining resonant frequencies of tank circuits, antennas, feed line systems, and parasitic circuits; aligning filters and traps; peaking coils, neutralizing and tuning transmitters before power is applied.

An Absorption Wave Meter for accurately identifying the frequency of radiated power from various transmitter stages; locating spurious emissions causing troublesome TV and radio interference, and many similar uses.

An Auxiliary Signal Generator providing a signal for tracing purposes and for preliminary alignment of receivers, converters, and I-F stages.

An R-F Signal Monitor for audible observation of hum, audio quality, and other audible characteristics of radiated power.

For Capacity, Inductance, and "Q" measurements in conjunction with other components of known value.

TECHNICAL FEATURES

- Covers 1.75 to 260 mc. in 5 bands.
- Adjustable sensitivity control.
- Size 3" x 3" x 7". Weight 2 lbs.
- Handy wedge-shape for easy access in hard-to-get-at places.
- Monitoring jack and B+ OFF switch.
- Rust-proofed chassis, aluminum case.
- Built-in power supply for 110 volts A.C.

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BARKER & WILLIAMSON, INC.

237 Fairfield Avenue
Upper Darby, Penna.

PRICE

$48 net

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 go on the air. The STA was effective September 29, 1952, and authorizes the outlet to operate with 12.5 kw visual and 0.3 kwural on channel 9. . . . The National Broadcasting Company will test a radio-type microphone in the studios of KNBC(TV), Hollywood, Calif., the Federal Communications Commission 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 is 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 75-line system with a 10 mc video band and a total channel width of 30 mc. Plans of the theatre group involve six separate interest 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)
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- 450B Microwave Power Meter or an -hp- 415A Standing Wave Indicator.

-hp- 485B Mounts are tunable and available in waveguide sizes 2" x 1", 1 3/4" x 1 1/8", 1 1/4" x 1 1/8", and 1" x 1 1/2". 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 1 1/8" 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.

For complete details, see your 'hp' field representative or write direct

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JOHNSON low-loss Steatite and porcelain insulators are rugged . . . performance proved throughout the years. Highly fracture resistant, dense molded and glazed for low moisture absorption. Available with DC-200 impregnation. Stable performance under adverse operating conditions. Extended creepage paths develop maximum voltage breakdown ratings, heavy integral mounting bases withstand heavy compression loads and considerable lateral stress. For complete information on the standard JOHN-SON insulators shown here, or types custom-built to specification, call or write today.

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Industrial Engineering Notes

(Continued from page 70A)

carly 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 allocations 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 amplifier tube sharing the same plate-drop-ping 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, specify greenohm

* 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!

In the heavy-weight division — fixed and adjustable Greenohms — up to 200 watt.

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 Decode 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.

you can stand pat with clarostat

Engineering data on request. Send us your resistance or control requirements for engineering aid and quotations. Try Greenohms!

Controls and Resistors

CLAROSTAT MFG. CO., INC., DOVER, NEW HAMPSHIRE

In Canada: Canadian Marconi Co., Ltd., Toronto, Ontario
A Holiday Greeting

We want to thank all our friends for their wonderful support in the past year... and to extend our best wishes for a very prosperous 1953

Airtron inc.
20 E. Elizabeth Ave., Linden, N. J.

Industrial Engineering Notes

(Continued from page 73A)

... 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.
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.

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.


Cable address: CLARELAY.
We're sorry, but we think it's only fair to tell possible new customers our Standing Room Only sign must be changed to Sold Right Out!

The design and production facilities of our microwave department are now taken over by the increasing requirements of our present customers. Because of our responsibility to them, this situation may continue quite a while.

We are sorry to say this because we enjoy making new friends. But we feel that we should tell those who might be interested in our engineering and manufacturing facilities, that for some time we may not be able to serve them.

Any change in the situation will be announced in this publication.
Guard Your Good Name!

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Dependable Electrical Protection for:
Television  •  Radio  •  Radar
Instruments  •  Controls  •  Avionics

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Approved for AIRCRAFT
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PROCEEDINGS OF THE I.R.E. December, 1952
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 usefulness 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**: Negligible.

**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*
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PRECISION COIL BOBBINS

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(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; Sep-
tember 25, 1952.

COLUMBUS
"Junction Transistor Physics,* by Dr. James
Rhines, Bell Telephone Laboratories; October 15,
1952.

DAYTON
"Recent Development on Television Camera
Design,* by N. M. Marshall, and R. J. Manzo, Gen-
eral Precision Laboratory; October 9, 1952.

DENVER
"Electronics in Strain Analysis,* by James Car-
sen, Hathaway Instrument Company; October 17,
1952.

DES MOINES-AMES
"Spectrum Analyzers and Their Uses,* by Bruce
Whaley, Hewlett-Packard; October 7, 1952.

EL PASO
Two Technical Films and Social Meeting; Sep-
tember 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.
Fitchian, 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 Opera-
tions,* by R. L. Adams, McPhar Engineering; Sep-
tember 29, 1952.

HAWAII
Short talks by: G. Reber, G. Stagner of RCA,
E. Sawyer of CAA, J. Erdman of IBM, Capt. Col-
mar, USCG, and L. H. Gilbert of State Department;
July 9, 1952.

"Magnetic Recorders, Their Design and Opera-
tional Considerations,* by Danny Dashell, 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 West-
ern Electronic Show and Convention at Long Beach,
California, by E. A. Pity; September 10, 1952.

INVERNESS
"Applications of Analogue Computer Tech-
tiques to Loud Speaker Design,* by B. N. Locanthi,
Jim Lansing Sound, Inc; September 18, 1952.

"Measurement of Wow and Flutter in Mag-
netic Tape Recording,* by John Mullin, Crosby
Enterprises; October 13, 1952.

KANSAS CITY
"Servomechanisms as Applied to Analog Com-
puters,* by Dr. A. C. Hall, Bendix Aviation Corpo-
ration; October 16, 1952.

LITTLE ROCK
"Electronic Generation of Musical Tones,* by
J. F. Jordan, Baldwin Piano Company; September
24, 1952.

(Continued on page 82A)
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—now in the pilot production stage
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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.

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.

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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, write or visit...there is no obligation, of course.

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Frequency range includes Citizens Band and UHF color TV Band.

These instruments comply with test equipment requirements of such radio interference specifications as MIL-I-6181, MIL-I-16910, PRO-MIL-STD-225, ASA C63.2, 16E4, AN-I-24a, AN-I-42, AN-I-27a, MIL-I-6722 and others.

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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.

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TYPE 252
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(JAN-R-19, Type BA30)
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For additional information on these 7 controls, write for Data Sheet No. 160

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Types 65, 90 and 95. These controls are used in military
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TYPE 90
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2 watt 70°C, 1 1/4” diameter variable composition resistor. Also available with other special military features not covered by JAN-A-94. Attached Switch can be supplied.
If you require exacting quality and dependable performance, let DX engineers figure with you on your next production run. Users of DX components enjoy exceptional freedom from field failures. This advantage can be yours at no extra cost. Write today.

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① Ideal for sub-panel mounting. Isolates tubes from shock and vibration. Mount retains compliance from minus 70° to plus 380° F. Invaluable for military and airborne equipment.

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to everyone who has a

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Here is a fresh approach to vibration
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Shock and vibration are absorbed from
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son unit mounts or engineered mount-
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design and construction of equip-
ment, but also contributes to far
longer useful life.

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dented, severe conditions of modern
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mountings, Robinson Met-L-Flex
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Goldtrip, T. E., Century House, Shaftesbury Ave., London W. C. 2, England

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Lynch, D. S., 427 Woodbine Ave., Townson 4, Md.

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Jones, W. C., NAS Annex, Solomons, Md.

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Miller, W. B., 1618 Rockwood St., Los Angeles 26, Calif.

Norkin, B. S., 3106 S. Llewelyn Ave., Dallas 8, Tex.


Soothall, T. W., Chief Division Engineer, American Forces Network APO 227 c/o Postmaster, New York, N. Y.

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"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 unfailling 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 snuffed out.

As a cycling control? Where it is desirable that equipment operate intermittently, the Flasher will cycle on and off at a predetermined 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.

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**FLASHERS FOR APPLICATIONS WITH VOLTAGES BETWEEN 3 and 32 VOLTS AC or DC.**

<table>
<thead>
<tr>
<th>LOAD</th>
<th>CARTRIDGE</th>
<th>PLASTIC CASE</th>
</tr>
</thead>
<tbody>
<tr>
<td>150 ma.</td>
<td>606</td>
<td>627</td>
</tr>
<tr>
<td>175 ma.</td>
<td>627</td>
<td>627</td>
</tr>
<tr>
<td>200 ma.</td>
<td>633</td>
<td>633</td>
</tr>
<tr>
<td>220 ma.</td>
<td>633</td>
<td>633</td>
</tr>
<tr>
<td>250 ma.</td>
<td>633</td>
<td>633</td>
</tr>
<tr>
<td>275 ma.</td>
<td>633</td>
<td>633</td>
</tr>
<tr>
<td>300 ma.</td>
<td>633</td>
<td>633</td>
</tr>
<tr>
<td>400 ma.</td>
<td>633</td>
<td>633</td>
</tr>
<tr>
<td>.75 amp 115V (5W lamp)</td>
<td>607</td>
<td>607</td>
</tr>
<tr>
<td>30 amp 115V (35W lamp)</td>
<td>608</td>
<td>608</td>
</tr>
<tr>
<td>Switching relay</td>
<td>609</td>
<td>609</td>
</tr>
</tbody>
</table>

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TUNG-SOL makes: All-Glass Sealed Beam Lamps, Miniature Lamps, Signal Flashers, Picture Tubes, Radio, TV and Special Purpose Electron Tubes.

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The 420-acre ANDREW Research Center, including a mile-long testing range, is devoted entirely to antenna research and development. In addition to the many Andrew standard models which have been developed here, several research and design problems have been undertaken on both prime and sub-contracts. The use of these facilities can be of material assistance in the design and manufacture of systems, associated equipment or in the development of custom antenna equipment.

The testing range utilizes this platform and various towers for antenna field testing. Recently, a full-scale model of the Empire State Building's central upper section was built on the platform for testing television transmitting antennas. The ANDREW "Snoe" antenna developed from the tests is now in use on the Empire State Building.

At this large, well-equipped Center, a wide range of equipment and setups are available, both indoors and out. Antenna problems are solved by antenna specialists—equipment and experience cover 50 KCS to 20,000 MCS—their knowledge allows ANDREW to accept a wide range of antenna development and engineering responsibilities.

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HOW MANY \text{db} - AT 5,000 MEGACYCLES?
AT 25,000 MEGACYCLES?

Precision variable attenuators

- Metallized glass attenuating elements
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- 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”? 

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Type 320AB PHASEMETER

- In 4 full scale ranges, 0°-360°, 0°-90°, 0°-180°, 0°-360°, without ambiguity
- Independent of voltage amplitude from 1 to 170 volts peak
- Independent of voltage wave form
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- Large, easily read, mirrored scale panel meter
- Ease of operation — ideal for production testing or laboratory use
- Eliminates tedious and inaccurate oscilloscope techniques
- Terminals for recorder... instantaneous response of output voltage to phase changes
- Incremental accuracy better than 1% of full scale
- Proven performance and quality workmanship

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MEMBERSHIP

(Continued from page 90A)

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Bradley, L. W., c/o International Business Machines Corp., 590 Madison Ave., New York 22, N. Y.
Brady, D. J., Box 463, Arnold, Md.
Brouh, H. T., 5757 Stoepel, Detroit, Mich.
Carlson, G. R., 967 Vernon Ave., Glencoe, Ill.
Carris, G. C., 851 N. Lorraine, Wichita, Kan.
Cassedy, E. N., Jr., 8702 Harron St., Takoma Park, Md.
Cherry, M. V., c/o W. I., Y.C., 331 Pine St., Wilkinsburg, 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., 1124 Empire St., Berlin, N. H.
Cox, S. M., Box 7164, Wright-Patterson Air Force Base, Dayton, Ohio
Crystal, D. G., 11330 Wellington St., North Hollywood, Calif.
Culbertson, J. T., Math Division, Rand Corp., Santa Monica, Calif.
Dayton, W. P., 4406 Classroom Blvd., Oklahoma City, Okla.
Dokowski, 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 Avene, Schenectady, N. Y.
Feigis, J. L., 775 Aircraft Control and Warning St., Cambria, Calif.
Finnean, W. J., Somerset Hotel, 5009 N. Sheridan Rd., Chicago 48, Ill.
Flowers, C. R., 561 Splendor St., Akron 10, Ohio
Freedman, L. M., 2064 Ocean Pkwy., Brooklyn, N. Y.
Fulien, R. E., 2001 Carroll Dr., Raleigh, N. C.
Garman, D. F., Box 323, Enon, Ohio
George, P. H., 2446 Penaasea Ave., Chicago 18, Ill.
Gerdes, J. W., 131 S. Main St., Natick, Mass.
Goetre, 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., 725 Arlington Ave., Toronto, Ont., Canada.
Grosse, R. H., 5434 Hillside Ave., Cincinnati 38, Ohio
Guttrie, D., 1115 W. Berry St., Fort Wayne, Ind.
Haerer, W. A., 117 Secor Ave., Apt. F-1, Garden City, L. I., N. Y.
Hagelaans, E. J., 1620 Roundhill Rd., Baltimore 16, Md.
Henry, J. R., 2133—19 St., Cuyahoga Falls, Ohio
Herbert, H. W., Box 11, Wadsworth, Pa.
Hertz, M., 2003 August Dr., Silver Spring, Md.
Hirsch, A., 2961 W. 97 St., Evergreen Park 42, Ill.
Hirschfeld, J. L., 1821 Catalpa Dr., Dayton 6, Ohio
Hodge, M. H., Jr., 503 Valley Ave., Washington, D. C.
Horner, G. F., 1125—59 St., St. Petersburg, Fla.

PROCEEDINGS OF THE I.R.E. December, 1952

(Continued on page 94A)
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."

CRYSRTALS 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 JAMES KNIGHTS COMPANY

SANDWICH ILLINOIS
how KAAL broke a bottleneck

A manufacturer of sub-miniature tubes used in guided missiles and proximity fuses came to KAAL recently with this problem: by using hand and semi-automatic methods to produce his bulbs, the reject rate ran very high. This caused a bottleneck, since production of the tube's internal elements was always far ahead of the bulb supply. KAAL's solution was to design and build the fully automatic bulb making machine, Model 1991, shown here. This machine—capable of making flat, oval, oblong, square and round bulbs—offered the perfect combination of production and precision by producing tubulated bulbs with precise internal dimensions at a rate of 1300 units per hour.

This is but one of hundreds of problems solved by KAAL. In every case, KAAL's experience and ability have resulted in the design, development and production of a machine engineered to produce results as specified. Working closely with your organization, KAAL's experienced staff of electronic and equipment engineers will, at your request, recommend a solution to your own specialized production problems. Learn how KAAL's more than 40 years of practical experience can benefit you... write KAAL now.

(Continued from page 92A)
Exceptional Temperature RANGE

Surflon 200°C

HOOK-UP WIRE

“Surflon” (Tetrafluoroethylene) hook-up wire is capable of operation from +200°C to -90°C, with no appreciable decomposition. This wide range of efficiency continually opens new applications for “Surflon”—especially where constant stability under exceptional temperature conditions is required for long periods.

Surflon

- is non-inflamable
- is resistant to chemicals
- has no known solvent

Because of low electrical losses, “Surflon” is adaptable for high frequency use. It has very high volume and surface resistivity. “Surflon” is available in hook-up wire sizes, with shield or jacket and also as coaxial cable.

MAKE SURPRENANT YOUR HEADQUARTERS FOR ALL TECHNICAL HOOK-UP WIRE INFORMATION

POLYPENCO

NYLON and TEFLOHN

rod, strip or tubing
means economical design!

- Now you can get the benefits of Nylon or Teflon and save the delay and cost of making molds as well. And by specifying Polypenco you can be sure of exceptionally good quality and uniformity because both of these modern materials are produced under rigid control—100% inspected and tested from start to finish. What precision jobs have you got for...

POLYPENCO Nylon

...the tough material that gives you a unique combination of abrasion resistance, impact strength and durability in use. Offers excellent machinability

POLYPENCO Teflon®

...the chemically inert material widely used for applications where resistance to heat, moisture, and chemicals is essential. Offers stable electrical properties over a wide frequency and temperature range.

We’ll supply Polypenco Nylon and Teflon from stock and show you how it is fabricated most economically... or fabricate it for you. For further information write:

POLYMER CORPORATION

of Pennsylvania

Reading, Pa.

*Trademark of E. I. DuPont Corp.
THE MODEL 302B measures 100 microvolts to 100 volts from 2 cycles up to 150 kc.

- Input Impedance is 2 Megohms shunted by 15 mmfds on the 0.001 and the 0.01 ranges and by 8 mmfds on the other ranges.
- Generous use of negative feedback provides customary Ballantine stability.
- Accuracy: 3% from 5 cycles to 100 kc; 5% elsewhere.
- Six decade range switch permits entire voltage range to be read on a single logarithmic voltage scale. Linear DIH Scale.
- Can also be used as a flat pre-amplifier with a maximum gain of 60 DIH. Because of the complete absence of AC hum, the amplifier section is extremely useful for improving the sensitivity of oscilloscopes.
- Available multipliers increase the voltage range to 1,000 or 10,000 volts.
- Available precision shunt resistors permit the measurement of AC currents as low as one-tenth of a microampere.
- Battery life over 100 hours.

For further information on this Voltmeter and other Ballantine Voltmeters and accessories, write for catalog.

**BALLANTINE LABORATORIES, INC.**

102 Fanny Road, Boonton, N.J.

**PRICE $225**

---

**BECO IMPEDANCE BRIDGE**

for measurement of
RESISTANCE • CAPACITANCE
INDUCTANCE

- Compact — 9" x 11" x 11" overall
- Exceptionally accurate • Wide ranges • Convenient operation from battery, or AC power line accessory amplifier • Features exclusive DEKADIAL for high precision readings.

---

**BROWN ELECTRO-MEASUREMENT CORP.**

4635-37 S. E. HAWTHORNE BLVD. PORTLAND 15, OREGON

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**MEMBERSHIP**

(Continued from page 94A)

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**NEWS—NEW PRODUCTS**

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**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 Nuclearon 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-Muller tubes and accessories, lead shields, flow counters; sample handling equipment, safety equipment, special electronics devices; and miscellaneous products and services.

(Continued on page 98A)
**BIRTCHE**

**TUBE CLAMPS**

Hold Tubes in Sockets under all Vibration, Impact and Climatic Conditions

83 VARIATIONS FOR STANDARD TUBES

NEW CLAMP FOR MINIATURE TUBES

---

**You can’t beat the system**

WHEN IT’S A SANBORN Recording System

SANBORN records are **inkless** and **permanent**. They are produced by a **heated** stylus ribbon which melts the heat-responsive, plastic-coated surface of the recording paper (Sanborn Permapaper).

The result is a clear, sharp tracing showing fine details of the phenomena being recorded.

This is just one of many SANBORN advantages.

---

**ILLUSTRATING**

**ONE REASON WHY**

**Sanborn**

---

SANBORN records are **inkless** and **permanent**. They are produced by a **heated** stylus ribbon which melts the heat-responsive, plastic-coated surface of the recording paper (Sanborn Permapaper).

The result is a clear, sharp tracing showing fine details of the phenomena being recorded.

This is just one of many SANBORN advantages.
TWIN Power Supply

Electronically Regulated for Precise Measurements

Two independent sources of continuously variable D.C. are combined in this one convenient unit. Its double utility makes it a most useful instrument for laboratory and test station work. Three power ranges are instantly selected with a rotary switch:

- 175-350 V. at 0-60 Ma., terminated and controlled independently, may be used to supply 2 separate requirements.
- 0-75 V. at 0-60 Ma. for single supply.
- 175-350 V. 0-120 Ma. for single supply.

In addition, a convenient 6.3 V.A.C. filament source is provided. The normally floating system is properly terminated for external grounding when desired. Adequately protected against overloads.

Twin Power Supply Model 210
Complete $130.00
Dimensions: 16" x 8" x 8" Shipping Wt. 35 lbs.
(Other types for your special requirements)

FURST ELECTRONICS
3326 W. Lawrence Ave., Chicago 25, Illinois

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 dual 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 1-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 100 A)
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!

|$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.

<table>
<thead>
<tr>
<th>STANDARD TYPES</th>
<th>REPLACE WITH THESE 5-STAR TYPES</th>
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</thead>
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<tr>
<td>2CS1</td>
<td>*GL-5670—h-f medium-mu twin triode.</td>
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<td>5Y3-SI</td>
<td>GL-6087—full-wave rectifier.</td>
</tr>
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</tr>
<tr>
<td>6AU6</td>
<td>GL-6136—sharp-cutoff pentode.</td>
</tr>
<tr>
<td>6BA6</td>
<td>GL-5749—remote-cutoff r-f pentode.</td>
</tr>
<tr>
<td>6BE6</td>
<td>GL-5750—pentagrid converter.</td>
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<td>*GL-6135—medium-mu triode.</td>
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<td>6SK7</td>
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<td>12AT7</td>
<td>GL-6201—high-Gm medium-mu twin triode.</td>
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<td>12AU7</td>
<td>*GL-5614—medium-mu twin triode.</td>
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<td>12AX7</td>
<td>*GL-5751—high-mu twin triode.</td>
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<td>12AY7</td>
<td>*GL-6072—low-noise medium-mu twin triode.</td>
</tr>
<tr>
<td></td>
<td>GL-5686—beam power amplifier.</td>
</tr>
</tbody>
</table>

* Slight electrical difference

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!
News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your L.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 1034)

JAMES MILLEN
MFG. CO., INC.
MAIN OFFICE AND FACTORY
MALDEN
MASSACHUSETTS

I T ' S  
Y O U R 
L O G I C A L 
C H O I C E

E L E C T R O N I C A L L Y  R E G U L A T E D
L A B O R A T O R Y
P OW E R  S U P P L I E S

E X C E L L E N T  L I G H T  D I S T R I B U T I O N  a f f o r d s
E A S E  I N  B E A D I N G .  G L A R E  R E D U C E " )  t o  a
m i n i m u m  b y  r e t a i n i n g  C O M P A C T  D E S I G N  o f
( r o w s  c a s e  e x t e n s i o n .

B E F O R E  C E D  L I G H T  P R I N C I P L E  p e r m i t s u s e
o f  s t a n d a r d  M E T A L  D I A L S  e l i m i n a t i n g  t r a n s -

t r e n t  m a t e r i a l s  t h a t  d i s c o l o r  w i t h  a g e  a n d  u s e .

R I P P L E  O U T P U T :  L e s s  t h a n
8 millivolts rms

L A M B D A  E L E C T R O N I C S
C O R P O R A T I O N
C O R O N A  N E W  Y O R K

E L L U M I N A T E D
I N S T R U M E N T S

E X C E L L E N T  L I G H T  D I S T R I B U T I O N  a f f o r d s
E A S E  I N  R E A D I N G .  G L A R E  R E D U C E " )  t o  a
m i n i m u m  b y  r e t a i n i n g  C O M P A C T  D E S I G N  o f
f r o n t  c a s e  e x t e n s i o n .

R E F L E C T E D  L I G H T  P R I N C I P L E  p e r m i t s u s e
o f  s t a n d a r d  M E T A L  D I A L S  e l i m i n a t i n g  t r a n s -

t r e n t  m a t e r i a l s  t h a t  d i s c o l o r  w i t h  a g e  a n d  u s e .

B U R L I N G T O N  I N S T R U M E N T  C O M P A N Y
B U R L I N G T O N ,  I O W A

W r i t e  D e p t .  1-1 2 2  f o r  c o m p l e t e  d e t a i l s .

B U R L I N G T O N  I N S T R U M E N T  C O M P A N Y
B U R L I N G T O N ,  I O W A

E L E C T R O N I C A L L Y  R E G U L A T E D
L A B O R A T O R Y
P OW E R  S U P P L I E S

B E N C H  M O D E L  5 0

- INPUT: 105-125 VAC, 50-60c
- OUTPUT #1: 0-500 VDC at
  500 ma regulated
- OUTPUT #2: 0-50 VDC, 0-200 VDC Bias Output,
- OUTPUT #3: 6.3 VAC at
  5A unregulated
- OUTPUT #4: 6.3 VAC at
  5A unregulated
- RIPPLE OUTPUT: Less than
  8 millivolts rms

L A M B D A  E L E C T R O N I C S
C O R P O R A T I O N
C O R O N A  N E W  Y O R K

I T ' S  
Y O U R 
L O G I C A L 
C H O I C E

E L L U M I N A T E D
I N S T R U M E N T S
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)

Make Miniature Transformers?
Meter Movements?
Relay Coils?

Above transformer is wound with 23,000 ft. of our No. 50 wire weighing only .07 lbs. Have trouble getting really fine wire? Write for price list of our full line highest quality fine enameled magnet and Litz wire. Immediate delivery all sizes—44 to 52 (.002" to .0008").

THE INSTRUMENT WIRE COMPANY
152 Church Street • Guilford, Conn.

TYPIFYING OUTSTANDING ADVANTAGES of Lenkurt precision-molded cores and precision-wound toroidal coils, this application features compactness and light weight, ease of mounting and assembly.

WHEN YOUR DESIGN problems call for maximum performance from filters, tuned circuits, and inductors, we invite you to draw upon Lenkurt's rich experience in obtaining the maximum performance from available materials.

MODERN FACILITIES at Lenkurt, one of the largest installations of its kind in the world, offers a dependable source of supply—geared to your largest quantity needs and your most-exacting quality requirements. Ask for literature on these outstanding components; recommendations and quotations on your specific problems.

LENKURT ELECTRIC SALES COMPANY
San Carlos 2 California
Now you can readily design your Electronic Equipment for unitized PLUG-IN UNIT CONSTRUCTION

New free Alden Handbook simplifies plug-in unit design. Presents complete line of basic components of tremendous flexibility for adapting your equipment to plug-in construction.

1. Utilize your circuitry in compact vertical planes using Alden Terminal Card Mounting System.

2. Make your circuits nest accessible plug-in units by mounting in Alden "20" Package or Basic Chassis.

3. Monitor your plug-in units with ALDEN SENSING ELEMENTS that spot trouble instantly.

4. Get fool-proof unit interconnections and accessible check points with Alden Unit Cable and Back Connectors.

Here's the story on "PAN-LITE"—ideal monitor to indicate circuit condition

PAN-LITE quickly replaces faulty elements.

The panel lights you've used — were bulbs easy to replace? Were spares durable and always on hand? Did the user have to call a service man to replace a light? Was it hard to find panel room to build in the lights you wanted? Did your equipment look like a Christmas tree, with a confusing glare of lights?

At last — here's a System so well thought out you need never use any other. You know a dead light means danger. Pan-Lite's 1-piece bulb and lens is so easily replaceable, it's never neglected. Spares are unbreakable, ready kept in kit, vest pocket, or taped right up as recess of equipment. Instantly replaceable. Glow like a red hot poker, yet never with glare that gives false signal. Tiny Pan-Lite is compact, punch into a .38" drill hole, take about 1/8" behind panel, mount on centers 1" apart, allowing 1000 Lx per sq. ft. of panel.

Now you can set indicator lights wherever needed. Avoid hazard of dead light because bulb replacement instant, easy, by anyone. For A.I.L Indicator needs, standardize on Pan-Lite, the light that really makes sense.

Send for Samples at 3 Pan-Lites with bright color replacement bulbs. Laboratory Work Kit No. 322, price $4.00. (Continued on page 1034)

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 1034)

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 Micro- wave 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)
You get all 3 in magnecorder first choice of engineers the world over!

HERMETICALLY SEALED TO MIL-T-27 SPECIFICATIONS

NYT offers a wide variety of transformer types to meet military and civilian specifications, designed and manufactured by specialists in transformer development.

Latest NYT service for customers is a complete test laboratory equipped and approved for on-the-spot MIL-T-27 testing and faster approvals.

NEW YORK TRANSFORMER CO., INC.
ALPHA, NEW JERSEY
Available in 14 Colors

Tensolon Hi-Temp Hook-Up Wire

- Extra Flexibility
- Free Stripping
- High Dielectric
- Rating -55 to +250°C

Built to meet rigid government requirements, Tensolon Hook-up Wires are available in sizes from AWG30 through 20 with stranded silver-plated copper conductors and the patented Tensulated Teflon® covering which eliminates pin holes and other irregularities.

SPECIAL KIT FOR LABORATORY REQUIREMENTS

Twelve 100 ft. rolls of AWG 22, in assorted colors in convenient compact container $124.00

Tensolite Insulated Wire Co., Inc., Tarrytown, N. Y.

Quality Comes First

- If performance and long life are the primary factors in your application of transformers, then submit your specifications to Acme Electric. Quality comes first in every Acme Electric transformer.

Acme Electric Corporation
4412 Water Street • Cuba, N. Y.

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 corrosion 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 future 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)
Equipment designers can now call on General Electric to investigate and approve applications of thytrons 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 thytron 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 thytrons than any other manufacturer—34 types in all. You are more apt to find the exact control tube you need!

- **THYTRON IS A G-E ‘FIRST’!** General Electric pioneered the thytron, 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 thytrons . . . 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.

---

**CHECK G.E.’S 34 TYPES FIRST!**

What are your thytron 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.
FOR MAXIMUM FLEXIBILITY
IN WAVEFORM TIMING

The Browning Model GL-22A Sweep Calibrator is designed to free its users from limitations encountered in the use of crystal calibrators.

here are its advantages

It can be used as the triggering source, or can be triggered externally by the output of the device to be calibrated. The external trigger may be recurrent, up to 100 KC, random, or “one shot”.

Using the internal trigger, the interval between successive markers is wholly independent of the trigger rate. The internal trigger is continuously variable from 200 to 5000 pulses per second.

The markers are produced through the keying action of a continuously variable gate, and thus can be restricted to the desired portion of an observed waveform. The gate pulse itself is also available as a useful output, of either polarity, and known duration.

The output markers, at 0.1, 1.0, 10, or 100 microseconds, accurate to ±1%, of either polarity, can be continuously varied to 50 volts amplitude — sufficient for either intensity or deflection modulation use. The available intervals, in conjunction with the customary ruled screens, permit accurate measurement of intervals from 0.01 microsecond to several thousand microseconds.

Send for data sheet giving full details.

BROWNING Laboratories, Inc.
Winchester, Mass.
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.

BERRI, CALIFORNIA  DALLAS, TEXAS  PHILADELPHIA 7, PENNSYLVANIA  DAYTON 2, OHIO
235 South Third Street  415 Fidelity Union  725 Widerauer Building  410 West First Street
DETROIT 2, MICHIGAN  NEW YORK 16, NEW YORK  CHICAGO 11, ILLINOIS  ERIE, PENNSYLVANIA
7310 Woodward Ave.  289 Madison Avenue  520 N. Michigan Ave.  1635 West 12th Street

LORD MANUFACTURING COMPANY • ERIE, PA.

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 nsec. The instrument has ranges of 1-mv, 3-mv, 10-mv, 30-mv, and 100-µv 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

DANCE STUDIOS

FUNERAL PARLORS

STEAMSHIPS

AMUSEMENT PARKS AND RECREATION CENTERS

strikes a NEW NOTE in continuous performance playback music

INTRODUCING THE

AMPEX 450

- 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

FEATURING

- 50 to 7500-cycle frequency response at 3 3/4 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 ELECTRIC CORPORATION
934 CHARTER STREET • REDWOOD CITY, CALIF.
For reliability in high voltage specify Guthman Flybacks—they won't 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.
**These American Electric Miniatures do BIG jobs!**

**Cooling and Ventilating**

**CENTRIFUGAL BLOWERS**
400 cycle, 60 cycle, or variable frequency types (320 to 1000 cps.)
Substantially flat output over full frequency range on variable frequency models with minimum watts loss.
Flower scrolls of latest design are molded of fibre-glass reinforced plascon; practically unbreakable, highly resistant to impact, deformation, heat and cold. Flower unit unusually small in size and weight for compact installation. Generally used when working against pressure heads ranging up to 1.2" water. Single or double end blowers. Clockwise or Counterclockwise rotation. Output range: 24 to 200 cfm. Made in sizes: Numbers 113, 2, 213, 3.

**AXIAL FLOW FANS**
400 cycle operation
In its smallest size this compact, light weight unit is equipped with a 2" fan protected with 18" mesh 2 ½" O.D. screen shroud. Other larger sizes special. Air stream is conical. Recommended for use at 0 static pressure where semi-directed air flow is required. Motor diameter 1.45". Rotation: Clockwise or Counterclockwise. Output: 30 cfm.

**PROPELLER FANS—400 cycle operation**
Built for limited space applications requiring maximum air movement with widely dispersed. Operates at 0 static pressure in ambient temperatures from —45° to +125° C. Made in 2, 3, 4 and 5½" fan diameters. Output range: 33 to 680 cfm.

**Motivating Cams, Timing Devices, Antennas, Clutches, Optical Equipment, etc.**

**MINIATURE INDUCTION MOTORS**
400 cycle, 60 cycle, single and poly phase, 2 to 8 pole. Frame diameters: 1.45", 1.75", 2", 2½" & 3½/16" Output torque range: ½ in. oz. to 50 in. oz.

**SYNCHRONOUS MOTORS**
400 cycle, 60 cycle, hysteresis and reluctance types. Single and poly phase: 2, 4 and 6 pole. Frame diameters: 1.45", 1.75", 2", 2½", 3½/16". Output torque range: 01 in. oz. to 10 in. oz.

Both induction and synchronous motors can be supplied for intermittent or continuous duty, with standard or high temperature insulation. Drive and synchronous motors: any standard shape.

Manufacturers also of INSTRUMENTS, SERVO-MOTORS AND SYNCHROS.
HIGH FREQUENCY POWER SUPPLIES
(Inductor—Alternator type—500 watt to 75 KVA output).

**TOBE DEUTSCHMANN CORPORATION**
NORWOOD, MASSACHUSETTS

**MINIATURE TO BE INTERFERENCE FILTER**
- Covers 0.35 to 1000 megacycles
- Handles up to 20 amperes
500 v.d.c./150 v.a.c., 0-1700 cps

In a space only 2" x 2" x 1 ⅛". you can get better-than-60 db attenuation throughout most of the useful range up to 1000 megacycles by using any one of the T232 series of Tobe interference filters. With their extremely low series resistance, these effective filters have negligible voltage drop and only slight components rise. Hermetically sealed, Series 1517 filters meet military specifications but are from 5½ to 4 10/16.

ATTENUATION vs. FREQUENCY IN A 50-OMS LINE

Can be expanded to cover receiving needs—write for free data sheet giving detailed information.

**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)
What is your Delay or Regulating Problem?

For the most effective solution use the SIMPLEST, MOST COMPACT, MOST ECONOMICAL HERMETICALLY SEALED AMPERITE THERMOSTATIC DELAY RELAYS

Provide delays ranging from 2 to 120 seconds.
- Actuated by a heater, they operate on A.C., D.C., or Pulsating Current.
- Hermetically sealed. Not affected by altitude, moisture, or other climate changes.
- Circuits: SPST only—normally open or normally closed.

Amperite Thermostatic Delay Relays are compensated for ambient temperature changes from -55° to +70°C. Heaters consume approximately 2 W. and may be operated continuously. The units are most compact, rugged, explosion-proof, long-lived, and—very inexpensive!

TYPES: Standard Radio Octal, and 9-Pin Miniature.

PROBLEM? Send for Bulletin No. TR-81

BALLAST-REGULATORS

- Amperite Regulators are designed to keep the current in a circuit automatically regulated at a definite value (for example, 0.5 amp).
- For currents of 60 ma. to 5 amps. Operates on A.C., D.C., or Pulsating Current.
- Hermetically sealed, light, compact, and most inexpensive.

Maximum Wattage Dissipation: T6 1/4L—5W. T9—10W.

Amperite Regulators are the simplest, most effective method for obtaining automatic regulation of current or voltage. Hermetically sealed, they are not affected by changes in altitude, ambient temperature (-55° to +90°C), or humidity. Rugged; no moving parts; changed as easily as a radio tube.

Write for 4-page Technical Bulletin No. AB-51

Amperite Regulator—with Amperite Voltage Variations

50%  2%

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 315/4)

27-Inch TV Picture Tube

The General Electric Co., Tube Dept., 1 River Road, Schenectady, 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 21 by 18-inch picture.

Recommended operating conditions for the 27EP4: anode voltage, 10,000 of volts grid #2 voltage, 300 volts grid #1 voltage, -33 to -77 volts, and ion-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. All 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 501201 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 amperes, 6.3 at 6.3 amperes. TV auto transformer with rating of primary 6.3, output 12.6 at 1 amperes with taps at 9.45 and 6.3 volts.

Merit has also announced six new IF-RF coils. Three 45-mc coils are for TV sound amplifier, sound discriminator, and sound detector use. They have 3-inch chip-type mounting. Two 262-ic and one 455-ic filter-type IF coils are for late model auto radio sets.

(Continued on page 116A)
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

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 auroral visual signals.

SPECIFICATIONS

<table>
<thead>
<tr>
<th>Model</th>
<th>MAX. COUNT CAPACITY</th>
<th>INPUT SENSITIVITY (MIN.)</th>
<th>OUTPUT</th>
<th>PANEL DIMENSIONS</th>
<th>OVERALL DIMENSIONS</th>
<th>POWER REQUIREMENTS</th>
<th>PRICE (F.O.B. FACTORY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>422</td>
<td>100</td>
<td>± 1 v. to ground; peak; at least 2 μ sec. wide</td>
<td>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.</td>
<td>15½&quot; x 8½&quot;</td>
<td>16½&quot; x 10¾&quot; x 13&quot;</td>
<td>117 v. ± 10% @ 90w.</td>
<td>$275</td>
</tr>
<tr>
<td>423</td>
<td>1000</td>
<td></td>
<td></td>
<td>19&quot; x 8½&quot;</td>
<td>20½&quot; x 10¾&quot; x 15&quot;</td>
<td>117 v. ± 10% @ 180 w.</td>
<td>$450</td>
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<tr>
<td>424</td>
<td>10,000</td>
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<td>425</td>
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<td></td>
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<td>$795</td>
</tr>
</tbody>
</table>

For complete information, please request Bulletin 2012.
**The Right Connection... right now!**

Dage RF connectors are designed right, engineered right, built right—and available now. Each part is carefully made—Dage connectors are precision assembled to assure a sure connection.

Check your specifications—be sure you're right—ask for Dage radio frequency connectors.

**ALWAYS SPECIFY**

![Type BNC UG-274/U](image)

Dage is versatile... any standard or special RF connector can be quickly produced at Dage. Write for Catalog 101.

**RADIO FREQUENCY CONNECTORS**

**WRITE FOR "THE STORY OF METAL SPINNING."** Find out how engineers design for lower costs; how to use the Teiner experimental shop and how Teiner provides all-gauge— all-metal—any-quantity spinning for industry. Read about this spinning shop, now largest in the east and tops in scientific experimental spinning. **Ask for Brochure 52 E.**

**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 100 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 speed available from 3,000 rpm to 11 r.p.m.

The new 400 motor meets the temperature, altitude and vibrations requirements of MIL-L-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 116A)
Announcing a NEW, Different kind of Capacitor

Johanson
Concentric High Ratio Air Capacitor

The new Johanson Concentric High Ratio Air Capacitor recommends itself to applications requiring a low minimum capacity, high Q, and stability. It has a maximum capacity of 35 mmfd and a minimum capacity of 1 mmfd. Because of this ratio of capacity, it has many varied applications in electronic equipment where capacitive adjustments need to be made over a wide range with great accuracy.

The new Johanson capacitor is constructed entirely of silver-plated brass and Pyrex glass, which makes it ideally suited for all applications of a high frequency nature. It is a high Q capacitor at and above 200 mc.

The friction spring of the new capacitor assures a permanent setting of the rotor. The vernier action of the rotor screw allows all adjustments up to eight full turns to be made quickly and precisely.

SPECIFICATIONS

Low minimum capacity, 1 mmf. High maximum capacity, 35 mmf.
High Q—better than 10,000 at 15 mc. Voltage breakdown over 500V DC.
High stability. High ratio—capacity at maximum is 35 times its minimum capacity.
Vernier action—better than 8 turns to accomplish the capacity change.

Capacity against rotation is a linear function.

Requires space .700 x 1" long behind panel.

Write for further information

MANUFACTURING CORPORATION
12 ROCKAWAY VALLEY ROAD, BOONTON, N.J.
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 "Stablex D" series, these capacitors are particularly adapted for use in equipment subjected to extreme altitude and climatic changes or similarly difficult operational variables.

"Stablex 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 0.0025 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 "Stablex D" capacitors have time constants in excess of 4,800 hours.

Contact Cleaner

Quietone Div., R. & L. Radio-Television, 1701 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 (GEC 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)
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**

---

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 rise-time 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**

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. Rise time 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*
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 118.)

Capacitors

The Johnson Manufacturing Corp., Boonton, N. J., announces development of a new concentric high-ratio capacitor with a maximum capacity of 35 μf, and a minimum capacity of 1 μf. 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 1SI and Type 5U1, have been developed by International Rectifier Corp., 1521 Grand Ave., El Segundo, Calif.

The type 1SI 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 ma. The Type 1SI 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 136.)

BOURNS precision wire-wound potentiometers accurately translate mechanical position into an electrical signal. Resolution of .001 inch attainable in all standard ranges from 1 to 6 inches.

Technical publication describing standard models and special applications available upon request.

BOURNS designs and manufactures other potentiometer instruments which measure such physical variables as gage pressure, differential pressure, altitude and acceleration.
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

TIMES FACSIMILE CORPORATION
540 West 56th Street 1923 L Street N. W.
New York 19, New York  Washington 5, D. C.

Here's the Answer...

to your OPEN WIRING CABLE SUPPORT PROBLEMS

Use the ALL NYLON "Nylor" 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
5249 N. Avondale Ave.  Chicago 30, Ill.

"It's SONODYNE
MULTI-IMPEDEANCE 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
Massachusetts"

"Excellent results in recording and
for comments in the showing of
motion pictures.
Amateur
New York"

"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 broadcasts purposes.
Producer and Director
Canada"

"Wonderful for wire recording pur-
poses and P.A. use. I use it mainly
for recording.
Sound Service
Massachusetts"

* Individual names available on request.

SHURE BROTHERS, Inc. — Microphones and Acoustic Devices
225 West Huron Street, Chicago 10, Illinois  Cable Address: SHUREMICRO
To the

**ELECTRICAL ENGINEER**
or

**PHYSICIST**

with experience in

**RADAR**
or

**ELECTRONICS**

Hughes Research and Development Laboratories, one of the nation's leading electronics organizations, are now creating a number of new openings in an important phase of their operations.

**THE COMPANY**

Hughes Research and Development Laboratories, located in Southern California, are presently engaged in the development and production of advanced radar systems, electronic computers and guided missiles.

**THE NEW OPENINGS**

The positions are for men who will serve as technical advisors to government agencies and companies purchasing Hughes equipment—also as technical consultants with engineers of other companies working on associated equipment. Your specific job would be essentially to help insure successful operation of Hughes equipment in the field.

**THE TRAINING**

On joining our organization, you will work in the Laboratories for several months to become thoroughly familiar with the equipment which you will later help users to understand and properly employ. If you have already had radar or electronics experience, you will find this knowledge helpful in your new work.

**WHERE YOU WORK**

After your period of training—at full pay—you may (1) remain with the Laboratories in Southern California in an instructive or administrative capacity, (2) become the Hughes representative at a company where our equipment is being installed, or (3) be the Hughes representative at a military base in this country or overseas (single men only). Compensation is made for traveling and moving household effects, and married men keep their families with them at all times.

**YOUR FUTURE**

In one of these positions you will gain all-around experience that will increase your value to our organization as it further expands in the field of electronics. The next few years are certain to see large-scale commercial employment of electronic systems. Your training in and familiarity with the most advanced electronic techniques now will qualify you for even more important future positions.

**How to apply:**

If you are under thirty-five years of age, and if you have an E.E. or Physics degree, write to the Laboratories, giving resume of your experience. Assurance is required that relocation of the applicant will not cause disruption of an urgent military project.

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.**

1 East 79th St., New York 21, N.Y.

**ELECTRONIC ENGINEER**

An established business, whose 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, 536-536 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 south west, 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 submit a complete application stating educational background and past work experience. John A. Green Co., 6015 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 compute 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, 21 Massachusetts Ave., Cambridge 39, Mass.

(Continued on page 124A)

*PROCEEDINGS OF THE I.R.E.*

December, 1952
This is the Boeing team's jet heavyweight

Here is a flight shot of the giant Boeing B-52 Stratofortress. An eight-jet heavy bomber, the Stratofort is a fast, husky teammate to the B-47 Stratojet medium bomber. It's 153 feet long, measures 185 feet from wing-tip to wing-tip, and is powered by eight Pratt & Whitney J-57 engines. Speed and other performance details are carefully guarded secrets.

This Boeing jet-bomber team is just another example of the trail-blazing that, over the past 35 years, has kept Boeing engineers at the head of the design parade.

If you measure up to Boeing standards, you can share this Boeing prestige. You'll work with men renowned in their fields, on such challenging projects as guided missiles, nuclear-powered aircraft, and the exploration of supersonic flight.

There are openings at Boeing right now for experienced and junior engineers in all fields, for aircraft

- DESIGN  - DEVELOPMENT
- RESEARCH  - PRODUCTION  - TOOLING
also for servo-mechanism and electronics designers and analysts, and for physicists and mathematicians with advanced degrees.

You can work in Seattle in the Pacific Northwest or, if you prefer, at Wichita in the Midwest. Boeing provides a generous moving and travel allowance, offers you special training, a salary that grows with you—and a future of almost limitless range.

You'll be proud when you say, "I'm a Boeing engineer!"

Write today to the address below, or use the convenient coupon:

JOHN C. SANDERS, Staff Engineer—Personal
Dept., J-12
Boeing Airplane Company, Seattle 14, Wash.
Engineering opportunities at Boeing interest me. Please send me further information.

Name ____________________________________________
Address __________________________________________
City and State _______________________________________

BOEING
Communication Engineers

ATTENTION!

The world's largest independent supplier of Carrier equipment offers permanent positions, good starting salaries, and unusual opportunity for progress. If you have had experience in any of the following fields, we can make you a very attractive offer:

1. Carrier Transmission Engineering
2. Carrier Equipment Installation and Maintenance
3. General Transmission Engineering

Write giving full details of your background to Personnel Director

AUTOMATIC ELECTRIC
1033 West Van Buren Street, Chicago 7, Illinois

---

CAREERS IN RESEARCH

The National Union Research Division offers opportunities to men interested in Permanent Positions with excellent future prospects. There are several openings on our research staff in the fields of Specialized Vacuum Tube Development and Electronic Circuit Design.

ENGINEERS PHYSICISTS TECHNICIANS

Are invited to inquire regarding these positions.

Benefits include:

- Free Hospitalization
- Medical Surgical Plan
- Life Insurance
- Profit Sharing Plan
- Paid Vacations
- Paid Holidays
- Merit Salary Reviews
- Excellent Working Conditions

NATIONAL UNION RESEARCH DIVISION
350 Scotland Road Orange, N.J.

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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. EPID-1, Radio Corporation of America, RCA Victor Div., Camden 2, New Jersey.

ENGINERS

The manufacturers 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 reimbursement of tuition expenses is extremely liberal. Interviews arranged at our expense. Replies strictly confidential. Remington Rand Inc, Eckert-Mauchly Division, 200 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)

SALES ENGINEER

Outstanding opportunity in capital equipment sales—heavy industrial process measuring and control equipment—for a graduate engineer with 2 or more years of successful capital equipment sales experience and a thorough knowledge of sheet process manufacturing and equipment in the paper, rubber, or plastics industry.

Our organization is the recognized leader in the development and manufacture of industrial uses of radioisotopes and our continued expansion offers unparalleled opportunity for a sales engineer capable of working with top management.

Interested applicants are requested to submit a complete resume of education and experience to:

INDUSTRIAL NUCLEONICS CORPORATION
1205 Chesapeake Ave.
Columbus 12, Ohio
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.
Electronic Engineers and Physicists

Our steadily expanding laboratory operations assure permanent positions and unexcelled opportunity for professional growth in

Research & Development
Guided Missiles
Radar
Electronic Navigation
Solid State Physics
Vacuum Tubes
Television

The Employment Dept.
Address inquiries to: 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, thyatron circuits, discriminators, magnetic circuitry and fractional horsepower 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 $4900.00 per annum. Write: Professional & Scientific Requirer, 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 $4000 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
To: Senior Servo Engineers
   Senior Electrical Engineers

You are invited to join the Bell Aircraft Engineering team and to contribute YOUR imagination and creative talents to revolutionary investigations and developments in the field of auto-navigation.

Experience and ability command a premium at Bell Aircraft Corporation. Challenging opportunities are available NOW at responsible levels for:

1. Engineers experienced in autopilots, gyro-stabilized systems, and automatic control systems.
2. Instrument design engineers experienced in the design of precision mechanisms and special devices.

BELL
Aircraft
CORPORATION

ENGINEERING PERSONNEL OFFICE
P. O. BOX 147
BUFFALO 5, N. Y.

R. S. V. P.

INERTIAL GUIDANCE SYSTEM DEVELOPMENT IS A LONG-RANGE PROGRAM AT BELL AIRCRAFT
MEMO: to Engineers, Physicists, Chemists and Metallurgists

FROM: GENERAL ELECTRIC

SUBJECT: CAREER OPPORTUNITIES

Those seeking long-range association with a leading company . . . those who wish to have the finest facilities and equipment available . . . those who recognize the importance of working with leading scientists . . . those who desire the challenge of diversified, pioneering projects and look for steady advancement . . . will find that a General Electric career meets all these requirements.

Positions are now open in Advanced Development, Design, Field Service, and Technical Writing in connection with:

MILITARY RADIO & RADAR
MOBILE COMMUNICATION
MULTIPLEX MICROWAVE
COMMUNICATIONS
ELECTRONIC COMPONENTS
TELEVISION, TUBES & ANTENNAS

Bachelor's or advanced degrees in Electrical or Mechanical Engineering, Physics, Metallurgy, or Physical Chemistry and/or experience in electronics industry necessary.

Do not apply, please, if your best skills are being used for vital defense work.

Please send resume to:
Dept. 12-2-T Technical Personnel
ELECTRONICS PARK
SYRACUSE, N.Y.

FLORIDA CALLS ELECTRONIC ENGINEERS

Graduate engineers for R & D in microwave components and receivers, SONAR, transistors, non-linear circuitry and computers.

Ideal sports, living and working conditions with excellent pay, unusual employee benefits and profit sharing.

Write for application to:
RADIATION, INC.
MELBOURNE, FLORIDA

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
32 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 382 W.

ELECTRONIC ENGINEER
B.S., June 1950, New York University. 2 years electronic design experience. Desires position as electronic sales representative in New York area. Box 382 W.

SYSTEMS ENGINEERS
For design and installation of radio communication systems of all types in HF, VHF and Microwave bands for use in foreign countries.

Applicants should have experience in either radio propagation studies and antenna design or telephone and telegraph terminal equipment.

These positions are not dependent on government contracts and employment would be in New York office with occasional overseas surveys or job supervision.

Write full details to Personnel Dept.
Radio Corporation of America
RCA International Div.
30 Rockefeller Plaza
New York 20, New York

PROCEEDINGS OF THE I.R.E. December, 1952
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

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 precision equipment. Practical and theoretical knowledge of materials, finishes, sheet metal, and machine shop design are basic. 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


- Dependable communications since 1931

Offers Challenging Opportunities in Guided Missile Programs

NEW YORK

**SERVOMECHANISMS ENGINEERS**

for research, design, development and test assignments on:

- Servomechanisms
- Gyroscopes
- Computers
- 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 plans.

WRITE: Mgr. Engineering Personnel
Bell Aircraft Corporation
P.O. Box 1, Buffalo 5, New York

ENGINEERS

USE YOUR EXPERIENCE
TO BUILD A SOUND FUTURE AT

SPERRY GYROSCOPE CO.
DIVISION OF THE SPERRY Corp. GREAT NECK, L. I., N. Y.
Positions Wanted

(Continued from page 128A)

ELECTRONIC ENGINEER
Age 37. Seeks position requiring initiative and broad experience. BS EE 1937; 4 years electrical construction and maintenance, steel mill; 5 years officer, Corps of Engineers; 6 years electronics 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.


(Continued on page 128A)

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 service 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 includes 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?


NORTH AMERICAN AVIATION, INC.
Aerophysicists, Electro-Mechanical Research Division
Dept. 7, Personnel Section
12214 Lockheed Blvd., Downey, California
North American Has Built More Airplanes Than Any Other Company In The World

PROCEEDINGS OF THE I.R.E. December, 1952

130A

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. Mathson, Employment Manager, Dept. IRC-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 130A)

TV BROADCAST ENGINEER

Desires responsible position with new TV station. 3 years AM broadcasting, 2 years TV. Last 2 years, Technical Supervisor, 50,000 watt AFRS broadcast station overseas. Considerable construction experience. Box 993 W.

ENGINEER—INSTRUCTOR


ENGINEER


JUNIOR ELECTRONIC ENGINEER

Age 26. USN-ETM 1/c, completed 4 years, evening at New York University toward BEE. Experience: 4 years TV, 1½ years research assistant in electronics for metropolitan university. Box 996 W.

ENGINEER

Senior communications engineer (supervisor) desires to locate in Canada. Thoroughly experienced in power international, relay, and medium wave broadcasting; aviation radar; 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 997 W.

(Continued on page 132A)
Positions Wanted

(Continued from page 1154)

ENGINEER

BSEE, electronics 1949. 2 years electronic design and development. 1 year development microwave components. Presently project engineer on radar plumbing systems. Desires sales or application engineering in New York City, Connecticut or Massachusetts. Age 27. Married. Box 598 W.

ELECTRONIC ENGINEER

BSEE., MN., age 28. 2 years Navy electronic Technician; 3 years college teaching; 3/5 years circuit design experience. Seeks position with supervisory and/or customer relations responsibilities. Box 599 W.

ENGINEER

BSEE., communications option, Iowa State College. Age 27, married, 2 children. 10 months experience research testing of servo-amplifiers, computer. 1 year experience as ground radar officer, USAF. Desires research and development position. Box 600 W.

ENGINEER—PRACTICAL SALES

Outstanding electronic, mechanical skills knowledge. 4 years supervisory military communications. 6 years shop and theory instru-
tor AM, FM, TV communications. Marine radio, motors and generators, pulse circuitry, 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 601 W.

ENGINEER

EE., communications 1949. MSEE. upon completion of thesis. Tau Beta Pi. Currently employed in TV research and development at

(Continued on page 1154)
ENGINERS
Electronic
RADAR
SERVO
COMPUTER

Make Your Move
In The
Right Direction

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.

ENGINERS
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.
WE WANT TWO MORE
SENIOR ELECTRONIC ENGINEERS

Here are two unique opportunities for experienced, progressive electronic engineers.

The Position  Supervision of projects in the development of electronic test and measuring equipment.

The Firm  The New London Instrument Company is a growing concern. Engineer-owned and engineering-minded, we stress and reward technical ability. We want men who can be left alone and do a good job.

The Salary  Open—AND LARGE.


Inquiries will be handled in confidence.

New London Instrument

NEW LONDON, CONNECTICUT

EXPERIENCED
RADAR AND COMPUTER
ENGINEERS

in one or more of the following fields:

- General radar and computing systems
- Servomechanisms
- Radar transmitter-modulators
- Generalized systems analysis
- Indicator systems
- Wide band IF amplifiers and receivers
- General pulse circuits
- Electro-mechanical design

UNUSUAL OPPORTUNITIES IN
LONG-TERM DEVELOPMENT OF
RADAR AND RELATED EQUIPMENT

SINCE 1912 A LEADER IN RESEARCH
DEVELOPMENT AND PRODUCTION

Gilfillan Bros.
1815 Venice Blvd., Los Angeles 6, California
BROCHURE ON REQUEST

DESIGN STAFF
ENGINEER

Transmission

BROAD experience in precision automotive transmission design, including extensive background in manufacturing operations. Helicopter or aircraft experience desired. Responsible for transmission design at staff level; and, to coordinate design problems with vendor manufacturers. A degree in mechanical engineering is preferred. However, equivalent experience will be accepted.

DESIGN STAFF
ENGINEER

Electrical

BROAD experience in aircraft electrical systems. Aircraft experience required. Experience in electronic systems including auto-pilot and radio desirable. Administrative ability and experience which will enable the individual to direct activities of a small design staff, coordinating all electrical and electronic activities within a large aircraft engineering department. Degree in electrical engineering preferred. However, equivalent experience will be accepted.

INDUSTRIAL
ENGINEERS

INDUSTRIAL or mechanical engineering degree or equivalent, plus experience in analyzing manufacturing problems related to methods (direct and/or indirect), plant layout processing, tooling and cost reduction.

HELICOPTER TEST
PILOTS

With not less than 250 Hours of Helicopter Time.

A-1-s-o

DRAFTSMEN

With two to five years experience, preferably in aircraft.

Send complete resume, including salary requirements, to EMPLOYMENT MANAGER

PIASECKI
Helicopter Corp.
Dept. “E”
Morton, Pa., A Phila. Suburb

PROCEEDINGS OF THE I.R.E.  December, 1952
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


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.

ELECTRONIC ENGINEER

USAF Guided Missile Officer. Age 25, married. BSEE, communications option with honors. BS in commerce. Graduate of USAF Airborne Electronics, Guided Missile Guid. (Continued on page 136A)

SPECIAL OPPORTUNITIES FOR SENIOR ENGINEERS

Convair, in beautiful, sunshiny San Diego invites you to join "engineers" engineering department. Interesting, challenging, essential long-range projects in commercial aircraft, military aircraft, missiles, engineering research and electronics development. Positions open in these specialized fields:

- Electrical Design
- Structural Design
- Mechanical Design
- Aerodynamics
- Servo-mechanisms
- Thermodynamics
- Operation Analysis
- Weights
- System Analysis

Generous travel allowances to those accepted. For free brochure, write Mr. M. T. Brooks, Engineering Dept. 800

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SAN DIEGO 12, CALIFORNIA

is offered for intelligent, imaginative engineers and scientists to join the staff of a progressive and self-sustaining, university-affiliated research and development laboratory. We are desirous of expanding our permanent staff in such fields as electronic instrumentation, missile guidance, microwave applications, design of special-purpose electronic computers, and in various other applied research fields of electronics and physics.

Salary structure and benefit programs are on a par with industry. In addition, there are many tangible advantages, such as our self-sponsored internal research policy, of interest to men with ingenuity and initiative.

CORNELL AERONAUTICAL LABORATORY, INC.
BUFFALO 21, NEW YORK

PROCEDINGS OF THE I.R.E. December, 1952
Model 705 WOBBULATOR

... for RF, IF, and Video Amplifier alignment and measurement

- Center Frequency of Swept Band—2.0 mc to 500 mc.
- Swept Bandwidth—up to 100 mc wide.
- Output—0.1 volt at 50 ohms, with calibrated continuously variable 90 db output attenuator to allow rapid, accurate gain measurement.
- Internal five inch CRT display of response of circuit under test; 0.05 mv. or more input to the high or low impedance probes from the circuit under test will give an adequate pattern.

Write for complete technical data

Canoga Corporation
5955 Sepulveda Blvd., Van Nuys, Calif., Box 361

There is Always One Leader in Every Field

BODNAR INDUSTRIES, Inc.
leads in the field of
TRANSILLUMINATED PLASTIC LIGHTING PLATES
BECAUSE OF Quality • Uniformity • Performance
Design & Layout “Know-How Service”
Quantity Production Promptly
NEW YORK — 19 Railroad Ave., New Rochelle (Home Office)
TEXAS — Jefferson Tower Building, Dallas
CALIFORNIA — 11056 Cumpston St., N. Hollywood
CANADA — 313 Montreal Trust Bldg., 67 Yonge St., Toronto
SPECIMEN PANEL (MIL-P-7788) SENT ON LETTERHEAD REQUEST

- this new AMPEREX plant is in full production in the manufacture of Transmitting Tubes • Special Purpose Tubes • Industrial Tubes • Electro-Medical Tubes • X-Ray Tubes • Ultra High Frequency Tubes • Fixed Vacuum Condensers • Hydrogen-Thyratron Tubes • Magnetrons • Geiger-Muller (Radiation) Counter Tubes

AMPEREX ELECTRONIC CORP., HICKSVILLE, LONG ISLAND, N.Y.

Positions Wanted

(Continued from page 1354)

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 broadcast, teaching, defense work in circuit development and engineering psychology. Amateur WQKNP. Interested in audio-visual arts. Box 630 W.

NEW YORK

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 631 W.

ELECTRONIC ENGINEER

Naval 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 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 1204)

New Firm

Hugo Woerdeman 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, ferroresonant circuits, magnetic pulse generators, magnetic frequency changers, low level signal converters.

Associated with Woerdeman are W. F. Delboeuf and K. L. Sanders, both magnetic amplifier specialists.

Woerdeman 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 pole 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 137.)
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 136 A)

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 138 A)

**REXOLITE 1422**

*(FORMERLY G. E. TEXTOLITE 1422)*

COMBINES EVERY DESIRABLE PHYSICAL, CHEMICAL, & ELECTRICAL PROPERTY IN ONE INSULATION MATERIAL FOR U. H. F.

**REXOLITE 1422**

- Meets JAN-P-77 and MIL-P-77A specifications.
- Specifically designed to meet the growing need for a U. H. F. insulating material that is low in cost.
- Withstands high temperature due to its thermosetting nature.
- Has outstanding electrical properties.
- Has low specific gravity — is strong and rigid with unusually high compressive and tensile strengths.
- Has excellent impact strength and hardness allowing its use under highly abusive conditions.
- Its dimensional stability and unusual chemical inertness allow its use where other materials fail.
- Readily machinable to extremely close tolerances.
- Available as centerless ground rods in any diameter up to 1". Also cast in larger diameter rods and sheets.
- Write today for technical bulletins and samples. Our engineering staff is always at your disposal.

Manufacturers of Non-strip wire, High Temperature Electrical Tubing and other extruded plastic products.

**THE REX CORPORATION**

56 LANDSDOWNE ST.

CAMBRIDGE, MASS.
ELECTRICAL RESOLVERS

- interchangeability
- temperature compensation — 60°F to +160°F
- highest accuracy
- adaptability to special circuit uses
- 400 cycle frequency

Now you can get the same Ford Electrical Resolvers, precision-built to the highest degree of operating efficiency for our own quality computers and automatic control equipment...to meet your extra special requirements!

FREE — fully illustrated brochure gives more details, describes Ford Instrument resolver systems. WRITE FOR YOUR COPY TODAY!

Address Dept. IRE-1.

FORD INSTRUMENT COMPANY
DIVISION OF THE SPERRY CORPORATION
31-10 Thomson Avenue, Long Island City 1, N.Y.

Come Again

to the 1953 IRE
Radio Engineering Show
March 23-26, New York

FS
MICROMETER HEAD
for the Electronics Industry

LARGE, LEGIBLE, EASY TO READ CALIBRATIONS, PLUS A THIMBLE STOP TO PREVENT THREAD JAMMING, ARE FEATURES FOUND IN FS MICROMETER HEADS WHICH HELP ENGINEERS SPEED UP THEIR WORK. THESE AND MANY OTHER FEATURES ARE DESCRIBED IN THE NEW BULLETIN ON FS MICROMETER HEADS, OBTAINABLE ON REQUEST.

FREQUENCY STANDARDS
P. O. BOX 66, EATONTOWN, N. J. • TELEPHONE ASEBURY PARK 1-1018

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 1174)

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)
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

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
SEL SYN
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.

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Irv. M. Cochran Co.
406 S. Alvarado St., Los Angeles, Calif.
high-precision thermistors
by BENDIX-FRIEZ

As temperature measuring elements and liquid level sensors, these temperature responsive resistors are the best you can buy. In standard or special types, their high-precision manufacture makes them precisely right for your job when it comes to resistance values, size, temperature coefficient, mountings and quality. Ask us about applications.

STANDARD TYPES FOR IMMEDIATE DELIVERY

<table>
<thead>
<tr>
<th>Size (inches)</th>
<th>@ +30°C</th>
<th>@ 0°C</th>
<th>@ -30°C</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.40 x 0.75</td>
<td>45.0 ohms</td>
<td>86 ohms</td>
<td>194 ohms</td>
</tr>
<tr>
<td>0.40 x 1.5</td>
<td>12,250 ohms</td>
<td>26,200 ohms</td>
<td>65,340 ohms</td>
</tr>
<tr>
<td>0.018 x 1.5</td>
<td>35,000 ohms</td>
<td>82,290 ohms</td>
<td>279,600 ohms</td>
</tr>
</tbody>
</table>

Used in this typical application for sensing the temperature of hydraulic oil.

Oscillograph Tube

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.

 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 138A)
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, computers, photometers, p.h. meters, etc.

6588
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. \( g_m = 2 \times 10^{-12} \).

6593
Electrometer Tetrode—The ultimate in low grid currents. \( g_t \) is the control element, \( g_m \) is an accelerator grid which may also serve as the plate in the inverted triode connection. \( g_m = 3 \times 10^{-12} \).

6592
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 triode, \( g_m = 5 \times 10^{-12} \).

679P
Electrometer Diode—Used as a clipper wherever high insulation is important. As an electrometer, it requires a high gain feedback amplifier circuit. \( R = 10^8 \) ohms.

VX-10
Electrometer Switch—For switching in high impedance circuits or remote locations. \( R = 10^8 \) ohms.

HI-MEG
Resistors—"Calibrated Insulators" for electrometer input circuits. \( R = 10^8 \) to \( 10^9 \) ohms.

HERMETIC SEALED Type RKH Plugs and KP. 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 are 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 scaled 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

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; special 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, 473, P.O. Box 73, Lincoln Heights Station, Los Angeles 31, Calif.

PROCEEDINGS OF THE IRE. December, 1952
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 14-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'Arsouval 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 144A)
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 x 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 0.5 watt.

(Continued on page 146)
Every TV station sends a COMPOSITE VIDEO SIGNAL when telecasting a program or a test pattern. This COMPOSITE VIDEO SIGNAL is composed of—(1) a synchronizing and blanking signal to lock the free running raster into a frame of two interlaced fields, and—(2) a video signal to control the amount of light and produce the picture (which may be a program scene or a test pattern for analysis purposes).

A television set will produce a picture only when it is supplied with a COMPOSITE VIDEO SIGNAL. To check any TV set properly, you must have a COMPOSITE VIDEO SIGNAL.

Why lose time and money waiting for that ideal scene or test pattern to check a TV set? In fringe or weak signal areas, you are strictly in the "driver's seat" with a SUPREME COMPOSITE VIDEO GENERATOR. Write SUPREME, INC., Dept. II, GREENWOOD, MISSISSIPPI for descriptive folder.

Since 1927

SUPREME
Testing Instruments

"SUPREME BY COMPARISON"

TUBE TESTERS • OSCILLOSCOPES
SIGNAL GENERATORS • MULTI-METERS
FOR RADIO AND TELEVISION

Model 100 dc motor is rated 1/50 hp at 27V 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 with 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 from page 146A)
MICROWAVE COMPONENTS

S BAND—3" x 1 1/2" WAVEGUIDE

DIRECTIONAL COUPLER, Broadband 250 MHz to 2000 MHz with 0.25 dB insertion loss and 20 dB return loss. Natty 292Y-BAAN-3A, 

WAVEMETER, 2000-1400 MHz, Hanning Filter. $25.50

REACTION WAVEMETER, M.I.E. G.E. 292Y-BAAN-3A, $33.50

LIGHT GUIDES, M.I.E. G.E. 292Y-BAAN-3A, $33.50

APU-5 & APU-15, Receive Transistor Chain, Model 4410. $10.50

RE-BEAM COUPLER, Broadband, 250 MHz to 2000 MHz. $17.50

MAGNETRON TO WAVEGUIDE, Outside 2 1/2" Diameter Cavity, with plate. $40.90

Rigidity 180° for use with 3/4" hollow waveguide. $24.50

TUBES, All types. $7.50

7/8" KLYSTRON CAVITIES for 2/18W and 3/18W $14.00

3/4" SP-2 FILTERS, type "N" input and output. $15.80

WAVEGUIDE TO 5/16" RIGID COAX, 2 1/4" long. $8.70

KNOB ADAPTED CHROME PLATED, 2 1/4" long. $2.50

AS 1A45 AP-151 Plek up Inside with "N" connection. $14.50

600 ECHO BOX, 10 C.T. UNIT, $14.20

VERTICAL ECHO BOX, 10 C.T. UNIT, $14.20

I. F. AMP, STRIP, 30 MC, 120 OHMs, gain 20 dB, 2 MHz bandwidth, use 6AG6 with "n" connector. $12.00

ANTENNA SUPPORT, Upright, 1/4" Tube. $2.50

STUB-SUPPORTED RIGID COAX, and plate. $5.00

RT ANGLES for above $2.50

WAVE L & DA FLEXIBLE SECTIONS, 15" Male to female $12.50

BAND 3, 0 to 3000 MHz. $75.00

1/2" RIGID COAX—90°/90° I.C.

RIGHT ANGLE BEND with flexible coax output. $8.00

STUB RIGHT ANGLE BEND with flexible coax output. $5.00

STUB SUPPORTED RIGID COAX, and plate. $5.00

RT ANGLES for above $2.50

WAVE L & DA FLEXIBLE SECTIONS $2.00

IN IMMEDIATE DELIVERY—FULLY GUARANTEED

X BAND—1 1/4" x 1/4" WAVEGUIDE

1 1/4" x 1/4" waveguide in 5 lengths, 1/20 30 Flanges in 3 lengths. $1.75

Retailing prices quoted either with or without drop base. See table below. $17.50

Bulkhead Feed-through Assembly $15.00

Pressure Gasket, Male and female $2.50

Pressure Gauge, 50 psig $2.50

Dual Oscillator, Mount. (Brackets to wall) with crystal, tuning, and SMA type, $10.00

Directional Coupler, 1145/4" Take off 20 db below $3.75

TR ATR Upconverter section for above $3.75

WAVEGUIDE Section 2 1/2" long inside to inside $4.50

WAVEGUIDE Section 2 1/2" long inside to outside $4.50

WAVEGUIDE Section 2 1/2" long inside to outside $4.50

UG 39 Flanges $1.00

UG-39 connector $1.00

WAVEGUIDE Connector, 1" inside to 1/2" inside $1.50

10 degree twist 6" long $8.00

AP-1A Assembly, less tubes $10.00

1/16" x 3/4" WAVEGUIDE

X Band Wave GD 1/16" x 3/4" OD 0.105 wall aluminum, per ft. $75

Sleeve Tuner Attenuator W.E. Model. $6.50

Bi-Directional Coupler, Type "N" Takeoff 25 db per coupling $17.98
Flying Saucers?

Frankly we don’t know if they’re fact or fiction, but if they are fact it wouldn’t surprise us a bit to learn that some extra-terrestrial manufacturer has incorporated Selenium Rectifiers and R. & Co. Germanium Diodes into the design. That’s because—as pioneers in the field of electronic development—we’ve had our hands in some of the most difficult projects and met some of the silliest requirements ever cooked up! Making drawing board dreams come true are daily chores at Radio Receptor Co. Inc.

GERMANIUM DIODES

Basic rectifier type Germanium Diodes feature polarity at a glance combined with simplicity of construction and sound design principles. The shaped chip design assembly because rectifiers can be at a glance built and built into practically any semiconductor application.

The correct direction of assembly is easily established over the quality of the product which is virtually being used in multitudes, computers, TV sets, cameras and other electronic applications.

GERMANIUM DIODES

Rectifiers and Germanium Detonation

SELENIUM RECTIFIERS

Rectifier Selenium rectifiers, in both miniature and industrial types, are current limited by an increasing number of engineers through the world because they are completely dependable under the most galling conditions. Years of experience have given Radio Receptor Co. a deep insight into the demystification of rectification.

Our Germanium Diodes and Selenium Rectifiers may hold the answer to many of your problems. Radio Receptor Engineers will be glad to study your requirements and submit their recommendations on both of these products

Germanium Transistors available in limited quantities.

RADIO RECEPTOR COMPANY, INC.

& Germanium Detonation

FLYING SAUCERS

Fast, Accurate, Reliable

The — SKL — Model 302 includes two independent filter sections, each having a continuously variable cut-off range of 20 cps to 200 KC. Providing a choice of filter types each section has 18 db per octave attenuation. When cascaded 36 db is obtained in the high and low pass setting and 18 db in the band pass position. With low noise level and no insertion loss this versatile filter can be used as an analyzer in industry and the research laboratory or to control sound in the communications laboratory, radio broadcasting, recording and moving picture industries.

SPECIFICATIONS

- CUT-OFF RANGE
  20 cps to 200 KC
- SECTIONS
  2 — can be high, low and band pass
- ATTENUATION
  36 db octave maximum
- INSERTION LOSS
  0 db
- NOISE LEVEL
  60 db below 1 volt
- FREQUENCY RESPONSE
  2 cps to 4 MC

SKL SPENCER-KENNEDY LABORATORIES, INC.

181 MASSACHUSETTS AVE., CAMBRIDGE 39, MASS.

CONTINUOUSLY VARIABLE FILTERS

MODEL 302

VARIEABLE ELECTRONIC FILTER

Bobbin Winder

A new calibrated 2-inch economy box-type cam which provides any winding traverse from 0 to 2 inches is outstanding feature on the new Model 119-A bobbin winder offered by George Stevens Mfg. Co., Inc., 1104 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.

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 164A)

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, finish 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 164A)
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.

Other "700" models up to 60 channels are available. Write today for a complete catalog of Heiland "700" oscillograph recorders.

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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 Hvl., 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 voltmeters 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 eps 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)
DUPLEXER

Bogart produces these units in large quantities, and at the same time insertion loss, a. f. c. coupling and gate attenuation are held to less than half of normally accepted tolerances, resulting in extremely fine performance at lowest cost.

FEEDHORN

This Feedhorn, one of many different types manufactured by Bogart, is characterized by a reflection coefficient and bandwidth not ordinarily found in a multiple twist and bend unit of this kind. Each Horn is calibrated and the complete data forwarded to the customer at time of shipment.

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and
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Bogart is fully equipped to execute stamping, spinning, electroplating, and special precision machine work. (Our laboratory, one of the finest in the East, is fully equipped to electrically test all products of our manufacture.)

Inquiries and problems concerning the manufacture, development and calibration of any microwave units are cordially invited.

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Fabricating "Know-how", the result of years of specialized experience—and the most modern facilities for rapid, low-cost, close-tolerance production are at your command when you specify Teflon or Kel-F® by the United States Gasket Company. Ours is the most complete line in the country—sheets, tape, rods, cylinders, tubing, bars, and custom-machined or molded parts to manufacturers' specifications.
Nobody knows oil capacitors like C-D. It's generally acknowledged that "nobody can duplicate C-D's Dykanol capacitor." You can count on the ruggedness and durability that have made C-D capacitors famous for 42 years and that is all too rare these days. Catalog No. 401 will show you how broad the line is. Write for it to: Dept. M122, Cornell-Dubilier Electric Corp., South Plainfield, N. J.

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world's largest manufacturers of capacitors
The Type 544-B Megohm Bridge is an accurate, simple-to-operate, portable test instrument for measuring resistances in the megohm range. 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 $240
Type 544-8B 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: 26½ pounds with a-c supply; 29½ pounds with batteries.