**AMPEREKEX AX-9903/5894**

**UHF and VHF Twin Tetrode for W-I-D-E Band Operation**

**RF Amplifier, Modulator, Frequency Doubler, Tripler**

**AX-9903/5894 CHARACTERISTICS**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filament Voltage</td>
<td></td>
</tr>
<tr>
<td>Series</td>
<td>12.6 v</td>
</tr>
<tr>
<td>Parallel</td>
<td>6.3 v</td>
</tr>
<tr>
<td>Filament Current</td>
<td></td>
</tr>
<tr>
<td>Series</td>
<td>0.9 a</td>
</tr>
<tr>
<td>Parallel</td>
<td>1.8 a</td>
</tr>
<tr>
<td>Maximum</td>
<td></td>
</tr>
<tr>
<td>d.c. Plate Voltage</td>
<td>600</td>
</tr>
<tr>
<td>d.c. Grid =2 Voltage</td>
<td>250</td>
</tr>
<tr>
<td>d.c. Grid =1 Voltage</td>
<td>-175</td>
</tr>
<tr>
<td>Plate Dissipation (w.)</td>
<td>2 x 20</td>
</tr>
<tr>
<td>d.c. Plate Current (ma.)</td>
<td>2 x 100</td>
</tr>
<tr>
<td>Grid to Plate</td>
<td>&lt; 0.08 mmfd</td>
</tr>
<tr>
<td>Input</td>
<td>6.7 mmfd</td>
</tr>
<tr>
<td>Output</td>
<td>2.1 mmfd</td>
</tr>
</tbody>
</table>

**MOUNTING POSITION:** Base up or down. Horizontal with anode leads in horizontal plane.

Fits 829B Type Socket.

- The AMPEREKEX AX-9903/5894 is an improved version of the 829B. The design of this tube incorporates features which produce considerably smaller output capacitances and which, therefore, result in higher resonant frequencies (approximately 500 mc. instead of 250 mc.). In addition, because of the low inductances of the connections between the cathode and screen-grid, more stable operation at high frequencies is effected.

- A most desirable design characteristic, also, is the incorporation of internal neutralizing condensers which are connected directly to the control-grids, making impossible self-oscillation in a tuned-plate, tuned-grid transmitter.

- Of importance in this new design are such features as:
  1. Direct and short connection between the pins and the anode, causing lower inductance and resistance.
  2. No insulating parts (mica or ceramics) between anodes, resulting in lower losses at high frequencies.
  3. "Screened" micas, thereby preventing possible losses due to contaminated micas.
  4. Zirconium-coated moly anodes, giving a higher degree of vacuum than possible with nickel anodes and barium getters.

- For the full story on how to use the AMPEREKEX AX-9903/5894 in your particular application, write to Application Engineering, Department N. Or if you prefer, ask for an AMPEREKEX representative to call.

- IMMEDIATE DELIVERY • Order from your local electronics parts distributor. If unavailable, write direct to our plant.

* Subject to prior sale

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What to SEE at The Radio Engineering Show

March 19-22, 1951 at Grand Central Palace, New York

267 Exhibits of Radio-Electronic Equipment

The series 400 Cell Type Screen Room, 10' x 10' x 18'. Panel construction permits moving or enlarging.

Represented by Wally Swank.

Electrolytic, mica, paper and metallized paper capacitors.

Solderless terminals and connectors, tools, amplifying tubing material, capstions, and radar pulse networks.

Airtron, Inc., Linden, N.J. Booth: 356
All types of exotic component flexible and rigid waveguides, microwave test equipment, slotted-sections, dummy loads, waveguide switches, shielded wired assemblies for ignition, thermocouple and electrical control of oscillators.


Alloyed and pre-alloyed, high quality alloy steels. Castings, forgings, special stainless steels. High strength structural designs.

Allied Control Co., Inc., New York, N.Y. Booth: 279
Relays-Electrical.

Alpha Metals, Inc., Brooklyn, N.Y. Booth: 326
Cen-Tri-Core "energized" resin filled solider.

Altec Lansing Corp., New York, N.Y. Booth: 309, 311
Audio equipment, microphones, amplifiers, loudspeakers, audio and power transformers, includes dynamic cardiods, capacitor microphones, high quality amplifiers ranging from 10 watts to 500 watts, recorders, industrial and sound system amplifiers from 15 watts to 250 watts, loudspeakers from 8" cone to 15" dipole and theatre speakers, transformers from radio replacement to high quality transformers, transformers to JAN or MIL specifications.

American Lava Corp., Chattanooga, Tenn. Booth: 64
Ceramic insulators for radio, television, radar, electronic components, wire communications, control equipment and household electrical equipment.

Coaxial cables polyethylene and teflon, 300 ohm twin-wire, RF connectors, AN connectors and fittings, Industrial connectors, AN conduit and fittings, Communication P.M. and UHF Transmitting, Radio Components and hardware, TV antenna rotator, plastics for electronics.

American Smelting & Refining Co., Whiting, Ind. Booth: 334
Sec. Federation Metals Division.

Display shows properties of glass and a series of "live" exhibits, facts shown are unique characteristics of hardened insulators, glass blocks, tubing, rod and miscellaneous electronic glass parts.

ATR DCAC inverters, battery eliminators, auto radio vibrators, heavy duty vibrators, vibrator power supplies, rectifier power supplies.

Amperex Electronic Corp., Brooklyn, N.Y. Booth: 19, 11, 12
High power transmitting tubes of all types for communication, industrial and special purposes—array tubes; fixed capacitors, G-M counters, magnetrons; miniature ultra high frequency tubes and subminiature types.

Anchor Metal Co., New York, N.Y. Booth: N-21
Shurfo resin core solder, a new development in cored solders that is particularly adapted to all solder connections where corrosion is an important factor. Also bar solder, solid wire solder, solder preforms, lead and tin products.

Andrew Corp., Chicago, Ill. Booth: N-9
Transmission Lines, Antenna Equipment, VHF and UHF antennas, FM & TV transmitting antennas, phasing & coupling equipment, HF power modules, direction finders, tower lighting equipment.

Anton Electronic Laboratories, Inc., Brooklyn, N.Y. Booth: 380
Full line of newly developed precision radiating antennas, using entirely new engineering and manufacturing principles. Record accuracy, speed and precision, assembled, tested on engineering display. Radially new portable radiation survey meter.

Arnold Engineering Co., Marengo, Ill. Booth: 25, 26

Nuclear measurement apparatus.

Audio Devices, Inc., New York, N.Y. Booth: 316
Display of recording and playback points and magnetic recording tapes and film. Audio circuits, Audio!tape and Audiofilm. Industrial film will be shown on the manufacture of Audiofilm.

Automatic Electric Sales Corp., Chicago, Ill. Booth: 290
Miniature telephone type relays and stepping switches for guided missiles, aircraft, etc.

Avison Instrument Corp., New York, N.Y. Booth: 333
Aviton subminiature electronic assemblies, magnetique magnetic particle switches and brakes, guided missile components, gyro's, serovemachinements, analog computers and high speed digital computers.

Bellantine Laboratories, Inc., Boonton, N.J. Booth: 100
Sensitive electronic voltmeters, Decade amplifiers, voltage multipliers, shunt resistors.

Coils, capacitors and components and test equipment.

Shock mountings, vibration isolators, aircraft mountings.

Bendix Radio Division of Bendix Aviation Corp., Towson, Md. Booth: 14 to 17
G.C.A. talkdown trainer which permits training of pilots and ground operators in techniques employed in talking down aircraft to safe landings when radar is used. Also used for evaluation of electronic flying aids.

Electronic instrumentation for industry and research. Events-Per-Unit-Time-Meter, Timer Interval Meter, electronic counters presettable to any desired number, nuclear scales, count rate meters, count rate computers, double pulse generators.

Bertlow Associates, Los Angeles, Calif. Booth: 314
Recording equipment, Concertone magnetic tape recorders.

Bird Electronic Corp., Cleveland, Ohio Booth: 244
Termaline RF wattmeters, coaxial switches, aircraft antennas, antenna filters, Termaline dummy loads.

Quartz crystals, crystal ovens, frequency standards.

Boeck Manufacturing Co., Inc., Danbury, Conn. Booth: 306
Cable winding machinery for the winding of individual coils, paper interleaf transformer coils, bobins and windows.

Boonton Radio Corp., Boonton, N.J. Booth: 276, 277

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Test Equipment
by PRD

ATTENUATORS and TERMINATIONS
IMPEDEANCE MEASUREMENT
and TRANSFORMATION
TRANSMISSION LINE COMPONENTS
FREQUENCY MEASURING DEVICES
DETECTION and POWER MEASUREMENT
SIGNAL SOURCES and RECEIVERS

Polytechnic RESEARCH
& DEVELOPMENT COMPANY, Inc.
202 TIL LARY STREET, BROOKLYN 1, NEW YORK

AS EXHIBITED AT THE
Radio Engineering Show
New York City
BOOTHES 268 and 269
March 18-22, 1951
Here is one of the fastest moving developments in electronics in recent years—General Electric's amazing new electrolytic-type capacitors. These Tantalytic capacitors have small size, excellent low-temperature characteristics, long operating life and in many cases, can replace bulky hermetically-sealed paper capacitors. Ratings presently available for consideration range from .02 μf up to 12 μf at 150 v dc. Units pictured are 1.0 μf at 150 volts, a size that is already on order in quantities of several hundred thousand.

Other features of G-E Tantalytic Capacitors include:

- No known limit to shelf life.
- An operating temperature range from $-55^\circ$C to $+85^\circ$C.
- Exceedingly low leakage currents.
- Ability to withstand severe physical shock.
- Completely sealed against contamination.

If you have large-volume applications where a price of 3 to 5 times that of hermetically-sealed paper capacitors is secondary to a combination of small size and superior performance—get in touch with us. Your letter, addressed to Capacitor Sales Division, Bldg. 42, Room 304, General Electric Company, Pittsfield, Mass. will receive prompt attention.

Apparatus Department, General Electric Company, Schenectady 5, N. Y.
TYPE 4W20000A POWER TETRODE
CLASS-B LINEAR AMPLIFIER—TELEVISION SERVICE
TYPICAL OPERATION (Per tube, 5-Mc. Bandwidth, 216 Mc.)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Synchronizing Level</td>
<td></td>
</tr>
<tr>
<td>Load Impedance</td>
<td>400 Ohms</td>
</tr>
<tr>
<td>Effective Length of Plate Line</td>
<td>Quarter Wave</td>
</tr>
<tr>
<td>D.C. Plate Voltage</td>
<td>3000 Volts</td>
</tr>
<tr>
<td>D.C. Plate Current</td>
<td>7.1 Amps</td>
</tr>
<tr>
<td>D.C. Screen Voltage</td>
<td>1000 Volts</td>
</tr>
<tr>
<td>D.C. Screen Current</td>
<td>600 Ma.</td>
</tr>
<tr>
<td>D.C. Grid Voltage</td>
<td>-310 Volts</td>
</tr>
<tr>
<td>Peak R.F. Grid Input Voltage</td>
<td>485 Volts</td>
</tr>
<tr>
<td>Plate Power Input</td>
<td>19.1 Kw.</td>
</tr>
<tr>
<td>Plate Dissipation</td>
<td>19.0 Kw.</td>
</tr>
<tr>
<td>Plate Power Output</td>
<td>20.1 Kw.</td>
</tr>
</tbody>
</table>

For the practical approach to high-power TV through channel 13, here is the tube . . . the new Eimac 4W20000A power tetrode.

Among the features of the 4W20000A are a unipotential cathode of thoriated tungsten heated by electron bombardment, a water-cooled anode rated at 20 kw dissipation, and coaxially arranged terminals.

This new tube's potential applications are not limited to TV service. Data on typical operation in class-C telegraphy or FM telephony as well as class-B linear TV amplifier service are included in a comprehensive data sheet . . . available for the asking.

Eitel-McCullough, Inc.
San Bruno, California
Export Agents: Frazor & Hansen, 201 Clay St., San Francisco, California

SEE THE 4W20000A at the March IRE Show, Booth 36
Many more wires can be crowded into a cable sheath when the wires are fine. But normally, wires don't transmit as well when they are fine and closely packed.

Bell engineers long ago learned to make wires do better work by loading them with inductance coils at regular intervals. The coils improve transmission and let messages travel farther. But originally the coils themselves were large, heavy and expensive. The cases to hold them were cumbersome and costly too.

So year after year Bell scientists squeezed the size out of coils. To make magnetic cores of high permeability they developed Permalloy. Tough but extra-thin insulation permitted more turns to a core.

New winding machines were developed by the Western Electric Company. Coil size shrunk to one-fiftieth. Some—like the one shown above—can be mounted right in cables themselves.

The 15,000,000 coils in the Bell System today mean thinner wires, more wires in a cable—more economical service for you. They demonstrate once more how Bell Telephone Laboratories work continually to add to your telephone's value.

**IT'S "LOADED" WITH BETTER TELEPHONE SERVICE**

Twenty of the Bell System's newest small loading coils—like the one at the left—are housed in the long black case, mounted in a cable splice. This type of installation permits the economical extension of city cables to serve out-of-town subscribers.
The finest we've ever built! That's our idea of the new "746". It's got lower torque, a new more accurate phasing adjustment, and a new method of ganging that makes it easy to put as many as twenty cups on a single shaft. Individual cups in a gang are easily replaced if necessary.

The new potentiometer is available with linear or non-linear windings to meet your specifications. Its attractive case is made of grey anodized aluminum.

The "746" is just one of the complete Fairchild family of precision potentiometers. What are your requirements? Write, giving details, to Fairchild Camera and Instrument Corporation, 88-06 Van Wyck Boulevard, Jamaica 1, N.Y. Dept. 140-13H.

**EASY REPLACEMENT**

To replace a unit in a "746" gang, loosen connecting band screws, remove 'cup', slip new "cup" under band, and tighten screws. This feature pays off in experimental work where circuit elements are changed periodically.

**ACCURATE PHASING**

A new type phasing adjustment is simpler and more accurate. A retainer plate clamps shaft to wiper arm. To adjust for phasing, loosen two screws, set the arm to the correct position, then tighten screws.

**FLEXIBLE DESIGN**

Typical of the special consideration Fairchild gives to its customers' special requirements is this plug-in version of the "746." Where fast servicing is a must, the advantages of this "quick-change" unit are quite apparent.

---

**SPECIFICATIONS**

<table>
<thead>
<tr>
<th>Accuracy (overall resistance)</th>
<th>0.5% (linear), 1.0% or better (non-linear)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical accuracy</td>
<td>0.025 in. F.I.R. max.; radial play—0.005 in. F.I.R. max.; shaft-center height stainless steel to 0.2500 diam. 0.0000, 0.0005 in.</td>
</tr>
<tr>
<td></td>
<td>Pilot hub—mached to 0.000 (±0.000, ±0.0005 in.)</td>
</tr>
<tr>
<td></td>
<td>1.5 oz-in.</td>
</tr>
<tr>
<td>Dimensions—diameter 1.750 max.; length (1 cup)</td>
<td>.800 in. ±.009 in.; added length per unit ganged .800 in. ±.002 in.</td>
</tr>
<tr>
<td>Case</td>
<td>Grey anodized aluminum</td>
</tr>
</tbody>
</table>

SEE THE TYPE 746 AND OTHER FAIRCHILD PRECISION POTENTIOMETERS AT THE RADIO ENGINEERING SHOW, BOOTHS 238-239
General Electric Permafil capacitors are designed for use at extremes in temperature—in high ambients—or in high altitudes where extreme cold is encountered. They are suitable for all blocking, by-pass and filtering applications.

These capacitors, while using paper dielectric, are treated with a plastic compound that retains its electrical stability at both high and low operating temperatures. Units are available in case styles CP-53, 61, 63, 65 and 70, as covered by specifications JAN-C-25—in ratings of .05 to 2.0 muf, 400 volts DC. Containers are metallic and are sealed with G-E long-life all-silicone bushings.

For full information on Permafil capacitors see your local G-E representative. Or write Apparatus Department, General Electric Company, Schenectady 5, New York.

Where space or weight are especially important

Permafil capacitors will average about 1/10 the size and weight of liquid-filled capacitors when designed to operate at 125°C.

Where short-life characteristics are permissible additional savings in size and weight are possible. If you have a short-life capacitor application in mind, G-E engineers would like to discuss it with you.
You hit the bulls-eye when you call upon Sprague application engineers to help you with critical capacitor problems.

Skilled in applying the essentials of capacitor design to save space and cost in complex military and civilian electronic equipment, Sprague engineers are ready to serve you.

If standard capacitors can solve your problem, they have the industry’s most complete line from which to recommend. If you need a special electrical or mechanical design to best solve your circuit or production problems, they will gladly work out the details without cost or obligation.

Time is of the essence today. If you have a capacitor, interference filter, or pulse network problem, contact SPRAGUE by 'phone, wire, or mail without delay.
A leading designer engineer visited our plant to work out a particularly difficult problem. Within a week, hand made samples were produced which fully met his requirements.

Asked what had impressed him most he said: "Your amazing versatility. We had no idea this could be done at all and you have shown us several ways you can do it. We have done business with you for years but until this visit I had no idea of the control you have over physical characteristics of your material. Your ability to economically produce complex shapes within close tolerances is far ahead of anything we have ever known. And I am greatly impressed by the modern equipment and the tremendous size of this business which makes nothing but technical ceramics."

We believe that you, too, will find here the answer to almost any technical ceramic problem.

AMERICAN LAVA CORPORATION
49TH YEAR OF CERAMIC LEADERSHIP
CHATANOOGA 5, TENNESSEE

An interesting fact of nature is that newborn opossums weigh not more than 4 grains and are not usually longer than one-half inch. Six of them can easily be held in a tablespoon.

1. The same spoon will contain several hundred ceramic screws 0.150” long, 0.086” screw diameter complete with slotted head, precision threads #2-56 and 0.018” diameter hole through the center. These have been successfully produced in AlSiMag in production quantities (Illustration is enlarged approximately five times.)

2. AlSiMag ceramic tubes 0.035” O.D. with 4 holes 0.006” I.D. are regularly and economically produced within tolerances of ±0.002”. (Illustration enlarged approximately seven times.)

More than 70 different raw materials are kept in stock in five large warehouse areas for production of the versatile AlSiMag technical ceramics.

Over two million AlSiMag ceramic pieces are produced and shipped each day. On many days the production is well in excess of three million pieces.

More than five thousand completely different custom made designs are made in AlSiMag each year.

3. Glazed coil forms, 8” in diameter, 23½” long with various pitch threads are made to a tolerance of ±2%, nothing less than ±0.12.

A leading designing engineer visited our plant to work out a particularly difficult problem. Within a week, hand made samples were produced which fully met his requirements.

Asked what had impressed him most he said: "Your amazing versatility. We had no idea this could be done at all and you have shown us several ways you can do it. We have done business with you for years but until this visit I had no idea of the control you have over physical characteristics of your material. Your ability to economically produce complex shapes within close tolerances is far ahead of anything we have ever known. And I am greatly impressed by the modern equipment and the tremendous size of this business which makes nothing but technical ceramics."

We believe that you, too, will find here the answer to almost any technical ceramic problem.

AMERICAN LAVA CORPORATION
49TH YEAR OF CERAMIC LEADERSHIP
CHATANOOGA 5, TENNESSEE

OFFICES: METROPOLITAN AREA: 671 Broad St., Newark, N. J., Mitchell 2-8159 • CHICAGO, 228 North LaSalle St., Central 6-1721
PHILADELPHIA, 1649 North Broad St., Stevenson 4-2822 • LOS ANGELES, 332 South Hill St., Mutual 9078
NEW ENGLAND, 38-8 Brattle St., Cambridge, Mass., Kirkland 7-4498 • ST. LOUIS, 1123 Washington Ave., Garfield 4959
HI, WIDE and HANDSOME POCKETSCOPES
are characterized by small size, light weight, and outstanding electrical performance. All units have frequency compensated attenuators as well as non-frequency discriminating gain controls. All units have both periodic and trigger sweeps from 1/2 cycle to 50KC. The amplifiers are direct coupled thus frequency response starts from 0 cycles. No peaking coils are used, thus, the transient response is good. Full expansion of trace, both vertical and horizontal, is built in.

Combination filter and graph screens are used for better visibility, thus traces can be observed even under high ambient light condition. Binding posts for convenience of connections, with effective shield, are used. S-14-A has sensitivity of 10 mv/inch with pass band above 200KC. S-14-B has sensitivity of 50 mv/inch with pass band above 1 megacycle. S-15-A is similar to S-14-A except that it has two independent CR Tubes for multi-trace oscilloscope work. Accessories such as carrying cases and probes are available.

POCKETSCOPES and RAKSCOPES have achieved a reputation for dependability and accuracy. The LINEAR TIME BASE can be used with the S-11-A POCKETSCOPE or with any other oscilloscope to convert the scope to trigger operation from 1/2 cycle per second.

WATERMAN RAYONIC TUBE DEVELOPMENTS
Since the introduction of Waterman RAYONIC 3MP tube for miniaturized oscilloscopes, Waterman has developed a rectangular tube for multi-trace oscilloscopy. Identified as the Waterman RAYONIC 3SP, it is available in P1, P2, P7 and P11 screen phosphors. The face of the tube is 1 1/4" x 3" and the over-all length is 9 1/8". Its unique design permits two 3SP tubes to occupy the same space as a single 3" round tube, a feature which is utilized in the S-15-A TWIN-TUBE POCKETSCOPE. On a standard 19" relay rack, it is possible to mount up to ten 3SP tubes with sufficient clearances for rack requirements. Photographic means of recording are under development and will be available shortly.

<table>
<thead>
<tr>
<th>TYPICAL OPERATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>TUBE</td>
</tr>
<tr>
<td>3SP</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>3MP</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

WATERMAN PRODUCTS CO., INC.

PHILADELPHIA 25 • PENNSYLVANIA • U.S.A.

Manufacturers of POCKETSCOPES® • RAKSCOPES® • PULSESOCES® and RAYONIC TUBES
WATERMAN INTRODUCES
TWO NEW CATHODE RAY OSCILLOSCOPES

Compact, Portable Instruments For Precision Pulse Measurement Adaptable To All Electronic Work, Including TV...

The PULSESCOPE

TO PORTRAY THE ATTRIBUTES OF THE PULSE:
SHAPE, AMPLITUDE, DURATION AND TIME DISPLACEMENT

Video Amplifier up to 11 MC • Video Delay 0.55 μs
Pulse Rise and Fall Time Better Than 0.07 μs

S-4-A SAR PULSESCOPE

Video Sensitivity 0.5 v p to p/in. • 5 Sweep 80 cycles to 800kc, either trigger or repetitive • A Sweep 1.2 μs to 12,000 μs • R Delay 3 μs to 10,000 μs, directly calibrated on precision dial • R Pedestal or Sweep 2.4 μs to 24 μs • Internal Crystal Markers 10 μs and 50 μs • Size: 9¼ x 11¼ x 10¼ • Weight: Less than 32 pounds.

S-5-A LAB PULSESCOPE

Video Sensitivity 0.1 v p to p/in. • Sweep 1.2 μs to 120,000 μs with 10 to 1 expansion • Sweep either trigger or repetitive • Internal Markers synchronized with sweep from 0.2 μs to 500 μs • Trigger Generator and built-in precision amplitude calibrator • Completely cased • Size: 16½ x 14½ x 17½ • Weight: Less than 60 pounds.

See these two NEW PULSESCOPIES...at the

CABLE ADDRESS:
POKETSCOPE, PHILA.
Our hat is off

to the I. R. E. engineers

Engineering is a conservative and modest profession, and rare is the occasion on which electronic engineers are publicly acclaimed. Yet these men are making priceless contributions to industrial progress and national defense.

Since we serve a large number of the country's radio-electronic equipment manufacturers, we have come to know and respect their engineering personnel.

It is, in a large measure, to these men that we are indebted for helping us maintain our reputation as perfectionists in sheet metal fabrication. Their exacting demands and advanced designs keep us ever alert to match their high standards in our own performance.

Gentlemen, we doff our hat in well deserved tribute. Let us shake your hands at Booths 49-50 at the I. R. E. Show.

KARP METAL PRODUCTS CO., INC.
223 63rd STREET, BROOKLYN 20, NEW YORK

 Specialists in Fabricating Sheet Metal for Industry
Announcing

WAVEGUIDE
TEST EQUIPMENT
2,600 to 18,000 mc!

The revolutionary new -hp- waveguide test equipment shown on the following pages represents the practical, economical adaptation of a new, fresh concept of waveguide instrumentation. Emphasis throughout is on functional simplicity and low cost; instruments are offered as individual basic components. Most equipment is based on entirely new designs developed either in the -hp- laboratories or by Varian Associates, microwave equipment and electron tube specialists.

Full frequency coverage from 2,600 mc to 18,000 mc is offered in 6 waveguide sizes: 3" x 1\(\frac{1}{2}\)", 2" x 1", 1\(\frac{1}{4}\)" x 3\(\frac{3}{4}\)", 1\(\frac{1}{4}\)" x 5\(\frac{5}{8}\)", 1" x 1\(\frac{1}{2}\)", .702" x .391". Instrumentation is now available in most of these sizes. Complete instrumentation for these frequencies will be provided during the forthcoming year.

HEWLETT-PACKARD COMPANY
2178D PAGE MILL ROAD • PALO ALTO, CALIFORNIA, U.S.A.
Sales Representatives in all principal areas.
Export: Frazar & Hansen, Ltd., San Francisco, Los Angeles, New York City
-hp- 809/810 Slotted Sections

Slotted sections are one of the most important measuring instruments in waveguide engineering. They are essential to the measurement of impedance, reflection and other transmission characteristics.

A single precision carriage (-hp-809B) mounts either slotted waveguide sections or coaxial sections covering the frequency range from 4.0 to 12.4 kmc. This results in maximum flexibility and minimum cost for complete frequency coverage. The carriage travels on a new 3-point, ball-bearing suspension system; and waveguide or coaxial slotted sections may be quickly interchanged. Carriage operates in conjunction with -hp- 442A Broad-Band Probe and -hp- 440A Coaxial Detector. -hp- 810B Waveguide Slotted Sections are available in sizes: 2" x 1", 1½" x 3/4", 1¼" x 5/8", 1" x 1/2". -hp- 806A Coaxial Slotted Section is available for frequency range 3.0 kmc to 12.0 kmc. -hp-S810A Waveguide Slotted Section, of conventional design, is available in size 3" x 1½" to cover the frequency range 2.6 to 3.9 kmc.

-hp- 280A, 281A Adaptors, Waveguide to Coaxial

For transition between waveguide and coaxial systems. Each adaptor covers the full waveguide range with a VSWR not exceeding 1.5. -hp- 280A with flexible cable, 3" x 1½" only. -hp- 281A, with Type N Jacks, sizes 3" x 1½", 2" x 1", 1½" x 3/4", 1¼" x 5/8", 1" x 1/2".

-hp- 370 Attenuators, Fixed

Fixed attenuation characteristics of 6, 10 or 20 db. For reducing power level, isolating system units and reducing reflection. Max. VSWR 1.15. Sizes: 3" x 1½", 2" x 1", 1½" x 3/4", 1¼" x 5/8", 1" x 1/2", .702" x .391".

-hp- 375A Attenuators, Variable Flap

For introducing variable power differences in a waveguide, or isolating power sources and loads. Consists of slotted waveguide section in which matched plate is moved. Max. VSWR 1.15. Sizes: 3" x 1½", 2" x 1", 1½" x 3/4", 1¼" x 5/8", 1" x 1/2", .702" x .391".

-hp- 380A Attenuators, Calibrated Variable

For use between 2,600 and 3,950 mc to create known attenuations or isolate sources and loads. Each instrument accurately calibrated at 3,000 mc. Max. VSWR 1.15. Sizes: 3" x 1½". (Other sizes to be announced.)

- hp- 485A Detector Mounts

For measurement of power between frequencies 2.6 to 18.0 kmc in conjunction with -hp- 430A Power Meter and Sperry 821 barretter. Also may be employed to measure relative level, or detect rf energy using a Type 1N21 crystal. Each mount is semi-tuned by means of a movable short. Additional tuning may be provided if desired by means of -hp- 870A Slide Screw Tuner or -hp- 880A E-H Tuner. Sizes: 3" x 1½" (for use with barretter only), 2" x 1", 1½" x 3/4", 1¼" x 5/8", 1" x 1/2", .702" x .391".

- hp- 840A, 841A Waveguide Tees

Rectangular series or shunt tees for coupling waveguide systems, as when dividing power or introducing impedances. Model 840A Series Tees branch from wide face of waveguide. Model 841A Shunt Tees branch from narrow face. Sizes: 3" x 1½", 2" x 1", 1½" x 3/4", 1¼" x 5/8", 1" x 1/2", .702" x .391".

Providing a new standard of broad-band operation plus traditional -hp- speed, accuracy, convenience and economy, for all types of precision microwave measurements.

See this new equipment at the I.R.E. Show or write your -hp- sales representative or factory for details.

- hp- 845A Hybrid Tees

Four-arm, rectangular hybrid tee. Composed of series and shunt tee constructed at same point in waveguide. Possess many properties of bridge circuit. Used for rapid determination of VSWR; as impedance transformer, as a bridge, etc. Sizes: 3" x 1½", 2" x 1", 1½" x 3/4", 1¼" x 5/8", 1" x 1/2", .702" x .391".

- hp- 920A Adjustable Shorts

Adjustable choke-type short for tuning or introducing reactance in combination with detecting sections, series, shunt or hybrid tees. Sizes: 3" x 1½", 2" x 1", 1½" x 3/4", 1¼" x 5/8", 1" x 1/2", .702" x .391".

HEWLETT-PACKARD hp INSTRUMENTS
Simple Design, Multi-Purpose Operation!

**-hp- 715A Klystron Power Supply**
Versatile power supply for operation of all types of low-power klystron oscillators in test-bench experiments. Beam voltage 250 to 400 v. at 50 ma. max. Reflector voltage 10 to 900 v. at 5 amperes. Internal square wave modulation, 1,000 cps; also provision for external modulation. 6.3 volt, 1.5 amp. filament supply.

**-hp- 530A Frequency Meters**
General purpose reaction type frequency meter covering the entire waveguide frequency band. Consists of a high "Q" resonant cavity tuned by a plunger. Micrometer scale indicates plunger position. Accuracy ±0.10%. Ranges: 5.85 to 8.20 kmc (1 1/2" x 3/4") and 8.2 to 12.4 kmc (1" x 1/2"). (Other sizes to be announced.)

**-hp- 870A Slide Screw Tuners**
For flattening waveguide systems. Consists of slotted waveguide section and adjustable probe on sliding carriage. Varying position and generation of probe sets up VSWR which can be adjusted to cancel existing VSWR in system. VSWR values up to 20 can be tuned with an accuracy of VSWR 1.02. Sizes: 3" x 1 1/2", 2" x 1", 1 1/2" x 3/4", 1 1/4" x 3/8", 1" x 1/2", .702" x .391".

**-hp- 880A E-H Tuners**
Matching section for tuning high power systems or for tuning systems where low leakage is essential. Consists of hybrid waveguide tee with moveable choke type shorts placed in shunt and series arms. Sizes: 3" x 1 1/2", 2" x 1", 1 1/2" x 3/4", 1 1/4" x 3/8", 1" x 1/2", .702" x .391".

**-hp- 440A Coaxial Detector**
A tunable crystal and bolometer mount, may be used as an rf detector for coaxial systems operating over the frequency range, 2.4 kmc to 12.4 kmc. A single adjustment provides rapid tuning. Equipment mates with Type N connectors and operates either with silicon crystal or bolometer.

**-hp- 442A Broad-Band Probe**
This probe may be combined with -hp- 440A to provide a highly sensitive, easily tuned detector for use with slotted sections. A micrometer depth adjustment provides quick control of rf coupling. This combination is specifically designed to operate with -hp- 809B and 810A/B Slotted Waveguide equipment.

**-hp- 910A Low Power Terminations**
For use wherever matched load is required, as in measurement of reflection, discontinuities or where waveguide must be properly terminated. Consists of tapered piece of resistive material terminating a waveguide section in its characteristic impedance. Max. VSWR 1.06. Average power 1 watt, sizes: 3" x 1 1/2", 2" x 1", 1 1/2" x 3/4", 1 1/4" x 3/8". Average power 1/2 watt, sizes: 1" x 1/2", .702" x .391".

**-hp- 912A High Power Terminations**
Used as dummy loads for high-power transmitters. Dissipate large amounts of power without undesirable reflection. VSWR less than 1.1. Forced air cooling required when operating at 50% rating or above. 250 watts average power, size: 3" x 1 1/2", 100 watts average power, 1" x 1/2". (Other sizes to be announced.)

In addition to waveguide equipment shown on these pages, -hp- offers the basic coaxial equipment used in major microwave research and development projects throughout America.
YOU CAN DO More -
DO IT Better WITH
GPL TELEVISION EQUIPMENT

Introduced only last year, this GPL equipment has already received wide industry acceptance for its flexibility, convenience and advanced design features. Developed for easy, attention-free operation, built with watchmaker's precision, the GPL line will do more, do it better, for years of dependable service. Write now for full details... act now for early deliveries.

Compact Camera Chain Gives
Improved Picture Control

Camera, control unit, power unit make up world's smallest, lightest broadcast chain. Improved picture quality with remote control iris, uniform focus adjustment for all lenses. Remote lens change, focus, pan and tilt also available. Simplified adjustments. Better accessibility. 8½" monitor tube.

GPL
the
Complete
NEW LINE
for
Studio and Field
that Increases
TV Efficiency

TV CAMERA CHAINS—TV FILM CHAINS
TV FIELD AND STUDIO EQUIPMENT
THEATRE TV EQUIPMENT
Single-Unit Sync Generator Requires No Adjustment

This unit, complete with power supply, is packaged for field use, may be removed from case for rack mounting. With binary counting circuits and pulse width controlled by delay lines, it provides circuit reliability better than present studio equipment and eliminates operator adjustments.

Video Recordings of Live-Program Quality

Precision electronic shutter provides steady interlace and eliminates shutter bar. High-fidelity sound recorded on the film simultaneously. New vacuum gate camera runs continuously without emulsion pile-up. Telecast recording looks and sounds like a live show.

Film Permanently Processed in 40 Seconds

The GPL Rapid Processor develops, rinses, fixes, washes, dries and waxes 16-mm film synchronously as it comes from the Recorder, or its own feed magazine. This facilitates rebroadcasts to other time zones. Operation is fully automatic, gives uniform, highest quality results.

First Professional Sync Projector for 16-mm Film

Designed for TV studio use. Has the reliability of professional 35-mm equipment. Sharper, steadier pictures, finer sound. Uniform illumination, ample light, with 100 foot-candles delivered to camera tube. May be used with any full-storage type film pick-up or with new special GPL Picticon Film Camera for greater sensitivity, freedom from shading, simplified control.

New "3-2" Projector Works with Any Image Orthicon Camera

A portable unit of tremendous utility. Used with standard studio or field cameras without special phasing, it makes transmission of motion pictures as simple as stills. Handles film features with results comparable to specialized iconoscope chains. Projects rear-screen effects. Projects commercials to camerass in the field, eliminating expensive studio stand-by facilities. For preview work, its synchronous motor simplifies sound scoring.

General Precision Laboratory

PROCEEDINGS OF THE I.R.E. March, 1951
"FOR
PERMEABILITY

a core made of CARBONYL IRON
POWDER means compact size
and efficient performance . . . . ."

"Permeability plus stability—these two qualities
determine the ability of a radio receiving set
to select and hold clear reception on a particular
wave band. In household, portable and automotive
receivers, compact size and weight reduction also become
important factors . . . . In the making of both RF and
IF coils we have come to rely upon cores made of Carbonyl Iron Powders.
We can trust their uniform quality and uniform crystal structure
to hold the permeability within plus or minus 1% over a period of years."

THE F. W. SICKLES COMPANY
CHICOPEE, MASSACHUSETTS

FOUNDED IN 1921—under the name
of Radio Development Co.,—the F.W.
Sickles Company are today the world's
largest makers of radio coils. Several
hundred different models of RF and
IF coils—made by this firm—are now
in daily use by manufacturers of elec-
tronic equipment, as well as by ama-
teurs, experimenters, radio service
men and government agencies, both
here and abroad.

The Sickles endorsement of Car-
bonyl Iron Powders is extremely grati-

fying to us . . . It is also important
evidence for the consideration of any
receiver or equipment manufacturer.
Let us send you the book described
at the right. It will cost you nothing
to get the facts . . . Ask your core
maker, your coil winder, your indus-
trial designer, how G A & F Carbonyl
Iron Powders can improve the per-
formance or reduce the size of the equip-
ment you make. The possible gains
and savings are far greater than here
indicated.

G A & F Carbonyl
TUNING...

Precision tuning units—made by The F. W. Sickles Company—for broadcast radio receivers

THIS FREE BOOK—fully illustrated, with performance charts and application data—will help any radio engineer or electronics manufacturer to step up quality, while saving real money. Kindly address your request to Department 35.

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Name
Company
Address
City Zone State

What to see at the Radio Engineering Show
(Continued from page 1A)

Firm          Booth

Borg Equipment Division—The George W.  272
Borg Corporation, Delavan, Wis.

Micropot—Ten Turn Potentiometer, Micropot,
Ten Turn Counting, etc.

W. H. Brady Co., Chippewa Falls, Wis.

Self-sticking identification products, wire
markers, colored wire markers, parts iden-
tification markers, pipe & conduit mark-
ers, safety signs, printed "scotch" roll
tape, masks & stencils, bin markers, spe-
cial self-sticking markers made to custom-
er's specifications, coil markers, instruc-
tion labels, product and trade mark identi-
fication markers, wiring assembly mark-
ers, inspection labels, balancing tapes, etc.

Brentano's, Technical Department, New
York, N.Y.

Books of all publishers in the fields of
radio, television, electronics and radar,
including nucleonics, atomic engineering,
computers and their related fields.

British Industries Corp., New York, N.Y.

Garfield record changers and phone units
Erwin multicore solder.


Magnesium fabricated products for radia-
tion reflectors and control boxes, portable
radio electronic cases, deep drawn magnesium
stamping and assemblies, welded frame
assemblies, pressurized radar housings,
magnesium plotting equipment and furni-
ture.

Browning Laboratories, Inc., Winchester,
Mass.  S-12, S-13

Model OJ-17 Oscilloscroscope, Model
GL-22A Sweep Calibrator, Model ON
Oscilloscroscope, Model MD-2, FM
Modulation Monitor, Models RV-160A FM
Tuner, RJ 12B FM-AM Tuner, RJ 20A
FM-AM Tuner.

Brujac Electronic Corp., New York, N.Y.

N-20

Two Precision Cathode Ray Oscilloscopes
have been developed for the observation
of random pulse transient or repetitive
phenomena in the dc to 1 Mc range. The
oscilloscope incorporates calibrated sweep
speeds from 1 sec/cm to 0.1 microsec/cm,
amplitude calibration, and casual mount-
ing of related controls. Two models are
available, one employing the 5YP CR tube
(4000 volts accelerating) and the other, the
5XP CR tube (11,000 volts accelerating).

Brush Development Co., Cleveland, Ohio 76, 71

Industrial and research instruments, mag-
netic recording equipment and components.
synthetic piezo-electric crystal elements.
"Hyper sonic" generators and ceramic
piezo-electric elements and transducers.

Burlington Instrument Co., Burlington,
Iowa

Display AC and DC electrical indicating
instruments, portable instruments, and
generator voltage regulators.

Bussmann Manufacturing Co., St. Louis,
Mo.

Bus and Functron fuses of all types for
the protection of radio, television and
electronic equipment of all kinds.

Caldwell-Clements, Inc., New York, N.Y.

"Telco-Tech," a television and telecommu-
nications engineering magazine, and "Ra-
dio & Television Marketing," a merchan-
dising and servicing trade magazine.

Caldyne Co., Winchester, Mass.

N-12

Vibration measuring equipment, Electro-
dynamic shaker, calibrators and power
supplies, High Sensitivity Accelerometer,
Vibroscope, Vibration Meter, Calvolters.

Cambridge Thermionic Corp., Cambridge,
Mass.

S-12

Terminal boards; terminals (lugs), slug-
tuned coils, slug tuned coil forms, phenolic
and ceramic; insulated terminals, phenolic
and ceramic; electronic hardware.

Camloc Fastener Corp., New York, N.Y.

339

Quick-operating fasteners, one-quarter
turn, latches, and quick release.

Cannon Electric Development Co., Los
Angesles, Calif.

Electrical connectors, multi-contact plugs
and receptacles for radio and electronic
circuits.

(Continued on page 26A)
SMALLEST SIZE YET
for conservatively rated
.5 watt controls!

You save appreciable space with Stack-
pole LR variable resistors—yet still have ample wattage capacity for most television and mobile radio applications. Only 57/64” in diameter, these sturdy controls are conservatively rated at 1/8 watt* and are exceptionally quiet, out-
standingly dependable.

Single LR controls are supplied with or without SP-ST or DP-ST line switches. Dual concentric controls—tops for do-
zens of space-saving applications—are available with practically any needed shaft or switch arrangement.

Write for details or samples to your
specifications.

Electronic Components Division
STACKPOLE CARBON COMPANY, ST. MARYS, PENNA.

*1/8 watt rating where voltage across units does not exceed 350 volts for linear tapers, or for non-linear controls having a taper of no less than 10% of the total resistance at 50% rotation and where voltage is not in excess of 225 volts.

STACKPOLE

FIXED AND VARIABLE CARBON RESISTORS • IRON CORES • CERAMAG® CORES
MOLDED COIL FORMS • MOLDED “GIMMICK” CAPACITORS • INEXPENSIVE
LINE AND SLIDE SWITCHES
The Arnold Engineering Company offers to the trade a complete line of

**Magnetic Materials**

**PERMANENT MAGNET MATERIALS**
- Cast Magnets, Alnico I, II, III, IV, V, VI, XII, X-900
- Sintered Magnets, Alnico II, IV, V, VI, X-900, Remalloy*
  - Vicalloy*
  - Remalloy* (Comol)
  - Cunico  Cunife  Cast Cobalt Magnet Steel

**HIGH PERMEABILITY MATERIALS**
- Deltamax Toroidal Cores  Supermalloy* Toroidal Cores
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*Manufactured under licensing arrangements with WESTERN ELECTRIC COMPANY

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SUBSIDIARY OF ALLEGHENY LUDLUM STEEL CORPORATION
General Office & Plant: Marengo, Illinois
Attention All Electronic Engineers

We are in production on the most advanced development in the history of resistors. It is the BORO-CARBOFILM RESISTOR. After over two years of intensive laboratory work the introduction of Boron in the making of Deposited Carbon Resistors has been perfected.

The result of this new development assures greatly increased range of resistance, temperature coefficient as low as 20 parts per million per degree C, greater stability and lower noise level.

What This Means to You

Briefly, this makes it possible for you to use the new, much improved BORO-CARBOFILM RESISTOR in place of larger and more costly wire-wound types. It also provides access to resistance ranges heretofore impossible to attain in film-type resistors. With their low temperature coefficient and small aging you will find wide-spread use for these new resistors in communications and nearly all types of electronic applications. Remember the name “BOROCARBOFILM®.” Available in ¼, ½, ½, 1 and 2-watt sizes.

In writing, kindly give your requirements in sizes and volume.

BORO-CARBOFILM RESISTORS are made under license arrangement with Western Electric Co., Inc.
A complete line for resistors too!

Unusual combinations of characteristics required in today's critical electronic circuits demand a complete range of resistor types. Specializing in resistors, IRC makes the widest line in the industry. This means ease of procurement—a single dependable source of supply for all your resistance needs. It also means unbiased recommendations—no substitution of units "just as good". IRC's complete line of products; complete research and testing facilities; complete network of licensees for emergency production—all add up to complete satisfaction for you.

PRECISION RESISTORS

IRC Precision Wire Wounds offer a fine balance of accuracy and dependability for close-tolerance applications. Extensively used by leading instrument makers, they excel in every significant characteristic. Catalog Bulletin D-1.

IRC Deposited Carbon PRECISORS combine accuracy and economy for close-tolerance applications, where carbon compositions are unsuitable and wire-wound precisions too expensive. Catalog Bulletin B-4.

IRC Matched Pairs provide a dependable low-cost solution to close-tolerance requirements. Both Type BT and BW Resistors are available in matched pairs. Catalog Bulletin B-3.

IRC Sealed Precision Voltmeter Multipliers are suitable and dependable for use under the most severe humidity conditions. Each consists of several IRC Precisions mounted and interconnected, encased in a glazed ceramic tube. Catalog Bulletin D-2.

CONTROLS

IRC Type W Wire Wound Controls are designed for long, dependable service and balanced performance in every characteristic. These 2-watt variable wire wound units provide maximum adaptability to most rheostat and potentiometer applications within their power rating. Catalog Bulletin A-2.


IRC Sealed Precision Voltmeter Multipliers are suitable and dependable for use under the most severe humidity conditions. Each consists of several IRC Precisions mounted and interconnected, encased in a glazed ceramic tube. Catalog Bulletin D-2.
is essential

**HIGH FREQUENCY and HIGH POWER RESISTORS**

IRC Type MP High Frequency Resistors afford stability with low inherent inductance and capacity in circuits involving steep wave fronts, high frequency measuring circuits and radar pulse equipment. Available in sizes from 1/4 to 90 watts. Catalog Bulletin F-1.

Type MV High Voltage Resistors utilize IRC's famous filament resistance coating in helical turns on a ceramic tube to provide a conducting path of long, effective length. Result: Exceptional stability even in very high resistance values. Catalog Bulletin G-1.

IRC Type MW High Voltage, High Voltage Resistors meet requirements for a small high range unit with axial leads. Engineered for high voltage applications, MW has exceptional stability. Catalog Bulletin G-2.

IRC Type MPM High Frequency Resistors are miniature units suitable for high frequency receiver and similar applications. Stable resistors with low inherent inductance and capacity. Body only 3/4” long. Catalog Bulletin F-1.

**POWER RESISTORS**

IRC Advanced Type BT Resistors meet and beat JAN-B-11 Specifications of 1/2, 0, 1 and 2 watts—combine extremely low operating temperature with excellent power dissipation. Catalog Bulletin B-1.

IRC Type BW Wire Wound Resistors are exceptionally stable, inexpensive units for low range requirements. Have excellent performance records in TV circuits, meters, analyzers, etc. Catalog Bulletin B-5.

IRC Type BTAV High Voltage Resistors, developed for use as discharge resistors in fluorescent "Quick Start" ballasts, withstand momentary peak surges of 6000 volts. Also suited to TV bleeder circuits. Catalog Bulletin B-1.

IRC Fixed and Adjustable Power Wire Wound Resistors give balanced performance in every characteristic—are available in a full range of sizes, types and terminals for exacting, heavy-duty applications. Catalog Bulletin C-2.

IRC Type FRW Flat Wire Wound Resistors fulfill requirements of high wattage dissipation in limited space—may be mounted vertically or horizontally, singly or in stacks. Catalog Bulletin C-1.

IRC Type MW Wire Wound Resistors offer low initial cost, lower mounting cost, flexibility in providing taps, and saving in space. Completely insulated against moisture. Catalog Bulletin B-2.

IRC Type LP Water-Cooled Resistors for TV, FM and Dielectric Heating Applications. Cooled internally by high velocity stream of water, adjustable to local water pressure and power dissipation up to 5 K.W.A.C. Catalog Bulletin F-2.

**INSULATED COMPOSITION and WIRE WOUND RESISTORS**

IRC Advanced Type BT Resistors meet and beat JAN-B-11 Specifications of 1/2, 0, 1 and 2 watts—combine extremely low operating temperature with excellent power dissipation. Catalog Bulletin B-1.

IRC Type BW Wire Wound Resistors are exceptionally stable, inexpensive units for low range requirements. Have excellent performance records in TV circuits, meters, analyzers, etc. Catalog Bulletin B-5.

IRC Type BTAV High Voltage Resistors, developed for use as discharge resistors in fluorescent "Quick Start" ballasts, withstand momentary peak surges of 6000 volts. Also suited to TV bleeder circuits. Catalog Bulletin B-1.

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IRC Type LP Water-Cooled Resistors for TV, FM and Dielectric Heating Applications. Cooled internally by high velocity stream of water, adjustable to local water pressure and power dissipation up to 5 K.W.A.C. Catalog Bulletin F-2.
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Amphenol's skilled engineering staff is ready to assist you with application engineering problems — the vital PLUS in our 9000 cataloged items.

RF TRANSMISSION LINES

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TEFLOM CABLE

FM ANTENNAS

TV ANTENNAS

COMMUNICATIONS ANTENNAS

AMATEUR ANTENNAS

TUBE SOCKETS

INDUSTRIAL TUBE SOCKETS

TERMINAL BLOCKS

HEAVY DUTY PLUGS

AND CONNECTORS

What to see at the Radio Engineering Show

(Continued from page 204)

Firm          Booth

Capitol Radio Engineering Institute, Washington, D.C. 357

Carboloy Co., Inc., Detroit, Mich. 61

Carboloy Permanent magnets (Alnico and other types.) Exhibit to show some of the
steps taken to provide a high quality per-
mament magnet. Some visitor participation
demonstrations to illustrate Carboloy qual-
ity.

Carter Motor Co., Chicago, Ill. S-18

Display of dynamos, dc to ac convert-
ers, magneto, and small rotary power
supply equipment for mobile radio.

Centralab, Division of Globe-Union, Inc.,

Milwaukee, Wis. 222, 223  
Ceramic capacitors, printed electronic
circuits, controls, switches, special cerami-
and components.

Century Geophysical Corp., Tulsa, Okla. 354
Flight test recording oscillographs, mini-
ture oscillographs, galvanometers, vibra-
tion amplifiers, refraction seismograph
equipment. Miniature seismometers, mini-
ture reflection seismograph amplifiers and
cable fault detector.

C.G.S. Laboratories, Stamford, Conn. 369
Airborne instrumentation mechanisms, mi-
crowave development, test equipment, elec-
tronic and remote controls.

Chicago Rivet & Machine Co., Bellwood, III. N-7
Rivets, tubular and split; automatic rivet
setting machines, single and multiple set-
ing, adjustable centers.

Cinch Manufacturing Corp., Chicago, Ill. 255, 256  
Tube sockets and shields, connectors, ter-
minal strips, lugs, clips, brackets, etc.

C. P. Clare & Co., Chicago, Ill. 204
Telephone type relays, open and hermeti-
cally sealed, spring driven stepping
switch, and sensitive relays meeting AN require-
ments for use in aircraft and other elec-
tronic apparatus.

Claroostat Mfg. Co., Inc., Dover, N.H. 254  
Fixed wire wound resistors, variable wire
wound resistors, variable carbon resistors,
attenuators, television and radio compo-
nents.

Cleveland Container Co., Cleveland, Ohio 207
Clevellite and Convestive laminated paper
base phenolic tubing, coil forms and tele-
vision deflection tube sleeves. Kraft, ace-
tate and combination tubing.

Sigmund Cohn Corp., New York, N.Y. 283
Filament wire and ribbons, grid wires,
electroplated wires, precious metals in
sheet, wire, ribbon and other forms. Rhodo-
rium plated solutions and gold cyanide.
Galvanometer suspension strip, enamelled
fine wire and etched wire.

Colling Winding Equipment Co., Oyster Bay,
N.Y. 355
Machinery to wind all types of coils, tat-
tice, single layer, hobbings, paper inserted.
New this year, a machine to determine the
gear set-up for universal winding, also a
machine to pi wind in multiple on dummy
resistor forms.

Collins Radio Co., Cedar Rapids, Iowa 75 to 80
Airborne communication and navigation
equipment. Ground station communication
equipment. Broadcast transmitters and
speech equipment. Amateur transmitters
and receivers.

Communication Products Co., Keyport, N. J. 18, 19, 20
Seal-O-Flange transmission lines. Q-Max
compositions and finishes. AM-FM TV an-
tennas, tower hardware, if switches, Auto-Drysure Dehydrators.

Condenser Products Co., Chicago, III. N-17
Capacitors, power supplies, pulse forming
networks.

Consolidated Engineering Corp., Pasadena, Calif. 384, 385
10 mil detector for checking any vacuum or
pressure system for minute leaks. Record.

(Continued on page 27A)
What to see at the
Radio Engineering Show
(Continued from page 26A)

Firm
Continental Carbon, Inc., Cleveland, Ohio
Corning Glass Works, Corning, N.Y.
Cossor
Curtis Development & Manufacturing Co.,
Inc., Plainfield, N.J.

Booth
224
375
223
359
221
363
91B, 95
241, 242
342
125
126 to 128
325
327

R E CO RD I A L L Y I NV I T E D T O V I S I T

A M P H E N O L

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SUBMERSION-PROOF CONNECTORS
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SPECIAL CABLE HARNESSSES
Meeting tower construction emergencies of all kinds... solving tower problems big and small... being on the job with knowledge and skill that gets the job done... that's the type of service which has made Truscon a world leader in radio tower engineering!

Truscon experience embraces all types of topographical and meteorological conditions... and supplying many different tower types: guyed or self-supporting... tapered or uniform in cross-section... for AM, FM, TV, or microwave applications.

Your phone call or letter to any convenient Truscon district office, or to our home office in Youngstown, will bring you immediate, capable engineering assistance. Call or write today.

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See the Truscon Exhibit, Booth 230, Institute of Radio Engineers Show

PROCEEDINGS OF THE I.R.E. March, 1951
A QUICK CHECK OF LOW RESISTANCE CONNECTIONS, BONDS, CONTACTS, etc.

Shallcross low resistance test sets greatly facilitate comparison tests between 2 and 800,000 micro-ohms. Their uses range from testing the electrical conductivity of bonds, welds and seals to contacts, filaments, armatures or for making any measurement under 1 ohm. Suitable units are available for either field, laboratory or production line use. Write for Bulletin LRT-1.

KELVIN plus WHEATSTONE RANGES IN ONE HANDY BRIDGE

Why pay for two instruments when one will do both jobs? Providing both Kelvin and Wheatstone ranges from 0.0001 ohm to 11.11 megohms, this Shallcross No. 638-R combined bridge is highly accurate and outstandingly convenient. Priced at only a little more than a single bridge with a limited range, it is a typical example of Shallcross instrument efficiency and economy.

DECADE RESISTANCE BOXES TO MATCH YOUR NEED...exactly

Over 40 Shallcross standard Resistance Boxes provide the widest assortment available today. Types range from 1 to 7 dials from 0.01 ohm to 111 megohms and are available in styles, sizes and prices for practically any laboratory or production testing need. Write for Bulletin.

SPECIAL DELAY LINES

Lumped delay lines "tailored" to specific applications have been announced by the Shallcross Manufacturing Co., Collingdale, Pa. A typical unit consists of eight pie-section low-loss filters having a rise time of 0.04 microseconds and a total delay of 0.3 microseconds. Maximum pulse voltage is ±100 volts and impedance is 500 ohms. Cutoff frequency is 8.5 megacycles and the maximum operating frequency approximately 2 megacycles based on a pulse delay error of not more than 2%. The unit consists of eight universally-wound coils of 3-strand #41 Litz wire and nine low T.C. silver mica capacitors. Many other types can be supplied.

NEW SHALLCROSS WHEATSTONE-MEGOHM BRIDGE

The new Shallcross 635-A Wheatstone-Megohm Bridge is a versatile direct-reading instrument for accurate measurements between 10 ohms and 1,000,000 megohms. It can be used to measure resistance elements and insulation resistance and to determine volume resistivity of materials. The instrument is basically a Wheatstone Bridge used in conjunction with a d-c amplifier. Two built-in power supplies operating on 115 volts, 60-cycles automatically provide the correct bridge voltages for the high and low ranges. Full information is available from the Shallcross Manufacturing Co., Collingdale, Pa.

METAL-ENCASED RESISTORS

Flat, metal-encased, Type 265-A wire-wound power resistors introduced by the Shallcross Manufacturing Company, Collingdale, Pa. are space wound, have mica insulation, and are encased in aluminum. At 175°C. continuous use they are conservatively rated for 7½ watts in still air and 15 watts mounted flat on a metal chassis. Write for Bulletin 122.
MAKE 16 GROUND CONNECTIONS IN 1 MINUTE!

Low-resistance joints that hold at over 125°C easily made with G-E PRECISION CONTROL FOR RESISTANCE WELDERS

Operators are making sixteen ground connections a minute to a television-receiver chassis with G. E.'s precision-control resistance welding method.

The compact electronic spot-welding control shown here has been specifically designed for use in conjunction with small bench welders or tongs and thus is ideally suited for many of the otherwise expensive assembly operations encountered in the manufacture of electronic equipment.

The panel provides for welding-current to control the amount of heat produced in the welds. Once set, successive welding currents remain constant to assure accurate and consistent welding of connections.

Complete data in Bulletin GEA-4175.

NEW! Unit-Bearing Motor for fans and blowers

- all angle operation
- improved appearance
- provision for 4-way mounting
- quiet operation
- requires no additional lubrication
- adjustable-speed operation available

Available in ratings from 25 millihorsepower to 1/12 horsepower to match many fan or blower sizes, this new G-E unit-bearing motor uses a new lubrication system and bearing design that permit reliable operation in any position. For extremely quiet operation, resilient cradle-base or end-ring mounting may be supplied. Suitable control is available for two-speed or adjustable-speed operation. More data in Bulletins GEA-5338 and GEC-219A.
replace tubes **BEFORE THEY FAIL!**
— record life with **G-E time meters**

A vacuum tube can usually be replaced _before_ it fails if you have an accurate indication of operating time on the electronic device on which the tube is used.

G-E time meters, with dependable Telechron® motor drive, record operating time in hours, tenths of hours, or minutes, and are supplied for 115-, 230-, or 460-volts. The molded Textolite® case harmonizes with other G-E 3½-inch instruments mounted on the same panel. For more information, including dimensions, write for Bulletin GEC-472.

---

**sure protection against overheating!**

This G-E flow interlock opens the electric circuit of your water-cooled components when water flow is lower than a preset minimum, closes it when flow is above this point.

Depending on adjustment, the interlock will actuate the electric contact for any flow between ½ and four gallons per minute. Cut-in, cut-out differential is 0.1 gpm.

Ratings: 10 amps, 120 or 240 volts a-c; maximum water-line pressure is 125 lb./sq. in. Unit is bronze with standard ½-inch fittings, is easy to install and adjust. See Bulletin GEC-411.

---

**select 10 ranges INSTANTLY with this HIGH SENSITIVITY VTVM**

**CALIBRATED RANGES**: .001 to 300 volts (10 cycles to 1.5 mc.); –52 to +52 db (ref. level –1 mw at 600 v.)

Just about everything you could ask for in a high-sensitivity vacuum tube voltmeter! Frequency range of this G-E Type AA-1 instrument is substantially flat from 10 cycles to one megacycle with voltage ranges of 0-01, 0-03, 0-0.1, 0-0.3, 0-1.0, 0-3.0, 0-10, 0-30, 0-100, 0-300, decibels from –52 to +52 in 10 ranges.

Ten-position pushbutton switch instantly selects range without passing through intermediate stages. This vacuum-tube voltmeter is stable, has high impedance input, uses full-wave rectification, and has an amplifier output of 3 volts. More in Bulletin GEC-461.
BUT it's simpler to design the radio around the battery!

Regardless of what size portable radio you are designing, you'll find compact, long-lasting "Eveready" batteries to fit it. "Eveready" brand batteries give longer playing life. They are the accepted standard for portable radios. Users can get replacements everywhere—they prefer portables that use "Eveready" batteries.

CONSULT OUR BATTERY ENGINEERING DEPARTMENT FOR COMPLETE DATA ON "EVEREADY" BATTERIES

"Eveready", "Mini-Max", "Nine Lives" and the Cat Symbol are trade-marks of

NATIONAL CARBON DIVISION
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

"Eveready" No. 950 "A" batteries and the No. 467 "B" battery make an ideal combination for small portable receivers.
YEA R AS PION EER 20 th YEAR AS PIONEER
Dumont pioneering in Cathode-ray Tubes...brought big pictures from the beginning

...in 1939 the Du Mont "Twenty"

Today's popular television picture sizes are the result of Du Mont's 20 years of pioneering in the cathode-ray tube field. In 1939 when television first became a commercial reality, Du Mont produced the 20AP4 Teletron.* It was this tube that showed the public, as well as the industry, that such size was not only practical but also the right size. While others were limiting their tube sizes to 7 and 10 inches, Du Mont was gaining the experience that is the reason for the acknowledged leadership Du Mont enjoys today in BIG picture tube sizes.
...when nobody dared!

...in 1951 the Du Mont "Thirty"

the Du Mont Bent-Gun used in all current Teletrons

Du Mont went on to introduce the popular 19 and 17 inch sizes that are the standards for today's receivers.

Du Mont now produces a complete line of BIG picture tubes in all the popular sizes climax ed in the new 30" Te letron. This latest design provides a picture of approximately 550 square inches, while the overall length is only 23\(\frac{1}{2}\)".

Most of today's leading TV receiver manufacturers call on this unparalleled knowledge in the design and manufacture of BIG picture tubes to assure the uniformly high quality they demand in their receivers.

ALLEN B. DU MONT LABORATORIES, INC.
CATHODE-RAY TUBE DIVISION
750 Bloomfield Avenue
Clifton, N. J.
The Du Mont Television Transmitter Division continues to set the pace in the television equipment field with their latest development, The Universal Color Scanner, shown at the right.

Providing for the Broadcaster, Color Television Researcher, TV Receiver Manufacturer a color signal standard for use with any color system proposed to date, the Universal Color Scanner is further proof that Du Mont consistently offers the finest, first.
An early pioneer in the development of television transmitting equipment, Du Mont's faith in the future of television has been fully justified. As a product of this faith, Du Mont is a leading manufacturer of television transmitting equipment.

Shown below is the new Du Mont all air-cooled, high- or low-band, 5 KW Oak Transmitter. The cumulative result of 6 years' experience with air-cooled transmitters, the Oak Transmitter has already had a highly successful debut with 18 months' field use on high-band operation. For most economical television broadcast operation investigate the Du Mont Oak Series Transmitter. The low initial cost, low installation cost, low operating cost and low-cost tube complement of the Oak Series Transmitter, add up to the lowest overall cost TV transmitting operation yet possible for a broadcast station.

Come see the 5 KW Oak Transmitter at the WABD installation in the Empire State Building during the IRE show, March 19 through March 22.
pioneering in Oscillography has been the greatest single influence in Concept, Design and Application!

THE TYPE 3RP-A
The modern, 3" flat-face cathode-ray tube which combines short length with high sensitivity; is free from trapezoidal distortions, and provides high light output.

THE TYPE 5YP
The newest design in 5" cathode-ray tubes which provides high sensitivity for high frequency applications at low and medium accelerating potentials.

THE TYPE 5XP
The multi-band intensifier principle and special deflection plate construction provide extreme sensitivity and high light output in a high-voltage cathode-ray tube.

THE TYPE 5SP
Dual-beam cathode-ray tube makes possible the presentation of two related or independent phenomena on a single screen.

THE TYPE 295
For single-transient recording.

THE TYPE 297
For finished-print recording.

THE TYPE 321
For moving-film recording.
THE TYPE 304-H
Sets a new standard of performance for general-purpose oscillography by providing high-gain AC and DC amplifiers, triggered sweeps, and other new circuit developments.

THE TYPE 303
Low, quantitative, wide-band, general-purpose cathode-ray oscillograph, incorporating time-amplitude calibration, sweep-sension, and signal delay.

THE TYPE 294-A
With high-voltage cathode-ray-tube operation and wide-band amplifiers, Type 294-A is especially suited for observing and recording high-speed transient signals.

THE TYPE 293
The Type 293 is designed for use in the standard impulse testing of high-voltage transmission equipment, and presents on the hot-cathode, sealed-off cathode-ray tube an accurate portrayal of the test impulse.

DISTRIBUTED AMPLIFIER
Development of the transmission-line-coupled, wide-band amplifier has extended the application of the cathode-ray oscillograph to frequencies beyond 150 megacycles.

ALLEN B. DU MONT LABORATORIES, INC.
INSTRUMENT DIVISION
1000 Main Avenue
Clifton, N. J.

write for catalog
more tuner per dollar...

DU MONT
SERIES T3C

INPUTUNER

for TV-FM
PERFORMANCE
UNSURPASSED!

DU MONT
SERIES T3C

PLUS complete coverage of standard FM broadcast band in addition to TV channels
PLUS continuous tuning action (Mallory-Ware Inductuner**) offering utmost in dependability
PLUS detent action for quick-click station selection
PLUS interchangeability — mechanically and electrically — with most switch-type tuners
PLUS simplest operation yet — covers all TV and FM channels — in four turns
PLUS dual-dial occupying same panel area as indicating devices used on most switch-type tuners

*Trade-Mark
**RTM PRM CO., INC.
the Volt-Ohm-Milliammeter that needs no introduction!
say SPEER before you say RESISTORS

...for consistent uniformity

Complete your circuits with R. F. coils...chokes...tubular and disc capacitors...high voltage condensers...capristors by

JEFFERS ELECTRONICS, INC.
DU BOIS, PA.

Another Speer Carbon Co. Subsidiary

SPEER
Resistor CORP.

A SPEER CARBON COMPANY SUBSIDIARY
ST. MARYS, PENNSYLVANIA
New
"Tilted-Offset" Gun
WITH
INDICATOR
ION TRAP

Solves one production line problem

Rauland's new Electron Gun offers two production line advantages which TV engineers have welcomed—advantages that help shave pennies off production costs and save minutes on production lines.

The superior design of Rauland's new Tilted Offset Gun eliminates one Ion Trap Magnet, cutting use of rare magnet alloy 50%. Yet, it gives better results—bending the electron beam only once and assuring maximum sharpness of focus.

Even more important is the exclusive Indicator Ion Trap which this gun features. In a matter of seconds—without even seeing the front of the picture tube—the single Ion Trap magnet is adjusted with absolute accuracy.

The magnet is simply moved until a vivid green glow on the anode tube is reduced to minimum. There is no need whatever for any equipment—any skill—any trained judgment. Actually, adjustment is made faster than test equipment could be attached.

To get the benefits that only Rauland offers, specify Rauland tubes with these exclusive advantages. For further information, write to . . .

THE RAULAND CORPORATION

Perfection Through Research

4245 N. KNOX AVENUE • CHICAGO 41, ILLINOIS

PROCEEDINGS OF THE I.R.E. March, 1951

RAULAND

The first to introduce commercially these popular features:

Tilted Offset Gun
Indicator Ion Trap
Luxide (Black) Screen
Reflection-Proof Screen
Aluminized Tube

Visit us in Booth 334—IRE Show
BALLANTINE
STILL THE FINEST IN ELECTRONIC VOLTMETERS

MODEL 300
MODEL 302B
MODEL 304
MODEL 305

<table>
<thead>
<tr>
<th>MODEL</th>
<th>FREQUENCY RANGE</th>
<th>VOLTAGE RANGE</th>
<th>INPUT IMPEDANCE</th>
<th>ACCURACY</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>10 to 150,000 cycles</td>
<td>1 millivolt to 100 volts</td>
<td>1/2 meg. shunted by 30 mfd.</td>
<td>2% up to 100 KC</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3% above 100 KC</td>
</tr>
<tr>
<td>302B Battery Operated</td>
<td>2 to 150,000 cycles</td>
<td>100 microvolts to 100 volts</td>
<td>2 mgs. shunted by 8 mfd. on high ranges and 10 mfd. on low ranges</td>
<td>3% from 5 to 100,000 cycles; 5% elsewhere</td>
</tr>
<tr>
<td>304</td>
<td>30 cycles to 5.5 megacycles</td>
<td>1 millivolt to 100 volts except below 5 KC where max range is 1 volt</td>
<td>1 meg shunted by 9 mfd. on low ranges, 4 mfd. on highest range</td>
<td>3% except 3% for frequencies under 100 cycles and over 3 megacycles and for voltages over 1 volt</td>
</tr>
<tr>
<td>305</td>
<td>Measures peak values of pulses as short as 3 micro-seconds with a repetition rate as low as 20 per sec. Also measures peak values for sine waves from 10 to 150,000 cps.</td>
<td>1 millivolt to 1000 volts Peak to Peak</td>
<td>Same as Model 302B</td>
<td>3% on sine waves 3% on pulses</td>
</tr>
<tr>
<td>310A</td>
<td>10 cycles to 2 megacycles</td>
<td>100 microvolts to 100 volts</td>
<td>Same as Model 302B</td>
<td>3% below 1 MC 5% above 1 MC</td>
</tr>
</tbody>
</table>

PRECISION SHUNT RESISTORS
Four different types of Precision Shunt Resistors, varying from 1 to 1000 ohms, permit the Voltmeters to be used to measure currents from 1 ampere to one-tenth of a microampere.

MULTIPLIERS
Five different types of Multipliers, whose input resistance varies from 5 to 40 megohms, permit the voltage range of the Voltmeters to be increased 10 or 100 times.

BALLANTINE pioneered circuitry and manufacturing integrity assure the maximum in SENSITIVITY • ACCURACY • STABILITY

- All models have a single easy-to-read logarithmic voltage scale and a uniform DB scale.
- The logarithmic scale assures the same accuracy at all points on the scale.
- Multipliers, decade amplifiers and shunts shown above extend range and usefulness of voltmeters.
- Each model may also be used as a wide-band amplifier.

For further information, write for catalog

BALLANTINE LABORATORIES, INC.
BOONTON, NEW JERSEY

PROCEEDINGS OF THE I.R.E.  March, 1951
The A.N. CONNECTOR TYPE mounting is approved by the Army and Navy as standard hermetic seal termination equipment. This type of mounting is particularly adaptable where shielded or cabled circuits are a necessity. Vibration-proof mounting with quick connect and disconnect is insured.

Approved—distinguished by spectacular performance in truck train communications and thousands of flying echelons—The Guardian Series 335 D.C. Relay! Hermetically sealed or with conventional open and special mountings, unit offers a wide variety of applications. Series 335 D.C., built to rigorous aviation standards, meets the 10-G Vibration Test and the Mil-R-6106. Generous coil winding area permits single windings up to 15,000 ohms. Parallel and double windings available.

Maximum voltage: 220 V.D.C. Power requirement: Normal, 3 1/2 watts. Max-resistance standard unit: 12,000 ohms. Applicable to time delay attract up to .06 second and release up to .01 second. Contact rating: 1/4" dia. silver, 12 amps. at 24 V.D.C. inductive load. Combinations up to 3 P.D.T. with 12 amp. contacts. Bakelite insulated, tested at 1500 V.—60 C.

WRITE OR WIRE... FREE CATALOG, SPECIFIC RECOMMENDATIONS, NO OBLIGATION.

GUARDIAN ELECTRIC
1628-C W. WALNUT STREET
CHICAGO 12, ILLINOIS

A COMPLETE LINE OF RELAYS SERVING AMERICAN INDUSTRY
When you specify Mallory Capacitors for television receivers or other equipment where heat is a problem, you can be sure they will stand the test. Mallory FP Capacitors are designed to give long, trouble-free performance at 85°C — naturally they give even longer service at normal temperatures. In addition, Mallory FP Capacitors are famous for their long shelf life. Write for your copy of the FP Capacitor Engineering Data Folder.

Mallory Precision Production pays off again in “shelf-life” demonstration

When a large radio and television manufacturer found it necessary to fall back on a supply of two-year-old capacitors, they found that every one of the Mallory Capacitors was ready for immediate use — without re-working of any kind. Because of the scrupulously careful manufacturing methods pioneered by Mallory, they were completely free of corrosion.

Mallory Capacitors have consistently set new high standards of dependability which far exceed normal specifications.

That’s service beyond expectations!
NOW FOR THE FIRST TIME

1kw AT 900 mc

PLUS CERAMIC CONSTRUCTION

GENERAL ELECTRIC

NEW GL-6019
See this great new G-E power tetrode at the I.R.E. Show in New York, March 19 to 22. Or wire or write for descriptive folder ETD-152. Electronics Department, General Electric Company, Schenectady 5, New York.
There's a TIC Potentiometer for every application

Miniaturization of precision potentiometers is keeping pace with the increased demand for smaller assemblies and compact design. Now you can minimize wasted space with TIC's outstanding, new RV3* and RV1-1/16" Miniature Potentiometers.

In spite of their thumbnail size the RV3 and the RV1-1/16 are precision, high linearity variable resistors, (or adjustable trimmers) of high stability — achieving a standard of performance hitherto unavailable in such miniature potentiometers.

Construction features include: precision machined aluminum base . . . low torque . . . all soldered connections except sliding contacts . . . palmy contacts . . . can be sealed to withstand all humidity, salt spray, and altitude specifications. Ganging if desired with TIC adjustable clamp ring.

RV3 available with linear resistance elements only — nine standard resistance values from 100 to 25,000 ohms. Power rating 6 watts at 25°C. Illustration shows RV3 with threaded bushing . . . servo mounting available if desired.

RV1-1/16 available with linear or non-linear resistance elements — nine standard resistance values from 100 to 50,000 ohms. Illustration shows RV1-1/16 with 3 tapped hole mounting . . . servo mounting or threaded bushing if desired.

RVP3* High Precision machined aluminum base Potentiometers . . . available in models for either linear or non-linear functions with standard resistance values up to 200,000 ohms. Linearity to ±0.1%. Eleven gang assembly shown — example of TIC's potentiometers multi-ranged with TIC's adjustable clamp ring. Can be supplied to meet various mounting requirements — single hole, 3 tapped hole mounting or servo mounting as desired.

Sine and cosine potentiometers available in RVP3* and RV2* bases.

Type RV1/4" and RV2" High Precision Potentiometers . . . semi-standardized types of precision machined aluminum base potentiometers with exceptionally high electrical accuracy and mechanical precision. For both linear and non-linear functions. Designed for precision instrument, computer and military applications. Accurate phasing of individual units possible with clamp-ring method of ganging. Ball bearing models available.

Type RV1 Translatory Potentiometers . . . actuated by longitudinal instead of rotary motion providing linear electrical output proportional to shaft displacement. Used as a position indicator, high amplitude displacement type pickup and for studying low frequency motion or vibration. Features exceptionally high linearity and resolution. Available in various lengths and resistance values.

Type RV3 Bakelite Base Precision Potentiometers . . . available in models for either linear or non-linear functions. Stock resistance values ranging from 100 ohms to 200,000 ohms and power ratings of 8 and 12 watts. 360° mechanical rotation or limited by stops as desired. Potentiometers of this type available to widely varying accuracy requirements (linearity to ±0.25%) — see TIC Bulletin RV3-250. Special models available for high humidity applications.

TECHNOLOGY INSTRUMENT CORP.
531 Main Street, Acton, Mass.
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PROCEEDINGS OF THE I.R.E. March, 1951
Cleveland Phenolic Tubing

Meets the Most Exacting Specifications!

A Grade for Every Need:

CLEVELITE
Grade E .... Improved post cure fabrication and stapling.
Grade EX .... Special grade for TV deflection yoke sleeve.
Grade EE .... Improved general purpose.
Grade EEX .... Superior electrical and moisture absorption properties.
Grade EEE .... Critical electrical and high voltage applications.
Grade XAX .... Special grade for government phenolic specifications.

COSMALITE
Grade SP .... Post cure fabrication and stapling.
Grade SS .... General purpose.
Grade SSP .... General purpose—punching grade.
Grade SLF .... Thin wall tubing—high dielectric and compression strength.

The Cleveland Phenolic Tubing
The First Choice of the Radio and Television Industries.
Excellent Service and Prompt Deliveries Assured.

* Trade Marks
Trim Assembly Time with the Tube with the Tab

Superior's pioneering in tubing technology is constantly at work to bring electronic manufacturers new developments—to help them produce better equipment, faster, at lower costs. Newest of these improvements is the integral tabbed round Lockseam® cathode. It is designed to eliminate a welding operation, cut assembly time, and provide superior performance.

These integral tabbed round Lockseam® cathodes may be valuable to you...but whether they are or not one thing is sure. If you use Seamless or Lockseam® cathodes in your product a Superior tube is available to do a Superior job. Our research and engineering facilities are ready at all times to help solve your tubing problems.

For more information about Superior Tubing and its possible place in your operation write to Superior Tube Co., 2500 Germantown Ave., Norristown, Pa.

SEAMLESS...? The finest tubes that can be made. Standard production is .010" to .121" O.D. inclusive, with wall thicknesses of .0015" to .005". Cathodes with larger diameters and heavier walls will be produced to customer specification.

Or LOCKSEAM®...? Produced directly from thin nickel alloy strip stock, .010" to .100" O.D., in standard length range of 11.5 mm to 12 mm. Round, rectangular or oval, cut to specified lengths, beaded or plain.

Which is the Better for Your Product...

Electronic Engineering — Life test rack and emission test set. Checking Superior assembled standard diodes under simulated customer conditions to determine if material meets minimum requirements.

To guard against contamination by processing lubricants, Superior tubing is thoroughly degreased before each annealing operation.

Part of inspection procedure on Lockseam Nickel Cathodes as they come off the production machine. Each cathode must undergo many rigid tests before being approved.

Superior

THE BIG NAME IN SMALL TUBING

All analyses .010" to 3/16" O.D.
Certain analyses (.035" max. wall) Up to 11/16" O.D.

*Mfd. under U.S. Pats.—SUPERIOR TUBE COMPANY • Electronic Products for export through Driver-Harris Company, Harrison, New Jersey.

PROCEEDINGS OF THE I.R.E. March, 1951
The patented SOLA Constant Voltage Principle provides the following advantages over ordinary transformer design: regulation within ±1% with total primary variations as great as 30%; automatic, instantaneous regulation; freedom from moving parts, maintenance and manual adjustments; self-protection against short circuit. They are available in a complete range of capacities and special types (such as frequency compensated or with harmonic filter).

SOLA Constant Voltage Transformers were widely employed during World War II wherever continuous precision performance of electrical and electronic units was mandatory. Typical defense applications include: observation and fire-control, radar, omni-directional ranges and other navigation aids, X-ray equipment, flight and navigation trainers, and photo-electric devices.

Often the precise voltage input upon which a device's design was predicated is not available. Yet, input voltage level must continuously meet design requirements for satisfactory performance. You can guarantee optimum performance for your unit by stabilizing input voltage with a SOLA Constant Voltage Transformer.

The engineers and sales representatives of the SOLA Electric Company will be glad to discuss the application of SOLA Constant Voltage Transformers to your specific requirements. Your phone call or letter will receive our prompt attention.

See the standard SOLA regulators and many new developments at Booth Number 21, I.R.E. Radio Engineering Show in New York.
PANORAMIC INSTRUMENTS

SPECTRUM ANALYSIS FROM AF TO UHF
with easier-to-use

PANORAMIC INSTRUMENTS

You'll collect data more quickly, simply, objectively... with the help of Panoramic instruments. Unexcelled for laboratory, research and production applications requiring spectrum or waveform analysis.

Spectral components are seen graphically on a cathode-ray tube as sharp vertical reflections distributed horizontally in order of frequency. Deflection height directly indicates component or signal level.

Whatever your problem—analyzing waveform distortions, noises, characteristics of AM, FM or pulsed signals, vibrations, spurious oscillations or modulations, response characteristics of filters or transmission lines or monitoring many frequency channels simultaneously—you'll find a Panoramic analyzer to answer your needs.

• Complete Display of these and other Panoramic Instruments in operation at the

IRE SHOW
BOOTH N-6

PANORAMIC
RADIO PRODUCTS INC.
12 SOUTH SECOND AVENUE, MOUNT VERNON, N.Y.

PANORAMIC SONIC RESPONSE INDICATOR G-2
for More Accurate Frequency Response Measurement
Used with Model AP-1, the G-2 allows visual inspection of the frequency range. Frequency characteristics of systems in the range between 40 and 20,000 cps. May be used for research, development or production line testing of frequency response characteristics of amplifiers, speakers, filters, transmission lines, receivers.

The G-2 is advantageous for study of systems in which the presence of noise or non-fundamental components obscure or distort the output at the exploring frequency.
• Calibrated log frequency scale
• Linear or log (40 db range) amplitude scale
• Slow, 1 cps sweep rate
• 10-step attenuator with 100 db range selects output voltages between 50 microvolts and 5 volts
• 3 selectable output impedances: 100 ohms; 500 ohms; 3000 ohms

PANORAMIC ULTRASONIC ANALYZER, MODEL SB-7
A New Direct Reading Spectrum Analyzer

An invaluable instrument for channel monitoring, tele-metroing, medical studies, and for investigating ultrasonic waveform content and ultimate audible noises and vibrations, the SB-7 allows overall observation of a 200Kc wide band or highly detailed examination of selected narrow bands.

Frequency Range: 2KC-300KC, linear scale
Scanning Width: Continuously variable, 200Kc to zero
Amplitude Scale: Linear and two decade Log
Input Voltage Range: 1mV-50V
Resolution: Continuously variable from 2KC to better than 500 CPS

PANDAPTOR, SA-8
PANALYZOR SB-8
For RF Spectrum Analysis where Maximum Resolution is a "Must"

Available in several types with maximum scanning widths ranging from 200 KC to 10 MC, both the SA-8 and SB-8 feature...
• Continuously Variable Resolution from 100KC to 100cps
• Synchronous and Non-synchronous Scanning
• Long Persistence Displays plus Intensity Grid Modulation for Analysis of Pulsed RF Signals
• Continuously Variable Scanning Width from Maximum to Zero

PANDAPTOR SA-3, SA-6
PANALYZOR SB-3, SB-6
For General RF Spectrum Analysis

Recognized as the fastest and simplest means of investigating and solving such RF problems as frequency stability, modulation characteristics, oscillations, parasitic, and monitoring under static or dynamic conditions, these models are available in over a dozen different types, designed to meet your particular application. Pandaport/units operate with superheterodyne receivers which tune in the spectrum segment to be observed.
**Ferramics**

**Cores**

**by**

**GENERAL CERAMICS**

Ferramics are soft magnetic materials featuring:

- **HIGH PERMEABILITY**
- **HIGH VOLUME RESISTIVITY**
- **HIGH EFFICIENCY**
- **LIGHT WEIGHT**
- **ELIMINATE LAMINATIONS**

---

**Table: Type of Ferramic Material**

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<thead>
<tr>
<th>PROPERTY</th>
<th>UNIT</th>
<th>A 34</th>
<th>B 90</th>
<th>C 159</th>
<th>D 216</th>
<th>E 174</th>
<th>G 254</th>
<th>H 419</th>
<th>I 141</th>
<th>J 472</th>
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</thead>
<tbody>
<tr>
<td>Initial permeability</td>
<td>at 1 mc/sec</td>
<td>15</td>
<td>95</td>
<td>220</td>
<td>410</td>
<td>750</td>
<td>410</td>
<td>850</td>
<td>600</td>
<td>330</td>
</tr>
<tr>
<td>Maximum permeability</td>
<td></td>
<td>97</td>
<td>183</td>
<td>710</td>
<td>1030</td>
<td>1710</td>
<td>3300</td>
<td>4300</td>
<td>1010</td>
<td>750</td>
</tr>
<tr>
<td>Saturation flux density</td>
<td>Gauss</td>
<td>840</td>
<td>1900</td>
<td>3800</td>
<td>3100</td>
<td>3800</td>
<td>3200</td>
<td>3400</td>
<td>1540</td>
<td>2900</td>
</tr>
<tr>
<td>Residual magnetism</td>
<td>Gauss</td>
<td>615</td>
<td>830</td>
<td>2700</td>
<td>1320</td>
<td>1950</td>
<td>1050</td>
<td>1470</td>
<td>660</td>
<td>1600</td>
</tr>
<tr>
<td>Coercive force</td>
<td>Oersted</td>
<td>3.7</td>
<td>3.0</td>
<td>2.1</td>
<td>1.0</td>
<td>0.65</td>
<td>0.25</td>
<td>0.18</td>
<td>0.40</td>
<td>0.80</td>
</tr>
<tr>
<td>Temperature coefficient of initial permeability</td>
<td>%/°C</td>
<td>0.65</td>
<td>0.04</td>
<td>0.4</td>
<td>0.3</td>
<td>0.25</td>
<td>1.3</td>
<td>0.66</td>
<td>0.3</td>
<td>0.22</td>
</tr>
<tr>
<td>Curie point</td>
<td>°C</td>
<td>280</td>
<td>260</td>
<td>330</td>
<td>165</td>
<td>160</td>
<td>150</td>
<td>70</td>
<td>180</td>
<td></td>
</tr>
<tr>
<td>Volume resistivity</td>
<td>Ohm-cm</td>
<td>$1 \times 10^6$</td>
<td>$2 \times 10^3$</td>
<td>$2 \times 10^5$</td>
<td>$3 \times 10^5$</td>
<td>$4 \times 10^7$</td>
<td>$1.5 \times 10^9$</td>
<td>$1 \times 10^6$</td>
<td>$2 \times 10^5$</td>
<td>---</td>
</tr>
<tr>
<td>Loss Factor:</td>
<td></td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>at 1 mc/sec</td>
<td></td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>at 5 mc/sec</td>
<td></td>
<td>---</td>
<td>---</td>
<td>---</td>
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<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>at 10 mc/sec</td>
<td></td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
</tbody>
</table>

---

**General CERAMICS and STEATITE CORP.**

General Offices and Plant: Keasbey, New Jersey

Makers of Steatite, Titanates, Zircon Porcelain, Ferramics, Light Duty Refractories, Chemical Stoneware, Impervious Graphite

Proceedings of the I.R.E. March, 1951
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

VISIT THE KENYON EXHIBIT
BOOTH 56—GRAND CENTRAL PALACE
MARCH 19TH-22ND

Write for details  KENYON TRANSFORMER CO., Inc.
840 Barry Street
New York 59, N. Y.
Good names to know for—fineer electronic metals & alloys

FILAMENT BASE METALS:
SYLVALOY
MODIFIED HILO
cobanic
tensite
UNIMET

CARBONIZED NICKEL:
RADIOCARB
DUOCARB
POLICARB
GRID WIRE:
MANGRID

—BACKED BY YEARS OF SPECIALIZED PRODUCTION

Since the inception of AC radio, Wilbur B. Driver Company has pioneered in the development and production of filament alloys, carbonized nickel and grid wire. Thus it is a logical conclusion that Wilbur B. Driver Company is the dependable source of supply for radio and electronic requirements... the choice when materials must be held to exacting and precise specifications.

It's WILBUR B. DRIVER for Critical Tube Alloy Requirements!

WILBUR B. DRIVER COMPANY
150 RIVERSIDE AVENUE, NEWARK 4, NEW JERSEY

PROCEEDINGS OF THE I.R.E. March, 1951
ELECTRONIC INSTRUMENTS
Audio to Microwaves

- Sweeping Oscillators
- Marker Oscillators
- Frequency Meters
- Analyzers
- Attenuators
- Reflectometers

Specialized Electronic Instruments for Civilian and Military Uses

See the MEGA-LINE and the SONA-LINE

AS EXHIBITED AT THE-
Radio Engineering Show
Grand Central Palace
New York City

BOOTH 22
March 19-22 1951

IF YOU ARE NOT ON OUR MAILING LIST, WRITE FOR OUR NEW CATALOG A51

ELECTRIC KAY COMPANY
14 Maple Avenue
Phone CAldwell 6-4000
Pine Brook, N. J.
Mr. Manufacturer:

To get the best delivery on OHMITE resistance components, tailor your needs to these “standard” OHMITE items...

**RHEOSTATS**

The Ohmite series of standard, close control rheostats is the most extensive available—so it is easy to select a size to fit your application. There are ten sizes, ranging from 25 to 1000 watts, with many standard resistance values in each size. All models have the Ohmite all-ceramic construction, with winding permanently locked in vitreous enamel, and smoothly gliding metal-graphite brush.

**RESISTORS**

The extensive range of Ohmite types and sizes makes possible an almost endless variety of standard resistors to meet your needs. The Ohmite line includes more than 60 core sizes, in a wide range of wattage and resistance values. There are also 18 types of resistor terminals available. Included in the standard Ohmite line are fixed, adjustable, tapped, non-inductive, and precision resistors. Specially developed vitreous enamel provides years of unfailing performance.

**TAP SWITCHES**

Ohmite tap switches are supplied in five standard models, rated at 10, 15, 25, 50, and 100 amperes, a.c. They combine high current capacity and a large number of taps with unusual compactness. Their sturdy, one-piece ceramic bodies provide permanent non-arcing insulation. Their heavy silver-to-silver contacts have a self-cleaning action and provide continuous, dependable contact with low resistance. Ohmite tap switches are supplied in enclosed or open, shorting or non-shorting types.

**OTHER PRODUCTS**

Ohmite offers an extensive line of standard precision, non-inductive resistors in ½- and 1-watt sizes, in the standard type, vitreous-enameded type, or hermetically sealed in glass. They have an accuracy of ±1%. Ohmite non-inductive vitreous enameded resistors are also available in standard 50-, 100-, and 160-watt sizes in a wide range of resistance values. In addition, Ohmite provides radio-frequency plate chokes, power line chokes, and dummy antennas.

**Write on Company Letterhead for Catalog and Engineering Manual No. 40**

OHMITE MFG. CO.,
4867 Roeurny St.,
Chicago 44, Ill.
WE WILL, without cost or any obligation whatever, design a PRODUCTION SAMPLE transformer (hermetically sealed to JAN-T-27 or MIL-T-27 Government specifications), or open type construction, if unit is to be used for awarded prime or sub-contract work. Our approach stresses quality of product, efficiency in service and an alertness to techniques that discard the old for more functional methods.

James W. Blackledge
PRESIDENT

SEND YOUR B/P SPECIFICATIONS
If you use the **880**
you will get
**BETTER PERFORMANCE**
**LOWER OPERATING COSTS**
and **LONGER LIFE . . .**

...with the

**ML-5658**

---

**THE ML-5658** is an improved and directly interchangeable version of the widely used 880. Designed originally as a better, more rugged tube for electronic heating equipment, it has since found extensive use in the high power broadcast field and in such exacting applications as cyclotron and synchrotron oscillators.

The ML-5658 incorporates in its design many of the outstanding features developed by Machlett Laboratories for all its industrial tubes. Typical of these design and process improvements which have given broadcast and industry better, more dependable tubes are:

1. **Kovar-to-glass seals.** The elimination of the inherently weak feather-edged copper seal—increasing seal strength and providing greater stability of the internal electrode structure.

2. **An improved, stress-free, self-supporting filament structure.** Which substantially eliminates filament distortion, provides uniform filament emission throughout tube life and reduces the complexity and the hazards of the older spring-supported filament construction.

---

3. **A unique pre-exhaust treatment of all parts and the thorough, high voltage exhaust of each tube on Machlett's special high voltage, high temperature exhaust system.**

These, and many other improvements in tube design and processing, provide for every installation which uses or contemplates the use of an 880 type tube, a far more rugged longer lived tube in the ML-5658. It will directly replace the 880 with no electrical or mechanical changes and will provide better performance, longer tube life and more economical operation.

The ML-5658, like other Machlett industrial tubes, is available with the Machlett automatic seal water jacket. This new jacket eliminates the use of tools and the hazard of tube breakage and water leakage. The jacket cannot be opened unless the water pressure is off, nor closed unless the tube is properly installed.

Complete technical data on both tube types is available upon request. Write direct to Machlett Laboratories, Inc., Springdale, Connecticut.

* Patent No. 2,324,559.  † Patent applied for.

Machlett Industrial and Broadcast Tubes will be exhibited at the 1951 I.R.E. Show 
Booth 96-97

---

**OVER 50 YEARS OF ELECTRON TUBE EXPERIENCE**

**MACHLETT**

---

PROCEEDINGS OF THE I.R.E. March, 1951
What to see at the Radio Engineering Show
(Continued from page 27-A)

Firm Booth
Radio, television, and electronic components.

Eitel-McCullough, Inc., San Bruno, Calif. 36
New transmitting type vacuum tubes for CW and pulse services, including the
4W20/08A power tetrode capable of 20 kw
peak output in TV service on channel 12.

Electric Motor Corp., Division of Howard Industries, Inc., Racine, Wis. 221
Represented by Wally Swank

Electrical Industries, Inc., Newark, N.J. 212
Hermetic Seals, glass-to-metal sealed ter-
minals and multiple headers for her-
metically sealing transformers, relays,
guided missiles, and electronic equipment
in general.

Electrical Reactance Corp., Franklinville, N.Y. 63
Hi-J ceramic capacitors, trimmers, choke
coils, wire wound resistors.

Plugging boards, precision recording of X
vs Y etc. on the “Variplotters Models”
24H and 295C, secondary time standards.
UHF generating equipment, function gen-
erating equipment, sine-curve potentialome-
ters to specification, and introduced an
automatic curve follower which will follow
a previously drawn or plotted line to an
approximate accuracy of one tenth of one
percent of full scale.

Electronic Instrument Co. Inc., Brooklyn, N.Y. 362
Testing and measuring equipment, Eico
Multi-Analyst electron tracer.

Electronic Measurements Co., Easton- town, N.J. 6-4
Power supplies, voltage regulated output
types.

Electronic Mechanics, Inc., Clifton, N.J. 328
Glass bonded mica (or) “Mylar” also
“Teflon,” and “Kel-F.” We mold, extrude
and fabricate the above.

Electronic Tube Corp., Philadelphia, Pa. 274, 275
Model H4A Strainalyzer, an improved
four channel cathode-ray dynamic strain
recorder. Cathode-ray tubes, multi-gun,
standard, and special purpose. Oscillo-
sopes, cathode-ray multi-channel. Ampli-
ders, etc. Electronic equipment, special de-
sign.

El-Tronic Inc., Philadelphia, Pa. 379
Nuclear measurement equipment.

Empire Devices, Inc., Bayside, L.I., N.Y. 349
UHF impulse generators, controlled im-
pulse, less than 0.001 microsecond, flat to
1,000 Mc. Resitive attenuators and termi-
nations of low VSWR to 4,000 Mc. Noise
and field intensity meter, 20 to 400 Mc in-
corporating standard impulse noise source,
slideback and meter indication, true peak
measurements. Broadband VHF and UHF
crystal mixers.

Engineering Research Associates, Inc.,
St. Paul, Minn. 304
Magnetic storage systems.

Erie Resistor Corp., Erie, Pa. 91
Erie Ceramics, ceramic trimmers, but-
ton silver mica capacitors and electronic
ultra-assemblies.

Fairchild Camera & Instrument Corp.,
Jamaica, L.I., N.Y. 239
Precision linear and non-linear potentiom-
eters, Oscillo-recorder cameras, Fairchild-
Polaroide oscilloscope cameras.

Federal Telecommunication Laboratories,
Nutley, N.J. 34
Electronic test equipment.

Federal Telephone & Radio Corp., Clifton,
N.J. 33
Transmitting, industrial, and rectifier
tubes, TV picture tubes, selenium recti-
fiers, high frequency cables, and mobile
radio telephone equipment.

(Continued on page 126A)
bendix Specialized Dynamotors are made for the Job!

Whenever DC power is required at other than the supply voltage, Bendix® Specialized Dynamotors function as DC transformers. They can be wound for any input or output voltage between 5 and 1200 volts, and they can deliver power up to 500 watts. Multiple outputs can be supplied to correspond with several secondaries on transformers, and their output voltages can be regulated within close limits regardless of input voltage or load variations. Bendix Specialized Dynamotors are tailored to the exact requirements of each application by the design of the windings used in standardized frames. This reduces the cost, size and weight to an absolute minimum, consistent with the operational requirements. Compliance with Government specifications is assured by the choice and treatment of materials and the basic design. A complete description of your requirements will enable our engineers to make concrete recommendations ... All orders are filled promptly and at moderate cost.
ACCURACY AND FLEXIBILITY WITH

NEW WATTMETER BRIDGE

Another addition to Sperry's complete line of microwave test and measuring equipment, Microline, is a new, highly-accurate Wattmeter Bridge. Model 123B is extremely versatile and will not be made obsolete by future requirements in bolometer operating resistance.

- With accuracy to which power dissipated in the bolometer element can be measured to ±3% of the full scale reading, this meter is capable of operation with either thermistor or barretter. This is possible by the selection of the proper plug-in unit (listed in table at right).

- Model 123B is calibrated in both milliwatts and DBM. Five power ranges are available 0-0.1, 0.3, 1.0, 3.0 and 10.0 milliwatts. Pulse power, as well as c-w power, can be measured with this bridge and appropriate bolometers.

- Write our Special Electronics Department for further details.

SPERRY GYROSCOPE COMPANY

DIVISION OF THE SPERRY CORPORATION, GREAT NECK, NEW YORK - CLEVELAND - NEW ORLEANS - NEW YORK - LOS ANGELES - SAN FRANCISCO - SEATTLE

PROCEEDINGS OF THE I.R.E. March, 1951
Not only is the Daven Company the largest supplier of transmission measuring sets, but it is also a source for every needed type of instrument for the measurement of the transmission characteristics of communication systems. It furnishes units to check all types of broadcast equipment and audio devices for commercial and industrial use as well as for organizations such as utilities, telephone and power companies. Therefore, whatever your requirements are in this field, write to Daven for complete catalog material, and outline your own particular problems for specific assistance from our engineering staff.

DAVEN TRANSMISSION MEASURING SET 7A

Equipment specially designed for use by utilities, telephone and power companies. May be directly applied to measuring gains or losses through amplifiers, repeaters, attenuating networks or communication lines.

**TRANSMISSION SECTION**
- **GENERATED FREQUENCIES:** 500, 1000, 2500 cycles per second.
- **OUTPUT LEVEL:** —13, 0, +4 and +10 dbm.
- **INPUT and OUTPUT IMPEDANCE:** 600 ohms over entire frequency range.

**RECEIVING SECTION**
- **FREQUENCY RESPONSE:** Within ±1.0 db from 50 to 15,000 cps.
- **AMPLIFICATION RANGE:** —10 to +30 db in 2 db steps.

DAVEN TRANSMISSION MEASURING SET 11A

A moderately priced instrument for broadcast equipment. A simplified, accurate, direct reading instrument, designed to make measurements in accordance with FCC regulations.

- **FREQUENCY RANGE:** 20 CY to 20 Kc.
- **ACCURACY:** ±0.1 db, 20 CY to 20 Kc.
- **RANGE OF LEVEL:**
  - +4 to —110 db
  - —10 to —124 db
- **APPLICATIONS:**
  - (a) Audio gain and loss measurements.
  - (b) Measurements of matching and bridging devices.
  - (c) Complex circuit measurements.
  - (d) Measuring mismatch loss.
  - (e) Frequency response measurements.
Lenz is producing electrically insulated wires, cords and cables of many types for Military Equipment, under approved Government Specifications.

With its extensive facilities and expert knowledge, gathered over almost a half century of wire and cable manufacture for the communications industry, Lenz is your ideal source for special and standard wire and cable products. Consultation on your requirements is invited!

**Approved under AN-J-C-48a AERONAUTICAL SPECIFICATION**

**Hook-Up Wires and Special Cables for Aircraft Electronic Instruments**

- Tinned Copper Conductors
- Extruded Plastic Insulation
- Cotton or Glass Braid Covered
- Color Coded as desired
- Saturation and Lacquer Coating containing Fungicides

- for Radar Instruments
- Electrical Instruments
- Radio Receivers
- Radio Transmitters
- Fuselage Wiring

**LENZ ELECTRIC**

1751 North Western Avenue

**LENZ MANUFACTURING CO.**

Chicago 47, Illinois

NOW ENJOYING ITS 47TH YEAR OF SUCCESSFUL BUSINESS
UTC Ultra compact audio units are small and light in weight, ideally suited to remote amplifier and similar compact equipment. High fidelity is obtainable in all individual units, the frequency response being ± 2 DB from 30 to 20,000 cycles.

True hum balancing coil structure combined with a high conductivity die cast outer case, effects good inductive shielding.

<table>
<thead>
<tr>
<th>Type No.</th>
<th>Application</th>
<th>Primary Impedance</th>
<th>Secondary Impedance</th>
<th>List Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-10</td>
<td>Low impedance mike, pickup, or multiple line to grid</td>
<td>50, 125/150, 200/250, 50 ohms</td>
<td>333, 500/600 ohms</td>
<td>$15.00</td>
</tr>
<tr>
<td>A-11</td>
<td>Low impedance mike, pickup, or line to 1 or 2 grids (multiple alloy shields for low hum pickup)</td>
<td>50, 200, 500 ohms</td>
<td>80,000 ohms overall, in two sections</td>
<td>15.00</td>
</tr>
<tr>
<td>A-12</td>
<td>Dynamic microphone to one grid or two grids</td>
<td>30 ohms</td>
<td>50,000 ohms overall, in two sections</td>
<td>14.00</td>
</tr>
<tr>
<td>A-20</td>
<td>Mixing, mike, pickup, or multiple line to line</td>
<td>50, 125/150, 200/250, 50, 125/150, 200/250, 333, 500/600 ohms</td>
<td>15.00</td>
<td></td>
</tr>
<tr>
<td>A-21</td>
<td>Mixing, low impedance mike, pickup, or line to line (multiple alloy shields for low hum pickup)</td>
<td>50, 200/250, 500/600 ohms</td>
<td>50, 200/250, 500/600 ohms</td>
<td>16.00</td>
</tr>
<tr>
<td>A-16</td>
<td>Single plate to single grid</td>
<td>15,000 ohms</td>
<td>60,000 ohms, 2.1 ratio</td>
<td>13.00</td>
</tr>
<tr>
<td>A-17</td>
<td>Single plate to single grid (8 MA unbalanced D.C.)</td>
<td>As above</td>
<td>As above</td>
<td>15.00</td>
</tr>
<tr>
<td>A-18</td>
<td>Single plate to two grids, split primaries</td>
<td>15,000 ohms</td>
<td>80,000 ohms overall, 2.3:1 turn ratio</td>
<td>14.00</td>
</tr>
<tr>
<td>A-19</td>
<td>Single plate to two grids (8 MA unbalanced D.C.)</td>
<td>15,000 ohms</td>
<td>80,000 ohms overall, 2.3:1 turn ratio</td>
<td>18.00</td>
</tr>
<tr>
<td>A-24</td>
<td>Single plate to multiple line</td>
<td>15,000 ohms</td>
<td>50, 125/150, 200/250, 333, 500/600 ohms</td>
<td>15.00</td>
</tr>
<tr>
<td>A-25</td>
<td>Single plate to multiple line (8 MA unbalanced D.C.)</td>
<td>15,000 ohms</td>
<td>50, 125/150, 200/250, 333, 500/600 ohms</td>
<td>14.00</td>
</tr>
<tr>
<td>A-26</td>
<td>Push pull low plate to plate, multiple lines</td>
<td>50, 125/150, 200/250, 333, 500/600 ohms</td>
<td>15.00</td>
<td></td>
</tr>
<tr>
<td>A-27</td>
<td>Crystal microphone to multiple plate</td>
<td>100,000 ohms</td>
<td>50, 125/150, 200/250, 333, 500/600 ohms</td>
<td>15.00</td>
</tr>
<tr>
<td>A-30</td>
<td>Audio choke, 250 henrys or 5 MA 6000 ohms D.C.</td>
<td>65 henrys or 10 MA 1500 ohms D.C.</td>
<td>10.00</td>
<td></td>
</tr>
<tr>
<td>A-32</td>
<td>Filter choke, 60 henrys or 15 MA 2000 ohms D.C.</td>
<td>15 henrys or 30 MA 500 ohms D.C.</td>
<td>9.00</td>
<td></td>
</tr>
</tbody>
</table>

UTC OUNCER components represent the acme in compact quality transformers. These units, which weigh one ounce, are fully impregnated and sealed in a drawn aluminum housing 7/8" diameter...mounting opposite terminal board. High fidelity characteristics are provided, uniform from 40 to 15,000 cycles, except for 0-14, 0-15, and units carrying DC which are intended for voice frequencies from 150 to 4,000 cycles. Maximum level 0 DB.
Jensen presents...
G-610 TRIAXIAL

a NEW loudspeaker which for the first time spans the full frequency range of the ear!

A new, skillfully integrated combination of three independently-driven units... two compression driver and horn combinations, plus heavy-duty direct radiator... with 3-channel electrical crossover and control network... achieving the widest frequency range and finest reproduction ever attained!

Write for Data Sheets 160 and 152 which describe the G-610 and other Genuine Jensen Wide Range Speakers.

JENSEN MANUFACTURING COMPANY Division of the Muter Company
6617 So. Laramie Ave., Chicago 38, PORTsmouth 7-7600 In Canada: Copper Wire Products, Ltd., 351 Carlaw, Toronto

664
NOW . . . custom transmitters
from prefabricated assemblies

You can now get the benefit of production line economies in a new Collins series 430 one or two kilowatt communications transmitter tailored for your specific requirements.

Completely constructed RF, power supply, and modulator components of new design are available for integrating in different combinations, forming finished transmitters to fulfill all requirements of ground-to-plane, shore-to-ship and point-to-point systems. The frequency range of these transmitters is 2 to 30 megacycles.

RF units can be supplied with or without Autotune* control. Manual tuned RF units may be worked in multiple to provide a multiplicity of fixed tuned instantly selectable channels or simultaneous transmissions on two or more frequencies.

Among the combinations available are the Type 431D one kilowatt, ten channel CW-FSK and phone autotuned transmitter illustrated here. It is made by combining a 507A-1A RF unit, a 506A-1 power unit, a 508A-1 power unit, a 509A-1 modulator unit, a 2-bay cabinet and a 1 KW blower.

Another combination, not illustrated, is the Type 434B-1 one KW, two simultaneous-channel CW-FSK only, manual tuned transmitter, which is made by combining two 507A-1 RF units, two 506A-1 power units, a 508A-1 power unit, a 2-bay cabinet, and a 1 KW blower. Several other combinations are available, one of which is certain to satisfy your exact needs.

Final assembly, and testing, may be accomplished at the Collins plant or at the installation site. We will be glad to give you details about the 430 series transmitter to fulfill your own requirements.

A New Kind of Television
R.F. Tuner . . . Combining the Best Features of Rotary and Turret Type Tuners!

The DX Rotorette

IMPROVED HIGH FREQUENCY PERFORMANCE
• High and substantially uniform gain on all channels.
• Good image rejection and adjacent channel attenuation because of rigid tracking and bandwidth control in manufacture.
• Excellent noise factor, low oscillator radiation and temperature compensated colpitts circuit for oscillator stability.
• Adaptable to U.H.F.
• Output designed for single or dual I.F. channel operation.

The DX Rotorette is a radically new design of turret switch tuner having an extremely low torque. The switch selects a completely tuned circuit for each channel. Having undergone an extensive period of laboratory development and field performance testing, the Rotorette assures reliable performance at an unusually low cost. Your inquiry will bring complete engineering data.

DX TOROID COILS
Special toroid winding equipment has been developed over a period of ten years by DX engineers. A wide range of sizes from 3/8” to 12” in diameter can be wound to your specifications for inductances and Q values. DX Toroids and filters are available in open, cased, potted or hermetically sealed types. Send us your specifications for quotation.

Other fine DX components include Deflection Yokes, Horizontal Output Transformers, Ion Traps, Speakers, R.F., I.F., and Oscillator Coils, Special Transformers, Filters and Focus Coils.

SEE US IN BOOTH 345A
AT THE I. R. E. SHOW

DX COMPONENTS
"the heart of a good television receiver"

DX RADIO PRODUCTS CO.
GENERAL OFFICES: 2300 W. ARMITAGE AVE., CHICAGO 47, ILL.
**NO. 1110A INCREMENTAL INDUCTANCE BRIDGE**

For accurate testing of television and communication components under load conditions.

This bridge has an impedance range of one millihenry to 1000 henries in five ranges. The inductance values are read directly from a four dial decade and multiplier switch. Range of this instrument can be extended to 10,000 henries through the use of an external resistance.

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Chairmen of Recently Formed IRE Sections

Palmer H. Craig
MIAMI SECTION

Palmer H. Craig, Chairman of the Miami Section, was born on January 10, 1901 at Cheviot, Ohio. He was graduated with honors from the University of Cincinnati in 1923 with the B.A. degree, and received the M.A. degree in 1924 and the Ph.C. degree in 1926.

Dr. Craig, who has had wide experience as a teacher, research physicist, and consulting engineer, has been affiliated with the University of Florida as head of the department of electrical engineering. He was supervisor of the War Research Laboratory of the University during the years 1943-1946, and chief engineer of radio station WRUF at Gainesville. He was also radio supervisor of the State of Florida under the Federal E.S.M.W.T. program.

He is presently director of Electronics Research Laboratory, and has been professor of engineering of the University of Miami, Coral Gables, Fla., since 1947.

Mr. Craig is also a member of the American Physical Society, the American Society for Engineering Education, and a Fellow of the American Institute of Electrical Engineers. The inventor of many electronics devices, he holds numerous patents, and is a registered professional engineer.

Robert E. Moe
EVANSVILLE-OWENSBORO SECTION

Robert E. Moe, Chairman of the recently formed Evansville Owensboro Section, was born in Appleton, Wis., on April 2 1912. He was graduated from the University of Wisconsin in 1931 with the B.S. degree in electrical engineering.

Mr. Moe joined the General Electric Company in May, 1934, as a student engineer, and was transferred to the receiver engineering department in Bridgeport in 1935, with assignments in component engineering, broadcast and television receiver design, and from 1941 to 1944, in government radar design.

He was in charge of design activities on radar receivers and indicators for the Government division of the Electronics Department at Syracuse, N. Y., from 1944 to 1948, and assumed his present duties as division engineer in the receiving tube division in January, 1949.

Mr. Moe has held office in two other IRE sections, the Connecticut Valley Section and the Syracuse Section. He has served on the Papers Review Committee for a number of years.

He is a member of Eta Kappa Nu and Tau Beta Pi, and is registered as a professional engineer in the States of New York and Kentucky.
One of the major accomplishments of communication engineers, and a most spectacular and valuable achievement, is television broadcasting. Its problems, genesis, status, and potentialities are capably analyzed in the following guest editorial by the President of the Television Broadcasters Association, the Vice-President of WOR-General Teleradio, and a Fellow and former Director of the Institute.—The Editor.

The Tide of Television

J. R. POPPELE

The arrival of television as a full-blown industry must come as a source of great satisfaction to the engineering fraternity. Like telephony, wireless, and radio, television was born, nurtured, molded, and brought to fruition in the minds, hearts, and hands of engineers and scientists.

Pride of accomplishment is an engineer's great reward. He moves from one object to another with insatiable curiosity and zest. His work, apparently, is never done, since the fulfillment of one task invariably leads to another. Having tackled a tough problem and surmounted it, he moves almost immediately to another challenging chore.

In that progressive movement lies the secret of television's success. First principles of visual scanning trace back to the late nineteenth century. Once the objective became clear, it excited the interest and curiosity of others, who picked up the challenge and toiled endlessly in the pursuit of a solution.

The brain and brawn, the heartaches and despair of momentary failure, and the ecstatic lift that accompanies success of a mission are written into the history of television development in broad, indelible terms. Names like Nipow, Braun, Campbell-Swinton, DeForest, Jenkins, Baird, Zworykin, Ives, Alexanderson, DuMont, and Farnsworth will live in the annals of engineering for their monumental contributions to the art of television broadcasting and reception. Each had a hand in shaping TV's destiny; the cumulative effort brought about the great new industry which has taken the nation by storm.

Forty years ago when I chose engineering as a profession, wireless telegraphy was considered the great engineering achievement. Within ten years, radio broadcasting, on a scale undreamed of at the turn of the century, began to develop.

The audion, truly a miracle of science, turned the "trick." Yet, the arduous labors that took radio out of the crystal stage era, out of battery-operated receivers to a national radio service of immense proportions and later to an international broadcasting service, were not achieved overnight by a single individual, but by thousands of engineers who set an objective and pursued it to its ultimate achievement.

It was almost predestined that television would evolve from this continuous process of development, since farsighted men envisioned just such an accomplishment even while they labored to harness the ethereal waves for powerful aural transmission.

Today, despite the dark clouds that hover over a world praying for peace, television has achieved a place among the nation's top ten industries and will continue to thrive. As it grows, it makes possible a service to the public unique in modern history. It informs, entertains, delights, and enlightens millions—in a manner that can be understood by anyone—pictorially!

Although we are proud of our accomplishments in this marvel of electronic magic, we have only scratched the surface of what may come in the future. Each generation brings with it an even greater mental capacity for coping with what may sometimes appear to be the impossible.

Who knows, perhaps children now attending kindergarten will some day bring us new glories in television not even imagined today. In an atmosphere of free enterprise and unhhampered individual initiative, great things are bound to evolve. This aura of freedom has made the United States the most fruitful nation in the world. This we cherish above all else. The tide of television will ebb and flow with the nation's fortunes, but it is a tide that will go on endlessly.
The Human Element in Research and Industry*

WALTER H. KOHL†, SENIOR MEMBER, IRE

Summary—This short article reemphasizes the need for "social engineering" as contrasted with the prevailing competence in the field of "technical engineering." Practical steps are enumerated for the establishment of a favorable atmosphere in which human beings can effectively and happily operate in the laboratory and factory. This covers suggestions for a reorientation on the part of the "worker" as well as on the part of management. The remarks are of a very general nature and applicable to all industries, but the experience on which they are based was gained in the electron-tube field.

Research is done by people. When the results lead to industrial applications, men and women turn the researcher's findings into tangible products in the factory. Everybody knows that this is so, but for a long period, especially during the beginning of the nation's industrial development, interest was centered around the material aspects of this transformation of thoughts into things until "The Material Age" became a byword of our time. Of recent years, the human factor has been emphasized more and more frequently. Many volumes have been written on this subject and these lines are only to emphasize again that there exists a problem of "social engineering" as well as one of "technical engineering." Observations during a prolonged career in the electron-tube industry, in the laboratory, the factory, and as administrator, make it appear that a reemphasis is not altogether amiss.

Originality of thought remains the keystone on which the structure of our technological society rests and on which progress and survival depend. The conception of an original idea, the finding of a basic principle, is essentially an individual effort. At the same time, it is often the last link in a chain of events which is tied to time, history, stimulation by others, and many fortuitous circumstances. This creative act is also the first link in another chain which projects into the future toward the ultimate aim of practical realization. When the problem has been stated—always the most difficult step—and a sound approach to its solution is indicated, a group effort will bring the most rapid solution. To gather the right people for a given task force is the challenging privilege of the director of research. To give loyal support to the group is the responsibility of the members of the team. This demands subordination without submission, personal tact, tolerance, and fair play—in other words, all the requirements of a truly democratic society. There is no sense in any one of the group pretending that he knows all the answers and that the other members are incompetent. The advice of the craftsman and technician should be sought freely by the engineer to ensure the practicability of his design and, incidentally, to give his assistants a share in the project at an early stage of the development. Contributions by others should be recognized freely and the originality of an invention clearly established in the records with the consent of all concerned, in order to avoid arguments at a later stage when it comes to the filing of a patent claim. There is also no justification in prescribing the lines of attack on the problem too narrowly and in not welcoming new suggestions if they are at all promising. The group should be provided with all facilities that are reasonably necessary and should not be encumbered by red tape. In research, an informal, loose organization is of great value, although it can be overdone at the expense of a satisfactory rate of progress, particularly in larger organizations where the director will find it difficult to keep in personal contact with all groups. Periodic reports by the group leaders then become necessary in order to inform the management of the state of affairs and provide a basis for future direction.

A misconception prevails in some administrative quarters about the intricacy of many problems and the proper allocation of funds. Fortunate indeed is the company which has technically qualified people at the top. They will listen very sympathetically to the pleadings of their chief engineer or their director of research. Unfortunately, the problems of tube manufacture and those connected with new developments are not generally appreciated. It is better not to embark on a project if sufficient funds are not available than to insist on having the work done in a haphazard manner. It is not implied here that new investigations always require large amounts of expensive equipment. It is necessary, however, that new procedures are tested under carefully controlled conditions, so that they can be successfully reproduced. More often than not, mysterious effects make their appearance which require extensive investigation before they are brought under control. All this takes time, people, and money. There are times, on the other hand, when too much money can do equal harm, especially when it comes from the public purse. It will lessen the incentive to apply all possible ingenuity to the job and will encourage wastefulness in material and manpower. There is evidently a happy middle road to be followed.

In order to get a job done, human beings have to become excited about it. This response presupposes a certain alertness on the part of the worker and an interesting job. In addition, it requires a fair return for the effort. Fortunately, these conditions apply to a large extent in the electron-tube industry. Many of the tasks
require a great deal of skill and the personnel is of better than average intelligence. Routine operations should be
left to the less skilled, but an effort should be made to
provide variety wherever it is appreciated. There are,
however, people who like routine jobs, but one should
not overlook the possibility that an apparently dull
person may respond to an opportunity and discover
latent qualities in himself that have never been tapped.

A sympathetic job selection is thus required. It is unfair
to keep anyone employed on a job for which he is
ill suited when a transfer to a different activity for
which he is better qualified may result in greater satis-
faction to all concerned.

The various difficulties that do arise in the co-ordina-
tion of people are remedied more easily when the group
is small. There prevails in it a sort of family atmos-
phere where each member knows the other’s qualities
and shortcomings and can readily make allowance for
them. The problem is to transfer this close-knit personal
relationship to a larger body of people, or to replace it
by a similar sense of allegiance to the company at large.

The attainment of this objective requires a very con-
scious effort on the part of the management. This
usually results in a variety of devices; among these one
finds the house organ, sports clubs, insurance systems,
credit unions, retirement plans, stock distribution, in-
centive pay, and so on. What is important in the over-all
plan is that everyone knows from past experience that
he is being treated fairly and thus willingly contributes
his best efforts to the benefit of the whole. It is very
desirable that the management from time to time
inform all of the working force of the general trend of
developments so that full confidence in its policies is
maintained.

It is only natural that the growth of an organization
requires the weeding out of weak members who impede
its progress and normal functioning. Such measures will
avoid the creation of a false sense of security on the
part of loafers. Rarely should such steps be necessary
in regard to employees of long service. It is the com-
pany’s responsibility to judge the value of a worker early
in order to avoid unnecessary hardship. When dismissals
become necessary, the reasons for them should be fully
explained. Furthermore, a continuous effort should be
made towards the further development of the members
of all groups by providing job training, educational
facilities, and stimulation through travel and attendance
at meetings of professional societies.

Another point that requires emphasis is the need for
periodic recognition of efforts whenever it is justified.
Promotions and pay increases naturally are the most
tangible evidence of the management’s satisfaction
with the services rendered. At the higher levels these
raises become, of necessity, less frequent and in adverse
times salaries may even have to be reduced. It helps a
great deal to maintain morale if the staff member or
the worker is drawn into the company’s confidence, so
to speak, and told which way the wind is blowing for
him. To a very large extent, recognition is the life blood
on which sincere effort feeds, and often at the disregard
of monetary return. A word of praise, assignment of
greater responsibility, inclusion at staff conferences, or
the granting of special privileges will do much to make
the worker feel that he is a trusted member of the family
and that the success of the whole depends on his efforts.
A sincere interest should be taken in his personal affairs
when adversity may put an unusual strain on his
shoulders.

It is very unfortunate that the smooth operation of a
large organization requires many routines which reduce
the individual worker to a number which is handled
efficiently by a business machine. This necessary evil
should be counteracted by decentralization and per-
sonal counsel wherever possible. Although information
and general directives are most conveniently distributed
by memoranda, an organization should be on its guard
against a not altogether rare disease which might be
called “memoranditis.” It thrives in all climates, dis-
regards age or sex, feeds on reams of paper, and inci-
dentally destroys the morale of the people affected by it.
It makes its appearance singly or in multiple copies. The
vicious kind feeds on arguments. To send such missiles
to the fellow next door, so to speak, is very poor tech-
nique. It is much better to talk things out than to
write them out. In some cases, arguments of a personal
kind have been carried into scientific publications. This
is very bad taste indeed and makes one question the
sincerity of the writer.

These loose-knit ideas on industrial relations, it is
hoped, will remind the reader of his broader responsi-
bilities toward the organization to which he belongs
and to society at large. The scientist and engineer have
now, in addition to their technical performance, the
task of interpreting their work to the public. This is
necessary in order to assure a sympathetic response to
their ever-expanding ideas and to preserve a favorable
climate in which to work, unobstructed by prejudice
and restrictions.
Moon Echoes and Transmission Through the Ionosphere

F. J. KERR†, SENIOR MEMBER, IRE, AND C. A. SHAIN†

Summary—Moon echoes at a frequency of about 20 Mc have been studied, mainly to obtain information on low-angle transmission through the ionosphere. Using a broadcast transmitter in its free time, with fixed aerial systems, thirty experiments were carried out in just over a year, echoes being received in twenty-four cases. Experimental results have been compared with those to be expected from an orthodox ray-theory treatment, and the following major discrepancies were found:

(1) Observed echo intensities were well below theoretical values.
(2) Minimum altitudes, at which echoes were first detected, were unexpectedly high.
(3) Ray deviations of several degrees in a vertical plane apparently occurred.

The anomalous values of echo intensities and minimum altitudes for detection correlate closely with the critical frequency of the F region, suggesting that the anomalies arose in that portion of the ionosphere. The cause may lie in departures from horizontal stratification in the F region, or in failure of the ray-theory treatment at very oblique incidence.

The received echoes showed two types of fading. One type was consistent with an ionospheric origin. The second has been shown to be due to the moon's libration, effective reflection taking place over a large proportion of the moon's surface. This, together with the elongation of short pulses on reflection, demonstrates that the moon is a "rough" reflector at this frequency.

I. INTRODUCTION

Information on the ionosphere has until recently been derived almost entirely from studies of radio waves reflected down again to earth. This method cannot give information about the region above the level of maximum ionization, so that little is yet known about this region.

The reception of solar and cosmic radio noise at the earth's surface has demonstrated that radio energy of sufficiently high frequency can penetrate the ionosphere, but several observers have reported anomalous effects (possibly arising in the ionosphere) at low angles of elevation. Further, the American group who made the first observations of radio reflections from the moon in 1946-47 found large variations and anomalies in the received echo intensity though no conclusions were reached as to whether these were atmospheric or lunar in origin. The use of solar emissions to study ionospheric transmission is handicapped by their great variability when the sun is active, and low intensity when it is quiet, especially at the low frequencies which are of greatest interest for an ionospheric study. A possible alternative is to work with radiation from discrete cosmic sources, but here again a severe limitation is imposed by the low intensity. Moon echoes are more suitable for the purpose, since the source of signal can be controlled, and the variations produced by reflection at the moon can be estimated with sufficient precision.

This paper describes moon-echo experiments carried out on a relatively low frequency, not far above that necessary for penetration of the ionosphere, with the particular object of investigating the structure of the upper part of the ionosphere. Transmissions were made from an Australian broadcasting station in its free time, and by the end of the investigation two receiving stations were operating in Australia, and three in America. The first results have been described in an earlier communication. Echoes were received on most occasions, but the echo intensity level and the time of appearance of echoes after moonrise departed from the expected values. An outline of the experimental results is given, followed by a theoretical discussion of the problems of reflection from the moon's surface and transmission through the ionosphere. The observations and theory are then compared in detail.

II. EXPERIMENTAL ARRANGEMENTS

A. Transmitter

Special transmissions were made from the high-frequency broadcasting station, Radio Australia, located at Shepparton, Victoria (36.3°S, 145.4°E). The transmitter (21.54 Mc, 70-kw output or 17.84 Mc, 50-kw output) was pulsed by landline signals from the Radiophysics Laboratory receiving station at Hornsby, New South Wales, 600 km away. The most frequently used signals were:

(a) A group of three 1/2-second pulses (used in searching for echoes, and for identification of weak echoes).

† In addition to the American work, moon echoes have been observed (at 120 Mc) by Z. Bay in Hungary, but no information on variations of echo intensity was obtained. ("Reflection of microwaves from the moon," *Hungarica Acta Physica*, vol. 1, pp. 1-22, 1946)

A single pulse, 2.2 seconds long (for studying short-period amplitude variations of the echo).

A group of pulses of length 1 millisecond and recurrence frequency 40 cps, extending over a total period of 2.2 seconds (for examining the fine structure of the received echo). These short pulses were generated at Shepparton, and controlled by landline signals.

The pulse group repetition period was 6 seconds in all cases. The time of travel of a radio wave to the moon and back is about 2.4 seconds. During some of the later tests, in which attempts were made to receive echoes in America, the timing of the emitted pulses was controlled to a small fraction of a second.

B. Receivers

A modified communications receiver was used at the main receiving point at Hornsby (33.7°S, 151.1°E). The intermediate-frequency bandwidth was normally 70 cps, but was increased to 1 kc during the limited work with millisecond pulses. In the early tests, using self-excited oscillators and regulated supplies, slight retuning was necessary every 10 to 15 minutes. Later, crystal-controlled local and beat frequency oscillators were introduced, giving an over-all frequency stability of about 1 cps over 30 seconds or 10 cps over 30 minutes. This stability was desired in studies of Doppler shifts and short-period fading. Another change carried out after the early tests was the addition of a filter, narrowing the "video" bandwidth to 6 cps with a consequent improvement of visual signal-to-noise ratio by $\sqrt{70/6}$ or 5 db.

The moon echoes were seen against a background of cosmic noise, which was large compared with receiver noise. The sensitivity of the system for the nearly monochromatic moon-echo radiation was therefore dependent primarily on the bandwidths of the filters used, and only to a small extent on the receiver noise factor. These bandwidths were measured by several different methods, and the results obtained were in good agreement.

The cosmic noise background varied with sidereal time and ionospheric conditions, but at the times of the various tests the noise power delivered to the receiver was always within 1.4 db of the value:

$$P_N = 2.4 \times 10^{-17} \text{ watt.}$$

(1)

The received signals were displayed on a long-persistence cathode-ray tube, with a 6-second time base, and photographed. (No great accuracy was sought in measuring the echo delay-time.) On such a display, the "minimum perceptible signal" is approximately equal to the root-mean-square value of the noise fluctuations. Echoes could also be detected aurally in a loudspeaker, and this method of detection was the more sensitive for weak echoes, by perhaps 2–3 db. The accuracy of estimation of the echo field intensities improved as the tests progressed, in consequence of the gradual improvement of the equipment used. The overall performance is believed to be known to within ±2 db, at least from July, 1948, onwards.

During the later tests, observations were also made at Rockbank, Victoria (37.8°S, 144.7°E), using the normal receivers of the station, with display and recording equipment similar to that at Hornsby. The over-all sensitivity of the receiving system was 3–4 db less at Rockbank than at Hornsby, mainly on account of the greater bandwidth.

C. Aerial Systems

The transmitting aerial at each frequency was that regularly used by Radio Australia for broadcast transmissions to the United States and Canada. Each aerial is a broadside array of sixteen elements, arranged in five tiers of horizontal radiators, and backed by a similar curtain of reflectors. The maximum of the beam is directed to 63° azimuth, 9° altitude, and the gain over an isotropic radiator is 20 db.

Reception at Hornsby was carried out on an array of two rhombic aerials, directed towards the region of the sky illuminated by the transmitting aerial. The directional diagram and gain of the receiving aerial were calculated by the methods given by Harper. A rough check on these results was obtained from comparisons of signals received on this aerial and on a half-wave dipole from suitable overseas stations. The main features of the diagram were confirmed and the gain shown to be within 1–2 db of the theoretical figure. The effective absorbing area in the maximum direction has been taken as 840 square meters, corresponding to a gain over an isotropic radiator of 17 db at 21.54 Mc. Possible uncertainty as to the reliability of the theoretical characteristics for low-angle reception arises from the situation of the receiving aerial, which is confronted by a ridge 600 yards away, at an elevation of about 5°. It is believed, however, that any effects due to this ridge would be much smaller than the anomalies actually found in echo intensity. This view is supported by the results on distant stations, mentioned above.

The composite directional diagram of the Shepparton-Hornsby system for an infinitely distant source is shown in contour form in Fig. 1, which is plotted in terms of azimuth and altitude at Shepparton. Lines of constant declination and hour angle are given in the same figure, so that the moon's track during each of the test periods can be determined, using the information presented later about the circumstances of each experiment. The approximate altitude of the moon at Hornsby and Rockbank may be obtained by adding +5° and −1.5°, respectively, to the corresponding value for Shepparton. This approximation is sufficiently accurate over the region of interest.

---


11 The diagram was a little different during the first seven tests.
The receiving aerial used at Rockbank was one of the normal rhombics of the station. Its gain over an isotropic radiator is 16 db at 21.54 Mc.

D. Operational Limitations

The working time of the system was severely limited. Initially, observations were restricted to the hours when no broadcasts were scheduled, namely 0230–0540 and 0930–1230, Eastern Australian Standard Time. The latter period was generally unsuitable, as the critical frequency of the $F_2$ region was normally too high to permit penetration of the ionosphere. Secondly, the moon passes through the aerial beam only on several successive days for two periods each month, and only some of these passages occur at an appropriate time of day.

III. General Results

A. Reception at Hornsby

Observations were made over a year on every day on which the circumstances were favorable in the

13 150° E time.

0230–0540 E.A.S.T. period, amounting to 28 days in all. Moon echoes were received at Hornsby on 22 of these days, for an average period of 30 minutes. (In addition, echoes were received on one day at Rockbank and not at Hornsby.) The less suitable 0930–1230 period was used only on two magnetically disturbed days, on one of which echoes were received.

Examples of the photographic records obtained are given in Figs. 2 and 3. The first illustrates the use of the group of three short pulses. At the start of the trace are the signals received directly from the transmitter, by $E$-region scatter, followed after about 2 1/2 seconds by the three echo pulses, generally unequal in amplitude.

Fig. 3 shows a series of three successive signals of the long pulse type (only the first of these is labelled in the figure). By this method a record of echo intensity is obtained over a series of 2.2-second periods, interrupted by breaks 3.8 seconds long. A longer sample is presented in Fig. 4. These records illustrate the type of fading observed. Smoothed intensity records for all the tests are given in Fig. 5, with the relevant data on the circumstances in each case. Two types of theoretical curve have been added for comparison. It can immediately be seen that the observed intensities were well below the levels expected theoretically, and also that the first appearance of echoes as the moon rose up through the aerial beam was always later than expected.

Fig. 2—Sample photographic record, illustrating the results obtained with the group of three short pulses.

Fig. 3—Three successive echoes obtained with 2.2-second signals, illustrating the rapid fading. The small fluctuations are due to cosmic noise, passed through an intermediate-frequency bandwidth of 70 cps and video bandwidth of 6 cps.
B. Reception at Rockbank

The moon echoes received at Rockbank displayed the same general characteristics as those received at Hornsby, i.e., they were deficient in intensity, the first reception was delayed, and they exhibited similar fading. These results are less reliable than those from Hornsby, as the receiver and display calibrations were not so well known. Also, in many of the observations the moon was passing through side-lobes, where the aerial performance was less certain.

Detailed comparisons between records made simultaneously at Hornsby and Rockbank are of value in relation to possible mechanisms for the short-period fading. Such a comparison, covering a period of 6 minutes, is shown in Fig. 4. The short-period variations are seen to be very different at the two receiving points.

\[ \text{HY} \]
\[ \text{RK} \]

0429 0430 0431 0432

\[ \text{HY} \]
\[ \text{RK} \]

0432 0433 0434 0435

Fig. 4—Simultaneous records of echo strength at Hornsby (HY) and Rockbank (RK), 0429-0435 E.A.S.T., October 29, 1948. The scales are linear in voltage, the Hornsby record being drawn to twice the scale of the Rockbank one.

C. Reception in America

During a visit to the United States early in 1948, J. L. Pawsey of this Laboratory arranged co-operation with American organizations in an attempt to receive moon echoes simultaneously at widely separated points on the earth. Receivers were operated in America, in the fifteen tests from July 30 onwards, at the following places:

3. Urbana, Ill. (University of Illinois).

This work did not meet with a great deal of success, as the times of the tests (limited by transmitter availability) were all in the middle of the day at these receiving points, so that $F_2$ critical frequencies were quite...
Echoes were received in America, however, on two occasions, August 1 and October 28, although only for short periods in each case.

IV. Theoretical Considerations

A. The Radar Equation

For simplicity it will first be assumed that all of the medium between the surfaces of the earth and the moon is nondeviating and nonabsorbing. This is believed to be very nearly true, except in the ionosphere, whose effect will be discussed later. Effects due to ground reflection and feeder losses have been included in the parameters describing aerial performance. (Numerical values given in this and the next subsection apply to reception at Hornsby.) Let

\[ P_T = \text{transmitter power output} = 70 \text{ kw} \]
\[ G_T = \text{transmitting aerial gain, relative to isotropic radiator} = 100 \]
\[ A_R = \text{absorption cross section of receiving aerial} = 840 \text{ (meter)}^2 \]
\[ d = \text{mean distance of moon from earth} = 3.84 \times 10^8 \text{ meter} \]
\[ \sigma = \text{echo cross section of moon, defined by equation (3) below.} \]

The flux density at the moon (power flow per unit area in the transmitted wave) is given by

\[ S_M = \frac{P_T G_T}{4\pi d^2} \]  \hspace{1cm} (2)

the scattered wave intensity at the receiving aerial by

\[ S_B = \frac{\sigma S_M}{4\pi d^2} \]  \hspace{1cm} (3)

\[ = 2.0 \times 10^{-20} \times \sigma \text{ watt (meter)}^{-2} \]  \hspace{1cm} (4)

and the power delivered by the aerial to the receiver by

\[ P_R = A_R S_B \]  \hspace{1cm} (5)

\[ = 1.7 \times 10^{-21} \times \sigma \text{ watt.} \]  \hspace{1cm} (6)

B. Reflection from the Moon—Long Pulses

The case where the pulse-length is large compared with the time of propagation across the moon’s depth will first be discussed. After a short build-up period in which the pulse front is spreading over the moon, the whole “illuminated” hemisphere of the moon will be contributing to the received echo. Two limiting types of reflection will be considered, corresponding to the cases of a perfectly smooth and a perfectly rough spherical surface.

Visual inspection indicates that the moon’s surface is at least to some degree rough, but this does not necessarily rule out the possibility of the moon’s reflecting radio waves as a smooth sphere. For example, reflection could conceivably take place from a region corresponding to the earth’s ionosphere. The present observational lower limit to the density of the moon’s atmosphere does not preclude this possibility.

Echoes from a smooth and a rough moon will differ in three ways, namely, (1) intensity, (2) fading characteristics, and (3) shape of echo pulse.

The two cases cannot be readily differentiated from the intensity measurements made, since other intensity anomalies were so large. The experimental determination of the type of reflecting surface has been based on a study of the fading, with confirmation from the limited work on the shape of short pulse echoes.

For a smooth, perfectly-reflecting sphere, whose radius is large compared with the wavelength, the incident energy is scattered uniformly in all directions, and the echo cross section is equal to the projected area of the sphere.\(^{14}\) When the sphere is partially absorbing, as the moon presumably is, the echo cross section will be nearly equal to the product of the projected area \((A)\) and the reflection coefficient for normal incidence \((\rho)\):

\[ \sigma \approx A \rho. \]  \hspace{1cm} (7)

The moon’s surface is believed to consist of rock, with a thin covering of meteoric dust. By analogy with terrestrial conditions, the dielectric constant of the surface material is probably about 5, leading to a power reflection coefficient of 0.15 for normal incidence. Little can be said about the reflection coefficient of a hypothetical lunar ionosphere.

In the alternative case of a large, perfectly rough body, the scattering is no longer isotropic, and the echo cross section will now be given approximately by:

\[ \sigma = A \rho D, \]  \hspace{1cm} (8)

where \(D\) = directivity of the scattered energy in the direction of the receiver.

To a first approximation, the echo from a rough moon can be taken as made up of specularly reflected components from elementary surfaces normal to the incident radiation. Thus all back scattering occurs at normal incidence, and so the corresponding reflection coefficient \((0.15)\) can be used.

Two types of scattering from rough surfaces are discussed in the literature. The first follows Lambert’s cosine law, which states that the energy scattered into any direction from a rough surface is proportional to the cosine of the angle between the incident ray and the normal to the surface, and to the cosine of the angle between the scattered ray and the normal. This effect, when integrated over a sphere, gives a directivity in the echoing direction of \(8/3\).\(^{15}\)

The second type involves an additional factor, well-known in planetary astronomy, which further increases the directivity. In regions towards the limb of the sphere, each “hill” shadows an area behind it, reducing the effective illuminated area capable of reflection to


directions away from the incident direction. The optical directivity of the moon to sunlight is 5.7. (This figure is derived from published data on the variation of apparent illumination with astronomical phase.\textsuperscript{14}) The corresponding figure for radio reflection would be less, if the surface irregularities are small, owing to the smaller apparent roughness of a surface for the longer wavelength. The 20-Mc directivity of a rough moon will be taken as 5. The uncertainty involved here is much smaller than the observed anomalies in echo intensity.

Theoretical performance figures can now be specified for the two types of lunar surface, with the moon at the maximum of the aerial diagram, and with ionospheric effects neglected, as shown in Table I.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|}
\hline
 & Smooth Moon & Rough Moon \\
\hline
Projected area, $A$ (square meter) & $9.6 \times 10^{12}$ & $9.6 \times 10^{12}$ \\
Echo cross section, $\sigma$ (square meter) & $6.4 \times 10^{-4}$ & $7 \times 10^{-4}$ \\
Echo flux density at the receiving aerial, $S_0$ (watts per square meter) & $3.0 \times 10^{-14}$ & $15 \times 10^{-18}$ \\
Echo power delivered to receiver, $P_R$ (watts) & $2.4 \times 10^{-12}$ & $12 \times 10^{-16}$ \\
Echo-to-noise ratio, pre-detection (db) & 20 & 27 \\
Echo-to-noise ratio post-detection (db) & 25 & 32 \\
\hline
\end{tabular}
\caption{Table I}
\end{table}

C. Reflection From the Moon—Short Pulses

When the pulse is short compared with the time taken to cover a distance equal to twice the moon’s radius (11.6 millisecond) only a small portion of the moon will be contributing to the received echo at any given instant. Under these conditions, a considerable difference exists between the behavior of a smooth and a rough sphere.

In the case of the smooth moon, even when it is completely illuminated by the pulse, the echo will come essentially from the first Fresnel zone, i.e., from a slice of the nearest portion of the moon with a radial thickness equal to a quarter wavelength. The contributions of other zones will nearly cancel one another, the net effect being a total field intensity of half that to be expected from the first zone alone.

Since the pulse-length must necessarily be greater than the time associated with the first Fresnel zone, the shortening of the pulse below the dimensions of the moon will have little effect on the echo intensity. Thus the peak intensity of the echo pulse would be nearly the same for short pulses (e.g., 1 millisecond) as for long pulses (e.g., 2.2 seconds). The duration of the echo pulse and hence its total energy would however be different in the two cases, with a consequent worsening of the signal-to-noise ratio for the short pulses, associated with the use of a greater receiver bandwidth.

In the case of a rough sphere reflecting short pulses, the echo pulse will have a long duration, corresponding to the passage of the pulse across the moon, but the instantaneous intensity will be well below that for the long pulses, as only a small portion of the moon’s surface will be contributing to the echo at any instant. The shape of the echo pulse will be related to the distribution of radar “brightness” across the moon’s disk. For Lambert-type scattering, the brightness would fall off from the center to the edges, according to a cosine relationship. The corresponding theoretical echo pulse-shape for a 1-millisecond incident pulse is shown in Fig. 6(b).

A different distribution of brightness would be obtained when the shadowing effect of the surface irregularities is taken into account. The increased echo directivity in this case, which was mentioned before, arises because a greater proportion of the energy falling towards the edges of the disk is scattered back in the incident direction. Thus there is an increase in the radar brightness at the outer portions of the disk, approaching more closely to the Lommel-Seeliger type scattering, which produces uniform brightness. Markov\textsuperscript{17} has in fact found that the distribution of optical luminosity over the disk at full moon is nearly uniform, except for an anomalous increase for a region near the outer circumference of the disk. The theoretical echo pulse-shape for this type of scattering is given in Fig. 6(c).

The unit of echo power in this figure is that for a smooth moon and long pulses. The scales of the curves for a rough moon have been adjusted so that the area beneath each curve is proportional to the corresponding directivity. Thus the three curves are directly comparable. It should be remembered that these shapes apply to the echo pulse entering the receiver, whose finite bandwidth will produce some distortion in the output pulse.

D. Libration of the Moon

If the moon reflects as a rough object, with the whole disk contributing to the returned echo, the moon’s libration would be expected to produce variations in the


echo about the root-mean-square value derived above. Libration, an apparent oscillation of the moon’s face as seen from a point on the earth, arises from the diurnal rotation of the observer on the earth and from variations in the moon’s orbit. It amounts to several degrees per day. A libration of $L^\circ$ per day corresponds to a linear velocity at a point on the moon’s limb of 0.4 $L$ m/sec, or to a Doppler frequency shift on reflection of $0.05 L$ cps for a 20-Mc wave. The returned echo will thus extend over a frequency band of finite width, and since the various frequency components are in a random phase relationship, their resultant will be continuously varying, giving the effect of fading.

The expected frequency spectrum can be derived by dividing the moon’s projected disk into narrow strips parallel to the axis of libration. Each point of such a strip can be shown to have the same linear velocity towards the earth. This velocity and hence the frequency shift is found to be proportional to the distance of the strip from the axis (Fig. 7(a)).

Fig. 7—(a) Effect of the moon’s libration ($L^\circ$/day). The strip shown produces a frequency displaced $|f| 	imes 0.05 L$ cps from the center frequency. (b) Frequency spectrum of echo, assuming uniform brightness across the moon’s disk, together with the closest-fitting Gaussian distribution.

On the assumption of uniform brightness across the moon’s disk (Subsection IV, C), the amount of energy reflected back from an elementary strip is proportional to its area. Hence the power spectrum curve is semi-circular in form, i.e.:

$$W(f) = \sqrt{1 - \left(\frac{f}{0.05 L}\right)^2}$$

where $f$ is frequency deviation from center frequency.

To test the dependence of the fading speed on the libration rate, it is convenient to represent the former, for a given sample of record, by the mean change of amplitude (regardless of sign) occurring in equal intervals of time, expressed in terms of the mean amplitude for the period.

The relevant theory, for a Gaussian power spectrum, has been worked out by Furth and MacDonald. Their results can be applied with sufficient accuracy by substituting the best-fitting Gaussian distribution (standard deviation = 0.03 $L$ cps) for the semicircular power spectrum. The semicircular and Gaussian curves are compared in Fig. 7(b). The theoretically-expected relation between fading speed and libration rate is shown in Fig. 8 (full line).

Fig. 8—Relation between speed of rapid fading and libration rate. The full line is the theoretical curve, while the crosses indicate experimental points for six days.

E. Transmission Through the Ionosphere

Before discussing the experimental results on transmission through the ionosphere, a theoretical treatment of the transmission problem will be developed along orthodox lines, neglecting the earth’s magnetic field. All but two of the tests took place at nighttime, so that absorption or deviation effects arising in the normal $D$ and $E$ layers may be neglected, leaving only the $F$ and sporadic $E(E_s)$ regions to be considered. The absorption and scattering produced by a cloud-like $E$ region is likely to have been small, since the experience of long-distance communication circuits suggests that they are very little influenced by $E_s$, under conditions in which a strong component coming down from the $F$ region is present.

The properties of rays incident obliquely on the $F$ region and returned to earth again have been studied in detail by several authors, including Appleton and Beynon, who are mainly concerned with the derivation of “maximum usable frequencies” (mu). For our purpose this work indicates a minimum angle of incidence below which energy cannot be reflected back to earth again, but will penetrate the ionosphere. The only published studies of the transmission problem itself are those of Bailey and Bremmer. Bailey treats only the

“ionospheric refraction,” or the deviation produced in a ray passing through the ionosphere, and in doing so introduces approximations which are not valid near the critical conditions. Bremmer shows that if a plane wave enters the ionosphere from outside it emerges as a divergent wave, so that the flux density incident on the earth will be less than that in the original plane wave. He studies the reduction in flux density due to this cause and to absorption, in passing through the F region, and shows that the former cause is dominant at sufficiently oblique incidence. His results as they stand are not accurate enough for low angles of elevation over a curved earth, and his treatment must be extended as follows:

![Fig. 9—Trajectory of ray through ionosphere.](image)

Bremmer applies Snell’s law to determine the trajectory of a ray through the ionosphere (see Fig. 9), and obtains an expression for the divergence produced by the ionosphere in a plane wave coming from outside the earth. This is

$$\frac{E}{E_0} = \sqrt{\frac{\sin i}{\sin \theta}} di, \tag{10}$$

where

$$\theta = \text{zenith angle of the extra-terrestrial source at the ionosphere}$$

$$i = \text{angle of emergence of ray from ionosphere}.$$

This expression can be computed for an assumed distribution of refractive index in the ionized region. Bremmer then discusses the case of a single parabolic layer, neglecting curvature, and presents some typical numerical results.

Curvature can be taken into account by means of a device used by Appleton and Beynon. They replace the curved earth case by an equivalent plane earth case in which the critical frequency $f_0$ is reduced to

$$f_0^2 = f_0^2 y_m,$$

where

$$f = \text{wave frequency}$$

$$y_m = \text{semithickness of the assumed parabolic region}$$

$$R = \text{earth’s radius}.$$

Use of this equivalence device in Bremmer’s expression for a parabolic layer yields the relation between the angles $i$ and $\theta$ for a curved parabolic region, and then by means of (10) the distribution of field intensity. The angle of arrival of the ray at the ground ($\theta$) for a given angle of emergence and layer height, and the corresponding altitude of the source at the ground ($\alpha$) can then be found by geometrical methods.

The field intensity according to this theory is given in Fig. 10 as a function of altitude for a number of values of the ratio of wave frequency to critical frequency, togethers with the theoretical relation between the angle of arrival and the (geometrical) altitude. The angle of arrival is always greater than the altitude, in consequence of ionospheric refraction. In fact, significant field strengths should be obtained in many cases with the source well below the horizon. The angle of arrival at the earth and angle of emergence from the ionosphere both have limiting values, corresponding to the critical ray found fridfrom mud considerations.

![Fig. 10—One-way transmission through F-region (ray theory). (a) Intensity against geometrical altitude. (b) Angle of arrival against geometrical altitude. The full-line curves are for $f/f_0 = 2$, 3, 4, 5, 6, semithickness = 100 km and the dashed-line curves for $f/f_0 = 3$, height = 250 km, semithickness = 50, 150 km.](image)

These curves are all for one-way transmission. In deriving theoretical curves for the conditions of the various moon-echo tests, two such curves must be combined, taking into account the different moon altitudes at transmitter and receiver. Curves obtained in this way are included in Fig. 5 for comparison with the observed echo intensities. The finite angular size ($\frac{1}{2}$) of a rough moon would produce a slight smoothing of the curves, but this is negligible compared with the observed anomalies.

V. FADING OF ECHOES AND EFFECTS DUE TO THE MOON (EXPERIMENTAL RESULTS)

A. Types of Fading

The fading of the echoes appeared to be of three main types:

- **Amplitude Fading**
- **Phase Fading**
- **Correlation Fading**
(1) Short-period fading over times of the order of seconds.
(2) Variations with periods of the order of minutes.
(3) Variations of the median intensity level from test to test.

Spaced receiver experiments were undertaken as part of the study of the various types of intensity variations. Very little was learned from the simultaneous reception in Australia and America, owing to the unsuitable ionospheric conditions at the American end. Some useful results were obtained, however, from comparisons of the records from Hornsby and Rockbank, 750 km apart.

The day-to-day variations were closely correlated at the two places, but the faster variations of types (1) and (2) showed no such correlation, although the qualitative similarity of the phenomena at the two places was established. This lack of correlation is consistent with the variations originating either in local ionospheric irregularities above the respective receiving sites, or in the moon's libration.\(^{25}\)

B. Rapid Variations

The rapid variations of type (1) occurred in times of the order of seconds. Since these records were taken after the signals had been passed through a 6-cps low-pass filter, the possibility arises that echo fluctuations of an even more rapid type might have been smoothed out by the filter. The absence of significant frequency components above about 2 cps could however be deduced from the characteristics of the audible echo signal, on which the 6 cps filter did not operate. This conclusion was drawn from the fact that the echo signal gave an impression to the ear of a pure tone\(^{26}\) (except during some deep fades), and was confirmed by a subsequent study of sound recordings.

It was shown in Subsection IV, D that, if the moon reflects as a rough object, libration would be expected to give rise to fading of echoes. To see whether the rapid fading observed was due to libration, the speed of fading has been compared with the rate of libration for portions of the records on six days. The experimental points of Fig. 8 indicate very good agreement with the theoretical curve for a rough moon, within the experimental uncertainty.

We can therefore conclude that the moon's surface acted as a rough reflector and that the rapid fading observed was due to the effects of libration.

C. Reflection of Millisecond Pulses

Additional evidence on the moon's reflecting properties was obtained by the use of short (1-millisecond) pulses. These experiments were disappointing however, owing to the low echo intensities received. When working with short pulses, a larger receiver bandwidth (1 kc) had to be used. This reduced the sensitivity of the system, raising the threshold to a level which was seldom exceeded by the echo. A moderately clear short-pulse echo pattern was seen on one occasion for about two minutes, but was not photographed successfully, owing to a technical fault. Visual observation showed that the echo pulse was elongated to several times the length of the transmitted pulse, which was in keeping with the hypothesis of a rough moon (see Fig. 6). Thus there are two results indicating that the moon reflected as a rough sphere. In neither case, however, was the accuracy sufficient to distinguish between the Lambert and Lommel-Seeliger types of scattering.

D. Slow Variations

The slow variations of type (2) cannot be due to libration, since it can be shown that, for a fading period of several seconds, medians taken over one or more minutes would seldom depart from the over-all median by more than 1-2 db. Thus another mechanism must be sought to account for this type of fading.

A study of the time intervals between successive maxima (of 1-minute medians) has shown that their frequency distribution was close to that which would be given by a random phenomenon. It is probable that this type of fading was due to the effects of ionospheric roughness.

Ratcliffe\(^{27}\) has studied the fading obtained on a "single" component reflected from the ionosphere, and attributes it to the beating between elementary waves of slightly different frequencies, scattered from irregularities in continual random motion relative to one another.

The speed of fading is then a function of the random velocities of the scattering centers. Ratcliffe quotes an analysis by S. N. Mitra of the fading of a 4-Mc signal reflected from the F region, leading to a value of 5 meters per second for the root-mean-square velocity of the scattering centers.

Similar effects must arise in transmission through an irregular region. These are referred to, but not studied quantitatively, by Ratcliffe. In the transmission case we imagine the irregularities of the region producing deviation of rays, fading of the resultant occurring as the motion of the scattering centers causes the paths of the various rays to change.

For the case of a center moving at 5 meters per second perpendicular to the wave direction, at a distance of 1,000 km from the receiver, it can be shown that the path length of a ray would be changed by a half-wavelength in a time of the order of several minutes. Thus the observed speed of the slow fading is consistent with an ionospheric origin.


\(^{26}\) Fading due to libration would be essentially similar only for receiver spacings up to several kilometers, since the phase addition of the various components reflected from a rough body as large as the moon is very sensitive to direction.

Neither the ionospheric effect discussed in this subsection nor the moon's libration can account for the day-to-day intensity variations, for which a new mechanism must be sought.

VI. EXPERIMENTAL EVIDENCE ON IONOSPHERIC ANOMALIES

A. Evidence for Vertical Plane Deviation

Examination of Fig. 5 shows that on many occasions the observed intensity decreased more rapidly in the latter part of the test than does the corresponding theoretical curve. This can be interpreted as an indication that the angle of arrival was significantly greater than the geometrical altitude, rendering the steep portion of the aerial diagram operative at lower altitudes.

After reploting the results in a form more suitable for showing up the effect, the results were found to be consistent with a vertical deviation of 5° for an altitude (Sheppardton) of 5°, decreasing to 1°–2° for an altitude of 25°. Evidence of vertical deviation of the same order of magnitude was also obtained from a study of the positions of the minima in the Rockbank curves.

An interesting exception to the general occurrence of large vertical deviation seems to have occurred on March 14, 1948. On this occasion, echoes were detected at a moon altitude 3° greater than the next highest over the whole series of experiments. The unusual feature of this particular test was the presence of a severe ionospheric disturbance, in which f₀F₂ was reduced from the normal 11 to 7 Mc and the equivalent height recorded at Canberra was 450–500 km. The observed behavior is suggestive of the "holes in the ionosphere" description of the disturbed F region, given by Eckersley,18 the wave received at 22° being undeviated because it passed through a hole in the region.

B. Correlation of Median Intensities with Vertical Incidence Data

The main features of the smoothed experimental results which cannot be accounted for on previous knowledge are the low echo intensities obtained and the lateness of the first detection of echoes from the rising moon. It has been shown above that libration could not account for long-period intensity variations. In both the anomalies, it seems more likely that a cause could be found in the ionosphere than at the moon. An attempt will therefore be made to establish a correlation with some ionospheric parameter.

The points at which the two rays Shepparton—moon and moon—Hornsby penetrated the F₂ and E regions can be determined approximately for any given time during the tests, from the azimuth and altitude of the moon and the height of the layer concerned. Vertical-incidence ionospheric data were available at 10-minute intervals for most of the test periods from the stations at Brisbane (27.5°S, 153.0°E) and Canberra (35.3°S, 149.0°E). Corresponding values for the estimated penetration points have been obtained by interpolation in both latitude and local time.

The first quantity to be compared with ionospheric data is a median intensity level for each of the tests. To bring all the medians to the same absolute basis, an attempt has been made to take the effect of the aerial directional diagram into account. This can only be done approximately, since the amount of deviation in the ionosphere, and hence the angles of emission and arrival, are not precisely known. To minimize the errors arising in this way, a restricted period of only 20 minutes was used in obtaining each median. A period near the time of optimum aerial performance, but not too near the time of first detection of echoes, was chosen in each case. This is the time when the aerial correction factor shows the smallest rate of change, so that a given vertical plane deviation will then have the smallest effect.

Fig. 11 shows a correlation diagram between the median intensity and the ratio of operating frequency to f₀F₂. The comparison covers all days for which reliable 20-minute medians could be obtained, excluding tests in which the moon was too far to the side of the aerial diagram, or the calibrations were uncertain. The figure contains points corresponding to the two receiving sites, Hornsby and Rockbank, with dashed lines joining points referring to the same day.

![Fig. 11—Relation between median echo intensity and f₀F₂.](image)

In each case, the value for f₀F₂ is that obtained for the estimated penetration point of the lower-altitude ray at about the middle of the 20-minute period (i.e., the Shepparton ray for reception at Hornsby, and the Rockbank ray for reception at Rockbank). The conditions for this ray have been regarded as the more significant in limiting penetration, in spite of small differences in the critical frequencies appropriate to the two rays, which generally had an opposing effect.

This correlation diagram establishes that quite a close relationship exists between median echo intensity and $f^o_{F_2}$, and suggests that an important part, if not all, of the deficiency in echo intensity is due to $F$ region effects. (The magnitude of this deficiency can be seen by comparison with the theoretical curve of Fig. 11 which is derived from the ray treatment of Subsection IV, $E$, for altitudes corresponding to those of the experimental points.)

A similar check has been carried out against $E_2$ data, although this comparison is less valid, since derivation of the ionospheric parameters for the penetration points from the observations at Brisbane and Canberra is not very satisfactory for a patchy layer such as $E_2$. With this limitation, the comparison showed no correlation between median intensity and $f_{E_2}$.

C. Limiting Penetration Conditions

The second anomaly in the experimental results was the lateness of the first detection of echoes. Fig. 12 shows a correlation diagram of the moon altitude (the lower of the pair of values) at which echoes were first detected, against the ratio $f/f^o_{F_2}$, omitting only those cases in which low angle conditions were unfavorable through considerations of aerial diagram or observing time. Theoretical curves have been added for comparison, for a symmetrical parabolic $F_2$ region with three values of semithickness. (During most of the tests, the semithickness was about 100 km.)

![Diagram](image)

Fig. 12—Relation between altitude at first detection and $f^o_{F_2}$ for the lower of the two rays. The full lines are theoretical curves, derived from the ray-theory treatment of Subsection IV, $E$, for a symmetrical parabolic $F_2$ region of height 250 km and semithickness 50, 100, 150 km, with account being taken of the aerial diagram.

Once again the experimental points are well away from the theoretical curve, but show a fairly close correlation with $f^o_{F_2}$. Also, as with the median intensities, no correlation could be found with $f_{E_2}$.

A possible interpretation of the diagram is that a simple relation exists between altitude of appearance and critical frequency for the lower values of $f/f^o_{F_2}$, which are associated with high limiting altitudes. Then, when the critical frequency falls to a low value, such that $f/f^o_{F_2} = 4$, a new factor becomes important and prevents the observation of correspondingly low values of limiting altitude. Such a factor could be introduced, for example, by $E_a$ ionization, or by inadequacies in a ray treatment. Reference to Fig. 11 indicates that the diagram of median intensities could be interpreted in a similar way, with the same group of points occupying an anomalous position away from a smooth curve that can be drawn through the rest of the points and up to meet the zero line.

The curves of Fig. 5 show that there is a large difference between the expected and actual altitudes of first detection, amounting to 10° or more. Greater interest however attaches to a comparison between the theoretical and experimental limiting angles of incidence on the $F_2$ region. Since the latter are not precisely known, all that can be done is to obtain a lower limit to the difference between these angles, corresponding to the case of no deviation. Using a method similar to that described in the earlier paper, this difference has been found to average about 3°. (This corresponds to the lower-altitude ray, in each case.) The actual anomaly between the theoretical and experimental limiting angles of incidence would then exceed this 3° figure by an amount corresponding to the deviation, i.e., by several degrees. Thus the total anomaly is quite large.

It should be pointed out that the difficulty in receiving echoes at low altitudes was not due to the lowered solar efficiency at these altitudes. The occurrence of vertical deviation means that the angle of emission of the ray would be up near the maximum of the aerial diagram well before echoes were in fact received.

In the earlier paper, some results of observations on 18-Mc solar noise were quoted, in which reception of noise bursts appeared to be possible with the sun’s altitude below the theoretical “shadow angle,” contrary to the moon echo results. The theoretical results of Subsection IV, $E$ indicate that the cutoff at the $F$ region is far from sharp, as the source altitude varies. Hence the apparent difference between the solar noise and moon-echo results is probably due to the greater intensity range of solar noise bursts, and not to any difference between the two directions of transmission through the ionosphere.

A comparison between the two directions of transmission is obtainable from the results at Hornsby and Rockbank. In the former case the transmitted ray has the lower altitude, in the latter the received ray. Comparison of the altitudes of first detection at the two places gave differences with a median value of 4.8°. This is nearly equal to the 5° which would be expected if the lower altitude ray were the limiting factor in each case, and $f^o_{F_2}$ were constant over the region of interest.

The tests represented in Figs. 11 and 12 are a little different, as the choice of suitable days for the two diagrams was based on different criteria.

If $a^o$ is the limiting altitude, echoes would appear at Hornsby for a Shepparton moon altitude of $a^o$, i.e., $(a+5)^o$ at Hornsby, and would appear at Rockbank at an altitude there of $a^o$. 

29 The tests represented in Figs. 11 and 12 are a little different, as the choice of suitable days for the two diagrams was based on different criteria.

29 If $a^o$ is the limiting altitude, echoes would appear at Hornsby for a Shepparton moon altitude of $a^o$, i.e., $(a+5)^o$ at Hornsby, and would appear at Rockbank at an altitude there of $a^o$. 

29 The tests represented in Figs. 11 and 12 are a little different, as the choice of suitable days for the two diagrams was based on different criteria.
D. Possible Interpretations

The general conclusion to be drawn from these low-frequency moon-echo experiments is that transmission of radio waves through the ionosphere is more difficult than had been expected on theoretical grounds, at least at low angles. Similar results were obtained by the American group, who studied moon echoes at 111.5 Mc. They report: "Frequently, even with the equipment to all appearances in satisfactory working order, no echoes are observed," whereas on other occasions echoes of 20 db above noise were received. The day-to-day variations reported by these workers appear to be of the same type as those observed in the present investigation, and so were presumably also of ionospheric origin.

In keeping with these results is the growing evidence that satisfactory long-distance communication can often be maintained on frequencies considerably in excess of the maximum usable frequency (muf) predicted from vertical incidence data. Thus, energy is being returned to earth by the ionosphere under conditions in which penetration would have been expected.

Green and Harrison have recently reported an improvement in their muf predictions, obtained by using an empirical correction factor. A simple increase of the muf factor in this way, however, is not sufficient to account for the moon-echo anomalies, particularly in the case of the 111.5-Mc results.

Smith-Rose attributes most muf anomalies to reflection from E, ionization. Additional evidence on the part played by E, in oblique-incidence transmission is obtained from the results of Appleton, Beynon, and Piggott. They describe experiments showing that amplitude variations of an F-layer first-order echo received at a distance of 685 km are due at least in part to absorption in the passage through the E, region. Furthermore, any deviation occurring in E, would be in the same direction as was observed in the moon-echo work, and could also help to account for the muf anomalies, in that E, deviation would increase the obliquity of incidence on F, and hence increase the muf.

However, the correlation of both moon-echo anomalies and muf forecasting errors with muf seem to indicate that E, and not E, is the important region. The authors consider the most likely explanation for the anomalous effects observed in both moon echoes and muf's would be found in an ionization distribution in the F, region very different from the symmetrical parabolic model usually assumed.

The theory shows that greater divergence and vertical deviation would be obtained from thinner layers (i.e., higher ionization gradients). The shape of the upper portion of the F region is unknown, but the ionization gradient there is physically more likely to be smaller than that of the lower portion. Also, a lower limit to the total thickness of the F region is imposed by the known thickness up to the level of maximum ionization. Extension of the hypothetical treatment of Subsection IV, E also indicates that a "G layer" above the F region, with a lower maximum ion density, could not account for the moon-echo anomalies, unless it were very thin, which is physically unlikely at such great heights. Moreover, it could have no effect at all on muf.

Other experimental evidence that F-region refraction is unexpectedly large has been obtained by Payne-Scott and McCready. With receiving equipment on a cliff-top, they observed 60-Mc radiation from the sun as it rose over the sea. Using an interference technique, they determined the apparent direction of the source, in relation to the corresponding direction for 200 Mc, which was assumed to be unaffected by the ionosphere.

Deviations of 25 to 55 minutes of arc were obtained, compared with the 12 to 13 minutes calculated from the formula derived by Bailey for a symmetrical parabolic F layer. A reexamination of these results shows that the deviation was too great, and its variation with altitude too rapid, to be accounted for by either a non-symmetrical F layer or a G layer.

A model involving horizontal irregularities seems more promising. There is increasing evidence that F, ionization is not homogeneous. Types of irregularities observed include the roughnesses studied by Ratcliffe, and the pressure movements observed by Munro. If the region were sufficiently uninhomogeneous, the secant relation between vertical and oblique incidence propagation would no longer be applicable. Increased divergence attenuation would be expected in oblique transmission, and increased vertical deviation would also be obtained, in the sense observed in both the moon-echo and solar noise work.

The other possible interpretation is that the discrepancies between theory and experiment are due to failure of the ray-theory treatment at very oblique incidence.

VII. Conclusions

The main experimental results from the 21.54-Mc study of moon echoes were:

(a) Echo intensities were lower than the theoretically expected values.

(b) Minimum altitudes, at which echoes were first detected, were unexpectedly high.

(c) The anomalous values of echo intensities and minimum altitudes for detection correlate with muf.
(d) The slow fading was consistent with an ionospheric origin.

(e) The fast fading (order of seconds) was associated with the moon's libration.

(f) Millisecond pulses were elongated on reflection from the moon.

(g) Ray deviations of several degrees in a vertical plane apparently occurred.

From these results it may be deduced that:

(a) The observations are inconsistent with an orthodox ray theory of transmission through a horizontally stratified ionosphere, and the discrepancies are probably due to the effect of irregularities in the $F_2$ region, or to inadequacies in the ray-theory treatment.

(b) The moon is a "rough" reflector at this frequency, and hence presumably at all higher frequencies.

Some General Properties of Magnetic Amplifiers

J. M. MANLEY†

Summary—The magnetic amplifier is discussed in general terms as a carrier system in which there is a modulation gain and a small demodulation loss. Relations are given which show how a magnetic modulator may exhibit a gain.

Some results of calculation and measurement on the type of circuit in which the modulator output consists of the even harmonics of the carrier source for dc signal input are given. It is shown that the ratio of dc gain to response rise time is a constant depending only on the carrier frequency, the losses in the nonlinear core, and its nonlinearity. The conditions for self-oscillation at the carrier even harmonics are also given.

In the course of some work on telegraph repeaters done in the Bell Telephone Laboratories, Inc., a number of years ago, some of the basic properties of magnetic amplifiers were derived. Because of the current interest in this subject, it was thought desirable to publish some of these results. First a general picture of the operation of a magnetic amplifier circuit will be given, then some of the quantitative results of analysis and experiment will be described.

General Picture of Magnetic Amplifier

The magnetic amplifier may be thought of as a complete carrier system having considerable modulating gain and only a small demodulating loss. The output of the magnetic modulator is connected directly to an efficient resistance demodulator input instead of through the usual intervening long transmission line. The carrier source supplies the energy required for amplification as the plate battery does in a vacuum-tube amplifier. A schematic is shown in Fig. 1. The signal input must contain a dc component in order that satisfactory recovery of the signal from the demodulator may be made. In some applications, the demodulator is not used.

![Fig. 1—A magnetic amplifier pictured as a carrier system.](image)

In an ideal magnetic modulator, a modulating gain is possible because the side frequency power is drawn in unequal amounts from the signal generator and the carrier generator. In fact, the ratio of power taken from the carrier source to that taken from the signal source is always as great or greater than the ratio of their respective frequencies if no losses are considered. An important factor in this is the fact that the voltage induced in a winding by varying magnetic flux is proportional to the frequency involved. Another important factor is the $90^\circ$ phase shift between this voltage and the corresponding flux. Thus, in magnetic modulation when the ratio of carrier to signal frequency is fairly high, it is possible for a small amount of power from the signal circuit to cause a large amount of power to be taken from the carrier source and converted into power at the side frequencies. The interchange of energy between the

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various frequencies brought about by the modulation is described in more detail below. On the other hand, it is impossible, in general, to get a modulating gain with a two-terminal resistance modulator, providing its voltage-current characteristic has a positive slope. The voltage across such a device is in phase with the current and their ratio is independent of frequency in the ideal case.

In an actual magnetic modulator, there are two additional sources of energy absorption in the signal input circuit. One of these is the loss in the magnetic core. This loss increases with frequency, being zero at zero frequency. The other is the loss in the resistance of the signal input winding. This, of course, is not zero at zero frequency and is the only one of the three losses which is effective in determining the de gain.

Another factor which affects the gain, even of the ideal magnetic modulator, is the inductance of the signal input winding. This inductance, together with the three input losses described above, may be thought of as limiting the bandwidth or rise time of the amplifier response. Ordinarily, the magnetic modulator gain is highest at zero input frequency unless there is positive feedback over a limited frequency band. As will be seen below, the dc gain is roughly proportional to rise time of the response and to the carrier frequency.

An ideal magnetic amplifier is effective at any frequency. Limitations on values of frequency which can be used in a practical magnetic amplifier may arise from consideration of the carrier source and from the fact of core losses. If the carrier frequency is such as to require vacuum tubes for the generation of sufficient carrier power, then for some applications the advantage of the magnetic amplifier is nullified. The influence of losses is discussed below.

It may be noted that a magnetic demodulator would be unsatisfactory in a magnetic amplifier because its loss would cancel the modulator gain. Consequently, a resistance demodulator which can be made to have a small loss nearly independent of frequency in the region of interest, is used.

Ordinarily a full-wave rectifier of copper oxide or selenium serves very well as demodulator. However, when a half-wave detector is used, the resulting direct current and signal, or part of them, flow through the output winding. This has a feedback effect which can be made positive or negative. Feedback can be had also with the full-wave detector, by shunting part of the output signal and dc through a separate winding for the purpose. The effects of this feedback are similar to those in a vacuum-tube amplifier. Signal phase shift through the magnetic amplifier is determined almost entirely by input and output circuits.

Another kind of feedback can occur through the modulation process. If the impedances connected to the magnetic modulator are such that a lower side-frequency current flows in a winding, then some power may be delivered to the input circuit instead of being absorbed from it. This negative resistance effect will increase the gain at certain frequencies and, if large enough, may cause oscillation to take place. The effect is discussed further below.

Because a modulator has a nonlinear voltage-current characteristic, a number of modulation products are generated when a carrier of frequency \( p \), a signal of frequency \( q \), and a dc bias are applied to it. The frequencies of these products are the sum and difference frequencies \( np \pm mq \), where \( m \) and \( n \) are integers and the number \( m + n \) is called the order of a modulation product. The new frequencies are the Fourier components of the distorted wave of voltage which is the result of applying the two-frequency wave and bias of current to the nonlinear voltage-current curve of the modulator. Ordinarily, the modulation products of low order have the highest amplitudes; hence, often, the high-order products may be neglected. In the magnetic modulator being considered here, those products for which \( m + n \) is even depend for their presence on the direct current. Among them are the carrier even harmonics \( 2np \) and the side frequencies \( (p \pm q) \). If the amplitudes of magnetizing forces of the signal and carrier are \( Q \) and \( P \), respectively, the amplitude of the modulation component \( np \pm mq \) is proportional to \( Q^n \) when \( Q/P \) is considerably less than unity.

![Fig. 2—Arrangement of cores and windings for one type of magnetic amplifier.](image)

In a magnetic amplifier, it is often desirable to select for output certain of the modulation products and to reject others. One way to do this is shown in Fig. 2. All the early work referred to in the opening paragraph was done with this type of circuit. In it, two magnetic cores, as nearly alike as possible, were wound as shown. Or, after the carrier windings have been put on, the two coils are placed together coaxially and the windings connected in series so that the direction of the magnetizing force in one core is opposite to that in the other. Then a single input winding and a single output winding are put on this combination. A cross section through this arrangement may be seen in Fig. 10(b). It is essentially the same as the one shown in Fig. 2. Considering principal modulation products only, the components \((2np \pm q)\) and \(2np\) appear in the signal output and input circuits but not in the carrier source circuits. Also

\[\text{Throughout, the term "frequency" refers to angular frequency in order to avoid the } 2\pi \text{ factors.}\]
the components \((2n+1)p\) and \([(2n+1)p+q]\) appear in the carrier source circuit but not in the signal output and input circuits.

The amplitudes of the side frequencies \((2np \pm q)\) are proportional to \(Q\) and the amplitudes of the even harmonics \(2np\) are proportional to the dc bias. Considering one value of \(n\) only, the output products \((2p \pm q)\) and \(2p\) when applied to a linear rectifier, yield the original signal \(1 + \cos qt\) at a higher amplitude. Since both of these products are proportional to signal amplitude, output is zero for zero input. Without the balancing of the two cores and the carrier windings, components involving odd multiples of the carrier would appear at the output, even when no signal is present, be rectified, and give some dc output.

It is seen that in this case, the actual carrier frequency is the second harmonic of the carrier source. In a practical circuit other even harmonics to a lesser extent will act as carriers also. This type of circuit, which in a certain cases has several advantages over the more commonly used one, was developed by E. T. Burton of these Laboratories who originated the work on magnetic amplifiers here in 1927.

The principal application in view then was that of a dc telegraph signal amplifier.

Another way to accomplish the separation of components as described above is to use a three-legged core with suitably disposed windings.

The magnetic amplifier circuit most frequently used now has the magnetic modulator in series with a generator and the load. Because of the wide variation of nonlinear coil (magnetic modulator) impedance with dc control, large amounts of ac power in the load may be controlled by small amounts of dc power. Using the carrier terms as we did for the other circuit, the actual carrier frequency here is that of the generator \(p\) and the principal side frequencies are \((p \pm q)\). This circuit has been used in two ways. The modulator load may be a demodulator feeding the actual load, in which case the output is an amplified version of the input. Or the demodulator may be dispensed with and the carrier used directly in the load. In the latter case the circuit is sometimes called a transducer.

With this second type of circuit, the output is not zero for zero input since the coil impedance does not become infinite. If several stages of amplification are to be used in tandem, additional means must be provided to balance out this residual output. In the first-mentioned type of circuit, the residual output may be made very small by selecting pairs of cores and adjusting the carrier source windings.

Another point of difference between the two types of circuit is in signal distortion. The second harmonic distortion of the signal is considerably smaller in the first-mentioned type unless the bias component of signal is large compared with the variable component.

The gain and output power of the two types are of the same order of magnitude.

In practice, the odd harmonics of the carrier are often allowed to flow in the carrier input circuit since this increases the output. The increase comes about through a straightforward modulation process. The flow of other modulation products in the input and output circuits may increase or decrease the gain, depending on the particular product. The amplitude of one or more of these products may be large because of self-resonance in the input winding when a large number of turns is used to obtain a high sensitivity.

It is desirable to prevent the flow of output components in the input circuit. To accomplish this, choke coils, simple and tuned, and filters have been used in various circumstances. These all have some effect on the input signal, either by introducing a loss or by slowing down the response, or both. Or an undesired resonance may occur. The effect of this part of the input circuit has not been taken into account in any of the calculations described here. An experimental result is given, however.

Consider the properties of the magnetic core which make it suitable for use in a magnetic amplifier. Since the coil with this core must be a modulator, it is necessary for its \(B-H\) curve to be nonlinear. Also it is desirable for it to have a large saturation flux density and small losses. Higher permeability, apparently giving greater nonlinearity for the same current, brings a disadvantage in the form of increased eddy currents unless the resistivity can be increased at the same time. Though the ferrite materials, though having small dc nonlinearity, may be superior to tape at high frequencies.

One difficulty with magnetic amplifiers is that under certain conditions, the side frequencies and even harmonics of the carrier which appear at the output, may be sustained after the signal input has been removed. In the case of the even harmonics, there are certain values of output impedance which permit this unstable situation and others which do not. It is shown below that the boundary between these two sets of values is definite. The conditions for the maintenance of the side frequencies after the removal of the signal are more complicated and have been discussed elsewhere.

2 Other core arrangements are sometimes used, but the result is the same.
The foregoing is a brief summary of various aspects of the operation of magnetic amplifiers. In the following, some quantitative analysis and results will be described briefly and some experimental results given. After this, the effects of some modifications of the simple circuit described above will be mentioned.

**Analysis**

In magnetic modulation, the writer's experience has shown that the best approach is to calculate the flux function corresponding to some appropriately assumed magnetizing force function, using a simple $B$-$H$ curve. In deciding what is appropriate, experimental results are very helpful. Where the circuit has a few resonances, one or two or possibly three sine waves often will give a satisfactory representation of the magnetizing force. When this is done a Fourier series for the flux is computed. From this a Fourier series for the voltage on any winding may be obtained. Then in each mesh, a simple circuit equation for each significant component of the series is written. Satisfaction of these equations then determines the magnitudes and phases of the assumed magnetizing force waves if the original assumptions were reasonable.

Where the circuit has a broad frequency characteristic, usually there are too many significant Fourier components in the magnetizing wave for the above method to be satisfactory. Then another approach must be found which deals with the wave forms directly. In the magnetic amplifier problems treated here, the first method of considering a few sine-wave terms has proved useful.

Experience has shown that in problems like this one where the magnetizing wave carries the core fairly well into saturation in both directions, the principal modulation effects can be calculated using a single valued $B$-$H$ curve. This greatly simplifies the work, because it is difficult to deal analytically with hysteresis loops, especially when the magnetizing force contains more than one sine wave. In those cases where the single valued curve can be used, the main effects of the loop are to introduce losses and phase shift with respect to the driving wave. The latter is of little consequence usually, but the former may prevent the finding of accurate solutions to the circuit equations because of the difficulty of computing losses.

**A. Open-Circuit Electromotive Forces**

The simplest calculation of value is that of the output even-harmonic voltages when no output current is allowed to flow. Here the magnetizing force is

$$H = Q + P \cos pt$$  

(1)

and a satisfactory representation for the $B$-$H$ characteristic of the core when losses are neglected is

$$B(h) = \frac{2B_m}{\pi} \arctan \frac{h}{a}$$  

(2)

This characteristic is shown in Fig. 3(b) where it is seen that $B_m$ is the saturation flux density and $a$ is inversely proportional to the slope for small $h$.

The Fourier coefficients of flux density may be computed in a straightforward way after (1) is put in (2). We have

$$B(h) = b_0/2 + \sum_{n=1}^{\infty} (b_n \cos np + a_n \sin np t).$$  

(3)

For the purpose of calculation, it is convenient to express (2) in the infinite integral form. The results are

$$a_n = 0$$

$$b_n = 4B_m/\pi (-)^{(n-1)/2} \text{ real part of } I_n \text{ n odd}$$

$$= 4B_m/\pi (-)^{n/2} \text{ imaginary part of } I_n \text{ n even},$$  

(4)

where

$$I_n = \frac{1}{n} \left\{ \left[ 1 + (r - jg)^2 \right]^{1/2} - (r - jg) \right\}^n,$$  

(5)

in which $r = a/P$ and $g = Q/P$. An approximation to this when $Q/P$ is a fair amount less than unity is

$$b_n = \frac{4B_m}{\pi} \left\{ \left[ 1 + r^2 \right]^{1/2} - r \right\}^n \sin^n \left[ \sin^{-1} \frac{g}{\left[ 1 + r^2 \right]^{1/2} + \pi/2} \right].$$  

(6)
A comparison of (5) and (6) for \( n = 2 \) is given in Fig. 4.

The output second-harmonic voltage amplitude is given by

\[
\varepsilon_2 = 2pN_0\frac{2Ab_2}{1}10^{-9} \text{ volts,}
\]

where \( N_0 \) is the number of turns in the output winding and \( A \) is the cross-sectional area in square centimeters of each core. Calculation and measurement of second- and fourth-harmonic electromotive forces were made for a coil having the following properties:

Core: 3.8 per cent chromium permalloy, 3 mils thick; mean diameter, 2.5 cm; cross-section area, 0.022 cm² each.

![Fig. 4—Second-harmonic flux-density component as a function of bias.](image)

![Fig. 5—Measured and computed values of second harmonic voltage.](image)

![Fig. 6—Measured and computed values of fourth harmonic voltage.](image)

Turns: Carrier, 400 each, input, 4,000; output, 200. Curves of these measured and computed voltages are plotted in Figs. 5 and 6. The agreement is seen to be fairly good except for the smallest value, \( P = 1 \). Probably the reason for this is that the assumed \( B-H \) curve (2) is unsatisfactory for small amplitude swings. Calculations have also been made using the straight-line \( B-H \) curve of Fig. 3(a) and also using a loop having straight-line branches as in Fig. 3(a). The results are essentially the same as those given above.

If a signal term \( Q \cos qt \) is added to the magnetizing wave (1), the most important side frequencies at the output are \( (np \pm g) \), \( n \) being even. Their amplitudes when \( Q/P \) is not too large are one-half the value of the \( n \)th harmonic amplitude given by (6). In the second type of circuit mentioned above, in which the load is in the carrier source circuit, we are interested in the variation of the carrier voltage with dc signal, to take the simplest case. In Fig. 7, the fundamental component of flux is plotted as a function of \( Q/P \) for several values of \( a/P \) when the magnetizing wave (1) is applied to \( B-H \) curve (2). These were computed from

\[
\frac{b_1}{4B_m/\pi} = \left( \frac{1 + r^2 - g^2 + [(1 - r^2 - g^2)^2 + 4r^2]^{1/2}}{2} \right)^{1/2} - r, \quad (8)
\]
which was derived from (4) and (5). The fundamental voltage across the coil is then

\[ \varepsilon_1 = p N I_2 A B_1 10^{-4} \text{ volts.} \]  

3. Second-Harmonic Output Current

The difficulty of deriving an analytical expression for the second-harmonic current lies in the fact that the low of this current affects the amount of second-harmonic generated voltage through intermodulation with higher components. This is a non-linear feedback effect depending on fifth and higher orders of modulation. So a numerical calculation had to be made, and this was limited to one case.

A B-H curve made up of three straight lines as shown in Fig. 3(a) was assumed. The magnetizing once wave is

\[ H = Q + P \sin \theta + S \sin (2\theta + 2\phi), \]  

where \( S \) and \( \theta \) are to be determined. If the flux density is expressed as the Fourier series (3), then

\[ \frac{R}{X_0} = \frac{\pi P}{2B_m S} (b_1 \cos \theta - a_1 \sin \theta) \]  

\[ \frac{X}{X_0} = \frac{\pi P}{2B_m S} (b_1 \sin \theta + a_1 \cos \theta) \]  

must be satisfied if (10) is a solution. In (11), \( X_0 \) is a reference value of reactance equal to the reactance of the output winding for very small values of output current. Calculation shows that the inductance corresponding to the reactance \( X_0 \) is approximately\(^3\)

\[ L_0 = \frac{4N_0^2 A 10^{-9}}{d} \frac{2B_m}{\pi P} \text{ h}y. \]  

where \( d \) is the mean diameter in centimeters of the core, and the other parameters have the same meaning as before. \( R \) and \( X \) are resistance and reactance, respectively, of the external output impedance. The coefficients \( b_1 \) and \( a_1 \) were computed for several values of \( S/P \) and \( \theta \) and their values put into (11). Because of the length of the calculations, they were done for only one value of \( Q/P \), and one value of \( h_0/P \). The results are shown in Fig. 8 where \( X/X_0 \) is plotted against \( R/X_0 \) for constant values of the amplitude ratio \( S/P \).

If we consider a fixed value of external reactance, second-harmonic current amplitude may be plotted against resistance of the load. Taking \( X/X_0 = -1.10 \), the output winding inductance is nearly tuned out and the solid curve of Fig. 9 results, the values having been

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\(^3\) The effective inductance of the carrier winding to the carrier for the same number of turns is approximately twice \( L_0 \).
taken from Fig. 8. The dashed curve of Fig. 9 is plotted from

\[ i_2 = \frac{e_2}{R} \]  

where \( e_2 \) is the open circuit electromotive force as found from (7). We also assume that the internal resistance \( R \) of the output winding is some constant fraction \( D \) of the reactance \( X_0 \) of this winding. Let \( R + R_0 = X_0 \) taking a value which by Fig. 8 will not permit self oscillation. Then second harmonic power is

\[ W_2 = \frac{e_2^2}{X_0^2} \left( 1 - \frac{D_0}{2} \right) \]  

where \( D_0 = R_0/X_0 \). When \( Q/P \) is considerably less than unity, a satisfactory approximation for \( b_2 \) in (6) yield for \( e_2 \)

\[ e_2 = 10^{-8} \beta B_m N_0 A \beta Q/P \]  

where

\[ \beta = \frac{(\sqrt{1 + r^2} - r)^2}{\sqrt{1 + r^2}} \]  

is a factor depending only on the degree to which the carrier wave swings the core into saturation. \( X_0 \) is the reactance of \( L_s \) at frequency \( 2f \). Hence from (12)

\[ X_0 = \frac{32}{\pi} 10^{-9} \frac{N_0^2 A}{d} \frac{B_m}{2} \]  

Combining (15), (16), and (18) we get for output power

\[ W_2 = \frac{4 \times 10^{-7}}{\pi^2} \rho B_m \beta Q^2 \frac{1}{P} (1 - D_0) \text{ watts,} \]  

where \( \rho \) is the volume (\( \pi Ad \)) of the core in cubic centimeters.

The input power is

\[ W_i = I_r^2 R_i \]  

\( R_i \) is the resistance of the input winding. A calculation for this is made in the Appendix, assuming, as shown in Fig. 10(b), that the inside diameter of the total winding is one-half the mean diameter of the core. This is known to use the winding space to the best advantage. The result is

\[ R_i = \frac{54 \times 10^{-4} N_i^2 \alpha}{\pi^3 kd} \]  

where

\[ \alpha = \frac{1 + 8 \sqrt{A/d}}{1 - 4 \sqrt{A/d}} \]  

and \( k \) is the proportion of output and input turns used for input.

The magnetizing force \( Q \) of the input is related to the input current by

\[ Q = \frac{0.4 N_i I_i}{d} \]  

And so we have for the dc gain

\[ C. \text{ Direct-Current Gain and Rise Time of Response} \]

The modulating gain from dc to second harmonic output may be computed if a few reasonable assumptions are made. This is very nearly the same as dc gain since the loss in the demodulator is small. Consider the simple equivalent circuit shown in Fig. 10(a). It is
\[
G = \frac{W_2}{W_1} = 1.2 \times 10^{-3} \beta^2 \frac{k}{(1 - D_b)} \quad (24)
\]

The rise time of response is entirely determined by the rise time of current in the input circuit. If there is no external resistance in the input circuit, then we may take for this time

\[\tau = \frac{L_i}{R_i}\]  

\[\tau = 3 \times 10^{-4} B_{m}^2 \frac{k}{P_{ad}} \text{ sec.} \quad (26)\]

Combining this with (24), we get the simple expression

\[G/\tau = 4 \beta^2 (1 - D_b) \quad (27)\]

which shows that under the conditions noted above, the rise time increases in direct proportion to increases in \(\tau\).

Taking an example from some of the early work referred to above, consider a pair of molybdenum permalloy cores each weighing 2.5 grams and having a mean diameter of 3 cm. A reasonable figure for \(D_b\) for these is 0.5. Using \(P = 2\), \(r = 0.2\), and \(k = 0.75\), we get

\[G = 0.063\beta, \quad \tau = 0.045 \text{ sec.}\]

If the carrier source frequency is 2,000 cycles, then \(G\) is about 29 db.

D. General Energy Relations

As mentioned above, it is possible to derive general relations which show how the interchange of energy between the various frequency components occurs in the modulation process. These show how it is possible to get a modulating gain in a magnetic modulator.

Consider the case where two generators of frequencies \(p\) and \(q\) are connected to a load \(Z\) and a magnetic modulator having a single-valued \(B-I\) curve. Also assume that only those current components of frequencies \(p, q, mp + nq, \) and \(mp - nq\) are allowed to flow. Let \(W_p\) and \(W_q\) be the powers absorbed by the magnetic modulator from the two generators and \(W_+\) and \(W_-\) the powers delivered to the resistance component of \(Z\) at the upper and lower side frequencies, respectively, by the modulator. Then it may be shown by processes, which space does not permit to be reproduced here, that

\[W_p + W_q = W_+ + W_- \quad (28)\]

and

\[W_p = mp \left[ \frac{W_+}{mp + nq} + \frac{W_-}{mp - nq} \right] \quad (29)\]

Relation (28), which states that the sum of the powers absorbed by the modulator is equal to the sum of the powers delivered to the load by the modulator, is to be expected from the conservation-of-energy law. No power is dissipated in the idealized modulator itself since it was assumed to have a single-valued \(B-I\) curve, i.e., to be purely reactive. Relation (29) shows that the power taken from each generator depends directly on its frequency. Similar results may be obtained in a generalization in which any number of side-frequency pairs are allowed to flow.\(^{12}\)

When only the lower side frequency \(mp - nq\) flows, we see from (29) that \(W_q\) is negative, i.e., power is delivered to the \(q\) circuit instead of being taken from it.\(^{14}\) This is the negative resistance effect which causes regeneration and if it is large enough to overcome the losses in the input circuit, oscillation will occur at frequencies determined by the resonances of the circuit.

If only the upper side frequency is allowed to flow, the modulating gain is

\[\frac{W_+}{W_q} = \frac{mp + nq}{mp - nq} \quad (30)\]

It is difficult to assign a definite value to the ratio \(W_p/W_q\) in the more practical case in which both upper and lower side frequencies flow because the ratio depends on the values of external resistance and reactance to both upper and lower side frequencies and because of the cross-modulation effects. The negative resistance introduced into the \(q\) circuit may or may not be large enough to make \(W_q\) negative or zero, depending on the impedance to the lower side frequency and the input circuit losses. If the impedance to the lower side frequency is not infinite, there is a regenerative effect, at least so that the ratio \(W_p/W_q\) is greater than \(mp/nq,\) the value it has when current at only the upper side frequency is allowed to flow.

E. Instability

As mentioned above in the general section, it is possible for an unstable situation to exist in a magnetic modulator under certain conditions. The results (28) and (29) may be obtained under similar conditions with a capacitance modulator the voltage of which is some arbitrary nonlinear single-valued function of its charge. A particular case has been worked out in detail by R. V. L. Hartley, "Oscillations in systems with non-linear resistance," Bell Sys. Tech. Jour., vol. 15, pp. 424-444; July, 1936. This was demonstrated by I. W. Hussey and L. R. Wrathall, "Oscillations in electromechanical systems," Bell Sys. Tech. Jour., vol. 15, pp. 424-445; July, 1936.

\(^{12}\) The results (28) and (29) may be obtained under similar conditions with a capacitance modulator the voltage of which is some arbitrary nonlinear single-valued function of its charge. A particular case has been worked out in detail by R. V. L. Hartley, "Oscillations in systems with non-linear resistance," Bell Sys. Tech. Jour., vol. 15, pp. 424-444; July, 1936. This was demonstrated by I. W. Hussey and L. R. Wrathall, "Oscillations in electromechanical systems," Bell Sys. Tech. Jour., vol. 15, pp. 424-445; July, 1936.

\(^{14}\) The relation of the sign of introduced resistance to the side frequency allowed to flow was shown first by R. V. L. Hartley under more restricted conditions. See E. Peterson, "Atomic physics and circuit theory," Bell Lab. Rec., vol. 7, p. 231; February, 1929. Also see footnote reference 9.
amplifier such that even harmonic output persists after the removal of input or arises from some temporary disturbance other than input signal. This is true for both types of circuit discussed above. Ordinarily, even harmonics are not present in a ferromagnetic coil which is being magnetized sinusoidally. However, it has been found experimentally that they do appear under certain output or input impedance conditions. 

A calculation similar to that described in Section B was made with the assumed magnetizing force as in (10) except for the absence of bias Q. This is,

$$H = P \sin pt + S \sin (2pt + 20).$$

(31)

From the results, permitted values of $X/X_0$ and $R/X_0$ were plotted one against the other as in Fig. 8 for constant values of the amplitude ratio $S/P$. One of these curves (for $S/P = 0.1$) is shown in dashed line on Fig. 8. This curve is nearly semicircular, centered at $X/X_0 = -1$, $R/X_0 = 0$. Within this curve lie all those for larger values of $S/P$. Calculation (using the $B$-$H$ curve (2)) shows that as $S/P$ approaches zero the curves $X/X_0$ versus $R/X_0$ approach a limiting curve which is the circle

$$(R/X_0)^2 + (1 + X/X_0)^2 = e^{-2} \sinh^{-1} r.$$  

(32)

This limit is just beyond the dashed curve of Fig. 8. Thus if the external impedance connected to the output winding (or one equivalent to it) lies within this circle, instability will result. For impedances outside the circle, generation of an even harmonic without dc input cannot occur. However if the impedance is near the limit, though outside it, the output-input curves shown in Figs. 4, 5, and 6 will be distorted as shown in Fig. 11. These latter curves were obtained experimentally. A mentioned before the internal resistance of the output winding must be included in the total circuit resistance $R$ of Fig. 8. That is, in reducing actual external resistance, we can never reach the zero value of $R$.

This effect of output without input, caused by an unstable condition should not be confused with a similar effect caused by a lack of carrier balance. If in the case where the modulator output consists of the carrier even harmonics $(2np)$ and the side frequencies $(2np \pm q)$, the carrier input coils are not perfectly balanced, a small amount of carrier $(p)$ will be present in this circuit. This will be rectified and appear in the signal output circuit as a dc component which has no relation to the input.

**Effects of Modifying the Simple Circuit Used for Analysis**

In the practical use of magnetic amplifier circuits it has been found desirable often to use circuit arrangements somewhat different from the simple one used in the preceding analysis in which only a few current components were allowed to flow. A few experimentally observed effects of the changes are described.

If instead of tuning the carrier input circuit in order to have sinusoidal carrier current, we connect the carrier generator directly to the windings, odd harmonics of the carrier frequency will flow in this circuit. This has the effect of increasing the second harmonic output as shown in Fig. 12 by a factor of about two. A simple computation using a cubic characteristic shows that this increase is the result of a straightforward modulation between the carrier, its third harmonic, and the dc signal. A study of general energy relations as given above shows that the flow of odd harmonics of the carrier increases both $W_4$ and $W_5$ in such a way that their ratio remains constant.
In order to make the amplifier operate on very small input currents, a large number of turns may be used on the input winding. In some of the early work discrepancies between calculated and measured values were traced to self-resonance in the input winding. These resonances allow large circulating currents which, through modulation with other components, may either increase or decrease the desired output. The same effect may arise when externally connected impedances resonate with a winding at an important frequency. This is seen in Fig. 13 in the case of the input circuit. Since the output winding is equivalent to the input winding except for impedance level, the effect is found there also, as shown in Fig. 14.

**APPENDIX**

Consider the winding for the toroidal coil shown in Fig. 10(b) to be made up of a series of rectangular helices, a typical turn of which is shown. The number of turns in each helix is

\[ n_1 = \frac{(d/4 - \sqrt{A})}{a}. \]

The number of helices is determined by the inner diameter of the winding space and is

\[ n_2 = \frac{(\pi d/2)}{a}, \]

\( a \) being the diameter of the insulated wire. The total number of turns that can be put in this space is then

\[ N = n_1 n_2. \]

The mean length of turn is

\[ l = d + 8\sqrt{A}. \]

The resistance of this winding is

\[ R = \rho \frac{8\sqrt{A} + d}{\pi a^2/4} N, \]

\( \rho \) being the resistivity. Let \( k \) be the fraction of \( N \) which is used for input winding. Then eliminating \( a^2 \) between the expressions for \( R \) and \( N_i \), we have for input resistance

\[ R_i = \frac{54 \times 10^{-6} N_i^2}{\pi^2 kd} \alpha \]

where

\[ \alpha = \frac{1 + 8\sqrt{A}/d}{1 - 4\sqrt{A}/d}. \]

**ACKNOWLEDGMENT**

The writer wishes to acknowledge the help of Miss M. C. Packer in numerical computation, and that of E. Peterson, who was consulted frequently during the project. His basic work in magnetic modulation suggested approaches to many of the problems.
Experimental Evaluation of Diversity Receiving Systems*

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Summary—Methods used in a long-range experimental study of fading with ordinary and diversity receiving systems are discussed. Results are expressed statistically in terms of the nonusable circuit time and also in terms of the number of fades per minute below least usable level.

Data for this analysis are obtained on semiautomatic equipment which measures the total time the signal spends in each of seven pre-established intervals of signal strength and counts the number of times the signal enters each interval. The instruments thus accomplish at the time of recording a substantial part of the analysis.

This paper deals with methods being used in a research program to evaluate the performance of diversity receiving systems which are of interest to the Signal Corps. Experimental techniques are described and the statistical concepts which have been adopted for presentation of performance data are discussed with respect to the problem of expressing the reliability of a facility in explicit terms. A review of experimental findings is presented in a companion paper which follows in this issue of the Proceedings.1

Diversity reception is a means for combating the fading of radio signals, so an investigation of it requires the recording and description of the fading encountered with the various systems considered. A high-speed strip recording of signal strength over a single radio channel reveals that signal strength varies in a random manner and that fading does not have a periodic characteristic. Since the frequency of fading and the total range of fading cannot be expressed explicitly with any real meaning, it follows that a mathematical treatment of the problem must be based on statistical concepts.

An established method for describing the fading of a signal is in terms of the probability that the signal amplitude will at a particular instant be less than a designated amplitude. Assuming that the signal at a single antenna is the resultant of many signals arriving in random phase, it can be shown that the probability that the signal amplitude will be less than $s$ is

$$P(s) = 1 - e^{-(s/s_0)^2}$$

where $s_0$ is the long term, root mean square of the signal amplitude. This function is shown graphically in the curve marked "nondiversity" in Fig. 1.

The improvement afforded by the use of diversity reception results from the fact that the signals received under different conditions do not generally fade together. These different receiving conditions might be attained, for example, with spaced antennas, by use of antennas of different polarization, or by using different frequencies. In the usual system, a separate receiver is used for each channel. The receiver outputs are connected to a circuit which selects the strongest signal as the diversity output. A diversity signal selected in this manner will fall below a particular amplitude only when the signals in all channels are simultaneously below that amplitude.

The probability that two independent events will occur at the same time is the product of the probabilities that each will occur by itself. Therefore, if the fading of the two signals in a dual diversity system were completely independent, the probability that the amplitude of both signals would be below a designated amplitude is the square of the probability that each (considered by itself) will be below that amplitude. Therefore, with a dual diversity system with completely independent fading on the two channels, the probability that the combined signal will fall below $s$ is $[P(s)]^2$. The function $[P(s)]^2$ is shown in the curve marked "dual" in Fig. 1. Similarly for triple diversity with completely independent fading this probability is $[P(s)]^3$.

The foregoing discussion assumes, first of all, that the signal is fading with a Rayleigh distribution and, second, that the fading of the two or three channels is completely independent. Based on such assumptions,
elonek, Fitch, and Chalk\(^2\) made an interesting analytical study of diversity improvement. But their analysis did not show what separation of antennas would give his uncorrelated fading nor what correlation exists for particular spacings or between the fading on two differently polarized antennas. It appears that this information must be obtained experimentally.

It is conceivable that a program could be directed toward determining a statistic which is a measure of the correlation between the fading on the several antennas. Presumably such information could then be interpreted in more practical terms to show the actual improvement in transmission capacity resulting from the use of various diversity systems. There appeared, on the other hand, to be considerable virtue in obtaining statistical results directly in terms applicable to the problem of engineering a receiving facility.

In selecting the terms in which the experimental results should be expressed, consideration was given to the manner in which diversity systems improve reception. For one thing, diversity reception smooths out the variations in signal strength resulting from fading. However, this can often be accomplished to a sufficient extent with automatic gain control or with limiters. The real value of diversity reception is presumed to lie in the decrease in the probability that the several diversity signals will be lost in the noise at the same time. The diversity improvement results from the fact that the combining circuit has more than one receiver from which it may select the strongest output and that the combined diversity signal will be unusable only if all of the contributing signals are unusable. If only one receiver contributes to the output at any time, the noise level is that from just one receiver.

Having established this as the basis for judging diversity performance, the experimental program was directed toward determining the fraction of the time for which a diversity signal was below various amplitudes. If, from measurements at a prospective receiving site, a least usable level can be determined, the experimental results will show what per cent lost time will result with the various diversity systems. It was also considered desirable to know how often the signal faded below various levels. The experiments were arranged to give this information also.

Let us consider the matter of unusable time in terms of an example. Fig. 2 shows typical simultaneous recordings of the fading of a nondiversity and a diversity signal. If the level shown by the solid line were the least usable level, the nondiversity system would have been unusable for a certain fraction of the total time. Also the signal faded below this level a certain average number of times per minute. With a combining system which selects only the strongest signal, the least usable level is the same for the diversity system. The curve here shows the amplitude of the stronger of the two diversity signals. The combined diversity signal will be unusable when this stronger signal is less than the least usable level.

It can also be seen here that the unusable time depends upon the location of the least usable level relative to the received signal. If, for example, the transmitter power were increased, both the diversity and nondiversity curves here would be shifted upward an appropriate number of decibels, thereby reducing the unusable time. Similarly, if the least usable level is established (as is

usually the case) by the interference picked up by the antennas, improved receiving antenna directivity favoring the desired signal and discriminating against the interference will reduce the unusable time.

A convenient measure of the least usable level relative to the received signal is the quantity $A$ shown in Fig. 2. The amplitude of the received signal is measured here in terms of its median. This is the value which it exceeds one half of the time. If the per cent unusable time is plotted as a function of $A$, one obtains curves of the type shown in the lower left corner of Fig. 2. The curves in this figure show the percentage time spent below various signal amplitudes. Signal amplitudes as shown are measured relative to the median.

Similar curves can be drawn for the fading rates. The curves in the lower right corner of Fig. 2 show the average number of fades per minute below the various signal amplitudes. Here again, signal amplitude is given relative to the nondiversity median. That is to say, the abscissa is the quantity $A$.

Such information as this could be extracted from strip records like the example used in Fig. 2. Although a very short sample is shown to illustrate the principles, many hours of data would be required to give reliable statistical information and the procedure would be costly and slow. For this reason, an instrument was developed which analyzes the fading signals directly in usable terms at the time it is received. A simplified diagram of this instrument is shown in Fig. 3. This instrument determines the time spent in each of seven preset intervals of signal amplitude. These times are indicated on

![Fig. 3](image-url)

**Fig. 3**—A simplified diagram of the recording instrument.

seven electrically operated clocks. Counters connected in parallel with the actuating coils of the clocks show the number of times the signal entered each interval. Because the median signal strength varies from one test to the next, the setting of the intervals bears no fixed relation to the median. The relation of the median to the various intervals during a particular experiment is determined by recording also the signal received with a nondiversity receiving system. The nondiversity and diversity recording is done with the same instrument on a sampling basis, recording the two during alternate ten-minute periods.

Fig. 3 shows also the diversity combining circuit. Selection of the strongest diversity signal is accomplished by use of a common load for the second detectors of the diversity receivers. The voltage developed in this load by the strongest signal biases the detectors of the other receivers so that (except when two signals are about equal) only one signal contributes appreciably to the combined output. The selection of the strongest signal is enhanced by the use of a common automatic gain control with which the gain of all receivers is determined principally by the strongest signal.

The second detector load is in the form of a voltage divider which is switched between the diversity and reference receivers for alternate ten-minute periods. The six taps on this voltage divider are connected to six dc amplifiers whose outputs control the conduction in six pairs of gas tetrodes. These gas tubes are connected in 60-cycle full-wave rectifier circuits whose outputs control a series of relay. With no signal at the input of the
receivers, all of the gas tubes are biased to nonconduction. As the input signal increases, a point is reached at which the pair of gas tubes at the top of Fig. 3 begin to conduct, closing the relay associated with this circuit. A further increase of 6 db in the input signal causes the next pair of gas tubes to conduct closing its relay. When the signal amplitude is less than that which causes the first pair of tubes to conduct, the clock marked “0” runs. When the signal amplitude reaches the point at which the first pair of tubes fires, clock “0” stops and the clock marked “1” starts. This same process is continued as amplitude of the signal increases through each of the intervals of signal level.

The taps on the voltage divider are adjusted so that successive channels fire at increments in the signal strength of 6 db measured at the input of the receivers. Thus the sixth channel fires when the receiver input is 30 db above the amplitude which fires the first channel. Calibrating the system in terms of receiver input voltages takes into account the nonlinear response of the receivers with their automatic gain control. Great care is taken to match the response characteristics of the non-diversity and the several diversity receivers. The calibration is therefore valid whether the recording instruments are connected to the diversity or the nondiversity system. If the diversity output is determined by only the strongest input signal, the response of the diversity system is that of each of the diversity receivers alone.

A clock which runs continuously is used to show the total recording time. The sum of the other seven clocks should agree with the reading of this clock providing a check against faulty operation or misreading. Actually there is slightly more lag in stopping the clocks than in starting them, due to the transients in the switching circuits. The total of the clocks for the seven intervals generally exceeds the reading of the continuous clock by one half to two per cent, depending on the rapidity of fading. The time measurements in those intervals where the signal spends most of the time are accurate to within about one per cent, although the percentage error is greater in those intervals where the time is made up of short periods.

The counters indicate the number of times the signal entered each interval. Except at the start and end of a run, the signal must have left each interval as often as it entered it. Each time it leaves an even-numbered interval it enters an odd-numbered interval either above or below it. Therefore, the sum of the counts in all even-numbered intervals should equal the sum of the counts in all odd-numbered intervals. These relations hold as well when the counts have been divided by the total recording time to give counts per minute, providing a check on some of the computations.

The principal reason for recording the nondiversity signal is to determine how the boundaries separating the intervals are situated relative to the median signal strength. It is pure coincidence when the median happens to be one of these boundaries. The median can be determined by plotting on suitable co-ordinates the per cent time spent below each boundary as a function of the signal amplitudes they represent and reading from the resulting curve the level corresponding to 50-per cent time.

Knowing then the relation of the median signal amplitude to the firing levels of the recording instrument, it is possible to plot curves for each test period of the type shown in the lower half of Fig. 2. When the curves obtained from several tests of the same diversity system are plotted on the same chart, the curves do not in general coincide, indicating some variability in the observed performance. As a general rule, the curves do fall into distinct groups. Average performance might be expressed by averaging the ordinates of the several curves. However, the variability in the performance is almost as significant a characteristic of the diversity systems as the typical performance. A number of established measures of variability could be used. A convenient method of showing this is to indicate areas on the graph which include the middle half of the group of curves for a particular diversity system. Examples of this presentation of the interquartile range will be found in the paper which follows.

The problem of diversity system evaluation is by its very nature a statistical problem. We feel that the methods discussed here for presenting the statistical findings are of great practical value. The terms in which diversity improvement has been expressed can be more readily related to the real communication problem than relatively abstract indices that might have been devised. Not only do the results permit comparison of the effectiveness of various antenna arrangements, but they provide also the information for weighing the values of a diversity system against other means for obtaining the same reduction in lost circuit time.

The recording equipment developed for these tests has greatly facilitated the processing of the statistical data by effectively performing a portion of the analysis at the time that the signals are received.

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Performance of Diversity Receiving Systems

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Summary—An outline is given of the study of diversity reception being carried out jointly by the Signal Corps Engineering Laboratories and Washington University, the purpose of which is to determine the characteristics, limitations, and relative merits of space, polarization, and frequency diversity systems.

Results are reported on various systems including dual- and triple-spaced-antenna diversity and several forms of polarization diversity. Frequencies in the range of 7 to 16 Mc have been investigated over a 900-mile path between New Jersey and St. Louis, Missouri. Improvement provided by the various diversity systems is presented graphically in terms directly applicable to the design of a transmission facility and the variability in improvement is indicated for its value in estimating departure from mean performance.

Over the past several years the Signal Corps Engineering Laboratory and Washington University have collaborated in a comprehensive investigation of diversity receiving systems. The amount of improvement available from various diversity methods has been established quantitatively and design procedures have been drafted. Developments at this stage of the program indicate that it may be possible to establish quantitative specifications for diversity systems to reduce by practically any desired amount the loss in transmission time due to deep fades.

Diversity receiving methods involve the use of two or more transmission channels which are separately identified at the receiving point and a combining circuit which either selects the strongest available signal or provides an output proportional to some combination of all signals. Separation of the transmission channels may be on a physical basis as with spaced-antenna diversity or on some other basis as in polarization diversity and frequency diversity. Those types of receiving diversity which would be practical for military purposes are to be investigated but the more complex systems such as the multiple-unit steerable antenna will not be considered. This report is limited to spaced-antenna and polarization diversity in the frequency range of 7 to 16 Mc.

A principal object of this investigation is the collection of necessary data for the evaluation of various diversity systems and formulation of procedures for their design. Attention is also being given to the receiving equipment problem to the end that more effective facilities may be developed as a consequence of the program.

To the greatest practical degree the experimental aspects of the program have been planned and implemented to provide data that are accurately representative of propagation behavior and the respective antenna systems and that do not reflect the characteristics of any particular receiving or recording equipment. The large volume of data involved is collected with semi-automatic recorders, thus minimizing the time required for processing and providing numerical information in a form directly applicable to statistical analysis. Details of the equipment and the statistical methods are presented in a companion paper.

The required long transmission lines from antennas to field laboratory are of identical length and are constructed of dual RG/8U cables to reduce pickup on these lines approximately 50 db below the signal level provided by the antennas. Antennas are all half-wave doublets and the horizontal elements are installed at a height of about 45 feet. The single antenna for the reference system is installed 2,000 feet from the center of the area for the diversity arrays. The only antennas in the area at a given time are those required for the particular array being tested. Receivers are matched in gain, in automatic-volume-control characteristic, and in impedance level at the input terminals. All equipment is recalibrated and re tuned each hour during recording periods and is further checked by strip oscillograph records and observation during actual operation. A condition is maintained at all times which permits the interchange of apparatus between channels without altering the data to a measurable extent.

A lengthy discussion of the analytical methods used is unnecessary at this point but it may be desirable to review briefly the graphical forms which have been adopted for the presentation of performance curves. Since the fading of radio signals may be described with reasonable accuracy by a Rayleigh probability function, a basic co-ordinate system derived from this type of distribution has been adopted. It possesses the advantage of yielding performance curves for a single-channel system which are straight lines in the ideal case and nearly straight for actual data. Interpolation is facilitated by this linear property. Fig. 1 shows a typical set of curves for a single-channel reference system and a two-channel diversity system. There is no mathematical reason to expect the diversity data to plot as straight lines even though the reference systems may be ideal and yield data having perfect Rayleigh distribution.

Data as recorded are first plotted for each recording period in a set of curves as shown in Fig. 1. In some cases, the data for a full day may be condensed into a single set of curves while in other cases a day may be broken into several periods, the data for each of which will be plotted separately. Data for the period in which the long-term median value of signal strength on the

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reference system are essentially constant may be represented by a single set of curves. This follows from the fact that the statistical analysis is based upon the assumption of a constant median value.

A more useful presentation for engineering purposes is obtained when the fading characteristic of a diversity system is referred to the median signal level which would exist without diversity. Fig. 2 shows such curves as derived from a graph such as Fig. 1 and depicts the percentage lost time plotted vertically as a function of the difference between median signal level and other lower levels. This graph only provides statistical information for the region below median level in the reference system but this represents no shortcoming because those situations in which the least usable level exceeds the median are of little or no practical importance.

Data have also been collected on the rapidity of fading or, more specifically, on the number of times per minute that the signal fades downward through various levels. This information may be of great value in the design of equipment where the frequency of fading would be a factor. In Fig. 3 the fades per minute are plotted vertically against signal level below median value.

Investigations have been conducted on three frequencies in the range of 7 to 16 Mc. The lower frequency used was 6.915 Mc, the intermediate 11.66 Mc, and the higher 15.72 Mc. Unmodulated carrier has been used exclusively. This is justifiable in the interest of simplicity and in that the results may be readily extended to other systems with modulation, as will be discussed later. Space diversity systems with dual and triple channels have been rather completely investigated and work on these is continuing. Several arrangements for polarization diversity have also been investigated and significant data have been collected.
Experimental work has been under way for nearly two years and has been conducted continuously over that period of time. Approximately 2,000 hours of recording are represented in the reliable data which have been processed up to the present. The particular frequency for use at any time is selected in terms of the propagation characteristics for the path in service.

All data here reported have been collected over the path from Red Bank, New Jersey, to St. Louis, Missouri. This is approximately 900 miles in length and lies in a generally east-to-west direction. Future tests are currently being planned between England and St. Louis, Missouri, for longer path information, from the Panama area to St. Louis for a north-south comparison and over a short path at frequencies below 7 Mc.

A large quantity of data has been collected and is presented in a relatively few charts. As might be expected, there is variability in the data collected for a given configuration from day to day and from season to season. This variability may be due to changes in ionospheric characteristics, to chance sampling of an inherently variable phenomena, and, to less degree, to errors of measurement. For the purposes of this paper, many sets of curves have been reduced to single lines which are representative of the weighted arithmetic mean of available data.

In planning this program it has been recognized that normal fading as encountered most of the time will not account for all losses in transmission. Interference and complete breakdown of ordinary ionospheric behavior are typical influences which cannot be included in this type of statistical analysis but which will have a very real effect upon continuity of service over a communication facility. This investigation has dealt exclusively with the problem of normal, short-period fading and the results are applicable in the absence of other influence such as those cited.

The following discussion on performance of the various types of diversity systems is divided into three sections covering two-antenna, spaced diversity, commonly called "dual"; three-antenna, spaced diversity also termed "triple"; and polarization diversity. Figs. 4 through 10 present various aspects of two-antenna spaced diversity and subsequent figures apply to the other forms.

Representative performance of dual diversity is depicted in Fig. 4. The data on which these curves are based were collected in December, 1949, for a frequency of 11.66 Mc during daylight hours. The cross-hatched areas represent the zones in which half of the curve for the respective days or periods were located. For one fourth of the time the performance was better than is indicated by the areas and for one fourth of the time the performance was poorer. The expression "interquartile range" is commonly applied to the area within the boundaries shown.2

In some cases the interquartile areas are wider than indicated in Fig. 4 while in others they are not so broad. These data may properly be characterized as typical and show the usual order of improvement afforded by dual diversity. The curves indicate, for example, that the reference system will have approximately two-per cent nonusable time if the median signal level is 15 db above least usable. If dual diversity with 200 feet separation is used, the percentage lost time drops to approximately 0.08 per cent and if the separation is increased to 1,000 feet, the lost time will be the order of 0.05 per cent. The increase in spacing from 200 to 1,000 feet contributes very little to the performance of the diversity system.

Fig. 5 presents graphically the information on number of fades per minute with a dual diversity system. It is evident that the number of fades is substantially reduced and that large spacings are not necessary as there is relatively little improvement in going from 100 to 1,000 feet. A single-channel system at this frequency will experience approximately three fades per minute if the median signal strength is 15 db above least usable level. Under the same conditions a dual diversity system will fade 0.2 times per minute which represents an

2 The two curves for the reference system result from the presentation of data for two separate dates on a single graph where the side-by-side comparison accentuates the variability in characteristics. The reference system has been quite consistent in its performance so it would be expected that a long series of data samples would yield an interquartile range somewhat wider than either in Fig. 4 but not so wide as the total area bounded by the extremes of the two curves. Other cases of this type occur in later figures.
improvement of approximately 15 to 1. Some variability is also obtained in the data on which these curves are based. The single lines shown represent the weighted arithmetic mean.

In the absence of evidence to the contrary, it might be expected that the performance of a given diversity array would be quite different at different frequencies and seasons of the year. As a matter of fact, the performance seems to be relatively free of such influences as indicated more specifically in Fig. 6. Here are shown performance curves for three frequencies and three seasons which fairly well cover a complete year. The poorest performance was obtained on 11.66 Mc and the best on 7 Mc. More recent data indicate that dual diversity is not always so good as here represented but additional information must be gathered before these latest results can be accurately reported. The curves shown in Fig. 6 are typical of the performance over a total experimental period of approximately two years up to February, 1950.

In so far as time and conditions permit, tests are scheduled in a manner which will provide a maximum of cross checking. For example, it is customary to repeat runs for a given frequency in all seasons for which it is usable and also to repeat on an interval of approximately one year as a long-range check on variability. Tests on dual diversity at 11.66 Mc and with a separation of 1,000 feet parallel to the path were conducted in December, 1948, and were repeated in December, 1949. The results are reported in Fig. 7 which has been drawn to show the interquartile range. It is apparent that there is some variability but this is to be expected in view of the changing ionospheric conditions on a cycle of much greater period. Efforts are being directed toward explicit co-ordination of diversity performance and ionospheric
characteristics which will make possible a direct forecast of diversity effectiveness when the ionospheric predictions are established. Some information on this subject is now on hand and will be reported at a later date, together with additional data presently being collected.

It has already been mentioned that large spacings are not appreciably more effective than shorter ones in overcoming the effects of fast fading. Other investigators have indicated that spacings of the order of several miles or more are advantageous in reducing the effects of slow fades. This investigation is limited to fades which occur at the rate of once each minute or more frequently. For such short-period fades a separation of 100 feet between diversity antennas provides a large increase in reliability of service. If the spacing is increased tenfold, the performance is not greatly improved. Fig. 8 is a presentation of data on dual diversity for four different spacings. If the median signal strength diminishing return in improvement per unit distance. This point is more clearly established when the data are presented in the form used in Fig. 9. Spacing has been selected as one of the axes and curves have been drawn for various median signal strengths relative to least usable value. For a median value 15 db above least usable level on the reference system, the principal part of the improvement is obtained in the first 200 feet of separation.

Since it is possible to arrange diversity antennas in many directions with respect to the arriving wave, the question naturally arose as to what geometric pattern would be the most effective. In the field facilities, provision is made for the erection of antennas along a line parallel to the direction of arrival and also along a line perpendicular to this direction. Resolution of the problem into two principal directions in this manner appeared to offer the simplest experimental means of determining the effect of geometrical placement. It is interesting to note that there is no marked advantage in one direction over the other as demonstrated by the data presented in Fig. 10. These data were collected under carefully controlled conditions which largely eliminated the influences of factors other than orientation. Earlier tests indicated that one direction or the other might have some small advantage but it has since been concluded that these apparent differences were due to changes in other test conditions.

Analysis of triple diversity, predicated upon fading of a single transmission channel in accordance with Ray-

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Fig. 9—Influence of spacing on performance of dual-spaced-antenna diversity system.

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2 Private communication from S. D. Browning, Mackay Radio and Telegraph Co. Inc., New York, N. Y.
vestigation supports these predictions and indicates that a high degree of reliability can be obtained with such a system. Typical data for a triple diversity system collected during daylight hours at a frequency of 11.66 Mc in the month of January, 1950, are presented in Fig. 11. The cross-hatched areas represent data lying in the interquartile range for spacings of 200 feet and 600 feet, respectively. The degree of variability indicated is common to the three frequencies here reported and the relative improvement of 600 feet separation over 200 feet is likewise typical. For the ionospheric conditions during the period of these tests, the reference system would have given between one- and two-per cent lost time if the median signal were 15 db above least usable level. For the same strength of signal, triple diversity with 200 feet extreme separation would give only approximately 0.01-per cent lost time or less than one hour in a year of 24-hour per day operation. If the reference system were to provide the same degree of reliability, the median signal would have to be approximately 30 db above least usable as can be estimated by projecting the reference curves to the 0.01-percentage line.

As the frequency is changed, some difference in performance of triple diversity is noted. The curves shown in Fig. 12 are representative of the performance for three frequencies in four seasons of the year. The difference between the performance of 15.72 Mc in April and 7 Mc in July and October is apparently due in part to difference in ionospheric characteristics as some degree of correlation is possible. As with dual diversity, perti-
different ionospheric information is being collected in an effort to establish a more explicit correlation.

The effectiveness of spacing has also been investigated for triple diversity and typical results are shown in Fig. 13. In all cases reported, the separation in triple diversity is given between extreme antennas. To facilitate comparison, a curve for dual diversity is included, showing its performance for a separation of 1,000 feet. Triple diversity with a separation of only 200 feet between extreme antennas provides substantial improvement over the best dual performance. Further improvement results from increased separation but in this case also there is diminishing return as a separation of 200 feet is exceeded.

![Fig. 13](image)

**Fig. 13**—Effect of antenna spacing on performance of triple-spaced-antenna diversity system. Performance of dual system is shown for comparison.

The reduction in fades per minute is also substantial with triple diversity as clearly indicated by the curves in Fig. 14. A median signal strength 15 db above least usable level will give from 6 to 7 fades per minute on the reference system, something over 0.1 fade per minute with dual diversity and 0.01 fade per minute or less with triple diversity. It may be concluded that the reduction in number of fades per minute bears a close correspondence to the reduction in lost time with the various diversity systems.

The figures quoted above for triple diversity performance become more meaningful when the fades per minute are expressed in terms of some larger reference. For example, 0.01 fade per minute below least usable level corresponds to one fade in one hour and 40 minutes or 14.4 fades in a 24-hour day. Since the expected lost time for the triple diversity system is of the order of 0.01 per cent or 0.14 minute per 24 hours, it follows that there will be the order of 14 fades per day each of approximate duration of 0.01 minute. It will be readily recognized that this order of improvement from the effects of normal fades is adequate for all practical purposes where other influences such as interference will usually account for a much larger loss of time.

In many respects, polarization diversity would be desirable, particularly in military communications. Several antenna arrangements for this form of diversity have been tried and considerable data have been collected on the most promising arrangements. The performance of one polarization diversity system is depicted in Fig. 15. The inverted-L arrangement consisted of a horizontal dipole approximately 50 feet above the ground and a vertical half-wave dipole suspended at one end of the horizontal element. Lead-ins were taken from the center of each antenna for a distance of 50 feet or more in a direction substantially normal to the plane of the two antennas. These precautions in the placement of lead-in lines were observed to minimize any possible interference effects due to the presence of the shielded leads in close proximity to the antennas.

The usual performance of dual diversity with 200 feet separation is also shown in Fig. 15 for reference. It ap-

![Fig. 14](image)

**Fig. 14**—Performance of triple-spaced-antenna diversity system with respect to fades per minute below respective levels.
pears from these data that polarization diversity is somewhat better than dual but this particular point requires some enlargement. Some evidence now available indicates that the poorest polarization performance is obtained when dual-spaced-antenna diversity gives best results. Conversely, when very poor diversity improvement is obtained with dual spaced antennas, the improvement from polarization diversity is greater. Investigation of this phenomenon has not been completed but the available experimental data are most interesting. Any conclusion as to the relative advantage of

polarization diversity compared with dual must be drawn with reservations which cannot be accurately expressed at this time.

Polarization diversity is effective in reducing the fades per minute and to about the same degree as spaced dual with separation of 200 feet. This conclusion may be readily drawn from the data plotted in Fig. 16 but is probably subject to the same restrictions as would apply to a conclusion on reduction in percentage lost time.

Polarization diversity has not been consistent in performance and has generally been characterized by a weakness of signal on the vertical element. The vertical component generally contributes to the transmission a relatively small percentage of the time and then only during deep fades of the horizontal component. Discrimination against high-angle signals by the vertical antenna in close proximity to the ground may account for this behavior. Another factor is possibly introduced by the node at high angle in the horizontal antenna pattern at higher frequencies. Further investigation of this entire problem is clearly necessary.

As with the other forms, polarization diversity exhibits some variability with frequency and seasons. Data collected with a T arrangement of antennas on three different frequencies and in three seasons are summarized in Fig. 17. The wide spread between the extreme curves supports the statement made earlier that the performance of this type of diversity has been quite inconsistent. Additional data are being collected to clarify many of the unresolved points so that more reliable conclusions may be reached.

Data have been obtained on four different antenna arrangements for polarization diversity which appeared to have possibilities from a practical standpoint. The inverted-L antenna has already been described. The T antenna is quite similar except that the vertical element is suspended from the center of the horizontal element. An inverted-V antenna was tested because it offers obvious advantages in simplicity of erection. A single pole was used and the two antennas were suspended from the top to opposite points on the ground at angles of 45° to the horizontal. The angle between antennas was thus 90° and the plane of the antennas was made normal to the direction of arrival. An X arrangement was also

![Fig. 16—Performance of inverted-L polarization diversity system with respect to fades per minute below respective levels.](image-url)
data on the performance of spaced-antenna and polarization diversity. Improvement provided by diversity is expressed in terms directly applicable to engineering design of a radio transmission facility. Triple-antenna space diversity is definitely superior to dual spaced or polarization and it appears that, of the latter two, dual spaced is generally more effective. The particular system to be used for a given installation will be determined by economic factors, reliability required, and allowable complexity at the receiving terminus. Certain unresolved points remain to be clarified and the investigation must be extended to other frequencies, paths, and types of diversity. What has already been accomplished indicates that the selection and design of diversity systems may ultimately be reduced to a reasonably explicit process directly related to performance specifications.

tried with two poles for support. The antennas were inclined at 45° to the horizontal and were in essentially the same plane. The separation at the centers where the antennas crossed was of the order of one foot.

The relative performance of the above-described antennas for polarization diversity is indicated by the curves in Fig. 18. While some of the differences may be due to normal variability in data, it appears that the inverted-L arrangement has some advantage over the others. All tests were not of the same duration but each was sufficiently long to provide a reasonably dependable sample of data.

Use of an unmodulated carrier in this work is not expected to impose any great limitation on the utility of the findings. Signal Corps Engineering Laboratories have conducted an extensive series of tests on facsimile, voice, and multichannel teletype circuits with several forms of modulation and with various controlled conditions of selective fade. This study indicated that distortion is low and that the percentage accuracy in signal reproduction is greatest when the carrier level is maintained or is restored by exalted carrier techniques. Thus it would appear that any system which maintains the carrier level will have a corresponding high fidelity in the handling of modulated signals.

The investigation here reported has yielded valuable

Fig. 17—Performance of T polarization diversity system for various seasons and frequencies.

Fig. 18—Comparative performance of various polarization diversity systems. The systems differ only in the physical arrangement of antennas.

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Television Image Reproduction by Use of Velocity-Modulation Principles

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Summary—The velocity television reproduction system described in this paper uses a combination of standard video principles for image pickup and velocity-modulation methods for picture reproduction. An analysis is presented which indicates the response of the system to a general video signal. It is shown that one form of presentation imparts a three-dimensional appearance to the image. Photographs are presented of standard broadcast television images reproduced on a conventional receiver converted to velocity-modulation reproduction.

I. INTRODUCTION

In the basic velocity-modulation television system, the scanning spots in the camera tube and kinescope move in synchronism. The kinescope beam current is maintained constant, and the horizontal velocities of the spots are varied to produce the changes of brightness in the image. Bright portions of the picture are reproduced by low writing velocities and dark portions are reproduced by high writing velocities. This basic velocity-modulation television system and its variations have received considerable attention in the past.

![Diagram](image)

Fig. 1—Experimental velocity-modulation reproduction system.

In the system described in this paper, the camera tube mosaic is scanned with constant velocity and the video signal is obtained in the usual manner. At the receiver the image is reproduced by varying the horizontal velocity of the spot on the screen of the kinescope by superimposing the video signal on the kinescope horizontal deflection voltage. No video voltage is applied to the kinescope grid so that the beam current is maintained constant. The block diagram of this system is shown in Fig. 1.

The quality of images obtained by velocity-modulation reproduction of standard television broadcasts is too poor for entertainment purposes. However, this system has some important features which are described in the following sections.

II. BASIC ANALYSIS

Equations are now presented which express the brightness along a horizontal line of the reproduced image in terms of the video signal generated by a conventional television camera. These equations are based upon the analysis of an ideal system with negligible aperture and transmission distortion. It is assumed that the light output of the kinescope screen is directly proportional to current density. In this classical system, the television camera functions in the normal manner, and a video signal is produced with an instantaneous amplitude proportional to the brightness along the horizontal line on the camera tube mosaic. After this video signal has passed through the appropriate transmission channels and through the video amplifier of the receiver, it is superimposed upon the horizontal sawtooth sweep voltage. The beam current of the kinescope remains constant during the active portion of its trace period.

The instantaneous horizontal position and velocity of the spot are given by

\[ x = v_0 t \pm k \cdot F(t) \]  

(1)

and

\[ \frac{dx}{dt} = v_0 \pm k \cdot F'(t) \]  

(2)

where \( x \) is the horizontal distance along the line, \( v_0 \) is the constant scanning velocity in the absence of a video signal, \( t \) is the time that has elapsed since the spot began scanning the line, \( F(t) \) is the video signal generated by the camera, and \( k \) is the proportionality constant which relates the video voltage with the resulting deflection on the kinescope screen. Since the brightness of the trace is inversely proportional to the absolute magnitude of the spot velocity, it follows from (2) that

\[ B(x) = B_0 \left| 1 \pm Q \cdot F'(t) \right| \]  

(3)

where \( B(x) \) is the brightness of the trace at a distance \( x \) along the scanning line, \( B_0 \) is the ambient brightness of the raster in the absence of the video signal, and \( Q \) is equal to \( k/v_0 \).

In the normal range of operation of this velocity-modulation system, the spot displacement \( k \cdot F(t) \) is of the order of one spot diameter and the term \( Q \cdot F'(t) \) is less than unity. To a first approximation, therefore, the parametric equations (1) and (3) become...
\[ x = v_0 t \]  \hspace{1cm} (4)

and
\[ B(x) = B_0 \left| 1 \pm Q \cdot F'(t) \right|. \]  \hspace{1cm} (5)

Equation (4) indicates that for small spot excursions there is negligible positional distortion of the reproduced picture element. Equation (5) indicates that to a first approximation there is produced a pattern whose brightness is proportional to the derivative of the video signal superimposed on a raster of brightness \( B_0 \).

### III. GENERAL ANALYSIS

An entirely different presentation is obtained if some operation is performed on the video signal prior to its insertion in the kinescope horizontal deflection circuit. This is readily achieved through the use of band-pass filters, differentiating and integrating amplifiers, or other wave-shaping circuits. In this case, the parametric equations are

\[ x = v_0 t \pm k \cdot g(t) = v_0 t \]  \hspace{1cm} (6)

and
\[ B(x) = B_0 \left| 1 \mp Q \cdot G'(t) \right| = B_0 \left| 1 \mp Q \cdot g'(t) \right|. \]  \hspace{1cm} (7)

where \( G(t) \) is the video signal \( F(t) \) after passing through the network. A response of particular importance is obtained when \( G(t) \) is the integral of \( F(t) \), so that
\[ B(x) = B_0 \left| 1 \mp Q \cdot F(t) \right|. \]  \hspace{1cm} (8)

It is evident from (8) that for signals of small magnitude and of the proper polarity, integration of the video signal produces a true reproduction of the televised image superimposed upon a raster of ambient brightness \( B_0 \). The contrast range of this image is obviously very limited. It should be noted that the desired integration may be performed by a standard uncompensated sweep amplifier, or by the inherent integrating action of the television camera tube operating into a high-impedance circuit.

Let us consider that the video signal \( F(t) \) is the square-wave signal shown in Fig. 2(a). The resulting response shown in Fig. 2(c) closely approximates the derivative of the square wave superimposed on a raster of uniform brightness. If this square wave, however, is integrated, it becomes the pyramid wave shown in Fig. 3(a) which produces the square wave of brightness response shown in Fig. 3(c). It is evident that Fig. 3(c) is, to a first approximation, a true reproduction of the original square-wave video signal on a background of uniform brightness. The rasters shown in these photographs were synthesized by use of a standard oscilloscope and an auxiliary sawtooth generator.

![Fig. 2—Velocity reproduction of square-wave signal. (a) Signal superimposed on horizontal sweep voltage, (b) portion of expanded raster, and (c) resulting image.](image1)

![Fig. 3—Velocity reproduction of pyramid signal. (a) Signal superimposed on horizontal sweep voltage, (b) portion of expanded raster, and (c) resulting image.](image2)

### IV. OVERLAP CONDITION

Upon consideration of the basic principles of velocity reproduction, it is seen from (2) that when the magnitude of \( k \cdot F'(t) \) is sufficiently large, the spot velocity will become negative. This will result in overlap of the reproduced line, and the retraced portion of the line will receive more than one contribution of brightness in the course of a single line period. This overlap condition is of importance for the reproduction of two-tone subject matter such as printing, maps, and circuit diagrams.

Velocity reproduction employing overlap is compared with standard television reproduction of a vertical black bar with a narrow test wedge in Fig. 4. Velocity reproduction of a standard television test pattern is shown in Fig. 5. This method of presentation results in the outlining of two-tone objects by a light band on one side and a dark band on the other side, so that only the outline of the televised object is visible. The width of these outlining bands is proportional to the magnitude of the video signal, and the relative positions of the bands are determined by the polarity of the video signal. The image has a unique embossed appearance although the original subject matter consists of two-dimensional material.
VI. Spurious Images in Standard Television Systems

This investigation indicates that spurious coupling between the video and deflection channels in a television camera or receiver will produce a velocity-modulated image superimposed upon the regular picture. A signal of 50 millivolts or less, spuriously coupled into the grid circuit of the horizontal deflection amplifier is sufficient to produce a halo effect which may be erroneously ascribed to excessive high-frequency peaking or to ghost images. This interference may be present in electrostatic or magnetic-deflection receivers due to improper design and construction or failure of component parts. Furthermore, stray voltages derived from the 60-cycle power system, the radio-frequency power supply, or the 4.5-Mc intercarrier beat frequency, may produce velocity-modulation distortion similar in appearance to that caused by stray voltages in the kinescope grid circuit.

Although this paper is principally concerned with velocity modulation in the horizontal direction, it is also recognized that stray signals coupled into camera or receiver vertical deflection circuits will produce spurious displacement of the scanning or writing spots in the vertical direction.

VII. Conclusions

It is felt that the principal importance of this investigation of velocity-modulation reproduction of video signals may be summarized as follows:

1. One form of velocity reproduction imparts a three-dimensional appearance to two-tone subject matter and may have some application for the reproduction of printed material and line drawings or for radar scope displays. However, the three-dimensional effect obtained bears no direct relationship to the true three-dimensional characteristics of the scene being transmitted.

V. Velocity Reproduction of Video Broadcasts

In order to observe velocity reproduction of typical television broadcasts, a 7-inch electrostatic-deflection television receiver was converted for velocity television reproduction. This conversion was accomplished by coupling the video signal into the grid circuit of the horizontal sweep amplifier through a capacitor of two micromicrofarads. The normal video input to the kinescope was disconnected and care was exercised to remove all traces of intensity modulation. A 1,000-micromicrofarad capacitor connected from the vertical sweep generator to the kinescope provided blanking during the vertical retrace period. Fig. 6 is a photograph from a regular television broadcast received on this converted receiver. Since differentiation is inherent in the velocity reproduction process, a considerable amount of detail is present despite the fact that the video signal was amplified by the uncompensated horizontal-deflection sweep amplifier.
2. The observation of standard television broadcasts on a modified receiver indicates that an apparent improvement in resolution may be obtained by the use of the proper degree of velocity modulation in combination with beam-intensity modulation.

3. This investigation indicates a type of picture distortion which may arise in standard television systems due to spurious signals coupled into the horizontal, or vertical, sweep circuits.

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Use of Image Converter Tube for High-Speed Shutter Action*

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Summary—The equipment described provides a means for obtaining high-speed photographs while utilizing a continuous light source. The device may be pulsed once for "one-shot" exposures or repetitively for motion pictures or stroboscope applications. The heart of the equipment is an image converter tube such as the 1P25. Images are impressed on the photocathode and the tube is pulsed electrically for a duration equal to the exposure time desired. The image will then appear on the fluorescent screen and may be viewed directly or photographed.

I. Introduction

HIGH-SPEED photography has found considerable use in the development of military projectiles, but the conditions under which these pictures have been taken are very limited. The need for a convenient means of taking such photographs has led to considerable research by various organizations into photographic methods.

The absence of a mechanical shutter which would allow an exposure time in the order of one microsecond, at a predetermined time with respect to the projectile flight, has, to the present, made it generally necessary to eliminate the shutter action entirely and to depend solely upon a light flash of proper duration to give the desired exposure. In such a system, synchronization is accomplished by triggering the light at the desired time of exposure. The camera shutter is then open for a relatively long time during which the film would become exposed by ambient light if preventive measures are not taken. This is generally accomplished by taking the pictures at night or by providing lightproof enclosures for the camera and subject matter.

The requirement of a darkened area for such a system limits its use in many ways. This disadvantage has been overcome somewhat by use of the Kerr cell as a shutter. However, it also has its faults, the most important being its low light efficiency. The use of an image converter tube as a high-speed shutter gives excellent promise of results similar to those of the Kerr cell but with much greater light efficiency.

Image converter tubes available at this time do not have 100-per cent light efficiency when used as high-speed shutters. A tube developed especially for this purpose could easily have a light efficiency exceeding 100 per cent, which compares with an efficiency of less than 50 per cent for the Kerr cell.

Bibliography


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II. Experimental Results

The model which has been used at the Naval Ordnance Laboratory in the experiments to be described, makes use of the 1P25 image converter tube as shown in Fig. 1. This is one of the tubes used during World War II as part of the "Snooperscope" and "Sniperscope," which were used for night observation with infrared sources of illumination. Such uses have been well described in recent magazine articles. The photocathode, which was purposely made most sensitive to infrared light, is at the left end of the tube and the fluorescent screen, which is a green phosphor, is at the right end. Fig. 2 shows how the tube is used to obtain high-speed photographs.

In operation, an image is focused upon the photocathode by a conventional lens system. The tube is then energized by a high-voltage pulse which is equal, in duration, to the exposure time desired. The negative polarity of the pulse is connected to the photocathode and the positive polarity of the pulse is connected to the accelerator and focusing electrodes. The applied voltage will cause the electrons leaving the photocathode to impinge upon the fluorescent screen and thereby reproduce the image as it appeared on the photocathode. The image will remain upon the fluorescent screen for the duration of the pulse plus an additional period determined by the persistence of the screen. The screen may be viewed as the action takes place or the image may be focused upon a photographic film. Hence, we have a device that may be used similarly to a conventional light shutter, but it should be kept in mind that it is not exactly equivalent to a mechanical shutter or Kerr cell, because the light output originates from a different source than the light input.

Fig. 3 shows a two-microsecond exposure taken of the edge of a wheel which is 9 in. inches in diameter and is rotating at 9,000 rpm. Obviously, this photograph does not prove that the exposure time was two microseconds, since a fifteen-microsecond exposure would have been sufficient, but the equipment exposure-time capabilities have been verified by other means such as photographing bullets in flight.

Photographs of small objects have been taken using two-microsecond exposures. Shadowgraphs have been taken using one-half-microsecond exposures. The present limitation upon conventional photographs (light being reflected from the object) is the difficulty in ob-
with much less subject lighting than required for "one-shot" photographs. It is, therefore, most convenient to use the device as a stroboscope when photographing repetitive action.

![Diagram](image)

**Fig. 6—Block diagram of stroboscopic application.**

Thus far the basic principles have been indicated, showing how the tube may be used as a light shutter, but, in practice, further refinements are required to make the apparatus perform satisfactorily.

It was first found necessary to prevent exposure of the photographic film by ambient light which leaked through the tube. These light difficulties were overcome by using an infrared filter ahead of the tube, so that only infrared light was allowed to enter the tube and reach the film. This light was made harmless by the use of orthochromatic film, such as Eastman's Lino- graph-Ortho, which is insensitive to red. Since the photocathode is peaked for infrared response, the addition of the filter causes very little loss in the intensity of the fluorescent output image.

To obtain proper voltage distribution across the tube electrodes for short pulses, a voltage divider circuit was designed as shown in Fig. 7. With such an arrangement, the voltage divider is effective on short pulses or continuous current. The condenser values are chosen so that their capacity, in combination with their respective electrode capacity, results in the proper apportionment of the pulse voltage. The condensers do not interfere with very long pulses or continuous operation, leaving control, under such circumstances, to the resistors. By keeping the resistors and condensers to their minimum values, no defocusing has been experienced throughout the pulse range from continuous operation to one-half microsecond. The minimum value of the condensers is determined by the interelectrode capacitance between the 600- and 4,000-volt electrodes. No external condenser is used across these points; hence, this capacity can be taken as a basis for computing the values of the other condensers. The minimum value of the resistors is determined by the power-output capabilities of the pulse power source and the power-dissipating abilities of resistors suitable for the circuit.

During early experiments, the pulse sources consisted of high-voltage pulse-forming networks discharged through hydrogen thyratrons. It was later found convenient to use a war-surplus radar modulator which has a choice of one-, one-half-, or two-microsecond pulse outputs. The magnetron was removed and a load resistor substituted for it. Practically the entire output of the modulator is dissipated in the load resistor since the image converter tube current is in the order of milliamperes and its voltage divider draws only a few milliamperes. The modulator had the advantage over our simple pulse-forming networks of a superior square wave form.

A square wave is required in order to obtain the maximum efficiency for a given exposure time.

### III. Conclusion

The present stage of development, for the complete system, is limited by the resolution capabilities of the fluorescent screen (or its size) and the over-all light efficiency of the tube. It is fairly certain that a tube can be built with a larger photocathode and fluorescent screen to give good picture quality and it is also fairly certain that such a tube could have a much greater light efficiency than the IP25. Therefore, it may be reasonably assumed that such a system can be developed to the point where one- or two-microsecond exposures can be taken, with good quality, using conventional lighting systems.

The use of such a system should considerably reduce the cost of projectile photography as well as provide a much more convenient means. It should also find applications in many instances where flash tubes are now used to stop action. It is also likely that uses will be found where flash tubes will provide all or part of the necessary illumination but where the image converter tube will be depended upon to "stop" the action. An example of such an application would be a condition where there was appreciable continuous light but not enough for the desired exposure. In such a case, it may be most economical to supply the supplemental light with a flash tube having a duration relatively long when compared with the exposure time desired.

It is recognized that this device will not fill all the needs for high-speed photography or stroboscopic observation, but it is expected to be more convenient and economical in some applications and a valuable supplement in others.
Standards on Electronic Computers: Definitions of Terms, 1950*

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Access Time. (1) The time interval, characteristic of a memory or storage device, between the instant at which information is requested of the memory and the instant at which this information begins to be available in useful form. (2) The time interval between the instant at which information is available for storage and the instant at which it is effectively stored.

Accumulator. A device which stores a number and, upon reception of a new number, adds it to the previous contents and stores the sum.

Accuracy. The quality of correctness or freedom from error. Distinguished from precision as in the examples:

(a) "... this procedure measures the precision (reproducibility) of the test, not its accuracy (closeness to the true value)."

(b) A four-place table correctly computed is more accurate but less precise than a six-place table containing errors.

See also: Precision.

Adder. A device which can form the sum of two or more numbers, or quantities, impressed upon it.

Adder, Algebraic. See Algebraic Adder.

* Reprint orders of this Standard, 50 IRE 8.51, may be purchased while available from The Institute of Radio Engineers, 1 East 79 Street, New York 21, N. Y., at $0.75 per copy. A 20-per cent discount will be allowed for 100 or more copies mailed to one address.
Address. Information (usually a number) which designates a particular location in a memory or storage device.

Algebraic Adder. An adder which can form an algebraic sum.

Amplifier, Torque. See Torque Amplifier.

Analog (in computer work). A physical system on which the performance of measurements yields information concerning a class of mathematical problems.

Analog Computer. A physical system together with means of control for the performance of measurements (upon the system) which yield information concerning a class of mathematical problems. In an analog computer quantities are represented without explicit use of a language.

See also: Language.

"And" Circuit. See Gate.

Arithmetic Element. That part of a computer which performs arithmetic operations.

Synonyms: Arithmetic Organ and Arithmetic Unit.

Arithmetic Organ. See Arithmetic Element.

Arithmetic Unit. See Arithmetic Element.

See also: Parallel Arithmetic Unit and Serial Arithmetic Unit.

Base (or Radix). See Radix (or Base).

Binary Cell. An information-storing element which can have one or the other of two stable states.

Binary-coded Decimal System. A system of number representation in which the decimal digits of a number are expressed by binary numbers.

Binary Digit. A digit of a binary number.

See also: Memory Capacity or Storage Capacity.

Binary Number System. A number system which uses two symbols (usually denoted by "0" and "1") and has two as its base, just as the decimal system uses ten symbols ("0, 1, ..., 9") and the base ten.

See also: Positional Notation and Radix.

Binary Point. The radix point in the binary system.

Block. A group of words considered as a unit.

See also: Word.

Break Point. A point in a program at which a special instruction is inserted which, if desired, will cause a digital computer to stop for visual check of progress during the initial checking of a problem.

Buffer. (1) An isolating circuit used to avoid reaction of a driven circuit upon the corresponding driving circuit. (2) A circuit having an output and a multiplicity of inputs so designed that the output is energized whenever one or more inputs are energized. Thus, a buffer performs the circuit function which is equivalent to the logical "or."

Bus (in computer work). One or more conductors which are used as a path for transmitting information from any of several sources to any of several destinations.

Carry. (1) A condition occurring in addition when the sum of two digits in the same column equals or exceeds the base of the number system in use. (2) The digit to be forwarded to the next column. (3) The action of forwarding it.

Cascaded Carry. A system of executing the carry process in which carry information can be passed on to place (N+1) only after the Nth place has received carry information or has itself produced a carry.

See also: Complete Carry, Partial Carry, Self-instructed Carry, Separately Instructed Carry and Stalling on Nines Carry.

Cell, Binary. See Binary Cell.

Character. One of a set of elementary symbols which may be arranged in ordered aggregates to express information.

Check Problem. A problem whose incorrect solution indicates an error in the operation or programming of a computer.

Circulating Memory. A memory consisting of a means for delaying information and means for regenerating an information or reinserting the information into the delaying means.

Clear (verb). To restore a storage or memory device to a prescribed state, usually that denoting zero.

Clock, Master. See Master Clock.

Code. (1) A system of symbols and rules for representing information. (2) Loosely, the set of characters resulting from the use of a code. (3) To express information by means of a code.

See also: Language.


Code, Instruction. See Instruction Code.

Coded Program. A description of a procedure for solving a problem by means of a digital computer. It may vary in detail from a mere outline of the procedure to an explicit list of instructions coded in the machine's language.

See: Program.

Column. In Positional Notation a position corresponding to a given power of the radix. A digit located in any particular column is a coefficient of a corresponding power of the radix.

Synonym: Place.

Command. One of a set of several signals (or groups of signals) which occurs as the result of an instruction; the commands initiate the individual steps which form the process of executing the instruction.

See also: Instruction.

Comparator. A circuit which compares two signals and supplies an indication of agreement or disagreement.

Complement. A number whose representation is derived from the finite positional notation of another by one of the following rules:

(a) True complement—Subtract each digit from the radix less 1, then add 1 to the least significant digit, executing any carries required.
Digital Computer. One in which information, numerical or otherwise, is represented by means of combinations of characters in such a way that the number of distinguishable combinations is much greater than the number of distinguishable characters. Thus, a digital computer is one which makes explicit use of a language.

See also: Language.

Dispatcher (in computer work). That part of a digital computer which performs the switching determining the sources and destinations for the transfer of words.

Double-Precision Number. A number having twice as many significant digits as are ordinarily used in a particular computer.

Dynamic Sequential Control. A method of operation in which a digital computer, as the computation proceeds, can alter instructions, or the sequence in which instructions are executed, or both.

Electrical Function Switch. See Function Switch.

Electrostatic Memory. A memory device utilizing electrostatic charge as the means of retaining information, involving usually a special type of cathode-ray tube together with associated circuits.

Electrostatic Memory Tube. An electron tube in which information is retained by means of electric charges.

Synonym: Storage Tube.

Equation Solver. A computing device, often of the analog type, which is designed to: (a) Solve systems of linear simultaneous (non-differential) equations, or (b) find the roots of polynomials, or both.

Error. The quantity which is subtracted from a calculated value to obtain the correct value.

Error, Round-Off. See Round-Off Error.

Error, Truncation. See Truncation Error.

Excess 3 Code. A code for numerical data in which each decimal digit \( d \) is represented by the binary number \((d+3)\).

Extract Instruction. In a digital computer, the instruction to form a new word by juxtaposing selected segments of given words.

Fixed-Point System. A system of number notation in which a number is represented by a single set of digits and in which the position of the radix point is not numerically expressed.

See also: Floating-Point System.

Flip-flop. An electronic circuit having two stable states and ordinarily two input terminals (or types of input signals) each of which corresponds with one of the two states. The circuit remains in either state until caused to change to the other state by application of the corresponding signal.

Floating-Point System. A system of number notation in which two sets of digits are used, the added set being included to denote the location of the radix point.

See also: Fixed-Point System.

Flow Diagram. A graphical representation of a sequence of operations.
Function Switch. A network or system having a number of inputs and outputs and so connected that signals representing information expressed in a certain code, when applied to the inputs, cause output signals to appear which are a representation of the input information in a different code.

Function Switch, Many-One. A function switch in which a combination of the inputs is excited at one time to produce a corresponding single output.

Function Switch, One-Many. A function switch in which only one input is excited at a time and each input produces a combination of outputs.

Function Unit. A device which can store a functional relationship and release it continuously or in increments.

Gate. (1) A circuit having an output and a multiplicity of inputs so designed that the output is energized when and only when a certain definite set of input conditions are met. In computer work, a Gate is often called an "and" circuit. (2) A signal used to enable the passage of other signals through a circuit.

Half-Adder. A circuit having two input and two output channels for binary signals (0, 1) and in which the output signals are related to the input signals according to the following table:

<table>
<thead>
<tr>
<th>Input to A</th>
<th>Output from S</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0 1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1 0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1 1</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

(See called because two half-adders may be used to form one adder.)

Holding Beam. A diffuse beam of electrons for regenerating the charges retained on the dielectric surface of an electrostatic memory or storage tube.

Input Equipment. The equipment used for introducing information into a computer.

Inscriber. Input transcriber.

Instruction. Information which, when properly coded and introduced as a unit into a digital computer, causes it to perform one or more of its operations. An instruction commonly includes one or more addresses.

Instruction Code. A code for representing the instructions which a particular digital computer can execute.

See also: Multiple-Address (Instruction) Code and Single-Address (Instruction) Code.

Instruction, Extract. See Extract Instruction.

Instruction, Transfer (of control). See Transfer (of control) Instruction.

Integrator. A device whose output is proportional to the integral of an input signal.

Language. A set of symbols, with rules for the combination of these symbols, which may be used to express information, such that the sum of the number of symbols and the number of rules is much smaller than the number of distinct expressible meanings.

See also: Code.

Major Cycle. In a memory device which provides serial access to storage positions, the time interval between successive appearances of a given storage position.

Master Clock. The primary source of timing signals.

Memory. Any device into which information can be introduced and then extracted at a later time. The mechanism or medium in which the information is retained commonly forms an integral part of a computer.

See also: Storage.

Memory Capacity. The maximum number of distinguishable stable states in which a memory device can exist is a measure of its capacity. It is customary to use the logarithm to the base two of that number as a numerical measure of the memory capacity. In this case, the unit of memory capacity is a binary digit.

Memory, Circulating. See Circulating Memory.

Memory, Delay-Line. See Delay-Line Memory.

Memory, Electrostatic. See Electrostatic Memory.

Memory Tube, Electrostatic. See Electrostatic Memory Tube.

Minor Cycle. In a digital computer using serial transmission, the time required for the transmission of one word, including the space between words.

Multiple-Address (Instruction) Code. An instruction in general consists of a coded representation of the operation to be performed and of one or more addresses of words in storage. The instructions of a multiple-address code contain more than one address.

Multiplier (in computer work). A device which has two or more inputs and whose output is a representation of the product of the signed magnitudes represented by the input signals.

Notation, Positional. See Positional Notation.

Number. (1) Formally: An abstract mathematical entity defined by the rules governing the relations and operations to which it is susceptible. In this sense, a number is independent of the manner of its representation. (2) Commonly: A representation of a number as defined above, such as a "binary number," or a "decimal number," or a sequence of pulses. (3) In a digital machine, a word composed only of digits and possibly a sign.

Number, Double-Precision. See Double-Precision Number.

Number System. Any system for the representation of numbers.

See for example: Binary Number System.

See also: Number and Positional Notation.

Operand. A word on which an operation is to be performed.

Operation. (1) The activity resulting from an instruction. (2) The execution of a set of commands.

Operation Code. That part of an instruction which designates the operation to be performed.
"Or" Circuit. See Buffer.
Order. The term Instruction is preferred. See Instruction.
Organ. A portion or subassembly of a computer which constitutes the means of accomplishing some inclusive operation or function, as: Arithmetic Organ.
Output Equipment. The equipment used for obtaining information from a computer.
Outscriber. Output transmitter.
Overflow. (1) The condition which arises when the result of an arithmetic operation exceeds the capacity of the number representation in a digital computer. (2) the carry digit arising from this condition.
Parallel Arithmetic Unit. One in which separate equipment is provided to operate (usually simultaneously) on an digits in each column.
See also: Serial Arithmetic Unit.
Parallel Transmission. The system of information transmission in which the characters of a word are transmitted (usually simultaneously) over separate lines, as contrasted to Serial Transmission.
Partial Carry. A system of executing the carry process in which the carries that arise as a result of a carry are not allowed to propagate.
See also: Cascaded Carry, Complete Carry, Self-instructed Carry, Separately Instructed Carry, Standing Nines Carry.
Place. See Column.
Plotting Board. A device which plots one or more variables against one or more other variables.
Point, Binary. See Binary Point.
Point, Decimal. See Decimal Point.
Point, Radix. See Radix Point.
Positional Notation. One of the schemes for representing real numbers, characterized by the arrangement in sequence of digits (symbols for integers) with the understanding that the successive digits are to be interpreted as the coefficients of successive integral powers of number called the radix or base of the notation.
The representation of a real number by the notation
\[ A_n A_{n-1} \cdots A_1 A_0 . A_{-1} A_{-2} \cdots A_{-m} \]
which is an abbreviation for the sum
\[ \sum_{i=-m}^{n} A_i r^i, \]
where the \( r \) is called the radix point, the \( A_i \) are integers \( 0 \leq |A_i| \leq r \) called digits, and \( r \) is an integer greater than one called the radix (or base). The signs of all of the \( A_i \) are the same as the sign of the number represented.
In the decimal number system, the radix is ten and the radix point is called the decimal point. In the binary number system, the radix is two and the radix point is called the binary point.
For some purposes the system of notation has been broadened to include the case in which the radix as-

sumes more than one value in a single number system.
In this case the notation
\[ A_n A_{n-1} \cdots A_1 A_0 . A_{-1} A_{-2} \cdots A_{-m} \]
is an abbreviation for the sum
\[ \left( \sum_{i=-m}^{n} A_i r^i \right) + A_0 + \left( \sum_{i=1}^{n} A_i \prod_{j=1}^{i-1} r_j \right). \]
Several such systems have been used. The biquinary system uses a radix which is alternately two and five for successive values of \( j \). The quinary vigesimal system uses a radix which is alternately five and twenty for successive values of \( j \).
For the names of various number systems, as characterized by their radix, see Radix.
Precision. Quality of being exactly or sharply defined or stated. A measure of the precision of a representation is the number of the distinguishable alternatives from which it was selected.
See also: Accuracy.
Problem, Check. See Check Problem.
Problem, Trouble Location. See Trouble Location Problem.
Program. (1) A set of instructions arranged in proper sequence to instruct a digital computer to perform a desired operation (or operations), such as the solution of a mathematical problem or the collation of a set of data. (2) To prepare a program (contrast with "to code").
See: Coded Program.
Radix (or Base) (of the positional notation system of numbers). The integer of whose successive powers the digits of a number are the coefficients.
Symbolically: \[ \cdots + a_{v} r^{v} + a_{v-1} r^{v-1} + \cdots + a_{r-1} r + a_{r} \]
is written \[ a_{v} a_{v-1} a_{v-2} \cdots a_{r} \] where \( r \) is the radix and the \( a_{i} \) are the integers \( 0 \leq a_{i} \leq r - 1 \). For example, in the number \( r \) written in the common decimal system, we have: \( r = 10 \); \( a_{v} = a_{v-1} = 0; a_{v-2} = 3; a_{v-3} = 1 \); \( a_{r} = 4 \).

Synonym: Base.
See also: Positional Notation.
The adjectives used for describing various number systems, as characterized by their radices are given below:

<table>
<thead>
<tr>
<th>Base or Radix</th>
<th>Adjective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two</td>
<td>Binary</td>
</tr>
<tr>
<td>Three</td>
<td>Tertiary</td>
</tr>
<tr>
<td>Four</td>
<td>Quaternary</td>
</tr>
<tr>
<td>Five</td>
<td>Quinary</td>
</tr>
<tr>
<td>Six</td>
<td>Senary</td>
</tr>
<tr>
<td>Seven</td>
<td>Septenary</td>
</tr>
<tr>
<td>Eight</td>
<td>Octonary (loosely called Octal)</td>
</tr>
<tr>
<td>Nine</td>
<td>Novenary</td>
</tr>
<tr>
<td>Ten</td>
<td>Decimal</td>
</tr>
<tr>
<td>Eleven</td>
<td>Undecimal</td>
</tr>
<tr>
<td>Twelve</td>
<td>Duodecimal</td>
</tr>
<tr>
<td>Thirteen</td>
<td>Ternary</td>
</tr>
<tr>
<td>Fourteen</td>
<td>Quaternary</td>
</tr>
<tr>
<td>Fifteen</td>
<td>Quinonary</td>
</tr>
<tr>
<td>Sixteen</td>
<td>Sexadecimal</td>
</tr>
<tr>
<td>Seventeen</td>
<td>Septendecimal</td>
</tr>
<tr>
<td>Eighteen</td>
<td>Octodecimal</td>
</tr>
</tbody>
</table>
### Number System

A number system is in which a quantity is represented. For example, associated with negative powers from those associated can be found in standard dictionaries while the "ary" word cannot.

#### Radix Point

The index which separates the digits associated with negative powers from those associated with the zero and positive powers of the base of the number system in which a quantity is represented. For example, binary point, decimal point.

#### Read

To extract information.

#### Register

A device capable of retaining information which is usually a subset of the aggregate information in a digital computer.

#### Register, Delay-Line

See Delay-Line Register.

#### Register, Static

See Static Register.

#### Resolver

Means for resolving a vector into two mutually perpendicular components.

#### Roll Out (verb)

To read out of a storage device by simultaneously increasing by one the value of the digit in each column and repeating this \( r \) times (where \( r \) is the radix) and, at the instant the representation changes from \( (r-1) \) to zero: (a) generating a particular signal, or (b) terminating a sequence of signals, or (c) originating a sequence of signals.

#### Round-Off (verb)

To delete less significant digits from a number and possibly apply some rule of correction to the part retained.

#### Round-Off Error

Error resulting from rounding off.

#### Routine

A sequence of operations which a digital computer may perform, or the sequence of instructions which determine these operations.

#### Scale Factor

(1) In analog computing, a proportionality factor which relates the magnitude of a variable to its representation within a computer. (2) In digital computing, the arbitrary factor which may be associated with numbers in a computer to adjust the position of the radix point so that the significant digits occupy specified columns.

#### Self-instructed Carry

A system of executing the carry process in which information is allowed to propagate to succeeding places only on receipt of a specific signal.

See also: Cascaded Carry, Complete Carry, Partial Carry, Self-instructed Carry, Standing on Nines Carry.

#### Separately Instructed Carry

A system of executing the carry process in which carry information is allowed to propagate to succeeding places only on receipt of a specific signal.

See also: Cascaded Carry, Complete Carry, Partial Carry, Separately Instructed Carry, Standing on Nines Carry.

#### Significant Digits

The digits of a number can be ordered according to their significance: the significance of a digit is greater when it occupies a column corresponding to a higher power of the radix. The significant digits of a number are a set of digits from consecutive columns beginning with the most significant digit different from zero and ending with the least significant digit whose value is known or assumed to be relevant.

#### Simulation

The representation of physical systems by computers and associated equipment.

#### Single-Address (Instruction) Code

An instruction in general consists of a coded representation of the operation to be performed and of one or more addresses of words in storage. The instructions of a single-address code contain only one address.

#### Storage

(1) Any device into which information can be introduced and then extracted at a later time. The mechanism or medium in which the information is stored need not form an integral part of a computer. (2) The act of storing information.

See also: Memory.
A Precision Decade Oscillator for 20 Cycles to 200 Kilocycles

CHARLES M. EDWARDS†, MEMBER, I.R.E.

During the past few years numerous technical articles have been written on the subject of oscillator circuits utilizing resistance-capacitance tuning elements. The more common types have been designated as bridge-stabilized, parallel, or phase shift. In most of these treatments, the authors have praised the results which can be obtained by resistance-capacitance tuning, namely, high frequency stability, good wave form, and constant output over a wide frequency range, but have made little mention of the frequency accuracy which could be expected. Some writers have estimated a few per cent as being realizable and there are available commercial units which are reliable to within 2 or 3 per cent. For some applications, frequency accuracy approaching 0.1 per cent is required of oscillators operating in the audio- and carrier-frequency ranges.

An RC-type oscillator with a frequency accuracy of 0.1 per cent over a range of 100 cps to 100,000 cps has been developed for a testing application at Western Electric. For the ranges of 20 cps to 100 cps and 100 kc to 200 kc, the accuracy is 0.5 per cent. The unit is composed of three sections: an RC oscillator, a power amplifier, and a power supply.

Fig. 1 presents a simplified version of the oscillator circuit which consists of a two-stage amplifier with a resistance-capacitance bridge circuit connecting the

Trouble-Location Problem. A test problem whose incorrect solution supplies information on the location of faulty equipment; used after a check problem has shown that a fault exists.

Truncation Error. Error resulting from the approximation of operations in the infinitesimal calculus by operations in the calculus of finite differences.

Unconditional Transfer (of control). In a digital computer which obtains its instructions serially from an ordered sequence of addresses, an instruction which causes the following instruction to be taken from an address which becomes the first of a new sequence.

Verification. The process of automatically checking one data typing or recording process against another for the purpose of reducing the number of human errors in data transcription.

Volatile. The attribute of a memory device that information is lost in the event of a power interruption.

Word. An ordered set of characters having a meaning and considered as a unit. Digital computers commonly use a fixed word length (that is, a fixed number of characters) which is a characteristic of each computer.

Write. To introduce information, usually into some form of storage.
output of \( V_1 \) to the input of tube \( V_1 \). The main tuning elements in the bridge are \( C_1 \), \( C_2 \), \( R_1 \), and \( R_2 \), while \( C_4 \) and \( R_3 \) are frequency-trimming elements. Thermistor \( R_5 \) is a negative-temperature-coefficient stabilizing element and lamp \( R_6 \) is a positive-temperature-coefficient stabilizing element.

The decade tuning in any one range is accomplished by three dials. Two of the dials have 10 values of resistors related on a decimal basis, with 100 to 1,000 cycles on the first and 10 to 100 cycles on the second. The third dial operates a linear potentiometer for continuous variations between 0 and 10 cycles. The hundreds decade dial has an additional position marked 0.1 cycle to provide for the 20-100 cycle range.

When the resistors on one dial are added in parallel to those on another, the frequency is the sum of the dials as indicated by the following relations:

\[
t_1 = \frac{1}{B R_{10}} \quad \text{and} \quad f_2 = \frac{1}{B R_{10}}
\]

where

\[
B = 2\pi C_9
\]

and

\[
R_0 = R_1 = R_2, \quad \text{and} \quad C_0 = C_1 = C_2
\]

then

\[
f_1 = f_1 + f_2 = \frac{1}{B} \left( \frac{1}{R_0} + \frac{1}{R_0} \right)
\]

Three ranges are provided through varying the capacitors \( C_2 \) and \( C_3 \) by factors of 10 to provide \( \times 1, \times 10 \) and \( \times 100 \). An additional resistor is added in parallel to the main tuning resistors when the range dial is thrown to position \( \times 100+100 \) kc.

Good tracking over the wide frequency range is accomplished by two trimming arrangements and a wide-band amplifier. A number of miniature rheostats, indicated as \( R_{1a} \) in Fig. 1, individually adjust each of the resistors on the hundreds and tens decades for trimming at the low end of the frequency range. Similarly, a number of miniature variable capacitors, labeled \( C_{1a} \) in Fig. 1, individually adjust the distributed capacity for each position on the hundreds and the tens decades for trimming at the high end of the frequency range.

The wide-band amplifier has a gain of approximately 200 and is compensated for minimum phase shift at the high and low frequency ends of the range. The effects on the oscillator frequency of amplifier phase shift and gain are related by the following approximate expression:

\[
\Delta f = \frac{4.5 \sin \theta}{A}
\]

where

\( \Delta f \) = change in oscillator frequency \( f \) from bridge frequency \( f_b \)

\( \theta \) = amplifier phase shift, including that caused by the feedback capacitor

\( A \) = gain of amplifier.

In addition to good frequency tracking and stability, the bridge-stabilized oscillator has good amplitude stability. When the oscillator amplifier changes gain it is readily shown that the percentage change \( \Delta A \) in the negative feedback ratio \( R/(R_4+R_5) \) is

\[
\Delta A = 100 \left( \frac{A_1 - A_2}{A_2} \right)
\]

Thus for amplifier gain changes as great as 100 per cent from 200 to 100, the amplitude of oscillations changes by only 0.5 per cent, when it is assumed that the resistance of the thermally controlled elements in the bridge varies directly in proportion to the voltages across them. In practice, it is found that the thermal elements vary as some power of the voltage output; therefore a 0.5 per cent change in feedback voltage may be accomplished by as little as 0.2 per cent change in output.

The power-amplifier portion of the unit utilizes negative feedback from the output transformer to the cathode of the input tube. The power-supply portion of the unit is arranged for operation on 115 volts, 60 cycles and includes a VR-150 tube for regulating the voltage supplied to the oscillator section.

Figs. 2 and 3 show the mechanical construction of the unit. Of special interest at the tuning decades in Fig. 3 showing the arrangement of main tuning resistors and small trimming rheostats and capacitors.

Performance results from the oscillator have been good. With monthly checking of frequency alignment can be maintained within 0.1 per cent. Changes in line voltage from 105 to 115 volts cause less than a 0.1 per cent change in frequency on any of the ranges. Including the output amplifier, the output level is constant to within 1 per cent over most of the frequency range and varies by only 5 per cent at the extremities. Harmonic output is less than 1 per cent over most of the range with the second harmonic increasing to about 2 per cent at the extreme edges.

![Fig. 2 — Front view of decade oscillator showing dials.](image-url)

![Fig. 3 — Top view of decade oscillator showing tuning elements.](image-url)

Although the top frequency on this oscillator is 200 kc, the author feels that it should be possible to design a resistance-capacitance oscillator, operating up to one megacycle which is stable and has better than 1 per cent frequency accuracy. In such an application, extra care would have to be exercised in wiring and mechanical stability. Carbon tuning elements would probably be required for low phase angle at this high frequency. Therefore, with carbon elements perhaps a constant-temperature oven might be necessary to maintain good frequency stability.
The General Design of Triple- and Quadruple-Tuned Circuits*

T. C. GORDON WAGNER†, ASSOCIATE, IRE

Summary—Relatively simple formulas for the design of triple-
d quadruple-tuned circuits are developed for the circuit parameters
cessary to produce a desired amplitude response. When using
e equations, the designer is given an almost arbitrary choice of
circuit Q's. An interesting condition is developed for the physical
alizability of triple-tuned circuits.

INTRODUCTION

A LTHOUGH the triple-tuned circuit has received

considerable attention, particularly in the recent

literature, the quadruple-tuned circuit has re-

ceived almost no attention.

The purpose of this paper is to establish concise de-
gn formulas for triple- and quadruple-tuned circuits.
These formulas are in a form which permits an almost
bitrary choice of circuit Q's and give virtually explicit
alues for the coupling coefficients for a given band-
ith and peak-to-valley ratio.

Previous analyses of the triple-tuned circuit make re-
strictive assumptions on the Q's of the three resonant
circuits, so that the results are inflexible and often im-
tractable. As a result of these restrictions, previous
authors seem unaware of the condition

where

which must be satisfied for a physically realizable
design.

The principal advantage of a multiple-tuned circuit
over less complicated circuits may be seen in a compar-
ion of the attenuation outside the pass band. The at-
tenuation provided by a properly designed n-tuned
circuit is given approximately by

where

is a constant defining the fluctuation in the pass band;
and

is the relative bandwidth; and

represents the departure from

the center frequency.

A SUMMARY OF DESIGN FORMULAS

The notation employed is generally similar to that
used in connection with tuned circuit analysis. In addi-
tion to the symbols defined by (1a) through (1d) we

define

where, \( f(u) = 0.5u^2 - 0.25u + 0.125 \).

The design formulas which are to be established are:

**Triple-tuned circuit formulas**

\[
\begin{align*}
x_0'/\alpha &= 0.171(M^2 + x_0^2)(M^2 + 5.85x_0^2), \\
M &= a + b + c + d.
\end{align*}
\]

\[
F(-d) = F(-a)
\]

or,

\[
F(-d) = F(-c)
\]

where in the above

\[
F(-p) = [M^2f_p(M) + 0.854x_0^2][M^2f_p(M) + 0.1463x_0^2],
\]

\[
K_{12} = \frac{F(-d) - F(-a)}{(a - d)} + (c - a)F(-d) = 0,
\]

\[
K_{23} = \frac{F(-b) - F(-a)}{(b - a)} + K_{12} + \frac{K_{12}}{(a - b)}(a + b - c - d)
\]

\[
K_{23} = \frac{F(-c) - F(-d)}{(d - c)} + (c + d - a - b)
\]

\[
K_{34} = \frac{F(-d) - F(-c)}{(d - c)} + K_{23} + \frac{K_{23}}{(d - c)}(c + d - a - b)
\]

\[
K_{34} = \frac{F(-d) - F(-c)}{(d - c)} + K_{23} + \frac{K_{23}}{(d - c)}(c + d - a - b)
\]
and
\[
F(-p) - F(-q) = \frac{(p-q)}{2} \left[ \frac{p+q - 0.293M}{1 - 0.293M} \left( M^2 f_2(p/M) + M^2 f_2(q/M) + 0.293x^2 \right) \right]
\]
\[\left( p - q \right) = \frac{1}{2} \left[ \frac{p+q - 0.293M}{1 - 0.293M} \left( M^2 f_2(p/M) + M^2 f_2(q/M) + 1.707x^2 \right) \right],
\]
the two functions \( f_1 \) and \( f_2 \) being given by
\[
f_1(u) = u^2 - 0.293u + 1.463,
\]
\[
f_2(u) = u^2 - 0.707u + 1.463.
\]
These functions which are to be evaluated for \( n = a/M, \ b/M, \) and so forth are graphed in Fig. 4, and the relation between \( a \) and \( M \) is graphed in Fig. 5.

**The General Electrical Equations**

The type of circuit under consideration consists of \( n \) resonant loops coupled in sequence, that is,
\[
Z_{ij} = 0, \text{ when } |i-j| > 1 \ (i, j = 1, 2, \ldots, n).
\]
An alternative representation is \( n \) resonant nodes. In order to fix one's ideas, two typical circuits are shown in Fig. 1. If we let \( \text{Det}(Z_n) \) be the impedance determinant of a network of the kind illustrated in Fig. 1, we find by conventional loop-current analysis that
\[
(Z_0Z_1Z_2\cdots Z_{n+1})i_0E^{-1} = \text{Det}(Z_n),
\]
\[
(r, s = 1, 2, \ldots, n), \quad (3a)
\]
where \( i_0 \) is the current source, and \( E \) is the output voltage; \( Z_0 \) includes the impedance of the generator, and \( Z_{n+1} \) includes the impedance of the load.

We shall assume that the bandwidth is small enough so that

A. The losses in each loop may be regarded as arising from a constant series resistance.

B. The mutual impedances \( Z_{ij}(i \neq j) \) are pure reactances and may be regarded as constant over the pass band.

C. The \( n \) loops are all resonant at the same frequency. Letting
\[
p = jx
\]
we find that \( \text{Det}(Z_n) \) is a polynomial of degree \( n \) in \( p \) and
\[
K_{in}E^{-1} = p^n + M p^{n-1} + \sum_{n=2}^{n-1} a_K p^K = F(p) \quad (3c)
\]
where \( K \) is a constant.

**The General Amplitude Response**

If we consider the absolute value of \( E \), we see that
\[
K^2i_0/|E| = F(p)F(-p) = G(x^2), \quad (4a)
\]
where \( G(x^2) \) is an \( n \)th degree polynomial in \( x^2 \). For the desired response the fluctuation of \( |E| \) must be limited or for convenience
\[
1 \leq |E_{max}/E|^2 \leq 1 + \sigma^2, \text{ when } 0 \leq x^2 \leq x_0^2.
\]
\( \sigma \) is a measure of the variation of \( |E| \) across the pass band. (\( \sigma = 1 \) for example, corresponds to a 3-dB variation.) At the same time we want a response for which \( |E_{max}/E|^2 \) is as large as possible outside the pass band. It may be shown that the \( n \)th degree polynomial in \( x^2 \), which satisfies both these conditions, is unique and is given by
\[
|E_{max}/E|^2 = 1 + \sigma^2 \cos^2 n\phi, \text{ where } x = x_0 \cos \phi. \quad (4b)
\]
The coefficient of \( x^n \) in (4b) is \( 4^{n-1}\sigma^2/x_0^{2n} \). Comparing (3c) and (4a) with (4b) yields
\[
F(p)F(-p) = \frac{x_0^{2n}x_0^{2n}}{4^{n-1}\sigma^2} [1 + \sigma^2 \cos^2 n\phi] = G(x^2). \quad (4c)
\]

The coefficients of \( F(p) \) depend upon the \( nQ \)'s and the \( n-1 \) coupling coefficients. Equation (4c) leads to \( n \) relations for the \( 2n-1 \) circuit constants, so that \( n-1 \) of them may be chosen arbitrarily and the remaining ones are then determined. For practical reasons it is usually convenient to let \( n-1 \) of the \( Q \)'s be the natural \( Q \)'s of the coils; the remaining \( Q \) (usually \( Q_0 \) or \( Q_n \)) and the coupling coefficients are then determined from the design equations.

**The Determination of \( F(p) \)**

In order to solve (4c) for \( F(p) \), let
\[
p_0 = jx_0 \cos \theta
\]
be a particular root of \( F(p) = 0 \). Then we may write the \( n \) roots as
\[
p_K = jx_0 \cos (\theta + K\pi/n), \quad (K = 0, 1, 2, \ldots, n - 1), \quad (5a)
\]
for these are all roots of \( G(x^2) = 0 \), and the remaining roots are the negatives of (5a). We put
\[
M = -\sum_{n=0}^{n-1} p_K = -jx_0 \sum_{n=0}^{n-1} \cos (\theta + K\pi/n), \quad (5b)
\]
and find that
\[
M = jx_0 \frac{\sin (\theta - \pi/2n)}{\sin \pi/2n}. \quad (5c)
\]
Then (6b) takes the form

\[
Z_{\Omega}z_{\Omega}K_{12}K_{23} \frac{2K}{\omega_0 \sqrt{L_{11}L_{22}}}
\]

\[
( p + a ) ( p + b ) ( p + c ) + K_{12}^2 ( p + c ) + K_{23}^2 ( p + a ) = F(p).
\]

On the other hand, from (5f(2))

\[
F(p) = ( p + M/2 ) ( p^2 + \frac{M}{2} p + M^2/4 + 3x_0^2/4 ),
\]

and equations (5g) become

\[
M = 2x_0 \sinh \left( \frac{1}{3} \sinh^{-1} \frac{1}{\sigma} \right)
\]

\[
2x_0^3/\sigma = M^3 + 3x_0 M.
\]

We identify (6c) with (6d) so that

\[
M = a + b + c,
\]

and putting \( p \) equal to \(-a\) and \(-c\) we find

\[
K_{12} = \frac{F(-a)}{c - a} = \left[ 1 + b/(c - a) \right] \left[ f(a/M) M^2 + \frac{1}{2} x_0^2 \right];
\]

\[
K_{23} = \frac{F(-c)}{a - c} = \left[ 1 + b/(a - c) \right] \left[ f(c/M) M^2 + \frac{1}{2} x_0^2 \right];
\]

where

\[
f(u) = \frac{1}{2} u^2 - \frac{1}{4} u + \frac{1}{8}.
\]

Equations (6c) through (6h) are a complete solution to the design problem, for the bandwidth \( x_0 \), and \( \sigma \) determined \( M \) from (6e). Now two of the \( Q \)'s may be almost arbitrarily chosen and the third determined from (6f). The coupling coefficients may then be found from (6g) and (6h).

Two of the \( Q \)'s may be chosen almost arbitrarily. In order to have a physically realizable solution, all of the \( Q \)'s must be positive and the squares of the coupling coefficients must also be positive. This requires

\[
\left| \frac{1}{Q_3} - \frac{1}{Q_1} \right| > \frac{1}{Q_2}.
\]

It is interesting to note that one solution which is very popular in the literature and assumes

\[
Q_1 = Q_3
\]

blows up completely unless \( Q_2 \) is identically infinite.

It often happens in practice that the value of \( M \) that can be physically obtained is greater than that which would be permissible from the standpoint of allowable \( \sigma \). In this case, the realizable \( \sigma \) may be determined from (6e(2)). The computations may be facilitated by a
In this case all the previous equations still apply.

We define under-critical circuits as those for which

\[ 0 > x_0^2 > -M^2/4 \]

In this case all the previous equations still apply.

**The Triple-Tuned Gain Bandwidth Product**

We put \( p = 0 \) in (4c) and (6c). When \( |Z_{01}| = 1/\omega_0 C_{10} \) and \( Z_{34} = 1/\omega_0 C_{34} \), we find

\[
(f_2 - f_1)E = i_0 \frac{K_{12}K_{23}}{2\pi\sqrt{C_{11}C_{33}}} \times \frac{4\sigma}{x_0^2}.
\]  

(7a)

For a given response, \( K_{12}K_{23} \) is a maximum when \( a = M, b = c = 0 \). Then

\[
(f_2 - f_1)E = \frac{i_0}{2\pi \sqrt{C_{11}C_{33}}} \frac{x_0^2}{M^2 + 3x_0^2} \times \frac{3(M^2 + x_0^2)}{M^2 + 3x_0^2}.
\]  

(7b)

**The Quadruple-Tuned Circuit**

We proceed as in the case of the triple-tuned circuit. The electrical equations take the form

\[
\frac{Z_{02}Z_{45}K_{12}K_{23}K_{34}}{\omega_0 \sqrt{L_{11}L_{44}}} = i_0 E^{-1}
\]

On the other hand, from (5f(1))

\[
F(p) = \left[ p^2 + \left(1 - \frac{\sqrt{2}}{2}\right)Mp + \frac{M^2}{2} \left(1 - \frac{\sqrt{2}}{2}\right)\right]
\]

\[
+ \frac{x_0^2}{2} \left[ p^2 + \frac{\sqrt{2}}{2}Mp \right]
\]

\[
+ \frac{M^2}{2} \left(1 - \frac{\sqrt{2}}{2}\right) + \frac{x_0^2}{2} \left(1 - \frac{\sqrt{2}}{2}\right).
\]  

(8b)

while equations (5g) become

\[
M^2 = (1 + \sqrt{2})x_0^2 \left[ \sqrt{1 + \frac{1}{\alpha}} - \sqrt{2} \right].
\]  

(8c(1))

\[
\frac{1}{\alpha} = \left\{ \sqrt{2^2} - 1 \right\} \left[ \frac{M^2}{x_0^2} + 1 \right] \left( \sqrt{2^2} - 1 \right)
\]

\[
\left[ \sqrt{2^2} - 1 \right] \frac{M^2}{x_0^2} + \sqrt{2} + 1 \]

(8c(2))

where \( \alpha^2 = 1 - E_{\text{min}}^2/E_{\text{max}}^2 \).

We identify (8a) with (8b) so that

\[
M = a + b + c + d.
\]  

(8d)

Putting \( p \) equal to \(-a, -d, -b, \) and \(-c \) we find for \( K_{34}^2 \) and \( K_{12}^2 \),

\[
K_{34}^2 = K_{41}^2 \left[ F(d - a) + (c - a)(a - d) \right] + \frac{F(a - c)}{(b - d)} = 0.
\]  

(8e)

\[
K_{12}^2 = \frac{F(-a)}{(c - a)(d - a) + K_{34}^2}.
\]  

(8f)
for $K_{34}$ we have the two formulations
\[ F(-b) - F(-a) = \frac{K_{34}(b + a - c - d)}{(a - b)(d - b)} \quad (8g) \]
\[ F(-c) - F(-d) = \frac{K_{34}(c + d - b - a)}{(d - c)(a - c)} \quad (8h) \]
facilitate computations in the above equations, we write
\[ \rho_1 = \left[ M f_1 \left( \frac{b}{M} \right) + \frac{x_0^2}{2} \left( 1 + \frac{\sqrt{2}}{2} \right) \right] \]
\[ \rho_2 = \left[ M f_2 \left( \frac{b}{M} \right) + \frac{x_0^2}{2} \left( 1 - \frac{\sqrt{2}}{2} \right) \right] \quad (8i) \]
\[ \frac{\rho_1 - \rho_2}{\rho_1 - \rho_2} = \frac{1}{2} \left[ \left( \rho_1 + \rho_2 - \left( 1 - \frac{\sqrt{2}}{2} \right) M \right) \right] \]
\[ M f_2 \left( \frac{p_1}{M} \right) + M f_2 \left( \frac{p_2}{M} \right) + \left( 1 - \frac{\sqrt{2}}{2} \right) x_0^2 \]
\[ \frac{1}{2} \left[ \rho_1 + \rho_2 - \frac{\sqrt{2}}{2} M \right] \]
\[ M f_2 \left( \frac{p_1}{M} \right) + M f_2 \left( \frac{p_2}{M} \right) + \left( 1 + \frac{\sqrt{2}}{2} x_0^2 \right) \quad (8j) \]
\[ u = \frac{1}{2} \left[ 1 - \frac{\sqrt{2}}{2} M + \frac{1}{2} \frac{\sqrt{2}}{4} \right] \quad (8k) \]
Equations (8c) through (8k) are a complete solution to the design problem. The bandwidth $x_0$ and $a$ determine $M$ from (8c); then three of the $Q$'s may be almost arbitrarily chosen and the fourth is determined by (8d); $K_{34}$ may be found from (8c), $K_{15}$ from (8f) and $K_{23}$ from (8g) or (8h). The calculations may be facilitated by graphs of (8k). These graphs and a graph of (8c) are shown in Figs. 4 and 5. The criteria for a physical solution in a form as simple as in the triple-tuned case have not been found; however, a physical solution may always be obtained by a sufficiently large value of $a$ or $d$.

Fig. 5—Flatness parameter for quadruple-tuned circuits.

The design equations of critical quadruple-tuned circuits are obtained by letting
\[ x_0 \to 0, \quad \alpha \to 0, \quad x_0' / 8 \alpha \to \frac{3 - 2 \sqrt{2}}{8} M^4, \]
We define under-critical circuits as those for which
\[ 0 > x_0^2 > - M^4 \left( \frac{1}{2} - \frac{\sqrt{2}}{4} \right) \]
and in this case all the previous equations still apply.

**Tuning Procedure**

A discussion of multiple-tuned circuits would be incomplete without a method of tuning. A procedure which is both a convenient method for tuning and for setting the coupling coefficients is the following:

(a) All circuits except the first are completely mis-tuned by short circuiting the coils $L_{22}, L_{33}, L_{44}$. A vacuum-tube voltmeter is connected to the input and the first circuit is tuned for a maximum indication $E_0$ on the voltmeter.

(b) The short circuit is removed from $L_{22}$, and the second circuit is tuned for a minimum indication $E_b$. Then
\[ E_b = \frac{1}{1 + K_{15} Q_1 Q_2} \quad (9a) \]

(c) The short circuit is removed from $L_{33}$, and the third circuit is tuned for a maximum indication $E_a$.
then

\[
\frac{E_a}{E_o} = \frac{1}{1 + \frac{K_{12}Q_1Q_2}{1 + K_{23}Q_3Q_4}} \quad (9b)
\]

(d) The short circuit is removed from \(L_{44}\), and the fourth circuit is tuned for a minimum indication \(E_o\), then

\[
\frac{E_a}{E_o} = \frac{1}{1 + \frac{K_{12}Q_1Q_2}{1 + K_{23}Q_3Q_4}} \quad (9c)
\]

All circuits are now in tune and the coupling coefficients have been measured. The only remaining problem is the removal of the voltmeter from the input circuit. One method is to take advantage of the fact that even when the voltmeter is disconnected all circuits but the first are in tune, so that the voltmeter may be removed from the input and used as an indicator in the plate circuit of the output tube, the input now being retuned for a maximum indication.

**Staggered Circuits**

The factorization of \(F(p)F(-p)\) given by (5f) has an interesting consequence. A \(2n\) tuned response may be obtained by \(n\) double-tuned stages, and a \(2n+1\) tuned response may be obtained by one single-tuned stage and \(n\) double-tuned stages. All stages are centered at the same frequency, but are staggered with respect to bandwidth. The equations (5f) through (5g) may be regarded as design equations for the general \(n\) for circuits of this type. For example, the quadruple tuned response may be obtained by two double-tuned stages with

\[
a + b = (1 - \sqrt{2}/2)M, \\
K_{12}^2 = \frac{M^2}{2}(1 - \sqrt{2}/2) + \frac{x_0^2}{2}(1 + \sqrt{2}/2) - ab, \quad (10a(1))
\]

\[
c + d = \frac{\sqrt{2}}{2}M, \\
K_{23}^2 = \frac{M^2}{2}(1 - \sqrt{2}/2) + \frac{x_0^2}{2}(1 - \sqrt{2}/2) - cd. \quad (10a(2))
\]

The maximum gain bandwidth product on a per-stage basis is given by:

\[
(f_2 - f_1)E = \frac{i_0}{2\pi \sqrt{C_{11}C_{22}C_{33}C_{44}}} \sqrt{8a}. \quad (10b)
\]

This is approximately \(\sqrt{4/\alpha}\) times that obtainable with identical stages with the same over-all \(x_0\) and \(a\). The fact that one of the stages has a bandwidth which is wider than the over-all bandwidth is of advantage in some applications. For example, the first stage may be designed to pass both the video and sound components of a television signal.

**Two Sample Calculations**

In order for the reader to better understand the use of the equations presented above, we give the numerical computations to design a triple-tuned and quadruple-tuned circuit to satisfy the following requirements: pass band of 15.6 to 16.4 Mc with the fluctuation not to exceed 1 db, an interfering signal at 14 Mc, and an input capacity and output capacity of 5 and 6 mfd respectively. The plate resistance of the input tube is \(4 \times 10^2\) ohms. The \(Q\) of all coils is 100.

(a) The Triple-Tuned Circuit. (Fig. 1(a))

\[
L_{11} = 20 \mu\text{h}, \quad L_{22} = 16.7 \mu\text{h},
\]

\[
L_0 = 16 \text{ Mc,} \quad x_0 = 0.05
\]

\[
a = 0.01 + 2.000.4 \times 10^4
\]

\[
= 0.015 = 0.25M = 3x_0 \quad (c - a) = 0.4x_0
\]

\[
b = 0.01 = 0.167M = 0.2x_0
\]

Let \(c = 0.035 = 0.583M = 0.3x_0\),

\[
M = 0.06 = 1.2x_0
\]

then \(R = 1.670/(0.035-0.01)\) ohms

\[
R = 66.7 \times 10^3\text{ ohms}
\]

\[
2/\sigma = (1.2)^2 + 3.6 = 5.33, \quad \sigma = 0.375
\]

The response is flat to 0.58 db.

\[
f(0.25) = 0.094 \quad f(0.583) = 0.150
\]

\[
K_{12}^2 = (1 + 0.2/4)(1.44 \times 0.094 + 0.375)x_0^2
\]

\[
= 0.765x_0^2 \quad K_{12} = 0.875x_0 = 0.0437
\]

\[
K_{23}^2 = (1 - 0.2/4)(1.44 \times 0.154 + 0.375)x_0^2
\]

\[
= 0.298x_0^2 \quad K_{23} = 0.546x_0 = 0.0273
\]

with \(g_{in} = 5 \times 10^{-3}\) mhos,

gain = \(g_{in}x_CK_{12}K_{23}(4x_0^2)\)

\[
= 5 \times 10^{-3} \times 1800 \times 0.546 \times 0.875 \times 1.5 \times 0.01
\]

\[
= 130
\]

At 14 Mc \(x = 0.267\), hence attenuation of 14 Mc is

\[
1.5 \times (0.267/0.05)^2 = 228.
\]

(b) The Quadruple-Tuned Circuit. (Fig. 1(b))

\[
L_{11} = 20 \mu\text{h}, \quad L_{44} = 16.7 \mu\text{h},
\]

\[
f_0 = 16 \text{ Mc,} \quad x_0 = 0.05
\]

\[
a = 0.015 = 0.15M = 0.3x_0 \quad (d - a) = 1.0x_0
\]

\[
b = 0.01 = 0.10M = 0.2x_0 \quad (d - b) = 1.1x_0
\]

\[
c = 0.01 = 0.10M = 0.2x_0 \quad (a - c) = 0.1x_0.
\]

Let \(d = 0.065 = 0.65M = 1.3x_0\),

\[
R = 1.670/(0.065 - 0.01) = 30 \times 10^3\text{ ohms}
\]

\[
M = 0.100 = 2x_0
\]

\[
\xi = 0.171(4 + 1)(4 + 5.85) = 8.44, \quad \alpha = 0.1185\]


Discussion on

"Properties of Some Wide-Band Phase-Splitting Networks"*

DAVID G. C. LUCK

Frederick E. Bond*: While reading the paper entitled "Properties of some wide-band phase-splitting networks," by David G. C. Luck, it appeared that there might be a simpler mathematical procedure for deriving the relationship between deviation from 90° phase difference and the ratio of the maximum and minimum frequency.

Specifically, consider equation (6) in the above-mentioned paper, which expresses the tangent of half the phase difference as a function of the circuit Q (as defined therein); the quantity r (the square root of the ratio of $f_2$ to $f_1$); and $f_0$ (the geometric mean of $f_1$ and $f_2$).

$$\tan \frac{\psi}{2} = \frac{Q \left[ \left( \frac{f_0}{f} - \frac{f}{f_0} \right) - \left( \frac{f_0}{r_f} - \frac{f}{r_f} \right) \right]}{1 + Q^2 \left( \frac{f_0}{f} - \frac{f}{f_0} \right) \left( \frac{f_0}{r_f} - \frac{f}{r_f} \right)}$$

The nature of this function suggests the following change of variables:

$$Q = \frac{k}{x_0}$$

$$K_12 = \frac{0.93x_0}{0.0465}$$

$$K_{23} = \frac{x_0(1.278 - 0.862 \times 1.0)}{(1.1)}$$

$$K_{23} = \frac{0.379x_0}{0.862x_0}$$

If $L_{22} = L_{33} = 5 \mu H$,

$$C_{23} = (20 \text{ mmf})/0.03075 = 650 \text{ mmf}.$$

With $g_m = 5 \times 10^{-5} \text{ mhos}$

Gain = $g_m V_x K_{12} K_{23} K_{34} (8\alpha/x_0^4)$

$$= 5 \times 10^{-2} \times 1800 \times 0.93 \times 0.615$$

$$= 0.845 \times 0.95/0.05 = 83.$$

At 14 Mc, the attenuation is $0.95 \times (0.267/0.05)^4 = 775.$

**CONCLUSION**

We have concerned ourselves, in this paper, with the design of multiple-tuned circuits for optimum amplitude response. One might think that better practical results would be obtained with flat designs. The opposite is actually the case. A small $\sigma$ requires a large ($M/x_0$) and consequently large coefficients for $F(p)$, but all the coefficients of $F(p)/F(-p)$ with the exception of the constant term are independent of $\sigma$. Thus the effect of reducing $\sigma$ is to require that the differences of large numbers be small numbers.

The design equations for the electrical parameters are expressed in terms of the invariant $F(p)$, so that these equations apply in form for any desired response characteristics, it being only necessary to determine the appropriate $F(p)$.


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Let
\[ f/f_0 = e^x \]
and
\[ r = e^y. \]

Then the above expression becomes
\[ \tan \frac{1}{2} \psi = \frac{4Q \sinh y \cosh x}{1 - 4Q^2(cosh^2 y - \cosh^2 x)}. \]

Now when \( f = f_0, x = 0 \). Therefore
\[ \tan \frac{1}{2} \psi_0 = \frac{4Q \sinh y}{1 - 4Q^2 \sinh^2 y}. \]

Combining (3) and (4)
\[ \tan \frac{1}{2} \psi = \frac{\cosh x}{1 + M \sinh^2 x} \]
where
\[ M = \frac{4Q^2}{1 - 4Q^2 \sinh^2 y} = \frac{4Q^2}{1 - Q^2 \left( \frac{1}{r} - \frac{1}{r} \right)}. \]

Note that \( M \) is equal to \( \sin^2 \frac{1}{2} \sigma \) where \( \sigma \) is defined in equation (11) in the paper under discussion. In equation (5) we have the phase difference expressed as a function of \( \psi \) (its value at the mean frequency \( f_0 \)); \( x \) which is equal to \( \log, f/f_0; \) and \( M \), which is a function of the circuit parameters \( Q \) and \( r \).

In order to find the location of the maxima and minima for the ratio \( \tan \frac{1}{2} \psi/\tan \frac{1}{2} \psi_0 \), setting the first derivative of equation (5) equal to zero yields
\[ \sinh x = 0, \quad \pm \sqrt{\frac{1 - 2M}{M}}. \]

Equation (7) shows immediately that in order to realize the double humps in the curves shown in Fig. 4 of the article in question, \( M \) must be less than 1/2 and greater than zero.

To find the values of \( \tan \frac{1}{2} \psi_m \), substituting (7) in (5) yields
\[ \tan \frac{1}{2} \psi_m = \frac{1}{2 \sqrt{M(1 - M)}}. \]

Now to determine the maximum deviation of phase difference from the average value,
\[ \sin \frac{1}{2} (\psi_m - \psi_0) = \frac{\tan \frac{1}{2} \psi_m - \tan \frac{1}{2} \psi_0}{\tan \frac{1}{2} \psi + \tan \frac{1}{2} \psi_0} = \frac{1 - 2\sqrt{M(1 - M)}}{1 + 2\sqrt{M(1 - M)}}. \]

For the quadrature case, then \( 1/2(\psi_m + \psi_0) = 90^\circ \) and
\[ \sin \frac{1}{2} (\psi_m - \psi_0) = \frac{1 - 2\sqrt{M(1 - M)}}{1 + 2\sqrt{M(1 - M)}}. \]

The first value of course refers to \( f = f_0 \) where \( x = 0 \). The second value refers to both \( f_{\text{max}} \) and \( f_{\text{min}} \); since \( \cosh x \) is an even function of \( x \) and \( x \) has logarithmic symmetry with \( f \).

From (11)
\[ e^x = \frac{f}{f_0} = \frac{1 - M + \sqrt{1 - 2M}}{M}. \]

The expression in (12) with the positive sign must refer to \( f_{\text{min}} \) since it is always greater than the value using the negative sign. Therefore
\[ \frac{f_{\text{max}}}{f_0} = \frac{1 - M + \sqrt{1 - 2M}}{M}, \quad \frac{f_{\text{min}}}{f_0} = \frac{1 - M - \sqrt{1 - 2M}}{M}. \]

Using corresponding values of \( M \) in equations (10) and (13), the desired relationship between maximum deviation and frequency spread can be obtained and the values in Fig. 6 of Dr. Luck's paper can be checked.

**David G. C. Luck**: The interest which has led Mr. Bond to work out an alternative to the methods used in my paper is greatly appreciated.

Introducing the substitute variables \( \eta \) and \( \sigma \), by equations (9) and (11) of my paper, I stated that this was done quite arbitrarily. The same statement applies also to the introduction of \( \theta \) and \( \rho \) by my equations (13) and (18). Various other arbitrary substitutions could, of course, have been used instead.

Mr. Bond chooses to use \( \cosh x \) wherever I used \( \cosec \eta, \sqrt{M} \) where I used \( \sin \frac{1}{2} \sigma \), and \( \sinh \gamma \) where I used \( \cot \rho \). These seem to me to be purely matters of personal preference. There is no need to justify by logic either his preference or mine. Mr. Bond also chooses to stop short of my final substitution (13), which in his notation would be
\[ \tan \frac{1}{2} \theta = \sqrt{\frac{M}{1 - M}} \cosh x. \]

\[ * \text{RCA Laboratories Division, Princeton, N. J.} \]
is final expression (5) for the phase difference-versus-frequency characteristic is essentially my equation (12), with \( x \) and \( M \) substituted for my \( \eta \) and \( \sigma \). This is again largely a matter of preference and, as Mr. Bond has shown, the essential results can be derived readily from his expression.

It is certainly Mr. Bond’s right to make his calculations in any self-consistent way he chooses. However, I cannot quite agree that it is simpler to determine maximum and minimum properties by the formal processes of taking derivatives, equating them to zero, and substituting back the results, than to determine these properties by inspection, in the light of common knowledge of the shapes of trigonometric functions.

Neither can I agree that it is simpler to compute numerical results from Mr. Bond’s quadratic expressions (1), (7), (8), (9), and (10) than to pick such results handy-made from the nearest trig table, with the aid of my expressions (13), (14), (15), and (16).

Unfortunately, I have not been able to find any really convenient expression for \( f_{\text{max}}/f_{\text{min}} \); for comparison with Mr. Bond’s equation (13), my notation offers,

\[
\frac{f_{\text{max}}}{f_{\text{min}}} = \left( \frac{1 + \sqrt{\cos \sigma}}{1 - \sqrt{\cos \sigma}} \right)^2 \tag{B}
\]

Also, for slide-rule computation, my expressions (17) and (18) can be written as

\[
Q = \frac{\sqrt{\cos \frac{1}{2} \psi}}{2 \cos \frac{1}{2} \psi} \sin \frac{1}{2} \sigma \tag{C}
\]

and

\[
\tan \rho = \frac{\sqrt{\cos \frac{1}{2} \psi}}{\sin \frac{1}{2} \psi} \sin \frac{1}{2} \sigma \tag{D}
\]

The intermediate variables \( \eta \) and \( \sigma \) (or \( x \) and \( y \)), which disappear from my final expressions, have the virtue of avoiding quadratic solutions in the inverse calculation of frequency ratios from desired phase-difference characteristics. If one accepts computation of quadratic forms anyway, Mr. Bond’s \( x \) and \( y \) seem to lose much of their utility. My introduction of \( \eta \) was based, however, on the further supposition that the graphical form of a cosecant is more generally recognized than that of \( f/f_0 + f_0/f \), which cosec \( \eta \) replaces. The same justification might apply to Mr. Bond’s use of \( \cosh x \), if he wishes to derive results, by inspection, from the graphical shapes of known functions.

**CORRECTION**

Albert S. Richardson, Jr., author of the paper “The remainder theorem and its applications to operational calculus techniques,” which appeared on pages 1336-1339 of the November, 1950, issue of the *Proceedings of the I.R.E.*, has brought the following errors to the attention of the editors:

On page 1337, the last three terms of equation (4) should read

\[ K_1 e^{s_{11}t} + K_2 e^{s_{21}t} + \cdots + K_n e^{s_{n1}t} \]

instead of

\[ K_1 e^{s_{11}t} + K_2 e^{s_{21}t} + \cdots + K_n e^{s_{n1}t}. \]

Also on page 1337, the right-hand side of the last equation on this page should read

\[ [e^{s_{n1}t} - 1] \]

instead of

\[ [e^{-s_{n1}t} - 1]. \]
Contributors to the Proceedings of the I.R.E.

John L. Glaser (S’42–A’51) was born in St. Louis, Mo., on January 21, 1921. He received the B.S. degree in electrical engineering in 1943 from Washington University in St. Louis. He served with the Anti-aircraft Artillery and Signal Corps during World War II. He was also an instructor at the MIT Radar School, as well as a radar and communications officer in the Panama Canal Zone.

In 1948, Mr. Glaser received the M.S. degree from Washington University, where he is now continuing graduate studies. He has been associated with the Diversity Reception Research Project at the University since 1946. He is a member of Sigma Xi.

M. A. Honnell (A’40–SM’47) was born at Lyons, France, in 1910. From 1928 to 1930 he was a radio operator with the Radiomarine Corporation of America. He received the B.S. degree in 1934, the M.S. degree in 1940, and the Ph.D. degree in 1945, all from the Georgia Institute of Technology. Mr. Honnell was on the engineering staff of the radio station in 1930 to 1936, and from 1938 to 1943. During 1935 he worked for the Van Nostrand Radio Engineering Service. In 1936 and 1937 he was with the radio division of the Pan American Airways at Miami. He started as an instructor of electrical engineering at Georgia Tech in 1937, and advanced to his present position of professor in charge of communications and electronics courses in 1945.

In addition to his regular teaching duties during the war, Mr. Honnell taught radio navigation in the Civilian Pilot Training Program and he was supervisor of ultra-high-frequency courses and also of a pre-radar school, under the ESMW program. He has been a faculty research associate of the Georgia Tech Engineering Experiment Station since 1944.

Mr. Honnell is a member of the American Institute of Electrical Engineers, the National Society of Professional Engineers, Tau Beta Pi, andEta Kappa Nu.

Asede W. Hogan (S’41–S’43–M’49) was born on March 31, 1918, in Sumrall, Mass. After receiving the B.S. degree in electrical engineering in June, 1941, from the University of Texas, he was employed by the National Advisory Committee for Aeronautics to design, and supervise, electrical installations for the Altitude Wind Tunnel at Cleveland, Ohio.

Upon completion of that project, he joined the RCA Victor Division at Lancaster, Pa., as a standards engineer for cathode-ray tubes. In 1944 he received a commission in the Naval Reserve and served as a sonar specialist at various shipyards. Upon leaving the Navy he was employed by the U.S. Naval Ordnance Laboratory at Silver Spring, Md. Mr. Hogan is now head of the Systems Section of the Guided Missiles Division.

F. J. Kerr (A’43–SM’49) was born at St. Albans, England, on January 8, 1918. He received the B.Sc. degree from the University of Melbourne in 1937, and the M.Sc. degree in 1940. Since 1940 he has been with the Division of Radiophysics of the Commonwealth Scientific and Industrial Research Organization in Sydney, Australia. During the war he was engaged in the development of radar equipment, and in studies of superrefraction. Recently he has been working in radio astronomy. He is at present spending a period at Harvard College Observatory, Cambridge, Mass., studying solar problems.

Walter H. Kohl (A’35–M’39–SM’43) was born in Kitzingen, Bavaria, Germany, on January 22, 1905. He received his higher education at the Technische Hochschule in Dresden, specializing in engineering physics. In 1928 he graduated with the degree of Dipl. Ing., and in 1930 completed his postgraduate work with the degree of Dr. Ing.

Immediately afterward, Dr. Kohl migrated to Canada and joined the Rogers Radio Tube Company Limited in Toronto, Ontario, late in 1930, as a development engineer. He stayed with that company until 1945. During this time he advanced from project engineer to chief engineer, vice-president, and director in 1944. His activities covered a wide field. He was a co-worker on development of the first cathode-ray tubes in Canada (1933); introduced a new process for the application of luminous screens (1935); and demonstrated the first electron microscope pictures of oxide cathodes and metal surfaces in Canada (1934). This led to his part-time appointment as a special lecturer in electronics at the McMaster Institute of the University of Toronto (1935–1940) and to his work on the development of the first electron microscope on this continent. Dr. Kohl published a book, “The Electron Microscope,” jointly with E. F. Burton in 1942 (2nd ed., Reinhold Publishing Corporation, New York, N. Y., 1946).

During World War II, he worked on the production of kilowatt, TR tubes, power triodes, and special receiving tubes contracted for the Canadian and British Armed Services. He introduced glass-to-metal seals by induction heating to pilot plant production (independent of earlier developments by others) and was responsible for engineering administration.

In November, 1945, Dr. Kohl joined the research division of Collins Radio Company in Cedar Rapids, Iowa, to set up a vacuum-tube laboratory for the further development of retransmitting and other high-power tubes. In 1949 he was appointed Consultant to the Director of Research. He has just completed the manuscript for a book entitled “Materials Technology for Electron Tubes,” to be published in 1951 by Reinhold Publishing Corporation, New York, N. Y.

Dr. Kohl was Chairman of the Papers Procurement Committee of the Cedar Rapids Section of the I.R.E. during 1950 and Chairman of the Toronto Section in 1932. He is also a member of the British IRE, the American Physical Society, the American Association for the Advancement of Science, the Electron Microscope Society of America, and the Iowa Academy of Science. He represents his company at that body and other Societies for Testing Materials where he has been a member of Committee B-4, Subsection 8 on Cathodes, since 1945.
Contributors to the Proceedings of the I.R.E.

Jack M. Manley (A’43–SM’49) was born in Farmington, Mo., on March 9, 1909. He received the B.S. degree in electrical engineering from the University of Missouri in 1930. Since 1930 he has been a member of the technical staff of the Bell Telephone Laboratories, Inc. For a number of years, he was concerned mainly with studies of nonlinear electric circuits. More recently he has been working on new multiplex methods for communication systems. Mr. Manley is a member of Tau Beta Pi, associate member of Sigma Xi, and member of the American Institute of Electrical Engineers.

Arthur H. Ross (S’40–A’41–SM’48) was born in Philadelphia, Pa., on May 31, 1902. He received the E.E. degree from Cornell University in 1926, and was a special graduate student at Massachusetts Institute of Technology from 1939 to 1940 and at Rutgers University from 1947 to 1949.

From 1926 to 1933, Mr. Ross was a member of the engineering staff of the Bell Telephone Company of Pennsylvania. From 1933 to 1939, he was engaged in the design and manufacture of radio communication equipment. Since 1940, he has been a radio engineer with the Signal Corps Engineering Laboratories at Ft. Monmouth, N. J., where he has been engaged in research in the field of high-frequency military radio communication methods and equipment.

C. A. Shain was born in Sandringham, Victoria, Australia, on February 6, 1922. He received the B.Sc. degree from the University of Melbourne in 1943 while serving with the Australian Army. Since 1943 he has been with the Division of Radiophysics of the Commonwealth Scientific and Industrial Research Organization in Sydney, Australia. He is at present engaged in work on galactic radio noise.

S. H. Van Wambeck (A’40–SM’46) was born in Minneapolis, Minn., on August 30, 1910. He received the B.S. degree in mechanical engineering in 1931, and the M.S. degree in electrical engineering in 1936, from Washington University, in St. Louis, Mo. From 1933 to 1935 he was engaged in research and development work on initiating explosives and ballistic test equipment at the Western Cartridge Company, East Alton, Ill. During 1935 and 1936 he was sales correspondent in the special motor division of the Emerson Electric Manufacturing Company, St. Louis, Mo. He served as instructor in electrical engineering at Oklahoma Agricultural and Mechanical College in 1936 and 1937, and in the same capacity at Rice Institute, Houston, Texas, from 1937 to 1942. Here he was also chairman of that department in 1941 and 1942. From 1942 to 1946 he was assistant professor in Washington University’s electrical engineering department, where he is presently associate professor. During this period, Mr. Van Wambeck was also engaged as consulting engineer by the following organizations: C. H. Guernsey and Company, Oklahoma City, Okla., on electric power systems, from 1937 to 1940; Seismic Explorations, Inc., Houston, Tex., on the development and design of geophysical equipment, 1938 to 1942; Knapp-Monarch Company, St. Louis, Mo., on problems related to the proximity fuse, among other assignments; from 1943 to present; and he was consultant on problems of instrumentation related to wind tunnel and flight test from 1942 to 1944 for the McDonnell Aircraft Corporation in St. Louis. From 1946 to 1949 he served as assistant director of the Diversified Research Project at Washington University and since July, 1949, as Director of the same project.

Mr. Van Wambeck is a member of the American Institute of Electrical Engineers, the Society for the Promotion of Engineering Education, Sigma Xi, and Tau Beta Pi. He was 1945–1946 Vice-Chairman and 1947 Chairman of the St. Louis Section of the IRE.

J. M. Manley

M. David Prince (S’45–A’50) was born in Greensboro, N. C., on March 27, 1926. He received the B.F. degree from the Georgia Institute of Technology in 1946, and served a year as an officer in the United States Navy. He then began graduate study at Georgia Tech while teaching part-time in the mathematics department, and was awarded the degree of M.S.I.E. in 1949. The television research on velocity modulation initiated during his graduate work was continued under the sponsorship of the school of electrical engineering and the Experiment Station of the Georgia Institute of Technology.

At the present time, Mr. Prince is on the faculty of the mathematics department, and is continuing with his graduate study in electrical engineering. In January, 1951, Mr. Prince expects to resign his position in the mathematics department to join the staff of the Georgia Tech Experiment Station as a research engineer.

C. A. Shain

M. David Prince

S. H. Van Wambeck

Arthur H. Ross

Thomas Charles Gordon Wagner (A’48) was born in Pittsburgh, Pa., on January 9, 1916. He received the B.S. degree from Harvard University in 1937, followed by the M.A. and the Ph.D. degrees from the University of Maryland in 1940 and 1943, respectively.

Dr. Wagner served as consultant and engineer for Washington Institute of Technology from 1941 to 1946. He was an instructor in mathematics at the University of Maryland from 1938 to 1943, and in 1946 he was appointed associate professor of electrical engineering at that university. Since 1947 he has also been associated with the Davies Laboratories, Inc., of Riverdale, Md. He is a member of Sigma Xi and the American Mathematical Society.

T. C. G. Wagner
Correspondence

Definition of Information*

During recent years a statistical theory of information has been developed by Shannon and others. In this theory the amount of information conveyed by a message is defined in terms of the set of possible messages with their appropriate probability measure. For the case of communication in the presence of noise, the received information depends on the transfer probabilities between the possible transmitted and received messages. If $p(x, y)$ is the probability that message $x$ is transmitted and message $y$ received, then, according to the formula proposed by Shannon, the rate of information transfer is

$$R = \int \int p(x, y) \log \left( \frac{p(x, y)}{p(x) \cdot p(y)} \right) \, dx \, dy,$$

where $p(x) = \frac{p(x, y)}{p(y)}$, and $q(y) = p(x, y)$. The theory of information deals with the problem of maximizing this rate of information transfer, given certain physical restrictions.

An obvious conclusion is that a different definition of information might lead one to different criteria for communication-link design. It seems desirable to examine the uniqueness of the definition. The basic definitions postulate which the author proposes that the definition of $R$ should satisfy is that $R$ is invariant under any transformation of $x$ and $y$ that merely amounts to a relabeling of the message symbols. In other words, if we consider the arbitrary transformations, $w = f(x, y)$, $z = g(x)$, (with $f$ the same function in both cases), and calculate the resulting distributions for $w$ and $z$, then the value of $R$ computed on this new basis should be the same. It can be verified that if $R$ is defined as in (1) the postulate is satisfied. Can the definition of $R$ be modified in a nontrivial way without violating the postulate? By embedding (1) in a certain class of possible definitions it can be shown that, at least for this class of definitions, (1) is the only admissible one. The class of definitions chosen was

$$R = \int \int q(x) F(x, z) \, dx \, dz - P(g(x, z)) \, dx \, dz,$$

where $q(x)$ is the conditional probability that $x$ was transmitted if $y$ was received. $F = F(u, v)$ is a function of two real variables to be chosen in such a way that the fundamental postulate is satisfied. It can be shown that with the usual continuity-type assumptions $F(u, v) = u \log u$ is the only possible selection within an arbitrary multiplicative constant, this choice leading to the expression (1) for $R$. Details of the derivation will be submitted to a mathematical journal.

EDGAR REICH
The Rand Corporation
Santa Monica, Calif.

Ascertaining the Critical Servo Gain*

One of the basic problems in servomechanism work is finding the critical system gain or gains from the system determinant equation that will produce instability. In this letter I hope to show a simplified method for determining these gains. The general form of the determinant polynomial is

$$S^3 + A_2 S^2 + A_1 S + A_0 = 0.$$

Now the coefficients of the $S$ terms ($A_1$ to $A_2$) are functions of the variable gain $K$, whose critical values we should like to ascertain. Equation (1) may be factored as in (2) into a number of quadratic factors, and one first-order factor if $n$ is odd.

$$(S^2 + aS + b)(S^2 + cS + d)(S + e) = 0.$$

At a critical gain, the coefficient of the first-degree term of $S$ in one quadratic factor must vanish, and the constant term in that factor must be greater than zero. Then (2) takes this form:

$$(S^2 + b)(S^2 + cS + d) \quad (S + e) = 0, \quad b > 0.$$

The algebraic expansion of (3) yields the characteristic equation of a servo system at a critical gain whose frequency of sustained oscillation is $\sqrt{b}/2\pi$.

Example: To illustrate what has been developed, let us take the following determinant equation, and find the $K$ necessary to cause sustained oscillations:

$$S^3 + 255S^2 + 18,350S^4 + 285,000S + K = 0.$$

From (3), the factors of (4) can be written so:

$$(S^2 + b)(S + e) = 0, \quad b > 0.$$

whose algebraic expansion is

$$S^3 + aS^2 + (b + e)S + be = 0.$$

Expression (6) is then the characteristic equation of any system, at a critical gain, having a fourth-degree determinant equation. We may now equate coefficients of like powers of $S$ in (4) and (6) to obtain the following simple set of simultaneous equations:

$$a = 255, \quad A_2 = 285,000, \quad \beta_1 + \beta_2 = 18,350, \quad \beta_1 \beta_2 = K.$$

The critical system gain is then $193,000$, and the frequency of sustained oscillation is 5.3 cps. This method may also be applied if it is desirable to find the critical value of some variable system component that would cause sustained oscillations.

ARThUR SCHLAM
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Brooklyn, N. Y.

Telepathic Communication*

A discussion of the possibility of telepathic communication in other publications, more recent speculation in your paper regarding remote control of mechanism through reception and amplification of "brain waves," and "comments on psychic physics"inquiring questions among those trained in the physical sciences as to the possible mechanisms by which such communication could take place. In this connection the writer suggests that the following lines (written in November, 1949) are appropriate considerations at this point.

Without attempting to question the validity of the data which Rhine and others have interpreted as demonstration of telepathic communication, it can be stated that such communication, if it does take place, must involve a transfer of energy, since no form of energy is required to activate the brain cells.

All methods of transmitting intelligence presently known involve some sort of wave motion, either in a physical medium or as electromagnetic radiation. Since a most noteworthy feature of all cases of reported telepathic communication is the absence of any effect of distance or physical barriers, the first category must be rejected. The electromagnetic spectrum, on the other hand, has been reasonably well explored from less than one cycle to at least 10⁹ cycles per second with no-reported cases of telepathic "interference." However, if electromagnetic radiation, and not some hitherto unknown means of energy transfer is to be postulated as the mechanism for telepathy, it should be sought in the extreme hyperfrequency range, as the following considerations will show.

It is well known in the communications field that the rate of transmission of intelligence in a uniform noise space is directly proportional to the bandwidth. Shannon

* Received by the Institute, October 2, 1950.
This application of Fourier transforms has been more thoroughly examined in a thesis in which it is shown that a law of nature equivalent to the uncertainty relation of Heisenberg governs the problem of broad banding. Thus it is possible to find the mechanical dimensions of smooth transmission lines replacing arbitrary line discontinuities, such as line transformers, transitions, and the like, which will give small reflections in a broad frequency band. Both continuous inhomogeneous lines (Fourier integrals) and step lines (Fourier series) have been studied in the thesis.

Using the same treatment and considering coupling instead of reflection in the original theory it now appears to be possible to propose an approximate theory of the directional coupler. A simple theory of its operation has earlier been presented by Mumford,2 who shows that an ordinary directional coupler consisting of two elements may be broad-banded by introducing a number of additional elements equally spaced with coupling factors proportional to the coefficients of the binomial expansion. The calculation is equivalent to that carried out in the thesis when dimensioning a step line with binomial distribution of the point reflections. Following the thesis it is also possible, for instance, to construct a directional coupler which optimizes the relationship between pass-bandwidth and the allowed $I_{min}/I_{max}$ level in the pass band.
1951 IRE National Convention Program

WALDORF-ASTORIA HOTEL and GRAND CENTRAL PALACE—MARCH 19–22

PROGRAM

Monday, March 19, 1951
9:00 A.M.—7:00 P.M.—Registration at Waldorf-Astoria Hotel.
11:00 A.M.—9:00 P.M.—Registration at Grand Central Palace.
11:00 A.M.—9:00 P.M.—Radio Engineering Show, Grand Central Palace.
10:30 A.M.—12:00 M.—Annual Meeting.
Principal Address by Dr. James W. McRae, Bell Telephone Laboratories, Murray Hill, N. J., Jade Room, Waldorf-Astoria Hotel.
2:30 P.M.—5:00 P.M.—"Information Theory.", "Television I—Color.", "Antennas."
"Power Tubes I—Theory.", "Frequency Control and Generation."
"Communication Systems."

Tuesday, March 20, 1951
9:00 A.M.—7:00 P.M.—Registration at Waldorf-Astoria Hotel.
9:30 A.M.—9:00 P.M.—Registration at Grand Central Palace.
9:30 A.M.—9:00 P.M.—Radio Engineering Show, Grand Central Palace.
10:00 A.M.—12:30 P.M.—Symposium: "Amplification of DC Signals.", "New Extensions of Network Theory."
Symposium: "Panel Discussion on Tube Reliability.", "Power Tubes II—Development."
"Propagation."
Symposium: "Broadcast Transmission Systems."
12:45 P.M.—President's Luncheon, honoring President-Elect Cogshall, Grand Ballroom, Waldorf-Astoria Hotel.
Symposium: "Panel Discussion on the Empire State Story."
8:00 P.M.—10:30 P.M.—Symposium: "Recent Advances in Color Television."

Wednesday, March 21, 1951
9:00 A.M.—7:00 P.M.—Registration at Waldorf-Astoria Hotel.
9:30 A.M.—6:00 P.M.—Registration at Grand Central Palace.
9:30 A.M.—6:00 P.M.—Radio Engineering Show, Grand Central Palace.
10:00 A.M.—12:30 P.M.—Symposium: "Industrial Instrumentation.", "Computers I.", "Circuits II—Filters."
2:30 P.M.—5:00 P.M.—"Electronic Instrumentation." "Computers II.", "Circuits III—General.", "Broadcast and TV Receivers."
"Microwaves III—Antennas and Artificial Dielectrics A."
"Radard Navigation."
6:45 P.M.—Annual IRE Banquet (dress optional), Grand Ballroom, Waldorf-Astoria Hotel.

Thursday, March 22, 1951
9:00 A.M.—2:30 P.M.—Registration at Waldorf-Astoria Hotel.
9:30 A.M.—9:00 P.M.—Registration at Grand Central Palace.
9:30 A.M.—9:00 P.M.—Radio Engineering Show, Grand Central Palace.
10:00 A.M.—12:30 P.M.—"Nuclear Science.", "Television II.", "Circuits IV—Amplifiers."
"Circuits V—Oscillators."
Symposium: "Simulation as an Aid to Design of Remote Control Systems.", "Microwaves V—Generators and Amplifiers."
Symposium: "Loudspeakers."

IRE Committee and Professional Group Meetings
Antennas and Propagation Group: Chairman, Newborn Smith; Tuesday, March 20, 8:30 A.M.—10:00 A.M., Maroon Room, Grand Central Palace.
Audio Group: Chairman, Leo L. Beraneck; Thursday, March 22, 8:30 A.M.—10:00 A.M., Blue Room, Grand Central Palace.
Broadcast Transmission Systems Group: Chairman, Lewis Winner; Tuesday, March 20, 9:30 A.M.—10:00 A.M., Blue Room, Grand Central Palace.
Circuit Theory Group: Chairman, J. G. Brainerd; Tuesday, March 20, 8:30 A.M.—10:00 A.M., Grand Ballroom, Waldorf-Astoria Hotel.
Instrumentation Group: Chairman, Ernst Weber; Tuesday, March 20, 8:30 A.M.—10:00 A.M., Moderne Room, Belmont Plaza.
Nuclear Science Group: Chairman, M. M. Hubbard; Thursday, March 22, 8:30 A.M.—10:00 A.M., Moderne Room, Belmont Plaza.
Professional Groups Committee: Chairman, W. R. G. Baker; Wednesday, March 21, 8:30 A.M.—10:00 A.M., Jade Room, Waldorf-Astoria Hotel.
Quality Control Group: Chairman, R. F. Rollman; Tuesday, March 20, 8:30 A.M.—10:00 A.M., Astor Gallery, Waldorf-Astoria Hotel.
Radio Telemetry and Remote Control Group: Chairman, W. J. Mayo-Wells; Thursday, March 22, 8:30 A.M.—10:00 A.M., Jade Room, Waldorf-Astoria Hotel.
Vehicular Communications Group: Chairman, Austin Bailey; Thursday, March 22, 8:30 A.M.—10:00 A.M., Maroon Room, Grand Central Palace.

Sections Committee: Chairman, J. F. Jordan; Tuesday, March 20, 5:00 P.M.—7:00 P.M., Jade Room, Waldorf-Astoria Hotel.
Standards Committee: Chairman, J. G. Brainerd; Thursday, March 22, 8:30 A.M.—10:00 A.M., Jade Room, Waldorf-Astoria Hotel.

Women's Program
Monday, March 19, 1951
Registration in East Foyer, Waldorf-Astoria Hotel.
2:30 P.M.—4:30 P.M.—Party in the Jansen Suite, Waldorf-Astoria Hotel, Refreshments, "Prizes with Surprises."

Tuesday, March 20, 1951
9:30 A.M.—4:00 P.M.—Guided Tour of Downtown New York, including Television Program, DuMont Studios, Wanamaker's Department Store (Johnny Olsen's Rum-pus Room), Broadway between 8th and 10th Streets, with Luncheon at Wanamaker's (including transportation).

Wednesday, March 21, 1951
10:30 A.M.—11:30 A.M.—Tour "Behind the Scenes" of Waldorf-Astoria Hotel.
1:00 P.M.—2:15 P.M.—Luncheon and Fashion Show, Sert Room, Waldorf-Astoria Hotel.
2:30 P.M.—Matinee (choice): "Affairs of State" or "Season in the Sun."

Thursday, March 22, 1951
10:00 A.M.—12:00 M.—Women's Forum, Jansen Suite, Waldorf-Astoria Hotel. Free to women registered at the convention.

SPEAKERS
Miss Nadine Miller, Director of Press and Public Relations of C. E. Hooper, Inc., measures of the size and reaction of the radio and TV audiences. Her topic: "What Is Your Hooperating?" is the question which haunts the radio stars. She speaks from wide acquaintance with the celebrities and a wealth of experience on the platform.

Miss Beatrice A. Hicks, a graduate engineer, a member of the Institute, President of the Society of Women Engineers, and executive of Newark Controls. She is admirably equipped to speak on the subject: "How Women Become Engineers," and to apprise the status of a profound educational change which ultimately may affect IRE.

Mrs. Douglas Horton, the former Captain Mildred McAfee, USNR, organizer and executive of women flyers of the U. S. Navy WAVES, and the first woman to serve on the Board of Directors of the National Broadcasting Company. Her experience and attainments qualify her to speak authoritatively of women in industry and the armed forces and services, and their position under conditions of national emergency.
The theory of wave-form detection by cross correlation is given. It is shown that a limiting case of cross correlation is equivalent to the method of "integration." Experimental results obtained from the MIT electronic correlator show signal-to-noise ratio improvements of 40 db (from -20 db to +20 db). A comparison of radar A-scope pictures completely masked by noise and clear cross-correlated presentations is made. The theory of detection by correlation is considered with respect to filtering by conventional methods. The paper includes the theory and technique of detection of multiple repetitive signals in random noise.

4. ERROR REDUCTION IN THE DETERMINATION OF ELECTRONIC SYSTEM PARAMETERS

L. S. SCHWARTZ
(Hazeltine Electronics Corporation, Little Neck, L. I., N. Y.)

In electronic system studies it may be necessary to make a satisfactory estimate of the most probable value of a time-varying parameter. Difficulty may be faced in meeting this requirement if the estimate must be made in limited time. If the time-varying parameter does not strictly constitute a stationary random process, the difficulty may be only partly overcome no matter how large the number of measuring equipments. The reason that the difficulty is only partly overcome is examined and quantitative relations between observed and correlated errors are derived for the case of the arithmetic mean.

5. CODING PROCESSES FOR BANDWIDTH REDUCTION IN PICTURE TRANSMISSION

A. E. LAEMMEL
(Microwave Research Institute, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.)

Many pictures have special properties which allow the use of coding processes for the purpose of saving either channel bandwidth or time of transmission. For example, a weather map consists of a network of black lines on a white background, the black area being considerably less than the white. Modern communication theory allows a calculation of just how much saving an ideal coding scheme can achieve when such restrictions are placed on the complexity of the picture. Several coding methods will be discussed and compared to the ideal. Block diagrams of the apparatus required will also be given.

7. SUBJECTIVE SHARPNESS OF ADDITIVE COLOR PICTURES

M. W. BALDWIN, JR.
(Bell Telephone Laboratories, Inc., Murray Hill, N. J.)

This is a report on the first numerical results to come from a laboratory experiment on the subjective sharpness of additive three-color pictures. The sharpness factor is isolated by using out-of-focus projection (of lantern slides) instead of actual television transmission.

An observer's acuity for defocus is greatest for the green component and least for the blue component, in an additive three-color picture. When the same picture is reproduced in monochrome (white, red, green, or blue) at the same brightness, his acuity for defocus is equal to that found for the green component.

8. COLOR MULTIPLEXING BY SINE-WAVE FUNCTIONS

NATHAN MARCHAND
(Sylvania Electric Products Inc., Bayside, L. I., N. Y.)

Multiplexing of the three color signals necessary for color television is accomplished using sine waves at the sampling frequency for each color. By phase shifting each sine wave and combining it with a dc term, three orthogonal functions are obtained. Each of these is modulated by a color signal. They are then combined and transmitted. The transmitted signal is the exact equivalent of pulse sampling. At the receiver, mixing the received signal with one of the sine-wave orthogonal functions will separate out the desired color signal.

Note
No papers are available in preprint or reprint form nor is there any assurance that any of them will be published in the PROCEEDINGS OF THE I.R.E., although it is hoped that many of them will appear in these pages in subsequent issues.
9. MEASUREMENT AND CONTROL OF COLOR CHARACTERISTICS OF FLYING SPOT COLOR SIGNAL GENERATOR

R. Moore, J. Fisher, and J. Chatten
(Philco Corporation, Philadelphia, Pa.)

The color fidelity of the Flying Spot Generator is affected by the spectral output of the cathode-ray-tube light source, the reflectance characteristics of the dichroic mirrors, and the spectral response of the three photomultiplier tubes. A measurement technique to evaluate the color fidelity of the generator will be described in this paper. This consists of a motor-driven light chopper placed between the light source and the slide holder, and the use of narrow-band interference filters having a known spectral transmission and bandwidth also placed in the optical path. Readings of red, green, and blue photomultiplier-tube outputs are taken for each interference filter used by means of a narrow-band electrical filter. From these data the performance of the color generator may be calculated, and trim filters with electrical matrix networks may be added so the taking characteristics will be the desired primary curves.

10. PERFORMANCE OF CARRIER SYNCHRONIZING CIRCUITS FOR COLOR TELEVISION RECEIVERS

E. M. Creamer, Jr., and M. I. Burgett
(Philco Corporation, Philadelphia, Pa.)

Dot-sequential color television pictures require the satisfactory reception of phase reference information concerning the color carrier. Certain aspects of transmitter operation and receiver tuner and intermediate-frequency amplifier design contribute significantly to successful determination of this phase reference. Results of objective and limited subjective tests show the effect of random and impulse noise on the operation of several carrier abstraction circuits and the resultant color picture. Color carrier static phase shift limits for various signal-to-noise ratios are determined by observed picture degradation. Benefits from pick-off noise protection and time gating in achieving ultimate circuit performance are indicated.

11. A SIMPLE PATTERN GENERATOR FOR COLOR TELEVISION SIGNALS

R. P. Burr, W. R. Stone, and R. O. Noyer
(Hazeltine Electronics Corporation, Little Neck, L. I., N. Y.)

The current interest in color television systems has, among other things, produced the need for a simple means of generating color television signals. In the early stages of the present monochrome television system, complete camera chains were soon discarded in favor of the simpler and more reliable monochrome pattern generator as a general laboratory and test line video-signal source.

The purpose of this paper is to describe a simple source of color television signals which may be added to an existing television installation with a minimum of effort. Satisfactory performance may be obtained for either simultaneous and dot-sequential systems employing current monochrome standards or the recently standardized field-sequential system.

12. THE DESIGN AND USE OF THE AUTOMATIC ANTENNA PATTERN RECORDER

J. W. Tiley
(Philco Corporation, Philadelphia, Pa.)

The general problem of microwave antenna pattern recording is discussed. Particulars of a recently built automatic pattern recorder, using a commercially available servo amplifier, a logarithmic attenuator of novel design, plotting on "standard" antenna pattern paper with speeds of 160° in two minutes, and with angular errors not greater than a tenth of a degree are given. The philosophy of the circuit design is discussed.

The major sources of error in a pattern measurement set-up are given and the practical findings of the author in tests involving several years of time and covering many of the usual types of antennas are discussed.

13. STAGGER-TUNED LOOP ANTIENNAS FOR WIDE-BAND LOW-FREQUENCY RECEPTION

D. K. Cheng and R. A. Galbraith
(Syracuse University, Syracuse, N. Y.)

This paper describes a system of stagger-tuned high-Q loop antennas designed for 100-kc loran pulse reception. The individual loop-antenna outputs are first added in a summing amplifier. Two methods, one analytical and one graphical, of determining the resultant response of the summing amplifier with stagger-tuned input channels are developed. Based upon the theoretical analysis, an experimental antenna array is then designed, which confirms its capability of achieving a wide bandwidth with small dimensions. The possibility of obtaining an array having omnidirectional reception properties is discussed and a squaring scheme of accomplishing this is also described.

14. THEORY OF THE CONCENTRIC-SLOT ANTENNA

T. Morita
(Harvard University, Cambridge, Mass.)

The object of this investigation is the study of the far-zone electromagnetic field produced by a concentric-slot antenna. The concentric-slot antenna consists of two concentric circular gaps made in an infinitely conducting plane. The inner slot is driven while the outer slot is a parasite tuned by a short-circuiting plunger. Expressions are obtained for the self- and mutual admittance of the slots. From these results the ratio and phase difference of the electric field in the two apertures are obtained as functions of the tuning of the parasitic slot. The field pattern is then calculated by the classical Kirchoff approximation. Experimentally determined patterns are presented to verify the theory.

15. OPTIMUM CURRENT DISTRIBUTIONS FOR ANTENNA ARRAYS WITH CIRCULAR SYMMETRY

Raymond H. DuHamel
(University of Illinois, Urbana, Ill.)

A procedure is developed for determining a continuous circular current distribution which will produce an optimum field pattern in the sense that for a given side-lobe level the beam width is minimum. The optimum patterns are derived from Tchebyscheff polynomials in a manner similar to that used by Dolph and Riblet for a broadband array. A method for determining the minimum number of radiators to approximate the continuous current distribution to a prescribed accuracy is given. The procedure is also applied to a circular array of antennas around a cylinder and to other arrays with circular symmetry.

16. DIRECTIONAL ANTENNA ARRAYS OF ELEMENTS CIRCULARLY DISPOSED ABOUT A CYLINDRICAL REFLECTOR

R. F. Harrington
(Ohio State University, Columbus, Ohio)

W. R. Lepage
(Syracuse University, Syracuse, N. Y.)

An antenna system with controllable directional properties can be obtained by disposed a system of properly phased current elements about a circular conducting cylinder. A general analysis is given, leading to formulas for the field patterns of such an array. The analysis is applicable to any distribution of amplitude and phase of the current elements, but the beam-co-phased case is emphasized. The solution is obtained by summing the known pattern function for a single element with reflector, over all the elements of the array.

17. CALCULATIONS FOR CLASS-C AMPLIFIERS WITH A REACTIVE LOAD

D. A. Cawood
(Sylvania Electric Products Inc., Flushing, L. I., N. Y.)

The object of this paper is to present a graphical-analytical method for the design of class-C amplifiers with two-concentric circular gaps made in an infinitely conducting plate. The necessary condition for a stable and mutual admittance of the slots. From these results the ratio and phase difference of the electric field in the two apertures are obtained as functions of the tuning of the parasitic slot. The field

Power Tubes I — Theory

E. L. Chaffee, Chairman
(Harvard University, Cambridge, Mass.)

March
18. THE EFFECT OF SECONDARY EMISSION IN POWER TUBES
Hsiung Hsu
(General Electric Company, Owensboro, Ky.)
Methods have been developed to determine the secondary currents by using the g-log chart reported by Chaffee. The effect of the secondary currents on the in-anteus power dissipations and on the operating condition of power amplifiers has been analyzed.

The space-charge limitation of the secondary current has been found to be of much greater significance than the effect of the initial velocities of the secondary electrons. The observations give a satisfactory explanation of the discrepancy in the earlier analysis of the space-current distribution due de La Sabliere and Hamaker.

9. REFLEX RESNATRON OPERATION AND ITS IMPLICATION FOR BANDWIDTH
M. Garbuny and G. E. Sheppard
(Westinghouse Research Laboratories, East Pittsburgh, Pa.)
The action of the reflex resonatron introduced in the accompanying abstract is explained and quantitatively described in terms of transit-time phenomena of the reflected electron bunches. In particular, date modulation results from deviations from the resonance condition for the transit times. The repeated interaction of the electron beam with the cavity field permits the combination of the high efficiencies of electron operation with low shunt resistances and allows, therefore, wide bandwidth. Experimental evidence for the theoretically expected bandwidth and efficiency behavior at varying reflex conditions as presented, performance data are compared with conventional resonatron operation, and improved utilization of the principles involved is discussed.

20. THE MULTIBEAM ELECTRON COUPLER—AN IMPROVED SPIRAL-BEAM ELECTRON TUBE FOR THE MODULATION AND CONTROL OF POWER AT UHF
C. L. Cuccia
(RCA Laboratories Division, Princeton, N. J.)
The electron coupler is a spiral-beam tube utilizing new principles for the control and modulation of power at ultra-high frequencies. It is placed between the generator and the load and acts as a unilateral control impedance—simulating very closely the control properties of vacuum tubes at low frequencies with the exception of the fact that it does not amplify. The electron couplers to be discussed are 1-kw tubes of improved cavity design in the 800-Mc range utilizing several electron beams, in which new methods of modulation have been incorporated resulting in good linearity characteristics, bandwidth in excess of 5 Mc, and requiring control voltages of less than 50-volts swing to control the power into the output over a range of 98 per cent of maximum.

21. A NEW SINGLE-CAVITY RESONATOR FOR A MULTINODE MAGNETRON
J. S. Needle, G. Hoh, G. R. Brewer, and H. W. Welch
(University of Michigan, Ann Arbor, Mich.)
A new magnetron which operates as a symmetrically driven coaxial-line oscillator is described. Design equations for this structure have been developed and several tubes have been constructed for operation at 14 cm. Performance data from one of these tubes are included, showing operation in the desired mode with continuous-wave output of 150 watts. The feasibility of wide-range tuning appears to make this magnetron unique, although emphasis to date has been directed toward the development of a non-tunable magnetron. A tunable magnetron of this basic design is now in the early stage of development.

Frequency Control and Generation
W. H. Doherty, Chairman
(Bell Telephone Laboratories, Inc., Murray Hill, N. J.)

22. THE GENERATION OF SINGLE-SIDEBAND SUPPRESSED-CARRIER SIGNALS BY A NEW BALANCING METHOD
H. M. Swarm
(University of Washington, Seattle, Wash.)
Single-sideband suppressed-carrier signals have been obtained by combining the outputs of two AM modulators and a carrier-cancellation amplifier. Both the carrier and modulating signals applied to the two modulators differ in phase by 90°. The carrier is thus cancelled after modulation and without the use of balanced modulators. Fewer adjustments are required for this method than for other conventional methods. The sideband cancelling adjustments are practically independent of the carrier-cancelling adjustments, thus making the desired over-all operation easier to maintain.

An automatic carrier suppression circuit may be incorporated to maintain the carrier below a prescribed level.

23. PRECISION FREQUENCY GENERATORS USING SINGLE-SIDEBAND SUPPRESSED-CARRIER MODULATORS
H. R. Holloway and H. C. Harris
(Sylvania Electric Products Inc., Bayside, L. I., N. Y.)
Often the need arises to develop a signal whose frequency does not bear a direct harmonic relation to a given frequency standard or to that of another signal source. The necessity also arises for a means to continuously shift the phase of a given signal any amount with respect to a comparison signal. Since the single-sideband suppressed-carrier modulator is a useful device for the generation of the sum or difference of two frequencies, this paper presents an analysis and design criteria for an electronic single-sideband suppressed-carrier modulator, and an electromechanical design which meets the need for both a single-sideband suppressed-carrier modulator and a continuously variable phase shifter.

24. STABILIZED VARIABLE FREQUENCY TRANSMITTER EXCITER FOR MILITARY HF EQUIPMENT
John Bush
(Signal Corps Engineering Laboratories, Fort Monmouth, N. J.)
The design of a tunable transmitter exciter is presented for use with or as part of high-frequency transmitters. The need for crystals for each assigned frequency of operation is eliminated without the attendant complexity and difficulties of heterodyne mixer, synthesizer, IGO, and other known systems.
The exciter covers a tuning range of 1 to 32 Mc and provides a choice of on-off telegraph (A-1); frequency shift teletype (F-1); phase-modulation telephony (F-3); or dc frequency shift facsimile or radiophoto (F-4) emission.

Automatic-frequency-control techniques utilizing a novel modulation cancellation method permit stabilization of output frequency at all points in the modulation cycle.

25. WIDE-RANGE DIRECT-READING PRECISION FREQUENCY METER AND SIGNAL SOURCE
B. Parzen
(Federal Telecommunication Laboratories, Inc., Nutley, N. J.)
This paper describes a compact instrument for rapid and precise frequency measurements between 30 cps and 1,000 Mc. It consists of a signal source capable of being set to any frequency between 0 to 30 Mc, two beat detectors for comparing the unknown frequency with the frequency of the signal source, and the necessary power supplies for mains operation. The 2-volt output of the signal source is also available as a jack for use as a precision frequency generator.
The frequency of the signal generator is directly indicated on 8 dials arranged on a decade basis. The desired frequency is obtained by merely setting the dials by means of the associated knobs in a manner strictly analogous to setting up a desired resistance on a 8-place decade resistance box. The frequency is dependent only on a single 100-kc crystal and a 10-kc range interpolation oscillator. An over-all accuracy of better than 1 part in a million plus 3 cps is obtained.

26. CRYSTAL CONTROL OF A 4-KW, 1,036-MC TRANSMITTER
J. W. Clark, R. W. Kane, W. G. Abraham, N. P. Hiestand, and S. F. Varian
(Varian Associates, San Carlos, Calif.)
This talk will describe a transmitter which was designed and built by Varian Associates for Central Radio Propagation Laboratory in connection with their study of the propagation characteristics of micro-
wave radiation. The transmitter radiates a continuous power of 4-kw at 1,036.8 Me with a frequency stability of one part in 107. Ninety-nine per cent of this energy is contained within a band 20 cycles wide. The output tube in the transmitter is a Varian Associates X-25 klystron, a three-cavity amplifier tube. This tube is driven by a frequency multiplier chain which in turn is excited by a General Radio 100-kc frequency standard. The layout of the transmitter will be described and the design of the klystron tube will be discussed in detail.

27. FREQUENCY STABILIZATION SYSTEM FOR MEASUREMENT OF MICROWAVE REFRACTION OF GASES

W. F. Gabriel
(NAVAL RESEARCH LABORATORY, Washington, D. C.)

The method is based upon a double-loop frequency-stabilized klystron oscillator system in which a high-Q resonant cavity (into which the gases are introduced) is the controlling element. One frequency control loop is a fast-acting all-electronic servo which corrects the oscillator against rapid fluctuations from the cavity resonance frequency. The other frequency control loop is a slow-acting motor servo which integrates out the small, steady-state frequency error left by the electronic loop. Frequency control to better than one part in 106 has been obtained and used in making accurate index of refraction measurements.

Communication Systems

A. G. Clavier, Chairman
(FEDERAL TELECOMMUNICATIONS LABORATORIES, Inc., Nutley, N. J.)

28. AM—FM ANALOGY

H. C. Harris
(Sylvania Electric Products Inc., Bayside, L. I., N. Y.)

In order to simplify some types of frequency-modulation calculations, this paper presents the “amplitude equivalent” of a FM wave. This concept is applied to the calculation of spectral distribution and to the solution of the network response to FM signals. Both aperiodic and periodic signals are considered and special emphasis is placed upon the steady-state analysis of periodic FM systems. The “amplitude equivalent” is found to be most helpful when the modulation of the signal is characterized by rectangular shapes. In these cases the method outlined is exact; however, in general, the method is approximate to any desired accuracy.

29. SURVEY OF ELECTRONIC COMMUTATION METHODS

Robert S. Butts
(Melpar, Inc., Alexandria, Va.)

Several time-division systems of multichannel radio communication and tele-metering have been described in recent papers. In this paper, a comparative analysis is made of several methods of electronic commutation of the signal sources. The analysis is intended to provide a summary of methods to aid the system designer in selecting the most applicable method for a particular system. The analysis includes such factors as speed, sensitivity, cross-talk, input power, size, and reliability. Methods included are: thyatron and multivibrator rings, binary-counter-driven matrices, delay lines, polyphase transformers, Scott "T" transformers, and rotary beam tubes.

30. HIGH-FREQUENCY RADIO COMMUNICATION SYSTEM UTILIZING PHASE-MODULATION TRANSMISSION AND SINGLE-SIDEBAND FREQUENCY MULTIPLIER CIRCUIT WHICH IN TURNO IS THE SMALL, STEADY-STATE FREQUENCY ERROR

H. F. Meyer and H. Y. Littlefield
(SIGNAL CORPS ENGINEERING LABORATORIES, Fort Monmouth, N. J.)

A high-frequency radio system is described wherein a conventional continuous-wave transmitter is phase modulated and single-sideband reception is accomplished by detection of the first-order sideband component of the transmitted signals. Multichannel frequency-division telegraph signals were transmitted over the system and tests were made to determine the optimum values of modulation index for four-, eight-, twelve-, and sixteen-channel operation. The system provides freedom from amplitude distortion produced by the transmitted signals. Multichannel frequency-modulation telegraphy and offers the feature of frequency diversity without increased bandwidth.

Theoretical and experimental comparisons are made between this system and a system of single-sideband transmission and reception.

31. ECHO DISTORTION IN THE FM TRANSMISSION OF FREQUENCY-DIVISION MULTIPLEX

W. J. Aldersheim and J. P. Schaper
(Bell Telephone Laboratories, Inc., Deal, N. J.)

The composite multiplex signals generated by frequency-division methods long standard in telephone communication can be transmitted by the new transcontinental broad-band FM radio relays. Signal intermodulation by echoes must be minimized. It is investigated in this paper experimentally and analytically.

Two types of echoes are considered:

(1) weak echoes with delays exceeding 0.1 microsecond, caused mainly by mismatched long lines, and

(2) powerful echoes with delays shorter than 0.1 microsecond, caused by multipath transmission and leading to selective fading. Using random noise signals, the distortion is evaluated as a function of various parameters of the echo, the base band and the radio-frequency modulation.

32. MANAGEMENT ASPECTS OF ELECTRONIC SYSTEMS ENGINEERING

R. I. Cole
(Watson Laboratories, AMIC, Red Bank, N. J.)

This paper cites that in the rapid growth of electronics engineering, management has not always appreciated the full magnitude of the “systems engineering” problem. In setting forth what alert management should attempt to accomplish, the systems engineering influence in research and development is discussed in some detail. In this regard particularly is it significant that more cannot be given to the planning of features that make for simpler maintenance in large complicated systems. Installation problems are dealt with briefly and particular emphasis is given to the noise reduction problem within the systems in order that the best optimum repeatable results are obtained. Lastly, the engineering management phases are covered from the standpoint of management assuming greater responsibility to see that proper engineering emphasis is given to proper maintenance of installed systems.

SYMPOSIUM

Amplification of DC Signals

(organized by Professional Group on Instrumentation)

I. G. Easton, Chairman
(General Radio Company, Cambridge, Mass.)

33. THE SERVOMODULATOR: A LOW-LEVEL DC INSTRUMENT

G. M. Attura
(Industrial Control Co., New York, N. Y.)

This paper describes a modification of the dynamic servomodulator which has resulted in two commercial instruments for very low-level dc measurements. Their basic action is to convert the unknown dc voltage into an ac signal whose value is then metered by an ac vacuum-tube voltmeter, or displayed on a cathode-ray oscilloscope.

To be acceptable as a general-purpose laboratory instruments, the following features must be engineered into their design: internal noise level approach the limiting thermal noise, gain stability with changes in amplifier gain and chopping cycle, some insensitivity to power line pickup in the input leads, and a high input resistance. The methods by which this is accomplished are described.

Due to the very low level of dc attainable, some precautions must be observed by the user: input circuit shielding, location away from strong magnetic fields, low noise power mains, and single ground system.

34. TRANSIENT RESPONSE OF SELF-SATURATING MAGNETIC AMPLIFIERS

E. J. Smith
(Polytechnic Institute of Brooklyn, Brooklyn, N. Y.)

There is no natural definition for "transient response" of a magnetic amplifier. From an applications point of view, the transient response of the cyclic average or rms load current, following a step change in control circuit voltage, is the most significant description of the transient behavior. An approximate analysis of the full-wave and double circuits, based upon "cyclic
which substantially eliminates drift in a number of dc amplifiers simultaneously. This method consists of sampling the voltage at the first grid of the dc amplifier with a mechanical switch, amplifying the error signal in a pulse amplifier, and distributing an amplified compensating voltage to an appropriate point in the dc amplifier, so as to reduce the input grid voltage to zero.

**SYMPOSIUM**

**New Extensions of Network Theory**

(Ororganized by Professional Group on Circuit Theory)

W. H. Huggins, Chairman
(Air Force Research Laboratory, Cambridge, Mass.)

**38. SIGNAL FLOW GRAPHS**

S. J. Mason
(Massachusetts Institute of Technology, Cambridge, Mass.)

The functional relationships entering a linear or nonlinear analysis problem may be expressed in the form of a signal flow graph. The graph aids visualization of the character of a given set of equations and systematizes their solution. For linear problems the graph itself, as contrasted with the original equations, may be manipulated to obtain the desired solution. In addition to its use in practical problems, the flow graph approach provides the base for a unified body of feedback theory. In particular, the statements and proofs of a variety of feedback theorems become very simple and direct when carried out in the language of flow graphs.

**39. SOME BIOLOGICAL APPLICATIONS OF RANDOM NETS**

A. Rapoport
(Committee on Mathematical Biology, The University of Chicago, Chicago, Ill.)

A random net is defined as an aggregate of points connected by directed line segments where, in general, several lines may issue from each point, such that only the probabilities of specific connections are known. If all connections are equi-probable, the “connectivity” of a random net may be defined and computed. This is the probability that a “path” exists between an arbitrary pair of points. The concept of connectivity can be applied to neural nets (in the mathematical biology of learning phenomena); to epidemiology (in the mathematical theory of contagion) or its social analogue (the spread of rumors); to genetics (in the probabilistic theories of ancestral trees); and so forth.

**40. SOME EFFECTS OF COMMUNICATION PATTERNS ON THE PERFORMANCE OF SMALL TASK-GROUPS**

A. Bavelas
(Massachusetts Institute of Technology, Cambridge, Mass.)

Experiments have been made with groups of five persons who have a specific task to perform and are constrained to use certain channels of communication. The effects of different patterns on speed and accuracy of performance, and on leadership and morale are shown to be significant. An attempt is made to explain these results in terms of the probability that information present at one point will be at some other point at a specified time.

**41. ELECTRIC NETWORK MODELS FOR PROBLEMS OF PROBABILITY**

W. E. Bradley
(Philco Corporation, Philadelphia, Pa.)

It is shown that the equations of state transitions with constant mean probability (Markov Processes) are analogous to those describing certain electrical networks and that physical comprehension of such problems and their method of solution is sometimes facilitated by the use of such a model. Particularly useful are the methods of transient analysis commonly used in electric circuit theory for the prediction of future states of a Markov process when the initial state is known. As an example of the method, it is applied to the simple statistical problem of the probability distribution of the count of particles arriving with constant mean probability.

**SYMPOSIUM**

**Panel Discussion on Tube Reliability**

(Ororganized by Professional Group on Quality Control)

E. D. Cook, Chairman
(General Electric Company, Schenectady, N. Y.)

42. Representatives from industrial users, government services, and tube manufacturers will present their viewpoints in regard to this important subject.

**Panel Members**

a. M. A. Achieison (Sylvania Electric Products Inc., Kew Gardens, L. I., N. Y.)


c. R. J. Frame (Wright Field, Dayton, Ohio)

d. J. E. Gorham (Signal Corps Engineering Laboratories, Belmar, N. J.)

e. N. H. Green (Radio Corporation of America, Harrison, N. J.)

f. J. W. Grenier (Bureau of Ships, Navy Department, Washington, D. C.)

g. F. D. Langstroth (Philco Corporation, Landisville, Pa.)

h. H. E. May (Motorola, Inc., Chicago, Ill.)

i. R. E. Moe (General Electric Company, Owensboro, Ky.)

j. A. L. Samuel (International Business Machines, Poughkeepsie, N. Y.)
43. A COAXIAL POWER TRIODE FOR 50-KW OUTPUT UP TO 110 MC
R. H. Rifeauer (Machlett Laboratories, Inc., Springdale, Conn.)

Use of a novel tube assembling and vacuum sealing technique, a thoreau cathode, and a reentrant anode in an integral water jacket have made possible the development of a coaxial ring seal power triode giving 50-kw rf output up to 110 Mc. The frequency bandwidth obtainable with this tube is suitable for television transmission. Increased power output ratings are available for lower frequencies.

Design requirements are examined for optimum electrode geometry, minimum capacitance and inductance of electrode terminal leads with maximum rf current carrying capacity, high rates of heat dissipation, high rf conductivity of the vacuum seals, and other desiderata. Mechanical features are discussed, and the circuit performance of the tube is analyzed for various applications.

44. A HIGH-POWER TETRODE
CLAYTON E. MURDOCK (Eitel McCullough, Inc., San Bruno, Calif.)

Described is a high-power tetrode of unique design particularly well adapted for television transmission in the vhf region up to 216 Mc. The tube uses a new unipotential, slotted-tungsten cathode which is heated by electron bombardment. The coaxial terminal arrangement of the tube is ideally suited for use in cavity circuits. Improvements in tetrode geometry and tube design for high power are described. The paper gives the general electrical characteristics and operating conditions for TV service.

45. THE REFLEX RESNATRON
GLENN E. SHEPPARD, M. GABRUno, AND J. R. HANSEN (Westinghouse Research Laboratories, East Pittsburgh, Pa.)

The design, construction, and performance of a device known as a "reflex resnaton" is discussed. Structurally this device is a tetrode consisting of two opposed nosed-in cavities. The electrodes of the tube are so arranged that good electron beam focusing is obtained. The electron flow is axial with respect to the cavities. As an amplifier this device produces outputs in excess of a kilowatt at a frequency of 560 Mc. The bandwidth of this device is suitable for television. Modulation is obtained in a unique manner.

46. TRANSMITTING TUBE SUITABLE FOR UHF TELEVISION
WAYNE G. ABRAHAM, F. L. SALISBURY, AND S. F. VARIAN (Varian Associates, San Carlos, Calif.)

This talk will describe a newly developed sealed-off klystron amplifier tube suitable for use in the final amplifier stage of a uhf television transmitter. The tube is capable of a continuous power output of 5 kilowatts. It has a bandwidth of 6 Mc and a power gain of 200 times. The tube is conservatively designed; the service life expected is several thousand hours. The tube is so made that the entire cathode structure can be replaced in the event of a failure.

47. FREQUENCY-MODULATED HIGH-EFFICIENCY KLYSTRON TRANSMITTER
MARVIN CHOUDROW AND S. P. FAN (Microwave Laboratory, Stanford University, Stanford, Calif.)

Theory and measurements of a 2-gap, single-cavity klystron intended for use in microwave relay lines is described. This tube has most of the useful characteristics of a reflex klystron as a frequency-modulated oscillator, but has many advantages not possessed by the reflex tube. Multiple transit hysteresis, as well as other types, is entirely absent; the mode is much smoother than on reflex and the efficiencies and power obtainable are much greater. Frequency modulation is obtained by modulating the drift tube voltage which controls the transit time between the two gaps. A power of 18 watts has been obtained at 10 cm with an efficiency of about 22 per cent.

48. SELECTIVE FADING OF MICROWAVES
A. B. CRAWFORD AND W. C. JAKES, JR. (Bell Telephone Laboratories, Inc., Holmdel, N. J.)

Observations of selective fading in a 450-Mc band centered at 3,950 Mc have been made as part of a study of microwave propagation over two line of sight paths in New Jersey. Much of the observed fading can be explained in terms of multiple path transmission in which path differences up to 7 feet were evident. These measurements were supplemented by angle of arrival observations at 1.25-cm wavelength. A computer of the analogue type was built for simulating the more complicated selective fading patterns.

Movie films will be presented to illustrate selective fading and angle of arrival data.

49. PROPAGATION STUDIES AT MICROWAVE FREQUENCIES BY MEANS OF VERY SHORT PULSES
O. E. DE LANGE (Bell Telephone Laboratories, Inc., Deal, N. J.)

Microwave pulses with a duration of about 0.003 microsecond were transmitted over a 22-mile path from Murray Hill, N. J., to Holmdel, N. J., in order to determine the effects of the transmission medium upon such pulses. During "fading" periods multipath transmission effects with path differences as great as 7 feet were observed, as well as some other effects. A microwave frequency of 4,000 Mc was employed.

This experiment was suggested as an ad-junct to one in which propagation studies were being made by the frequency sweep method. Results obtained by the two methods are generally in agreement.

50. LOW-FREQUENCY IONOSPHERIC SOUNDINGS WITH ATMOSPHERICS
WILLIAM J. KESSLER AND WALLACE F. ZETTROUER, II (University of Florida, Gainesville, Fla.)

The use of atmospherics pulses, produced by remote and local lightning discharges, for ionospheric measurements below 100 kc is described. A discussion on the characteristics of lightning discharges as pulse radiators and the spectrum of the radiated field is included.

Oblique-incidence measurements made during the night with sounding pulses produced by lightning discharges originating in remote thunderstorms over a wide range of distances yield reflection heights in the vicinity of 85 kilometers. A limited number of vertical-incidence soundings with pulses obtained from overhead thunderstorms gives a mean reflection height of about 90 km over Gainesville, Fla.

51. THE EFFECT ON PROPAGATION OF AN ELEVATED ATMOSPHERIC LAYER OF NONSTANDARD REFRACTIVE INDEX
L. H. DOBERRY (Cornell University, Ithaca, N. Y.)

It is shown by the method of geometrical optics that elevated layers whose gradient of refractive index differs from standard may radically affect the field of a transmitter placed above the layer. Departures from the standard atmosphere which are so slight that they are often present may result in serious difficulty in communication between aircraft when both are flying above the layer. A tri-linear refractive index model of the atmosphere is treated in some detail. It is shown that above the layer this results, within a certain range of distances, in a decrease of field strength. Following this "radio hole" there is a region of interfering rays and the resulting interference pattern is shown. The effect of some nonlinear refractive index models is indicated. Comparisons are made with experimental results.

SYMPOSIUM

Broadcast Transmission Systems

(organized by Professional Group on Broadcast Transmission Systems)

R. W. Hodgkins, Chairman
(Station WGAN, Portland, Me.)

52. MASTER CONTROL FACILITIES FOR A LARGE STUDIO CENTER
R. H. TANNER (Northern Electric Company, Ltd., Belleville, Ont., Canada)

A study of the Master Control requirements of a 21-studio center in Montreal, capable of feeding eight outgoing network lines and five transmitters, and the methods
ed to fulfill them. A preset switching stem, using an unusually small number of layers, is employed in conjunction with an intensive visual and aural monitoring system, based on the "crossbar" switch first signed for automatic telephony. The same type of switch is used in a system which allows each subscriber to connect any one of fifty program sources. In addition, a dialing system extends a similar choice to fifty executive offices around the building.

I. ELECTRONIC INSTRUMENTATION AM, FM, AND TV BROADCASTING THROUGH USE OF THE CATHODE-RAY OSCILLOGRAPH

P. S. CHRISTALDI

(DuMont Laboratories, Clifton, N. J.)

The cathode-ray oscillograph is the most important single tool at the disposal of the broadcast engineer. It is useful in the conduct of routine measurements at the broadcasting station, for signal monitoring purposes, and is indispensable in the making of roof-of-performance tests on installations, required by the Federal Communications Commission.

This paper will describe some of the broadcast station measurement techniques employing the modern cathode-ray oscillograph. Methods for making use of the cathode-ray oscillograph in conducting routine equipment tests, in making actual measurements, and in satisfying the measurement requirements as promulgated by the FCC will be discussed.

It is felt that the cathode-ray oscillograph is not as widely applied in broadcasting as it might be, and an attempt will be made to show the broadcast engineer how simply and effectively it can be employed.

54. PERFORMANCE OF SECTIONALIZED BROADCASTING TOWERS

CARL E. SMITH

(United Broadcasting Company, Cleveland, Ohio)

With a sectionalized tower, high-angle radiation can be minimized and ground-wave radiation can be maximized. For example, with a two-section tower the top section can be fed by a conductor shielded within the lower section. This terminal plus a connection to the ground and the lower section gives a threeterminal network which can be properly fed at the base.

Theoretical and experimental results show an equivalent power increase over a quarter-wave antenna of 113 per cent and 90 per cent over a 590 tower. This affords an inexpensive way of effectively increasing the power of a radio broadcasting station.

55. INCREASED ECONOMY AND OPERATING EFFICIENCY OF TELEVISION BROADCAST STATIONS THROUGH SYSTEMIC DESIGN

R. A. ISBERG

(Electronic Systems Consultant, KRON-TV, San Francisco, Calif.)

The operating efficiency of a television station is largely dependent upon its planning with respect to floor plans and equipment layout. The number of operating personnel is directly affected by these factors along with the program structure.

Independent television stations operating in small markets must face one or more years of red ink operation before their income will pay operating expenses. During this initial phase of operation it is especially desirable to eliminate all operating activities in one location for maximum utilization of man power.

A number of innovations in system engineering were instituted at KRON-TV. Studio and film facilities are provided at the transmitter building and all control equipment including transmitter control panels are grouped into a U-shaped console. This console affords an efficient working area for two men who have all the equipment required for adjustment within an arm's reach.

56. TECHNICAL CONSIDERATIONS OF TELEVISION RECORDING

G. EDWARD HAMILTON

(American Broadcasting Company, New York, N. Y.)

Television Recording presents the problem of integrating two complex variables: the sciences of motion picture and television techniques. The prime problem is to weigh the merits and limitations of both processes in order to realize the optimum results from the sublimation of the two.

Television recording is required to reproduce into the output of television a replica of the original signal scheduled for this type of transmission. Factors affecting this requirement include system resolution, brightness range, film and film development characteristics, system gamma, and others. System element transfer characteristics must be weighed individually and collectively in order that corrective measures may be introduced where required.

SYMPOSIUM

Panel Discussion on Performance of DC Amplifiers

(Organized by Professional Group on Instrumentation)

ERNST WEBER, Chairman

(Polytechnic Institute of Brooklyn, Brooklyn, N. Y.)

57. A panel qualified to discuss design, performance, and application aspects of dc amplifiers of many types will present brief prepared remarks. Following this the audience will be invited to participate with questions and comments aimed at bringing out the capabilities of existing designs and the problems still requiring solution.

58. EDUCATIONAL REQUIREMENTS FOR DEVELOPMENT ENGINEERS IN ELECTRONIC AND COMMUNICATION TECHNOLOGY

M. J. KELLY

(Bell Telephone Laboratories, Inc., New York, N. Y.)

The expansion of research in the physical sciences has provided new knowledge which is having a profound effect on electronic and communication technology. This new situation has shifted the emphasis from scientific training from practice to fundamentals. The need for graduate programs in schools, and training programs on the graduate level in development laboratories is therefore emphasized.

The problems facing universities, technical schools and development laboratories will be discussed, and the Bell Telephone Laboratory's training program described.

59. MAKING ENGINEERING EDUCATION PROFESSIONAL

B. R. TEARE, JR.

(Carnegie Institute of Technology, Pittsburgh, Pa.)

Engineering education, like engineering practice, may be either professional or sub-professional. Engineering education is made professional through developing in the student the capacity for the orderly, analytical treatment of problems that are new to him and by preparing him to continue to learn after he leaves college, rather than by choice of subject matter and distribution of hours among different courses. Professional situation problems and problems to teach the art of learning from experience are powerful tools for these purposes. Examples are given.

60. USING TESTS TO SELECT ENGINEERS

WARREN G. FINDLEY

(Educational Testing Service, Princeton, N. J.)

Undergraduate colleges of engineering find tests of mathematical aptitude or achievement, comprehension of scientific materials, and spatial visualization, in that order, most helpful in selective admissions. Best selection is obtained when test results are used in conjunction with previous school records.

Testing for admission to graduate study in engineering presents the added problem of adapting procedures to the specialized branches. New tests are needed to apply knowledge, creative talent, biographical information.

In selecting engineering graduates for industrial positions, tests are most useful as supplements to other types of evidence and in proportion as previous testing data are lacking.

61. ORIENTING THE ENGINEER IN INDUSTRY

E. W. BUTLER

(Federal Telephone and Radio Corporation, Clifton, N. J.)

Our industrial civilization is becoming more complex each year in its economic and social as well as its technical aspects. At the
same time greater concentration on the technical curriculum is required in engineering schools. As a result, there is a tendency to severely restrict or eliminate the time available to acquaint the student with the non-technical aspects of industry. He, therefore, enters industry unprepared to solve the non-technical problems. The author feels that both the technical schools and industry must give wider recognition to this situation. The paper discusses the writer's observations of engineers' problems outside the scope of their technical training and offers suggestions as to how the university and industry may work together to better the situation.

Circuits I—Synthesis and Analysis

J. G. Brainerd, Chairman
(University of Pennsylvania, Philadelphia, Pa.)

62. NETWORK SYNTHESIS APPLIED TO FEEDBACK CONTROL

John G. Truxal
(Purdue University, Lafayette, Ind.)

The principles of network synthesis are applied to the synthesis of servomechanisms. From the specifications, the poles and zeros of a suitable transfer function of the system are determined. The second step involves the determination of the transfer function of the system—either considered as a filter or as a system subjected to multiple disturbances—is based on several relationships between pole and zero positions and system performance which clarify certain aspects of the general servomechanism synthesis problem.

63. NETWORK SYNTHESIS BY THE USE OF POTENTIAL ANALOGUES

R. E. Scott
(Massachusetts Institute of Technology, Cambridge, Mass.)

The synthesis of lumped-parameter passive networks is greatly facilitated by the use of the two-dimensional potential analogue. Two devices utilizing this principle will be described. The first machine plots gain and phase functions continuously on the face of a cathode-ray tube. It is useful for obtaining experimentally the locations of poles and zeros to give a desired gain and phase response. The second machine yields the real and imaginary parts of the network function. Properly processed these functions give the transient response of the network, and the device and its use in the problem of synthesis for a prescribed transient response.
with respect to velocity and density modulation is completely defined.

### Microwaves I—Waveguides A

**R. Bown, Chairman**

(Bell Telephone Laboratories, Inc., Murray Hill, N. J.)

73. DEVELOPMENT OF WAVEGUIDE SWITCHES FOR COMMERCIAL AND MILITARY APPLICATIONS

**T. N. Anderson**

(Airtron, Inc., Linden, N. J.)

This paper gives a discussion of the various means for accomplishing switching in a waveguide circuits. A discussion is given of the advantages of the various types of construction and the electrical performance which may be achieved using these. The development of waveguide switches which have reflections equivalent to ordinary transmission line components and which are capable of broadcast band operation at power levels equivalent to that of rigid waveguide is given.

Both military and civilian applications for waveguide switches are discussed along with techniques employed for obtaining the required mechanical and electrical performance. The various drive mechanisms which have been developed for use with these switches are also discussed. A discussion of a commercial application of a waveguide switch for extremely stringent electrical requirements is also discussed (broadband VSWR less than 1.02 and crosstalk at 90 dB) and the mechanism employed in its construction is described.

74. LOW-LOSS WAVEGUIDE TRANSMISSION

**S. E. Miller and A. C. Beck**

(Holmdel Radio Research Laboratory, Bell Telephone Laboratories, Inc., Red Bank, N. J.)

Above 5,000 Mc, the use of circular electric waves in round waveguides is attractive for low-loss transmission from the standpoint of minimizing guide size and delay distortion, but is subject to the restrictions inherent in a multimode medium. Experiments conducted on a 500-foot 4.732-inch inside-diameter line indicate that the small attenuations theoretically attainable using circular electric waves can be approximated in practice. Observed losses are somewhat above the theoretical values due to mode conversion and roughness of the waveguide wall. Under certain conditions, mode conversion can also result in signal distortion.

75. DOMINANT WAVE TRANSMISSION CHARACTERISTICS OF A MULTIMODE ROUND WAVEGUIDE

**A. P. King**

(Holmdel Radio Research Laboratory, Bell Telephone Laboratories, Inc., Red Bank, N. J.)

This paper presents some dominant wave transmission characteristics of multimode round waveguide lines in the 4-kMc range of frequencies. The use of such waveguide lines offers the advantages: (1) lower transmission losses than obtainable with single mode rectangular waveguide, and (2) the relative ease of making good joints.

Possible mode conversion effects, including dominant mode elliptical polarization, have been examined and found to be innocuous. As a result, cross-polarized dominant waves can be used to provide two reasonably independent signalling channels at the same frequency in one pipe. The experimental results obtained with a straight line 2.812 inches inside diameter and 150 feet long is given.

76. RADIAL PROBE MEASUREMENTS OF MODE CONVERSION IN LARGE ROUND WAVEGUIDE WITH $TE_{10}$ MODE EXCITATION

**M. Aronoff**

(Holmdel Radio Research Laboratory, Bell Telephone Laboratories, Inc., Red Bank, N. J.)

Measurements of mode conversion in 2-inch inside diameter and 4.736-inch inside diameter round waveguide excited with $TE_{10}$ energy were made at 9,000 Mc. A short probe sampled the radial electric field around the inner periphery of the waveguide wall and the resulting response indicated the presence of the undesired modes. Mode conversion caused by waveguide ellipticity, surface imperfections (scratches, bumbs and holes), and imperfect joints was measured and found to agree well with available theory.

The technique described has been found useful in electrically testing the worth of individual sections of commercially drawn waveguide for use in transmitting the circular electric wave.

77. A BROADBAND MICROWAVE QUARTER-WAVE PLATE

**A. J. Simmons**

(Naval Research Laboratory, Washington 25, D. C.)

Differential phase shift between two orthogonal $TE_{01}$ waves in circular hollow waveguide is achieved with a reflectionless array of capacitive pins. Using transmission-line theory, an analysis of such a structure is made and, under the assumption that the pin susceptance varies with frequency as $jwC$, a broadband 3-pin array acting as a quarter-wave plate may be designed. Such an array, which is only one inch long at X band has been tested. A voltage ellipticity ratio of less than 1.1 and VSWR less than 1.2 is maintained over a 12 per cent band.

78. THE PRECISION MEASUREMENT OF THE EQUIVALENT CIRCUIT PARAMETERS OF DISSIPATIVE MICROWAVE STRUCTURES

**A. A. Olmer and H. Kuss**

(Microwave Research Institute, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.)

The precision method to be described analyzes a general dissipative terminal structure in the simplified equivalent circuit consisting of two resistive and two reactive parameters between specified reference planes.
The network parameters are determined independently of any absolute distance measurements, which generally involve the greatest source of error. The method is based on A. Weissfloch's idea of utilizing a network with separated lossy and lossless parts.

The input data obtained for different settings of a variable short-circuiting plunger at the output side are plotted in the reflection coefficient plane and fitted analytically by the best possible circle. From the location of the center and the radius of this circle, two resistive network parameters and an input reference plane shift are determined. The remaining lossless portion of the network is analyzed precisely by the tangent relation method yielding a shunt network.

SYMPOSIUM
Panel Discussion on the "Empire State Story"
(Organized by Professional Group on Broadcast Transmission Systems)

F. Marx, Chairman
(American Broadcasting Company, New York, N. Y.)

70. A detailed discussion of the electronic, electrical, architectural, and mechanical constructional features of the Empire State broadcasting facilities by a group of specialists who are specifically involved in the activity.

Panel Members
a. O. B. Hanson (National Broadcasting Company, New York, N. Y.)
b. F. G. Kear (Kear and Kennedy, Washington, D. C.)
c. W. F. Lamb (Shrive, Lamb and Harmon, New York, N. Y.)
d. B. H. Richardson (Starrett Bros. and Ekin, New York, N. Y.)
e. G. Ghring (Radio Corporation of America, Camden, N. J.)
f. T. E. Howard (Station WPIT, New York, N. Y.)
g. R. D. Cripe (DuMont Television Network, New York, N. Y.)
h. F. Marx (American Broadcasting Company, New York, N. Y.)

SYMPOSIUM
Recent Advances in Color Television
A. G. Jensen, Chairman
(Bell Telephone Laboratories, Inc., Murray Hill, N. J.)

80. The subject will be covered in a co-ordinated series of papers by a panel of several leading engineers from companies currently engaged in color television research. The speakers and their topics will be:

A. PRINCIPLES OF ADDING COLOR TO TELEVISION
W. T. Wintringham
(Bell Telephone Laboratories, Inc., Murray Hill, N. J.)
86. THE RAYTHEON SELECTION MATRIX FOR COMPUTER AND SWITCHING APPLICATIONS
Kenneth M. Reehler
(Raytheon Manufacturing Company, Waltham, Mass.)
This paper outlines the design requirements for the three selection matrices used in the Raytheon computer, discusses circuit tail presentations for self-checking the selections as made, and lists the advantages of the design. Photographs are used to clarify circuit details, and illustrations and packagings in construction and handling techniques.

Previous types of selection matrix input drivers employing bi-stable elements such as p-flops inherently perform a selection when they should be non-selecting or "reset." To overcome this difficulty a new simple type matrix input-column driver has been developed which is tri-stable. It can be fully reset on both sides.

87. SATURABLE REACTORS AS SUBSTITUTES FOR ELECTRON TUBES IN HIGH-SPEED DIGITAL COMPUTERS
James G. Miles
Saturable reactors offer prospects as reliable, permanent, low power, active circuit elements for drastically reducing the number of electron tubes required in high-speed digital computer. Magnetic-amplifier type p-flops are described which are operated by large pulses of less than one microsecond duration and at repetition rates up to 400,-30 pulses per second. Illustrations show applications of magnetic flip-flops as counters and registers for binary-coded numbers, and as memory-controlled operating devices. Core configurations are described and core material characteristics are critically compared. Desirability of integrated amplifiers with associated magnetic amplifier circuit components such as rectifiers are set forth.

88. FERROMAGNETIC CORES FOR THREE-DIMENSIONAL DIGITAL STORAGE ARRAYS
William N. Papian
(Servomechanisms Laboratory, Massachusetts Institute of Technology, Cambridge, Mass.)
Recently developed "rectangular" hysteresis-loop magnetic materials permit compact information-storage assemblies where the selected storage cell is located by intersection of three space-coordinate planes. The selection switching is inherent in the array based on each core's ability to distinguish between several values of occurring current.

Quantitative data, and the dependence of performance on hysteresis-loop shapes, are given in terms of "information-retention" and "signal" ratios. A metallic core with excellent signal ratios and a 20-microsecond response time, and a ferritic core with fair signal ratios and a 4-microsecond response time bracket the results to date.

89. DEPENDABLE SMALL-SCALE DIGITAL COMPUTER
J. J. Connolly
(Teleregister Corporation, New York, N. Y.)
The manipulation of large amounts of stored data, with relatively simple arithmetical operations, at reasonable speeds and with the utmost dependability, is the problem presented in inventory accounting systems applicable to department stores, mail order houses, railroads, airlines and all common carriers as well as government services wherever large inventory records are required.

A system having the above characteristics has been constructed and proven itself in dependability.

The system employs a magnetic drum with storage capacity in the millions of binary digits, and input, selection or translation, programming, arithmetical and output functions.

Plug-in subassembly construction, the use of the magnetic drum for translation, category storing as well as programming, and circuit design based on highlighted variations in operating conditions and rate of component deterioration, are factors which contribute to dependability with minimum maintenance.

90. AN ASYNCHRONOUS CONTROL FOR A DIGITAL COMPUTER
D. H. Gridley
(Naval Research Laboratories, Washington, D. C.)
The sequential control circuits of the Naval Research Laboratory Electronic Digital Computer have been designed for asynchronous operation under the surveillance of checking circuits. A given electronic control element within a sequence transmits an action-initiating signal to the operation circuits, and action-complete signal must be received from the activated circuits before the advance to the next control element of the sequence is made. If the operation-complete signal is not received, the computer is stopped and the status of most operational elements may be displayed by indicators. A general discussion of the sequence-control and checking circuits will be given to indicate the method of detecting errors in high-speed computer operation.

Circuits II—Filters
W. E. Bradley, Chairman
(Philco Corporation, Philadelphia, Pa.)
91. TIME DOMAIN FILTERS
James Snyder
(Signal Corps Engineering Laboratories, Fort Monmouth, N. J.)
In the study of gunfire, there arises the problem of discriminating between muzzle blast and the shock wave generated by the bullet. Solutions based on frequency discrimination are not feasible because of the well known shock excitation of filters; neither are simple amplitude methods applicable. The problem and methods of dealing with it are discussed and considered given to the extension of the methods to the general problems of discrimination between dissimilar transients.

92. PULSE RECEPTION FILTERS
D. L. Waidelich
(University of Missouri, Columbia, Mo.)
Filters used in the reception of pulses must as nearly as possible maximize the signal to noise ratio, as well as fulfill other less important requirements. An RC filter was chosen for compactness, and an analysis of its response to pulses was made. Curves of gain, signal-to-noise ratio and shift of the response peak were obtained in such a form that they are suitable for design use. With the aid of these curves circuit parameters for the best signal-to-noise ratio may be determined. Experimental results were found to agree closely with the predicted results.

93. OPTIMUM NONLINEAR FILTERS
Henry E. Singleton
(General Electric Research Laboratory, Schenectady, N. Y.)
Standard forms for synthesizing arbitrary invariant finite state transducers consist of storage elements combined with sets of comparison and coincidence devices. The system transfer function of an arbitrary nonlinear system may be characterized by a higher order autocorrelation function of the input and crosscorrelation functions between the input and output. The optimum mean-square filter, when based on a multi-dimensional series expansion of the system function, is expressed in terms of a higher order correlation function. Only if the probability distributions of the signal and noise are Gaussian, does the filter reduce to a linear device. For finite state filters the criterion of minimum probability of error is employed, and the design equations represent surfaces in a hyperspace.

94. NONLINEAR SAMPLING FILTERS
Warren D. White
(Airborne Instruments Laboratory, Mineola, L. I., N. Y.)
H. E. Singleton, of MIT, has shown that, for the case of a filter operating from sampled input data, it is possible to obtain an optimum system operator in the form of a multi-dimensional Taylor's series. Following this lead, the author shows that the optimum system operator can be expressed in closed form and that special relations exist when the input can be expressed in terms of Markoff processes. It is shown that, in general, the ideal filter requires an infinite memory capacity. Practical approximations are possible, however, in which only a finite memory capacity is required. One such practical filter is considered in detail and compared with the optimum linear filter.

95. STATISTICAL FILTER THEORY FOR FEEDBACK SYSTEMS SUBJECT TO SATURATION
George C. Newton, Jr.
(Massachusetts Institute of Technology, Cambridge, Mass.)
A theory for the design of compensating networks for feedback-control systems and
filters is developed herein. The novel feature of this theory is its consideration of saturation and transient performance in addition to the usual steady-state behavior. This theory is essentially an extension of the researches of Wiener and Lee in statistical methods for filter design. Saturation is handled by limiting the rms signal levels at critical points in the linear model used as the design basis for the physical system. Transient performance is handled by limiting the integral-square errors to a set of transient signals.

96. ELECTRONIC FILTER
Howard T. Sterling
(The Electronic Workshop, Inc., New York, N. Y.)

A new electronic filter circuit is described, with response characteristics substantially identical to those of a conventional constant-k filter. Simple resistance-capacitance networks are used as the frequency-determining elements. Such a filter with a slope of 18 db/octave beyond cutoff (equivalent to a conventional full-damp filter) can be constructed with only three ganged elements. Cutoff frequency is variable over a wide range, and damping is independent of frequency. Tolerance of circuit elements and tracking tolerance on the ganged elements is relatively uncritical. The circuit has the further advantage of high input impedance and low output impedance.

Electron Tubes II—
Special Tubes and Techniques
G. D. O'Neill, Chairman
(Sylvania Electric Products Inc., Bayside, L. 1., N. Y.)

97. THE PLASMATRON, A CONTINUOUSLY CONTROLLABLE GAS TUBE
E. O. Johnson and W. M. Webster
(RCA Laboratories Division, Princeton, N. J.)

The "plasmatron," a new type of low-impedance electron tube, is described. This tube utilizes an independently produced gas discharge plasma as a conductor between a hot cathode and an anode. Continuous modulation of the anode current can be affected by varying either the conductivity or the effective cross-section areas of this plasma. The first method is accomplished by the modulation of an electron ionizing beam which changes the plasma density and hence its conductivity. The second method makes use of the gating action of positive ion sheaths which surround the wires of a grid located between the anode and cathode. The plasmatron appears to have considerable promise for such applications as motor drive, loudspeaker drive, and the many other uses which require the high current and low voltage operation that the high-impedance vacuum tube cannot supply.

PROCEEDINGS OF THE I.R.E.

98. SWITCHING TIME LIMITATIONS IN HYDROGEN THERATRONS
J. H. Woodford, Jr., and E. M. Williams
(Carnegie Institute of Technology, Pittsburgh, Pa.)

The switching time in thyratrons is shown to be described by

\[ \Delta t_s = \frac{1}{\alpha E_0} \log_a \left( \frac{1 - a}{1 - b} \right) + \frac{L}{R} \log_{10} \left( \frac{1 - a}{1 - b} \right) \]

in which \( \Delta t_s \) is time of transition between the fractions \( a \) and \( b \) of total change in load voltage, \( \alpha \) a tube parameter, \( E_0 \) anode supply voltage, and \( L \) and \( R \) load parameters. The tube parameter \( \alpha \) must be experimentally determined; however, examples of its variation between tubes and dependence on pressure are given. Cavity enclosures are necessary to minimize circuit inductances and with such enclosures commercial hydrogen thyratrons have switching times of two to six milli-seconds.

99. A NEW TYPE HEATER CATHODE TUBE FOR PORTABLE BATTERY-OPERATED EQUIPMENT
George W. Baker
(Kip Electronics Corporation, New York, N. Y.)

The heater of this new heater cathode-type tube operates at 1.25 volts and a current equivalent to that required by filament-type tubes used in battery operated equipment. This tube permits the use of circuits requiring separately insulated cathodes in dry battery-operated equipment. The first tube made in pilot plant quantity is Kip KP53, a double diode in a subminiature T2 envelope. Samples of these tubes will be shown.

100. NEW VACUUM-TUBE MATERIALS
E. B. Fehr and A. P. Haase
(General Electric Company, Oceanside, Ky.)

A new spacer material which shows great promise as an effective substitute for mica in vacuum tube applications has been developed. This material, chemically and thermally, possesses mechanical and electrical properties similar, and in some cases superior, to mica. This paper treats the development and application of this new material and reports experience obtained with it in a number of tube types.

A new anode material for use in vacuum tubes has been investigated. This material is compared with those presently used, and application experience and life test information are presented.

101. PROPERTIES OF INTERFACES IN METAL TO CERAMIC SEALS
W. A. Christoffersen and R. P. Wellinger
(University of Illinois, Urbana, Ill.)

The thickness of the interface resulting from the bonding of metals to ceramics has been increased by ionic diffusion, which is intensified by passing a current through the interface. This has made it possible to determine the mechanical and electrical properties of this critical layer. Appreciable changes in tensile strength of the seal and interface material have been observed. The electrical conductivity stays approximately the same as that of the ceramic. This process, in addition to enlarging the interface so that its properties can be studied, provides a new means of making metal to ceramic seals. It also shows the limitation of ceramics used in tube construction under extreme conditions of temperature and electric field.

Microwaves II—
Waveguides B
H. A. Wheeler, Chairman
(Wheeler Laboratories, Great Neck, L. I., N. Y.)

102. ON THE EXCITATION OF SURFACE WAVES
Georg Goubau
(Signal Corps Engineering Laboratories, Fort Monmouth, N. J.)

The total field excited on any waveguide consists of the regular wave and a suplementary field which provides for the continuity of the total field at the point of excitation. In the case of open waveguides this supplementary field is, however, shows an orthogonality to the field of the regular wave similar to that which occurs in closed waveguides. Thus the amplitude of a surface wave which is excited by a dipole or any other power source can be determined easily by means of the red reciprocity theorem. This method is demonstrated in several examples.

103. INTERACTION BETWEEN SURFACE WAVE TRANSMISSION LINES
Allan A. Meyerhoff
(Signal Corps Engineering Laboratories, Fort Monmouth, N. J.)

An important question in connection with surface wave transmission lines is the interaction between them or with other wires which may act like surface waveguides. This question is treated for two parallel lines with the provision that the coupling is small. The problem is related to the problem of coupled circuits; the space variable for the currents in the lines corresponds to the time variable for the currents in the circuits. When the two lines are identical there is maximum interaction as is the case for identical circuits. The theoretical treatment is supplemented by the consideration of several typical examples.

104. A NEW DIRECTIONAL COUPLER PERMITTING FULL POWER TRANSFER
K. Tomiyasu and S. B. Cohn
(Sperry Gyroscopic Company, Great Neck, L. I., N. Y.)

A new directional coupler capable of transferring up to the total power from one waveguide to another is described and analyzed. This coupler which can carry nearly the maximum power of the waveguide has been used as a high-power divider as well as in high-power attenuators. The coupling element is a long slot containing a grid of wires in the common narrow wall of the two
This paper will discuss the effects of meteorological phenomena—wind, icing, reduced visibility, etc.—on the operation of aircraft and on the minimum interval between successive aircraft arrivals or departures. The need for more accurate and reliable localized forecasts, especially short-term ones, will be indicated and the results of a study of short-term forecasting at Washington National Airport will be summarized. Requirements for better weather measuring instruments and possible measuring techniques will be discussed.

108. AIRCRAFT AND AIRPORT CHARACTERISTICS
L. P. Tabor
(The Franklin Institute, Philadelphia, Pa.)

The dispatch with which aircraft can land at any airport depends on a number of variables: among them are runway-taxiway configuration, flight and taxi characteristics of aircraft, minimum safe separation distance between aircraft and type of control exercised. The Franklin Institute has designed a simulator capable of analyzing various proposed traffic control systems taking these variables into account. The results of an analysis of several systems will be presented. Also to be discussed is a program for the measurement, at several airports, of the important aircraft flight and taxi characteristics. The outline of this experimental program will be presented along with results to date.

109. ECONOMIC DEMAND
F. B. Lee
(Civil Aeronautics Administration, Washington, D. C.)

From economic studies there emerges a pattern which clarifies the dependence of the amount of air traffic on the size, location, and economic character of communities. From this pattern it is possible to predict the demand (passenger, mail, and cargo) which will be placed on individual airports and air routes in the future. These predictions set the requirements of volume and distribution of air traffic which an electronic control system must satisfy.

This paper will also discuss the traffic delays experienced at major U.S. air terminals and the effect which surveillance radar has had in reducing the number of aircraft delayed and the magnitude of delay. The expected effect of new aids such as airborne transponders and automatic radar displays will be presented.

110. HUMAN ENGINEERING
P. M. Fitzs
(Ohio State University, Columbus, Ohio)

Although there is a persistent trend toward automaticity, part of the task of air navigation and traffic control will undoubtedly be performed by human operators. This fact imposes certain requirements on the design of mechanical and electronic components for the system. The present paper discusses the implications of three general requirements based on human capacities and limitations: those based on the capacity of a human operator in handling information and making decisions; those based on the capacity of a human operator in responding quickly to directional and spatial information and in manipulating controls; and those based on the capacity of men and machines to function as a system.

Much information is already available about how human beings perform air navigation and traffic control tasks, and much remains to be found out by research. Principles governing the design of information displays and communication equipment will be reviewed briefly in order to illustrate the state of present knowledge.

111. TRAFFIC CONTROL THEORY
D. H. Ewing

This paper will summarize the results of several study projects on this subject sponsored by the Air Navigation Development Board. Included will be a discussion of the amount and type of control to be exerted at the various stages of aircraft flight in order to minimize delays en route and in terminal areas.

SYMPOSIUM
Some Systems Problems of Air Traffic Control
Donald G. Fink, Chairman

107. WEATHER
N. A. Lieurance
(U. S. Weather Bureau, Washington, D. C.)

112. MICROWAVE METHODS IN GAS ANALYSIS
Joseph Weber
(U. S. Naval Ordnance Laboratory, White Oak, Md., and University of Maryland, College Park, Md.)

The composition of certain gas mixtures can be determined by microwave measurements on single resolved collision broadened spectral lines. The mole fraction of an absorbing gas in a mixture is uniquely determined by a measurement of the area under the absorption line. The limitations imposed by adsorption and presently available klystron power devices are discussed.

The composition of binary gas mixtures can be determined by measurement of the peak absorbance coefficients if the collision cross sections are known. A microwave spectroscope is also effective in the analysis of isotopic gas mixtures because isotopic substitution shifts the absorption lines by relatively large amounts.

Apparatus for utilizing microwave spectroscope as an analytical tool is described, experimental results are presented, and compared with those obtainable by a mass spectrometer.

113. SPARK-OVER OF AIR AT RADIO FREQUENCIES
W. Caywood, Jr.
(Carnegie Institute of Technology, Pittsburgh, Pa.)

Radio-frequency sparkover characteristics of air at atmospheric pressure are of great importance to radio engineers dealing with problems of air insulation. It is well known that breakdown strength of air is less at radio frequencies than at power frequencies. There has been considerable disagree-
ment in the literature, even for relatively simple, nearly uniform field configurations of the amount of the difference.

This paper contains:

(a) A brief review of the theory of ac breakdown, showing the reason for a dependence on frequency.

(b) New, accurate experimental values of breakdown at up to two megacycles. These provide reliable data for high-frequency power transmission lines and similar applications.

(c) A new, experimentally derived relationship between gap length and frequency. It is shown that if a plot is made of (sparking-over voltage) + (air density) as a function of (frequency) X (gap length) V, all data taken lie on one single curve.

114. X-RAY LIQUID LEVEL GAGE

JOHN E. JACOBS and ROBERT F. WILSON
(Coolidge Laboratory, General Electric X-Ray Corporation, Milwaukee, Wis.)

A liquid level gage has been developed using semi-conductors as x-ray detectors that is capable of gaging the level of liquid in thin Walled steel vessels to a close precision. The gage may be used for inspection of filled containers or as a control element for the filling process. By virtue of the natural amplification of the semi-conductor detector the required instrumentation is greatly simplified.

115. NOISE FIGURE STANDARDS

M. SOLON, I. W. HAMMER, AND P. H. HAAS
(The National Bureau of Standards, Washington, D. C.)

Noise figure standards to 30 Mc are now available at the National Bureau of Standards. Establishing these standards required generalizing the theory of noise figures and determining the uniqueness and accuracy of noise figure measurements. The technique used to verify the theory was to show the invariance of the equivalent noise resistance of a special four-terminal network from measurements of its noise figure with a temperature limited diode. This was done at 4.3, 12, and 30 Mc. The limits of error for noise figure measurements with the present equipment is ±0.2 decibel.

This theory and technique have other applications; one is the impedance measurement of two-terminal networks.

116. NEW LIMITS FOR LOW-LEVEL RF ENERGY MEASUREMENTS

W. K. VOLKERS
(Millivac Instruments, New Haven, Conn.)

At low voltage or energy levels rf crystal diode detection follows a square law. By combining a conventional "excitation" signal identical in frequency and phase with a small modulated signal the limit for low level rf energy measurements can be drastically lowered. The method described employs a special crystal diode probe having an excitation terminal and a dual signal generator producing both the unmodulated excitation signal and the modulated signal for measurements. Small fractions of a billionth of a watt can thus be measured over practically all high- and low-frequency ranges. The method improves the already excellent voltage measuring sensitivity of the well known probe-and-tuned-amplifier-combination by more than twenty decibels.

Computers II

J. W. FORRESTER, Chairman
(Massachusetts Institute of Technology, Cambridge, Mass.)

117. A SAMPLING ANALOGUE COMPUTER

JOHN BROOMALL and LEON RIEBMAN
(Moore School of Electrical Engineering, University of Pennsylvania, Philadelphia, Pa.)

The sampling analogue computer has already found a number of applications and conceivably can be used in many other cases where the accuracy of the result need not exceed 0.1 per cent of "full scale." The theory of operation has been covered elsewhere. This paper discusses the use of the sampling computer in determining W from W = KfX/X where K is a system constant, X, Y, and Z are independent input variables and W is the computed result or answer.

A particular application of the computer is given together with a review of sources of error and suggestions for further improvements. A pulse-to-dc converter is described to permit use of any number of these computers in tandem.

118. A TIME DIVISION MULTIPLIER FOR A GENERAL-PURPOSE ELECTRONIC DIFFERENTIAL ANALYZER

R. V. BAUM and C. D. MERRILL
(General Aeronautical Corporation, Akron, Ohio)

An electronic device for producing the products of two variable voltages is described. Sources of systematic error are briefly analyzed and the methods used to reduce such errors are discussed. The characteristics of the multiplier are summarized and compared with those of the servo-multiplier previously employed in analogue computers. Finally, the use of this multiplier in a high speed differential analyzer to solve nonlinear ordinary differential equations is illustrated.

119. A HIGH-SPEED PRODUCT INTEGRATOR

ALAN B. MACNEE
(University of Michigan, Ann Arbor, Mich.)

A high-speed product integrator has been developed. A one-hundred point solution is obtained on a cathode-ray tube screen every 1.67 seconds. The product integrator employs components of a conventional differential analyzer together with a set of motor driven potentiometers. This product integrator has been used for the evaluation of solutions of the Fourier, Schomilch, and superposition integral equations. An accuracy of the order of 2 per cent is achieved.

120. PLUG-IN UNITS FOR DIGITAL COMPUTATION

G. GLINSKI and S. LACEK
(Computing Devices of Canada, Ltd., Ottawa, Ont., Canada)

To widen the scope of application of high-speed electronic digital data handling systems, the development of individual computer "units" has been undertaken. These units may be assembled into various systems of varying degree of complexity.

The "S" series of units, some of which are described in this paper, provides basic units for a serial digital computer. This "S" series consists of such basic units as: amplifiers, binary scalers, buffers, cathode followers, decoders, delay lines, filter-flips, gates, half-adders, matrices, memory, oscillators, etc.

As an example of simplification introduced by unitized construction, it was possible to build a relatively complex data handling system (4,000 units) out of 80 basic functional units.

121. A FIVE-DIGIT PARALLEL CODER TUBE

J. V. HARRINGTON and K. N. WULFESBERG
(Air Force Cambridge Research Laboratories, Cambridge, Mass.)

and

G. R. SPENCER
(Philco Tube Laboratory, Cambridge, Mass.)

A cathode-ray type coder tube which will convert a signal voltage into a five-digit parallel binary code is described. The coding pattern is obtained by printing a material of low secondary emission ratio on metal targe segments having a high secondary emission ratio. The pattern is segmented "digitwise" so that the code signals may be obtained in parallel, and the coding pattern is derived from the so-called "cyclic" system which is self-quantizing.

Circuits III—General

R. L. DITZOLD, Chairman
(Bell Telephone Laboratories, Inc., Murray Hill, N. J.)

122. A LINEAR OPERATIONAL CALCULUS OF EMPirical FUNCTIONS

R. G. PIETY
(Phillips Petroleum Corporation, Bartlesville, Okla.)

An operational calculus (based on the generating functions of DeMoivre and Laplace) is derived to evaluate the convolution and also its inversion, between empirically obtained functions. The operations are carried out by the ordinary algorithms for multiplication and division of polynomials. The cross and auto correlations of time series are similarly computed. A time series is represented by a polynomial in x where the coefficients of the successive powers of x are equal to the values of the time series at successive equal intervals of time. The development of a function in terms of the translated values of another (obtainable with generating functions) is applied to network synthesis.

123. PULSE TRANSFORMER CONSIDERED AS A WIDE-BAND NETWORK

M. GUNTHER RUDENBERG
(Raytheon Manufacturing Company,Walther, Mass.)

The method of distribution, already suc-
1951 IRE National Convention Program

124. SINGLE-TAPPED COIL DELAY LINE

S. G. Lutz
(new York University, New York, N. Y.)

Sonar lag lines and radar delay lines are critical in theory but exacting sonar requirements justify more complex structures. Following a survey of desirable line properties, those configurations involving no more than one singly tapped coil per section are listed and compared, showing that they are practical cases of a section, termed 4t; including all distributed capacitances of center tapped coil plus two capacitances to ground. This section is a low-pass-band-pass per which sometimes can be made confusing, or whose low-pass delay characteristic is required to be compensated by adjusting the location of the band-pass cutoff frequencies. The matching technique is presented for this purpose.

125. NICKEL ACOUTIC DELAY LINE

T. F. Rogers
(Air Force Cambridge Research Laboratories, Cambridge, Mass.)

AND

S. J. Johnson
(Anderson-Shaw Laboratories, Hartford, Conn.)

The effect of a magnetic field upon a nickel acoustic delay line has been studied. An attempt was made to affect a nonmechanical method of changing its delay time. Changes of delay up to 0.3 per cent at 1,000 oersteds have been noted and can be explained on the basis of a change in the velocity of propagation of the 1 Mc transverse (shear) sonic waves used. Accompanying the change in velocity is a probable change in the transmittivity throughout the nickel line; at high field strengths output signals have been detected over 100 times in amplitude of those ceived at H = 0.

126. AMPLIFIER SYNTHESIS ON EQUAL-RIPPLE BASIS

DeForest L. Trautman and J. A. Aseltine
(University of California, Los Angeles, Calif.)

This paper describes a method of designing bandpass amplifiers with equal-ripple Chebyshev response, yielding data in terms of pole and zero locations in the complex-frequency plane. No restriction is placed on the type of coupling between stages, and bandwidth may be as large as desired with no approximations necessary in the design.

The method consists of mapping the bandpass frequency plane onto a transform plane where the pass bands appear as a circle. The poles placed symmetrically on another circle whose radius is a function of the ripple desired provide the required equal-ripple response. The inverse mapping yields their locations in the bandpass frequency plane, and is determined by the correct amount to accommodate the zeros required by the various interstage coupling networks.

Broadcast and TV Receivers

J. D. Reid, Chairman
(American Radio and Television, Inc., North Little Rock, Ark.)

127. WIDE-ANGLE DEFLECTION YOKE DESIGN

H. Thomas
(Allen B. DuMont Laboratories, Inc., East Paterson, N. J.)

In order to describe the variable and interdependent factors bearing on deflection yoke design, the first part of this paper discusses the main yoke performance characteristics; e.g., sensitivity, spot and pattern distortion, neck shadow, and linearity. The electrical features and mechanical dimensions bearing on these characteristics are then correlated to the normal operating conditions, to heating, shrinking, cross coupling, and manufacturing cost. The compromises necessary to obtain a balance between sensitivity and neck shadow and between spot and pattern distortion are developed in detail, with a final suggestion toward some means to standardize yoke performance measurements.

128. SEMI-AUTOMATIC FABRICATION OF AUDIO AND VIDEO EQUIPMENT

W. H. Hannabas, R. Bair, Jr., and J. Caffiaux
(Sylvania Electric Products Inc., Bayside, N. Y.)

Design principles are given for arriving at functional structures for electronic subassemblies and complete equipment, the objectives of the designs being a reduction of labor in the fabrication of mass produced items. In three examples—an AM radio, a television IF strip and an interphone amplifier—application is made of modern etching, stamping, and other printed-circuit techniques.

129. UHF CONVERTER

B. F. Tyson
(Sylvania Electric Products Inc., Flushing, L. I., N. Y.)

During the introductory period of uhf television broadcasting, converters will be required for reception of uhf stations on existing vhf receivers. A uhf converter is described which features simplicity of operation and low cost. The converter is designed so that at the time of installation its local oscillator is preset to a fixed frequency and uhf stations are selected with the regular vhf receiver controls.

Performance characteristics are given including conversion efficiency, noise figure, and local oscillator stability. The possibilities of interference from harmonics of the uhf receiver local oscillator are examined and other limitations in the operation of the converter are explained.

130. POWER SUPPLIES FOR TELEVISION RECEIVERS

A. M. Levine and S. Moskowitz
(Federal Telecommunication Laboratories, Inc., Nutley, N. J.)

The characteristics of voltage doubling and tripling units using selenium rectifiers and having load currents from 100 to 500 milliamperes are discussed. These characteristics include output voltage regulation and ripple factor.

Since the voltage-doubler type of power supply is more economical, the receiver designer should attempt to obtain the direct-current-circuit voltage requirements to a maximum of 285 volts. Methods of meeting this condition include the use of high-efficiency deflection components such as Ferrite core transformers and deflection yokes, and the elimination of negative bias voltages.

Several examples of receiver design are described in which the direct-voltage requirements have been reduced, yet allowing full 70-degree deflection.

131. RADIO RECEIVER SUBMINIATURIZATION TECHNIQUES

Gustave Shapiro
(National Bureau of Standards, Washington, D. C.)

A subminiature radio receiver, tuning from 190 to 550 kc, has been developed. Total volume of this twelve-tube unit is 55 cubic inches. This compactness is made possible by fourteen new components, including rf inductors and IF transformers using high temperature litz, glass dielectric capacitors, tantalum electrolytic capacitors, and audio inductors wound with ceramic insulated wire. Linearity of permeability tuning is accomplished through the use of a nonlinear screw drive. Design and fabrication techniques, which make this receiver adaptable to quantity production, will be discussed.

Microwaves III—Antennas and Artificial Dielectrics A

A. G. Hill, Chairman
(Massachusetts Institute of Technology, Cambridge, Mass.)

132. THE STUDY OF ARTIFICIAL DIELECTRICS OF THE OBSTACLE TYPE

Charles Susskind
(Yale University, New Haven, Conn.)

The analysis of artificial dielectrics consisting of arrays of small metallic elements has been considerably extended by several workers, both in this country and abroad. In determining the "bulk" properties (such as permittivity, permeability, and refractive index) of these media analytically, various methods of attack can be employed; in addition, experimental measurements on a small
sample can be frequently utilized to predict the performance of microwave prisms, lens antennas, etc. This paper presents a survey of the analytical and practical techniques now used in the design of artificial dielectrics, as well as an outline of further problems and possible methods of solution.

133. ISOTROPIC ARTIFICIAL DIELECTRIC
RUSSELL W. CORKUM
(Air Force Cambridge Research Laboratories, Cambridge, Mass.)
Isotropic artificial dielectric media composed of a three-dimensional cubic array of metal or dielectric spheres have been investigated.
Theoretical expressions using the Clausius-Mosotti relation have been derived for the index of refraction, dielectric constant, and magnetic permeability of this type of dielectric. These quantities are independent of frequency, so long as the size of the spheres and the spacing between spheres are small compared to the wavelength within the resulting dielectric media.
Samples using steel and fused-quartz spheres have been fabricated and the dielectric properties measured in rectangular waveguide at a frequency of 5,000 Mc. Standard waveguide techniques are readily adaptable to this type of dielectric.
Experimentally determined values of the dielectric properties are in good agreement with theoretical values, and the theoretical expressions are assumed valid.

134. A VIRTUAL SOURCE IN MICROWAVE OPTICS
KENNETH S. KELLHEER
(Naval Research Laboratory, Washington, D. C.)
Many principles from optics can be carried over directly into the microwave field. One of these, the concept of a virtual source, is discussed in this paper. An electromagnetic horn, used as a real source, is placed in the neighborhood of an imaging reflector to produce a virtual source. The imaging reflector is so designed that as the horn moves along a uniform rate on a circular path, the virtual source moves at approximately the same rate on a nearby linear path. The reflector design is investigated by geometrical optics methods, as well as by an experimental arrangement utilizing parallel plates and a focusing objective.

135. EXPERIMENTAL PROTOTYPE OF THE RINEHART-LUNEBERG LENS
ELLEN C. FIN
(Air Force Cambridge Research Laboratories, Cambridge, Mass.)
Propagation of electro-magnetic waves in the TEM mode between parallel conducting surfaces is along geodesics on the mean surface. The application of this principle by R. F. Rinehart to the derivation of the geodesic analogue to the Luneberg dielectric disk is reviewed.
The theoretical surface of revolution may be used in the design of a metal plate antenna, by the addition of a toroidal bend or conical skirt termination.

EXPERIMENTAL RESULTS are presented for a thirty-six inch diameter model at 9,100 and 2,800 Mc. The radiation patterns exhibited uniformly good characteristics for all positions of the feed on the periphery.

136. PROPAGATION OF MICROWAVES BETWEEN PARALLEL CONDUCTING SURFACES
K. S. KUNZ
(Case Institute of Technology, Cleveland, Ohio)
The propagation of microwaves in the TEM mode between parallel conducting surfaces fills with a medium of varying index of refraction, n, is along rays that minimize the optical path length along the mean surface. Since the optical path length is determined both by the index n and the curvature of the mean surface, there is always a family of surfaces with equivalent focussing properties. Two important cases are: (1) a flat surface with variable n; (2) a curved surface with n = constant. The latter permits one to construct practical analogs of devices requiring a variable index of refraction.

137. PHASE SHIFT OF MICROWAVES IN PASSAGE THROUGH PARALLEL-PLATE ARRAYS
D. J. EPSTEIN
(Laboratory for Insulation Research, Massachusetts Institute of Technology, Cambridge, Mass.)
The phase shift experienced by a normally incident wave in its passage through a parallel-plate slab has been measured for slabs of various thickness and plate-spacing. A range of thickness from 1/4 to 4λ has been covered, and the plate spacing has been varied from 0.66a to 0.96a. Measurements were carried out at various frequencies in the K-band range using an interferometer technique. The experimental results exhibit general agreement with the theory of Carlson and Heins. The slight discrepancy which does exist appears due to the finite thickness (0.020 inch) of the plates used.

Radar and Radio Navigation
J. A. PIERCE, Chairman
(Harvard University, Cambridge, Mass.)

138. ON THE MEASUREMENT OF THE RADAR ECHOING AREAS OF CONDUCTING BODIES
J. R. MENTZER
(Ohio State University Research Foundation, Columbus, Ohio)
In this paper, various aspects of the technique of measurement of radar areas by means of models are discussed. These include the following: (1) Means of measuring the absolute sensitivity of a continuous-wave reflection measuring system, and (2) a discussion of a theoretical and experimental determination of the scattering properties of finite cylinders of infinite conductivity in an incident plane-wave field.

139. POLARIZATION PROPERTIES OF TARGET REFLECTIONS
E. M. KENNAUGH
(Ohio State University Research Foundation, Columbus, Ohio)
The dependence of radar echoing upon antenna polarization may be utilized in three ways: (1) to improve target echo response, through increased echo area and reduction of echo area fluctuations; (2) to discriminate against undesired targets proper choice of polarization; and (3) identify classes of targets by their polarization characteristics. A method of representing the polarization transforming properties of radar targets by use of a polarizability sphere is discussed. Echo areas become proportional to chord lengths, and polarizability transformations are defined by geometric operations. Applications to specific problems are made, using this simplified method analysis.

140. THE USE OF CIRCULAR POLARIZATION AS A MEANS OF REDUCING RADAR PRECIPITATION RETURN
WARREN D. WHITE
(Airborne Instruments Laboratory, Mineola, L. I., N. Y.)
Under the supervision of Watson Laboratory, Air Materiel Command, a series of experiments has been performed to evaluate the effectiveness of circular polarization as a means of reducing or eliminating precipitation return from air search radar display. Incidental to the experiments, considerable development was necessary on means for producing a radar beam which was circularly polarized throughout.
Results of the experiments are presently in some detail. Precipitation returns have been reduced by as much as 30 db with only 6- to 8-dB loss, on aircraft signals. Consideration of the effect of ground reflections on other matters, however, limits the practical use of aircraft to precipitation ratios about 15 db.

141. AN ICW SYSTEM FOR DISTANCE MEASUREMENT
J. LYMAN, G. B. LITCHFORD, AND C. GREENSKY
(Sperry Gyroscope Company, Great Neck, L. I., N. Y.)
The initial development of a method for aircraft distance measurement using intermittent continuous-wave phase comparison technique will be described. With this technique, a short (1/600 second) transmission is made with a duty cycle of 1/3 per cent. During this transmission, two low and high (1.2 and 18.6 kc) tone modulations are sent to a co-operating station from which distance is to be measured. The loop phase change which takes place on each modulation is a coarse and fine measurement of the time of flight of the signal and hence the direct measurement of distance. By variable frequency telemetering, distance information is obtained at both cooperating stations, during the 1/60-second transmission period. The experimental system at 5,000 Mc requires 150 kc of spectrum for each group of aircraft.
145. DESIGN AND CONSTRUCTION OF A BILLION-VOLT LINEAR ELECTRON ACCELERATOR

**Marvin Chodorow, E. L. Ginnoton, John M. King, Robert E. Khyl, Richard Neal, and Paul Pearson**

(Microwave Laboratory, Stanford University, Stanford, Calif.)

This paper concerns the design and construction of the first 80 feet of a 220-foot linear electron accelerator to produce billion-volt electrons. The accelerator operates at a frequency of 3,000 Mc, and the power is supplied by klystrons, each delivering 10 megawatts of pulse power, fed into the accelerator at intervals of ten feet. The klystrons are run as amplifiers to insure proper phase relations in the separate operating sections. Various components of the accelerator, and preliminary results will be described.

146. PRECISE MEASUREMENT AND REGULATION OF MAGNETIC FIELDS WITH RADIO-FREQUENCY TECHNIQUES USING NUCLEAR RESONANCE

**H. A. Thomas**

(National Bureau of Standards, Washington, D. C.)

Protons in a water sample placed in a small radio-frequency coil surrounding the sample if the coil is excited at the resonance frequency, \( f_0 = H/2\pi \) where \( H \) is a known constant. This resonance phenomenon may be used to measure magnetic field strengths to an accuracy of one part in forty thousand and to regulate magnetic fields to within a few parts per million with relatively simple radio-frequency apparatus. This paper includes a brief discussion of the phenomenon and the radio-frequency techniques involved.

147. A HIGH-PRECISION MAGNETIC-FIELD MEASURING INSTRUMENT

**R. W. Kane, E. C. Levinthal, and E. H. Rodgers**

(Varien Associates, San Carlos, Calif.)

This paper will be concerned with the description of an instrument using the principles of magnetic induction designed to measure and control magnetic fields with a precision much greater than heretofore available. Essentially the technique reduces the problem of measuring magnetic fields to one of measuring frequencies.

Using these principles, fields have been controlled to 0.0002 per cent. Relative measurements of the field have been made with a tolerance accuracy of about 0.001 microsecond. Details of the timing circuits, a novel cascade cavity-enclosed hydrogen-thyratron pulse and test results are described. Factors existing making accuracy are discussed in detail.

**Television II**

148. PARALLEL OPERATION OF VACUUM TUBES AT UHF TO OBTAIN HIGH TRANSMITTER POWER

**W. H. Sayer, Jr., and Elliott Mehrbach**

(Allen B. DuMont Laboratories, Inc., Passaic, N. J.)

In order to obtain a transmitter power output of 1 kw in the uhf television band (475-890 Mc) it has been found necessary to use multiple operation of low power tubes at this time. This paper describes methods of multiplexing triodes and tetrodes in coaxial-type cavities at these frequencies. A discussion of the design of these circuits mechanically and electrically will show the feasibility and simplicity of using multiple low-power tubes. Performance data of a transmitter operating at a 1-kw power level at 600 Mc are included. Sliding showing details of mechanical construction of amplifiers and frequency multipliers will be shown.

149. AN ULTRA PORTABLE TELEVISION PICKUP EQUIPMENT

**L. E. Flory, W. S. Pike, J. E. Dilley, and J. M. Morgan**

(RCA Laboratories, Inc., Princeton, N. J.)

A completely portable industrial television pickup equipment will be described. Utilizing the Vidicon photoconductive pickup tube, the equipment is completely self-contained, battery operated, and can be carried as a back pack with a hand-held or tripod-mounted camera, cable connected to the pack. An ultra-high-frequency transmitter serves to link the unit with its base over short distances. A sound channel is provided by pulse modulation at line frequency. A radio link in the opposite direction serves for issuing instructions and provides a means of transmitting a reference frequency for control of the synchronizing generator. The equipment will be demonstrated as a part of the paper.

150. THE TECHNIQUE OF DOT ARRESTING FOR TELEVISION TRANSMISSION USING DOT INTERLACE

**K. Schlesinger**

(Motorola, Inc., Chicago, III.)

The improvement of horizontal detail by dot interlace may be realized by applying synchronous sweep-velocity modulation to the line scan in both terminals. This dot-arresting technique may be assisted by some additional intensity modulation of the scanning beams.

The dot-arresting method is highly compatible in that it requires no modifications of equipment beyond the addition of synchronized dot-deflection circuits.

The paper presents the theory of dot arresting and shows practical circuits for its application. A monoscope picture generator is used to test the performance of dot arresting.
151. A SWEEP FREQUENCY METHOD FOR MEASURING THE TRANSMISSION-AMPLITUDE CHARACTERISTIC OF A TELEVISION TRANSMITTER

J. R. Ragazzini, Chairman (Columbia University, New York, N. Y.)

The method of measurement described enables the complete transmission-amplitude characteristic to be displayed on the screen of a cathode-ray oscillograph when the transmitter is operating under normal conditions of modulation. The relative response at any sideband frequency, above or below the carrier, can be measured directly on the oscillograph screen.

The equipment is relatively simple and can be easily assembled in a compact unit for routine transmitter testing or built into the transmitter as an aid in tuning.

 Circuits IV—Amplifiers

J. R. Ragazzini, Chairman (Columbia University, New York, N. Y.)

152. RF AMPLIFIER DESIGN FOR LOW NOISE FIGURE

R. Guenther

(Signal Corps Engineering Laboratories, Fort Monmouth, N. J.)

Based on matrix algebra, a general amplifier theory is developed which permits the treatment of all types of amplifiers. Single-stage amplifiers, as well as cascade arrangements, are described. Impedance gain and noise figure are derived for the most common radio-frequency amplifier circuits. The noise figure is considered with emphasis on minimizing it and on a comparison of different circuits. Graphs are given for determining the optimum noise figure and the associated amplifier characteristics for numerical calculations. The treatment includes the tube capacities which are not tuned out by the tuned circuits. Numerical examples demonstrate the use of the graphs for design purposes and in determining the absolute minimum of the noise figure of a particular tube and circuit.

153. HF AMPLIFIERS WITH DIRECT COUPLING

E. L. Crosby, Jr., and K. F. Umpleby

(Bendix Aviation Corporation, Baltimore, Md.)

This paper proposes the use of a type of direct coupling in order to further the present important objectives of compactness, simplicity, and reliability in high-frequency amplifiers. This has been accomplished simply by the “removal” of a considerable number of components. The high-frequency intermediate-frequency amplifier and the radar video amplifier have been used in the study of this technique. An example of the design for a unit of each type is given in detail. It appears that circuits of these types are suitable for use in television receivers. Also described is a unit comprising an intermediate-frequency amplifier, detector and video amplifier having an over-all gain of 130 db, bandwidth of 3.2 Mc, and measuring 3½” x 2¼” x 4¾”. It is believed that a new order of compactness and reliability has been achieved in these amplifiers. The paper discusses the advantages and limitations of the method and an appendix treats of the effect of series reactance in the by-pass capacitors.

154. DISTRIBUTED AMPLIFICATION: ADDITIONAL CONSIDERATIONS

J. Weber

(U. S. Naval Ordnance Laboratory, White Oak, Silver Spring, Md., and University of Maryland, College Park, Md.)

It is known that the input conductance resulting from transit time and cathode lead inductance often limits the gain-bandwidth product obtainable with distributed amplifiers. Several methods have been investigated for neutralizing this input conductance and their range of usefulness is discussed. These methods have been successfully employed in the design of an amplifier employing 6AK5 tubes. This amplifier has a 400-Mc bandwidth and is described. The neutralization affects the gain-bandwidth product, and relations are deduced for the allowable tolerances. The “power paradox” is discussed and explained with reference to plate dissipation requirements.

155. DISTRIBUTED AMPLIFICATION FOR PULSES

G. F. Myers

(Naval Research Laboratory, Washington, D. C.)

This is a discussion of broad-band distributed-line amplification as applied to the construction of a low-gain 100-Mc amplifier capable of producing a 100-volt video driving signal for a fast-sweep oscilloscope. Pulse amplification is the primary consideration and methods of saving power and simplifying the circuit will be discussed. Importance of tube selection and importance of selection of type of filter to be used will be illustrated. The underlying idea is simplicity and dependability in an amplifier that can readily be duplicated.

156. CATHODE-COUPLED CLIPPER RESPONSE

P. F. Ordung and H. L. Krauss

(Yale University, New Haven, Conn.)

This paper discusses the factors affecting the speed of response of the cathode-coupled clipper circuit when it is driven by essentially rectangular pulses. The effect of various circuit capacitances on the output wave form is demonstrated. The transient build-up time for the circuit tested is shown to be approximately 50 millimicroseconds, indicating that sine waves with frequencies as high as 10 Mc could be clipped with fine wave form. Oscillograms of the various voltages present in the clipper circuit are given.

SYMPOSIUM

Telemetering System

(W. J. Mayo-Wells, Chairman (Applied Physics Laboratory, The Johns Hopkins University, Silver Spring, Md.)

The use of mobile telemetry in the guidance missile program is presented in its general aspects. Methods by which data are generated, transmitted, recorded, and reduced are discussed. The progress made during the last decade, the diversity of developments, and the standardization process of the Research and Development Board are presented as historical background to present-day test-range procedures. Ti problems encountered in present telemetering development and general principles governing mobile telemetry are briefly outlined. A number of the newly developed equipments together with their salient features are discussed.

158. FM/FM TELEMETRY

M. V. Kiebert, Jr. (Ramond Rosen Engineering Products, Inc., Philadelphia, Pa.)

FM/FM telemetering systems are described with general circuit details of both the transmitting and receiving ends of the link outlined. Both high-speed and low-speed sampling with associated data presentation are delivered and described as analysis techniques. Magnetic data storage and associated problems are briefly outlined. General design criteria for system linearity and signal-to-noise requirement for a given accuracy under a given condition are outlined. The basic design of critical transmitting and receiving system element such as subcarrier oscillators and discriminators are outlined along with some of the design problems associated with each element.

159. TECHNIQUES AND APPLICATIONS OF FM/FM TELEMETRY

W. J. Mayo-Wells (Applied Physics Laboratory, The Johns Hopkins University, Silver Spring, Md.)

Realizing the impossibility of doing justice to any one technique or application of the FM/FM system to radio telemetry programs, it has been thought better to provide a guide to the present trends in the field.

Such problems as commutation and demodulation, magnetic recording, and au
Microwaves IV—Antennas and Artificial Dielectrics B

H. A. ZAHN, Chairman
(Signal Corps Engineering Laboratories, Fort Monmouth, N. J.)

12. THE HALF SPACE AS A SPHERICAL TRANSMISSION LINE
L. FELSEN and N. MARCUVITZ
(Polytechnic Institute of Brooklyn, Brooklyn, N. Y.)

The virtue of a spherical mode analysis of electromagnetic field in a half space excited by a small slot in an infinite plane is assessed. If the slot is rectangular and fed by a rectangular wave guide propagating the TE mode, it is shown that the far field in the slot space can be closely approximated by two spherical modes. Since the dominant (dipole) mode carries practically all the radiated power, the half space is considered as a single-mode transmission line, and the equivalent circuit for the slot coupling the rectangular guide to the spherical guide is computed analytically and measured experimentally. Results are compared. The equivalent circuit can be utilized to determine the impedance properties of obstacles in the half space.

164. PHYSICAL LIMITATIONS ON MINIMUM SIDE LOBES IN BROADSIDE ARRAYS
J. RUZE
(Air Force Cambridge Research Laboratories, Cambridge, Mass.)

The side-lobe radiation of antenna arrays may be reduced by properly tapering the current distribution. It is possible to choose the side-lobe level as low as desired and achieve the necessary phase delay by an off-axis suppressor. The side-lobe suppression is obtained without an excessive loss of antenna gain. However, as the permitted side-lobe level is decreased the antenna currents must be maintained ever more precisely to realize this low radiation.

A theory will be presented relating the distribution of side-lobe magnitude as a function of current precision, and of the size of the array. Further laboriously computed pattern data will be compared with the simpler statistical predictions.

165. THE BEHAVIOR OF MICROWAVES IN FOCAL REGIONS
FRANCIS J. ZUCKER
(Air Force Cambridge Research Laboratories, Cambridge, Mass.)

While geometric optics is of great usefulness in the design of microwave radiating systems, it is well known that it does not suffice for the description of phenomena on the border of the geometric shadow and in the neighborhood of foc and caustics. The present discussion extends the work of Debye, Ficht, and others in describing diffraction effects in focal regions. A fairly complete description is given of amplitude, phase, and energy relations near a geometrical focus. The exact transition from the geometric to the wave picture is exhibited for microwave systems with and without aberration.

166. A MICROWAVE SCHMIDT SYSTEM
H. N. CHAIT
(Naval Research Laboratory, Washington, D. C.)

A novel antenna system having good wide-angle characteristics has been developed using the techniques of Schmidt optics. The far-field radiation patterns of this antenna system indicate that it is possible to sweep a 3° beam through plus or minus 10 beamwidths with a side-lobe level of 19 db or less, and a maximum loss of 2 db in antenna gain. The antenna consists of a horn feed, a circular reflector, and a Schmidt-type lens to correct for the aberrations of the reflector. The off-axis performance of this system has been studied both experimentally and theoretically. The conformance of the Schmidt with the Abbe sine law and the location of the minimum circle of confusion are also discussed.

Audio

B. B. BAUER, Chairman
(Shure Brothers, Inc., Chicago, Ill.)

167. A SINGLE-ENDED PUSH-PULL AUDIO AMPLIFIER
ARNOLD PETERSON and D. B. SINCLAIR
(General Radio Company, Cambridge, Mass.)

An audio amplifier circuit for push-pull operation of two output tubes that provides a direct output to a grounded load is described. This circuit preserves the distortion cancelling features of push-pull operation but avoids any necessity for close magnetic coupling between halves of a split primary of an output transformer, and it simplifies the application of feedback from the output stage to preceding single-ended stages. Methods for using this circuit with triode and beam-power output tubes are given, and the ultimate possibility of eliminating the output transformer for driving a loudspeaker is discussed.

168. THE APPLICATION OF DAMPING TO PHONOGRAPH REPRODUCER ARMS
WILLIAM S. BACHMAN
(Columbia Records Company, Inc., New York, N. Y.)

Large forces are developed at the stylus tip of a conventional phonograph reproducer arm due to excitation of the resonance of the arm mass with the suspension compliances. This paper presents an analysis of the problem and describes a reproducer arm design in which mechanical resistance is introduced in the pivots. By this means, control of the arm resonance is obtained without increasing the stylus tip impedance of the reproducer.
169. TRANSIENT TESTING OF LOUDSPEAKERS
O. K. Mawardi
(Harvard University, Cambridge, Mass.)

A transient technique for the testing of loudspeakers is presented. It is shown that a study of the response to a unit impulse function may reveal significant characteristics of loudspeakers. The results obtained by the present technique are shown to be in substantial agreement with the steady-state methods of measurements.

170. A PRACTICAL SPEECH SILENCER FOR RADIO RECEIVERS
R. C. Jones
(Polaroid Corporation, Cambridge, Mass.)

An automatic device will be described which sets a relay one way when the input is speech and the other way when the input is music. The device, termed an "automatic music-speech discriminator," may be used to silence the radio when the program material is speech, and not otherwise. When so employed, the device silences speech after one or two syllables and reactivates the speaker on the radio about one second after the last syllable of speech. The device will be demonstrated on speech, orchestral music, operatic music, and "singing commercials."

SYMPOSIUM
Nuclear Reactors

(Organized by Professional Group on Nuclear Science)
M. M. Hubbard, Chairman
(Massachusetts Institute of Technology, Cambridge, Mass.)

171. WHAT IS NUCLEAR ENGINEERING?
Alvin M. Weinberg
(Oak Ridge National Laboratory, Oak Ridge, Tenn.)

Since the discovery of nuclear fission, no useful mechanical energy has been extracted from uranium principally because of the many technological difficulties encountered, the lack of motivation, and the enormous economic backing necessary for such a development. The deteriorating post-war political situation has now supplied the motivation and the necessary economic aid. Consequently, the investigation of military requirements for atomic powered vehicles, more nuclear fuel, and more powerful bombs, is being expedited.

The situation is not hopeless. The world may regain its senses and return to peaceful ways when nuclear technology can be applied solely for peaceful uses.

172. THE REACTOR AS A RESEARCH TOOL
D. J. Hughes
(Brookhaven National Laboratory, Upton, L. I., N. Y.)

The chain reacting pile is extremely useful as a research tool because it produces high intensities of neutrons of a wide range of energies. The neutron flux (number of neutrons per cm² per second) available in research reactors is as high as 10¹⁵. Many methods are used to select neutrons of particular velocities for specific measurements, such as mechanical shutters, crystal diffraction, and mirrors. The highest energy neutrons (about 10 million electron volts) are those emitted in the uranium fission and lower energies are selected by collisions of the fission neutrons with moderator nuclei (graphite or heavy water).

173. BACKGROUND RADIATION MONITORING FOR CONTROL OF AN AIR-COOLED PILE
Frederick P. Cowan
(Brookhaven National Laboratory, Upton, L. I., N. Y.)

Since small concentrations of radioactive argon are discharged from an air-cooled pile, radiation monitoring stations are desirable in the vicinity. Operation of the pile is based on the records of such stations and on meteorological predictions of atmospheric dilution. Detection devices utilized in the Brookhaven stations include several G-M counters, an ionization chamber with associated electrometer and a continuous dust monitor. Data is recorded photographically and on charts. Normal background amounts to about 1 m per day on the ion chamber, 30 c/cm on a thin-wall G-M tube 10 inches long and 15 c/cm on a similar tube with 1 inches lead shield. Peaks due to rainfall and the effect of snow cover are clearly apparent. Sizable peaks in natural dust activity are caused by temperature inversions. The apparatus has been in service for 2 years and has a data collection efficiency of 85 to 90 per cent. Only small increases in the average background beyond the BNL site boundary result from operation of the pile.

174. INSTRUMENTATION IN THE BROOKHAVEN NUCLEAR REACTOR
J. E. Binns
(Brookhaven National Laboratory, Upton, L. I., N. Y.)

The useful product of the nuclear reactor is neutrons; the unwanted byproducts are heat, dangerous radiations, and dangerous radioactive substances. Instrumentation has been provided for the measurement and control of these products and byproducts, as well as for the measurement of certain parameters used in the experimental study of the pile. Considerations of safety have received special attention.

Television III—Receivers

A. V. Bedford, Chairman
(RCA Laboratories Division, Princeton, N. J.)

175. SYNCHROEJECTION: A HORIZONTAL-DEFLECTION SYSTEM POSSESSING INHERENT NOISE IMMUNITY
W. K. Squires and K. R. Wendt
(Sylvania Electric Products Inc., Flushing, L. I., N. Y.)

Contemporary television deflection output circuits require accurately timed driving wave forms. Noise alters this timing, displacing the scanning lines. Factors contributing to this noise susceptibility and contemporary solutions are described. The noise susceptibility is largely dependent on the method of supplying energy to the deflection coils. The energy may be supplied so as to attain noise immunity. A simple circuit is described which does this. Advantages and limitations of experimental synchroejection circuits are evaluated. A practical system is described. Several circuit configurations are considered and measurements of their noise immunity given. Practical design formulæ are developed. The use of a thyratron output tube is considered and a gas tube circuit having good performance and extreme simplicity is described.

176. INTERNAL TELEVISION RECEIVER INTERFERENCE
Bernard Amos and William Heiser
(Allen B. DuMont Laboratories, Inc., East Paterson, N. J.)

Interference resulting from harmonics of the video and sound intermediate frequencies will be described, and an analysis made of the video detector to show the approximate magnitude of these harmonics for representative television signals. An examination of intermediate frequencies in the 20-20 Mc region will be made to show the distribution of these harmonics, and to determine an optimum frequency to minimize the number of interfering signals. The reduction in the number of interfering harmonics when an intermediate frequency in the 41-Mc region is used, will be shown and an optimum frequency selected. Finally other means of eliminating any remaining harmonics will be described.

177. AN RF AMPLIFIER FOR THE UHF TELEVISION BAND
B. F. Tyson and J. G. Weissman
(Physics Laboratories, Sylvania Electric Products Inc., Bayside, L. I., N. Y.)

In the design of uhf television tuners it may be necessary to include an rf amplifier stage for improvement of noise figure and reduction of local oscillator radiation. This paper describes an experimental rf amplifier employing a Sylvania type 5768 disk-sec-planar truide in a grounded-grid circuit. The amplifier is continuously tunable over the 475- to 890-Mc band and has a power gain of 15 times. When used ahead of a crystal mixer it improves the overall noise figure by 3 to 6 db and substantially reduces the local oscillator radiation.

178. TELEVISION LINE SELECTOR WITH AUTOMATIC IDENTIFIER
Joseph Fisher
(Philco Corporation, Philadelphia, Pa.)

The television line selector is a device for observing the video voltage waveform of any scanning line in a frame interval. The oscilloscope presentation utilizes a slow sweep with a repetition rate of 30 cps and a sweep duration of 60 usec. By means of a single control, any line in a television frame...
Circuits V—Oscillators

W. N. Tuttle, Chairman (General Radio Company, Cambridge, Mass.)

180. OSCILLATOR FREQUENCY INDETERMINACY
Lion Riebman
(University of Pennsylvania, Philadelphia, Pa.)

This paper extends the theory of oscillators to include the effects of random noise. The oscillator is considered as a highly regenerative amplifier of the tube and circuit noise. A striking result is that no practical oscillator can produce a pure sine wave, but rather an output over a continuous frequency spectrum. This analysis shows the close relationship between lock-in range, local oscillator noise, and multifrequency operation.

181. SIMULTANEOUS OSCILLATIONS IN OSCILLATORS
Hans Schaffner
(University of Illinois, Urbana, Ill.)

An oscillator with two degrees of freedom can under certain conditions oscillate simultaneously at two different frequencies. The ratio of the two frequencies may be rational or irrational. For both cases, the conditions necessary for the existence of simultaneous oscillations will be discussed.

Such simultaneous oscillations may occur in high-frequency oscillators. In most cases, they are undesired and their suppression, for example, one of the major problems in the construction of tunable klystrons. They may, however, also be used for the generation of very high frequencies through harmonic loading.

182. AMPLITUDE STABILIZATION OF OSCILLATORS BY NONLINEAR NETWORKS
Louis Rosenthal
(Rutgers University, New Brunswick, N. J.)

The amplitude of oscillators can be stabilized by means of networks that are nonlinear to the root-mean-square value of the applied voltage. These networks consist of elements such as thermistors and lamps. An oscillating system can be broken down into an amplifier and feedback network forming a closed loop. The system statically adjusts itself so that

\[ A^2 = 1 \]

where \( A \) is the gain and \( \beta \) is the static feedback factor. The amplitude stability can be described as

\[ \frac{DE}{E + AS} = \frac{1}{A} \]

where \( DE/E \) is the per-unit change in amplitude corresponding to the per unit change in gain (\( dA/A \)). The factor \( S \) is the dynamic feedback factor or the slope of the nonlinear characteristic at the operating point.

The nonlinear bridge and potentiometer as stabilizing networks are considered in detail, together with experimental observation.

183. STABILITY OF OSCILLATIONS IN A NONLINEAR SYSTEM
Norman R. Scott
(University of Connecticut, Storrs, Conn.)

Methods of nonlinear-mechanics, particularly those developed by Kryloff and Bogoliuboff, are used to investigate amplitude and frequency stability of generalized oscillator circuits. Analysis of an equivalent single-loop oscillator circuit containing a nonlinear negative resistance closed upon a resonant circuit permits determination of amplitude and amplitude stability. Criteria are developed for stability of simultaneous oscillations in multiply-resonant circuits. The method of Kryloff and Bogoliuboff yields no quantitative information about frequency stability, due to failure of convergence of the series representing frequency change, but it is shown qualitatively that reducing the second-order curvature improves frequency stability.

184. TUNED COUPLED CIRCUIT FOR OSCILLATOR APPLICATION
Roy A. Martin and R. D. Teasdale
(Georgia Institute of Technology, Atlanta, Ga.)

A steady-state analysis is given of an important double-tuned coupled circuit to determine the input admittance when the primary \( Q \) is high and the secondary \( Q \) is low. Particular emphasis is placed on the phase variation of the admittance with frequency. Dimensional analysis and phase illustrate the effect of varying the coefficient of coupling and the secondary \( Q \).

Mathematical expressions are obtained for the points where the phase passes through zero and are used in a discussion of bandwidth.

SYMPOSIUM
Simulation as an Aid to Design of Remote Control Systems

(Organized by Professional Group on Telemetry and Remote Control)

C. H. Doersam, Jr., Chairman
(Special Services Center, Port Washington, L. I., N. Y.)

185. SIMULATION—ITS PLACE IN SYSTEM DESIGN
H. H. Goode
(Aeronautical Research Center, University of Michigan, Ypsilanti, Mich.)

The place of simulation in system design is developed in relation to all other steps in the design process. From this, the relation of simulation to both the analytical attack on the one hand and to a final operational system on the other is developed. The facilities for simulation are then broadly reviewed with a description of presently available analog and digital facilities. This leads naturally to the program to be followed in a simulation setup. In this discussion the pitfalls to be avoided are emphasized. Then simulation of a human link in a system is discussed. Finally, a critique of simulation is given with relation to cost, time, difficulty of execution, treatment of nonlinearities, and noisy inputs.

186. DETAILED SIMULATION OF A THREE-AXIS GUIDED MISSILE SYSTEM (TYPHOON)
A. W. Vance
(RCA Laboratories Division, Princeton, N. J.)

1. General description of the over-all system in block diagram form, including:
   a. The characteristics and limitations of Typhoon in computing the motion of a rigid body,
   b. Aerodynamic function generation characteristics of Typhoon,
   c. The characteristics and limitations of the guidance simulation equipment of Typhoon.

2. The results of the solution of a particular problem are given, with a discussion of the various data.

3. Methods used to avoid and evaluate errors are outlined as follows:
   a. Tests of components.
   b. Search for time lag errors by extension of the time scale.
   c. Comparison with test problems.
187. THE APPLICATION OF THE SIMULATOR TO THE DESIGN OF AUTOMATIC CONTROL SYSTEMS
Leo Bowin
(Sperry Gyroscope Company, Great Neck, L. I., N. Y.)

The use of the simulator for both theoretical analysis and design evaluation is illustrated by synthesizing a simplified automatic heading system that includes a ship and associated steering apparatus. After a frequency analysis of the system is made, it is placed on the simulator where setting up problems are considered. Responses for various ship configurations can be run off easily and rapidly. The design is evaluated by studying the actual controller together with the ship dynamics on the simulator. The system frequency response and controller linearity characteristic can be obtained using computer elements. The simulator can be used to determine the ship hydrodynamic coefficients from data obtained during actual field operation of the system.

188. REAL TIME SIMULATION OF FEEDBACK CONTROL SYSTEMS
Albert C. Hall
(Rendix Aviation Corporation, Detroit, Mich.)

The increasing complexity of automatic control systems is discussed and the need for augmenting presently available analysis techniques is pointed out.

The effective use of computing machines (simulators) to determine the performance of proposed designs, and methods of application are discussed. However, a more significant application of computing machines is in the development of design techniques. Here the computing machine is used to help the engineer evolve a philosophy of design which conforms to an optimum system. Methods of simplification in the study of complex systems are important, and computing machines are particularly useful here. The solution time of the simulator is significant in determining its scope. The dynamic properties of computing machines are discussed.

189. DIGITAL COMPUTERS IN SIMULATED CONTROL SYSTEMS
Jay W. Forrest
(Servomechanisms Laboratory, Massachusetts Institute of Technology, Cambridge, Mass.)

Digital computers should be especially useful in simulating control systems where "logical complexity" excludes use of more conventional equipment. "Logically complex" systems have multiple courses of action which may result from human participation and decisions or from important nonlinearities and double-valued functions in physical equipment. Such circumstances may arise in training of personnel teams, developing military tactics, and studying systems such as air traffic flow which involve a number of relatively free but interdependent participants.

At the other extreme, the digital computer should be useful where generality of the machine and simplicity of setup readily permit simulation studies which would not justify constructing simpler, custom-made, special-purpose equipment.

PROCEEDINGS OF THE I.R.E.

190. LOW-DISTORTION FREQUENCY-MODULATION MODULATORS
A. R. Vallarino and C. Greenwald
(Federal Telecommunication Laboratories, Inc., Nutley, N. J.)

The problem of generation of very-low-distortion frequency-modulated signals using high modulating frequencies has been solved by the use of microwave klystron modulators in conjunction with recently developed linearity indicators. The solution is based on determining the most linear portion of the klystron characteristic by the use of the linearity indicator, as the klystrons are inherently very linear over certain ranges of their characteristics.

Throughout the microwave frequency range, distortions of better than 70 decibels with deviations from linearity 0.1 Mc have been obtained. By the use of the heterodyne method, the carrier-frequency range has been extended downwards to 1 Mc with the same distortions.

191. 1,700- TO 2,400-MEGACYCLE TRIODE AMPLIFIER
E. M. Osilund and H. G. Miller
(Federal Telecommunication Laboratories, Inc., Nutley, N. J.)

This is a neutralized buffer amplifier with grounded-grid 2CS9 triode, intended normally for isolating a mismatched antenna and long cable from a driving klystron. Wide tuning range and sufficient gain is achieved by a suitable design. Bandwidth is 20 Mc, power gain about unity. Power level 10 to 15 watts, plate efficiency about 22 per cent.

Neutralizing is accomplished by a variable loop coupling directly between input and output cavities, with series stub at one end. Neutralizing is adjusted for linearity of klystron frequency modulation in the presence of a frequency-sensitive load.

Input and output matching are accomplished by two slug coaxial tuners in conjunction with input cap and output fixed loop. The input cavity is a \( \frac{3}{2} \) wave coaxial line, tuned by sliding short. The output cavity is a quarter-wave radial line tuned by radial slugs.

192. A K-BAND AMPLIFIER KLYSTRON
(Varian Associates, San Carlos, Calif.)

Varian Associates type X-15 klystron amplifier tube will be described. This tube is a three-cavity K-band amplifier klystron with waveguide input and output which operates at a nominal frequency of 23,000 Mc. It has a power gain of 5 db and a power output of 50 milliwatts. The mechanical structure of the tube will be described and performance curves shown.

193. MODE INTERACTIONS IN MAGNETRON OSCILLATORS
R. R. Moats
(Sylvania Electric Products Inc., Flushing, L. I., N. Y.)

The magnetron is described in terms of its properties as a feedback oscillator, b show that nonlinear circuit theory may be applied in discussing mode interactions. The interaction of modes in a nonlinear feedback oscillator with two resonances is considered and it is shown that when large amplitude oscillation associated with one mode of resonance is present, this oscillation tends to suppress oscillation associated with the other mode. These theoretical observations are supported directly by measurement of the loading effect of an oscillating mode in a magnetron upon small amplitude externally supplied oscillations in another mode. They are supported also indirectly by observation of the performance of several different types of magnetrons.

194. GUIDING PRINCIPLES IN PRODUCTION OF SUBMILLIMETER WAVES
H. Von Foerster and J. S. Schaffner
(University of Illinois, Urbana, Ill.)

n oscillators operating with frequency-dependent circuitry where each one obeys the wave-function

\[ F(t) = \sum \frac{A_i}{\sqrt{2}} \cos (2\pi f_i t - \phi_i) \]

can produce a radiation power of

\[ P = \left( \sum \frac{A_i^2}{\sqrt{2}} \right)^{\frac{1}{2}} \]

This formula breaks up into two terms:

\[ P = P_1 + P_2 = \sum \frac{A_i^2}{\sqrt{2}} + \sum \frac{A_i^2}{\sqrt{2}} \]

The first term \( P_1 \) is always existent and reduces to \( nP_0 \), where \( P_0 \) is the power produced by a single oscillator. The second term \( P_2 \) describes an amount of coherence and vanishes by complete incoherence. The study of the region between complete incoherence (\( P_2 = 0 \)) and complete coherence (\( P_2 = n^2 - n \)) leads to the discussion of the expression of the form

\[ \sum \sum \frac{A_i^2}{\sqrt{2}} \cos (\phi_i - \phi_0) \]

Certain correlations between the phase functions and the amplitude functions define finally the value of \( P \).

The application of these considerations to mass-radiators and a theory of high density electron bunches is discussed.

SYMPOSIUM

Loudspeakers

(Organized by Professional Group on Audio)

J. K. Hilliard, Chairman
(Altec-Lansing Corporation, Hollywood, Calif.)

195. AMPLITUDE AND PHASE MEASUREMENTS ON LOUD-SPEAKER CONES
M. Corrington
(Radio Corporation of America, Camden, N. J.)
Amplitude and phase measurements have been made of the mechanical motion at different points on the cone diaphragm for various critical frequencies. From these the use of various peaks and dips in the sound pressure curve can be determined. Such information is helpful when making changes to improve the cone design.

196. DESIGN ELEMENTS FOR IMPROVED BASS RESPONSE IN LOUDSPEAKER SYSTEMS

HOWARD T. SOUTHER


The history of the art is reviewed and a short discussion of the current status engaged in. Ideals are posed, principally those dealing with range and distortion requirements.

Subjective requirements are suggested as related to range response, power and distortion limits. Objective limits of driver units and space are considered.

Comparative responses of flat baffles, solid enclosures, reflex boxes, horns, and especially folded corner horns are shown. The benefits of acoustic low-pass filters in connection with the last are exposed and equivalent circuits are disclosed.

The economics of low-frequency reproduction are discussed accompanied by construction hints and design data for the experimenter.

197. DIRECT RADIATOR LOUDSPEAKER MOUNTING

HARRY F. OLSON

(RCA Laboratories Division, Princeton, N. J.)

Variations in the response frequency characteristic of a direct radiator loudspeaker are produced by the resonance and diffraction effects introduced by the mounting arrangement. Variations in the response are also produced by the diffraction effects introduced by the outside configuration of the cabinet. Grills, screens, and cloths used as coverings for loudspeakers introduce variations in the response frequency characteristic due to the lumped acoustical impedance presented by these systems. Experimental data will be given to show the effect of these elements upon the response of direct radiator loudspeakers. Demonstrations will be arranged to show the effect of the mounting arrangement, cabinet and grill upon the response frequency characteristic of a loudspeaker.

198. PHYSICAL AND ELECTRICAL CONSTANTS OF DIRECT-RADIATOR LOUDSPEAKERS

L. L. BERANEK

(Acoustics Laboratory, Massachusetts Institute of Technology, Cambridge, Mass.)

This paper presents physical and electrical constants of direct-radiator type loudspeakers of a number of manufacturers. The application of these constants in the design of loudspeaker baffles will be discussed.
Institute News and Radio Notes

TECHNICAL COMMITTEE NOTES

The Standards Committee, under the Chairmanship of J. G. Brainerd, held a meeting on January 18. A proposed Standards on Graphical Symbols for Single (one) Line Electrical Engineering Diagrams, prepared by the IRE Symbols Committee in co-operation with RTMA and ASA, was presented to the Standards Committee. This Committee instructed its representatives on ASA Committees to vote for approval of the proposal. In two months, the Standards Committee will reconsider the proposal with additional material which will have become available. It will then be possible to standardize the use of symbols for publication by the IRE. . . . Arthur F. Van Dyck, the IRE Representative on ASA Sectional Committee Z17, "Preferred Numbers," has written an article on this subject which was published in the February PROCEEDINGS. . . . J. R. Ragazzini will represent the IRE on the ASA Sectional Subcommittee Z10.14, "Nomenclature for Feedback Control Systems." . . . A meeting of the Committee on Electron Tubes and Solid-State Devices was held on December 8, under the Chairmanship of L. S. Nergeraard. This Committee is again making preparation for the 1951 Electron Devices Conference, to be held at the University of New Hampshire at Durham. H. J. Reich was appointed Chairman of the Conference for 1951. Complete details will be published as they are formulated. The Committee on Electron Tubes and Solid-State Devices is giving serious consideration to the formation of a Professional Group. . . . The Circuits Committee held a meeting on December 13. C. H. Page, Vice-Chairman, presided in the absence of the Chairman, W. N. Tuttle. Comprehensive reports on the activities of the various subcommittees were given by their respective Chairmen. . . . A meeting of the Antennas and Waveguides Committee was held on December 28, A. G. Fox, Chairman, presiding. The Committee has been concerned with examining the proposed Standards on Receivers: Definition of Terms, and has given particular attention to waveguide terms.

Program Announced for IRE National Convention

The complete program of the 1951 IRE National Convention (March 19-22), together with 100-word abstracts of the technical papers, appears on pages 292-315 of this issue. The program consists of: 210 papers presented at 43 sessions; the Radio Engineering Show comprising 267 exhibits; the Annual Banquet that this year is different from menu to program; the President's Luncheon with special tables for Professional Group members; and a "get-together" Cocktail Party in the world-famous Starlight Roof of the Waldorf.

The Joint Technical Advisory Committee held a meeting on January 9 under the Chairmanship of J. V. L. Hogan. The Committee approved the reprinting of a limited number of copies of JTAC, Vol. IV, and also the publication of a supplement to Vol. IV, copies of which have been sent to the Federal Communications Commission. Another volume, Vol. VI, has been prepared by the JTAC, and will be available within a short time.

Professional Group Notes

The Institute's Professional Groups are busy with plans for the 1951 National Convention, as reported in these notes in the February issue. In addition to the symposia and technical meetings being arranged for the Convention, the following Group activities deserve notice in this column:

The Committee on Professional Groups held a meeting this month with the Policy Development Committee on January 11. The meeting was called at the instigation of the Policy Development Committee in order to discuss the broad question of publication policy as related to Professional Group activity, so that whatever recommendations made may work out through such a cooperative meeting might be given to the Board of Directors. The members present adopted several suggestions which will be reported to the Executive Committee of the Board of Directors at its next meeting.

On January 9 the IRE approved a petition to form a Professional Group on Airborne Electronics, and appointed the initial Administrative Committee. Joseph General, John E. Keto, George Rapaport, and R. J. Shank will serve on the Committee for a three-year term. J. F. Byrne, Ludlow B. Hallman, Charles J. Marshall, and Paul G. Weigert will serve for a two-year term; and G. H. Arenstein, A. S. Brown, J. W. Heyd, and H. Kruetter will serve for a one-year term. John E. Keto is the Group's Acting Chairman.

The IRE Professional Group on Antennas and Propagation is soliciting papers from its members for the regular joint spring meeting of the United States National Committee of the International Scientific Radio Union (URSI) and the Professional Group. The meeting will be held on April 16, 17, and 18, at the National Bureau of Standards in Washington, D. C., and will celebrate the semicentennial of the founding of the Bureau. Subjects of the technical sessions at this spring's meeting will be: radio propagation, antennas, and antennas. Advance registration fee for the meeting will be $2.00 and will include the cost of the program and of the smoker on April 17.

The Audio Professional Group is currently conducting a national wide election for new officers and new members of the Group's Administrative Committee. Those elected will assume office on July 1, the officers for a one-year term and the new members for a three-year term.

Six hundred and thirty-five new members have been enrolled in the Professional Group on Broadcast and Television Receivers, which now has a total membership in excess of 900.

The IRE Professional Group on Broadcast and Transmission Systems has added more than 200 new members to its roster, as a result of a recent letter mailed to chief engineers of broadcast stations and manufacturers of broadcast equipment. This brings the Group's membership to over 1,100.

As a result of the recent organization of the Professional Group on Circuit Theory, applications for membership in the Group have been accepted and the membership totals more than 1,200.

A highly successful Conference on High Frequency Measurements, sponsored by the IRE Professional Group on Instrumentation in co-operation with the AIEE and the National Bureau of Standards, was held on January 10, 11, and 12 in Washington, D. C. Five hundred and forty-nine people attended the Conference and 315 people went on guided tours of four Government institutions. At the luncheon held in conjunction with the Conference, T. G. LeClair, President of the AIEE, and I. S. Coggeshall, President of the IRE, presented a scroll to E. U. Condon in commemoration of the fiftieth anniversary of the National Bureau of Standards. Abstracts of papers presented at the Conference appeared in the February issue of the PROCEEDINGS OF THE IRE.

The card announcing formation of the IRE Professional Group on Radio Telemetry and Remote Control was mailed to members of the IRE in eight Sections has resulted in 125 applications for membership in the new Group to date, and more are being received each day.

Headquarters has received a petition for formation of a new Group in the field of Industrial Electronics. It is hoped that the Institute's Executive Committee may take action on the petition early in February. Eugene Mittelmann of Chicago is the Group's promoter.

Voice of America Announces Call for Radio Personnel

The Voice of America has announced continual vacancies now existing in New York City and overseas for experienced radio men, including studio, recording, field (remote pick-ups), maintenance and transmitter technicians.

Applications (Standard Form 57) should be sent to: U. S. Department of State, Personnel Branch, 250 West 57 Street, New York 19, N. Y.

Applicants are urged not to telephone, since the office is not equipped to supply data in answer to such calls.
IEE Schedules Electrical Instrument Design Conference

The Committee of the Measurements Section of The Institution of Electrical Engineers has arranged a Conference on Electrical Instrument Design, to be held in The Institution Building in London from May 28 to May 30, 1951. The following topics will be discussed: "Trends in Modern Instrument Design and Construction," "The Limits of Measurement Present and Future," "Materials and Components," and "Techniques in the Field of Radiation."

Calendar of COMING EVENTS

Joint Meeting of the Association for Computing Machinery and the Industrial Mathematics Society, Wayne University, Detroit, Mich., March 27, 28
URSI Spring Meeting, Washington, D. C., April 16-18
IRE Southwestern Conference, Dallas, Texas, April 20-21
1951 New England Radio Engineering Meeting, Sponsored by North Atlantic IRE Region, Copley Plaza Hotel, Boston, Mass., April 21
1951 Convention of SMPTE, April 30-May 4, Hotel Statler, N. Y.
1951 Annual Meeting of the Engineering Institute of Canada, Mount Royal Hotel, Montreal, May 9-11
1951 IRE Technical Conference on Airborne Electronics, Baltimore Hotel, Dayton, Ohio, May 23-25
IRE 7th Regional Conference, Seattle, Wash., June 20-22
1951 Summer General Meeting of AIEE, Royal York Hotel, Toronto, Canada, June 25-29
1951 IRE West Coast Convention, San Francisco, Calif., August 22-24

URSI-IRE Spring Meeting to Be Held in Washington

The IRE Professional Group on Antennas and Wave Propagation and the United States National Committee of the International Scientific Radio Union (URSI) have scheduled their regular Spring Meeting for April 16, 17, and 18 in Washington, D. C. The sessions will take place at the National Bureau of Standards in recognition of the Bureau's centennial.

Administrative meetings will be held on Monday, April 16, and the technical sessions will be held on the following days. An inspection trip of the National Bureau of Standards is being arranged for the afternoon of April 16; an informal social evening will take place on April 17, when a summary of the Zurich General Assembly of the URSI will be presented.

Technical sessions, sponsored by the following four URSI Commissions, will be held on radio propagation, noise, and antennas:


Advance registration cards may be obtained from the Secretary, Newbern Smith, National Bureau of Standards, after March 1. The registration fee is $2.00 in advance or $2.50 at the time of the meeting.

Openings Announced for Engineers in California

Scientific and engineering positions in the field of electronics are now available in the following California laboratories: U. S. Navy Electronics Laboratory, San Diego; U. S. Naval Ordnance Test Station, Inyokern, China Lake; U. S. Naval Ordnance Test Station, Pasadena Annex, Pasadena; U. S. Naval Air Missile Test Center, Point Mugu; U. S. Naval Civil Engineering Research and Evaluation Laboratory, Port Huemene; Institute of Numerical Analysis, National Bureau of Standards, Los Angeles.

Further general information may be obtained by writing to the Board of U. S. Civil Service Examiners for Scientists and Engineers, Navy Department, 1030 East Green Street, Pasadena 1, Calif.
IRE People

John B. Merrill (S’48–A’50) has been appointed a general manager of the tungsten and chemical division of the Sylvania Electric Products Inc.

Mr. Merrill has been with Sylvania since 1941, when the company purchased the fluorescent powder division of the Patterson Screen Company. In 1943, Mr. Merrill was appointed plant manager at Towanda and the activity was expanded to include the manufacture of tungsten in many forms. He was named general manager of the tungsten and chemical division when it was created in October, 1945.

Donald L. Herr (SM’46), recently appointed head of the guided missile research and development section of the Hughes Aircraft Company, received one of the A. Cressy Morrison prizes for 1950, awarded to him by the New York Academy of Sciences for his paper on electromagneticics, and for his remarkable work in the field of engineering.

The winner of numerous prizes and awards as a student at the Moore School of Electrical Engineering, Mr. Herr maintained an exceptionally high standing in his graduate work as National Tau Beta Pi Fellow and MIT Scholar at the Massachusetts Institute of Technology. He is to receive the doctorate this spring from the Polytechnic Institute of Brooklyn, where he has been an adjunct professor in electrical engineering.

He has been associated with the Bell Telephone Laboratories, the RCA Manufacturing Company, and the General Electric Company in Schenectady, N. Y. Having served for two and one-half years in the Navy as Officer-in-Charge of the Electrical Minewiping Section of the Bureau of Ships, he received two commendations for his outstanding work, and was named Prize Essayist of the American Society of Naval Engineers in 1945. After World War II Mr. Herr held a prominent position in the Control Instrument Company in Brooklyn, N. Y., and then became a senior engineer of the Reeves Instrument Company in New York, N. Y., where he was responsible for the development of two new analogue computers and the development, design, and large-scale production of new, high-precision analogue computer components. He is the author of more than twenty-five articles, which have appeared in all the principal technological publications.

Mr. Herr is a Fellow of the New York Academy of Sciences, Honorary Member of the American Society of Naval Engineers, member of the American Institute of Electrical Engineers, American Society of Mechanical Engineers, American Ordnance Association, and American Association for the Advancement of Science. He is a past member of the Institute of Aeronautical Sciences, American Mathematics Society, and the American Physical Society. Mr. Herr is also a member of Sigma Xi, Beta Pi, Sigma Tau, Eta Kappa Nu, Pi Mu Epsilon, Delta Phi Alpha and Hexagon Honor Societies, and he appears in American Men of Science.

David R. Hull (A’36–F’47) has been elected by the directors of the Raytheon Manufacturing Company to be a vice-president. Captain Hull, U. S. N. (retired), has been assistant manager of the equipment divisions of the company.

John B. Merrill

Lawrence C. F. Horle (A’14–M’23–F’25), a former president of the Institute, died after a brief illness on October 28, 1950, at the Barnabas Hospital in Newark, N. J.

A native of that city, Mr. Horle received his degree in mechanical engineering from the Stevens Institute of Technology in 1914, where he stayed on as an instructor until 1916. During World War I he served as an expert radio aid for the Navy. His subsequent career included the following positions: chief engineer of the de Forest Radio Telephone and Telegraph Company, New York; consultant, Department of Commerce Radio Laboratory, Bureau of Standards, Washington; chief engineer, Federal Telephone and Telegraph Company, New York; and vice-president, Federal Telephone Manufacturing Company, Buffalo. His most important contributions to radio were in the field of standardization of terminology and ratings.

In addition to his long-standing affiliation with the IRE, Mr. Horle was chief engineer of the Radio and Television Manufacturers’ Association. In 1948 he received the IRE Medal of Honor for his contributions to standardization work, both in peace and war.

L. C. F. Horle

Donald B. Harris (SM’45) has been appointed technical assistant to the president of Airborne Instruments Laboratory, Inc., Mineola, L. I., N. Y. Formerly he was executive assistant to the director of research of Collins Radio Co., Cedar Rapids, Iowa.

Mr. Harris, who is the new assistant to Hector R. Skifter (A’31–M’36–SM’43), was graduated from Yale University with the B.A. degree in 1922. He was associated with Northwestern Bell Telephone Co. for 23 years, with time out for war assigned duties.

As a member of the National Defense Research Committee, Division 15, Mr. Harris was the principal technical aide at Harvard University’s Radio Research Laboratory. During the war he was also a member of three Joint Chiefs of Staff committees where, as at Harvard, he was closely associated with AIL personnel. He concluded his affiliation with Northwestern Bell Telephone as transmission and protection engineer in the Iowa area.

Mr. Harris, who was formerly Chairman of the Cedar Rapids Section of the Institute, has published five papers, holds or has pending 12 patents. He is a member of the IRE Board of Editors. He belongs also to the American Physical Society, and the American Association for the Advancement of Science.

Isaac L. Auerbach (S’46–M’49) has joined the staff of the Research Division of Broughs Adding Machine Company in Philadelphia as a research engineer.

He received the degree of B.S. in electrical engineering from the Drexel Institute of Technology in 1943. Following his graduation he served in the Navy with the Naval Research Laboratory as a radio engineer. He received the degree of M.S. in applied physics from Harvard University.

Prior to joining Broughs he was senior engineer of design, development, and production at the Eckert-Mauchly Computer Corporation, and engineer in charge of the tube division of the Electronic Tube Corporation. He published a paper recently on the packaging of electronic systems.

He is a member of the Association for Computing Machinery, Eta Kappa Nu, and an associate member of the American Institute of Electrical Engineers.

Isaac L. Auerbach
industrial Engineering Notes^1

CONTROLS

The National Production Authority issued an order recently establishing a ceiling on the number of defense rated orders that manufacturers are required to accept for certain electronic components and parts. Its purpose, NPA explained, is "to prevent unnecessary diversion of distribution to civilian users by equalizing the distribution of defense orders among the electrical component and parts manufacturers." NPA Administrator William H. Harrison stated recently that his agency planned no direction affecting color television. Mr. Harrison was replying to a week-end telegram from Frank Stanton, CBS president, who was asked for a conference with NPA officials to discuss a resolution in which a group of wholesalers urged NPA to prevent color television production. Complete allocation of cadmium, effective February 1, was ordered by the NPA, and the over-all provision of cadmium for civilian uses in January was limited to one third the amount of cadmium consumed in January, 1950. This is a hard cut under the 90 per cent allocated in December. Beginning February 1, every purchase of more than 25 pounds of the strategic material requires NPA approval. Defense and essential civilian production will require almost the total available supply of cadmium, NPA said in issuing an order which places cadmium under allocation, prohibits certain uses, and limits inventories. This order is designed both to meet defense requirements and to distribute equitably the remaining supply through normal channels to essential civilian uses. Provision is made in this connection, NPA added, for the needs of new and small businesses. NPA issued an order designed to conserve cadmium for defense and highly essential civilian needs, but listed certain electronic components for which cadmium may be used under specific limitations. Included in the list of cadmium-containing items which may be produced under the new order are: copper-base alloys containing not more than 1 1/2 per cent cadmium for parts inside electronic tubes, resistance welding electrodes, multistrand railroad signal bond wire, and shunt wire leads for motors and generators; low melting point alloys for dry-type rectifier elements, fire protective systems, safety devices, electrical fuses, dental use, and inspection gauges.

TV PICTURE TUBE PRODUCTION CONTINUES AT PEAK PRODUCTION

Production of television tubes in November continued at its peak fall rate, running slightly above October. A total of 851,872 cathode-ray tubes were sold to equipment manufacturers in November, and 914,804 were produced for all purposes. Approximately 98 per cent of the tubes sold to set makers were 16 inches or larger, and more than 60 per cent were of the rectangular type.

NEW MICA, ASBESTOS INSULATION DEVELOPED BY NAVAL LABORATORY

The Naval Research Laboratory has announced development of two improved electrical insulating materials: a mica paper, and domestic asbestos from which impurities are removed by new methods.

The mica paper, the Navy said, is expected to find its greatest application in electrical condensers. "It will stand intense heat and is stronger and has greater capacitance than kraft papers," according to a Navy report.

In the asbestos development, the Navy moved to reduce the dependence upon foreign fibers and developed a procedure involving wetting of asbestos fibers instead of the conventional air-fluffing or screening method of cleaning.

INDUSTRY STATISTICS

Television manufacturers shipped 5,661,-
000 television sets to dealers in 36 states and the District of Columbia during the first ten months of 1950, according to RTMA reports. RTMA's estimates represent shipments by nonmembers as well as Association members. Sales to dealers in October, 1950, are estimated at 781,000, compared with 928,000 sets shipped in the preceding month.

FCC ACTIONS

The FCC recently adopted its rulemaking proposal to permit remote control operation of low-power noncommercial FM broadcast stations under certain conditions. The FCC ruling became effective on January 25, 1951. This should be helpful to non-profit educational stations which work on small budgets and cannot employ licensed operators for remote control operation, the FCC said.

MOBILIZATION

Secretary of Defense George Marshall recently directed the Secretaries of the Army, Navy, and Air Force to spread contracts across industry as widely as possible. This action is intended to broaden the scope of the military procurement program, and to take up the slack in industries now facing cut-backs because of material shortages.

Officials believe that the new policy, including more extended use of negotiation in contract letting, will result in military business for a greater number of electronic manufacturers. This can include television set producers who have not been able to obtain military contracts, they said.

Possible changes in military electronic specifications to conserve critical materials were discussed during a three-hour formal conference between officials of the NPA Electronics Products Division and Captain Henry E. Bernstein, Director of the Armed Services Electro Standards Agency.

The meeting, which was also attended by a representative of the Electronics Production Resources Agency and a Signal Corps officer, was called with the view of exploring possible methods of changing JAN specifications to conserve scarce metals. A survey will be conducted among the military agencies on possible changes.

At the same time, NPA officials emphasized to RTMA that the agency will assist industry engineers in obtaining scarce materials to be used in substitution for other metals, which are more scarce, as the result of new developments in their conservation programs.

DEFENSE DEPARTMENT REQUESTS LAW TO CONTROL MAGNETIC RADIATIONS

The Department of Defense has asked Congress to enact a law which would enable the President to control all types of electromagnetic radiations, including radio and TV stations, which might be used to guide an enemy plane or missile in an attack on the United States. A suggested draft of the proposed bill was submitted to the Armed Services Committees of Congress.

The purpose of the proposed legislation, the Department said, is "to provide the necessary Executive authority to control electromagnetic radiations, not only during hostilities or a proclaimed emergency, but also during time of strained international relationships when a surprise attack on the United States is a possibility." This control would extend to anything "capable of emitting electromagnetic radiations between ten thousandths and one hundred thousand (0.010-100,000) megacycles per second" to the extent he deems such control necessary to safeguard the country.

Current concepts of warfare and recent experience, Defense officials said, demonstrate the necessity to control electromagnetic radiations in the United States, its territories and possessions, during periods of critical international relationships, for the purpose of denying their use to a potential enemy for navigation of piloted or pilotless aircraft or missiles directed towards targets in the United States.

SIGNAL CORPS ANNOUNCES NEW RADIOS ARE UNDER PRODUCTION

The Signal Corps has announced that "more flexible" and "faster" communication will be brought to the battlefield by a new series of radio sets now in production which are expected to be issued to troops early this year.

The new sets, when connected together in various combinations, produce a variety of completed sets, the Signal Corps said. Thirty different sets of these can be obtained by varying the combinations in the manner of "building blocks."

Applications of this "building block" principle not only makes for flexible communications, the Signal Corps explained, but also for economy in procurement. The blocks are manufactured separately, and are designed primarily for vehicular use, but may be readily modified with a field kit and used on the ground.

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Books

Essentials of Electricity for Radio and Television by Morris Slurzberg and William Osterheld


This text presents elementary background material on the essentials of electricity as will be required by radio amateurs or students in high school or trade school. It should also prove useful to laboratory assistants and technicians employed in the power or communications industry. It is not suitable, nor is it intended for use by the professional engineer. It is not particularly slanted towards radio, most of the material being common to all electrical engineering, and electron-tube material being very scarce.

Introductory comments are presented on communications during which the need for knowledge of electricity is pointed out. The text follows with some elementary physics of static electricity and discussions of batteries; simplicity often requires that the true situation, too complex for discussion, be greatly compromised. Typical are such statements as "a second factor that affects the capacitance is the thickness of the dielectric, because if its thickness is reduced, fewer distorted electron orbits will oppose the electrostatic field. This results in a greater number of electrons being stored in the conductor, which increases the capacitance" (page 310). Also, the pass-characteristic diagrams of Article 12.2 present an interesting idea which probably is at once helpful to the nondoctrinaire reader, and confusing to the discerning one. These diagrams show the usual amplitude-versus-frequency curve; however, the area of the diagram below the curve is differently shaded from the remaining area. The area is entitled "frequency band passed," the latter area is entitled "frequencies eliminated."

SIMON RAMO
Hughes Aircraft Co.
Culver City, Calif.

Operational Calculus by B. Van der Pol and H. Bremmer

Published (1950) by Cambridge University Press, 51 Madison Ave., New York 10. N. Y. 409 pages +3-page index +xxiii pages. 97 pages. 97 figures. 6 x 10. $10.00.

The use of the Laplace Integral for the solution of problems lies upon the advantage that discontinuous functions of a real variable are transformed to functions of a complex variable which are analytic and may be readily handled. The full solution of the problem depends upon a table of functions and their transforms for the recognition of the original function to which the transformed function arrived at corresponds.

In this book the operational calculus is based on the two-sided or, more usually expressed, bilateral Laplace Integral (taken between minus infinity and plus infinity), contrary to the usual practice where the lower limit is taken as zero. The authors claim for this choice that thereby the class of functions suited to an operational treatment is larger, the transformation process is simplified, and the whole treatment may be made more rigorous. Multiplication of the given function by the unit function reduces the bilateral integral to the type of problem where a driving force is applied suddenly or a switch is closed. Here, the lower limit becomes zero.

The first half of the book deals with fundamental principles and the establishment of general rules, and the second half, with a variety of applications. An unusual chapter deals with the application to Bessel functions and Legendre functions and developments, not only familiar fundamental relations, but others which are less well known.

The book was written with the pure mathematician especially in mind. The endeavor has been to give the operational calculus a rigorous mathematical basis. Illustrative examples are, for the most part, taken from pure mathematical, rather than technical fields.

The authors have indicated sections of the book which, taken together, form an al-
cost complete course for the "practical" man. However, in the opinion of this reviewer, the engineer may more profitably obtain a detailed course from an elementary book in order to appreciate the wealth of material in this advanced and scholarly work.

Attention should be directed especially to the comprehensive list of original and transformed pairs in the "dictionary" at the end of the book.

FREDERICK W. GROVER
Union College
Schenectady, N. Y.

The Anatomy of Mathematics by R. B. Borelshner and L. R. Wilcox
Published (1950) by The Ronald Press Co., Inc., 36 W. 40th St., New York 16, N. Y. 364 pages + 4-page appendix + 1-page index + 1-page pages. $3.50.

This reviewer has found this a truly delightful text. It deals with the axiomatic method in mathematics. Much of the subject matter is that dealt with in treatises on algebra, e.g., the theory of sets, groups, and fields is developed from the standpoint of illustrating the logical structure of mathematics. The development is much less terse than that customarily encountered in algebraic treatises, a considerable amount of time and effort being devoted to a discussion of the logical context of the material presented. The authors have chosen real number theory as a medium for illustrating the concepts and methods developed. In a manner consistent with the philosophy of the axiomatic method, a new mathematical theory is introduced with a concise abulation of the basis consisting of the functions, relations, operations, and the like, which remain unchanged. In addition to the basis, the axioms or postulates are clearly stated in each new development. The authors have demonstrated the method of induction as a powerful tool in proving many theorems throughout the text.

The book is written in such a manner that it does not appear to require any mathematical prerequisites on the part of its readers. Definitions are collected and summarized at convenient intervals throughout the book. The concepts are illustrated by application to many instances in real number systems. An excellent selection of problems is introduced as projects to enable the reader to develop the subject matter as well as to develop the theories further.

Recognizing the topic limitations imposed by the care and thoroughness with which the authors have developed their subject, this reviewer would like to point out that work followed by a consistent volume in which the theories are applied to instances chosen from geometry and the physical sciences. The authors are to be congratulated on their excellent work.

LLOYD T. DEVORE
General Electric Co.
Syracuse, N. Y.

Static and Dynamic Electricity (Second Edition) by W. R. Smythe

This book was first published in 1939. The new edition offers substantial improvements of old material and important additions of new material. The changeover to rationalized mks units, in particular, should make this a more generally useful reference than was the first edition.

The author applies basic principles of electricity and magnetism to the solution of a wide variety of challenging problems. The material includes electrostatics, potential distributions, magnetism, induction, electron transients, ac circuits, eddy currents, electromagnetic waves and radiation, waveguides and resonators, and relativistic motion of charged particles. The presentation is extremely thorough and many original results are presented. The material is not designed for the neophyte, but is primarily devoted to research men and graduate students in mathematics, physics, and electrical engineering.

The excellent problems given with every chapter must be considered an integral part of the text, for they frequently contain valuable results. References to useful problems are included in the unusually complete index. Many questions are from the Cambridge University examinations as reprinted by Jean with the possible exception of Weber's recent book.

The application given here of conformal mapping and inversion methods to potential problems is the best treatment known to this reviewer. Two completely new chapters dealing with electromagnetic waves include a complete discussion of boundary conditions in microwave systems. A constant notation is adopted to distinguish phasor, scalar, and vector quantities.

The type setting and proof reading for this book must have been a difficult task. The author and the publishers deserve congratulations on the fine appearance and the freedom from errors. The only slips noted were an incorrect negative sign on page 128 and a misleading, if not incorrect, use of a and b in Fig. 8.06.

Some of the "modernized" nomenclature appears to be of dubious value. "Electromotive force" and "capacitance" for dielectric constant are uninspired terms at best and will probably find new converts.

Although many books are listed, reference is seldom made to periodic literature, even when classic papers appear as appendices. The material on transients and ac circuits, while interesting, seems rather out of place. The omission of Chapters 9, 10, and parts of 6 would have left a better integrated treatment and should have permitted a more attractive selling price.

These few objections are relatively minor. This valuable work should prove an authoritative text and reference for many years to come. It warrants careful study by the serious student and research man.

R. S. TREADALE
Georgia Institute of Technology
Atlanta, Ga.


Response of Physical Systems by John D. Trimmer
Published (1950) by John Willey and Sons, Inc., 440 Fourth Ave., New York 16, N. Y. 240 pages + 6-page index + 1-page index pages. 91 figures. $4.00.

In this unusual book, the author has made a generally successful attempt to stress the broad concepts of system, "forcing" (a new term coined to avoid force as too closely linked to mechanical systems) of the system, system response, and the interrelation of these concepts as expressed by a "law." The value or usefulness of these systems was determined by the response criteria. One of these is the "error," defined as the instantaneous differences between the desired and the reference quantities, and applying to indicating instruments, servomechanisms, and automatic controls; the other is the "distortion," primarily applying to amplifiers. With the systematic development of this terminology, a very good and detailed treatment by means of classical differential equations is given of first- and second-order systems; higher-order systems are reduced to approximate combinations of independent first and second considerations. The further chapters on feedback and distributed systems, on systems with time-varying parameters, and nonlinear systems can be considered only as brief expositions with special examples. In the appendix a brief treatment of the Laplace transform is given.

The most attractive feature of this book is the emphasis on the point of view and the selection of the examples from widely separated fields such as nuclear reactors, electronics, mechanics, and so forth, unified by the consistent terminology. Though the mathematical treatment is generally good, it is not uniform and occasionally lacking in clarity. Disturbing is the inadvertent mixture of real and complex notation, particularly on page 30, where this makes an equation manifestly incorrect. It is doubtful that students in economics or in sociology will find much of direct use for them, because of the lack of illustrative examples in these fields. For anyone interested in physical systems, this volume should prove very stimulating reading.

ERNEST WEBER
Polytechnic Institute of Brooklyn
Brooklyn 1, N. Y.

Wave Guides by H. R. L. Lamo
t
Published (1950) by John Willey and Sons, Inc., 440 Fourth Ave., New York 16, N. Y. 109 pages + 6-page index + 2-page index + 4-page index + 1-page index pages. 37 figures. $4.00.

This third edition of a book, intended to supply a compact statement on waveguides for individuals of average scientific attainment, has been expanded over previous editions appearing in 1942 and 1946. Basic theory and the more useful expressions are given in a manner to present a perspicuous view of the subject. Frequently correlations are given between theories or results as appearing in published articles by different authors in various publications. The bibliography includes publications from all over the world so that further details can be found if the reader should require them. In spite of the book's small size and brevity, it is quite comprehensive and the development of the various chapters follows in logical order. This book fills a need much the same as does a vest pocket book on fundamentals of higher mathematics, which gives the most useful expressions and tables.

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<td>Pasadena 4, Calif.</td>
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<td>S. T. Fife</td>
<td>Univ. of Louisville</td>
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<tr>
<td>Louisville (5)</td>
<td>Louisville, Ky.</td>
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<td>R. M. Krueger</td>
<td>Palmier H. Craig</td>
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<tr>
<td>Collins Radio Co.</td>
<td>1014 Catalonia St.</td>
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<td>Cedar Rapids, Iowa</td>
<td>Coral Gables, Fla.</td>
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<td>J. C. Berner</td>
<td>William H. Elliot</td>
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<td>Ecole Polytechnique</td>
<td>4747 N. Larkin St.</td>
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<td>1430 St. Denis</td>
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<td>Montreal, Que., Canada</td>
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<td>3325 49th Loop</td>
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<td>Albuquerque, N. M.</td>
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<td>D. D. Chipp</td>
<td>Dumont Tel. Network</td>
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<tr>
<td>513 Madison Ave.</td>
<td>New York 22, N. Y.</td>
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<td>M. W. Bullock</td>
<td>C. M. Smith</td>
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<tr>
<td>Capital Broadcasting Co.</td>
<td>403 West First St.</td>
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<td>Lincoln 8, Neb.</td>
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<td>J. T. Henderson</td>
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<td>Division of Physics</td>
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<td>C. A. Gunther</td>
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<td>Westinghouse Atomic Power Div.</td>
<td>Bette Field</td>
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<td>P. O. Box 1468</td>
<td>F. E. Miller</td>
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<tr>
<td>Portland 6. Ore.</td>
<td>3122 E. 73 Ave.</td>
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<td>L. J. Giaconetto</td>
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<td>RCA Laboratories</td>
<td>Princeton, N. J.</td>
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<td>209 Fowle Rd.</td>
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<td>R. Rodgers</td>
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<td>Terry (7)</td>
<td>Mutual Tel. Co.</td>
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<td>Box 2000</td>
<td>Honolulu 5, T. H.</td>
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<td>Houston (6)</td>
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<td>Kansas City (5)</td>
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<td>London, Ontario (8)</td>
<td>Mrs. G. L. Curtis</td>
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<td>1388 Bryd Street</td>
<td>6005 El Monte</td>
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<td>Los Angeles (7)</td>
<td>W. G. Hodson</td>
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<td>524 Hampton Rd.</td>
<td>Burbank, Calif.</td>
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<td>Louisiave (5)</td>
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<td>Route 3</td>
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<td>Miami (6)</td>
<td>F. B. Lucas</td>
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<td>840 N. E. 88 St.</td>
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<td>Milwaukee (5)</td>
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<td>800 S. Fifth St</td>
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<td>Montreal, Quebec, Canada</td>
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<td>2110 College Ave.</td>
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<td>New Mexico (7)</td>
<td>Box 6000</td>
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<td>4110 Alverado</td>
<td>Montreal, Que., Canada</td>
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<td>New York (2)</td>
<td>C. H. Badenham</td>
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<td>Bell Tel., Inc.</td>
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<td>Whippany, N. J.</td>
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<td>North Carolina-Virginia (3)</td>
<td>S. C. Carrier</td>
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<td>246 Riddick Engineering Lab.</td>
<td>N. C. State College</td>
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<td>R. B. Lucas</td>
<td>Raleigh, N. Car.</td>
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<td>Ottawa, Ontario (5)</td>
<td>E. L. Webb</td>
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<tr>
<td>31 Dunvegan Rd.</td>
<td>Ottawa, Ont., Canada</td>
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<td>Philadelphia (3)</td>
<td>C. M. Simnett</td>
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<td>Pittsburg (4)</td>
<td>RCA Victor Div.</td>
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<td>W. H. Hamilton</td>
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<td>Henry Surtevant</td>
<td>P. O. Box 1468</td>
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<td>Princeton (3)</td>
<td>E. J. Giaconetto</td>
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<td>R. Rodgers</td>
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<td>Rochester (4)</td>
<td>Princeton, N. J.</td>
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<td>Rochester, N. Y.</td>
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Airborne Electronics

Chairman: John F. Kety
Wright Field Dayton, Ohio

ANTENNAS AND PROPAGATION

Chairman: Newbern Smith
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Abstracts and References

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NOTE: The Institute of Radio Engineers does not have available copies of the publications mentioned in these pages, nor does it have reprints of the articles abstracted. Correspondence regarding these articles and requests for their procurement should be addressed to the individual publications, and not to the IRE.

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ACOUSTICS AND AUDIO FREQUENCIES

534.2:551.553
The Fine Structure of Atmospheric Turbulence in Relation to the Propagation of Sound over the Ground—E. G. Richardson. (Proc. Roy. Soc. A, vol. 203, pp. 149-164; September 22, 1950.) Simultaneous measurements of the fluctuations in sound intensity at a distance from a steady source, and of the atmospheric turbulence at points along the sound path, are used to discuss the relation between sound scattering and intensity of turbulence. The effect of the latter on the phase relations between signals received at two points is demonstrated.

534.212
The Propagation of a Sound Pulse in the Presence of a Semi-infinite, Open-ended Channel: Part 2—W. Chester. (Proc. Roy. Soc. A, vol. 203, pp. 33-42; September 7, 1950.) The asymptotic behavior of the disturbance at great distances from the wave front is discussed. For an incident Heaviside unit pulse, the wave inside the channel also tends to behave like a unit pulse, the correction term being a function of the distance from the wavefront. The case of an arbitrary pulse is also considered. The results are used to estimate the proportion of energy which returns along the channel when the incident pulse is of finite duration. Part 1: 2583 of 1950. See also 1560 of 1950.

534.321.2:621.3.018.7†
The Effect of Nonlinear Distortion on the Perception of Musicians—W. Weitbrecht. (Fernmeldeze.t, vol. 3, pp. 336-345; September, 1950.) An experimental method is described in which pairs of electrically generated tones selected from the common chord of C in the octave 523.25-1046.50 cps, on the tempered and again on the just scale, are presented to listeners after passage through a pentode circuit of known adjustable nonlinear-distortion factor. The presentation of the properly tuned combination is alternated with the same combination mismatched, the listener stating whether or not he can hear a difference. Results are shown in charts. The harmonics and combination tones in the audio output are also observed objectively. The response of the ear to extraneous sounds is discussed. Characteristic differences are noted for different musical intervals.

534.321:9:621.315.616
Propagation of Low Frequency Ultrasonic Waves in Rubber and Rubber-like Polymers—P. Hatfield. (Bril. Jour. Appl. Phys., vol. 1, pp. 252-256; October, 1950.) Experiments covering a frequency range 50-350 kc and temperature range 0-60° are described. The velocity of low-amplitude ultrasonic waves varies from 1.1X10^6 to 1.8X10^6 cm in different rubbers at room temperature; absorption varies from <0.1 to 2 db per cm at 50 kc and from 0.7 to 11 db per cm at 350 kc. Applications of these materials as acoustic lenses and as ultrasonic transmission media are discussed.

534.782.07

534.845
Absorption of Sound by Porous Materials—C. Zwicker. (Research, London), vol. 3, pp. 400-407; September, 1950.) The control of reverberation by pure porosity effects is examined theoretically for normal incidence of the sound waves on a wall of infinite extent. The coefficient of sound absorption can be determined in terms of the wave impedance and pressure coefficient, which can be measured by interferometer methods. They may also be deduced if the porosity, specific flow resistance, thickness and structure factor (a parameter depending upon the angle between the cell axes and the normal to the front surface) are known. See also 1560 of 1949 (Zwicker, van den Eijk, and Kosten) and Reference back.

621.395.61
The Tube Microphone—H. J. Griese. (Aek. elektronik, Ubertragung, vol. 4, pp. 259-266; July, 1950.) Description and analysis of operation of a microphone in which the sound pickup member, of spherical or exponential horn shape, is connected to the transducer by a slimmer tube. Directional characteristics and frequency-response curves are shown and discussed, and various constructions are illustrated.

621.395.61:621.396.645
The Brief-Case Field Amplifier—Hathaway and Kennedy. (See 112.)

621.395.623.7
Sensitivity, Directivity and Linearity of Direct-Radiator Loudspeakers—H. F. Olson. (Audo Eng., vol. 34, pp. 15-17, October, 1950.) Discussion of the characteristic curves of direct-radiator dynamic loudspeakers show that rigid large-angle cones with suspensions of high mechanical resistance produce more uniform frequency response and directional characteristics than loudspeakers with light vibrat- ing systems which, though possessing greater sensitivity and giving greater intensity directly in front of the cone, have considerably greater nonlinear distortion. The heavier type, however, also handles much greater power without overloading.

621.395.623.7
A New Loudspeaker of Advanced Design—D. J. Plach and P. B. Williams. (Audio Eng., vol. 34, pp. 22-23, 65; October, 1950.) The loudspeaker comprises three independently driven reproducers, covering the whole audio range from 18 to 18000 cps, with crossover at 600 cps and 4 kc. In the low-frequency unit a 3-inch voice coil drives a 15-inch plastic diaphragm shaped like the mouth of a horn, into the throat of which the mid-frequency unit is inserted. This uses a dished plastic diaphragm driving through an annular gap into a horn formed by part of the magnet system of the low-frequency unit. The flare of this horn passes smoothly into that of the low-frequency diaphragm, which thus acts as an extension of the mid-frequency horn and provides good high efficiency down to and below the crossover at 600 cps. The high-frequency unit is independently mounted in the front of the assembly. It also has a flared horn, the diameter of the mouth being 1.5 inches. Tests indicate the high quality of the reproduction of all types of broadcasting material.

621.395.623.7:001.4
Transient Testing of Loudspeakers—M. S. Corning. (Audio Eng., vol. 34, pp. 9-13; August, 1950.) A theoretical discussion of the relation between the sound-pressure curve of a loudspeaker and its transient response to a suddenly applied unit sine wave is illustrated by experimental results on a 12-inch loudspeaker. It is concluded that the unit sine wave is preferable to the unit impulse as a test, because it is easier to interpret, since it emphasizes the ringing of peaks of nearly the same frequency as its own.
Abstracts and References

2.36.07:621.397.5
2.36.06:621.397.6
2.36.05:621.397.7
2.36.04:621.397.8
2.36.03:621.397.9
2.36.02:621.397.10
2.36.01:621.397.11
2.36.00:621.397.12

Designing the Bridgeport U.H.F. Antenna—R. M. Scudder. (Electronics, vol. 23, pp. 76-80; November, 1950.) The development and construction of a television antenna sensibly omnidirectional in the horizontal plane with a voltage SWR < 1.15 in the band 520-535 Mc. The antenna consists of a linear array of vertical 2 1/2 inch dipoles on 109 inch centers, with coaxial feed, and has an overall height of 40 ft. Its power gain is 17 and vertical beam width 3°. See also 2425 of 1950.

2.36.07:621.396.71

Asymptometrically Driven Antennas and the Sleeve Dipole—R. King. (Proc. I.R.E., vol. 38, pp. 1154-1164; October, 1950.) General expressions for impedance and current distribution of asymptometrically driven antennas are derived. Experimental results are presented for cylindrical 3/4 antenna, driven \( \lambda/4 \) from one end, are evaluated and its wide-band properties are discussed.

2.36.07:621.396.72

Dielectric Directive Radiators—P. Mallach. (Fermatschech. Z., vol. 3, pp. 325-328; September, 1950.) A discussion of end-on radiators, particularly the tubular type. Radiators made of materials with dielectric constants ranging from 2.5 to 64 were investigated. An experimental setup for obtaining the radiation pattern is described, and the effect of variation of axial ratio and form is shown in graphs. The tubular dielectric radiator is smaller than the equivalent horn; the dielectric-rod radiator even smaller. See also 1604 of 1949.

2.36.07:621.396.73

Coaxial Feed System for Antennas—J. F. Clemens. (Electronics, vol. 23, pp. 154, 182; October, 1950.) A variation of the "delta match" method enables any unbalanced coaxial cable to be used to feed balanced horizontal antennae. Formulas are given for calculating the total inductive reactance between feed points and the length of shorted cable required for resonance. Results obtained with experimental antennae at 300 Mc and 29 Mc are described.

CIRCUITS AND CIRCUIT ELEMENTS

2.36.01:621.342.2

Optimum Use of Nickel Alloy Steel in Low-LL. Transformers—L. W. Howard. (Audo Eng., vol. 34, pp. 20-21, 50; October, 1950.) Discussion of the design and manufacturing problems involved in the production of small transformers for various low-level applications. The transformers are as small as possible and are hermetically sealed. For some of the longest-live type, high-tension shielded transformers, Interlaced copper shielding rings are used. Owing to their low saturation point, these steels are not suitable for high-level applications, for which sillicon steels are preferred.

2.36.00:621.342.1

Design of Broad-Band Transformers for Linear Electronic Circuits—H. W. Lord. (Electronics, vol. 29, pp. 69, 182; April, 1950.) Paper presented at the AIEEE Summer and Pacific General Meeting, Pasadena, Calif., June, 1950. Analysis and design data are given for multivibrator transformers intended to operate with negligible variation of gain and phase and with low distortion. Generalized frequency-response curves are given for a range of relevant circuit parameters. The performance of a typical 3-w transformer is in close agreement with theory over the frequency range 20,000-30,000 cps.

2.36.01:621.342.4


2.36.01:621.342.2

The Statistical Analysis of Electrical Noise—D. K. C. MacDonald. (Phil. Mag., vol. 41, pp. 814-818; August, 1950.) Recent papers by Meltzer on electrical noise (see 2141 of 1950 and 292 above) are criticized. In particular, no distinction was made between two-terminal and four-terminal noise, and no knowledge of the results for the investigation of the statistical properties of the given frequency range is published. The results of a general discussion of the statistics of noise and spectrum of fluctuations are applied to determine the noise characteristics of a given circuit configuration, and the limiting current by elementary Mean charges of magnitude e.

2.36.01:621.342.2


2.36.01:621.342.2

32-Channel High-Speed Communicator—N. Alpert, J. Luongo and W. Wiener. (Electronics, vol. 23, pp. 94-97; November, 1950.) An electronic switching device for information channels, using a system of binary counters and gating tubes to obtain a sampling rate of 1,000 per second.

2.36.01:621.342.2

Tantalum Electrolytic Capacitors—M. Whitehead. (Bell Lab. Rec., vol. 28, pp. 448-452; October, 1950.) Capacitors of the conventional foil type using tantalum instead of aluminum, and a new type in which the anode is a highly porous cylinder of sintered tantalum are described. The advantages of the tantalum capacitors are found in a general discussion of their properties, including their relatively small size, low permissible operating temperature and high leakage resistance.

2.36.01:621.342.2

Mention of a Useful Extension of Thévenin's Theorem—L. Tann-Teichal. (Proc. I.E.E. (London), Part I, vol. 97, pp. 234; September, 1950.) "Thévenin's Theorem: If an impedance \( Z \) be connected between two terminals of a network, the potential difference between any second pair of terminals will be equal to that between the terminals of two generators, operating in parallel and having internal electromagnetic
forces equal to the voltages across the second pair of terminals when \( Z = 0 \), and internal impedances, equal to the Thévenin impedance of the network measured between the first pair of terminals, and to \( Z \), respectively.

**Corollary:** The current in any branch of the network, any Thévenin impedance, an equivalent \( Y \) impedance, or an equivalent \( \Delta \) impedance in the network will, for any value of \( Z \), be numerically equal to the terminal voltage of the two generators, if their internal electrootive forces are made numerically equal to the currents, or impedances concerned, when \( Z = \infty \) and when \( Z = 0 \), respectively.

621.392.5: 621.396.419.5

The parameters of a Passive Four-Pole that May Violate the Reciprocity Relation—B. D. H. Tellegen and E. Klauss. (Philips Res. Rep., vol. 3, pp. 1191–1196; October, 1950.) The general problem of transforming an impedance which changes with frequency into a resistance nearly independent of frequency is considered. A simple procedure for the general solution is evolved and design formulas for the appropriate matching section are derived. The formulas give the parameters of the matching section for any value of selected frequencies. The technique is mainly applicable to cases where the half-bandwidth is small compared with the center frequency; it can be applied to all types of transmission line whose characteristic impedance is known.

621.392.5

The Design of Frequency-Compensating Matching Sections—V. H. Rumsey. (Proc. I.R.E., vol. 38, pp. 1191–1196; October, 1950.) The property of these quadrupoles at a given frequency are investigated theoretically and the conditions are determined for a quadrupole to be passive. See also 980 and 2745 of 1949 and 1879 of 1950 (Tellegen).
Abstracts and References

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357.312.8:539.23


357.525.029.64

Microwave Gas Discharges—M. A. Blondi. (Elect. Eng., vol. 69, pp. 806–809; September, 1950.) AIEE Winter General Meeting paper. The discharge in a gas excited at microwave frequencies is discussed from a purely physical viewpoint. Some results of experimental investigation are given and a formula for the complex conductivity is developed from the known properties of electrons and ions.

357.527.4

Positive Point-to-Plane Spark Breakdown of Compressed Gases—T. R. Poord. (Nature (London), vol. 164, pp. 21–22, 1950.) Account of an experimental investigation of anomalous decrease of spark breakdown potential with increase of pressure in air, N₂, (oxygen-free), 'm', and SF₆. The occurrence of the phenomenon appears to depend on the presence of (a) a divergent field and (b) a gas which forms negative ions.

357.56:538.56

The Refractive Index and Classical Radiative Processes in an Ionized Gas—K. C. Westfold. (Phil. Mag., vol. 41, pp. 599–616; June, 1950.) Hartree's classical methods are used to find the effect of the refractive index on the absorption and reflection of light in an ionized medium with no magnetic field, and to confirm the results of Smed and Westfold (95 of February). A quantum theory interpretation is also given.

357.562:537.311

The Electrical Conductivity of an Ionized Gas—R. S. Cohen, L. Spitzer, Jr., and P. M. Routly. (Phys. Rev., vol. 89, pp. 230–238; October 15, 1950.) "The interaction term in the Boltzmann equation is expressed as the sum of two terms: a term for the usual form for close encounters and a diffusion term for distant encounters. Since distant encounters produce small deviations from the mean, it is more important for close encounters, consideration of only the diffusion term gives a reasonably good approximation in most cases and approaches the true temperature increases or the density decreases. It is shown that in evaluating the coefficients in this diffusion term, the integral must be cut off at the Debye shielding distance, not at the mean interionic distance. The integro-differential equation obtained with the use of this diffusion term permits a more precise solution of the Boltzmann equation than possible with a Cowling theory. While one pair of coefficients in this equation has been neglected, the remaining coefficients have all been evaluated, and the resultant equation agrees numerically for the velocity distribution function in a gas of electrons and singly ionized atoms subject to a weak electric field. Special techniques were required for this numerical integration, since solutions of the differential equation proved to be unstable in both directions. For high temperatures and low densities, the conductivity is about 68 per cent of the value given by Cowling's second approximation."
main sizes and shapes are due to the tendency of the ferromagnetic system towards a state of minimum energy.

338.221  Ferrromagnetism at Very High Frequencies. Part 2: The Magnetoconductivity of Dispersions in a Ferrite — G. T. Rado, R. W. Wright, and W. J. Emerson. (Phys. Rev., vol. 80, pp. 273–280; October 15, 1950.) "The magnetic spectrometer is known to contain two regions of pronounced dispersion. One occurs at radio frequencies, resembles a resonance, and is proved to be due to domain-wall displacement, while another occurs in the microwave frequency range, exhibits typical resonance characteristics, and is attributed to domain rotations."

Part 2: 1949 of (Rado and Rado).

338.52/53  Calculation of Currents Induced in a Solid Sphere of Ferrite by Mutual Inductance with an Endless Solenoid—A. Colombani. (Compt. Rend. Acad. Sci. (Paris), vol. 231, pp. 570–572; September 18, 1950.) Corresponding formulae to those previously given for a spherical shell (2766 of 1950) are derived for a solid sphere within an endless solenoid.

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.53: 551.503.50  The Influence of High-Altitude Winds on Meteor-Trail Ionization—C. D. Elyett. (Phil. Mag., vol. 41, pp. 694–700; July, 1950.) Mechanisms whereby winds can cause changes in meteor-trail ionizations are discussed in the light of observations from different sources. Assuming that fluctuation rate depends on frequency, short-and medium-height variations of meteor-trail echoes can be correlated with phase and amplitude variations of waves reflected from the ionosphere. A causal connection is suggested. See also 359 below.

621.306.9: 523.53  The Fluxuation and Fading of Radio Echoes from Meteor Trails—Greenbow. (See 359.)

523.72: 523.74: 621.306.82  The Solar Atmosphere and the Origin of Radiofrequency Radiation—S. A. Korff and Y. Beers. (Phys. Rev., vol. 80, pp. 489–499; November 1, 1950.) Short discussions of the physical conditions prevailing in the sun’s atmosphere. The tendency in some recent papers to attach too much physical significance to the “equivalent noise temperature” T is deprecated, since T is only a measure of the available power of a noise source and gives no information regarding the mechanism of the source.

523.72: 621.396.82  Solar Radiation of Wavelength 1.25 Centimetres—J. H. Piddington and H. C. Mimsitt. (Aust. Jour. Sci. Res., Ser. A, vol. 2, pp. 539–553; November 1950.) Observations of a period of about six months are described. The observed average intensity corresponded to a black-body temperature of 10° K, with a Kλ one day’s variation being 3 to 4 per cent. No day-to-day variations were < 2 to 3 per cent, which was the limit of observational accuracy. Short-period fluctuations were < 2 to 3 per cent, even during intervals to those previously given for the distribution of intensity over the solar disk, measured by a method analogous to the Mciielson interferometer technique, was consistent with 4 per cent. Noisy spots were considered to be a uniform disk and 16 per cent from a narrow annulus surrounding it.

523.72: 621.396.82  Solar Radiation at a Wavelength of 3.18 Centimetres—H. C. Mimsitt and N. R. Lahbrum. (Aust. Jour. Sci. Res., Ser. A, vol. 3, pp. 60–71; March, 1950.) Observations were made daily from November 24, 1948, to March 1, 1949. An accurate measurement of the received intensity was obtained by one technique, and a continuous record over several hours was made by a less accurate method. The estimated equivalent black-body temperature at 2.67 per cent for the 3.18 cm wavelength and temperature increments per unit increase of sunspot area were less than for longer microwaves. Observations were also made during the eclipse of November 1, 1948, and the distribution across the disk. Results were consistent with either 74 per cent of the radiation coming from the visible disk and the remainder from the unobscured part of the bright disk covering the whole of the radiation coming from a uniform disk of diameter 1.1 times that of the visible disk.

523.72: 621.396.82  Radio-Frequency Radiation from the Quiet Sun—B. F. Smull. (Aust. Jour. Sci. Res., Ser. A, vol. 3, pp. 34–59; March, 1950.) The chromosphere and the corona are considered as two regions of uniform temperature with a discontinuity at the boundary; because of the uncertainty in determining the temperatures in the range of values is considered. The intensity distribution across the emitting disk is derived for frequencies from 60 to 30,000 Mc, and the size of the emitting disk is estimated from that of the optical disk. The apparent temperature (an equivalent mean square of the density at the earth) has a maximum as a function of frequency for each coronal temperature, and as a function of coronal temperature for each frequency. All observed apparent temperatures correspond to chromosphere temperatures from 10° to 3×10° K and coronal temperatures from 2.5×10° to 3×10° K. The effects of a possible general solar magnetic field are small in relation to those due to uncertainties regarding temperature.

523.752: 621.396.82  The Derivation of a Model Solar Chromosphere from Radio Data—J. H. Piddington. (Proc. Roy. Soc. A, vol. 203, pp. 417–434; October 10, 1950.) The basic data used are recent radio measurements of disk temperature at frequencies between 60 and 24,000 Mc. The coronal contribution to this is calculated and subtracted to obtain the chromosphere component. Finally an expression is derived giving separately the two components as functions of frequency and position on the disk, the values obtained are in reasonable agreement with experimental observations. The radio results are combined with data on the intensities of spectrum lines at various levels in the chromosphere to obtain the distribution of electron density and temperature. A marked departure from conditions of hydrostatic equilibrium is indicated.

523.78 "1948.11.1": 621.396.82  Measurements of Solar Radiation at a Wavelength of 50 Centimetres during Eclipse of November 1, 1948 — W. N. Christianen, D. E. Yubiley, and B. Y. Mills. (Aust. Jour. Sci. Res., Ser. A, vol. 2, pp. 506–523; December, 1948.) Observations were made at three well-separated places in Australia. Abrupt changes in the slope of the flux-density curves were correlated with the covering and uncovering of the disk by the earth’s shadow. The mean brightness, viz., sunspots past and present, and one prominence; these areas contributed about 99 per cent of the total received power. Of the remaining four-fifths, about 40 per cent originated outside the visible disk. No effects of any general solar magnetic field were detected.

523.78 "1948.11.1": 621.396.82  Solar Radiation at a Wavelength of 10 Centimetres during Eclipse Observations—J. H. Piddington and J. V. Hindman. (Aust. Jour. Sci. Res., Ser. A, vol. 2, pp. 524–531; December, 1949.) Observations were made at Sydney both before and after the eclipse of November 1, 1948, and conditions during the eclipse were related to the varying day-to-day level of radiation frequency disk distribution. Over the solar disk was determined, the mean intensity radiation coming from near the limb, and some radiation from beyond the limb, leaving the small high-intensity area was isolated. The excess of circularly polarized component either right- or left-hand, observed at eclipse maximum was smaller than the value to be expected for a general solar magnetic field 50 gauss and above.


537.53: 537.311  The Electrical Conductivity of an Ionized Gas—Colson, Spitzer, and Rottly. (See 335.)

550.381  The Origin of the Earth’s Magnetic Field—E. C. Bullard. (Obserc. vol. 70, pp. 139–143; August, 1950.) The Halley Lecture 1950. The author prefers a hypothesis resembling the self-excited dynamo moton of the earth’s fluid conducting core producing effects similar to those due to the motion of the dynamo rotor. Electric currents would thus be generated in the core and these could account for the main field, their variations due to the effects of irregular whirls and eddies near the surface of the core or changes in the oscillations of the fluid. The nature of the field within the core can be expected to be on such a hypothesis is discussed, and the possible value of solar observations in this connection is pointed out.

550.391  The Experimental Determination of the Geomagnetic Radial Variation—S. K. Runcorn A. C. Benson, A. F. Moore, and D. G. Ritches. (Phil. Mag., vol. 41, pp. 783–791; August 1950.) "Theories of the origin of the dipole components of the earth’s main magnetic field are of two types: distributed theory attribute it to a fundamental property of the earth’s core, whilst the current systems are generated in the core and these could account for the main field, their variations due to the effects of irregular whirls and eddies near the surface of the core or changes in the oscillations of the fluid. The nature of the field within the core can be expected to be on such a hypothesis is discussed, and the possible value of solar observations in this connection is pointed out.

550.384  "Sudden Commencements" in Geomagnetism—W. Jackson. (Nature (London), vol. 166, pp. 691–692; October 21, 1950.) Two types of normal sudden commencement are recognized, according to the main movement is not, or is, preceded by a smaller movement.
Traditionally, the ionospheric reflection of radio waves is a subject of great interest due to its role in the transmission of signals over long distances. This phenomenon is influenced by various factors, including the frequency of the transmitted signal, the altitude and latitude of the observer, and the time of day. The Earth's ionosphere, being a dynamic and complex layer, plays a crucial role in the behavior of radio waves. The absorption and reflection properties of the ionosphere are subject to changes caused by solar activity, geomagnetic storms, and other natural phenomena.

The ionosphere is composed of layers with distinct properties. The lower layers, such as the E-layer and F-layer, exhibit different behaviors due to the variation in electron density with altitude. The F-layer, for example, is characterized by a sharp increase in electron density, which is responsible for the reflection of radio waves. The F-layer is further divided into the F1 and F2 regions, each with its own characteristics.

The behavior of radio waves as they propagate through the ionosphere is governed by the refraction and reflection properties of the layers. The refraction of radio waves occurs when the waves bend as they pass through the ionosphere, changing the direction of propagation. Reflection occurs when the waves bounce off the ionosphere due to changes in the refractive index of the layers.

The Alfvén effect, discovered by Hannes Alfvén, is a phenomenon where waves propagate without the displacement of the medium. This effect is crucial in understanding the propagation of radio waves through the ionosphere. The Alfvén effect is significant in regions with a high electron density, such as the F-layer.

The absorption of radio waves in the ionosphere is a complex process and is influenced by various factors, including the electron density, wave frequency, and the presence of charged particles. The absorption of radio waves can lead to the dissipation of energy, which can affect the transmission of signals.

In summary, the study of the ionospheric reflection of radio waves is essential for understanding the propagation of signals over long distances. The ionosphere's dynamic nature requires continuous monitoring and research to improve the efficiency and reliability of communication systems.
shaped pores run together to form rounded cavities. Measured values of the dielectric constant for material sintered at different temperatures are compared with values given by Böttcher’s formula.

666.1.037.5
High-Temperature-Lamp Seals—E. J. G. Besson. (Elect. Times, vol. 118, pp. 605–608; October 19, 1950.) A description is given of the molybdenum-tungsten seal, which is in common use but is inconveniently large and costly when large currents (150 amp or more) have to be carried. The construction of a quartz/molybdenum-iron sintered seal, which has been described, which has been developed for very-high-wattage mercury- and gas-discharge lamps.

MATHMATICS
517.564
On the Characteristic Values of Spherical Wave Functions—C. J. Bouwkamp. (Philips Res. Rep., vol. 5, pp. 87–90; April, 1950.) The first five terms of a power series expansion are given for characteristic values of spherical wave functions of which both order and degree are integral and $n > m$. Numerical values are given for the case where $m = 1$.

517.942.82
Note on the Inversion of the Laplace Transform—M. R. P. Asia. (Phil. Mag., vol. 41, pp. 541–544; June, 1950.) The “pair property” of the Fourier transform is shown to exist also for the Laplace transform for particular classes of functions.

519.21:621.396.822

681.142
SEAC. The National Bureau of Standards Eastern Automatic Computer—Tech. Jour. Nat. Bur. Stand., vol. 34, pp. 121–127; September, 1950.) A general description of the computer is given, with examples of its application in optical design and on the reduction of a partial differential equation representing the flow of heat through a chemically reactive material. The present input-output unit uses a manual keyboard for direct input and a teletype printer for direct output, with a hexagonal decimal system (base 16) for both numbers and instructions. For indirect operation punched paper tape is used, with an input and output rate of 30 words per min., which can be increased to 10,000 words per min. by the use of magnetic wire or tape. The present memory unit is a set of 16 delay lines. The addition of a parallel system of 45 electrostatic tubes with a greatly reduced access time is in progress.

681.142
The N. B. S. Computer Program—Tech. Bull. Nat. Bur. Stand., vol. 34, pp. 128–129; September, 1950.) An outline of the various phases of the program are given and on digital computers, including design, construction, and technical services. In addition to SIAC, a second machine, the NBS Western Automatic Computer (SWAC), has now been completed at the NBS laboratories at Los Angeles. Five of the Equipment is used by industrial firms for various governmental services.

516:621.396:397

512.9

517.43
Calcul Opéralionel [Book Review]—L. Labin. Publishers: Masson et Cie, Paris, 145 pp., 1948, French. (Sci. (London), vol. 63, p. 1046; September 1, 1950.) “This work may be regarded as a list of general rules of the operational calculus ... The text is intended from the viewpoint of Laplace transform and complex variable ...” [It recommended to those who have an adequate knowledge of the underlying mathematical theory.

517.93:534.014.1/2

MEASUREMENTS AND TEST GEAR
512.3082
British Developments in Instrumentation J. H. Jupe. (Electronics, vol. 23, pp. 182, 2 October, 1950.) Brief descriptions of a wide range of instruments and techniques are given. Service for measuring the size of carbon particles in flames, a direct-reading midget magnetometer using the Hall effect in Ge and with the ranges covering 0–250,000 gauss, and electron gauges of many types, new photocells, including one mounted by an alternating field, 15-channel cathode-ray camera with fite cathode-ray tubes as an integral part of the unit, and a low-frequency analyzer. An echo-free room is also noted.

512.3083:4:621.396:611.21.012.8
Measurement of the Electrical Characteristics of Quartz Crystal Units by Use of Bridge-Test-Network C. H. Rotherham a. H. F. Huber, Jr. (Proc. I.R.E., vol. 38, p. 1213–1216; October, 1950.) The equivalent circuit of a crystal with a capacitance load is an effective inductance and an effect resistance in series; this, in parallel with a network of two equal capacitors and a resistance forms a network with a zero transmission f o u n d . Screening of such a system is relatively simple, as the source and the detector have common earthed terminal. Stray capacitance are included in the calibration of the network. The measurement of the crystal circuit is about 3 Mc was estimated to be within 0.3 per cent for the equivalent series restance, a within 2.3 per cent for the equivalent paralle series resistance.

512.317:3:621.396.611.2
Correlation Measurements on Coupl-Circuits—W. F. Dilts (Philips Res. Rep., vol. 91–115; April, 1950.) Analysis is given of a circuit consisting of a tube feeding two tuned circuits with capacitive and resistive as well as inductive coupling; universal resonance curve are presented. The conditions for symmetrical response curves are investigated. Methods measuring inductive coupling coefficients are reviewed. Techniques are suggested for measuring the parameters of coupled circuits without loss of accuracy due to disturbance of the normal operating conditions.
117.332 394 Audiometric Measurements at Microwave Frequencies—A. C. Beck and R. W. Dawson. C. I. R. E., vol. 38, pp. 1118-1189; October, 1950.) An investigation of skin effect at 9 KMc. half-poles and polishes showing the effect of different surface treatments on the resistivity of copper. Electroplated copper, even when polished, was found to have considerably higher resistivities than the solid metals.


117.335.2 621.396.19.13 396 Some Experiments on the Use of Frequency modulation in Electrical Measurements—L. Toms and J. F. Ward. (Proc. I. E. E., Part 97, pp. 645-659; October, 1950.) Characterization of a crystal varicap produced in the frequency or phase of a waveform of an oscillator normally of high frequency stability. A full description of the measured changes in the frequency of the varicap was given.

117.384 397 Microwave Power Measurements—R. D. B. (Alto Frenquenza, vol. 19, pp. 115-136; May, 1950.) Discussion of methods based on the change in incidence of a cosmic ray over the frequency range of the instrument. A note is made on the effect of the beam and blanking of the oscilloscope. A new type of microwave link was presented at the meeting.

117.7.7 621.385.3 621.315.59 398 Production of Transistors—L. P. Johnston and R. E. Brown. (Electronics, vol. 23, pp. 96-99; October, 1950.) Alternating-current apparatus for rapid determination of transistor gain, current gain, and input capacitance under different bias and load conditions.


117.7.25 621.383.3 401 A High-impedance Voltmeter—T. A. Ledgard. (Electrical Engineer, vol. 145, pp. 467-469; August, 1950.) Design and use of a large-sensitivity photocell for amplification of the movement of the pointer of a moving-coil instrument. A light Al wire attached to the pointer moves over a pair of differentially connected Se cells, so that the pointer of 100 mv. 1 v, 10 v and 100 v at 1 mV per volt is available, and also a 1000-v range at 0.1 mV per volt.


621.317.733 403 Wien-Bridge Network Modifications—R. A. Uzdin. (Electronics, vol. 23, pp. 192-198; September, 1950.) When a network is used as an RC oscillator circuit, stray capacitance across the series resistor produces undesirable effects. These can be counteracted by the use of a trimmer capacitance in the oscillator. This modification results in a more constant output and an extended frequency range.

621.317.755 404 A Fast Sweep Circuit—N. L. Davis and R. E. White. (Electronics, vol. 23, pp. 107-109; October, 1950.) When an oscilloscope sweep of 100 inches per second is used, one using a modified rater scan and the other using a hydrogen thyratron. The circuits and methods of calibration are described and typical applications of the equipment are illustrated.

621.317.755 405 Automatic Beam Blanker for Oscillo- scopes—A. L. Dunn, A. R. McIntyre, and A. L. Bennett. (Electronics, vol. 23, pp. 94-95; September, 1950.) A circuit is described in which the sweep is released by a signal to the trace which is completed. This eliminates the ground fogging caused by scattered electrons.

621.315.755:621.385.029.63 406 The Travelling-Wave Cathode-Ray Tube—Owaki, Terahata, Hada, and Nakamura. (See 503.)

621.315.755:621.385.029.64 407 The Travelling-Wave Cathode-Ray Tube—Owaki, Terahata, Hada, and Nakamura. (See 503.)

621.317.772 408 On an Oscilloscope for Decimeter Waves—H. G. Möller. (Elektrotechnik Berlin, vol. 4, pp. 246-249; July, 1950.) By introducing a dielectric covering on the deflecting plates the full sensitivity of a cathode-ray tube can be retained at higher frequencies. A formula is derived connecting phase velocity with the dimensions of the dielectric for the E0 mode of operation. Numerical examples are calculated.

621.317.772 409 Precision Phasemeter for Audio Frequencies—W. R. Kritz. (Electronics, vol. 23, pp. 102-106; October, 1950.) The design of the instrument is based on the method of Razzaghi and Zahidi (1724 of 1950). To obtain an accuracy within 0.5% when measuring the phase difference between two sinusoidal voltages it was necessary to design each section, including the ring-modulator phase-detector bridge, so as to be linear with one set of co-ordinates.

Methods are described for self-calibration of the instrument.

621.317.784:621.317.733 410 A Bolometer Bridge for the Measurement of Power at High Frequencies—R. A. Soder- man. (Gen. Radio Exper., vol. 25, pp. 1-8; July, 1950.) Description of Type 1651-A bridge. Measurements of power up to 500 mw may be made frequencies from 3 Mc to 5 Mc by substitution or direct-reading methods to within ±10 per cent or ±20 per cent, respectively. Thermistor or barometer bolometers with resistances in the range 25-400 Ω may be used.

621.396.615 411 Signal Generator Output Systems—H. M. Hold. (Bell. schweiz. elektr. Tech., Ver., vol. 41, pp. 798-801; October 14, 1950.) In German.) The calibration of the attenuators usually fitted to signal generators is usually valid for a particular load impedance. The factors affecting the voltage at the output terminals of a generator are investigated. For accurate knowledge of the terminal voltage, the load impedance, the no-load voltage V, and the internal impedance Z of the generator must be known. Formulas giving V and Z in terms of measured impedances are derived.

621.396.615:621.396.19.13 412 Design for a Webblulator—M. G. Scroggie. (Wireless World, vol. 56, pp. 369-372; October, 1950.) Design and construction details are given of an instrument for use with the simple cro previously described (1458 of 1950). The circuit used is adapted for use with a low-power amplifier. The advantages of giving FM up to 30 per cent and of requiring only one tube.

621.396.615.14 413 A Wide Range Microwave Sweeping Oscil- lator—M. E. Hines. (Bell. Tech. J., vol. 29, pp. 553-559; October, 1950.) Description of a test oscillator using the BTL 1553-416A triode (510 below). A mechanical tuning device varies the frequency of the oscillator, a low-frequency-to-frequency band 3.6-4.5 Mcf.

621.396.615.14 414 Microwave Sweeping Generator—L. C. Eismann. (Electronics, vol. 23, pp. 101-103; November, 1950.) A Type 6616 reflex klystron feeds a resonant cavity tuned by a motor-driven plunger. Frequency sweep is 2.6-3.4 Mcf; sweep rate, 8-10 cpa.

621.396.826.029.51:535.568.1 415 Polarimeter for the Study of Low-Frequency Radio Echoes—E. H. Benner and H. J. Piller. (Rev. Sci. Instr., vol. 21, pp. 820-834; October, 1950.) A description of the equipment, with a brief note of typical experimental results. A pulse signal at a carrier frequency of 150 Mc is received, after reflection from the ionosphere, on crossed loop antennas which separate the two components of the elliptically polarized down-coming wave. By arranging that the cathode-ray tube, to which the two loops are connected through balanced amplifying chains, is illuminated only for the desired echo, a direct picture of the polarization of the reflected wave is obtained. Arrangements are included to enable the sense of rotation to be determined.

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

534.321.9.001.8 416 Measuring Water Velocity by an Ultrasonic Method—W. B. Hess, R. C. Swengle, and S. W. Sincalder. (Electronics, vol. 29, pp. 687-688; November, 1950.) Description of a method still in the experimental stage. Two 500-kc transducers are mounted at a fixed distance from the submerged pipe. Measurement of the phase angle between the transmitted and received signals are made in quick succession using (a) the upstream, (b) the downstream transducer and the other for reception. From the two measured phase angles the water velocity is deduced. Average error in tests of the equipment was about 1 per cent.
PROCEEDINGS OF THE I.R.E.

621.315:212—621.317:39
Measuring Cable Ecarteility—(Elec.
Procs., vol. 118, p. 430; September 14, 1950.)
Continuous control on the manufacture of
cables with extruded insulation is provided by
an instrument which indicates any core ec-
centricity. Operation depends on comparison of
the height of the cable which is placed in the
various coils mounted in a gauge head through
which the cable, fed with constant ac, passes.

621.316:718
An Electronic Speed Control for the Tow-
ing Carriage of a Ship-Model Testing Tank—
I.E.E., Part II, vol. 97, pp. 651–662; October,
1950.) A description of equipment fitted to the
carriage of one of the tanks at the National
Physics Laboratory. To meet similar require-
ments on the constancy and setting of carriage
speed, a closed-loop automatic control system
was developed. Details of its original features
are given. Mathematical analysis of the system
shows that by incorporating a special feedback
network the stability is little affected by large
variations of gain. Test results after six months’
operation of the arrangement, with the manually
controlled Ward-Leonard system previously used.

621.317:39—531:717.1
The Electronic Measurement of Silver,
Roving, and Yarn Irregularity, with Special
Reference to the Analysis of the Fibre-Bridge
Circuit—P. H. Walker. (Journ. Textile Inst.,
v. 41, pp. 446–466; July, 1950.) Irregularities are
determined from measurements of the
change of capacitance caused by passing the
material through the air gap of a fixed capaci-
tor forming one arm of a bridge, the other arms
being provided by a specially wound trans-
former, varying the capacitance of a selec-
tive pentode amplifier is used to increase
the sensitivity.

621.38:001.8
Symposium on Electronics, London,
September 5–8, 1950—Elec. Times, vol. 118,
p. 411; September 14, 1950.) Summarized ac-
counts of the lectures at the opening ceremony
of the conference arranged by the Electronics
Group of the Scientific Instrument Manufac-
turing Association and of the papers pre-
sented at the various sessions, with a review of
some of the instruments exhibited.

621.384.6
Electronics and the Electrostatic Gener-
p. 1150; October, 1950.) Discussion of the
construction and operation of particle accelera-
tors using Van de Graaff electrostatic gener-
ators to give the required high voltage.

621.384:012.27
The Synchroclyotron at Amsterdam—C. J.
August–September, 1950.) General descrip-
tion, with sectional diagrams and photographs
of equipment capable of accelerating protons to
energies of 10 kev.

621.387:43
On the Temperature Variations in Alco-
hol-Argon-Filled G-M Counters—O. Parkash.
(Phys. Rev., vol. 80, p. 303; October, 15 1950.)
Some properties of Diamond as a Crystal
Counter—H. E. and J. Rossel. (Helv.
In French.)

621.391:029.62
Propagation of Waves Between
Optical Range—D. W. Heightman. (Jour.
Tech. Dig. (France), vol. 4, pp. 157–161;
1952.) A qualitative survey of tropospheric
and ionospheric wave propagation in the frequen-
cy band 30–200 Mc. Theoretical treatment is
limited to explanations of the basic principles
involved. A knowledge of the easily recognized
meteorological conditions associated with

621.396.11:621.396.74
Measurement of Small Angles of Eleva-
Part 2: The Comparison Method Using T
Arrays with a Wavelet and Charged Parti-
cles—L. Pungs and H. Fricke. (Arch. der
Uebertragung, vol. 4, pp. 309–315; Aug-
1950.) The theory of the method was given
Part 1 [310 of 1950 (Short). The voltages
from the two comparison antennas are applied
to the fixed systems of goniometer, the orientation of the results
for providing a measure of their ratio, as
hence the angle of elevation of the reck
wave. Design details are given for antenna
systems for measurements with 2.4-m waves. A
table of ranges measurable with different
transmitters is supplied. The effect on the uneven terrain on the calibration can be eli-
minated by providing a horizontal artificial ear
or a series of vertical screens of wire mesh.

621.396.11:629.02—531.74
Measurement of Small Angles of Eleva-
Part 3: The Frequency Dependence of
Comparison Method—H. Fricke. (Arch. der
Uebertragung, vol. 4, pp. 315–320; Aug-
Transmissions is necessary to be able
operate over a range of frequencies. Analy-
ical given of the effect on the goniometer calib-
varied. The results of this analysis show a
change of (a) the ratio of wavelength to
axial dimensions, (b) the radiation coupled
and (c) the effects due to feeder-cable inequi-
lities. The theory is shown by measurement
made at a certain wavelength of 1.5 m ±
16 per cent variation.

621.396.11:629.02—531.74:621.396:67
Short-Wave Installations with Controla
Directional Characteristics and their Appli-
cation to the Measurement of Angles of In-
dence—P. Kostoffel, and Vogt. (Arch. elekt.
Uebertragung, vol. 4, pp. 325–330; July and August,
1950.) The advantages of electrical over mechanical meth
of controlling angular characteristics are indicated and the technique of elec-
trical control is discussed. A description is given of an installation at Brückm-Main for me-
urging angles of incidence of waves at
rhombic antennas. Measurements on Ameri-
and British short-wave broadcast transmis-
sions are reported; the vertical angles lie be-
and 41°, the angle of incidence increasing with
wavelength. Deviations from great-circle pa-
are also investigated; for the British trans-
ter the dispersion of these deviations is sig-
ificantly greater than for the more distant Am-
erican transmitters.

621.396.11:629.63/64
Propagation of Waves of Frequency 30
10,000 Mc/s—P. Marisé, L. de Broglie. (Ra-
Tech. Dig. (France), vol. 4, pp. 157–161;
1952.) A qualitative survey of tropospheric
and ionospheric refractive index of the at-
mosphere taken into account by using the fac-
or degree of curvature of the path.
Examples of daily and seasonal variations are
shown graphically. Expressions are de-
for minimum height and radiation angle of
direct ray. Focusing effect and multiple re-
actions at the surface of the sea are discussed.
part is derived indicating the conditions under which this may occur. The method of calculating diffraction losses is de-
daled and two abacs due to Bullington (802 of 396) are reproduced. An illustrative numerical example of the received intensity of a PM signal under given conditions.

de Broglie comments in a general way on application of geometrical optics in the theory of the propagation of radio waves.

\[ S \cdot J u l y, \ 1950. \) Full details are given of an E. F., vol. 38, pp. 1212–1222; October, 1950.) Discussion on 217 of 1950.

\[ \text{It is in South Africa in the low frequency region which these effects may occur. The importance of the clearance and the fact range of values of field intensity that may have beyond 200 miles.} \]

\[ \text{Polycrystal for the Study of Low Frequency Radio Echoes—Benner and Nearhood.} \]

RECEPTION

\[ \text{The Measurement of Atmospheric Radio Noise in South Africa in the Low Frequency Region—D. Hogg.} \]

\[ \text{Full details are given of an example of a wave field in which a vertical antenna exceeds a superheterodyne receiver tuned to kc and having a bandwidth of 6 kc. The voltage is eventually applied to a circuit which is used in 20 minutes of operation. Calibration voltages are applied by the receiver near the Johannesburg surroundings noise level is 1 or 2 \( \mu \)v per m during day, rising to 20 \( \mu \)v per m and 100 \( \mu \)v per m during winter and summer nights, respectively.} \]

\[ \text{A summer thunder may raise the level to 1000 \( \mu \)v per m in the afternoon. Graphs are given for the observed data with thunderstorm activity is discussed. Agreement of the measured values with those predicted from data in Report 5 of the U. S. Army Signal Corps is usual.} \]

\[ \text{An Advanced Amateur Receiver—R. P. Iland.} \]

\[ \text{A receiver providing good reception for AM, FM, PM, and ssb with carrier suppression. Some detail on the modulated noise level is 3 or 4 \( \mu \)v per m in the afternoon.} \]

\[ \text{An amateur carrier principle prevents loss of modulation makes possible the selection of other sidebands at will, thus enabling unwanted sidebands to be cut out more easily. Application of the modulation principle is demonstrated on the clear band at will, thus enabling unwanted sidebands to be cut out more easily. Application of the modulation principle is demonstrated on the clear band.} \]

\[ \text{Some Statistical Functions useful for the Study of Background Noise—Blanc-Lapierre.} \]

\[ \text{A theoretical survey of the factors involved in determining the effect on a wanted signal of several interfering signals, including noise. Suggestion are made for the use of oscillators and oscillator radiation, are considered. The design and characteristics of an experimental converter, continuously tunable through the band from 200 to 700 kc, developed for uhf television investigations at Bridgeport. Conn. See also 1792 of 1950 (Murakami).} \]

\[ \text{Interference Caused by More Than One Signal—R. M. Wilmotte.} \]

\[ \text{An exact open-form solution of the equation for the output signal from a network is derived, the input being an angle-modulated signal. By using transfer functions which are linear in terms of frequency a solution in closed form is obtained. Particular examples are examined to determine the effects of the transfer function characteristics on the output signal. The analysis supports the view that linear phase characteristics are more important than flat amplitude characteristics for the reduction of distortion.} \]

\[ \text{The TD-2 Radio Relay System—C. E. Clutta.} \]

\[ \text{A skeleton description of a relay system with 33 repeater stations, providing two-way communication facilities between New York and Chicago and operating in the band 3.7–4.2 kc. Each of the six channels available in each direction is 10 kc wide. An alarm system indicates the failure of the transmission system.} \]

\[ \text{An up-to-date High-Fidelity Receiver us-} \]

\[ \text{Modern Valves: Part 1—The Low-Frequency Amplifier—J. Rousseau.} \]

\[ \text{A design and construction of a high-fidelity receiver with wide-band fixed-tuned high-frequency stage. The oscillator is crystal-controlled and tuning is accomplished by a tuner which covers the lowest frequency band and becomes a tuned intermediate-frequency system on the higher side.} \]

\[ \text{Design, Construction and Final Adjustment} \]

\[ \text{The Overseas Radio Installations at Frankfurt a. M.—F. Ellrott.} \]

\[ \text{An account of the installation of the radio station for telephony transmitting and receiving equipment.} \]

\[ \text{Stations and Communication Systems} \]

\[ \text{The special quartz-crystal frequency-control arrangement is described. Multichannel ssb transmission is used, with transmitter frequency range of 5–23 MHz in three bands. Receivers are of the double-diversity type. See also 2893 of 1950 (Kronjäger).} \]

\[ \text{S.B.A.C., Farnborough—(Electrician, vol. 145, pp. 580–582; September 15, 1950.) Brief details of some electronic exhibits at the exhibition arrangement by the Society of British Aircraft Constructors at the RAE Aerodrome, September, 1950.} \]

\[ \text{Nonlinear Distortion in Frequency Modulation—L. J. Libois.} \]

\[ \text{The assumption of a quasistationary condition is justified when the modulation frequency is relatively low, provided that the rate of variation of the instantaneous frequency remains within certain limits. Under these conditions the nonlinear distortion introduced by the following is calculated: (a) linearity of static characteristics of the system; (b) variation of propagation time with frequency within the modulation band, (c) insufficient amplitude limitation before the discriminator; (d) reflections in feeders and multiple transmission paths. While elimination of the effects due to the first three causes imposes severe limiting conditions of operation, feeder reflections and multipath transmission are probably the most troublesome, since they can only be reduced by shortening feeders as much as possible and by using highly directive antennas and well-isolated transmission paths.} \]

\[ \text{ Distortion: Band-Pass Considerations in Angular Modulation—M. T. C. the end of this paper.} \]

\[ \text{A theoretical consideration of the characteristics of the signal, including noise. Suggestions are made for the use of oscillators and oscillator radiation, are considered. The design and characteristics of an experimental converter, continuously tunable through the band from 200 to 700 kc, developed for uhf television investigations at Bridgeport. Conn. See also 1792 of 1950 (Murakami).} \]

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going traffic from London is routed accordingly, being sent by transmitters at Portishead and Chewton (or Rugby) under a frequency contract with Burnham. Incoming traffic is handled at Burnham by 32 receivers on the high-frequency band (4-22 Mc) using any antenna selected from a fan-shaped array of high-gain rhombic antennas, supplemented by omnidirectional antennas. On low frequencies four receivers are used with Bellini Toni crossed loops or a nonresonant T-antenna. There are also available vertical and horizontal resonant at 1.3 and 3 Mc, and a nonresonant inverted L-antenna for the 500-2000 kc frequency band. By an elaborate switching system the amplified signals from any of the antennas may be distributed to any desired combination of the receivers. Ease of working is secured by a comprehensive telephonic intercommunication system.


diagram is obtained by high-frequency, low permeability, and close mesh. Formulas are derived for predicting the attenuation produced by a given screen; these are, in general, confirmed by the experimental results.

**TELEVISION AND PHOTOTELEGRAPHY**

621.397.24/26 450

Television from France—M. J. L. Pulling, (W. E. J. World, vol. 56, pp. 353–354; October, 1950) Successful transmissions from Calais used a combination of microwave and meterwave radio links in series, followed by normal television and coaxial-cable links to the transmitter in London. Line communication was used for the sound channel. See also Electrician, vol. 145, pp. 573–574; September 15, 1950.

621.397.24: 621.396.72 460


621.397.26 461

High-Speed F.M. Facsimile—J. V. L. Hogarth and C. V. Osserman, (F.M.-TV, vol. 18–20; 40; October, 1950) The material for transmission, on a revolving drum, is scanned at a rate of 36.2 square inches per minute. The video signal is produced in the usual way and at an equivalent amplitude of a 13-kec subcarrier which is then converted to a vestigial-sideband AM signal and applied to a FM transmitter. At the receiver, the FM signal is converted into a video signal and fed to a recorder. This uses electrolytic recording paper on a revolving drum, mains-synchronized with an AM modulator. Spec signals are transmitted for a period of about 10 seconds to indicate page separation points.

621.397.26: 621.396.65 462

Television for Scotland—(Líneas, vol. 118, p. 421; September, 14, 1950) A brief note on the project for a microwave link to extend the television service to Scotland.

621.397.31: 2: 778.5 463

Television Transmission of Images of Variable Transparency by Non-storage Systems: Present Systems and Proposed New System for High Definition—R. Monmot. (Onde Electrique, vol. 362–361; September, 1950) Theoretical and practical aspects of nonstorage systems in telefilm technique are discussed. Two particular scanning systems are described: (a) the Farnsworth line-scan tube; and (b) the "flying spot." Their operation as high-definition systems is discussed and their merits are compared. The proposed new system uses a projector with continuously moving film but without a compensating lens, and combines (a) and (b) for line scan and picture analysis, respectively. The scanning spot takes the form of a short line and the screen is slightly brighter.

621.397.5: 083.74 464


621.397.5: 083.74 465


621.397.5: 083.74(45) 466

Abstracts and References

A process which improves the solidity of the deposit and enables it to withstand better the harsh effects of atmospheric pollution, consists in depositing on the mica by evaporation a thin layer of Cr and then applying a top layer of Pt. By repeating this method of protection is to apply a very thin layer of silver on the metal layer. Iconoscopes with transparent screens and symmetric electron-optical systems are particularly suitable for simple types of equipment where the absorption in the metal layer and the consequent reduced sensitivity are relatively unimportant.


621.307.611.2  Light-Transfer Characteristics of Image Orthicon—K. B. James and A. A. Rowona. (RCA Rev., vol. 11, pp. 364-376; September, 1950.) The signal-output-light-input characteristics are given for various target voltages and target-mask spacings. The effects of the element-exposure distribution on the transfer curves are considered. The presence of ghost images can be minimized by defocusing by adjustment of the photocathode voltage, or by using types of anti-ghost tubes are described briefly.


621.307.611.2  New Television Camera Tubes and Some Applications outside the Broadcasting Field—V. K. Zveruevii. (Jour. Soc. Mos. Pit. Telew. Eng., vol. 5, pp. 227-242; September, 1950.) The operation and performance characteristics of television camera tubes, from the iconoscope to the image orthicon. Clauses are briefly described; recent developments being particularly considered. The application of the vidicon in industrial television equipment and possible uses of television technique in astronomy are outlined.

621.307.612  Permanent-Magnet Lenses for Television Tubes—R. B. Overton: D. Hadfield. (Electro. Eng. (London), vol. 21, pp. 401-420; September, 1950.) A brief account of the various lens systems which are in current use in television tubes, and a description of the efforts of some of the leading manufacturers for the improvement of the lens equipment.


621.307.612  [Picture] Analysis' Tubes with Transmittal Signal-Plate—P. Tarbes. (Bell. sviss. elektr. tech. Ver., vol. 40, pp. 562-565; August 20, 1949. In French.) Paper presented at the International Television Conference, Zurich, 1948. All of the methods of obtaining satisfactory thin layers of Pt or Pd on mica, by evaporation or catedohotic deposition, are discussed. A tube operated at a final-anode voltage of 25 kV, the use of a cathode-ray tube operated on the back of a built-in screen to give a picture 13 X 10 inches. The picture is sufficiently bright for daylight viewing, but due to the screen color, the vision is effective only up to about ±3°. The circuits are conventional, except for the cathode-ray-tube supply, which is obtained through a voltage-tripler rectifier from a 4-kv damped sine wave developed in a ring transformer connected in the output circuit of a pentode.

attended with various illumination patterns confirmed the theoretical conclusions. The maximum picture quality \(N_{\text{max}} = 1\), where \(N_{\text{max}}\) is the highest transmitted frequency divided by the scanning speed, and \(S\) is the length of the scanning aperture edge; this corresponds to a doubling of the usual bandwidth.

621.397.8:029.63

Television Transmission and Reception on 480 Mc/s—M. Morgan. (Jour. Tele., 39, pp. 232-244, 1960.) For experimental electron relay links the frequency band 570-490 Mc was chosen because suitable tubes are available and because of the adoption of AM with vestigial-sideband modulation. A general description is given of the transmitting and receiving equipment, which was used in the demonstrating investigation following the paper by Lance (467 above) at the International Television Congress, Milan, 1949.

621.397.62004.5/6


TRANSMISSION

621.390.619.13

Linearization of Modulation Characteristic with Relatively Large Frequency Deviation—R. Satas. (Arch. elektr. Übertragung, vol. 4, pp. 232-244, July, 1950.) A Marconi analysis is given for an FM circuit in which a push-pull arrangement of two tubes with square-law \(I_{\text{e}}/V\) characteristics is connected as a variable reactance in parallel with the LC circuit determining oscillator frequency. Experimental results for the particular case of an FM transmitter with carrier frequency 2 Mc and deviation 150 kc give good support to the theory. The highest ratio of frequency deviation to carrier frequency attainable with low nonlinear distortion was 0.15-0.25, using reactance tubes of specially suitable type.

621.307.61:621.390.619.13:14

14773

Generalized Distortion Analysis for UHF, TV Transmitters—Evans. (See 477.)

621.390.667

Automatic Audio Gain Control—Hathaway. (See 318.)

TUBES AND THERMIONICS

533.583:621.385

Getter Materials for Electron Tubes—W. Espe, M. Knoll, and M. P. Wilder. (Electronics, vol. 23, pp. 80 86, October, 1950.) The requirements of getter materials for use as bulb coating, or flash getters are specified. The suitability of various metals for each application is discussed with reference to the vapor pressure of the metal and its efficiency as a getter. Over 70 references are given.

621.307.533:621.385.832

Note on the Image Formation in Cathode-Ray Tubes—R. Darrein. (Philips Res. Rep., vol. 5, pp. 128-130, April, 1950.) The theory of G. N. Darrein is applied to the electron beam in a cathode-ray tube with a conventional type of gun. Neither the paraxial crossover nor the cathode image yields the smallest possible spot, but at an intermediate point, the location of which depends on the relative values of the beam radius at crossover and where the cathode image is formed. In practical cases this point nearly coincides with the crossover point.

PROCEEDINGS OF THE I.R.E.

621.385.029.63/4


621.385.029.63/54

Traveling-Wave Valves—H. Kleinwächter. (Elektrotechnik Berlin, vol. 4, pp. 245-246, July, 1950.) Research work abandoned during the war was continued with development of a traveling-wave tube on lines different from present designs. Retardation of the wave was effectuated by surrounding the evacuated cylinder enclosing the field with a dielectric box at the external diameter increasing in the direction of propagation. Methods of using the transverse electron energy and of increasing the efficiency were also investigated.

621.385.029.63/4:04

The Traveling-Wave Cathode-Ray Tube—K. Okuda, T. Hada, and T. Nakamura. (Proc. I.R.E., vol. 38, pp. 1172-1180, October, 1950.) Pairs of repeatedly folded parallel wires are used instead of the conventional electron gun. The phase difference of the traveling wave and the electron velocity are equalized, thus making the deflection sensitivity independent of frequency. A theoretical analysis of the principle is given; the sensitivity may be easily increased to 0.1 mm per v at 30 kMc. The invariance-spectrum method is used to obtain experimental confirmation of this analysis. Measurements of the degree of AM and observations of unit wave voltage form are described to illustrate the applications of the tube.

621.385.032.213:546.841:3

Thermionic Properties and Activation of Thoria and Related Complex Metal Acids. Part 1. Consideration of properties of the particular A, in a germanium or germanium of intrinsic type, is divided immediately after high-temperature activation in 1-2 minutes. Richardson's equation holds for short-period emission within a factor of 2. The field intensity increases progressively as the temperature activation is raised. Values of A and B in the equation fall slightly until an activation temperature of about 500°K is reached, when they increase particularly A, in greater proportion than the current, reaching values of 100 amp per cm² and over 2.5 v, respectively. Large current densities are not always obtained, especially when the cathode has been treated with bulb coating to render it less fragile. To assure a long life, the operating temperature should not greatly exceed 600°K. A suggested explanation of the observed effects is the formation of insertion atoms of thorium during the progressive crystalization produced by the initial heating.

621.385.032.210:530.167.3-001:8


621.385.2

The Electric Field at a Thermionic Cathode as a Function of Space Current—P. L. Copeland and D. N. Egenberger. (Phys. Rev., vol. 70, pp. 308-309, October, 1946.) The field given by Ivey (780 of 1950) for calculating the field at the cathode of a diode is examined analytically, and it is concluded that the function expressing the ratio of the field in the absence of current to that in the presence of current does in fact depend on tube geometry.

621.385.201

Theory and Experiments on Electrical Fluctuations and Damping of Oscillations in a-Carrier-Cathode Tubes and Circuits. R. F. Diemer. (Philips Res. Repr., vol. 5, pp. 131-152, April, 1950.) The internal resistance and the noise are calculated for tubes with two hot cathodes operated in parallel. Measurements on such tubes with indirectly heated cathodes confirm the theoretical calculations and show that contrary to Furt's theory (249 of 1948), the equivalent output resistance of such tubes does exceed the real cathode temperature. Measurements on tubes with directly heated cathodes are not in such good agreement with theory; the slight discrepancies are discussed.

621.385.2:021.359.0

The p-Germanium Transistor—W. Plann and J. H. Scaff. (Proc. I.R.E., vol. 38, pp. 1151-1154; October, 1950.) A brief description of some characteristics of the p-g-like germanium is given, and also an account of the laboratory observance of the properties of the p-type transistor, which has a higher cut-off frequency and a lower current multiplication than the n-type. The forward current characteristics of the very highly resistive p-type transistors has a negative-resistance region of the voltage maximum type so that, if the series resistance is low, the current in the transistor may be suddenly increase in emitter currents occurs; this phenomenon has been called the "snap effect.

621.385.3:021.359.6

The Transistor as a Reversible Amplifier—W. Plann and J. H. Scaff. (Proc. I.R.E., vol. 38, pp. 1155-1226; October, 1950.) The "forming" process which has been used on the p-g-like germanium to increase the effective current of an electrostatic as a collector does not seriously reduce its efficiency as an emitter. If the process is applied to both contact points, an improved reversible transistor amplifier is obtained.

621.385.3:029.04

Design Factors of the Bell Telephone Laboratories Traveling-Wave Traveling-Wave—K. M. Ryder. (Bell Sys. Tech. Jour., vol. 29, pp. 496-530. October, 1950.) A cross-space planar triode for use at 4 Mc with a gain bandwidth product of 200 Mc is discussed. Consideration of electrode spacing, input output circuit elements, and emission current density are discussed in terms of gain-bandwidth power-bandwidth figures of merit. Also see 2950 of 1949 (Morton).

621.385.029.04/4

Traveling-Wave Tubes [Book Review]—J. R. Pierce. Publishers: D. Van Nostrand New York, N. Y., 223 pp., 1950, $4.50 (Phys. Rev., vol. 87, p. 1229, October, 1950.) "A most competent treatment of the theory of the traveling-wave tube, containing the generally accepted basic theory which will serve as a self-contained guide to tube designers, as well as material of more controversial nature which will inspire many fruitful discussion and will stimulate creative thought."

621.385.029.04/6

MISCELLANEOUS

621.390:029.029.69

No science has grown faster or gone farther than electronics since those first amazing crystal receivers picked words and music out of the air. And in the development of modern radio, TV, communications and other electronic equipment, one of the prime contributions to dependability, long life and compactness has come from the use of ceramic components as perfected by Hi-Q.

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<table>
<thead>
<tr>
<th>Frequency Range</th>
<th>890-960 MCS</th>
<th>1750-2110 MCS</th>
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<tr>
<td>Type Number</td>
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<tr>
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<tr>
<td>Gain Over Half Wave Dipole Decibels</td>
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<td>15 20 25 29</td>
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<td>18° 10° 7° 5°</td>
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<tr>
<td>Net Weight, Pounds</td>
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<td>10 65 150 380</td>
</tr>
<tr>
<td>Thrust Due to Wind Loading at 30 Pounds/FT Pounds</td>
<td>127 509 1145 3200</td>
<td>127 509 1145 3200</td>
</tr>
</tbody>
</table>

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ATLANTA

BUENOS AIRES
"Theory, Design and Measurements on Delay Lines," by C. P. Perez; September 1, 1950.
"Regulated Power Supplies of Tension," by Gerardo Borrego; September 15, 1950.
"Carrier Telephony," by Raul Rago; October 20, 1950.
"Ionosferic Interferences," by Ivo Ranzi; December 10, 1950.

CLEVELAND
Social Meeting; December 18, 1950.

DES MOINES-AMES

DETROIT
"Radio Communications on the Amazon," by Mr. Fox, Radio Station WGAER, Cleveland, Ohio; September 15, 1950.
"Color Television," by W. L. Everett, University of Illinois; January 12, 1951.

EMPORIUM

EVANSTON-OWENSBORO

HAWAII

HOUSTON

INKOPHENS
"PAM/FM Telemetering System and Data Reduction Techniques," by Mr. Chisolm, Massachusetts Institute of Technology; March 22, 1950.

(Continued on page 76A)
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(Continued from page 74A)

"Slot Radiators," by Mr. Johnson, Air Force Instrument Laboratory; April 5, 1950.


"Measurement and Recording of Physical Quantities," by M. Robertson, Consolidated Engineering Corporation; October 18, 1950.


LOUISIANA

"Maintenance of Employee Morale," by H. V. Harris, Pacific Telephone & Telegraph Company.

"Governmental Procurement Procedure," by L. Sells, United States Naval Procurement Office.


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**Power Factor:** Less than .1% at 1 Megacycle

**Working Voltage:** 600 VDC Test Voltage 1200 VDC

**Dielectric Constant:** P-100 14K N-750 88K N-2200 265K NPO 35K N1500 165K

**Coding:** Capacity, Tolerance and TC stamped on Disc

**Insulation:** Durrez Phenolic—Vacuum Waxed

**Min. Leakage Resistance:** Initial 5000 Megohms After Humidity 1000 Megohms

**Leads:** #22 Tinned Copper (.026 Dia.)

**Lead Length:** 1/4" Body 1", 5/16" Body 1-1/4", 1/2" Body 1-1/2"

**Tolerances:** ±5% ±10% ±20%

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custom or standard the guaranteed components

(Continued from page 76A)

San Antonio
Nominating Committee Report and Election of Officers; January 26, 1950.

San Diego
*Millimeter Wave Generation,* by L. M. Fit; Stanford University; December 12, 1950.

Schenebeck

Seattle
*Single-Sideband Modulation Methods,* by M. Swain, University of Washington; December 19, 1950.

Toledo

Twin Cities

Vancouver
*Conducted Tour of Cedar Automatic Plant,* by A. Hardy, B. C. Telephone Company Ltd; December 18, 1950.

Washington


Williamsport

Subsections
Hamilton
*Optical Effects with Radio Microwaves,* by A. B. McCall, McMaster University; December 9, 1950.

Long Island
*New Coupling Circuit for Audio Amplifiers,* by H. McIntosh, McIntosh Engineering Company; December 5, 1950.

Northern New Jersey

Procurement Feature

Four desks to help manufacturers get orders, will be staffed by procurement personnel from Munitions, Air Force, Navy and Signal Corps on the third floor, Radio Engineering Show.

U. S. Armed Forces Exhibit

78A
MYCALEX is a highly developed glass-bonded mica insulation backed by a quarter-century of continued research and successful performance. Both pioneer and leader in low-loss, high frequency insulation, MYCALEX offers designers and manufacturers an economical means of attaining new efficiencies, improved performance. The unique combination of characteristics that have made MYCALEX the choice of leading electronic manufacturers are typified in the table for MYCALEX grade 410 shown below. Complete data on all grades will be sent promptly on request.

**MYCALEX** is efficient, adaptable, mechanically and electrically superior to more costly insulating materials

- Precision molds to extremely close tolerance
- Readily machineable to close tolerance
- Can be tapped threaded, ground, slotted
- Electrodes, metal inserts can be molded-in
- Adaptable to practically any size or shape

MYCALEX is available in many grades to exactly meet specific requirements

**CHARACTERISTICS OF MYCALEX GRADE 410**

Meets all the requirements for Grade L-4A, and is fully approved as Grade L-4B under Joint Army-Navy Specification JAN-1-10

- Power factor, 1 megacycle: 0.0015
- Dielectric constant, 1 megacycle: 9.2
- Loss factor, 1 megacycle: 0.014
- Dielectric strength, volts/mil: 400
- Volume resistivity, ohm-cm: $1 \times 10^{15}$
- Arc resistance, seconds: 250
- Impact strength, Izod, ft-lb/in. of notch: 0.7
- Maximum safe operating temperature, °C: 350
- Maximum safe operating temperature, °F: 650
- Water absorption $\%$ in 24 hours: nil
- Coefficient of linear expansion, °C: $11 \times 10^{-6}$
- Tensile strength, psi: 6000

**MYCALEX** is specified by the leading manufacturers in almost every electronic category

---

**CORPORATION OF AMERICA**

Owners of 'MYCALEX' Patents and Trade-Marks

Executive Offices: 30 Rockefeller Plaza, New York 20 • Plant and General Offices: Clifton, New Jersey
This 32-head exhaust unit, shown at the left, is one of the many specially designed machines used by Haydu Brothers to insure the high vacuum of all small tubes at high production rates. Stage-tests at intervals throughout production guarantee complete quality control!

Developed to meet every requirement of the electronic industry for dependable, high-performance vacuum tubes.

Built to exacting standards of precision using the latest production equipment.

Guaranteed by the name...
How Centralab Engineers solved a problem in Electronics for Ultra-High Speed Photography

CERAMIC TUBULAR DIELECTRIC REPLACES 30' OF STANDARD SOLID DIELECTRIC COAXIAL CABLE—LIGHT INTENSITY BETTERED 900 TIMES

Ultra-speed photographs are taken with the light of an electric spark. Former method used 30 feet of coaxial cable transmission line — charged with 10,000 V— and discharged across a spark gap.

To replace the bulky cable, Centralab developed a tubular ceramic condenser (2" O.D. x 6 1/2" long) with silver electrodes fired to the inner and outer surfaces. The condenser is charged to 10,000 V and discharged exactly like the cable — however with a gain in light intensity of 900 times! Characteristics of the new Centralab ceramic condenser are:

- Dielectric Constant: 6000 at 1 megacycle
- Capacity: 24,000 mmf.
- Velocity propagation: 0.27 x velocity propagation in air.
- Impedance: Approx. 1 Ohm
- Decay time, peak to 1/e peak: 2 x 10^-7 second
- Rise time, O to peak: 5 x 10^-7 second
- 50% of peak limits: 1.6 x 10^-7 second

Centralab engineers know their electronics and ceramics! This single ceramic development greatly advanced the photostudy of turbulence, ultra-sonic wave structure, and other high-speed phenomena. But this is just one of literally thousands of electronic component problems solved by Centralab. For Centralab engineers have compounded and tested over 20,000 different ceramics. So if you have a problem in electronics — in radio or radar . . . in TV, FM or X-ray — that Centralab Ceramics might solve . . . don’t hesitate, call us in today!

You won’t regret it for Centralab is the industry’s pioneer in Printed Electronic Circuits and carbon controls — the leader in the industry for the widest variety of fine quality ceramic capacitors — high voltage, by-pass coupling or temperature compensating types — in flat, tubular, disc or cylindrical shapes.

Photograph and its technical data is gratefully accredited to Dr. J. C. Hubbard, Messrs. J. A. Fitzpatrick and W. J. Thaler, Dept. of Physics, Catholic U., Washington, D.C.

For more Centralab developments that can help you ➔
Centralab Components

See them at the I.R.E. SHOW – Booths 232-33

PRINTED ELECTRONIC CIRCUITS

Are complete or partial circuits (including all integral circuit connections) consisting of pure metallic silver and resistance materials fired to CRL’s famous Steatite or Ceramic-X and brought out to convenient, permanently anchored external leads. They provide compact miniature units of widely diversified circuits — from single resistor plates to complete speech amplifiers. No other modern electronic development offers such tremendous time and cost saving advantages in low-power applications.

CERAMIC CAPACITORS

Centralab ceramic capacitors give you permanence never before achieved with old-fashioned paper or mica condensers. Ceramics are impervious to moisture, and have unmatched ability to withstand any temperatures normally encountered in electrical apparatus. Ceramics make possible tremendous space saving; many Centralab ceramic capacitors are 1/16 the size of ordinary capacitors. You can rely on Centralab ceramic capacitors for close tolerance, high accuracy, low power factors, and excellent temperature compensating qualities.

SWITCHES AND CONTROLS

Look to Centralab for standard and special purpose switches — single or multi-section (phenolic or steatite) — single or multi-pole — rotary, slide or lever action — shorting or non-shorting contacts — for AM-FM-TV as well as for medium duty power applications. In controls — it’s Centralab all the way. For Centralab introduced Carbon controls to the electronic industry 25 years ago! New Model 2 Radiohms are America’s most modern controls for TV-AM-FM. Centralab Model 1 Radiohm is the outstanding truly miniature unit — the standard of the hearing aid industry.

Ampec is a full 3-stage, 3-tube speech amplifier. Gives you truly highly efficient reliable performance. Size: 1 1/4" x 1 5/8" x 340" over tube sockets! Widely used in hearing aids, mike preamps and other amplifier applications where small size and outstanding performance counts. Bulletin No. 973 in coupon below.

High voltage ceramic capacitors. Capacitance: 5 to 500 muf, 5 KV to 40 KV D.C. working. Ideal for portable or mobile equipment. Primarily designed for high voltage, high frequency gear. For complete information, check Bulletin No. 42-102 in coupon below.

Medium Duty Power Switch for R.F. or 7 1/2 amp. 110-115 V. application. 1, 2 or 3 poles — up to 20 sections per shaft. Contacts, collector rings coin silver mounted on Grade L5 Steatite. Cat. No. 722.
Centralab Triode Couplats save space and weight. They actually replace 5 components normally used in audio circuits. Triode Couplats are complete assemblies of 3 capacitors and 2 resistors bonded to a dielectric ceramic plate. Available in a variety of resistor and capacitor values. Bulletin No. 42-6 in coupon below.

Centralab Vertical Integrators give you big savings in assembly costs, particularly in TV vertical integrator networks. One type consists of 4 resistors and 4 capacitors brought out to 3 leads ... reducing the formerly required 16 soldered connection to only 3! There’s a big saving in the number of parts handled, too! Bulletin No. 42-22.

Ceramic Disc Hi-Kap Capacitors hold thick-ness to a minimum. Make possible very high capacitance in extremely small size. Use in HF pass and coupling. Bulletin No. 42-4R.

Tubular Ceramic Capacitors — Type TCZ show no capacitance change over wide range of temperature. Type TGN have special ceramic body to vary capacitance according to temperature. Bulletin No. 42-18.

Min-Kaps are very tiny capacitors used where space is at an extreme premium. Ask for Bulletin No. 42-24.

New high quality Model 2 Resistors are designed for lower noise level, longer life. Bulletin No. 42-83.

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Because of 20 years of engineering skill and proven craftsmanship, Bliley crystals are always "Welcome Aboard" as dependable electronic gear in communications equipment and special electronic devices.

Shown
Bliley Type
BH-6

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PROCEEDINGS OF THE I.R.E.  March, 1951
"How can I save, in order to trim the price of this set another $2.50?"

The answer, Mr. TV-set Designer, is simple: G.E.'s 6BN6 gated-beam tube. It replaces three tubes and associated components, serving as a combined limiter, discriminator, and audio-amplifier.

6BN6 cost is right in line with other receiving types. You get three tubes’ performance, yet you pay for only one!

Ask for Bulletin ET-B28, which tells the full story of this amazing G-E economy tube, also charts its performance. Or if you prefer to discuss the 6BN6 in person, an experienced G-E tube engineer gladly will call on you. Wire or write Section 12, Electronics Department, General Electric Company, Schenectady 5, New York.

**6BN6**

GATED-BEAM MINIATURE

Typical Operating Conditions, TV Application, 4.5 mc

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plate supply voltage</td>
<td>270 V</td>
</tr>
<tr>
<td>Plate load resistance</td>
<td>33 megohms</td>
</tr>
<tr>
<td>Accelerator voltage</td>
<td>100 V</td>
</tr>
<tr>
<td>Cathode resistance</td>
<td>200 to 400 ohms</td>
</tr>
<tr>
<td>Min signal voltage for limiting action</td>
<td>1.25 + RMS</td>
</tr>
<tr>
<td>Audio output voltage</td>
<td>12.3 V RMS</td>
</tr>
<tr>
<td>AM rejection, with 2-v input signal</td>
<td>25 db</td>
</tr>
</tbody>
</table>

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**GENERAL ELECTRIC**
CHECK "Proof of Performance"
with these PROVED B&W PERFORMERS

For those "proof-of-performance" tests required by the FCC, here's a combination that will enable you to comply with the least amount of time ... trouble ... and money!

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For fundamentals from 30 to 15,000 cycles measuring harmonics to 45,000 cycles; as a voltmeter and db meter from 30 to 45,000 cycles. Min. input for noise and distortion measurements is 3 volts. Calibration: distortion measurements ±5 db, voltage measurements ±5% of full scale at 1000 cycles.

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Provides combined RF detector and bridging transformer unit for use with any distortion meter. RF operating range: 400 kc to 30 mc. Single ended input impedance: 10,000 ohms. Bridging impedance 6000 ohms with 1 db insertion loss. Frequency is flat from 20 to 50,000 cycles.

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**STUDENT BRANCH MEETINGS**

(Continued from page 844)

**UNIVERSITY OF MINNESOTA, IRE-AIEE BRANCH**


Discussion: "Your Electrical Engineering Option," by Associate Professors Cartwright, Beeklund, Anderson, University of Minnesota, January 10, 1951.

**COLLEGE OF THE CITY OF NEW YORK, IRE BRANCH**


**NORTHEASTERN UNIVERSITY, IRE-AIEE BRANCH**


**UNIVERSITY OF NOTRE DAME, IRE-AIEE BRANCH**


**OHIO STATE UNIVERSITY, IRE-AIEE BRANCH**

Field Trip: Columbus Sewage Treatment Plant, December 14, 1950.


**PENNSYLVANIA STATE COLLEGE, IRE-AIEE BRANCH**


First Preliminary Student Prize Paper Competition; December 7, 1950.

Second Preliminary Student Prize Paper Competition; December 14, 1950.

**PRINCETON UNIVERSITY, IRE-AIEE BRANCH**

Field Trip: RCA Laboratories, Princeton N. J., January 5, 1951.

**RENSSELAER POLYTECHNIC INSTITUTE, IRE-AIEE BRANCH**

*Color Television," by H. F. Hicks, Rensselaer Polytechnic Institute; December 14, 1950.

**UNIVERSITY OF TEXAS, IRE-AIEE BRANCH**


**UNIVERSITY OF TOLEDO, IRE-AIEE BRANCH**


Election of Officers; January 9, 1951.

(Continued on page 88A)
No one can say exactly how long it has taken Nature to perfect the California redwoods' secret of longer life. But we of Thomas can say that a great amount of time and effort have been spent in increasing the service life of our product.

This time and effort, as a part of our research program, have led to the use of new materials, new design improvements, new construction methods which are continuing to give the Thomas tube an ever-longer "lease on life."

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Passaic, New Jersey
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A new transmission line based upon a new plastic—TEFLON

CP TEF-LINE transmission line, utilizing DuPont Teflon insulators, greatly reduces high frequency power losses. Furthermore, operation of transmission line at frequencies heretofore impossible owing to excessive power loss now becomes easily possible. For TV, FM and other services utilizing increasingly high frequencies, TEF-LINE by CP is a timely and valuable development worthy of investigation by every user of transmission line.

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MEMBERSHIP

The following transfers and admissions were approved and will be effective as of March 1, 1951:

Transfer to Senior Member
Carson, V. S., 215 Furches St., Raleigh, N. C
Carter, J. M., 2510 Wetherburn Rd., Baltimore, Md
Chandler, V. H., 711 Beech St., Manchester, N. H
Chapman, F. W., 1736 Graefeld Rd., Birmingham, Mich
Clegg, R. M., 3215 Washington Blvd., Indianapolis, Ind
Franklin, P. J., 3855 Rodman St., N.W., Washington 16, D. C
Harriss, S. J., Capehart-Fransworth Corporation, Fort Wayne, Ind
Humphreys, T. L., 2505 Elliot Pl., Washington 20, D. C
Ivey, H. F., 618 Brookdale Gardens, Bloomfield, N. J
Lei, R. P., 101 McCullie Ave., Syracuse 5, N. Y
Mazzola, J. R., 584 Hogert Rd., River Edge, N. J
Meisinger, H. P., Hull Rd. & Old Courthouse Rd., R. D. 3, Vienna, Va
Nachtigall, S., 183 Ocean Pkwy., Brooklyn 18, N. Y
Neuber, R. E., 130 Willowood Ct., Emporia, Pa
Nos, H. A., 1154 S. Hale Ave., Chicago 43, Ill
Rabenson, J. G., 105 Bayfield Blvd., Oceanside, N. Y
Rudner, M. A., 4501 Merrydale St., Dayton 3, Ohio
Simpson, A. D., 92 Jackson St., Matawan, N. J
Simpson, O. T., 7 Chestnut Pkwy., Garden City, Chester, Pa
Sunstein, E. D., 464 Constabletown State Rd., Balta, Cynwyd, Pa
Sze答应, C. S., 4245 S. Knox Ave., Chicago 41, Ill
Windsor, R. B., 445 Riverside Terr., Kettering, N. J

Admission to Senior Member
Avery, R. E., Airborne Instruments Laboratory, 160 Old Country Rd., Mineola, L. I., N. Y
Apstein, M., 4611 Maple Ave., Bethesda, Md
Bagella, P. F., 37-30 Warren St., Jackson Heights, L. I., N. Y
Lister, G. H., 1048 E. 176 St., Cleveland 19, Ohio
Merryman, P. J., 114 State, Bridgeport 3, Conn

(Continued from page 86A)

(Continued on page 118A)
Do you know about these

NEW TUBES for
Pulse Modulator Applications

UNITED

HIGH VOLTAGE—HIGH VACUUM DIODES

These new United Graphite Anode Diodes have been developed to fulfill the important aims of the Armed Services program for decreased size ... increased ruggedness ... and increased reliability of Electron Tubes. Complete technical data sent on request.

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Max. Dimen.: Height 7-3/8" Diameter 2-1/16"
Ratings: Ef 5.0 volts If 10.25 amps. epx 25 kv lo 300 ma ib 1.50 amps.

Type 578
Max. Dimen.: Height 6-1/2" Diameter 2-5/16"
Ratings: Ef 5.0 volts If 6.0 amps. epx 40 kv lo 100 ma ib 750 ma

Type 576
Max. Dimen.: Height 7-1/2" Diameter 2-5/16"
Ratings: Ef 5.0 volts If 14.0 amps. epx 25 kv lo 500 ma ib 2.5 amps.

Type 371-B
Max. Dimen.: Height 8-3/4" Diameter 2-5/16"
Ratings: Ef 5.0 volts If 10.3 amps. epx 25 kv lo 300 ma ib 1.50 amps.

Type 3B24W
Max. Dimen.: Height 4-1/2" Diameter 1-9/16"
Ratings: Ef 5.0 volts If 3.0 amps. epx 20 kv lo 60 ma ib 300 ma

Type 3B29
Max. Dimen.: Height 4-3/4" Diameter 1-9/16"
Ratings: Ef 2.5 volts If 4.75 amps. epx 16 kv lo 65 ma ib 250 ma

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Men are needed who have demonstrated outstanding experimental or analytical ability or who have recently received the MS or PhD degree with high honors in EE, Physics or Applied Mathematics.

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With demonstrated ability to apply electronic techniques to new and novel physical measurement and instrumentation applications. Advanced degree, preferably Ph.D., in physics required. Industrial experience desired. Age 28-45. Salary dependent upon training and experience.

Reply, in confidence, giving full details to Engineering Research Dept.

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A leading new (1946) company in the field of high quality electronic equipment has openings for outstanding

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Engineers of outstanding ability and five to ten years experience in the development and design for production of electronic equipment are desired.

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the IRE National Convention
to arrange interview.
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Marion makes the meter upon which the Reed DIOTRON depends for much of its accuracy of indication. It provides a linear power scale and allows full scale measurements of 1 mw, 10 mw, 100 mw, 1 watt and 10 watts into 600 ohms. A corresponding true root mean square voltage scale is also included.

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MICA TRIMMER

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Long term program of research and development in the fields of Radar, Guided Missiles, Computers, Electron Tubes, and related equipment.

Please do not answer unless you meet the above requirements.

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To direct the development of non-linear circuits. Must have degree in Electrical Engineering or Engineering Physics. Several years experience required in the analysis and experimental investigation of magnetic amplifiers, pulsed circuits, or electronic circuits operating at carrier and radio frequencies.

Local interviews arranged

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POSITIONS OPEN

(Continued from page 94A)

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B.S. or M.S. to work on circuits and miniaturization problems relating to electronic equipment and technique. Must be capable of job planning and project control. Minimum 5 years experience in both audio and TV circuit design and equipment production. Prefer engineering physics.

(Position continued on page 98A)

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For Work in Fields of Radar Servomechanisms Telemetering Microwaves Communications

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PROCEEDINGS OF THE I.R.E. March, 1955
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Erie manufactures a complete line of Ceramic and Button Mica Capacitors for transmitter and receiver applications: Fixed Ceramic and Mica Capacitors, Variable Ceramic Capacitors, Carbon Suppressors, Custom Injection Molded Plastic Knobs, Dials, Bezels, Name Plates and Coil Forms. Complete technical information on request.

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March 19-22 1951

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2. Outstanding record of ingenuity.
3. Ph.D., M.S., or equivalent. Those presently employed at their highest skill in defense work need not apply.

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Send resume and salary requirements to:
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OPPORTUNITIES FOR
ENGINEERS and
PHYSICISTS

or electrical engineer with some mechanical design experience and major interest in electronics. Positions is with physics laboratories Sylvania Electric Products Inc., Bayside, Long Island. Please address replies to Personnel Manager, 40-22 Lawrence Street, Flushing, New York.

PHYSICIST
To conduct research on gaseous discharges. Prefer man with Ph.D. in physics and experience in atomic physics, spectroscopy and chemistry, or M.S. with two years experience in nuclear research or gas discharges or thermionic emission. Position is with Long Island laboratory of nationally known electronics company. Box 645.

ELECTRONICS SALES ENGINEERS
Positions open for mature graduate sales engineers over 28 years of age, preferably with practical experience in application of dielectric heating to industrial problems. Excellent opportunities for type of individuals interested in affiliation with successful rapidly expanding organization. Locations in Chicago and other territories. Box 646.

ENGINEERS AND PHYSICISTS
Electrical engineers and physicists in university connected research institute outside continental United States. Min-

(Continued on page 102A)
Over 50 standard types to choose from. Made of hard glass, preformed with microscopic air cushioning. Absolutely free from internal strain. Tin dipped for easy soldering. Write for Bulletin 849 for complete information.

Over 100 standard types available. All headers vacuum tight, with cushioned glass preforms. Completely strain free, tin dipped, silicone treated. Many optional features including CRT closures. Full information can be obtained by writing for Bulletin 850.

Practically any type of sealed terminal or multiple header can be produced to exact customer requirements. Whether your problem involves a new design or the application of a standard item, E-I engineers offer complete collaboration.

Contains 81 standard terminals, 11 different headers. All economy priced items—picked to solve practically any problem. Transparent case with labeled bins for easy selection. Complete kit sells for only $10.00—check or money order.

ELECTRICAL INDUSTRIES INC
MANUFACTURERS OF SPECIALIZED ELECTRONIC EQUIPMENT
44 SUMMER AVENUE, NEWARK 4, NEW JERSEY

PROCEEDINGS OF THE I.R.E. March, 1951
at your service

Standard Coil, the company that gave TV the most widely accepted tuner, "The Standard Tuner," and its subsidiary, Kollsman Instrument Corporation, stand ready with their vast facilities (six factories strategically located from coast to coast, plus highly experienced engineering and research staffs) to work with you on any of your military or civilian electronic problems.

Standard COIL PRODUCTS CO. INC.
CHICAGO • LOS ANGELES • BANGOR, MICH.

Over 4,000,000 "Standard Tuners" Now In Use
Your sealed assemblies can be kept tight with

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Kovar-Glass Seals

Metal-to-glass seal making has been highly perfected by Stupakoff. When you specify Stupakoff Seals, you get well-designed, accurately-made products that are easy to assemble, technically strong, have high flashover ratings, provide high resistance to thermal shock and are dependable. They’re made in a wide variety of standard types and sizes, or in special designs to meet your specific needs.

Stupakoff seals are all made with Kovar Metal, which is readily bonded with hard glass producing no undesirable structural stresses. It has substantially the same expansivity as hard glass from -80°C to the annealing point of glass. These characteristics of Kovar make Stupakoff Seals dependable.

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Latrobe, Pennsylvania

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*For Electrical and Electronic Applications*

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RESEARCH ON: Antennae, Servomechanisms, Microwave cts. and other phases of communications and navigation equipment.

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AND
SENIOR RESEARCH ENGINEERS
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- Gravimetric Equipment
- Optical Equipment
- Computers
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- Test Equipment
- Electronic Design
- Flight Test Instrumentation

are offered excellent working conditions and opportunities for advancement in our Aerophysics Laboratory. Salaries are commensurate with ability, experience and background. Send information as to age, education, experience and work preference to:

NORTH AMERICAN AVIATION, INC.
Aerophysics Laboratory
Box No. N-4, 12214 South Lakewood Blvd.
Downey, California

Two to ten years' experience in research, design, development or test. Patent history desirable but not necessary. A variety of positions open for men with Bache-
or's or advanced degree quali-
fied in one or more of the following fields:

- RELAYS
- TELEMETERING
- PULSE CIRCUITS
- UHF TECHNIQUES
- SERVO-MECHANISMS
- INSTRUMENTATION
- QUALITY CONTROL
- LOW POWER APPLICATION
- TEST EQUIPMENT RELATING TO ABOVE FIELDS

These are PERMANENT POSITIONS with Sandia Corporation in Albu-
querque, New Mexico. Sandia Laboratory is operated by Sandia Corpor-
a, a subsidiary of Western Electric Company, under contract with the ATOMIC ENERGY COMMISSION. This laboratory offers good working conditions and liberal employee benefits, including paid vacations, sick leave, and a retirement plan.

Albuquerque, center of a metropolitan area of 150,000, is located in the Rio Grande Valley at the foot of the Sandia Mountains... the heart of the "Land of Enchantment." Climate is sunny, mild and dry the year round.

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ALBUQUERQUE, N.M.
And Blaw-Knox is proud of the fact that this compliment from *The Fort Industry Company was prompted by the performance of all 13 Blaw-Knox Antenna Towers now in the service of this successful broadcasting organization.

Whether you contemplate light-weight towers for mobile communications or a sky-raking TV support, you can depend on Blaw-Knox engineered structures to get the most out of your transmitting equipment.

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BLAW-KNOX DIVISION OF BLAW-KNOX COMPANY

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PROCEEDINGS OF THE T.R.E. March, 1951
General Electric can build and test JAN-C-25 CAPACITORS in mass production quantities.

Apparatus Department, General Electric Company, Schenectady 5, New York.
SEE

Sheldon

BOOTHs 390-1-2

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RADIO ENGINEERING SHOW

March 19-22

Grand Central Palace

New York, N.Y.

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A Division of ALLIED ELECTRIC PRODUCTS INC.

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Company _________________________________________________________

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Over 1,000,000 Selenium Rectifiers have been produced by International Rectifier Corporation during the past three years. These include miniature rectifiers, high voltage and high power rectifiers of many different designs and capacities, for a wide variety of applications.

We specialize exclusively on the design and manufacture of Selenium Rectifiers of top quality for peak performance. We cooperate closely with your engineers in developing units to meet their requirements as to dimensions, weight, capacity and application. Your inquiry is invited.

TYPE V-HF SERIES
5 MILLIAMPERES DC

Circuit-Half-Wave. In 3/8" OD Phenolic Tube with ferrule at each end for insertion in Fuse Clips. Overall length varies to 9" depending on the DC output voltage rating.

PARTIAL LIST OF TYPE V-HF SERIES RECTIFIERS AVAILABLE

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TYPE V-HF SERIES
11 MILLIAMPERES DC

Circuit-Half-Wave. In 3/8" phenolic tube with flat leads. The overall length of rectifiers in this series varies up to 9", depending on the DC output voltage rating.

PARTIAL LIST OF TYPE V-HF SERIES RECTIFIERS AVAILABLE

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TYPE V-HM SERIES
5 MILLIAMPERES DC

Circuit-Half-Wave. In 3/8" metallic case with flat leads, the negative lead being grounded to the case. Overall length varies to 0.890", depending on the DC output voltage rating. Also available in hermetically sealed units.

PARTIAL LIST OF TYPE V-HM SERIES RECTIFIERS AVAILABLE

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STANDARD SELENIUM CELL SIZES

Cell Type No. U V Y Z W
Cell Diam. (In.) 1/8 1/4 3/8 1/2 1
Current Rating (mA) 1.5 5 11 20 72

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Lockheed invites you to participate in long-range production program, developing the aircraft of the future.

Lockheed offers an attractive salary commensurate with your ability and background in aeronautical science. In addition, Lockheed provides generous travel allowances for those who qualify.

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2. A minimum of three years’ experience in advanced electronic systems development including radar microwave techniques, vacuum mechanics, computers and fire control.
3. Familiarity with airborne electronics equipment requirements—

Write today—giving full details as to your educational background and salary requirements. Address replies:

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LOCKHEED Aircraft Corporation
Burbank, California

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For the design of servo-amplifiers, pulse circuits, amplifiers, antenna, VHF-UHF-transmitters & receivers.

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emperatures going up...

1940

1945

1951

sizes coming down...

Aerovox Capacitors

In tune with the trends of the times! That, quite aptly, describes Aerovox progress in meeting today’s miniaturization and temperature requirements. Tremendous reductions in capacitor sizes and startling increases in operating temperatures (illustrated above) have resulted from such specialized engineering “know-how.” And in many instances Aerovox has found it necessary to develop materials and techniques all its own.

This continuous program of “search and research” is one of the outstanding reasons why Aerovox has the ready answer to your most critical capacitor needs.

Let Aerovox collaborate on your miniaturization and temperature-rating problems. Descriptive literature may be had by writing on your company letterhead.
Positions Open

(Continued from page 106A)

CHIEF ENGINEER

Chief Engineer for manufacturer of visual recording equipment and electronic devices. Experience in electronic and audio-circuit design. Complete responsibility for engineering, from design and through production. Salary: $15,000. Reply: Box 650.

TEST FACILITIES ENGINEER

Test Facilities Engineer experienced in design of test equipment for ultra-precision mechanical or electrical assemblies. Salary: $8,000 to $12,000. Reply: Box 651.

ELECTRONIC ENGINEERS—PHYSICISTS

Electronic engineers and physicists; at least one year experience in circuit work; to do design and development of electronic test equipment and geophysical instruments. Southwestern Industrial Electronics Co., P.O. Box 13038, Houston, Texas.

ELECTRONIC ENGINEERS

Research and development engineers and physicists, with educational background in mechanical, electrical or electronic engineering, physics or engineering physics for openings in plant and laboratory instrumentation, physical measurements, geophysics, and industrial electronics. Prefer two to four years experience in experimental research design and development of instruments, servo-mechanisms, electronic apparatus, optical equipment, intricate mechanisms of allied fields. (Continued on page 110A)

Project Engineers!
Junior Engineers!

Come with Motorola!

Now is your opportunity to work with an organization of top electronic engineers. You engage in the long-term development programs that continue through war or peace—constant improving radio communications for Civil Defense, Public Safety, Transportation, and Industry.

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PROJECT ENGINEERS

An Invitation is Extended to

ELECTRONIC & RADIO ENGINEERS

ATTENDING THE I R E CONVENTION

TO VISIT OUR PLANT AND INVESTIGATE THE OPPORTUNITIES AVAILABLE AT PRESENT IN OUR ENGINEERING DIVISION

APPLY OR PHONE FOR APPOINTMENT

EMPLOYMENT OFFICE

SPERRY GYROSCOPE CO.
DIVISION OF THE SPERRY CORP.
GREAT NECK, L.I., N.Y.
There is no more useful and dependable instrument made

ONLY $39.50 AT YOUR DISTRIBUTOR
Positions Open

(Continued from page 108A)

Positions are of immediate and permanent importance to our operations. Write Personnel Director, Research and Development Department, Phillips Petroleum Company, Bartlesville, Oklahoma.

ELECTRICAL ENGINEERS

Leading manufacturer of X-ray equipment requires 3 men to train for position of sales engineers in east and middlewest. Excellent opportunity, depression proof business, stimulating field. If you can sell, like to work on your own, mingle with troublesome field service problems, don't mind occasional dirty hands or lack of a swivel chair and secretary, this is a worthwhile opportunity. Our men do well financially but work hard. If you want a soft berth, please don't reply. Previous sales helpful but not essential. State education, experience, reason for making change and past earnings. All replies held strictly confidential. Arrangements will be made to interview qualified applicants. Mr. Ed. Smith, Personnel Mgr. The Kelley-Koett Mfg. Company, 212 West Fourth Street, Covington, Kentucky.

Procurement Feature

Four desks to help manufacturers get orders, will be staffed by procurement personnel from Munitions, Air Force, Navy and Signal Corps on the Third Floor, Radio Engineering Show.

U. S. Armed Forces Exhibit

MICROWAVE ENGINEER

Established Chicago electronic manufacturer seeks a senior staff engineer experienced in microwave design and development. Manufacturing experience desirable. Must be a graduate engineer and have experience on 1,000 to 10,000 Mc equipment (2 yrs. minimum). Work will be in connection with Government contracts.

Submit résumé of education and experience, together with salary requirements and availability.

Box 652
The Institute of Radio Engineers, Inc.
1 East 79th Street, New York 21, N.Y.

CIRCUIT ENGINEERS

Physics laboratories, Bayside, L.I., N.Y., needs junior and senior engineers to work on government sponsored projects in the field of radar and navigation. Jr. engineers: B.S. in E.E. or physics and a minimum of one year’s experience in Circuit development essential. Good background in pulse, r.f. or servo techniques desirable. Sr. engineers: B.S. in E.E. or physics and a minimum of 5 years experience in Circuit development essential. Good background in pulse, r.f. or servo techniques desirable.

Please address replies to:
Personnel Manager
Sylvania Electric Products, Inc.
40-22 Lawrence St.,
Flushing, N.Y.

TRANSFORMER DESIGN ENGINEER


TRANSMITTER ENGINEER

Excellent opportunity for a capable Transmitter Engineer for our Application Dept. A broad experience in power tube circuits with concentration in broadcast or VHF range is necessary.

This is a permanent position with one of the oldest power tube companies in America, associated with a world wide organization. We offer excellent possibilities for advancement. Salary commensurate with ability. Write for full details in confidence.

AMPEREX ELECTRONIC CORP.
25 Washington St., Brooklyn

Semi-Conductor Research

The International Business Machines Corporation has an opening for a qualified physicist in an expanding program of research and development on semi-conductors.

Qualifications include Ph.D. or equivalent with extensive experience and fundamental background in Solid State Theory.

Applications with details should be sent to the Manager of the Engineering Laboratory, International Business Machines Corporation, Poughkeepsie, New York.
Sylvania's physicists, chemists, and engineers have carried out fundamental research and development work on color television tubes for a considerable period of time. Basic investigations into practical aspects of television tubes for home entertainment have been conducted at Sylvania's Research Laboratories atRANDA, Pennsylvania, and BAYSIDE, New York. Typical of the exceptional facilities and advanced research techniques used at the Sylvania laboratories is the demountable vacuum system shown in the photo.

Developmental samples of phosphors for color television tubes may be placed in the tube for study and test. Similarly, developmental grids of three-color electron guns may be placed in the neck of the demountable evacuated envelope and characteristics studied. Continual basic research has enabled Sylvania to pioneer in developing television tubes for a complete selection of phosphors for color pictures. It has also paved the way for further advanced search into the design and construction of color television tubes and circuits. Typical of Sylvania's never-ceasing emphasis on productive basic research.

Color Television Research
Accelerated by Study of Color Phosphors in Demountable Vacuum System

The operator is observing a spot of light on the phosphor screen of a developmental color television tube. By varying voltages applied to a three-color electron gun inserted in the demountable vacuum system, she can obtain data useful in improving both phosphors and gun designs for color television tubes.

SYLVANIA ELECTRIC
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.

ELECTRICAL ENGINEER

Six years experience in electromechanical and industrial electronics and measurements. Professional engineer. New York area preferred. $7,500 per year. Box 500 W.

SALES ENGINEER

Graduate "Salesmanship for Engineers" course at CCNY. B.E.E. communications—N.Y.C. 1950. Single, age 24. Looking for job as junior or trainee that needs (Continued on page 114A)

ScientistS AND Engineers

for challenging research and advanced development in fields of

RADAR
GYROSCOPES
SERVOMECHANISMS
MECHANICAL SYSTEMS
ELECTRONICS CIRCUITS
APPLIED PHYSICS AND MATH
PRECISION MECHANICAL DEVICES
ELECTRICAL SYSTEM DESIGN
GENERAL ELECTRONICS
INSTRUMENTATION
MICROWAVES
COMPUTERS
AUTOPILOTS

Scientific or engineering degree and extensive technical experience required.

Write:
Manager, Engineering Personnel

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Specify GLENCO MINIATURE CERAMIC PLATE CAPACITORS

... for minimum size
... maximum dependability
... convenient rectangular shape

GLENCO SUBMINIATURE CAPACITORS
FOR COUPLING AND BYPASS APPLICATIONS

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<td>0.80</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TYPE TC — TEMPERATURE COMPENSATING CERAMIC PLATE CAPACITORS

TYPE CBM — MINIATURE COUPLING AND BYPASS CAPACITORS

TYPE SMCB — SUB-MINIATURE COUPLING AND BYPASS CAPACITORS

GLENNITE* ACCELEROMETER

MODEL A403 (ILLUSTRATED)

We are currently designing a number of other types of accelerometers and strain gauges. We invite inquiries concerning units of special design. Electronic equipment can also be supplied for use in conjunction with this equipment—cathode followers, amplifiers, filters and recording equipment.

*Registered Trademark

- SENSITIVITY: 10 mV/g
- RESONANT FREQUENCY: 8 kc
- USEFUL FREQUENCY RANGE: 3 to 4000 cps
- CAPACITANCE: 1500 mmf
- SIZE: 1 7/16" diam. x 3/4"
- WEIGHT: Approx. 1 ounce
- MOUNTING: 3—2 x 56 machine screws spaced 120° apart on a 1 1/4" diameter circle
- MAX. DIRECTIVITY: Perpendicular to mount
- TEMPERATURE RANGE: —60° C to +90° C
- ACCELERATION RANGE: 0.1 to 600g
- CABLE: 4 ft. shielded cable supplied
- CALIBRATION: Instruments individually calibrated at 2g from 20 to 1500 cps
- MOVEMENT: Compressional

GULTON MFG. CORP.
METUCHEN • NEW JERSEY

NOTE/ A FEW TERRITORIES ARE STILL OPEN FOR WIDE AWAKE REPRESENTATIVES IN SELECTED AREAS — INQUIRIES INVITED.

PROCEEDINGS OF THE I.R.E. March, 1951
ENGINEERS AND PHYSICISTS

Electronic and mechanical engineers and physicists are needed at all levels for
Research, Development and Production
of diversified military electronic equipment.

Operating since 1942.

Pre-Korean commitments require continuous expansion
of our facilities.

For interview during I.R.E. Convention and Show, please
inquire at Waldorf Astoria Hotel desk for Company representative
in AIL suite. Or write immediately to Personnel
Director of

AIRBORNE INSTRUMENT LABORATORY, INC.
160 Old Country Road, Mineola
LONG ISLAND, N.Y.

OPENINGS EXIST FOR OUTSTANDING JUNIOR
CISI O N MECHANICAL INSTRUMENTS MAY
PAY LABORATORIES A RELOCATED IN THE
THE TECHNI C IANS; APPLICANTS FOR THESE POSITIONS
QUALIFY, ALSO INDIVIDUALS WITH GOOD
BACKGROUNDS IN APPLIED PHYSICS. A FEW OPENINGS EXIST FOR OUTSTANDING JUNIOR
E. E.'S AND PHYSICISTS, ALSO EXPERIENCED TECHNICIANS APPLICANTS FOR THESE POSITIONS
MUST APPLY IN PERSON. THE COMPANY LABORATORIES ARE LOCATED IN THE
PLEASANT RESIDENTIAL SUBURBS OF WASHINGTON.

ENGINEERS

NATIONAL UNION
RESEARCH DIVISION

The Research Laboratories of one of the nation's larger electronics manufacturers has vacancies for
electronic engineers and engineering physicists qualified in the following fields:

- Tube-research and development
- Electronic circuit design
- High vacuum systems

This organization can offer excellent prospects for security and personal advancement due to our continued
growth. Our location is in suburban New Jersey with convenient commuting distance of New York City.

Whether you have a background in electron tube or circuit design, or are a recent graduate and interested in
our field, we would like to hear from you. Send your résumé to:

PERSONNEL DEPARTMENT
NATIONAL UNION
RESEARCH DIVISION
330 Scotland Rd., Orange, N.J.
If you contemplate the purchase of an OSCILLOSCOPE now, or within the near future, we sincerely urge you to wait until the convention of the Institute of Radio Engineers on March 19 to 22.

We will be in Booth No. N-20, where we will present, for the first time, our brand new oscilloscope featuring many desirable and important advancements.

Our LABSCOPE is not the result of research confined within our walls. We solicited the cooperation of a cross-section of the nation's outstanding engineers, asking them to tell us what they would like to have in a scope. Then we designed it...to serve the greatest number of the most discriminating and exacting engineering organizations.

We want you to see our new LABSCOPE...to subject it to rigid examination...to compare it feature for feature...to prove to yourself that the LABSCOPE is the instrument you want.

P.S. If you are unable to attend the convention and SEE it, drop us a line and we'll send you the data sheets on our LABSCOPE.
The "HERCULES"—Here is a revolutionary new microphone that provides the ruggedness, the clear reproduction, and the high output long needed for public address, communications, recording at an amazingly low price! Can be placed on a desk, in the hand, or on a stand.

Model 510C . . . . . . . Code: RUTF
Model 510S (with switch) . . . . . . Code: RUTUS

The "GREEN BULLET"—Specially designed to provide quality music and speech reproduction at moderate cost. A streamlined unit that lends itself to fine-quality, low-cost installations where durability is an important factor. Features high output, good response, high impedance without the need of a transformer.

Code: RUDAL

The "RANGER"—Recommended for those applications where long lines are used and a rugged hand-held microphone is needed. Ideal for outdoor public address, mobile communications, ham, audience participation shows, etc. Designed for clear, crisp natural-voice response of high intelligibility. Has heavy-duty switch for push-to-talk operation.

Model 505B (Medium Impedance) . Code: RUDAY
Model 505C (High Impedance) . . . Code: RUDAX

The "DISPATCHER"—Complete dispatching unit. Designed to handle the most severe field requirements of paging and dispatching systems. Ideal for police, railroad, taxicab, airport, bus, truck and all emergency communications work. Operates both microphone and relay circuits. High output, high speech intelligibility. Unit is preassembled.

Code: RUDAF

CONTROLLED RETRACTANCE CARTRIDGE—Available for service installation. Ideal for replacement of crystal cartridges in Shure cases of Models 707A, 708 and carbon cartridges in the 100 and "CB" series. Can also be used in most semi-directive microphones where space permits. Supplied with rubber mounting ring.

Code: RUTC

* Specific information provided on request.

Patented by Shure Brothers, Inc.

SHURE BROTHERS, Inc.

Microphones and Acoustic Devices
225 West Huron St., Chicago 10, Ill. • Cable Address: SHUREMICR
SET UP THE CAMERA
SNAP THE SHUTTER
SEE THE PRINT

ALL IN 3 MINUTES—or even less
with the Fairchild-Polaroid Oscilloscope Camera

The easiest way is the fastest way when you're photographing oscilloscope images with the Fairchild-Polaroid Oscilloscope Camera.

No more darkroom processing! With this new camera it takes only two minutes (less if you're fast) to set up and snap the picture, one minute to finish a print. Each 3½ x 4¼ print records traces exactly one-half life size to make comparisons easy.

Write for complete data and prices on F-284 Oscilloscope Camera Kit including camera, carrying case, and film. Fairchild Camera and Instrument Corporation, 88-06 Van Wyck Boulevard, Jamaica 1, N.Y. Dept. 120-14C.

S P E C I F I C A T I O N S

LENS—Special 75 mm. 1/2.8 W. Icssk Oscillo-anastigmat.

SHUTTER—Wollensak Alphax; speeds 1/25 sec. to 1/100 sec., "time," and "bulb."

FOCUS—Fixed (approx. 8 in.)

PICTURE SIZE—3½ x 4¼ in. (2 or more images per print; 16 exposures per roll of film.)

IMAGE SIZE—One-half reduction of scope image.

WRITING SPEED—to 1 in./sec at only 3000V accelerating potential; higher speeds at higher voltages.

DIMENSIONS—Camera, 10½ x 5¼ x 6¼ in.; hood, 11 in. length, 7½ in. dia.; adapter, 2 in. width, 6½ in. max. dia.

WEIGHT—Complete, 7¼ lb.

Typical of the work being done with this camera is this 3½ x 4¼ print of 35-milli-second single-sweep transient—one of a series of accelerometer-output recordings that made possible the completion of nine recorded "drop-tests" in 40 minutes.

F A I R C H I L D
OSCILLOSCOPE RECORDING CAMERAS

In the Fairchild-Polaroid Oscilloscope Camera and the Fairchild Oscillo-Record Camera at the Radio Engineering Show, Booth 238-239.

PROCEEDINGS OF THE I.R.E. March, 1951
117A
"NOFLAME-COR"
the TELEVISION hookup wire

fits perfectly
into this picture

MEETS GOVERNMENT SPECIFICATION AN-J-148a
FLAME RESISTANT
HEAT RESISTANT
HIGH INSULATION RESISTANCE
EASY STRIPPING
HIGH DIELECTRIC FACILITATES
POSITIVE SOLDERING
Also is not affected by the heat of impregnation...
making it an ideal wire for use in connection with coil and transformer leads

No "Nicking" problem in using this proven wire. Not being an extruded plastic, its diameter uniformity can be absolutely guaranteed. This eliminates nicking of conductors and constant resetting of blades in the cutting process. Available in all sizes, solid and stranded, in over 200 color combinations... "NOFLAME-COR" assures maximum output and minimum rejects.

"made by engineers for engineers"

No "blobbing" of insulations under soldering heat, because "NOFLAME-COR" is NOT an extruded plastic. Production executives specify it as the most efficient heat-resistant wire yet developed. Save time, money and assembling headaches. Investigate!

CORNISH WIRE COMPANY, Inc.
50 Church Street,
New York 7, N. Y.

Branch Offices

PHILADELPHIA  BOSTON  CLEVELAND  CINCINNATI  CHICAGO
DETROIT  MINNEAPOLIS  ST. LOUIS  ATLANTA
DALLAS  DENVER  LOS ANGELES  SAN FRANCISCO  SEATTLE

MANUFACTURERS OF QUALITY WIRES AND CABLES FOR THE ELECTRICAL AND ELECTRONIC INDUSTRIES
IMPEDEANCE MEASUREMENTS

SPEED AND CONVENIENCE

FTL-42A IMPEDOMETER

Rapid, accurate measurement of impedance, reflection coefficient and standing wave ratio. Small size, convenient for field use.

50 to 500 Mc.

Can be inserted in various sizes of solid coaxial line or flexible cables.

Make three readings, plot diagram and read off impedance to ± 5%.

$400.00.

F-30A SLOTTED LINE

R-30A SLOTTED LINE

Write impedance measurements in the range of 60 to 1000 cycles per second. Accuracy ± 2%.

50 to 2000 Mc range covered with slightly reduced accuracy.

Axial line 250 centimeters long having a surge impedance of 70 ohms ± 0.5 ohms.

$195.00.

On display at booth 34.

1951 IRE Radio Engineering Show

Write for FTL-30A and FTL-42A brochures.

Federal Telecommunication Laboratories, Inc.

500 Washington Avenue
Nutley 10, New Jersey
Instruments that multiply manpower

Are you taking advantage of the great time savings made possible by Brush recording analyzers?

Throughout industry, in research and production, Brush oscillographs provide immediately usable graphs of data which formerly took many man-hours to obtain and plot. In combination with other Brush instruments, these analyzers can be applied to a host of specialized problems... electrical, mechanical or acoustical.

Call your nearest Brush representative to have him analyze your opportunities for manpower savings with Brush instruments.

THE Brush DEVELOPMENT COMPANY
Dept. F-3, 3405 Perkins Avenue, Cleveland 14, Ohio, U. S. A.

PIEZOELECTRIC CRYSTALS AND CERAMICS • ELECTROACoustics • MAGNETIC RECORDING • ULTRASONICS • INDUSTRIAL AND RESEARCH INSTRUMENTS

W. A. BROWN & ASSOC.
3834 Mt. Vernon Ave.
Alexandria, Virginia

BURLINGAME ASSOC.
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New York 13, N. Y.

R. M. COLDWELL
289 Fairfield Avenue.
Hartford, Conn.

EVERETT ASSOCIATES
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Kansas City 8, Mo.

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P. O. Box 435
Old Albuquerque, New Mexico

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Washington 5, D. C.

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Box 1471
Hollywood 28, Calif.

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ARMIN LEICH
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Indiopolis, Indiana

HUGH MARSLAND
20 North Walker Drive.
Chicago 6, Illinois

M. P. ODELL
2536 Eutid Avenue.
Cleveland, Ohio

H. M. RICHARDSON
2210 Fathay Tower.
Minneapolis 2, Minn.

ANTHONY R. SATULLO
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Detroit 14, Michigan

J. Y. SCHOOKMAKER
2011 Cedar Spring Avenue.
Dallas 1, Texas

A. C. WICKMAN, LTD.
P. O. Box 9, St.
Toronto, Ont., Canada

(Continued from page 121A)

WHILE THE ELECTRONS FLOW, this Brush D. C. Amplifier and Oscillograph measures and records the time constants of a reactor, eliminating hours formerly required for plotting. Write for Bulletin 460 and 540.
Sanborn Amplifier Recorders are being found outstandingly useful in a wide variety of industrial recording applications. Records are produced *directly*, and continuously, by *heated stylus* on plastic coated record paper (Permapaper), in true rectangular coordinates, and are sharp, clear, and permanent. Elimination of the ink flow type of recording permits the use of these recorders in any position and at any angle. The writing arm (or arms) is driven by a D’Arsonval moving coil galvanometer with an extremely high torque movement (200,000 dyne cm per cm deflection).

The single channel Model 128 is a vacuum tube recording voltmeter capable of reproducing electrical phenomena from the order of a few millivolts to more than 200 volts. Standard paper speed is 25 mm sec. Slower speeds of 10, 5, and 2.5 mm/sec are available. A variety of interchangeable amplifiers is available.

The multi-channel Model 67 provides for the simultaneous registration of *up to four* input phenomena on one record using, in a multiple system, the same principles and methods as the single channel Model 128.

In addition, this vertically mounted, metal cased amplifier-recorder provides a choice of eight paper speeds: 50, 25, 10, 5, 2.5, 1.0, 0.5 and 0.25 mm/sec, and further provides for the use of 4-, 2-, or 1-channel recording paper. Complete versatility of recording is offered in this unit by means of interchangeable amplifiers which permit the registration of stresses, strains, velocities, etc., along with the usual D.C. or A.C. phenomena.

The recorder and amplifier units of which the above models are comprised are also available separately.
The Only Seals You Can Hot Tin Dip at 525° F. for Easy Assembly Soldering, for a Strain and Fissure-Free Sealed Part with Resistance of over 10,000 Megohms!

Recent

Hermetic Seal Achievements...
by the world's leading supplier of quality headers

Whether your specifications call for the simplest or the most complicated hermetic seals, call on the source used by this country's leading industries. Hermetic's experience, know-how and engineering talent are unrivaled in this field. Such specialization assures you of quality hermetic headers in unlimited shapes that withstand -55° F. sub-zero conditions, swamp test, temperature cycling, high vacuum, high pressure, salt water immersion and spray, etc.

Important: Terminals and Headers are available in RMA Color Code.

Hermetic Seal Products Co.
29-31 South 6th Street, Newark 7, New Jersey

SIT HERMETIC'S BOOTH NUMBER 129 AT THE 1951 I.R.E. SHOW, GRAND CENTRAL PALACE, MARCH 19-22

PROCEEDINGS OF THE I.R.E.  March, 1951

123a
ASTATIC has never introduced a new cartridge that has won wider, more immediate acclaim than its "AC" Crystal Series. The new mechanical drive system of the "AC" Cartridges affords a new low inertia ... smoother response characteristics, higher tracking excellence, lower needle talk resulting. Now, those who need immunity to extremes of temperature and humidity, along with such performance excellence, will find an optimum answer in the new Ceramic "AC" Models. External physical characteristics are the same. Performance characteristics of the Ceramic and Crystal models appear below. Note that output of the Ceramic units is entirely adequate for the two-stage audio amplifiers used in most radios and phonographs.

**SPECIFICATIONS—CRYSTAL MODELS**

<table>
<thead>
<tr>
<th>Model</th>
<th>List Price</th>
<th>Minimum Needle Pressure</th>
<th>Output Voltage</th>
<th>Frequency Range</th>
<th>Needle Type</th>
<th>For Record</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>AC-2</td>
<td>8.90</td>
<td>5 gr.</td>
<td>0.4</td>
<td>60-10,000</td>
<td>A-3 (10 mil sapphire tip)</td>
<td>Standard 78 RPM</td>
<td>ASWY</td>
</tr>
<tr>
<td>AC-2</td>
<td>8.90</td>
<td>5 gr.</td>
<td>0.4</td>
<td>50-10,000</td>
<td>A-1 (10 mil sapphire tip)</td>
<td>Standard 78 RPM</td>
<td>ASWY</td>
</tr>
<tr>
<td>AC-AG</td>
<td>9.90</td>
<td>6 gr.</td>
<td>0.1**</td>
<td>50-10,000</td>
<td>A-G (10 mil sapphire tip)</td>
<td>Standard 78 RPM</td>
<td>ASWY</td>
</tr>
</tbody>
</table>

**DOUBLE NEEDLE TURNOVER MODELS:**

<table>
<thead>
<tr>
<th>Model</th>
<th>List Price</th>
<th>Minimum Needle Pressure</th>
<th>Output Voltage</th>
<th>Frequency Range</th>
<th>Needle Type</th>
<th>For Record</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACD-1</td>
<td>9.50</td>
<td>6 gr.</td>
<td>0.2**</td>
<td>60-10,000</td>
<td>A-1 (10 mil sapphire tip)</td>
<td>Standard 78 RPM</td>
<td>ASWY</td>
</tr>
<tr>
<td>ACD-11</td>
<td>9.50</td>
<td>6 gr.</td>
<td>0.2**</td>
<td>50-10,000</td>
<td>A-1 (10 mil sapphire tip)</td>
<td>Standard 78 RPM</td>
<td>ASWY</td>
</tr>
</tbody>
</table>

**SPECIFICATIONS—CERAMIC MODELS**

<table>
<thead>
<tr>
<th>Model</th>
<th>List Price</th>
<th>Minimum Needle Pressure</th>
<th>Output Voltage</th>
<th>Frequency Range</th>
<th>Needle Type</th>
<th>For Record</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACD-2</td>
<td>9.50</td>
<td>5 gr.</td>
<td>0.2**</td>
<td>60-10,000</td>
<td>A-1 (10 mil sapphire tip)</td>
<td>Standard 78 RPM</td>
<td>ASWY</td>
</tr>
<tr>
<td>ACD-2</td>
<td>9.50</td>
<td>5 gr.</td>
<td>0.2**</td>
<td>50-10,000</td>
<td>A-1 (10 mil sapphire tip)</td>
<td>Standard 78 RPM</td>
<td>ASWY</td>
</tr>
</tbody>
</table>

More than one reason was given by most men as the basis for selecting an ad. To avoid making a prejudiced selection, the researcher took the first reason in 99% of the answers, on the basis that the most important factor would be stated first. This may be a fallacy, however, interpretation was avoided, in an attempt to be factual.

Most secondary reasons given were answers #1 and #2. And this may be considered in next month's report. This will be a continuing study.

Recent Catalogs

- "Two Laboratory Reports, #1 & #2, have been released by Technology Instrument Corp., 1053 Main St., Waltham, Mass.
- Report #2 concerns itself with "Low-Frequency Characteristics of the Type 320-A Phase Meter." This is an instrument which utilizes a pulse position comparison method for measuring the phase angle difference between two electrical signals. Report #2 is devoted to "The Determination of the Q of Coils By Means of an A-Z Angle Meter And The Series Resonance Method," "Type 500—A Wide-Band Decade Amplifier," and "Network Calculators."

- "Instrument Specialties Co., Inc., Little Falls, N. J., has printed Catalog 46, which deals with the complete line of microprocessed springs of behrullum copper for many applications. Also given is information on engineering, toolmaking, and the sample service offered by the firm.
The MOST VERSATILE AND SENSITIVE Oscilloscope EVER Built!

A new LAVOIE LA-239A OSCILLOSCOPE

Some of the outstanding advantages of the...

- Takes the guesswork out of pulse techniques.
- Accurately measures amplitude, width, separation, repetition rate and rise time without the need of additional equipment.
- Accurate timing markers provide means of calibrating the linear time base.
- Internal trigger generator permits pulse generator and oscilloscope to be triggered simultaneously, while sweep delay circuit allows a small portion of image to be expanded TEN TIMES normal size.

INCREASED PRODUCTION NOW PERMITS A REDUCTION OVER FORMER LIST PRICE WITH SPECIAL REDUCTIONS TO TECHNICAL SCHOOLS AND NON-PROFIT ORGANIZATIONS

Write for Technical Bulletin LA-239A giving complete detailed information.

Specialists in the Development and Manufacture of UHF Equipment

MORGANVILLE, N.J.
6. ANTENNAS
Treats antennas from the electromagnetic-theory point of view, emphasizing the engineering aspects. Presents the fundamental theory of point sources, pattern and gain considerations, and results of measurements, as well as data on linear, loop, and helical antennas. Covers the basic antenna, the cylindrical antenna, soil and mutual impedances, and arrays of linear antennas.

7. TRANSMISSION LINES AND NETWORKS
Presents the theory of transmission lines and four-terminal networks, with applications both to power and communication fields. Takes up special considerations relating to power transmission, telephone and telegraph transmission, and telephone and telegraph transmission lines. Applies the theory of four-terminal networks to a variety of circuits, matching networks, and filters.

8. FREQUENCY MODULATED RADAR
Tells what is known today about f-m radar. Covers everything from background and special characteristics, to operational techniques and specific applications. Gives thorough principles of distance and speed determinations by f-m radar. Considers some of the specifications of the radio portions and circuits of the f-m radar system, as well as some of the circuitry techniques, and various measuring instruments, etc.

9. ELECTRONICS: EXPERIMENTAL TECHNIQUES
Explains the design and construction of electronic circuits for 40 fundamental experiments. Discusses circuits that are widely used in physics research; provides a good background for the design of new circuits. Includes 20 circuits, such as pulse amplifiers, counting circuits, etc. as well as various other experiments.

10. VACUUM EQUIPMENT AND TECHNIQUES
Discusses the development of high vacuum equipment for use in electromagnetic separation plants. Discusses various fundamentals in vacuum practice as the operation of a vacuum, gaseous diffusion, thermal conduc-

tivity of gases, vacuum, etc. Treats all the vacuum materials and equipment and recent developments in leak-detection and testing techniques. Edited by A. Gorter, and R. R. Wackerling, both of the Radiation Laboratory, Dept. of Physiology, Univ. of Calif. Vol. II of the McGraw-Hill National Energy Series, 417 pages, illus. 8.50

What to see at the Radio Engineering Show
(Continued from page 604)

Firm
Booth

Federated Metals Division, American Smelting & Refining Co., Whiting, Ind.
Federated and Federated Gardiner brass and copper core, solder, alloy tubing, and lead in wire form, with a tungsten dust flux incorporated. Federated and Federated Gardiner brand RTS solder (a tin-lead solder). Cooper anodes, cast, electrodeposited and rolled for all copper plating operations.

Federated Purchaser, Inc., New York, N.Y.

Ferris Instrument Co., Boonton, N.J.
Radio receiver testing equipment.

Filtron Co., Inc., Flushing, L.I., N.Y.
Radio frequency interference suppression filters.

Fisher Radio Corporation, New York, N.Y.
High quality FM and AM receivers. High quality audio amplifiers.

Ford Instrument Co., Div. of The Sperry Corp., Long Island City, N.Y.
Synchro and resolver system, differentials (mechanical). Integrators.

Freed Transformer Co., Inc., Brooklyn, N.Y.
Transformers, reactor, wave filters, High 'O' toroid inductors, precision laboratory measuring instruments.

Fusrotech Electronics, Chicago, Ill.
Wide-band DC amplifiers, power meter, regulated power supplies of various capacities.

Gates Radio Co., Quincy, III.
A new model 10KW high frequency communications and broadcast transmitter, a display of frequency control and transmission line items in the higher powered ranges and broadcast station accessory equipment.

General Ceramics and Steatite Corp., Keasby, N.J.
Silicate type loss insulators, feramics, hermetically sealed terminals, porcelain for standard and special uses, dielectric constant tantalate materials, magnetic amplifiers.

General Electric Co., Schenevuctady, N.Y.
Electronics equipment and components.

General Electric Co., Electronics Dept., Vacaville, Calif., N.Y.
125 to 150 cathode ray, transmitting, and receiving tubes; TV and industrial tubes; Germanium diodes; loudspeaker tone arms; planograph cartridges; TV components, projectors.

General Precision Laboratory, Inc., Pleasantville, N.Y.
5 to 5-11 New Design TV camera chains for field and studio, and standard television chain for better picture quality; precision projectors for standard film chains and for portable machines for use with image orthicon camera. Projectors are finest professional machines designed for TV Camera. Chains feature remote control of iris, lens, charge, and focus (pan and tilt also available).

92, 93 Custom electronic distortion, UHF admittance meter, bolometer bridge, VHF and UHF oscillators, two-signal audio generator, indicator, crystal detector, amplifier circuits, random noise generator, octave-band filter, r.f. and a.c. bridge, dielectric measuring equipment, vacuum-tube voltmeters, megohmeters, power amplifier, resistors, capacitors, inductors.

John Gombe Co., Inc., Irvington, N.J.
Custom built electronic components, precision machined parts, surveyor's benchmarks, crystal holders, crystal vibrators, jacks and connectors, beryllium copper connectors.

(Continued on page 128A)

PROCEEDINGS OF THE I.R.E.
March, 1943

Check list of selected, recent McGRAW-HILL BOOKS

1. THEORY AND APPLICATION OF INDUSTRIAL ELECTRONICS
Thoroughly treats the entire field of industrial electronics. Breaks the field down to its basic principles; showing many practical applications of electronic circuits and devices. Covers electronic instrumentation of both electrical and non-electrical quantities, control and electronic power, including ignition heating and deflection heating.

By John M. Carst, Prof. of Elec. Eng., Purdue U., with the assistance of C. F. Rude, Research Eng., F.R.M. Corp. 290 pages, Illus. In Press

2. THEORY AND DESIGN OF TELEVISION RECEIVERS
Gives physical explanations and mathematical theory for the behavior of various television circuits from the engineering viewpoint, as well as discussing their practical design and construction. Covers tables, graphs, and cross-section schematic drawings that save time and reduce construction work. Covers standards governing television transmission, the operation of every circuit and section, and receiver servicing techniques.


3. HIGH-SPEED COMPUTING DEVICES
Covers the various mathematical methods, physical mechanisms, and circuits developed for use in automatic computing. Takes up the general character of computing machines and the special problems involved in using them, showing many uses to which large scale machines can be put. Discusses switches and gates, delay elements, large-scale digital systems, etc. How digital electronic circuits are made. Supervised by C. H. Tompkins and J. H. Wakefield. Edited by W. W. Titter, Jr. 410 pages, 90 illus., 86.50

4. RADIO ENGINEERING HANDBOOK
Completely revised fourth edition brings you detailed data and practice covering all areas of radio engineering. Emphasis is placed on applications presented in a full range of tables, charts, equations, formulas, and diagrams. Covers everything from theory to practical circuits, such as pulse amplifiers, counting circuits, etc. as well as various other fields.

By W. W. Titter, Jr., Prof. of Radio Engineering, Columbia University, and C. F. Basil, Research Engineer. 166 pages, 113 illus., 8.50

5. HIGH FREQUENCY MEASUREMENTS
A thorough and critical discussion of high-frequency phenomena applied to measurements emphasizing modern concepts of instrumentation, and extended, this edition, to cover the entire useful radio-frequency band of present day applications. Shows the procedures for measuring the practical units, providing a complete listing of all the procedures for use for a specific problem.


AS EXHIBITED AT THE
Radio Engineering Show
New York City
March 19-22, 1951

McGraw-Hill Book Co., Inc., Dept. IRE-3-51
327 W. 41st St., New York City 18, N.Y.
Send me the bound handbook. To be 10 days' examination on approval. In 30 days I wish to return unwanted books postpaid. I pay delivery charge if you wish to return with this coupon. Name required. Revise prices. See page 2 for names.

March 19-22, 1951

This offer applies to U.S. only.
It's JFD for Facilities For Defense

...one of the world's largest producers of television antennas and accessories... invites orders for prime and sub-contract work. Our Facilities For Defense have been used, in the past, by such industry leaders as RCA, PHILCO, ADMIRAL, PILOT, MOTOROLA, BENDIX, STROMBERG-CARLSON and many others. Personnel and production machinery are geared to the standard of quality and mass production that meets your "deadlines" and lowers your costs.

Can we serve YOU?

For experience, know-how, dependability and financial responsibility—you can count on JFD's Facilities For Defense. Phone, wire or write direct to Mr. Albert Finkel, Vice-President.

DIVISION OF CONTRACT OPERATIONS

MANUFACTURING CO., Inc.
6137C 16th AVENUE, BROOKLYN 4, N. Y.
FIRST in Television Antennas and Accessories
Proving Ground for DEPENDABILITY

This part of our equipment for testing airborne radar antennas may give you some idea of the job that Dalmo Victor is prepared to do. Prepared by years of experience in a specialized field of the engineered design, development and production of complex electro-mechanical equipment. During these years a skilled staff of engineering specialists has been organized and integrated with a team of production experts.

As a result, Dalmo Victor offers you a service unique in the electro-mechanical field. Our mechanical and electronic engineers offer a proven record of ingenuity and sound design supplemented by the services of staff specialists in micro-waves, servos, metallurgy, stress and vibration. Our production staff offers years of experience in the manufacture and fabrication of complex parts, in a variety of materials and by a variety of processes. (As an example, Dalmo Victor has been continuously fabricating in magnesium since 1943, and introduced magnesium wave guide in 1944.) To this is added the best in equipment and a corps of craftsmen especially selected for their individual skills. Top this off with a testing laboratory that is completely equipped for mechanical and electronic testing under sea level, altitude and extreme temperature conditions, for both components and complete equipment.

The result is a competent, resourceful, reliable and integrated team capable of assuming the complete responsibility for designing, producing and testing unusual electro-mechanical equipments from development through production.

If this is your need, Dalmo Victor is at your service.

Dalmo Victor
SAN CARLOS
CALIFORNIA
STEP UP COIL PRODUCTION with MICAFOIL WINDERS

Toroidal • Sector • Telephone Relay • Standard Relay • Loud Speaker • Choke • Field • Honeycomb • Transformer • and Many Other Types of Coils and Armatures Wound Accurately and Quickly

MODEL RW TOROIDAL WINDER with Coil Supports—automatically winds toroidal coils around 360° or sector coils up to 270°. Winds in either direction. Made in three sizes for single wire from 18 to 38 AWG, double or stranded wires from 2 x 18 to 2 x 26 AWG. Maximum winding speed 200 RPM.

MODEL OGA AUTOMATIC WINDER with removable semi or fully automatic paper interleaving attachment. Adaptable for multiple coil winding with or without interleaving and for interweaving of cotton threads. Made for five speed ranges from 70 to 3000 RPM. Wire sizes from 8 to 44 AWG.

MODEL OOFA-PEM MULTIPLE FINE-WIRE WINDER with fully automatic paper interleaving device, for flanged or flangeless coils. Winds up to 6 coils at a time with individual paper interleaving. MODEL OOFA-PEB winds up to 10 flangeless coils with common paper interleaving. Wire sizes from 24 to 44 AWG. Winding speeds from 360 to 3000 RPM.

MODEL OOFA AUTOMATIC FINE-WIRE WINDER with removable semi or fully automatic paper interleaving attachment. Will wind wires from 24 to 44 AWG at certain speed ranges between 950 and 6000 RPM. Attachment available for winding two coils simultaneously. MODEL OOFA-T, similar to above, winds up to 12,000 RPM.

MODEL AWO-A SMALL ARMATURE WINDER—Fully automatic for mass production of small two-pole armatures with straight or skewed slots. Wire is guided by adjustable guide blade. Wire sizes (without insulation) from 23 to 44 SWG. Winding speed 700 RPM.

MODEL AW0-A SMALL ARMATURE WINDER—Fully automatic for mass production of small two-pole armatures with straight or skewed slots. Wire is guided by adjustable guide blade. Wire sizes (without insulation) from 23 to 44 SWG. Winding speed 700 RPM.

NATIONAL REPRESENTATIVES

COSA CORPORATION
405 Lexington Ave., New York 17

SEE these Coil Winders in Operation at NEW YORK Show Room

Office—CHRYSLER BLDG.—4 Blocks from the IRE Show Telephone: 0Regon 9-3560
MODEL 100
Berkeley Basic Scaler

SINGLE HI-VOLTAGE CONTROL simplifies operation, prevents inadvertent overvoltage of GM tubes. Single continuous control from 0 to 2,500 volts.

TRUE DECIMAL PRESENTATION for easy reading. No interpolation, no lights to add. Results are presented in direct reading form on illuminated panels of the two electronic counting units. A 6-place mechanical register extends total capacity to 99,999,999. Selectable electronic scale of 10 or 100.

SMALL, LIGHTWEIGHT for easy portability. Weighs only 18 lbs.; measures 9 3/4" x 10 3/4" x 14 1/2". Baked enamel finish permits easy decontamination.

ACCESSORY OUTLETS are provided for external clock, timer, loudspeaker, or output pulse per count to drive count rate meter or counting rate computer and recorder.

LOW COST—The Berkeley Model 100, produced in quantity, provides a basic Geiger-Muller scaler at minimum cost.

PRICE . . . $330.00

*MODEL 110
Berkeley Universal Scaler

This versatile scaler has all the features of the Model 100, plus:

POSITIVE OR NEGATIVE HI-VOLTAGE SUPPLY, selectable by simple internal switch, permits use with either GM or scintillation detectors.

BUILT-IN PREDETERMINED COUNTER provides presettable scaling factors of 100, 200, 400, 1,000, 2,000, 4,000, 10,000 and 20,000.

PRICE . . . $395.00

For complete information, write for Bulletin IRE-100

SEE OUR DISPLAY AT BOOTH 378
IRE SHOW NEW YORK, MAR. 19-22

Berkeley Scientific Corporation
2200 WRIGHT AVE. • RICHMOND, CALIF.
Tuning Forks

for precision frequency control

A complete line of tuning fork resonators to meet your reference standard... timing... or speed control requirements.

ACCURATE... Manufactured in accuracies up to 1 part in 10,000 for operation from -40 to +75°C... and up to 1 part in 100,000 for operation from 0 to +75°C.

COMPENSATED... Thermal compensation method employed maintains fork accuracy throughout rated operating temperature range without benefit of oven control or warm-up time.

RUGGED... Internally shock-mounted using relatively permanent, semi-inorganic, silicone rubber—a desirable feature for stringent shock and vibration applications.

HERMETICALLY SEALED... Solder-sealed evacuated container prevents barometric pressure and relative humidity variations from affecting fork accuracy.

FREQUENCIES... 100 cycles and from 700 to 3,000 cycles for accuracies up to 1 part in 10,000—from 1,000 to 3,000 cycles for accuracies up to 1 part in 100,000.

Available individually—as a part of compact sub-assemblies—or in completely engineered equipment constructed to your specifications.

Write Dept. A for complete information or telephone HYacinth 2-1800.

PHILAMON LABORATORIES
5717 Third Avenue  Brooklyn 20, N.Y.

(Continued from page 110A)

What to see at the
Radio Engineering Show

(Continued from page 110A)

Firm

Booth

Kester Solder Co., Chicago, III.

"Resin-free" core solder, plastic resin-core solder, "Specialized" flux-core solder, industrial external soldering fluxes, soldering paste and salts, soldering accessories.

Kety Manufacturing Corp., New York, N.Y.

Small high precision synchro, servo amplifiers, resonators, servo motors, specialty transformers, rotary switches, Navy audible signal equipment.

Kings Electronics Co., Brooklyn, N.Y.

Kings Microwave Co., Tuckahoe, N.Y.

Coaxial connectors, rf fittings, microwave components and equipment.

James Knights Co., Sandwich, III.

Quartz crystals, mounted and unmounted, supersonic crystals, frequency standards, quartz crystal ovens.

Kulka Electric Mig. Co., Inc., Mt. Vernon, N.Y.

Barrier type terminal blocks, jumpers, solder tags, electrical wiring devices, junction boxes, aircraft thimbles, identification tags, switches, wiring assemblies made to specification.

Kuprian Manufacturing Co., Binghamton, N.Y.

Flexible shaft couplings and flexible shaft assemblies for remote control of potentiometers, timers, switches, repeaters, resolution counters and other instruments, and components. Electrostatic wire shielding and push-pull controls.

Lambda Electronics Corp., Corona, L.I., N.Y.

Laboratory power supplies.

La Pointe-Cassicold Corp., Windsor Locks, Conn.

Television, FM, UHF, VHF antennas; TV, microwave, UHF, VHF; towers; TV accessories; lightning arresters.

Lavie Laboratories, Morgantown, N.J.

UHF equipment, meters, receivers, transmitters, test equipment.

Lesch Relay Co., Los Angeles, Calif.

Relays, electronic and hermetic sealed.

Linde Air Products Co., New York, N.Y.

Xenon gas, synthetic crystals: calcium tungstate and calcium tungstate rods, as grown or polished (1½ inch cross section). Saphire and ruby boles and rods, titania (Rutile) boles. Fine alumina polishing powders.

Littelfuse, Inc., Chicago, III.

Fuses and fuse mountings.

Lord Manufacturing Co., Erie, Pa.

Latest developments in vibration-control mountings and equipment bases. Temperature mountings which maintain efficiency from -80° to +250° F. Radiospatial mounting bases for airborne electronic equipment under actual flight conditions.

M B Manufacturing Co., New Haven, Conn.

Industrial electronic vibration fatigue equipment for vibration testing of structures and materials to MIL-S-22, vibration measuring equipment, vibration isolators, engineering consultation for improvement of design and vibration testing laboratory service.

Machlett Laboratories, Inc., Sprague, Conn.

Electron tubes for broadcast and industrial application.


Audio amplifiers and loud speakers, magnetic recording equipment.

P. R. Mallory & Co., Inc., Indianapolis, Ind.

Mercury batteries, rectifiers, capacitors, noise filters, high frequency tuners, switches, relays, plug, vibrators, resistors, fuses, and variable.

(Continued on page 114A)
• Is your source of supply dependable in these times of critical shortages?
• Are there signs of "too little, too late"?
• Take advantage of FAR R-E-A-C-H-I-N-G Federated Purchasing Power!
• SERVICE is more important than ever—now!
• Let FEDERATED assure your smooth flow of electronic supplies.

ENGINEERS:

We cater to your professional requirements. Talk to our representatives at the Radio Engineering Show. They will tell you how we can give you specialized service.

SPECIAL RADIO SHOW OFFER

Heavy duty steel-encased Capacitors

1 MFD 10,000 VDC $24.00
2 MFD 7,500 VDC 19.50
2 MFD 12,500 VDC 38.00

Special Purpose Tubes

WL 655/658 (Westinghouse) $25.00
WL 652/657 (Westinghouse) 42.00
827 R (RCA) 59.00

"Mr. Fed" says: "You get this 1200-page Reference Manual FREE with your order."

Get it faster—the FP way! Put your name on our mailing list by writing us on your letterhead.
This versatile supply is a combination of the widely used Sorensen NOBATRON and a filter-variable output circuit. The result gives a continuously variable output voltage against line and load changes through the full range of the instrument. Look at the specifications tabulated below—check them against your requirements. Where range of output, adaptability to diverse applications is essential, the Sorensen RANGE may well be your instrument of choice.

### ELECTRICAL SPECIFICATIONS

<table>
<thead>
<tr>
<th>Model No.</th>
<th>SR-10</th>
<th>SR-30</th>
<th>SR-50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output range</td>
<td>0 - 135 VDC</td>
<td>0 - 30 VDC</td>
<td>0 - 13 VDC</td>
</tr>
<tr>
<td>Current range</td>
<td>1 - 10 amps</td>
<td>3 - 30 amps</td>
<td>5 - 50 amps</td>
</tr>
<tr>
<td>Input voltage</td>
<td>95 - 130 VAC, 50 - 60 cycles, single phase</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regulation accuracy</td>
<td>± 0.25 percent at any voltage setting from 3 VDC to top rating</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ripple</td>
<td>RMS max. 1% of output setting</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Meters — standard. Coarse and fine adjustment available.

Write for complete information

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**What to see at the Radio Engineering Show**

(Continued from page 1334)

**Firms**

Manufacturers Thread Grinding, Inc.,
Gatontown, N.J.

Wave meters and special micrometers, and component parts for the electronics trade. These wave meters and special micrometers feature high accuracy and resatability, achieved by use of special screw threads and invar materials.

Marconi Instruments, Ltd., New York, N.Y.

Industrial, electro-medical, nuclear and laboratory electronic measuring equipment. Particular emphasis on frequency measuring and generating devices from 50 kc to 9,000 kc. Universal and admittance bridges, Q meters, directional test sets and power measuring devices.

Marion Electrical Instrument Co., Manchester, N.H.

"Ruggedized," hermetically sealed electrical indicating instruments which comply with all latest government specifications, special scale-changing instruments for use in ray detection, etc., bakelite cased meters, low powered induction heating equipment and meters designed to meet special requirements.

W. L. Maxson Corp., New York, N.Y.

A precision phase meter, designed to measure the phase difference between two audio signals with an accuracy of one tenth (0.1) degree, frequency range 50-50,000 cps. Included are exhibits of Unimac snap acting switches, and Langvin Mig. Corp. transformers, audio amplifiers, etc.

McGraw-Hill Companies, New York, N.Y.

Books and publications of interest to electronic and nuclear engineers.

Measurements Corp., Boston, N.J.

Standard signal, FM signal, square wave, and pulse generators. UHF radio noise and field strength meters, megacycle meters, crystal calibrators, intermodulation meters, vacuum tube voltmeters, peak voltmeters, I.C.R. bridges, megohm meters, rf attenuators, oscillators, special test instruments.

Mepco, Inc., Morristown, N.J.

Precision resistors Jan-R-98; precision resistors standard; meter multiplier resistors Jan-R-24, resistor assemblies, special resistors.

Microwave Equipment Co., No. Caldwell, N.J.

Microwave test equipment, waveguide components, radar assemblies, microwave antennas, laboratory test instruments, waveguide test instruments.


Meters and test equipment, filters, power supplies, transformers, capacitors.

Milivac Instruments Corp., Schenectady, N.Y.

DC microvoltmeters, rf millivoltmeters, dc and low frequency millivolt-recorders.

Motorola, Inc., Chicago, Ill.

Mobile and portable radio equipment.

Mocon Corporation, Newark, N.J.

Capacitors: Ceramic, miniature Hi-K ceramic, temperature compensating, and miniature stand-off. Capacitors of special design, printed circuit assemblies, miniature noise filters. Capacitor wiper mechanism—high stability rf coils, high temperature composition resisters.


Ceramic capacitors, wire-wound resistors, potentiometers, rf and if coils, switches, loud speakers, and transformers.

Mycalex Corp. of America, Clifton, N.J.

Mycalex (glass bonded mica) insulating materials, sheets, rods and fabricated parts, capacitor dielectrics. Lucite molded components and end products such as "Mycalex 410" and "410X" tube sockets, trimmer capacitors, miniature tie-in terminals, telemetering switching devices.


Waveguide assemblies, radar components, precision instruments manufactured to your blueprints and specifications.

(Continued on page 1164)
GUIDED MISSILES using brain work for defense—
provide protection against attacking enemy aircraft.
Designed and "flight-proven" by Fairchild, this
surface-to-air missile is another development
g geared to the requirements of our Armed Services.

Homing on radar impulses reflected by attacking
aircraft, these missiles improve in accuracy as
they approach their objectives.

Designed and built by the Fairchild Guided Missiles
Division working closely with the Navy Bureau of
Aeronautics and Naval Research Laboratories,
this is an example of combining the practical and
theoretical to obtain superior results.
Multi-Channel Oscilloscopes

As specialists in multi-channel oscilloscopes, ETC offers a broad line for critical testing, production and research needs. In addition to standard types incorporating 2, 4, and 5 wave forms on a single tube, many special designs and adaptations are regularly produced for specific uses. Full details on any type will gladly be sent on request.


**DC Microvolt Meter**

The new MV-15A dc microvolt meter has a full scale sensitivity of 10 μv and an impedance of 1,000 ohms is available from Millivac Instrument Corp., P.O. Box 28, New Haven, Conn.

**Literature**

A new tube substitution manual arranged in nine parts providing text and data on general tube classifications; circuit modifications in which additional rectifiers are needed; substitute battery types; substitute 150-ma types; substitute 0-ma types; substitute transformer and generator types; TV receiver types; TV picture tube and change-over diagrams may be obtained from the Advertising Dept., Spain Electric Products Inc., Emporium, Pa.

A new folder describing paper-thin stainless steel has been published by U.S. Steel Corp., Middletown, Ohio. Complete information is given on how the material is supplied, along with typical mechanical properties. Of special importance is the description of Armo an 17-7PH thin gauge strip, which (according to the manufacturer) has a tensile strength, comparable to the best high carbon spring steel.

(Continued on page 138A)

---

**HANDBOOK OF CONTROL MOTOR DATA CHART**

Send for your free copy today.

Transicoil Products: CONTROL MOTORS, PRECISION GEAR TRAINS, INDUCTION GENERATORS, SERVO AMPLIFIERS

**TRANSICOIL CORPORATION**

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**IF**

If we could read the minds of engineers and scientists for a year ahead...

And if we could foresee equipment changes made necessary by rapidly changing conditions...

Then, and only then, would it be feasible to produce standard Transicoil Control Motors and gear trains. As things stand, however, each Transicoil motor and its gearing assembly is specifically made for a particular job—and that spells real efficiency. Transicoil makes 'em the way you want them. They're shipped to you ready for instant use without any worries about trying to adapt standard units that are only "almost right".

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**NEW PRODUCTS**

Manufacturers have invited PROCEEDINGS to write for literature and further technical information. Please mention your I.R.E. affiliation.

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Transicoil Products: CONTROL MOTORS, PRECISION GEAR TRAINS, INDUCTION GENERATORS, SERVO AMPLIFIERS

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**DC MICROVOLT METER**

The new MV-15A dc microvolt meter has a full scale sensitivity of 10 μv and an impedance of 1,000 ohms is available from Millivac Instrument Corp., P.O. Box 28, New Haven, Conn.
KINGS

Microwave Equipment

KINGS proudly introduces a new and complete line of microwave equipment. Many improvements in design and construction are your assurance of the finest in precision instrumentation. Our engineering department is ready to cooperate on your most exacting microwave and research problems. Inquiries are invited.

KINGS MICROWAVE CO., INC.

50 Marbledale Road, Tuckahoe 7, N.Y.
an affiliate of Kings Electronics Company, Inc.

News—New Product

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your IRE affiliation.

(Continued from page 137A)

Plug-in Line-Voltage Regulator

For steadier TV pictures despite line voltage fluctuations, Clarostat Mfg. Co. Inc., Washington St., Dover, N. H., offers an automatic line-voltage regulator.

The amplifiers have separate input and individual outputs and are specifically designed to be used in the video circuit of television transmission and test sets. Each amplifier has unity gain within per cent and the frequency response is such that at low frequencies a 60-cps square wave will not be deteriorated and at high frequencies, the response is down not more than 3 db at 11 Mc and 6 db at 13 Mc. The inputs of this unit are of the "biased" type and have a relatively high input impedance so that all of the amplifiers can be paralleled across a video line with minimum disturbance to the drive source. Each amplifier delivers, to a 1-ohm output line, either the same or opposite polarity of the signal it received by the operation of a toggle switch. Low-frequency compensation is of an advanced type and uses only highly stable components.

100-A Dynamic Analyzer

The 100-A, dynamic analyzer, manufactured by Industrial Control Co., 14 Undercliff Ave., New York 52, N. Y., is an instrument that facilitates the measurement of frequency and transient response of low-frequency systems by electronic methods. It is particularly applicable to the servomechanism, either as a closed loop, or in its individual components.
News—New Products

(Continued from page 138)

Of chief interest is the flexibility of the
sets. The generating mechanisms are
integrated on a separate shock-mounted
frontal chassis, which is easily accessible
through panel cutouts in the case. The
teams themselves are mounted with
board apparatus. A vertically
integrated electronic chassis furnishes the
set for the speed drive, the excitation
gears, etc. This construction allows the
manufacturer to quickly modify the unit for
special tests, by changing gear ratios, add-
signal generating components, etc.

The range of modulating frequencies is
0.1 to 50 cps for transfer function
. Phase measurements can be made
accuracies of ±1°. For the transient
damping characteristics of the first overshoot can be
In better TV reception, partic-
larly in rural districts or areas ex-
erience line-voltage fluctuations, is a
doly accessory. With male and female
connections at either end, it plugs between the TV set's attachment plug
the outlet. Two models are available:
A rated at 300 watts, for sets con-
ing 200 to 300 watts, and TV-B rated
75 watts, for sets consuming 300 to

Externally Coated
G-M Counters
The Raytheon Manufacturing Co., 55
pel St., Newton, Mass., is now using a

dispersion graphite coating as a coating on
outside of their CK1026 radiation
inter tubes.

The coating is manufactured by the

n Colloids Corp., Port Huron,

Raytheon claims to have selected this

dispersion graphite coating, known as "dag"

ersion 154, because it is chemically

, electrically conductive, opaque, and
ters well to any glass surface despite

crashing.

The unusual factor about this use of
dispersion 154 is that it is applied

durable coating on the outside
tube. A coating applied in this man-

performs the function of a mechanical

, permitting a clip to be snapped

without danger of scaling a surface when forced on or off.

Other features which the tube possesses:
all glass construction, self-quench-
ing; 800 to 950-volt operation; long life

togen atmosphere; and the ability to

in a wide temperature range.

(Continued on page 140A)
The 600-D Dynamic Microphone (T-50) is standard equipment on the famous SCR-399. It insures high intelligibility speech transmission—helps get the message through clearly. It is an example of E-V research-engineering that, over the years, has created such fine electro-acoustic products for military and civilian use.

Again E-V serves in vital communications! The 600-D Dynamic Microphone (T-50) is standard equipment on the famous SCR-399. It insures high intelligibility speech transmission—helps get the message through clearly. It is an example of E-V research-engineering that, over the years, has created such fine electro-acoustic products for military and civilian use.
In the course of a current assignment, these components were developed. We invite inquiries regarding similar requirements where an unusual approach and exceptional engineering ability and material know-how are requisites.

**NETWORKS** • **FILTERS** • **TRANSFORMERS** • **REACTORS**

**ELECTRONIC COMPUTER Corp.**

265 Butler Street, Brooklyn 17, N.Y.

Triangle 5-2324
• adds a new broadband waveguide-output klystron

Designed for high-power laboratory and antenna measurements as well as for use as a stable transmitter tube in fixed and mobile service, the new Varian X-21 Klystron covers the frequency range 9100 to 11,000 mc with power output of at least 2 watts. It is illustrated at right above. The two resonant cavities are integral and have self-contained feedback. Output mates with standard UG-39U flange for ½- by 1- by 0.050-in. waveguide. Low microphonic construction. Weight, 4½ oz.

**Typical Operation:** Frequency, 10,000 mc; beam voltage, 1270 v; beam current, 98 ma; power output, 5.9 w; load VSWR, less than 1.1.

Two tunable waveguide-output reflex klystrons: X-12 for the frequency range 12,400 to 17,500 mc, and X-13 for 8,200 to 12,400 mc, left and center in the illustration. Power output, X-12, minimum of 10 milliwatts at the ends of the tuning range. Power output, X-13, 100 milliwatts minimum. Widely used for transmitter service and as local and bench oscillators as measurement power sources. Single screw tuners cover entire frequency ranges.

**Typical Operation:**

<table>
<thead>
<tr>
<th></th>
<th>X-12</th>
<th>X-13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency, mc</td>
<td>15,200</td>
<td>10,000</td>
</tr>
<tr>
<td>Beam Voltage</td>
<td>600</td>
<td>500</td>
</tr>
<tr>
<td>Beam Current, ma</td>
<td>50</td>
<td>48</td>
</tr>
<tr>
<td>Reflector Voltage</td>
<td>326</td>
<td>475</td>
</tr>
<tr>
<td>Power Output, mw</td>
<td>50</td>
<td>400</td>
</tr>
<tr>
<td>Load VSWR, max</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>Modulation Bandwidth, mc</td>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td>Temperature Coefficient, mc per deg C, max</td>
<td>0.25</td>
<td>0.25</td>
</tr>
</tbody>
</table>

NEW, Traveling Wave Amplifier, Model 3010, using type V32 tube. Gain of 25 db ± 3 db from 2500 to 3300 mc without tuning. Useful gain with somewhat reduced bandwidth through 1800-mc region. In 56-lb portable unit, 35 by 7½ by 9 in, including focusing coil and rf matches. External power supplies. Standard Type N 50-ohm coaxial connectors for input and output.

---

### News

**Signal Splitter Eliminates Adjacent Channel Interference**

J. L. A. McLaughlin, 5729 La Jolla Blvd., La Jolla, Calif., specializing in the field of heterodyne elimination, announces the new Series 10 Signal Splitter, a selectable single-sideband converter for eliminating adjacent channel and heterodyne interference. Either sideband can be rejected with high attenuation.

The Series 10 signal splitters are a single, dual, and triple units. The latter as suitable for frequency or space diversity reception. Single and dual units as mounted on a standard rack panel 5 inches high, and triple on 8½ inches high.

**Closed Circuit TV Transmitter**

The Dumitter, just announced by the Television Transmitter Div., Allen B. DuMont Laboratories, Inc., Clifton N. J., permits TV camera signals to be distributed to a large number of standard TV receivers over connecting cables.

**Signal Splitters**

Models are available with information bandwidths of 200, 2500 and 5,000 cp within ±1 db suitable for the reception of high speed telegraphy, voice, and transoceanic broadcast reception.

Series 10 signal splitters can be employed with standard single or diversity communication receivers.

---

**Closed Circuit TV Transmitter**

The Dumitter is a compact, completely portable unit. It takes the composite video signal from any standard TV camera chain and feeds it via a single coaxial cable to the antenna terminals. A carrier signal of the frequency of either Channel 2 or 4 (optional on the Dumitter controls) is used. Up to 125 receivers can be driven simultaneously, with transmission of over several thousand feet.

(Continued on page 142A)
VARIAN MICROWAVE ENGINEERING

... produces a series of relay-link reflex klystrons

Following the modern design of other Varian waveguide-output klystrons designed for use with a matched load, this new series is engineered for uniform and stable characteristics, long life and low distortion. Intended primarily for broadband relay-link transmitter and local oscillator service, any one tube can cover a larger range with reduced performance.

Two production X-26 klystrons cover the frequency range from 6575 to 7425; four additional tubes under development complete the frequency range from 5925 to 7725 mc, each covering 300 mc. Additional tubes for frequencies up to 8200 mc can be produced to order.

High uniformity in each type and high performance characteristics are combined with simplicity of adjustments in service replacement.

TENTATIVE SPECIFICATIONS

<table>
<thead>
<tr>
<th>Electrical Characteristics</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Beam Voltage, max volts</td>
<td>750</td>
</tr>
<tr>
<td>Beam Current, ma max</td>
<td>80</td>
</tr>
<tr>
<td>Heater Voltage, volts</td>
<td>6.3</td>
</tr>
<tr>
<td>Heater Current</td>
<td>0.8</td>
</tr>
<tr>
<td>Reflector Voltage, volts</td>
<td>0 to —1000</td>
</tr>
<tr>
<td>Power Output, watts min</td>
<td>0.5</td>
</tr>
<tr>
<td>Load VSWR, max</td>
<td>1.1</td>
</tr>
</tbody>
</table>

Typical Performance, X-26B

| Frequency, mc              | 7425  |
| Beam Voltage, volts        | 750   |
| Beam Current, ma           | 70    |
| Reflector Voltage, volts   | 350   |
| Power Output, watts        | 0.75  |
| Load VSWR, less than 1.1   | 33    |
| Modulation Bandwidth, mc   | 33    |
| Modulation Distortion at ± 3 mc deviation, db | —40 |
| Temperature Coefficient, mc per deg C, less than | 0.07 |

NOW also in production, for television relay service, the Varian X-17 klystron. It covers the frequency range 1990 to 2100 mc with 5 watts minimum output power.

VARIAN associates

99 Washington St.
San Carlos, Calif.
TELEVISION & FM ANTENNA GUIDE

This excellent handbook will save you much testing and readjusting and insure the best reception from any antenna system. It gives you the characteristics, dimensions, advantages and disadvantages of all VHF and UHF antennas and allied equipment, including herefore unpublished information on new types recently tested by the authors. It tells how to determine the right type of antenna for a specific location, locate space loops, determine signal strength, etc.; how to mount various types of antennas on different kinds of roofs or window sills; how to minimize noise and avoid standing waves in transmission lines, and all other installation procedures. Handy tables give comparative data, and there is full, clear instruction in all fundamental antenna principles.

MOVIES FOR TV

This complete, practical book gives you all the information you need to choose the best equipment, operate it most efficiently, and make the most effective use of movies on TV programs. It explains the operation of all leading makes of cameras, projectors, sound and kinescope recording equipment, different types of lenses, etc., giving the advantages, disadvantages, and relative costs of each. It shows what may go wrong and how to avoid trouble, what type of picture is good on television and what is not, how to light movies for best TV reception, how to insure good shots on location, combine live scenes with movies, produce special effects, titles, newstills, different types of commercials, and much else that will be of utmost practical aid to station personnel and program planners.

RADIO & TELEVISION MATHEMATICS

This unique book of 721 problems and solutions shows what formulas to use, what numerical values to substitute, and each step in solving all problems commonly encountered in radio, television, and industrial electronics. The problems are conveniently arranged under radio and electronic topics so that you can quickly find the solution you want. Formulas listed according to use, complete tables, and a review of the use of powers of 10, the j-operator, polar vectors, etc. are given at the end of the book.

TELEVISION FOR RADIOMEN

An outstanding basic reference on the operating principles and function of every part and circuit in today's television receivers and on the chief principles of transmission together with practical instruction in installation and alignment procedures, testing equipment and how to use it, adjustment and trouble-shooting. The many illustrations include 3 large, complete diagrams of RCA, GE, and Philco projection receivers folded into the book.

Acme Electric has been identified with the electronic industry since the crystal set days. The vast store of experience that Acme engineers have accumulated over these many years can be of considerable value in helping you solve your electronic transformer problems. We offer transformer engineering cooperation and facilities to build quality transformers in quantity production.

ACME ELECTRIC CORP
443 Water Street
What to see at the Radio Engineering Show

(Continued from page 136A)

II Booth

Ceramic Radio Products, Inc., Mount Vernon, N.Y. N-6

ceramic analyzer, AP-1, for high speed visual ysis of harmonics, vibrations, noise, modulation and acoustics. Ultrasonic analyzer, SD-7, for analysis of spectrum from 2 kc and 30 kc. Sonar response testor, G-2, a visual curve tracer for to respond. Panalyzer and Panadapt for simple high speed of spectrum stud- and monitoring.

Metal Products Corp., Long Island City, N.Y. N-10

ridge Transformers, Ltd., Tolworth, Surrey, England 263
	o and power transformers. The CBF must transformer with a "C" type core a 35 octave band width.

cor, Philadelphia, Pa. 43, 44

tributions in the microwave industry. triples equipment, microwave communica- ion relay, television relays, and Lorand advance design techniques and ap- ications. Cathode-ray tubes and details miniature and sub-miniature tubes.

rad Electronics Corp., Brooklyn, N.Y. S-7

vision broadcast studio equipment, television equipment, microwave and tvatory test equipment including all- spectrum analyzer, signal generators, all sources, radio cue system.

Technic Research & Development Co., c., Brooklyn, N.Y. 268, 269

vision waveguide and coaxial compo- ns and electronic test equipment for the F and microwave ranges. Attenuators, ed sections, frequency meters, signal trators, spectrum analyzers, power eers, and bolometers.

Ver & Brumfield, Princeton, Ind. N-5

ter Instrument Co., Inc., Great Neck, L., N.Y. 135

te-speed electronic counters, counter lograms, megacycle frequency meas- ment equipment, electronic computer components.

vision Apparatus Co., Inc., Elmhurst, L., N.Y. 205

tronics and measuring instruments es, accessories, rf signal generators, FM sweep signal generators, vacuum tube meters, cathode-ray oscillographs, ed-ray tube testers, vacuum tube ters, multi-range volt-ohm-db-milliam- ters, circuit analyzers, high potential it probes, rf test probes, etc.

ato Recording Corp., Paramus, N.J. 305

heater and tape recorders, associated amplifiers, blank recording disks. Special atte ntion to recording equipment and to newly developed tape transport mechanism which nthches to any 15 inch transcription turn e. The output of this device feeds nly into ordinary speech input equip- ment.

lectric Corp., Frederick, Md. 394

etrical relays.

duct Development Co., Inc., Arlington, J. 222

eries of coaxial transmission lines (c.t.) cover all applications through the microwave frequencies. Special "Broad- band" series for continuous frequency service. Microwave antennas and reflec- ive relay towers, reflectors, reshaping equipment, adapters to cable, and solid electric cable assemblies.

iblers' Authorized Binding Service A Print Shop Binding) Chicago, Ill. 361

hibling of scientific periodicals.

amid Electric Co., North Bergen, N.J. 208

etrotic, paper and oil impreg- nated paper capacitors (flow and high- tage) for transmitting and receiving military usage. "Glasseal" hermetically packed miniature paper capacitors in metal cases, featuring a glass-metal seal.

(Continued on page 147A)

PROOFS OF THE I.R.E.

March, 1951

LOW-COST PROTECTION

for Airborne Electronic Equipment

New LORD

*TEMPREOF Mountings

- Exceed AN-E-19 Drop Test Requirements
- Designed for JAN-C-172A Equipment
- Maintain Efficiency from +80°F to +250°F

*Temperature-proof

Here is reliable vibration protection for base-mounted airborne electronic equipment... and for other apparatus which must function properly above and below usual temperatures. And TEMPROOF Mountings are priced to meet the needs of manufacturers in competitive markets.

TEMPROOF Mountings provide superior protection by maintaining their high vibration-isolating efficiency from —80°F to +250°F. Selective-action friction dampers prevent excessive movement at resonant frequencies. Equipment does not sag or droop... mounting drift is negligible. The unusually wide load range of TEM- PROOF Mountings makes it possible to standardize on one mounting for several types of equipment, and to effect additional economies in purchasing, storage and assembly.

For complete information on TEMPROOF Mountings, or for specific recommendations concerning their use, write to Product and Sales Engineering Department. A quantity of Vibration Isolation and Natural Frequency Charts in full color is available. Copy of each will be sent free upon request.

LORD MANUFACTURING COMPANY • ERIE, PA.

Canadian Representative: Railway & Power Engineering Corp., Ltd.

Vibration-Control Mountings... Bonded-Rubber Parts
Standard
RADIO INTERFERENCE
and FIELD INTENSITY
Measuring Equipment
Complete Frequency Coverage - 14 kc to 1000 mc!

VLF!
NM - 10A
14kc to 250kc
Commercial Equivalent of AN/URM-6.
Very low frequencies.

HF!
NM - 20A
150kc to 25mc
Commercial Equivalent of AN/PRM-1.
Self-contained batteries. A.C. supply optional. Includes standard broadcast band, radio range, WWV, and communications frequencies.

VHF!
NMA - 5
15mc to 400mc
Commercial Equivalent of TS-587/U.
Frequency range includes FM and TV Bands.

UHF!
NM - 50A
375mc to 1000mc
Commercial Equivalent of AN/URM-17.
Frequency range includes Citizens Band and UHF color TV Band.

These instruments comply with test equipment requirements of such radio interference specifications as JAN-1-225, ASA C63.2, 16E4(SHIPS), AN-I-24a, AN-I-42, AN-I-27a, AN-I-40 and others.

STODDART AIRCRAFT RADIO CO.
6644-C SANTA MONICA BLVD., HOLLYWOOD 38, CALIFORNIA
Hillside 9294

MANY NEW DEVELOPMENTS AND DESIGNS
for MILITARY & CIVILIAN USE
by HUGH H. EBY, INC.
BOOTH 346 I.R.E. SHOW

• sockets
• connectors
• jacks
• terminal strips
• binding posts

Hugh H. EBY, INC.
4700 Stenton Ave.
What to see at the Radio Engineering Show

(Continued from page 145A)

in Booth

Electric Co., Inc., New York, N.Y. 314

all speakers for all industrial, commercial, and military applications.

Corporation of America 4 to 9

Victor Div., Camden and Harrison, N. Y., tube parts and machinery, broadcast and test equipment, electronic components.


Electronics, New York, N. Y. S-2

Electronic magazine, technical articles in the field of radio-television, also exhibiting the "Electronic Library" books, 15 low priced technical books dealing with radio, audio, and servicing.

Magazines, Inc., New York, N. Y. 94A


Materials Corp., Chicago, Ill. 338

ilacps"; ceramic capacitors guaranteed for lifetime, temperature compensating types, general purpose types.

Receptor Co., Inc., New York, N. Y. N-16

imum rectifiers and customers' equipment showing application of rectifiers, and stress test runs on small wave rectifiers at 20,000 for bias application, and bridge rectifiers at 40 mA, vibrations running to many kilowatts, a dielectric heating machine with a motor manufactured thereon.

& Television News,"- Electronic Engineering" Davis Publishing, Chicago & New York

gines, Inc., New York, N. Y. 271

et recording oscillographs, and all types. A new circuit element that may used as an oscillator, filter or oscillator is very high sensitivity and stability.

erone, Inc. Newark, N. J. Theatre 312A

netic tape recorders.

and Corp., Chicago, Ill. 344

vision tubes.

these Manufacturing Co., Alhambra, Mass.

tronic tubes, radio components, stored ray welding equipment, magnetic tape using mechanism for automatic digital computer and precision sound depth sounders.

es Instrument Corp., New York, N. Y. 144

AEAC differential phase measuring equipment has made the mathematical approach to rectifier and engineering problems economically feasible. Precision induction type power bars for 400 and 1,000 volt operation, standard instrumentation parts and servo-systems, components, constituting a complete producing engineering, control and test equipment.

es Soundcraft Corp., New York, N. Y. Theatre 312B

ink transcription and recording disks, magnetic sound recording film, magnetite film, television picture tubes, magnetic recording tape.

ness Manufacturing Corp., Montclair, N. J., N. Y. Set metal fabrication of exacting standards, engineering and design.

F. Rider Publisher, Inc., New York 243

Ser Service Manuals (AM-FM-TV-P.A.), electronic textbooks, one of the most recent being the "Encyclopedia on Cathode Ray Oscillographs and Their Uses." Specialized service of the organization is the publication of technical literature.

inson Aviation, Inc., Teterboro, N. J. S-4

iation control engineers demonstrating the use of vibration and shock control units, presses and systems, Met-Flex, the all-weather recycled mounting system, Special and engineered mounting systems.

(Continued on page 149A)

P R E S T O . . . . most carefully made recording discs in the world

step 0 - sealing and packing

Lacquer recording surfaces are vulnerable to grit and dust and need complete protection from these abrasives. The smallest particle of dirt between adjacent discs can result in permanent damage to their surfaces, showing up in "pops" or "clicks" when reproduced.

At PRESTO, the last, and one of the most important steps in disc production, is air-tight sealing and packing. Discs are sandwiched between specially treated fibre end pieces. The entire rim of this circular stack of discs is then sealed with tape and they are carefully packed in triple-reinforced cartons ready for shipment around the world.

This extra protection against surface damage is still another reason why PRESTOS are known and preferred as the finest, most permanent recording discs available.

Visit PRESTO's booth at the I R E SHOW March 19th to 22nd at New York City

RECORDING CORPORATION

Parsons, New Jersey

Mailing Address:

Box 500, Hackensack, New Jersey

In Canada:
Walter P. Dwyer, Ltd.
Dominion Sq. Bldg.
Montreal, Canada

Overseas:
M. Simon & Son Co., Inc.
25 Warren Street
New York, New York
In the laboratory...

In the field...

Repeated tests by leading set manufacturers prove it to be **Best!**

**the Tarzian Tuner**

Tops in overall performance
High in quality
Low-priced — offering maximum performance per dollar cost

Manufacturers are invited to:
1. Write for complete technical data
2. Request engineering service
3. Write for prices and availability
4. Inquire about latest, advanced developments

**SARKES TARZIAN, INC.**
**TUNER DIVISION**
Bloomington, Indiana

**OTHER TARZIAN-MADE PRODUCTS**
- Air Trimmers
- Centre-Kooled Selenium Rectifiers
- Cathode-Ray Tubes

**STATIONS WTTTS (5000 WATTS) AND WTTV (CHANNEL 10)**
Owned and operated by SARKES TARZIAN in BLOOMINGTON

**NORTHERN RADIO**
**Diversity Receivers**

**for the best in**
**DIVERSITY RECEPTION**

Integral assemblies of 2 or 3 specially designed Receivers with self-contained power supplies, Master Oscillator, IF Monitor, and Modulation Selector Panel. Supplied with any combination of terminal equipment for reception of radio tele-printer, undulator tape and program service, or for remote use where intelligence is transmitted via landline or UHF link.

See the specifications in the 1950 I.R.E. Directory. For complete data on the precision-built Northern Radio line, write today for your free latest Catalog P-4.

Visit our Display, Booth 307, IRE Show N.Y.C., Mar. 19-22

**NORTHERN RADIO Co., Inc.**
143 West 22nd Street, New York 11, N.Y.

Pace-Setters in Quality Communication Equipment
What to see at the Radio Engineering Show

(Continued from page 147A)

Electronic Associates, Inc., is a co-ordinated group of electronic engineering consultants fully equipped to perform electronic research, development and production. They include engineering, production, and administrative personnel capable of handling a wide range of problems including design studies, applied research, and the production of highly complex electronic devices.

More detailed information will be furnished on request.

Electronic Associates, Inc.
Long Branch, New Jersey

RESEARCH - DEVELOPMENT - PRODUCTION

"Black boxes" to your specifications

RESEARCH - DEVELOPMENT - PRODUCTION

Plotting Boards—such as the Variplotter Model 205 Series for accurately presenting X vs Y, curve following, point plotting, etc.

Special Test Equipment

Computer Potentiometers

Regulated Power Supplies

Electronic Associates, Inc.
Long Branch, New Jersey

Plant facilities comprise laboratories; model, welding and machine shops; paint, anodizing, and test departments; assembly and tool rooms; foundry and other contributing functions of production.

A few of the many products the Concern has manufactured are illustrated here.
STANCOR

High-Fidelity

Output Transformers

±1 db FROM 20 TO 20,000 cps

Premium Quality at Low Cost

Stancor has taken advantage of the most advanced design and manufacturing practices to bring you a series of output transformers combining outstanding audio response with very moderate cost.

Extensively interleaved "trifilar" windings, extremely tight coupling, and careful electrical balance result in audio fidelity to please the most critical specialist. An inexpensive, but thoroughly practical, type of mounting is used since elaborate shielding is not required at the audio output power level.

Listed part numbers have a maximum power level rating of 50 watts and provide a wide selection of impedances for popular amplifier applications.

<table>
<thead>
<tr>
<th>PART NO.</th>
<th>PRI. IMP. (P.P.)</th>
<th>SEC. IMP. IN OHMS</th>
<th>MAX. PRI. D. C. PER HALF</th>
<th>NET PRICE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-8050</td>
<td>1500</td>
<td>B, 16</td>
<td>200 ma</td>
<td>$10.86</td>
</tr>
<tr>
<td>A-8051</td>
<td>2500</td>
<td>B, 16</td>
<td>150 ma</td>
<td>10.86</td>
</tr>
<tr>
<td>A-8052</td>
<td>3000</td>
<td>B, 16</td>
<td>125 ma</td>
<td>10.86</td>
</tr>
<tr>
<td>A-8053</td>
<td>5000</td>
<td>B, 16</td>
<td>150 ma</td>
<td>10.86</td>
</tr>
<tr>
<td>A-8054</td>
<td>9000</td>
<td>B, 16</td>
<td>100 ma</td>
<td>10.86</td>
</tr>
<tr>
<td>A-8060</td>
<td>1500</td>
<td>500</td>
<td>200 ma</td>
<td>10.86</td>
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<tr>
<td>A-8061</td>
<td>2500</td>
<td>500</td>
<td>150 ma</td>
<td>10.86</td>
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<tr>
<td>A-8062</td>
<td>3000</td>
<td>500</td>
<td>175 ma</td>
<td>10.86</td>
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<tr>
<td>A-8063</td>
<td>5000</td>
<td>500</td>
<td>150 ma</td>
<td>10.86</td>
</tr>
<tr>
<td>A-8064</td>
<td>9000</td>
<td>500</td>
<td>100 ma</td>
<td>10.86</td>
</tr>
</tbody>
</table>

For complete specifications and prices of more than 450 stock part numbers, including other high fidelity transformers, see the current Stancor catalog. Ask your distributor for a copy or write direct.

STANDARD TRANSFORMER CORPORATION
3582 ELSTON AVENUE, CHICAGO 18, ILLINOIS
Here's why those in the know—demand

**CANNON PLUGS**

**Time Delay Generator**

The Model A2 time delay generator, designed by the Rutherford Electronics Co., 241 S. Robertson Blvd., Culver City, Calif., produces variable time delays ranging from 0.4 microsecond to 100,000 microseconds. Five delay ranges are provided, giving a full scale reading of 10 microseconds on the lowest range and progressing by decade steps to the highest range of 10,000 microseconds. Blocking oscillator and single shot multivibrator output waveforms are provided.

Your requirements are responsible for the 8 to 10 design advantages found in each type of Cannon Plug. That's why engineers know the specification is right when it calls for CANNON. The DP Connector Series is just one of many Cannon types—world's most complete line. Request bulletins by required type or describe connector service you need.

**CANNON ELECTRIC**

Since 1915

LOS ANGELES 31, CALIFORNIA

REPRESENTATIVES IN PRINCIPAL CITIES

SEE THE LATEST DESIGNS IN CANNON PLUGS AT THE RADIO ENGINEERING SHOW IN NEW YORK, MARCH 19-22.
Before Thomas and Skinner Engineers were called in by Associated Research, Inc., to redesign the permanent magnet assembly for the Keeler Polygraph, commonly called the "lie detector," the magnetic unit weighed a total of 5.57 pounds.

After redesigning, the unit weighed only 2.93 pounds— with the bonus of 30% more gauss in the air gap.

The compact, weight-saving unit engineered by Thomas and Skinner consists of .58 of Alnico V, 1.82 pounds of iron circuit and 0.47 pounds of pole pieces . . . compared with the old assembly of 5.10 pounds of Alnico I and 0.47 pounds of pole pieces.

This material saving, space saving application is typical of the permanent magnets by Thomas and Skinner. Behind every recommendation is the accumulated experience of 50 years of specialization in problems of this type—a half century of designing, engineering and producing magnetic units.

Call in Thomas and Skinner for a review of your permanent magnet applications.

Specialists in magnetics: permanent magnets and laminated cores

THOMAS & SKINNER Steel Products Company  
1120 East 23rd Street • Indianapolis, Indiana

Universal dependability

The "Planet" trade name marks the most completely reliable line of popular type, dry electrolytic condensers that high-quality materials, the best workmanship, and long experience can produce.

All "Planet" Capacitors carry a 1-year replacement guarantee, are attractively packaged, and manufactured in specifications and mounts best suited to your needs.

For complete information write today for our latest catalog "C-2".
What to see at the Radio Engineering Show
(Continued from page 149-A)

Firm Booth
Sprague Electric Co., North Adams, Mass. 27, 28 311
Capacitors, resistors, radio noise filters, magnetic wire, hearing aid batteries.
Square Root Mfg. Co., Yonkers, N. Y. 231
Antennas, corona shield horizontal deflection transformers, tubular capacitors, high volt-
age capacitors, ceramic disk capacitors, toroidal coils.
Standard Electric Time Co., Springfield, Mass. 270
Timers, chronometers, custom-built voltage distribution and test panels, clock systems, hydraulic network analyzers.
Standard Pierzo Co., Carlisle, Pa. 203
Quartz crystal units for frequency control.
Standard Transformer Corp., Chicago, Ill. 360
Transformers, reactors, power supplies.

Model 359

SPECIAL ACCURATE

• Dynamic Mutual Conductance . . .
  Readings in Micromhos.
• Permits choice of 3 A.C. signals, .25, .5, and 2.5 volts.
• Vaneer adjustment permits accurate setting of grid voltage.
• Optional self-bias arrangement.
• Provision for insertion of plate milli-
  ammeter for measuring plate current.
• Separate A.C. meter measures line
  voltage at all times.
• D.C. grid bias and D.C. plate and
  screen voltages.
• Tube life and gas test for accurate
  matching of tubes.
• Tests all tubes normally encountered
  in all phases of electronic work.
• Designed with professional accuracy
  for engineers and engineering tech-
  nicians.

See the Model 539 at your jobbers or
write for additional information today!

The HICKOK ELECTRICAL
INSTRUMENT COMPANY
10551 Dupont Ave., Cleveland, O. 0.

Our 10th Anniversary

PROCEEDINGS OF THE I.R.E. March, 1951

New Rider Publications—

Encyclopedia on Cathode-Ray Oscilloscopes and Their Uses
by John F. Rider and Seymour D. Uslan

• THIS IS THE ONLY BOOK that completely
covers the oscilloscope as a laboratory fa-
cility. All scopes produced during the past
10 years—more than 70 different models—are
clearly described, with specifications and
wiring diagrams. Planned to serve all bids,
the book is especially valuable to engineers
in various forms of research.

An outstanding feature of the encyclopedia
is the comprehensive compilation of 1,600
complex waveform patterns listing the har-
monic content and the exact phase and amplitude
of each. This information has never before
been published.

CONTENTS: Introduction; Principles of Electrostatic
Deflection and Focusing; Principles of Electromagn
etic Deflection and Fo-
cusing; Mechanical Character-
istics; The Electron Gun Design; Horizontal and
Vertical Screens; Spot Displacement; Linear Time Bases
(Sweep Circuits); The
Basic Oscilloscope and Its Modifications;
Synchronization: Phase and Frequency Meas-
urements; Nonlinear Time Bases; Auxiliary Equip-
ment; Testing Audio Alignment of AM, FM, and TV Receiv-
ers; Waveform Observa-
tion in Television Receivers; AM, FM, and TV
Transmitter Testing; Electrical Measur-
ments and Scientific and Engineering Applica-
tions; Complex Waveform Patterns; Special Purpose Cathode-Ray Tubes; Commercial
Oscilloscopes and Related Equipment. Appen-
dixes: Characteristics of Cathode-Ray Tubes;
Cathode-Ray Tube Basing; Photography. Bib-
liography, Index.

992 pp. • $9.00

Vacuum-Tube Voltmeters (2nd Ed.)
by John F. Rider

• THE ONLY BOOK devoted entirely to the
subject of the vacuum-tube voltmeter, the
new edition is completely rewritten and twice
the size of the original. After outlining un-
derlying theory, it goes on to discuss design,
construction, calibration, maintenance, and
applications. The emphasis is on practical
considerations, specially valuable are the
step-by-step procedures applying the device
to many uses.

CONTENTS: Fundamentals of Vacuum-Tube Volt-
eters; Diode Vacuum-Tube Voltmeters; Triode
Vacuum-Tube Voltmeters; Selsyn, tetrode
- amplifier, Vacuum Tube Voltmeters;
Tuned Vacuum-Tube Volt-
ometers; Tuned Vacuum-Tube Volt-
meters; Slide-back Vac-
um-Tube Voltmeters; Vacuum-Tube Volt-
meters for D.C. Voltage, Current, and Resistance
Measurements; Probes for D-C and R-F
Design and Construction, Calibration, Applica-
tion and Testing. Vacuum Tube Volt-
meters, Bibliography, Index.

380 pp. • $9.00
WIRÉS -- Measured, Cut and Stripped Automatically Fast at Low Cost

This IS WHAT YOU GET BY USING ARTOS AUTOMATIC MACHINES

1. Cut wires from 1” to 60’ in length
2. Strip up to five inches
3. Handles wires from 26 gauge to 000 gauge

Applications of Artos Machines throughout the automotive, radio, telephone, and electrical appliance industries have the economy-improving efficiency-increasing values of fully automatic cutting, measuring, and stripping of wires.

Artos machines are available in a variety of models. There is probably one to meet your exact requirements, in either bench or floor models.

Artos Engineering Co.
DEPT. IR, 2735 S. TWENTY-EIGHTH STREET • MILWAUKEE 46, WIS.

PARTRIDGE

the AUDIO TRANSFORMERS that pass all tests!

The test of time, no less than test by leading technicians, has proved the range of Partridge Audio Transformers to be the most efficient and reliable in the world. For example the famous

*WILLIAMSON Output TRANSFORMER, of which there is no U.S. equivalent (vide "Audio Engineering" Nov. 1949) is produced to the original specification and comes to you for $21.00, mail and insurance paid. Then there is the

*PARTRIDGE CFB 20 Watt output type, universally accepted as without rival anywhere. Here are some brief figures: Series leakage induct. 10 mH, primary shunt induct. 130 H, with C core construction and hermetically sealed—to you for $30.00, mail and insurance paid.

Send for fullest data, including square wave tests, distortion curves etc. We'll rush this Air Mail together with list of U.S. stockists.

YOU CAN JUDGE FOR YOURSELF of the RADIO ENGINEERING SHOW, N.Y.
(STAND 263) March 19th-23rd 1951 where the range of Partridge Audio transformers is being exhibited.

NOTE. We despatch by insured mail per return upon receipt of your ordinary dollar check.

Jobbers are invited to handle the transformers that the States is eager to buy—remember, immediate delivery from large stocks in New York!

PARTRIDGE TRANSFORMERS LTD.
ROEBUCK ROAD • TOLWORTH
SURRY • ENGLAND
What to see at the Radio Engineering Show

(Continued from page 155A)

Firm Booth
Superior Electric Co., Bristol, Conn. 106, 109, 110
Powerstat variable transformers, stabiline automatic voltage regulators, type EM electro mechanical), automatic voltage regulators type IE (instantaneous electronic), dc power supplies, ac power supplies, 3-way binding posts.

Superior Mfg. Co., Boston, Mass. 72
New high temperature wire insulators, hook-up wires, hook-up aircraft thermal couple telemetry wire.

Wally Swank, Syracuse, N.Y. 221

Switchcraft, Inc., Chicago, Ill. 337
Phone jacks, phone plugs, microphone jacks and plugs, telephone and military type jacks, push button switches, rotary switches and lever-action switches, and associated products.

Syntex Corporation, Oaks, Pa. N-1
Laminated plastics products; sheets, rods, tubes, fabricated parts, molded laminated and molded macerated products.

(Continued on page 157A)

TOWER, MAST and ANTENNA SUPPORT

Headquarters

- Guyed supporting towers for TV-FM antennas
- TRYLON Vertical Radiators
- Micro-wave relay towers
- Complete antenna systems with switching units
- Communications antenna supports ... and dozens of special items

Hundreds of installations in all parts of the world, under all conditions of use attest to Trylon Tower dependability. As specialists in antenna supports for over 18 years, Trylon offers a broad, time-tested line of standard units plus complete facilities for the economical production of special types and designs.

Write for literature on any desired type—or, better yet, outline your antenna support problem for recommendation by Trylon specialists.

See Us at Booths 47-48, I.R.E. Show

TRYLON

Trylon Towers are made only by

WIND TURBINE CO.

WEST CHESTER, PA.
ELECTRONICALLY REGULATED
LABORATORY
POWER SUPPLIES

AS EXHIBITED AT THE-
Radio Engineering Show
Grand Central Palace

Our 1951
Advance
March 19-22 1951

BOOTH #345
VISIT OUR DISPLAY
OF CURRENT AND
NEW MODELS

LAMBDA ELECTRONICS
CORPORATION
CORONA NEW YORK

ELECTRONICALLY REGULATED
LABORATORY
POWER SUPPLIES

- INPUT: 105 to 125 VAC, 50-60 cy
- OUTPUT #1: 200 to 325 Volts DC at 100 ma regulated
- OUTPUT #2: 6.3 Volts AC CT at 3A unregulated
- RIPPLE OUTPUT: Less than 10 millivolts rms

For complete information write for Bulletin G

LAMBDA ELECTRONICS
CORPORATION
CORONA NEW YORK

ELECTRONICALLY REGULATED
LABORATORY
POWER SUPPLIES

- INPUT: 105 to 125 VAC, 50-60 cy
- OUTPUT #1: 200 to 325 Volts DC at 100 ma regulated
- OUTPUT #2: 6.3 Volts AC CT at 3A unregulated
- RIPPLE OUTPUT: Less than 10 millivolts rms

For complete information write for Bulletin G

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I.R.E. SHOW

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N. Y. 12, N. Y.
What to see at the Radio Engineering Show
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Firm
Booth
Tech Laboratories, Inc, Palisades Park, N. J. 211
Reverberation generator, attenuators, potentiometers, switches.
Tech-Master Products Co., New York, N. Y. 267
Improved custom quality 60 type TV bas and kit, TV conversion kits, booster kits, automatic gain control kits, TVlarity TV components, adjustable knife edge mounting brackets. New Lo-Cost Universal TV Kit.
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- MORE OUTPUT . . . LOWER COSTS . . . from EXCLUSIVE SPEED FEATURE. Universal motors permit variable speeds without changing belts and pulleys. Coil design permitting, speeds as high as 7500 RPM are not uncommon.
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- EASIEST TO OPERATE. In one hour, any girl can learn to operate a GEO. STEVENS machine.

Transformer winder Model 375 multiple winds power, audio, automotive, fluorescent ballast and similar types of coils. Winds wire from No. 18 B&S to 46 B&S up to 9" O.D. Maximum economy is possible by using mandrels up to 30" long. Thirty or more coils may be wound at one time. All turns are accurately registered by Model 50 or 51 6" full vision clock face Dial Counter. Set-ups can be changed in less than 5 minutes. A gear chart is furnished to quickly determine wire spacing.

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Paper feed:—A tilting table for pre-cut paper is furnished making paper feed simple and fast, or a new roll paper feed for extra economy is available at a small additional cost.

Motor equipment:—Variable speed, uniform torque 1/2 H.P. motor with foot treadle control.

Tension equipment:—12 T-1 tensions and spool rack. Tensions will handle 6" spools.

Mounting:—Ground steel channel base ensures rigidity and permanent alignment. Machine is shipped mounted on bench ready for use.

There is a GEO. STEVENS machine for every coil winding need. Machines that wind ANY kind of coil are available for laboratory or production line. . . Send in a sample of your coil or a print to determine which model best fits your needs. Special designs can be made for special applications. Write for further information today.

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ROCEEDINGS OF THE I.R.E. March, 1951

PROCEEDINGS OF THE I.R.E.
Manufacturers and Designers of
Continuously Variable
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Model
D6-DUAL,
Heavy Duty

- DUAL regulated outputs, continuously variable, 0 to 600 volts.
- Maximum current 200 milliamperes each, or 400 combined.
- Regulation better than .5%.
- 6.3 volts AC at 10 amperes center-tapped.
- Ripple voltage less than 10 millivolts.
- Stabilized bias supply.
- Request Bulletin 53 for Detailed Information.

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- Continuously variable, 0 to 350 volts.
- Ripple voltages less than 10 millivolts.
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Economy Way to Get Volume!
If it's VOLUME you need on small tubular metal parts similar to these, be sure to look into Bead Chain's MULTI-SWAGE Process. Send the part (up to \(\frac{3}{4}\)" dia. and to \(1\frac{3}{4}\)" length) and your specs for a quotation. Chances are you'll find a new way to effect important savings.

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Many prominent users of solid pins for electronic and mechanical purposes have cut costs by switching to Multi-Swaged tubular pins... without sacrificing strength or accuracy. Often this is possible to accomplish.

Typical Applications —
As terminals, contacts, bearing pins, stop pins, male-female connections, etc., in a wide variety of electronic and mechanical products: — Toys... Business Machines... Ventilator louvres... Radio and Television apparatus... Terminal-boards... Electric Shavers... Phonos Pick-ups, etc. For DATA BULLETIN, write to

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Manufacturers of BEAD CHAIN — the kinkless chain of a thousand uses, for fishing tackle, novelty, plumbing, electrical, jewelry and industrial products.

PROCEEDINGS OF THE I.R.E. March, 1951
What to see at the Radio Engineering Show

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Has a special department making Unusual Cables for the electronic field

May we quote on your GOVERNMENT SPECIFICATIONS

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Shielded or Unshielded
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Processed by a cable with these extra features:

- Special termination for 1900 series crystals;
- Special type 1900 series multi-frequency crystal generator;
- Type 2000 monochrome camera, type 11 video distribution amplifier.

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Whether it's TUBES or HERMETICS you can be sure of POSITIVE LEAK TESTS by using the VEECO MASS SPECTROMETER LEAK DETECTOR

This instrument is a simplified, portable Mass Spectrometer, specifically designed to be extremely sensitive to Helium.

In operation, a jet of Helium is directed at points of suspected leakage. When a leak is encountered, the Helium serves as a "tracer," and flows to the Leak Detector where it immediately produces a visual or audible signal. It's that simple. Even unskilled personnel can operate it.

The Veeco Leak Detector is being used by leading manufacturers of electronic tubes and hermetically sealed devices. It has been proved to be the fastest, most sensitive device for precisely locating very small leaks. One manufacturer reports that the Veeco paid for itself in 36 hours!

Stop in for a demonstration or send your sample for test.

Write for Literature LD-3.

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AS EXHIBITED AT THE-
Radio Engineering Show
Grand Central Palace
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March 19-22 1951

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Can Be Your Problem...

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Made Only by
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The First
All-Metal • All-Weather
Shock Mounting Systems

First with MET-L-FLEX, Robinson pioneered, in 1946, all-metal, all-weather vibration and shock mounting systems. Built for the electronic and instrument panel installations of today's high performance commercial and military aircraft, more than 50,000 all-metal systems have been delivered. Robinson MET-L-FLEX unit mounts and complete mounting systems meet specifications JAN-C-172A and AN-E-19. Mounting systems in JAN form factors and special designs are available—write today for full engineering data.

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TETERBORO, NEW JERSEY
Vibration Control Engineers

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...But It's Our Business

Metec...
MEMBERS AND GUESTS OF THE I. R. E.

Engineers of the Hughes Research and Development Laboratories will be attending the I.R.E. convention in New York. Many of these men were formerly located in the eastern area and are anxious to renew old acquaintances during this brief sojourn from their various research and development assignments in the general fields of advanced electronics, guided missiles, automatic control, synthetic intelligence, and precision mechanical engineering.

Friends and former associates of Hughes representatives are cordially invited to contact us during the sessions, at the show, or through the Headquarters of the Hughes Research and Development Laboratories at the New York Office, Telephone Pl.aza 7-7343.

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Hughes Aircraft Company
CULVER CITY, CALIFORNIA

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- Core and Coil encased in molded self-extinguishing plastic
- No rejects from careless handling
- No supersonic singing
- No corona discharge
- No fire hazard
- Moisture proof

Used in high efficiency 66°-70° circuit provides full deflection with up to 14KV anode potential

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See, too, the
NEW SQUARE ROOT complete line of CONDENSERS
Glass . . . Paper . . . Ceramic

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1951 ALLIED CATALOG

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One Complete Dependable Source for Everything in Electronics

Simplify your purchasing—send your consolidated orders to ALLIED—the single, complete source for all Electronic Supplies. Depend on ALLIED for the world's largest stocks of special tubes, parts, test instruments, audio equipment, accessories—complete quality lines of electronic supplies. Our expert Industrial supply service saves you time, effort and money. Send today for your FREE copy of the 1951 ALLIED Catalog—the only complete, up-to-date guide to Electronic Supplies for Industrial and Broadcast use.

ALLIED RADIO CORP.
833 W. Jackson Blvd., Dept. 35-C-1, Chicago 7, Illinois

SEND FOR FREE 1951 ALLIED CATALOG
Filamentary Type Beam
Power Output Pentode

A new Type 5851, ruggedized subminiature tube, has been announced by the National Union Radio Corp., 350 Scotland Rd., Orange, N. J.

Designed for use in military and other applications where the tube is subjected to excessive shock and vibration, this tube is suitable for frequency doubler operation up to 400 Mc producing 120 milliwatts. The 5851 filament requires only 55 ma current at 2 1/4 volts; it also may be operated at 11 volts at 110 ma.

This tube in T-3 envelope has a plate dissipation rating of 1 1/2 watts. As a class-A amplifier, it will deliver 650 milliwatts audio output at 10 per cent total harmonic distortion.

The 5851 is designed and tested for shock at 500 g. It may be soldered into the circuit or used with a standard subminiature socket.

Ratings and mechanical data can be obtained by requesting 5851 data sheet.

Scientific Electric has been a designer and manufacturer of scientific electrical equipment for metallurgical research and bombarding of vacuum, X-ray, neon, fluorescent, and television tubes since 1921. The units we build are not restricted to degassing tubes, but are also used for making glass-to-metal seals (as in metal TV tubes), for surface hardening, brazing, silver soldering, soft soldering, and annealing of metals.

Induction heating units built by Scientific Electric, with stepless control from 0 to maximum, are known to electronic manufacturers the country over, a majority of whom employ our high-frequency equipment for many of the uses outlined above. They have found that faster production at lower unit-cost is the result. See us at BOOTH 60—Radio Engineering Show

Five Kilowatt
BOMBARDER

This induction heating unit is very popular with cathode-ray and receiving tube manufacturers. Available in high-bay (occupies floor space 12" x 24") or low-bay (occupies floor space 25" x 30") metal cabinets. Line R.F. filters keep radiation to a low value. Output is continuously variable and designed to match a wide range of load coils. Let us install this bomber in your production line to speed up production and reduce costs. Input voltage 220v. 60 c.p.s. single phase.

Custom-Built SPOT WELDERS

High-capacity, condenser discharge bench welders with stepless power control and vernier pressure adjustment, for the vacuum tube industry. Unit is mounted underneath work bench (except for welding electrodes and supports) leaving the work area free and uncluttered by transformers, controls, and mechanical equipment. Standard units are made in sizes from 50 mf.d. to 2,500 mf.d., custom-built units to your requirements.

Both units are 3 1/2" wide, 10 1/2" high, 8" deep. The heads can be tilted backwards 30° from normal upright position. Power supply available for these welders in kilowatt ratings of 1/8, 1/2, 3/4, 1, and 2 KVA stepless power control.
NOW! A Better Frequency Standard Crystal

THE JKG-9

* Absolute Hermetic Sealing
* Dependable Vacuum
* Higher Q
* No Supersonic Reflections
* Greater Stability

JAMES KNIGHTS takes pride in presenting the JKG-9, first of a series of new crystals employing a glass envelope for absolute hermetic sealing. A dependable vacuum can be maintained, resulting in higher crystal Q and absolute freedom from the effects of supersonic reflections.

Although now available only in limited quantities and only in the 90 to 200 kilocycle range, it is planned to use this mounting on higher frequencies.

Excellent thermal insulation is afforded by the glass and vacuum, utilizing the principle of the thermos bottle. In oven operation, for instance, a thermostat cycle of several degrees will result in a change of only a fraction of a degree at the crystal—providing stability never before possible!

LESS CRYSTAL “AGING”—Greater cleanliness is achieved in the new JKG-9 because glass is not porous and does not degas as does metal. Temperatures that would be destructive to the characteristics of a crystal are necessary for complete degassing of metal holders, whereas clean glass holders are relatively easy to degas. Because no fumes are emitted by the sealing operation, crystal “aging” is substantially reduced.

With minimum power dissipation, as employed in modern oscillator design, the new JKG-9 provides a new standard of stability plus years of trouble-free precision operation.

STANDARD SIGNAL GENERATOR

MODEL 84—300-1000 Megacycles

OUTPUT VOLTAGE: Continuously variable from 0.1 to 100,000 microvolts. Output impedance, 50 ohms.

MODULATION: Sine Wave: 0-30%, 400, 1000 or 2500 cycles. Pulse: Frequency, 60 to 100,000 cycles. Width, 1 to 50 microseconds. Delay, 0 to 50 microseconds. Sync. output, up to 50 volts, either polarity.

POWER SUPPLY: 117 volts, 60 cycles. (Also available for 117 volts, 50 cycles; 220 volts, 60 cycles; 220 volts, 50 cycles.)

DIMENSIONS: 12” high x 26” wide x 10” deep, overall.

WEIGHT: Approximately 135 pounds, including external line voltage regulator.

MEASUREMENTS CORPORATION

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Check BUD "STANDARDS"

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* Many items which you may consider SPECIAL are regular stock items in the extensive BUD line. We manufacture over 2200 different electronic components and sheet metal products, any one of which may be just what you need. Regardless of whether you make these types of products or purchase them from outside suppliers, it will pay you to investigate our specialized production facilities. Do this now—and avoid costly delays when a SPECIAL is required.

Since we make so many different sheet metal products and electronic components, you will find that one of our stock items will fulfill your requirements. In addition, a slight change in one of our standard models will eliminate your paying for and waiting for special tools, dies and other equipment. This means lower costs and faster delivery for you!

Whether your requirements are large or small, we save you time and money. Our engineering department is available without obligation for consultation on your problems. Send us your blue prints for estimates, or our representative will call at your convenience.

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Nickel alloy, filament wire and ribbon: flat—grooved—crowned.

Grid wire electroplated.

Alloys for special requirements.

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at the I.R.E. Show

March 19, 20, 21, 22

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GALVANOMETERS

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dependable instruments

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A model for every use.
10 — 500 cycles AC
Meets AN Specifications also 60 cycles
Single pole and double pole
Make-before-break contacts
Contacts in air or in liquid

See

Complete HEILAND LINE
at the Radio Engineering Show
BOOTH 336

These Choppers convert low level DC into pulsating DC or AC so that
servo-mechanism error voltages and the output of thermocouples
and strain gauges, may be amplified by means of an AC rather than a
DC amplifier.
They are hermetically sealed, precision vibrators having special
features which contribute to long life and low noise level.

STEVENs ARNOLD INCORPORATED
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WRITE FOR THESE CATALOGS...
280
10-500 cycles
246A
60 cycles

166
What to see at the Radio Engineering Show

Itron Booth

Itron Instrument Co., Cleveland, Ohio 362

Instruments for X-ray and radioactivity measurement, dosage control, personnel protection, health survey, decontamination quality control, prospecting and civil defense. Components for radiation measuring instruments, including Hi-Meg Resistors, Geiger-Counter tubes, electrometer tubes, high voltage regulators and other miniature electronic tubes. The Model 89 Portable Survey Meter, Model 517 Voltage Regulator Power Supply, Model 510 Roentgen Ameter, Model 522 Detector-Meter and Model 521 Accelerometer.

Itron Inc., Stepeny, Conn.

Capacitors, groups of capacitors and capacitors with circuitry contained within nephlovs, glass-like ceramic bodies.

Valdes Robinson Inc., Long Island City, N.Y.

Trilux retaining rings will be exhibited and demonstrated. Actual application of he rings in a diverse number of electronic products will be made available.

Vard Leonard Electric Co., Mt. Vernon, N.Y.

Electric control devices, vitrohm resistors and rheostats, magnetic relays and contacts, power resistor handbooks, an authentic treatise on power resistors.

Procurement Feature

Four desks to help manufacturers get orders, will be staffed by procurement personnel from Munitions, Air Force, Navy and Signal Corps on the third floor, Radio Engineering Show.

U. S. Armed Forces Exhibit

27 years of service to the Radio Manufacturing Industry

BAUMAN & BLUZAT

- Condensers
- Selenium Rectifiers
- Quartz Crystals
- Speakers
- Vibration Mounts
- Transformers
- Germanium Crystal Diodes
- Relays

Defense contracts and sub-contracts assumed

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Sales & Service

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All Phones—H-U 6-8009

216

358

347

(Continued on page 171A)
Of particular interest to all who need resistors with inherent low noise level and good stability in all climates.

**HIGH VALUE RANGE**
10 to 10,000,000 MEGOHMS

This unusual range of high value resistors was developed to meet the needs of scientific and industrial control, measuring and laboratory equipment—and of high voltage applications.

**SEND FOR**
**BULLETIN 4906**

It gives details of both the Standard and High Value Resistors, including construction, characteristics, dimensions, etc. Copies with Price List mailed on request.

**STANDARD RANGE**
1000 OHMS TO 9 MEGOHMS

Used extensively in commercial equipment, including radio, telephone, telegraph, sound pictures, television, etc. Also in a variety of U.S. Navy equipment.

**THE S.S. White INDUSTRIAL DIVISION**
Dept. G-R, 10 E. 40th St.
NEW YORK 16, N.Y.
**News—New Products**

Manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

(Continued from page 161A)

**New Miniaturized Oscilloscope**

Features typical of large precision boratory oscilloscopes are characteristic of the new miniaturized oscilloscope announced by the Hycon Mfg. Co. In an instrument of this small size its adequacy regarding regard to testing of high-frequency equipment and portrayal of pulse type waveforms is unique.

Now being produced by Hycon Mfg. Co., 2961 E. Colorado St., Pasadena 8, Calif., for the Air Forces and the Navy in large quantities, this miniaturized oscilloscope, 9 X 6 X 14 in., is particularly designed to endure rough handling. The water case is water tight. Its easy portability makes it especially useful for serving television, radar, and all uhf equipment in the field.

The wide-band and linearity features of the instrument have heretofore been unduplicated in laboratory-type equipment. Its sweep frequency range is from 3 to 90,000 cps. Vertical amplifier response is flat within 3 db from 0.1 to 2 kc; while horizontal response is flat within 2 db from 0.1 to 100 kc. Faithful reproduction of wave forms with 3 microsecond rise time at 100 kc square waves is an unusual feature. Other features are the incorporation of blanking amplifier and a synchronizing amplifier, and a circuit design which maintains a sweep return time ratio of not less than 5 to 1 at all frequencies. Deflection sensitivity exceeds 0.5 volt per inch at all voltages from 105 to 125 volts and at line frequencies from 50 to 1,000 cps. Blurred radar pulses up to several hundred feet in frequency may be portrayed faithfully by making direct connections to the deflection plates.

*Andrew Corp., 363 E. 75th St., Chicago 19, Ill., has released Bulletin 10-1, a general price list, on coaxial cable, rigid coaxial transmission lines, antennas, antenna tuning equipment and components, and tower lighting equipment.

(Continued on page 171A)
**3000 Mc BENCHTEST PLUMBING**

**Magnetron Coupling Type**
- **1 1/4 x 1 3/8 Waveguide**
- **1/2 x 1 1/2 Waveguide**

**Price**
- **$12.00**
- **$4.00**

**Description**
- *Klystron Mount, HDS56 complete with shielding and wiring.*
- *Flange Adapters.*
- *Variable Stud Tuner.*
- *Mod. to Type 'N' Adapter.*
- *Wattmeter Type 'N' Adapter.*
- *Directional Coupler, Type 'N' Adapter.*
- *Crystal Mount, Equipped with turnstile and circular adjust.*

**Price**
- **$12.00**
- **$18.50**
- **$63.00**
- **$18.00**
- **$32.50**
- **$80.00**

**23,000 to 27,000 Mc BENCHTEST PLUMBING**

**1/2 x 1/4 Waveguide**

**Description**
- *Klystron Mount, 1/2 x 1/4 Waveguide.*

**Price**
- **$25.00**

**27,000 Mc to 40,000 Mc BENCHTEST PLUMBING**

**Magnetron Coupling Type**
- **40 D Twist, 1/4 x 1/4 Waveguide**

**Price**
- **$32.50**

**Description**
- *C.W. 40 D Twist, 1/4 x 1/4 Waveguide.*

**Price**
- **$35.00**

**R.F. Equipment**

**SM Radar—Heavy, high power one megawatt ballast radar.**

**Description**
- *SM Radar—Heavy, high power one megawatt ballast radar.*

**Price**
- **$9.00**

**FLEX COAX SECTION**

**Description**
- *FLEX COAX SECTION.*

**Price**
- **$8.50 each**

**COMPANY**

**Call Paul J. Plisner**

**Telephone**
- **Main-4-8373**

**Address**
- **131 Liberty Street, New York, N.Y.**

**Deft**
- **1-3**

**Supplemental Problems**

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**Supplemental Problems**

**SOLVE YOUR RADAR MAPPING AND NAVIGATION**

**Call Paul J. Plisner**

**Telephone**
- **Main-4-8373**

**Address**
- **131 Liberty Street, New York, N.Y.**

**Deft**
- **1-3**

**Supplemental Problems**

**SOLVE YOUR RADAR MAPPING AND NAVIGATION**

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**Telephone**
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**Address**
- **131 Liberty Street, New York, N.Y.**

**Deft**
- **1-3**

**Supplemental Problems**
What to see at the
Radio Engineering Show

(Continued from page 167A)

Firm

Ward Products Corp., Div. of The
Gabriel Co., Cleveland, Ohio
Pocketscopes, Pulescopes, Hydraulics
Tubes, Conduit and pipe markers, high pro-
duction identification methods. Aircraft
hydraulic markers, pressure sensitive con-
tact labels.

Waterman Products Co., Inc., Philadelphia
Pocketscopes, Pulescopes, Rackscop
es and Rayonic tubes. Pocketscopes are miniaturized cath-
ode ray oscilloscopes, exceedingly small in size but complete in performance. Two
new Pulescopes will be shown for accurate pulse determination, in amplitude, shape, duration and time displacement. Miniaturized cathode ray tubes both round and rectangular will be exhibited.

Webster-Chicago Corp., Chicago III
Pocketscopes, Pulescopes, Hydraulics
Tubes, Kinescopes, and "Electronic
Memory" wire recorders, dictation ma-
chines and WEB-COR tape recorder.

Western Lithograph Co., Los Angeles
107
E-Z code wire markers, business systems,
cable, conduit and pipe markers, high pro-
duction identification methods. Aircraft
hydraulic markers, pressure sensitive con-
tact labels.

Westinghouse Electric Corp., Pittsburgh,
Pa.
65 to 69
Hipersail cores, recto and selenium recti-
fiers, tubes, AB "DIE-ION" circuit break-
ers, electrical instruments, hipermin V tor-
sids and other magnetic alloys, linestarters
and pushbuttons.

Wind Turbine Co., West-Chester Pa.
48
Sections of TRYLOM Towers.

The Workshop Associates, Inc., Needham,
Mass.
39
Parabolic antennas for microwave relay
systems various other special duty anten-
as.

A QUALIFIED STAFF OF RESEARCH ENGINEERS IN
THE FIELD OF RADIO CONTROL AND TELEMETERING

Raymond Rosen Engineering Products, Inc.
has recently developed new and improved
high stability, high output, resistance-
capacitance discriminators of outstanding
characteristics.

RAYMOND ROSEN ENGINEERING PRODUCTS, Inc.
32nd & Walnut Streets • Philadelphia 4, Pa.

"INSTANTANEOUS
S RECYCLING IS ONLY ONE
OF MY MANY ASSETS!"

All types of
AGASTAT
TIME DELAY
RELAYS

are solenoid actuated — pneumatically timed. For AC and DC
service. It will pay you to take time out to investigate Agastat
Time Delay Relays. Information and literature on request.

AMERICAN GAS ACCUMULATOR COMPANY
1027 NEWARK AVENUE • ELIZABETH 3, N. J.
**Exalted-Carrier Diversity Receiver**

_A New standard of performance in high-frequency reception_

Combines all advantages of the best diversity reception plus new exalted-carrier detection which eliminates selective fading distortion and greatly reduces interference from interfering stations within the received channel.

Supplied in compact three-receiver combination with high continuity-of-service factor and switching flexibility.

New diversity selector chooses strongest of the three signals and completely rejects the weaker signals.

For reception of voice, program, or tone-multiplex transmitted by either amplitude or phase modulation.

Exalted-carrier adapters also available for single-receiver use.

_Inquiries invited_

_CROSBY LABORATORIES, INC._

126 Herricks Road, Mineola, N.Y., GArden City 7-6487

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**TYPE S**

DURENE (PLASTIC FILM) CAPACITOR

- DURENE ZERO-LOSS CAPACITOR CAP. 0005
- PLASTIC FILM IDEAL SUBSTITUTE FOR MICA OR CERAMIC CAPACITORS
- EXCELLENT POWER FACTOR .0005
- CAP. FROM 0.0005 TO 20 MFD

**TYPE S1**

IN TUBES

- HIGH MOISTUREPROOF STABLE CAPACITY RANGE LONG LIFE
- EXTREMELY HIGH "Q" VOLTAGES FROM 500 TO 20000 VOLS

Send for samples and literature. *For dependability always specify Dumont_

_CROSBY ELECTRONIC CORP._

505 6TH AVE. CAPACITORS FOR EVERY REQUIREMENT

308 DYCKMAN ST., NEW YORK N.Y.

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**Only with CO-AX air-spaced articulated R.F. CABLES**

**4mm/ft**

_THE LOWEST EVER CAPACITANCE OR ATTENUATION_

<table>
<thead>
<tr>
<th>LOW ATTENUATION</th>
<th>IMPEDANCE</th>
<th>ATTENUATION 1000V</th>
<th>SPEAKER</th>
<th>DRAIN</th>
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**HIGH POWER FLEXIBLE**

**PHOTOCELL CABLE**

**SEND FOR SAMPLES AND LITERATURE**

**V.L.C.**

*Very Low Capacitance cable.*

**DUMBMETRONE CABLES LIMIT**

CONTRACTORS TO H.M. GOVERNMENT

138A CROMWELL ROAD LONDON SW7 ENGLAND

---

_PROCEEDINGS OF THE I.R.E._

March, 1951
The horn is built of cast aluminum, beyond 15,000 cps. When used with a 2- to 15-inch cone speaker and proper network, it handles 25 to 30 watts of program material. Its impedance is 15 ohms.

Model CHU-5 provides uniform response to 12,000 cps with usable output beyond 15,000 cps. When used with a 2- to 15-inch cone speaker and proper network, it handles 25 to 30 watts of program material. Its impedance is 15 ohms.

The horn is built of cast aluminum, and is flared for widest distribution pattern. Paired with each Model CHU-5 is a four-page pamphlet (including wiring diagram) to cover network. Complete data are supplied for the necessary choices and capacitors and constants take into consideration cone speakers of 4, 8, or 15 ohm impedances.

University Speakers functioning under water—This is the submergence-proof MM-27, designed for tough naval combat and railroad service. Like all UNIVERSITY speakers, it more than meets requirements! This one is installed and operates year-round for swimming instruction.

University LOUDSPEAKERS
...will do more!
...last longer!
...sound better!

UNIVERSITY ENGINEERS, through painstaking research, recognize both idiosyncrasies of the human ear and the severe conditions under which sound equipment must many times be called upon to operate. They meet this double challenge by combining the finest engineering human ingenuity can devise with rugged, all-weather, all-climate construction. The result is better-performing, super-durable reproducers. For reliability plus, for installations that function day-in, day-out under the most grueling conditions — specify UNIVERSITY loudspeakers.

UNIVERSITY LOUDSPEAKERS • INC
80 SO. KENSICO AVE., WHITE PLAINS, N Y

HIGHER ATTENUATION...at no greater cost

Built to match the most exacting requirements for radio interference reduction, ACE SCREEN ROOMS cost little or no more than home-made rooms of far lower filtering and shielding efficiency. Used and approved by leading laboratories and plants.

SCREEN ROOMS
READY-BUILT • READY TO INSTALL

✓ Provide attenuations of 100 to 140 db.
  —at frequencies from 0.15 to 10,000 mc.
✓ Easy to install—easy to move to a new location or to enlarge.
✓ Fully proved in more than 6 years of use.
✓ Standard and special types available for every need.
200 MC BAND WIDTH AMPLIFIERS


Band Width: 100 KC to 200 MC. Gain: 20 db.
With the Model 202P: very fast pulses, transients and other high frequency voltages can now be amplified.
With the Model 202P: vacuum tube voltmeters and oscilloscopes are ten times more sensitive.
With the Model 202P: the output voltage of signal, sweep and pulse generators is ten times greater.

Other Wide-Band Chain Amplifiers available:
Model 200A — 10 db Gain. Model 204 — 40 db Gain.

Makers of chain amplifiers, temperature controls, variable electronic filters and power supplies.
Write for Bulletin 202P-1-E

SKL SPENCER-KENNEDY LABORATORIES, INC.
186 MASSACHUSETTS AVE., CAMBRIDGE 39, MASS.

MAGNETIC AMPLIFIERS • INC
Affiliate of GENERAL CERAMICS & STEATITE CORP.
11-54 44th DRIVE, LONG ISLAND CITY, N.Y.—TEL. STILLWELL 6-2191

ANNOUNCES PACKAGED MAGNETIC AMPLIFIERS

■ Standard Units
■ Push-Pull or Single
■ Completely Self-contained
■ As Easy to Install as a Transformer

Other Standard or Specially Engineered Units:
SATURABLE REACTORS, SATURABLE TRANSFORMERS,
PRE-AMPLIFIERS, PHASE SENSITIVE DEMODULATORS,
HIGH FREQUENCY MAGNETIC AMPLIFIERS

See us at the IRE SHOW BOOTH 136

GRAPHITE METALLIZING CORPORATION
1001 NEPPERHAN AVENUE, YONKERS 3, NEW YORK

Where the Requirements are Extreme...
Use SILVER GRAPHALLOY
For extraordinary electrical performance

THE SUPREME BRUSH AND CONTACT MATERIAL

IN BRUSHES
- for high current density
- minimum wear
- low contact drop
- low electrical noise
- self-lubrication

IN CONTACTS
- for low resistance
- non-welding character

Graphite is a special silicium-imregnated graphite

Accumulated design experience counts — call on us!
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 172A)

New Meters

Production of a new 1 1/4-inch vu and 1 1/4-inch db meter has been announced by International Instruments, Inc., 331 East St., New Haven 11, Conn. These instruments are designed to measure the strength of audio signals as applied to communication equipment, and are claimed to be the smallest and lightest made. Both types of instruments are completely self-contained, ready for installation.

(Continued on page 177A)

GREEN ENGRAVER
Proved Profitable —

Fast, rugged, convenient—and inexpensive. The Green Engraver is tops for low-cost performance—rips out precision work on metal, plastic or wood ... cuts four lines of letters from 3/64" to 1" on curved or flat surfaces... operates by seize... makes anyone an expert engraver...engraves panels, name plates, scales, dials, molds, lenses and instruments. (Also widely used for routing, profiling and three dimensional modeling.) Electric etching attachment available.

Special attachments and engineering service available for production work.

FREE—Fact-packed folder. Send for yours today

See us at Booth 264

GREEN INSTRUMENT CO.
361 Putnam Ave.
Cambridge, Mass.

PROCEEDINGS OF THE I.R.E.
March, 1951

ANNOUNCING

Two additional R. F. Heads are now available for the Model 708 Spectrum Analyzer shown below:

- S Band 2500 to 3400 megacycles.
- X Band 6200 to 7100 megacycles.

WRITE FOR DETAILS

MODEL 708 SPECTRUM ANALYZER

Frequency range—8500 mc to 9600 mc.
Receiver—Double conversion superheterodyne.
IF bandwidth—approximately 10 kc.
Sweep frequency—10 cps to 25 cps.
Minimum frequency dispersion—1 mc/inch.
Maximum frequency dispersion—10 mc/inch.
Signal input attenuator—100 db linear.
Power—115V or 230V, 50 cps to 800 cps.

GREEN I N S T R U M E N T  C O.
14315 Bessemer St., Van Nuys, Calif. • Box 361

 HOW SELETRON RECTIFIERS GAVE CHICAGO A LIFT

When the power company changed over to alternating current in certain Chicago areas it meant that existing elevators operating on D.C. had to be converted fast, or the good people of the town would be "grounded." Ther Electric & Machine Works solved rectification problems for considerably more than 100 famous buildings in the Windy City by designing complete power supply and regenerative braking equipment employing SELETRON rectifiers. Illustration shows a typical 3 bank unit built for Clinton Realty Co. Installations have also been made in the Sears Roebuck and Western Electric Buildings, and many others.

Elevator operation is but one of many uses for rugged, efficient SELETRON selenium rectifiers—they are useful in hundreds of industrial applications for economical conversion of alternating current to D.C.

Write us now concerning your rectification problems—and request Bulletin No. PEC-8.

See us in booth N-16 at the IRE Show

SELETRON DIVISION
RADIO RECEPTOR COMPANY, Inc.

RADIO RECEPTOR COMPANY, Inc.

Manufacturing and Sales Offices: New York City, Chicago, Los Angeles, San Francisco
MODEL 79-B

SPECIFICATIONS:
- FREQUENCY: continuously variable 60 to 100,000 cycles.
- PULSE WIDTH: continuously variable 0.5 to 40 microseconds.
- OUTPUT VOLTAGE: Approximately 150 volts positive
- OUTPUT IMPEDANCE: 6Y6G cathode follower with 1000 ohm load
- R. F. MODULATOR: Built-in carrier modulator applies pulse modulation to any r.f. carrier below 100 mc.
- MISCELLANEOUS: Displaced sync output, individually calibrated frequency and pulse width dials, 114 volt, 40-60 cycles operation, size 14"x10"x10", wt. 31 lbs.

MEASUREMENTS CORPORATION
BOONTON • NEW JERSEY

2 PURPOSE TELEDAPTER

- TELEVISION WAVE FORM OBSERVATION
- RADAR PULSE

LOW $195 F.O.B. PLANT

- Converts a DuMont 208 or 304 Scope for use with TV and Radar pulse type signals. Response 3 db down at 0.3 M.C.
- Completely self-contained including power supply. No modifications to the 208 or 304 Scope required.
- Size matches both Type 208 and 304 scopes and tie plates are furnished to fasten both instruments together.

Write for Type 1000 Data Sheet

Convert your Type 208 and 304 Scopes for TV and Radar testing, for only $195.00

ELCO CORPORATION
190 W. Glenwood Ave., Phila. 40, Pa.
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 175A)

These instruments are available in three case styles: 1½-inch square water-proof case (as illustrated) 1½-inch round waterproof case complete with "O" ring for making a waterproof seal to the panel, and 1½-inch round flange mounting case with commercial type of seal.

These meters contain a D'Arsonval type subminiature meter movement developed by International Instruments to reduce the size and weight of electrical and electronic instruments.

Static Magnetic Memory Device

Developed by Harvard Computation Laboratory and manufactured by Alden Products Co., 117 N. Main St., Brockton, Mass., the Static Magnetic Memory, an entirely new device for recording and storing information in digital calculating machinery, could constitute one of the most important developments of recent years. It is predicted that within 5 years the SMM delay line will replace 90 per cent of the vacuum tubes in many applications.

Based upon the discovery of a ferromagnetic alloy having a fairly rectangular hysteresis loop of low coercive force, the Static Magnetic Memory operates essentially as a magnetic trigger pair which requires no vacuum tubes to maintain position. The unique characteristics of the SMM storage device mean permanent information storage comparable to magnetic drum storage but independent of mechanical movement, a variable information handling rate ranging from zero to 30,000 cps with probable increases in the future limit, and pulse information storage without power.

Application in scientific and technological fields of this new information storage device can be made wherever pulse storage and control in the field of computer operation is involved.

(Continued on page 179A)

1500 VOLT POWER SUPPLY
FOR PHOTO MULTIPLIER TUBES

Regulated and Continuously Adjustable from 600 to 1500 V.D.C. at 0-1 Milliamperes

Positive Terminal Grounded

Regulation: Output voltage varies less than .01% per volt change of line voltage. Output voltage varies less than 1 volt with variations of output current between 0–1 milliamperes. (Internal impedance less than 1000 ohms.)

Also available with 2 or 3 independently regulated and independently adjustable outputs.

I. R. E. SHOW — BOOTH 363

FURST ELECTRONICS
14 S. JEFFERSON STREET
CHICAGO 6, ILLINOIS

CABINETS • CHASSIS • PANELS • RACKS

Planning ELECTRONIC EQUIPMENT?
Investigate the ECONOMIES of PAR-METAL HOUSINGS!

We manufacture Metal Housings for every purpose — from a small receiver to a deluxe broadcast transmitter. And the cost is low!

Because we specialize in the Electronics field, Par-Metal Products excel in functional streamlined design, rugged construction, beautiful finish, and economy.

Remember, Par-Metal equipment is made by electronic specialists, not just a sheet metal shop.

WRITE FOR CATALOG!

PROCEEDINGS OF THE I.R.E. March, 1931
TEKTRONIX TYPE 512
CATHODE RAY OSCILLOSCOPE

- Bandwidth, DC—2 mc
- Sensitivity Range, 5 mV/cm to 50 V/cm [10,000:1]
- Sweep Range, .3 sec/cm to 3 usec/cm
- 1 kc Square Wave Amplitude Calibrator
- Power Supply—Regulated, 105V to 125V
- Portable—Weight 53 lbs.

The Tektronix Type 512 Cathode Ray Oscilloscope was designed specifically as an aid to the development engineer. Convenient comparison of related waveforms, at actual D.C. operating levels, permits intelligent analysis of circuit operation. The 3% accuracy of time and amplitude measuring facilities allows precise determination of circuit characteristics.

Price $950 f.o.b. Portland, Ore.

TEKTRONIX, INC.
712 S. E. Hawthorne Blvd. Portland 14, Ore.

DO YOU KNOW?
that a PILOT LIGHT CAN IMPROVE YOUR PRODUCT
..... add attraction — safety — service?

Ask DIALCO

THIS MAY BE THE ONE
Designed for low cost NE-51 Neon
- Built-in Resistor  •  Patented
- U/L Listed  •  Rugged
Catalogue Number 521308 — 997
for 110 or 220 volts.

SAMPLES
for design purpose
NO CHARGE

NEW! Write for the
"HANDBOOK OF PILOT LIGHTS."
Write us on your design problems.

The DIAL LIGHT COMPANY of AMERICA
Foremost Manufacturer of Pilot Lights.
900 BROADWAY, NEW YORK 3, N. Y. TELEPHONE SPRING 7-1300

Now Available!
MICRODIMENSIONAL WIRE
Custom-Enamelled to your specifications

The enamel-insulation of our microdimensional wire meets the high standards of quality set by all our products. The enamel is uniform, tough, flexible and has high dielectric strength... Send us your specifications or inquire for further details.

SIGMUND COHN CORP.
44 GOLD STREET
NEW YORK 7, N. Y.

SINCE 1901
News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical formation. Please mention your I.R.E. affiliation.

(Continued from page 179A)

Plug-In Noninterchangeable Base and Sockets

Alden Products Co., 17 N. Main St., Brockton, Mass. announces the addition of the Alden "20" noninterchangeable base and sockets to its line of plug-in components.

(Continued on page 181A)

LEADERS in COIL WINDING EQUIPMENT

MACHINES FOR PRODUCTION AND LABORATORY USE

MOTORS • SPEED CONTROLS • GEARS • CAMS • TENSIONS

And All Necessary Related Equipment for Coil Winding

For actual demonstration of this and other models visit our booth #355 at the I.R.E. Show, March 19th to 22nd.

COIL WINDING EQUIPMENT CO.
37 W. MAIN ST. OYSTER BAY, N.Y. TELE. OYSTER BAY 6-1285

COMPAKT-RUGGED

This rugged 25 Watt rheostat with proven dependable lock tab prevents contact arm deformation... its steel pin resists over 40 pounds torque... assuring constant current regulation.

To make it rugged, we have housed the pure mica strip (on which the resistance element is bound) in vitreous enamel and in turn embedded this in a ceramic base... insuring a compact, inseparably bonded unit.

These units are constructed to meet your exacting demands—AND ON SHORT NOTICE.

We also manufacture a wide range of resistors to serve your specific need.

May we quote on your requirements?

DYNAMIC RESISTOR CORPORATION
6 Cutter Mill Road Great Neck, N. Y.

POWER LEVEL METER

The Standard Instrument for Noise Measurement. The DIOTRON has been developed as a new standard for the measurement of noise, and is particularly suited for the accurate assessment of underwater sound. Its unique circuit offers the advantages of robustness, simplicity; and complete independence of waveform. It covers a frequency range from 40 cycle to 10 megacycles per second. The substantial sensitivity to harmonic content which characterizes standard a-c vacuum tube voltmeters is entirely absent in the DIOTRON.

FURTHER DETAILS ON REQUEST

*PATENT APPLIED FOR

Reed Research Inc.
1048 Potomac Street, N.W.
Washington 7, D.C.

THE

Reed

DIOTRON

P O W E R  L E V E L  M E T E R

D Y N A M I C

RESISTOR CORPORATION
6 Cutter Mill Road Great Neck, N. Y.

179A
JACOBS ADJUSTABLE SEPARATOR
U.S. Patent #1,950,170—March 6, 1934—others pending

Made of Lucite for the rapid and efficient construction of open 2-wire R. F. feedlines. Provision is made to give spacings from $\frac{1}{2}$" to 6". Light in weight, but rugged. Price: $5.00 per dozen.

Charles F. Jacobs
P.O. Box 406, Church St. Station, New York 8, N.Y.

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ATTENUATORS and SWITCHES
at the I.R.E. SHOW
Grand Central Palace, New York City
MARCH 19-22

TECH LABORATORIES
PALISADES PARK
NEW JERSEY

ONE OF OUR
PRECISION PRODUCTS

PISTON ATTENUATOR
for Signal Generator TS-497/U
Attenuation range 120 Db. Integral Monitoring Coil.

Manufacturers Thread Grinding, Inc.
P.O. Box 66 EATONTOWN, N.J.

MODEL 410-A
ULTRA-LOW FREQUENCY OSCILLATOR
with frequency range of 0.02-20,000 cps

FEATURES:
1. BOTH SINE AND SQUARE WAVE. 2. COMPLETELY
   ELECTRONIC OPERATION. 3. EXCELLENT AMPLITUDE CON-
   STANCY. 4. LOW DRIFT AND DISTORTION.

DESCRIPTION: This oscillator, Model 410-A, covers the sub-audio and
the entire audio range. It provides both sine and square wave at
any frequency range between 0.02 and 20,000 cps.

Precisely engineered and constructed, the Model 410-A is
ideal for medical research, geophysical and seismological
instruments, and design and development of servo-mechanisms
and vibration controls.

KROHN-HITE INSTRUMENT CO.
580 MASSACHUSETTS AVE., CAMBRIDGE 39, MASS., U.S.A.

ZOPHAR
--- WAXES --- COMPOUNDS

Anti-Corona high heat-resistant compounds for Fly Back Transformers.

Waxes and compounds from 100°F to 285°F Melting Points for electrical, radio,
television, and electronic components of all types.

Pioneers in fungus-resistant waxes.

Our efficient and experienced laboratory staff is at your service.

Visiting Engineers to the IRE show are invited to call Mr.
Mayer or Mr. Saunders at South 8-0907 if they wish to
discuss their wax problems either at our plant or other
convenient place. Our staff is

at your service.

ZOPHAR MILLS, INC.
112-130 26th Street,
Brooklyn 32, N.Y.

PROCEEDINGS OF THE I.R.E. March, 1931
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 179A)

Oscillo-Record Camera Delivers Finished-Prints

A new oscillograph-record camera recently announced by the Instrument Div., Allen B. DuMont Laboratories, Inc., Clifton, N. J., provides, in one minute, a complete record of an oscillograph image. No darkroom facilities are required. Waveform comparison is immediate. The camera is designed specifically for application with any standard, 5-inch, cathode-ray oscillograph.

The camera employs the Polaroid-Land process for delivering a finished print at the termination of each completed exposure or set of exposures. By means of a sliding mount, the camera may be positioned so that several traces can be recorded on a single print, for side-by-side comparisons. There is also a built-in detent which divides a single print into one, two, or three separate exposure areas.

The lens aperture is f/2.8; and the lens is coated to minimize halation. Shutter settings are 1/100, 1/50, 1/25, time, and bulb.

Fractional HP Motors

The Cycloh Motor Corp., Div. of Howard Industries Inc., Racine, Wis., announces their new fractional HP motor model 2900, now being manufactured as a 2-speed hysteresis motor for use in tape recording applications. Model 2900 is also available as nonsynchronous capacitor motor and torque motor with high resistance rotors.

Model 2900 is rated 1/100 to 1/15 hp. It is used in powering blowers for electronic equipment, telegraph switching equipment, tape pullers for automatic code equipment, etc.
**PROFESSIONAL CARDS**

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<th>Name</th>
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<td>LESTER W. BAILEY</td>
<td>Registered Patent Agent</td>
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<td>Senior Member IEEE</td>
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<td>PATENT OFFICE PRACTICE specializing in</td>
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<td>32-44 Francis Lewis Blvd., Flushing, L.I., N.Y.</td>
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<td>Telephone: Independence 3-300</td>
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<td>ALFRED W. BARBER LABORATORIES</td>
<td>Specializing in the Communications Field and</td>
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<td>in Laboratory Equipment</td>
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<td>Offices, Laboratory &amp; Model Shop at:</td>
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<td>1076 Morena Blvd., San Diego 10, Calif.</td>
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<td>INDUSTRIAL ELECTRONICS, RADIO &amp; TELEVISION</td>
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<td>Write 17th Floor, 100 Broadway, New York 5, N.Y.</td>
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<td>SPECIALISTS IN TRANSMISSION &amp; MERCURY</td>
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<td>EDWARD J. CONTENT</td>
<td>Acoustical Consultant</td>
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<td>Functional Studio-Theater Design</td>
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<td>CROSBY LABORATORIES, INC.</td>
<td>Murray G. Crosby &amp; Staff</td>
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