A low aerial view showing a portion of Houston, Texas, and Rice Hotel (circled), where the 4th Southwestern IRE Conference and Radio Engineering Show will be held May 16-17, 1952. For further details see page 494.
Many people realize and take advantage of the fact that "the tough ones go to UTC." Many of these "tough ones," while requiring laboratory precision, are actually production in quantity. To take care of such special requirements, the UTC Laboratories have a special section which develops and produces production test equipment of laboratory accuracy. The few illustrations below indicate some of these tests as applied to a group of units used by one of our customers in one production item of equipment:

The component being checked here is a dual saturable reactor where the test and adjusting conditions necessitate uniformity of the complete slope of the saturation curve. The precision of this equipment permits measuring five widely separated points on the saturation curve with saturating DC controllable to .5% and inductance to .5%.

Servomechanisms and similar apparatus depend, to a considerable degree, on phase angle operation. The transformer adjusted in this operation requires an accuracy of .05 degrees phase angle calibration under the resonant condition of application. With wide change in voltage and temperature range from -40 to +85 degrees C., the phase angle deviation cannot exceed .2 degree. To effect this type of stability, specific temperature cycling and aging methods have been developed so that permanent stability is effected.

This test position involves two practical problems in a precision inductor. The unit shown is adjusted to an inductance accuracy of .3%, with precise (high) Q limits. It is then oriented in its case, using a test setup which simulates the actual final equipment so that minimum inductive coupling will result when installed in the final equipment.

The hermetic sealing of transformers involves considerable precision in manufacturing processes and materials. To assure consistent performance, continuous sampling of production is run through fully automatic temperature and humidity cycling apparatus. It is this type of continual production check that brings the bulk of hermetic sealed transformers to UTC.

**United Transformer Co.**

150 Varick Street
New York 13, N.Y.
Export Division 13 East 40th Street, New York 16, N.Y.
Cables: A-1Lab
National Conference on AIRBORNE ELECTRONICS

May 12, 13, 14
Biltmore Hotel, Dayton, Ohio

The IRE Professional group on Airborne Electronics joins with the Dayton Section in sponsoring the 1952 NATIONAL CONFERENCE ON AIRBORNE ELECTRONICS May 12, 13, 14. The Conference committee, working with research laboratories, universities, and electronic and aircraft industries have made arrangements for the largest and best Conference held to date! Over 70 papers will be presented covering over 14 general topics including communication, navigation propagation, computers, instrumentation, antennas, components and vacuum tubes. In addition to a high-powered technical conference, complete with a display of commercial equipment, there will be an excellent social program.

For information write the Dayton Section, IRE c/o Far Hill, P.O. Box 44, Dayton 9, Ohio.

CINCINNATI ENGINEERING BUILDING

Spring Technical Conference
Cincinnati IRE

The Spring Technical Conference will be held Saturday, April 19, 1952 at the Engineering Society Headquarters Building, Woodburn and McMillan Street, Cincinnati, Ohio. Advance registration and reservations for hotel accommodations and for the Luncheon and Banquet may be made by mail.

Registration may also be made at the door the morning of the conference. Papers concerning UHF Television, Color Television and the Megacycle Meter will be presented.

Announcing the dates:
1953 IRE National Convention and Radio Engineering Show
March 23-26, 1953; New York City
Also See Page 2A Calendar

NEREM
New England Radio Engineering Meeting

The 5th annual Radio Engineering Meeting of the North Atlantic Region will be held on Saturday, May 10, 1952 at the Copley Plaza Hotel, Copley Square, Boston.

Featuring the radio engineer’s role in the present emergency, the technical program for this one-day event will include papers on Test Instruments, Color Television, High Frequency, Instrumentation and Radiation.

IRE Meetings and Exhibits Speed Electronic Progress!
How to tell Quality in Teflon*

You’ll have all these properties with FLUOROFLEX-T®

“Teflon” powder is converted into Fluoroflex-T rod, sheet and tube under rigid control, on specially designed equipment, to develop optimum inertness and stability in this material. Fluoroflex-T assures the ideal, low loss insulation for uhf and microwave applications . . . components which are impervious to virtually every known chemical . . . and serviceability through temperatures from −80° F to +900° F.

Produced in uniform diameters, Fluoroflex-T rods feed properly in automatic screw machines without the costly time and material waste of centerless grinding. Tubes are concentric—permitting easier boring and reaming. Parts are free from internal strain, cracks, or porosity.

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

*DuPont trade mark for its tetrafluoroethylene resin.
+Resistoflex trade mark for products from fluorocarbon resins.

“Fluoroflex” means the best in Fluorocarbons

RESISTOFLEX CORPORATION

RESISTOFLEX CORPORATION, Belleville 9, N. J.
SEND NEW BULLETIN containing technical data and information on Fluoroflex-T.

NAME.................................................. TITLE.................................. COMPANY.................................................. ADDRESS..................................................
MEET JAN-R-26A!

Designed to withstand the rigid Characteristic G humidity tests of the most stringent specification of them all—JAN-R-26A—Sprague's new Blue Jacket Wire-Wound Resistors give trouble-free service in military electronic and electrical equipment exposed to extremely damp climates!

These outstanding new members of the Sprague resistor family are now available in tab terminal styles RW29 through RW39 in wattage ratings up to 166 watts.

You'll find the complete Blue Jacket Story with performance specifications in Engineering Bulletin 110, just off the press. Get your copy without delay.

YOU'LL KNOW THESE REMARKABLE RESISTORS BY THEIR VITREOUS ENAMEL BRIGHT BLUE JACKETS
Electrons probe the future

In 1927, Bell Laboratories physicists demonstrated that moving electrons behave like light waves, and thus launched the new science of electron optics.

Now, through the electron beams of the electron microscope and electron diffraction camera, scientists learn crucial details about the properties of metals far beyond the reach of optical microscopes or chemical analysis.

At the Laboratories, electron beams have revealed the minute formations which produce the vigor of the permanent magnets used in telephone rings and magnetron tubes for radar. The same techniques help show what makes an alloy hard, a cathode emit more electrons and how germanium must be processed to make good Transistors.

This is the kind of research which digs deep inside materials to discover how they can be made better for your telephone system ... and for the many devices which the Laboratories are now developing for national defense.

BELLE TELEPHONE LABORATORIES

Improving telephone service for America provides careers for creative men in scientific and technical fields.
Ferroxcube 3C cores are nickel-free

Applications:
- I-F Transformers
- Permeability Tuning Devices
- Low-Loss Inductors
- Saturable Core Reactors
- Horizontal Output Transformers
- Deflection Yokes
- Telephone Loading Coils

When your drawings call for Ferroxcube 3C cores for your TV deflection yokes and horizontal output transformers, you can forget about procurement problems. These ferrite cores are nickel-free . . . and delivery will be made exactly as scheduled by you!

Improved temperature stability, high saturation flux density, and high permeability are among the other advantages of Ferroxcube 3C.

Complete technical data is yours for the asking in Engineering Bulletin FC-5101A, available on letterhead requests.

Ferroxcube is the modern core material

Ferroxcube Corporation of America
A Joint Affiliate of Philips Industries and Sprague Electric Co., Managed by Sprague
Saugerties, New York
FOR QUALITY

It has taken years of constant research and development to make Amphenol the keyword in the electronics industry. Specifying Amphenol is specifying quality! From the inclusion of only the best of top-grade materials to the last rigid inspection of the finished component, nothing is overlooked in making every Amphenol connector or cable the best in quality that can be produced.

A copy of Amphenol's B-2 General Catalog will be sent on request.

AMERICAN PHENOLIC CORPORATION
1830 S0. 54TH AVENUE - CHICAGO 50, ILLINOIS
COMPLETE LINE OF CORES TO MEET YOUR NEEDS

★ Furnished in four standard permeabilities—125, 60, 26 and 14.

★ Available in a wide range of sizes to obtain nominal inductances as high as 281 mh/1000 turns.

★ These toroidal cores are given various types of enamel and varnish finishes, some of which permit winding with heavy Formex insulated wire without supplementary insulation over the core.

For high Q in a small volume, characterized by low eddy current and hysteresis losses, ARNOLD Moly Permalloy Powder Toroidal Cores are commercially available to meet high standards of physical and electrical requirements. They provide constant permeability over a wide range of flux density. The 125 Mu cores are recommended for use up to 15 kc, 60 Mu at 10 to 50 kc, 26 Mu at 30 to 75 kc, and 14 Mu at 50 to 200 kc. Many of these cores may be furnished stabilized to provide constant permeability (±0.1%) over a specific temperature range.

HIGH Q TOROIDS for use in Loading Coils, Filters, Broadband Carrier Systems and Networks—
for frequencies up to 200 K C

MOLYBDENUM PERMALLOY POWDER CORES
(New technical data now available)

The Arnold Engineering Company
Subsidiary of Allegheny Ludlum Steel Corporation
General Office & Plant: Marengo, Illinois

PROCEEDINGS OF THE I.R.E. April, 1952
low-loss miniature TUBE SOCKETS

OFFER ALL THESE ADVANTAGES:

- CLOSER TOLERANCES
- LOWER DIELECTRIC LOSS
- HIGH ARC RESISTANCE
- HIGH DIELECTRIC STRENGTH
- GREAT DIMENSIONAL STABILITY
- IMMUNITY TO HUMIDITY
- HIGH SAFE OPERATING TEMPERATURE

- cost no more than PHENOLIC TYPES

These glass-bonded mica sockets are produced by an exclusive MYCALEX process that reduces their cost to the level of phenolic sockets. Electrical characteristics are far superior to phenolics while dimensional accuracy and uniformity exceed that of ceramic types.

MYCALEX miniature tube sockets, available in 7-pin and 9-pin types, are injection molded with great precision and fully meet RTMA standards. They are produced in two grades, described as follows, to meet diversified requirements.

- MYCALEX 410 is priced comparable to mica-filled phenolics. Loss factor is only .015 at 1 mc., insulation resistance 10,000 megohms. Conforms fully to Grade L-4B under N.M.E.S. JAN-1-10 “Insulating Materials Ceramic, Radio, Class L.”

- MYCALEX 410X is low in cost but insulating properties greatly exceed those of ordinary materials. Loss factor is only one-fourth that of phenolics (.083 at 1 mc.) but cost is the same. Insulation resistance 10,000 megohms.

MYCALEX TUBE SOCKET CORPORATION
Under Exclusive License of
MYCALEX CORPORATION OF AMERICA
30 ROCKEFELLER PLAZA, NEW YORK 20, N.Y.

MYCALEX CORPORATION OF AMERICA
Owners of 'MYCALEX' Patents and Trade-Marks
Executive Offices: 30 ROCKEFELLER PLAZA, NEW YORK 20 — Plant & General Offices: CLIFTON, N.J.
for RADAR BEAM OR TRAFFIC CONTROL

BY GUARDIAN

"SPOT" YOUR CONTROL PROBLEMS

Small . . . to save weight and space in radar and guided missile equipment, Guardian Relays prove that quality still comes in small packages. Basic . . . flexible . . . government approved . . . Guardian Relays are ruggedly built and hermetically sealed to withstand every atmospheric condition, including the rigors of supersonic flight. Guardian Relays, specified in devices that count—detect—indicate—direct—shoot—convey—compute—sort—package—vend—meter—hold the answer to your control problem. Write.

This unit tabs 900 or more overlapping cars per minute at split-second contact. As car wheels hit a pneumatic tube stretched across traffic lanes the compression closes an electrical contact on a diaphragm, operating a Guardian Series 125 D.C. relay. The relay responds to every impulse but the counter unit registers only every other impulse to compensate for rear wheel contact.

SERIES 125 D.C. RELAY

WRITE—WIRE—TELETYPES—PHONE NOW!

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

A COMPLETE LINE OF RELAYS SERVING AMERICAN INDUSTRY

PROCEEDINGS OF THE I.R.E. April, 1952
With this one **NEW** instrument read frequency directly, automatically, without calculation—**in 1 second or less**!

Any frequency to 10,000,000 cps displayed here the split-second unknown is connected! No other equipment needed, no interpolation. (Frequency counted below, 10,168,438 cps.)

A daily work-saver for laboratory or production line!

Here are just a few time-saving uses!

- Measure exact frequency of transmitters and crystal oscillators
- Calibrate sub-audio, audio and supersonic test oscillators
- Measure rpm electronically up to 600,000,000 rpm
- Establish frequencies for filter characteristic determination
- Monitor frequency drift with precise accuracy
- Make rapid checks of crystal frequency
- Read total random events per unit time
- Use as precision frequency standard
REVOLUTIONARY NEW
-hp- 524A FREQUENCY COUNTER

- No figures to add, no calculations!
- No complex equipment set-up!
- Easily used by non-technical personnel!
- Production-line speed, instantaneous readings!
- Laboratory accuracy, 1/1,000,000 ± 1 count!
- Broad coverage, .01 to 10,000,000 cps!

-hp- 524A Frequency Counter sets new standards for accurate, high-speed frequency measurement in the laboratory or on the production line. It counts frequency instantly, automatically, without effort on your part. It performs all functions of a frequency standard, interpolating system, and detector. For frequency determination it eliminates expensive, hard-to-maintain harmonic amplifiers, transfer oscillators, multi-vibrators, and oscilloscopes.

Two Types of Measurement

1. **Direct Counting for High Frequencies**  - The equipment counts and displays directly—unknown frequencies over exact time intervals of 10, 1.0, 0.1, 0.01, and 0.001 seconds. Counting and display periods are equal and automatically cycled. The count is displayed repetitively or "held" as in frequency counting.

   **Circuit Description**
   - **hp- 524A** operates on pulse counting techniques. The unknown is applied through a wide-band squaring amplifier to a fast gate controlled by a time base generator. When the gate is open, unknown is applied to counting circuits. When gate is closed, counting circuits remember and display the counted frequency in cps, or the period in microseconds. Time base circuits are controlled by a highly stable crystal oscillator with instantaneous stability of 1/1,000,000; accuracy of 2/1,000,000 per week.

New -hp- 520A High-Speed Scaler

This new -hp- equipment is an aperiodic 10 mc scaler offering precise accuracy and high-speed operation for easy measurement of "fast" circuits and nuclear parameters. This equipment is built into -hp- 524A Frequency Counter, and is also available as a separate instrument.

- **hp- 520A** Scalor will count period pulses from 0 cps to 10 mc. Double-pulse resolving time is 0.1 µsec. Triple-pulse resolving time is 0.2 µsec. Scalor delivers 1 output pulse per 100 received, and displays residual count on two panel meters. Instrument may be used with conventional 10² pps scalers to increase count capacity. $600.00 f.o.b. factory.
Here are the coils you want ... the way you want them!

Take advantage of one of C.T.C.'s most popular and useful services—the winding of slug tuned coils to exact specifications. Single layer or pie types furnished. You can be sure your specs—military or personal—will be faithfully followed to the last detail of materials and methods, and with expert workmanship.

C.T.C. coil forms are made of quality paper base phenolic or grade L-5 silicone impregnated ceramic. Mounting bushings are cadmium plated brass and ring type terminals are silver plated brass. Terminal retaining collars of nylon-phenolic also available in types LST, LS5, LS6.

Wound units can be coated with durable resin varnish, wax or lacquer. Both coils and coil forms are furnished with slugs and mounting hardware—and are obtainable in large or small production quantities. Be sure to send complete specifications for specially wound coils.

All C.T.C. materials, methods, and processes meet applicable government specifications. For further information on coils, coil forms or C.T.C.'s special consulting service, write us direct. This service is available to you without extra cost. Cambridge Thermonic Corporation, 468 Concord Avenue, Cambridge 38, Mass. West Coast manufacturers, contact: E. V. Roberts, 5014 Venice Blvd., Los Angeles, and 988 Market Street, San Francisco, California.

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

custom or standard ... the guaranteed components

---

**COIL FORM SPECIFICATIONS**

<table>
<thead>
<tr>
<th>Coil Form</th>
<th>Material</th>
<th>Mounting Stud Thread Size</th>
<th>Form O.D.</th>
<th>Mounted O.A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>LST</td>
<td>L-5 Ceramic</td>
<td>8-32</td>
<td>3/8”</td>
<td>1/2”</td>
</tr>
<tr>
<td>LS6</td>
<td>L-5 Ceramic</td>
<td>10-32</td>
<td>3/8”</td>
<td>1/2”</td>
</tr>
<tr>
<td>LS5</td>
<td>L-5 Ceramic</td>
<td>1-32</td>
<td>3/8”</td>
<td>1/2”</td>
</tr>
<tr>
<td>LS8</td>
<td>L-5 Ceramic</td>
<td>1/4-28</td>
<td>3/8”</td>
<td>1/2”</td>
</tr>
<tr>
<td>L5M</td>
<td>Paper Phenolic</td>
<td>8-32</td>
<td>3/4”</td>
<td>2”</td>
</tr>
<tr>
<td>LS3</td>
<td>Paper Phenolic</td>
<td>1/4-28</td>
<td>3/4”</td>
<td>1 1/2”</td>
</tr>
<tr>
<td>LS41</td>
<td>Paper Phenolic</td>
<td>1/4-28</td>
<td>3/4”</td>
<td>2”</td>
</tr>
</tbody>
</table>

*These types provided with spring locks for slugs.

Fixed lugs. All others have adjustable ring terminals. LST, LS5, LS6 also available with fixed terminals secured by nylon-phenolic collars.

**NEW NYLON-PHENOLIC COLLARS.**

Terminals held securely; soldering spaces doubled; excellent for both bifilar and single pie windings. Show an increase in Q and many new benefits over metallic rings—without impairing in any way the moisture- and fungus-resistant qualities of coil form assemblies.

**NEW CERAMIC COIL FORM KIT.**

Helps you spark ideas in designing electronic equipment or developing prototypes and pilot models. Contains 3 each of the following 5 C.T.C. ceramic coil form types: LST, LS5, LS6, LS7, LS8. Color-coded chart simplifies slug-identification and gives approximate frequency ranges and specifications. Nylon-phenolic collars to replace metallic rings available with kit for all ceramic coil forms except LS7 and LS8.
This great, new plant at Quincy, Mass. — bringing the total Receiving Tube Division manufacturing area to 400,000 square feet — is devoted exclusively to the production of Raytheon quality tubes. It is now operating full blast to meet, and meet promptly, the tremendous demand for Raytheon Reliable Miniatures.*

*RAYTHEON WAS THE FIRST...

...to develop ARINC Reliable Tubes and produce them in quantity. CK5654, the first ARINC type, was initially shipped in October 1947.

Close to 400 Raytheon distributors are at your service on these tubes. Application information is yours for the asking from Raytheon at Newton, Chicago, Los Angeles.

RAYTHEON MANUFACTURING COMPANY
Receiving Tube Division
Newton, Mass., Chicago, Ill., Atlanta, Ga., Los Angeles, Calif.

RELIABLE SEMI-MINIATURE AND MINIATURE TUBES - GERMANIUM DiODES AND TRANSISTORS - HARMONIC TUBES - RECEIVING AND PICTURE TUBES - MICROWAVE TUBES

Proceedings of the I.R.E. April, 1952
**MALLORY Midgetrols**

**do a trouble-free job for you**

When you use Mallory Midgetrols you take advantage of outstanding carbon control design, construction and performance features that pay off on your production line... and in the homes of your customers.

**ON THE LINE**— Exclusive two-point shaft suspension eliminates side play and makes possible use of heavy pressure to attach knobs without control damage.

Two-point suspension also results in a shorter shaft bushing and thus saves space in chassis arrangement.

Versatility of design permits Mallory to make quick delivery of standard units adapted to meet production emergencies... for short runs... for experimental work... or for service replacement stocks.

**IN THE HOME**— Two-point suspension eliminates shaft wobble—thus prevents damage to the carbon element.

Resistance drift is sharply limited because the phenolic base of the carbon element resists extremes of temperature and humidity.

Quiet operation and smooth tapers because of the fine molecular structure of the carbon and exclusive methods of application.

Long-lasting performance because of precision design and construction.

You can see that Mallory Midgetrols offer real advantages in production and in use—advantages that build satisfaction for your dealers and their customers because of the trouble-free performance of Mallory Midgetrols. Write or call Mallory today for additional information on the job Mallory Midgetrols can do for you.

Television Tuners, Special Switches, Controls and Resistors

**SERVING INDUSTRY WITH**

Electromechanical Products—Resistors • Switches • TV Tuners • Vibrators

Electrochemical Products—Capacitors • Rectifiers • Mercury Dry Batteries

Metallurgical Products—Contacts • Special Metals • Welding Materials

P. R. MALLORY & CO., INC., INDIANAPOLIS 6, INDIANA

PROCEEDINGS OF THE I.R.E. April, 1952
This new CLARE Type "R" d-c Relay embodies many features of the famous CLARE Type "K" Relay, which was the first to combine the advantages of a telephone-type relay with the small size, light weight and resistance to vibration required to meet the rigid demands of aircraft service.

In appearance, the Type "R" resembles the Type "K", but, through hardly noticeable structural differences, CLARE has given the new Type "R" even greater sensitivity and operating range. Both relays use the same contact springs, but the Type "R" coil is longer and of larger diameter, to provide greater winding space. Life expectancy of the new relay has been not only increased but multiplied.

The CLARE Type "R" Relay retains in an improved form the reed armature suspension which discerning engineers have come to recognize as one of the subtler reasons for the superior performance of CLARE Type "K" Relays over other relays of comparable size and somewhat similar appearance.

The Type "R" is available as either an open or hermetically sealed relay. Clare sales engineers are located in principal cities to give you firsthand information on this new relay and to cooperate with you on any complex relay problem. Call them or write to C. P. Clare & Co., 4719 West Sunnyside Avenue, Chicago 30, Illinois. In Canada: Canadian Line Materials Ltd., Toronto 13. Cable Address: CLARELAY.

Write for CLARE Bulletin No. 115

CLARE RELAYS
First in the Industrial Field
Designed for Application

Grid Dip Meters

Millen Grid Dip Meters are available to meet all various laboratory and servicing requirements.

The 90662 Industrial Grid Dip Meter completely calibrated for laboratory use with a range from 225 kc., to 300 mc., incorporates features desired for both industrial and laboratory application, including three wire grounding type power cord and suitable carrying case.

The 90661 Industrial Grid Dip Meter is similar to the 90662 except for a reduced range of 1.7 to 300 mc. It likewise incorporates the three wire grounding type cord and metal carrying case.

The 90651 Standard Grid Dip Meter is a somewhat less expensive version of the grid dip meter. The calibration while adequate for general usage is not as complete as in the case of the industrial model. It is supplied without grounding cord and without carrying case. The range is 1.7 to 300 mc. Extra inductors available extend range to 220 kc.

The Millen Grid Dip Meter is a calibrated stable RF oscillator unit with a meter to read grid current. The frequency determining coil is plugged into the unit so that it may be used as a probe.

These instruments are complete with a built-in transformer type A.C. power supply and inter-terminal terminal board to provide connections for battery operation where it is desirable to use the unit on antenna measurements and other usages where A.C. power is not available. Compactness has been achieved without loss of performance or convenience of usage.

The incorporation of the power supply, oscillator and probe into a single unit provides a convenient device for checking all types of circuits. The indicating instrument is a standard 2 inch General Electric instrument with an easy to read scale. The calibrated dial is a large 270° drum dial which provides seven direct reading scales, plus an additional universal scale, all with the same length and readability. Each range has its individual plug-in probe completely enclosed in a contour fitting polystyrene case for assurance of permanence of calibration as well as to prevent any possibility of mechanical damage or of unintentional contact with the components of the circuit being tested.

The Grid Dip Meters may be used as:
1. A Grid Dip Oscillator
2. An Oscillating Detector
3. A Signal Generator
4. An Indicating Absorption Wavemeter

The most common usage of the Grid Dip Meter is as an oscillating frequency meter to determine the resonant frequencies of demagnetized tuned circuits.

Size of Grid Dip Meter only (less probe): 7 in. x 3½ in. x 3½ in.
Connector Problem?

...We’ll take it from HERE

Good ideas for electronic circuitry sometimes run afoul of connector problems. Maybe existing connector units won’t hold air pressure gradients, won’t stand the heat, aren’t rugged enough for the job. Or maybe it’s a question of altitude, or under-water application. But if you can sketch the circuit, we’ll take it from there. We’ve engineered so many special connectors, solved so many “impossible” problems, that whatever the requirements are, we can usually provide the answer.

WRITE TODAY for specific information, or send us your sketches. We’ll forward recommendations promptly.

BREEZE
Special CONNECTORS

BREEZE CORPORATIONS, INC.
41 South Sixth Street
Newark, New Jersey
RETIRED...

*One Eimac 3X2500A3... after 11,000 hours of FM broadcast service on 94.9 Mc

Before Eimac tubes are put out to pasture, they earn their retirement. Here's a typical story:

George D. Tate
Chief Engineer
WMRC

Eitel-McCullough, Inc.
San Bruno, California

Dear Sirs:

Thought you may be interested to know that we have just retired one of your 3X2500A3 tubes with a little over 11,000 hours of use.

This tube was used in our FM Station which operates on 94.9 Mc, with an ERP of 79,000 watt; this means an input of 10,5000 watt which in my opinion is pushing any pair of tubes for FM service.

This tube had to operate at a plate current of 1.33 amp. at 3500 volts.

We are highly pleased with this tube.

Very truly yours,
Radio Station WMRC-WMRC-FM

George D. Tate
Chief Engineer

* For complete technical data on the 3X2500A3 or 3X2500F3 triodes... or any other Eimac tube, write:

EITEL-McCULLOUGH, INC.
SAN BRUNO, CALIFORNIA

EXPERIMENTAL ELECTRONIC MATERIALS
EXPORT AGENTS: FRAZAR & HANSEN • 301 CLAY STREET • SAN FRANCISCO 11, CALIFORNIA

PROCEEDINGS OF THE I.R.E. April, 1952
MUST YOUR EQUIPMENT BE RADIO INTERFERENCE FREE?

IF YOURS IS A TOUGH RF INTERFERENCE PROBLEM — LET FILTRON SOLVE IT . . . .

FILTRON'S engineering department, cooperating with engineers of leading companies, has solved RF Interference Suppression problems throughout the country.

If your equipment must meet the RF Interference limits set by the military specifications, consult with FILTRON'S engineers in the earliest stages of design. FILTRON can furnish RF Interference Suppression Filters whose size, weight and overall configuration will fit into your equipment.

FILTRON has custom designed over 1000 different types of RF Interference Suppression Filters for equipment that meets military RF Interference Suppression limits and specifications.

FILTRON'S completely equipped screen rooms are always available for the RF Interference testing of your units and equipment.

An inquiry on your company letterhead will receive prompt attention.

FILTRON can best solve your RF Interference problems because:

- FILTRON'S engineering, research and design divisions are staffed by experienced RF Interference Suppression filter engineers.
- FILTRON'S modern shielded laboratories are equipped to measure RF Interference from 14 KC to 1000 MC in accordance with military specifications.
- FILTRON'S production facilities, comprising a capacitor manufacturing division, coil winding division, metal fabrication shop, metal stamping and tool and die shops, are exclusively producing the highest quality components for FILTRON'S RF Interference Suppression Filters.
- FILTRON'S extensive production facilities permit us to meet your delivery requirements. NOW!

THE FILTRON CO., INC.
_FLUSHING, LONG ISLAND, NEW YORK

LARGEST EXCLUSIVE MANUFACTURERS OF RF INTERFERENCE FILTERS

PROCEEDINGS OF THE I.R.E. April, 1952
The reputation of your product rests upon the reliability of every part that goes into its construction. Ohmite electrical controls . . . rheostats, resistors, and tap switches . . . have been engineered for long life . . . built to give years of trouble-free service without maintenance. That's why more manufacturers have standardized on Ohmite wire-wound resistance units for controlling electrical currents and voltages, than any other rheostat or resistor on the market.

Ohmite Manufacturing Co., 4860 Flournoy St., Chicago 14, Illinois.
• Every El-Menco Capacitor is factory-tested at more than double its working voltage, thus assuring a wide margin of safety, regardless of the nature of the application.

• From the midget CM-15 (2-525 mmf. cap.) to the mighty CM-35 (3,300 - 10,000 mmf. cap.) dependability is a predetermined certainty. That is why El-Menco's have won such universal acclaim in both military and civilian services.

Write on your business letterhead for catalog and samples.

El-Menco

MOLDED MICA MICA TRIMMER
CAPACITORS

Radio and Television Manufacturers, Domestic and Foreign, Communicate Direct With Factory—

THE ELECTRO MOTIVE MFG. CO., INC.

WILLIMANTIC, CONNECTICUT
C a p a c i t o r  A n a l y z e r s  •  T r a n s m i s s i o n  T e s t  S e t s  . . .  a n d  c u s t o m - b u i l t  e l e c t r o n i c  s p e c i a l t i e s

m e a s u r i n g  e q u i p m e n t  •  G a l v a n o m e t e r s  • R o t a r y  S e l e c t o r  S w i t c h e s  •  A t t e n u o t o r s

2 2 A

S H A L L C R O S S  M A N U F A C T U R I N G  C O M P A N Y

8 2 8 5

R

3 6 S T A N D A R D  T Y P E S
F R O M  W H I C H  T O  C H O O S E !

Write for Shallcross Engineering Data Bulletin L-17

S H A L L C R O S S  M A N U F A C T U R I N G  C O M P A N Y
C o l l i n g d a l e ,  P a .

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 64)

diameter, of the suspension enclosure. The system can be used as a replacement for most galvanometer systems in common use.

The Type 51 galvanometers are available in 4 types having sensitivities per mm division of 4, 2, 1, and 0.5 microamperes, respectively. The units are particularly adaptable to bridge and potentialmeter circuits, or wherever indication of precise circuit balance is required. Each unit employs the rugged taut-suspension moving-coil principle with a pointer reading on a scale calibrated in 15 divisions of 1 mm either side of center.

High Voltage Tubular Ceramic Capacitors

By settling on a 6,000 volt rating for its new tubular ceramic capacitors, Aero-vox Corp., New Bedford, Mass., simplifies the ordering and stocking problems, yet insures an adequate safety factor in avoiding voltage breakdowns.

Type SI-TV high voltage tubular ceramic capacitors are of the Hi-Q brand manufactured by the Electrical Reactance Corp., an Aerovox subsidiary, for distribution to and through Aerovox jobbers. These ceramics are available only in the 6,000 volt rating, but in eleven capacitance values from 4.7 to 47 ufd.

Capacitor for Low-Voltage Distribution

Westinghouse Electric Corp., 306 Fourth Ave., Pittsburgh 30, Pa., states that in 1951, a development was completed that enables the capacitor to "leapfrog" the distribution transformer from the high-voltage side to the secondary side. The designers have produced a 3-kva, single-phase, 240-volt shunt capacitor sufficiently low in cost so that one can be inserted in each secondary line of a transformer of 15 kva or larger.

The unit is housed in an extruded aluminum tube having a porcelain insulating lid. The assembly is about 164 inches long and 43 inches in diameter. It is connected to the line by a wire small enough to act as a fuse, should an internal short-circuit develop.

(Continued on page 24A)
SYLVANIA SOCKETS... report for Active Duty!

Sylvania's full line of high quality sockets meets rigid military and civilian requirements

JAN 7-Pin Miniature Socket (Shield Base Type)

For active military duty, Sylvania produces the JAN 7- and 9-Pin miniature sockets. These are available in Low Loss Phenolic and Steatite with Beryllium Copper Silver Plated contacts. The contacts and center shield tab are hot tin dipped after complete assembly.

1. 7-Pin Miniature Socket (Bottom Mounting)
2. RMA 9-Pin Miniature Socket (Shield Base Type)
3. Octal Socket (Top Mounting)
4. Duo-Decal Cathode Ray Tube Socket

BRUSH and the future of magnetic recording...

Multiple recording head capable of recording 14 channels simultaneously.

MAGNETIC RECORDING is only an infant in the field of electronic devices, but it is a lusty infant. First developed to record sound, it has already invaded many other widely diversified fields.

Brush engineers have pioneered many of the developments in magnetic recording. From Brush laboratories came the first practical tape recorder for general use—the Brush Soundmirror.* Other Brush developments have made possible the application of magnetic recording to memory storage, to instrumentation, to multiple channel recording.

Right now in the Brush laboratories, scientists, and engineers are working on projects that will bring new applications, new techniques, and new devices to the field of magnetic recording. In this field, as in piezoelectrics and ultrasonics, Brush's business is the future.

Write for further information about magnetic recording equipment.

*T.M. Reg.

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 22A)

Frequency-Marker Generator

Polarad Electronics Corp., 100 Metropolitan Ave., Brooklyn 11, N.Y., announces its precision frequency marker, Model FM-L.

This frequency marker produces calibration signals at precisely determined intervals of 1 mc within the frequency range of 950 to 2,040 mc. Means are provided for selecting particular frequency markers and rejecting all others. Frequencies can be determined to an accuracy of one part in one hundred million. An interpolation oscillator produces a comparison signal by which the frequency of an unknown signal is determined to within ±10 kc. Markers are available at 10 mc or 1 mc intervals throughout the entire frequency.

Power Rheostat

Tru-Ohm Products, Division of Model Engineering and Manufacturing Co., 2800 Milwaukee Ave., Chicago 18, Ill., announces the development of the Tru-Ohm Power Rheostat. This item augments the firm's line of resistors, which include variable, fixed, "Econohm," "Ribohm" resistors, etc.

An extra deep core, on which the resistance wire is toroidally wound, means a more conservative power rating. Resistance values, either uniformly or taper wound, are available. Standard resistance tolerance is 10 per cent; tolerances as low as 5 per cent are available.

These resistors are available with such variations as off positions, screw driver control, shaft assemblies for special mounting conditions, etc. Prompt engineering service is available for all special requirements. Knobs are furnished upon request.

Technical literature, further data, and complete catalogs on the full TRU-OHM line of resistors and rheostats are available upon request.

(Continued on page 32A)
CAN MATCH YOUR SWITCH
SPECIFICATION WITH
INEXPENSIVE STANDARD TYPE
STACKPOLE

20 STANDARD
LOW-COST TYPES
for instruments, radios, appliances,
toys and other uses

SP ST
SP DT
DP DT
DP ST
DP DT
with spring return
TP DT
with spring return
Midget
3-POSITION SLIDE
Triple-pole Double-pole

SP DT
with spring return
4P DT
with spring return
4P DT
no indent
4P DT
with indent
PUSH TYPE
momentary contact

3-POSITION DP
4-POSITION SP
SP DT PLUNGER TYPE
with spring return
DP DT PLUNGER TYPE
with latch
4-GANG SP DT
3-AMP. SP ST
3-AMP. SP DT

Write for Catalog RC-8
Electronic Components Division
STACKPOLE CARBON CO., St. Marys, Pa.

STACKPOLE
FIXED RESISTORS • VARIABLE RESISTORS • IRON CORES
CERAMAG® FERRITE CORES • LINE & SLIDE SWITCHES
CHOKE FORMS • GA CAPACITORS
**TYPE 45**
(JAN-R-94, Type RV3)

\(1/8\) watt, \(3/4\)" diameter variable composition resistor.
Also available with other special military features not covered by JAN-R-94. Attached Switch can be supplied.

**TYPE 35**
(JAN-R-94, Type RV3)

\(1/2\) watt, \(1\frac{1}{16}\)" diameter variable composition resistor.
Also available with other special military features not covered by JAN-R-94. Attached Switch can be supplied.

**TYPE 252**
(JAN-R-19, Type RA30)

2 watt, \(1\frac{3}{8}\)" diameter variable wirewound resistor. Also available with other special military features not covered by JAN-R-19. Attached Switch can be supplied.

**TYPE 25**
(JAN-R-19, Type RA30)

4 watt, \(2\frac{1}{2}\)" diameter variable wirewound resistor. Also available with other special military features not covered by JAN-R-19. Attached Switch can be supplied.

For additional information on these 7 controls, write for Data Sheet No. 160

**EXCEPTIONALLY GOOD DELIVERY CYCLE** on military orders due to enormous mass production facilities ... Immediate delivery from stock on more than 170 different types and resistance values ... Please give complete details on your requirements when writing or phoning for further information.

NEW COMPLETE CTS CATALOG. Write for your copy today.
MEETS MILITARY SPECIFICATIONS

\(-55^\circ\text{C} \text{ to } +150^\circ\text{C}\) ... complete aridity to saturation ... are the unprecedented temperature and humidity range of Types 65, 90 and 95. These controls are used in military equipment subjected to extreme temperature and humidity.

**TYPE 65**

\(\frac{3}{4}\) watt 70°C, \(\frac{3}{16}\)" diameter miniaturized variable composition resistor.

**TYPE 90**

1 watt 70°C, \(\frac{1}{4}\)" diameter variable composition resistor. Attached Switch can be supplied.

**TYPE 95**

2 watt 70°C, \(\frac{1}{4}\)" diameter variable composition resistor. Also available with other special military features not covered by JAN-R-94. Attached Switch can be supplied.

Specialists in Precision Mass Production of Variable Resistors

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New York 18, N. Y.
SAFE Capacitor Specifications

- From tiniest metallized-paper capacitor symbolizing miniaturization, to giant oil capacitor for atom-smashing Betatron, you are SAFE in specifying Aerovox. For Aerovox makes all categories, types, sizes and ratings. More than that: with a background experience second to none, Aerovox engineers are always ready to study your circuitry, components, operating conditions and anticipated life. Thus capacitor selection is custom-fitted to your exact requirements. And that is why Aerovox capacitors have such outstanding service records.

- Literature on request. Submit that capacitance problem for engineering aid and quotations.

INTERFERENCE FILTERS
For military and civilian needs, particularly aircraft and radio-equipped vehicles.

MICA CAPACITORS
Dozens of different types, including low-loss molded casings and the silver micas.

MOLDED PAPER TUBULARS
For extra-severe service. Aerolene impregnant eliminates necessity of stocking both oil and wax tubulars. No deterioration in stock.

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From tiniest tubulars to giant steel-case units in ratings up to 50,000 volts.

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Hermetically-sealed with vitrified ceramic seal, in tubular metal case.

METALLIZED-PAPER
Full utilization of space-saving factor, together with self-healing feature.

MICRO-MINIATURES
Molded thermo-plastic tubulars. Two sizes: 3/16" d. x 7/16" l.; 1/4" d. x 9/16" l.

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Widest choice of containers, terminals, mountings, combinations. In 85°C and higher temperature ratings.

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PROCEEDINGS OF THE I.R.E. April, 1952
Here's the "inside" story on the MICRO Hermetically Sealed Switch.

When the Air Force needed a hermetically sealed switch for positive performance under conditions conducive to condensation, icing, low atmospheric pressure, dirt, and oil, the MICRO division of Minneapolis-Honeywell came up with the answers and the switch.

It's not surprising that Fusite, as the pioneer in glass-to-metal terminals, was given the job to produce the terminals that would furnish a safe, sure and rugged seal.

While originally conceived for military applications, design and construction was kept clean, simple and inexpensive to assure its application in peace-time products.

What Fusite Terminals have done for MICRO they can do for your electrical product. Write for catalog of the Fusite line of single, multiple, and plug-in terminals, Department A.

See our catalog folio J-5 in Product Engineers' section of Electrical Catalogs (E. R. R.)

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Advance Professionally FASTER

In Career-Building Positions at RCA

Career-minded engineers have found the way to more rapid advancement and professional development through challenging assignments at RCA, on long-range military and commercial projects.

RCA IS A GOOD PLACE TO WORK

At RCA you receive recognition for your accomplishments. You work in close collaboration with distinguished scientists and engineers. You enjoy highest professional recognition among your colleagues. You have unexcelled facilities for creative work. The surroundings in which you work are pleasant and stimulating. You and your family enjoy outstanding employee benefits. Opportunities are excellent for advancement in position and income.

DIVERSIFIED LONG-TERM PROGRAM

Positions open are career opportunities of a lifetime. They are not "emergency" jobs. They offer lifelong employment opportunities to men who expect more from their work than is provided by an ordinary engineering assignment. They cover not only revolutionary new military projects, but also trailblazing commercial projects for important electronic advances of the future. Such diversification of products and markets represent long-term employment opportunities independent of wars or depressions.

If you aspire to a career-building future, investigate the positions now open at RCA.

MAIL RÉSUMÉ

If you desire to consider any of the positions listed, write us for a personal interview—include a complete résumé of your education and experience. Send résumé to:

MR. ROBERT E. McQUISTON, Manager
Specialized Employment Division, Dept. 94-D
Radio Corporation of America
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TRANSFORMER and COIL DESIGN
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TECHNICAL SALES
ELECTRONIC EQUIPMENT FIELD SERVICE
The makers of BUSS Fuses take every precaution to be sure that the highest standards of quality are maintained. EVERY BUSS FUSE IS ELECTRONICALLY TESTED. A sensitive testing device rejects any fuse that is not correctly calibrated, properly constructed and right in all physical dimensions.

This insistence on perfection is the reason why you can always rely on BUSS Fuses. Manufacturers and service men the country over have learned they can depend on BUSS Fuses for the right protection under all service conditions.

Here's another reason why it pays to standardize on BUSS Fuses: You can get all your fuses from one source. The line is complete—dual-element (slow blowing), renewable and one-time types... in sizes from 1/500 ampere up.

If you have a special problem concerning electrical protection, let our engineers help you select the right fuse—or design a new fuse, or fuse mounting, to meet your needs. Our staff of engineers and laboratory are at your service.

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

Forcing is out of fashion for installing radio batteries in newly-designed receivers...and understandably so, since there are compact, long-lasting "EVEREADY" brand batteries already available as standard types — to fit any size set you're designing.

Whether they have a farm radio or a pocket portable, users find replacements everywhere... and they prefer radios that use the famous "Eveready" "Nine-Lives" batteries!

Write to our Battery Engineering Department for full details on the "EVEREADY" brand radio battery line.

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

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1751 North Western Avenue  •  Chicago 47, Illinois
IN BUSINESS SINCE 1904
A high-precision time-measuring device designed for general-purpose functions in laboratory work.

The calibrated sweep delay of the Type 256-D will measure time intervals up to 1000 microseconds with an accuracy of ±0.1% of the full scale ranges of 100 μ-secs. or 1000 μ-secs. A movable marker indicates the portion of the sweep which is expanded on shorter delayed sweeps. Delayed sweeps are of 4-, 10-, and 25-microsecond durations. Undelayed sweeps are available in six ranges from 4- to 4500-microseconds.

Response of the video amplifier is within ± 1 db at 20 cps; down less than 3 db at 8 mc, no more than 6 db at 11 mc. Sensitivity is 0.7 peak-to-peak volt per inch. Pulse response is such that a rise time of 0.01 microsecond will be reproduced as a rise time of 0.04 microsecond or less.

Crystal-controlled timing markers calibrate the delay circuits. Delayed and undelayed sweeps may be started by external trigger pulses of either polarity or by built-in trigger generator providing 1 microsecond pulses of either polarity, having a rise time of 0.3 microsecond and amplitude greater than 100 volts. Trigger repetition rates up to 2000 P.P.S. are available.

Electrically similar to the Type 256-D. Calibrations in yards instead of microseconds. Designed especially as test equipment for electronic ranging systems, or as an accessory unit for radar systems.

Provides undelayed sweeps of 800, 2000, 4000, 20,000 and 200,000 yards in addition to a 4500-microsecond sweep. Delayed sweeps of 800, 2000 and 4000 yards may also be selected.
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OUR BUSINESS IS SELENIUM RECTIFIERS

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Cartridge Type — up to 60 ma.,
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Ratings up to 230 KW, Efficiency to 87%, Power Factor 95%

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A recent month’s production included Rectifiers to supply 40 microamperes, 1,000 volts, and Rectifiers with a capacity of 140,000 amperes, 14 volts. Owned and managed by Engineers who are specialists in the design and manufacture of Selenium Rectifiers. Submit your problems for analysis and we will be glad to offer our recommendations.

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PROCEEDINGS OF THE I.R.E.  April, 1952
Solve your hermetic seal problems with **GENERAL CERAMICS**

**SOLDER-SEAL TERMINALS**

General Ceramics' low-loss STEATITE sealed leads feature superior mechanical strength that insures permanent, positive hermetic sealing under practically any operating condition. Immune to severe thermal shock, they are easily soft-soldered to closures without developing the strains that are an incipient cause of trouble in many other types of leads. There are no rubber or plastic gaskets to deteriorate. Resistance to mechanical shock and vibration is excellent. The types shown are standard and can be supplied promptly from stock. For complete information on these and for consultation on custom-made terminals to your specifica-
tion, phone, call or write today.

**SOLDER-SEAL OFFERS:**
- EASE OF ASSEMBLY
- SUPERIOR STRENGTH
- NON-DETERIORATION
- PERMANENT SEALING
- RESISTANCE TO HEAT
- EXTREMELY LOW-LOSS

**TYPE D-3405**

**TYPE D-3540**

**TYPE D-3946**

**CAPACITOR END SEALS**

**SOLDER LUG TYPES**

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**GENERAL CERAMICS AND STEATITE CORP.**

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PROCEEDINGS OF THE I.R.E. April, 1952
Radio frequency circuit design often requires the accurate measurement of Q, inductance and capacitance values. For this application the Type 160-A Q-Meter has become the uncompromising choice of radio and electronics engineers in this country and abroad.

Each component and assembly used in the manufacture of this instrument is designed with the utmost care and exactness. Circuit tolerances are held to values attainable only in custom built instruments.

With the 160-A Q-Meter, as with other Boonton Radio Corporation instruments, the keynote in design is to embody accurate direct reading features which save time and simplify operation.

**SPECIFICATIONS**

- Oscillator Frequency Range: 50 kc. to 75 mc. in 8 ranges.
- Oscillator Frequency Accuracy: ±1%, 50 kc.—50 mc.
- ±3%, 50 mc.—75 mc.

- Q Measurement Range: Directly calibrated in Q, 20-250. "Multiply-Q-By" Meter calibrated at intervals from x1 to x2, and also at x2.5, extending Q range to 625.

- Q Measurement Accuracy: Approximately 5% for direct reading measurement, for frequencies up to 30 mc. Accuracy less at higher frequencies.

- Capacitance Calibration Range: Main capacitor section 30-450 mmf, accuracy 1% or 1 mmf whichever is greater. Vernier capacitor section +3 mmf, zero, −3 mmf, calibrated in 0.1 mmf steps. Accuracy ±0.1 mmf.

Catalog "H" containing further information available upon request.

(In Canada, direct inquiries to RCA Victor Co., Ltd., Montreal.)

---

**EXAMINE THESE Direct Reading Features WHICH SIMPLIFY ACCURATE MEASUREMENTS**

1. **OSCILLATOR FREQUENCY DIAL.**

   This large 4½" open faced dial has eight overlapping frequency ranges, each calibrated directly in kilocycles or megacycles, with scales conveniently divided for maximum readability. A vernier drive enables fine settings to be made with ease. All frequency ranges are accurate to within ±1% except the 50-75 megacycle range which is accurate to ±3%. The clearly marked range change switch located directly beneath the frequency dial facilitates rapid and positive selection of the desired frequency band.

2. **Q-TUNING CAPACITANCE DIALS.**

   L-C dial serves twofold purpose of (1) conveniently and accurately indicating tuning capacitance directly in MMF, and (2) providing an effective inductance scale which also becomes direct reading at certain defined frequencies shown on frequency reference plate. Incremental capacitance dial at right calibrated from +3 MMF through zero to −3 MMF, accurate to ±0.1 MMF.

3. **Q-VOLTMETER AND MULTIPLIER METER.**

   For the indication of Q values the 160-A Q-Meter employs a Weston Model 643 Meter calibrated directly in terms of Q over the range from 20-250. The damping of the meter movement is ideal for the rapid determination of exact resonance without sluggishness or overshoot. The lance type pointer provides Q readings to be obtained to the nearest unit. Located directly beneath the Q voltmeter is the "Multiply-Q-By" meter which provides Q multiplier factors of X1 to X1.5 in 0.1 steps, X2, and X2.5 thereby extending the useful range of Q indication to 625. This meter is carefully matched to a particular thermocouple element for maximum accuracy.
An instruction sheet recently received from a valued customer. The company knew the properties it wanted... and left it to Plastoid to work out the details.

Here, in two simple photographs, is a perfect illustration of Plastoid's service to the electronic industry.

For your wire or cable needs, get in touch with Plastoid. In addition to supplying all standard constructions, our excellent staff of engineers and production men will gladly cooperate with you in designing — and producing — cable to fit your requirements.

Make it?
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— WE KNOW HOW!

The finished job... a custom-engineered SYNKOTE 3/8" cable with 30 individually-shielded conductors, fungus-resistant, flexible, designed to "take it" at −50°C or +60°C.

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For your wire or cable needs, get in touch with Plastoid. In addition to supplying all standard constructions, our excellent staff of engineers and production men will gladly cooperate with you in designing — and producing — cable to fit your requirements.
Rigorous Tests Prove New Precision Wire Wounds
Best of All for JAN-R-93 Specifications

No other resistor so far exceeds JAN-R-93 Specifications as IRC’s newly developed Precision Wire Wounds! This is the impartial verdict of the most modern electrical and mechanical testing equipment applied to our own and competing resistors.

Largest producers of resistors in the world, IRC makes rigorous, thorough testing a continuous job, rather than an intermittent one. Pre-testing proves the design soundness of every IRC product. Tests-in-production safeguard product quality. And tests-in-service are your warranty that IRC resistors will meet your every requirement.

ALL NEW Type WW Wire Wound
Resistors for JAN Equipment—Industrial Applications—Miniaturization

Specifically designed for close tolerance requirements, new IRC Type WW Wire Wounds offer the finest balance of accuracy and dependability, excel in every significant characteristic under extreme heat and humidity conditions. Choice of leading producers of military equipment, these newly developed Precision Wire Wounds far surpass JAN-R-93 Characteristics & Specifications! High stability suits them to a multitude of industrial uses, and compactness and small size make them ideal for miniaturization.
NEW WINDING FORMS AND TECHNIQUES — NEW TYPE INSULATION — NEW TERMINATIONS — GIVE NEW CLOSE TOLERANCE EFFICIENCY

New Winding Forms hold more wire — provide higher resistance values. Non-hygroscopic ceramic forms assure high insulation qualities, high mechanical strength, and low coefficient of thermal expansion.

New Winding Technique, developed by IRC engineers, eliminates possibility of shorted turns or winding straights. All wire used receives rigid insulation tests of special enamel coating. Additional production tests assure high quality in the finished resistor.

New Type Insulation insures long life under all environmental conditions. Winding is multiple vacuum impregnated with a new compound developed by IRC chemists. This has the unique characteristic of retaining the same consistency throughout the entire range of temperatures to which the resistors may be subjected. It is neither glassy hard nor tacky soft under any conditions. Result — A higher degree of stability and freedom from noise, and much greater resistance to humidity.

Test the IRC Industrial Service Plan and you'll always use it to get maintenance, pilot-run or experimental quantities of standard resistors in a hurry. Your nearby IRC Distributor has these units on his shelf, can make 'round-the-corner delivery without delay. He's a good man to talk with about JAN Specifications, too. Ask for his name and address.

Typical Cycling and Load Tests Show Minimum Change in Resistance of New IRC Precision Wire Wounds

A glance at the adjacent chart will show the negligible resistance change undergone by IRC Precision Wire Wounds subjected to the most stringent and protracted cycling and load tests. Here is your assurance that new IRC Precision Wire Wounds withstand the toughest kind of service without loss of efficiency. This is only one of the many rigid tests applied to IRC Precision Wire Wounds.

SIZES AND RANGES

NEW TERMINATIONS. All precision resistors, with the exception of WW-10, are provided with rugged lug terminals for solder connections. These provide dependable and strain-free winding terminations, WW-10, because of its small size, has wire lead termination 2" long.

405 N. Broad St., Philadelphia 8, Pa.
INTERNATIONAL RESISTANCE CO.

Please send me Technical Data Bulletin (Number) __, ond/or name and address of nearest IRC Distributor __

NAME ____________________________

TITLE ____________________________

COMPANY ____________________________

ADDRESS ____________________________

CITY ____________________________ ZONE ______ STATE ______
ADVANCED TRAINER...
FOR THE FIRST GUIDED MISSILES GROUP, U.S. ARMY

The United States Army Field Forces today is training its first Guided Missiles Group with Fairchild Missiles. In firing these advanced type anti-aircraft missiles, the Army Field Forces is preparing now for the day when missile batteries will defend cities and vital military installations.

Firing on the desert missile range at Ft. Bliss, Texas, officers and enlisted cadres are learning the skills and techniques necessary for the tactical application of these new weapons under conditions similar to those in actual combat.

Fairchild's Guided Missiles Division also is providing similar anti-aircraft missiles for the United States Navy and the United States Air Force. Its advanced engineering and technical facilities are being devoted to the design and development of new missiles and improved versions of current missiles to provide our Armed Forces with the latest and best possible weapons.
If you want to get tough in your assemblies,

specify

power resistors

*The green-colored power resistors so conspicuous these days in dependable radio-electronic and electrical assemblies, are GREENOHMS. No tougher resistors made. That statement is sustained by laboratory tests. Likewise by countless case histories out in the field.

Unimpaired wire winding firmly imbedded in exclusive cold-setting inorganic cement. Exceptional heat conduction and surface radiation. Heavy overloads handled without damage. Severe heat-shock resistance permits extreme on-off operation without flinching. And Greenohms last and last.

Choice of standard types. Also in virtually unlimited special types. Wide selection of resistance values, wattages, taps, terminals, mountings. And remember, Greenohms cost less though they offer you more!

you can stand pat with clarostat

Engineering data on request. Send us your resistance or control requirements for engineering aid and quotations. Try Greenohms!

Controls and Resistors

CLAROSTAT MFG. CO., INC., DOVER, NEW HAMPSHIRE

In Canada: Canadian Marconi Co., Ltd., Toronto, Ontario
For much more than metals for electronic applications...see REVERE!

- This Raytheon Magnetron is just one of a number using Revere Metals—and Revere know-how. Revere and Raytheon work closely together, consulting on such matters as the properties of copper and brass, brazing methods, machining, suitability of metals for glass-to-metal seals, and so on. In other words, Revere goes much beyond merely supplying metals. Through the Revere Technical Advisory Service our knowledge and skill are available. They have proved invaluable to many companies. And by the way, do not forget that this collaboration is freely given. If you purchase from distributors and would like to avail yourself of our assistance, simply ask your Revere Distributor. He will be glad to put you in touch with us, without obligation.

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Raytheon Magnetron, Type RK 5/26, made by Raytheon Manufacturing Co., Waltham, Mass. This is a super-high frequency, pulse-type, tunable magnetron cavity oscillator, to operate in the 23.3 centimeter band. It is capable of delivering 700 kilowatts of peak power under pulsed conditions.

PROCEEDINGS OF THE I.R.E. April, 1952
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Each line provides adjustment over a two decade range, and as much as 1.1 milliseconds delay with excellent rise time is obtainable in a single unit of relatively small size.

**Characteristics**

All units have a characteristic impedance of 1000 ohms, permitting series connection if desired. For the latter reason no terminating resistor is included. Two selector switches on each unit permit adjustment in 1\% steps. Accuracy is ±1\% of maximum delay (±2\% for the 1.1 millisecond unit). Voltage rating of all units is 500 volts. Delay to rise time ratio at maximum delay is approximately 50.

**Type of construction**

These delay lines differ from previously available lines in that they are true variable length lines, rather than tapped lines. This permits the use of low impedance loads; if a suitable resistor is shunted across the load, the latter may have any value equal to or greater than 1000 ohms without causing reflections.

*Please write for specifications on our component series*

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  - 0.5 MMF—550 MMF
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- Style 3139 2.0—6.0 MMF
- Style 3132 1.0—3.8 MMF

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- Style 357 5 MMF—1,000 MMF
- Style 362 5 MMF—1,500 MMF
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- Temperature Compensating and By-Passing
- Style 2322 15 MMF—6,000 MMF
- Style 2336 15 MMF—6,000 MMF
- Style 318 15 MMF—6,000 MMF
- Style 319 15 MMF—6,000 MMF
- Style 325 15 MMF—6,000 MMF
- Style 326 15 MMF—6,000 MMF
- Style 323 and 324 15 MMF—6,000 MMF

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- Style 412 10 and 20 KV—500 MMF
- Style 414 10 and 20 KV—500 MMF

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- Style 412 15 MMF—6,000 MMF
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Permanent Characteristics

The solid molded construction gives Bradley units a wide safety factor. They are not crowded for performance because they are rated at 70°C ..., not at the usual 40°C. Under continuous full load for 1000 hours, the resistance change is less than 5 per cent.

They withstand all extremes of temperature, pressure, and humidity. And, don't forget that Bradley units require no wax impregnation to pass salt water immersion tests.

Bradley units are packed in honeycomb cartons to keep the leads straight and avoid tangling during assembly operations. Made in standard R.T.M.A. values in ½ and 2 watt ratings from 10 ohms and 22 megohms; 1 watt from 2.7 ohms to 22 megohms. Let us send you an A-B resistor chart.

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

There, in two words, is the net result of all the engineering which TUNG-SOL has put into the 5881. This completely new tube is designed to operate in circuits for which the 6L6 is specified and is completely interchangeable wherever the 6L6 is now in use. Full utilization of the design and production techniques which have proved themselves over the past 15 years, has created this exceptionally reliable tube. The 5881 has tremendous overload capacity. It maintains high efficiency throughout its life and provides low cost operation through reduced maintenance.

The 5881 is manufactured under laboratory conditions accompanied by the most severe tests. It is rugged both mechanically and electrically. Here are six major features which assure its premium performance:

1. Glass button stem permits compact construction with high resistance to mechanical shock.
2. Rugged mica low-loss base provides full lifetime electrical insulation and minimizes base leakage.
3. Cathode materials of exceptional stability give more uniform emission with greater life expectancy. Cathode is not poisoned by inactivity during standby periods.
4. Maximum control of grid emission achieved by gold plating and carbonizing.
5. Zirconium anode coating is most active under overload conditions providing ample gettering action to prevent accumulation of gases.
6. Life tests are made under severe overload conditions to assure adequate safety factor.

Where reliable service is essential in audio circuits, the TUNG-SOL 5881 is a "must." Order it from your regular TUNG-SOL supplier.
Are you headed for trouble with your vibrator power supply units?

Specification of vibrator frequency, voltage and size is no guarantee that your power supply unit will do its job right ... permit your mobile radio equipment to operate properly.

To get long, trouble-free performance, the power circuit must be designed so that the characteristics of the vibrator are in balance with the transformer and buffer capacitor.

That kind of designing is a job for experts ... engineers with specialized knowledge, skill and experience.

Experienced manufacturers of mobile communications equipment turn to Mallory because they know Mallory has facilities, knowledge and engineering skills that are available nowhere else.

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You'll save yourself time, trouble and expense in connection with vibrator power supply units by calling on Mallory while your plans are in the design stage. Write or telephone Mallory today.

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BN Connectors are small, lightweight connectors designed for use with small cables such as RG-55/U, RG-58/U and RG-62/U. They are widely used for Video, I. F., Trigger Pulse and Low-Power R. F. applications.

During its many years of collaboration with our Armed Forces, Kings has developed engineering skills and production know-how that have won them "top-priority" with radio and electronic engineers everywhere. Constant research and rigid quality control are responsible for the increasing demand for Connectors by Kings.

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Up-to-date news of every British development

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Published monthly, $4.50 a year.

**Recent Editorial Contents**


Your dollar buys more "instrument" ... in our Model #630

by R.L. Triplette
President

Because we build every major part of our instruments the quality is carefully controlled. For example, we know we have more torque driving our pointers because we designed and built the complete instrument. We know we have sustained dependability in the shafts and switch contacts of our test equipment for the same reason. Cycle tests for switches exceed several times the rigid requirements of the armed forces.

There is another important value to you. Because we make our own components we eliminate the profit another manufacturer would make in selling them to us. And this "profit" is passed on to you.

Consider these features of Model 630 V.O.M., for example—

One Hand Operation—One switch with large recessed knob has a single position setting for each reading. Leaves one hand free. Eliminates switching errors, trouble, saves time.

Ranges—AC-DC Volts: 3-12-60-300-1500-6000 (AC, 5000 Ohms/Volt; DC, 20,000 Ohms/Volt). 60 Micro-Amps. 1.2, 12, & 120 Mil Amps. DB scales at 1.73V on 500 Ohm line, 0-66 DB output.

Highest Ohm Reading—To 100 Meg in steps of 1000-10,000-100,000 Ohms—100 Megohms.

Yes, with us it's a matter of personal pride to make "Triplette" stand for better construction and more service for your test equipment dollar.

R.L. Triplette
President
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Bluffton, Ohio

Model #630
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  many types of problems in tower design
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  Truscon district office, or to our home office in
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  capable engineering
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Subsidiary of
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 HERMETIC Leads the Field in its Miniaturization Program

A MAJOR ACHIEVEMENT
in
Electronic Applications

Multi-Terminal Headers from .600” to 1.000” Outside Dimension

HERMETIC's new multi-terminal headers
600 Series with 14 terminals and 1000 Series with 21 terminals, both utilizing the same configuration, are models of precision electronic engineering.

600 Series has 14 terminals; 10 on a pitch circle of .350” dia. and 4 on a pitch circle of .140” in an outside dimension of .600” in any configuration shown.

1000 Series has 14 terminals in the outer pitch circle of .656” and 7 terminals on the inner pitch circle of .312” in an outside dimension of 1.000” in any configuration shown.

These new units join HERMETIC's already well-known ceramic-metal, multi-terminal headers: 750 Series, 800 Series and 900 Series. All of units listed are also available in standard or special tubular arrangements.

In addition to their exclusive design features, they will withstand mass spectrometer leak tests, -55°F sub-zero conditions, swamp test, temperature cycling, high vacuum, high pressure, salt water immersion and spray, etc. They are the only headers 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 meg-ohms.

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INSULATOR CAP
INSULATOR
HEATER
CATHODE

SOLID ALUMINUM OXIDE HEATER INSULATOR MECHANICALLY SEPARATES HEATER FROM CATHODE TO ELIMINATE SHORTS

DOUBLE WELD CONNECTIONS
SESELFED HEATER CONNECTIONS—

ARC-RESISTANT MELOMINE BASE
WITH INTER-PIN BARRIERS

- We are not in the standard vacuum tube business, but we are in the business of developing and manufacturing a reliable line of special purpose electron tubes—tubes that will serve and meet the stiff and varied operational requirements of aviation, ordnance, marine and other fields of modern industry. Typical of these are receiving type tubes such as Full-Wave Rectifiers, R-F Pentodes, Twin Triodes, and the Beam Power Amplifiers illustrated above and described below. All of these tubes are exhausted on a special automatic exhausting machine capable of extra high evacuation, and are aged under full operating and vibration conditions for a period of 50 hours. In addition to the tubes described above, Eclipse-Pioneer also manufactures special purpose tubes in the following categories: gas-filled control tubes, Klystron tubes, spark gaps, temperature tubes and voltage regulator tubes.

RATINGS

Heater voltage—(A-C or D-C) ... 63 volts
Heater current ... 0.6 amps
Plate voltage—(max.) ... 300 volts
Screen voltage—(max.) ... 275 volts
Plate dissipation—(max.) ... 10 watts
Screen dissipation—(max.) ... 2 watts
Max. heater-cathode voltage ... 300 volts
Max. grid resistance ... 0.1 megohms
Warm-up time ... 45 sec.

(Plate and heater voltage may be applied simultaneously)

TYPICAL OPERATION

Single-Tube, Class A, Amplifier
Plate voltage ... 250 volts
Screen voltage ... 250 volts
Grid voltage ... −12.5 volts
Peak A.F. grid voltage ... 12.5 volts
Zero signal plate current ... 4 ma
Max. signal plate current ... 47 ma
Zero signal screen current ... 4.5 ma
Max. signal screen current ... 7.0 ma
Plate resistance ... 45,000 ohms
Transconductance ... 4,000 mhos
Load resistance ... 5,000 ohms
Total harmonic distortion ... 0.8%
Max. signal power output ... 4.0 watts

PHYSICAL CHARACTERISTICS

Base ... Intermediate shell axial 8-pin
Bulb ... 7.9
Max. overall length ... 3¾ in.
Max. seated height ... 2½ in.

Other E-E precision components for servo mechanism and computing equipment:
Synchrons • Servo motors and systems • Rate generators • Gyros • Stabilization equipment • Turbine power supplies and remote indicating-transmitting systems.

For detailed information, write to Dept. G

ECLIPSE-PIONEER DIVISION of BENDIX

TETERBORO, NEW JERSEY

Export Sales: Bendix International Division, 72 Fifth Avenue, New York 11, N.Y.
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VOLT-OHM-MILLIAMMETER
OUTSELLS ALL OTHERS COMBINED BECAUSE

A covers all ranges necessary for Radio and TV set testing
B includes the Simpson 50 Microampere Meter Movement known the world over for its ruggedness
C no bulky harness wiring, thus eliminating all intercircuit leakage at this high sensitivity
D molded recesses for resistors, batteries, etc.
E easy battery replacement
F covered resistors to prevent shorts and protect against dust and moisture

- all components—including case and panels—are specially designed and completely tooled for maximum utility...not merely assembled from stock parts

ranges
20,000 Ohms per Volt DC,
1,000 Ohms per Volt AC
Volts, AC and DC: 2.5, 10, 50, 250, 1000, 5000
Output: 2.5, 10, 50, 250, 1000
Milliamperes, DC: 10, 100, 500
Microamperes, DC: 100
Amperes, DC: 10
Decibels (5 ranges):
-12 to +55 DB
Ohms: 0-2000 (12 ohms center), 0-200,000 (1200 ohms center), 0-20 megohms (120,000 ohms center)

prices
Model 260 $38.95; With Roll Top $46.90. Complete with test leads and operator's manual. 25,000 volt DC Probe for use with Model 260, $9.95.

SIMPSON ELECTRIC COMPANY
5200 W. Kinzie St., Chicago 44, Illinois Phono: COLUMBUS 1-1221
NOW...9000 records per minute!
with the NEW POTTER high speed
TELEDELTOS RECORDER
IMMEDIATELY VISIBLE
INSTANTANEOUS
PERMANENT
DIGITAL

Designed to record measurements obtained on Potter Electronic counters, scalers, chronographs and frequency-time counters.

The Potter Instrument Co. High Speed Teledeltos Recorder provides a permanent recording of digital information at rates up to 150 six-digit answers per second. The measurements are transferred to electrically sensitive paper using four stylus for each digit arranged in the famous Potter (1-2-4-8) read-out. The records are indexed intermittently and controlled by the events being measured.

Write for information on specific applications to Dept. SV

POTTER RECORDING COUNTER CHRONOGRAPH

Measures time intervals up to 0.10000 second in increments of 2.5 microseconds. (Higher resolutions are also available.) Applicable to projectile velocity measurements, frequency measurements, geophysical measurements, telemetry and wherever micro-second timing is required.

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

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 58A)
tube, and 0.005 ufd on a ½ X ½ inch tube. These GP3 Ceramicos have been available on special order since 1949, and are now made in volume-production quantities. Baked enamel, clear lacquer, dipped phenolic insulation or low-loss molded phenolic insulation are available.

Miniature GP3 Ceramicos are flash-tested at 1,500 v dc, and are designed to withstand 700 v dc life test at 85°C for 1,000 hours. Standard capacitance tolerance is ±80 per cent, ±20 per cent and power factor is 2.5 per cent maximum. Write for data sheet.

Capacitors for UHF Coupling

Known as Type 502C, this ½-inch diameter ceramic capacitor is fitted with hollow connections to accommodate leads or pins from subminiature electron tubes. These new capacitors find broad use in the rf heads of uhf band TV sets.

Available capacitance values range up to 22 µf at 500 volts dc working. Performance characteristics are similar to

(Continued on page 62A)

See New IRE Directory Questionnaire
Pages 131-3A
Wilcoxon

Choice of the Airlines

Twenty-seven airlines in the United States and Hawaii have purchased Wilcoxon communications and navigation equipment. These purchases include everything from large ground station transmitters and receivers to complete air-borne multichannel communications systems. Some purchasers use Wilcoxon equipment exclusively. The Wilcoxon Company is both grateful and proud of this fine tribute to the performance, stamina, and dependability of its products.

Wilcoxon Electric Company
14th and Chestnut
Kansas City 1, Missouri, U.S.A.
RPM
to .001%

DIRECT-READING DIGITAL INDICATION OF
ROTATIONAL SPEEDS TO .001% ACCURACY

METHOD: Mechanical rotation is trans-
formed into a series of electrical im-
pulses by a magnetic tachometer pick-
up. This device consists of a 60 tooth
gear mounted on a double-bearing shaft
and a magnetic sensing element mount-
ed near the periphery of the gear. En-
tire assembly is mounted in a small cast
housing approximately 7 x 5 x 3 inches.
Shaft of ¼” diameter extends 4” beyond
outside wall of case.

MECHANICAL COUPLING is made to
primary rotating element. As shaft and
gear revolve pulse is generated each
time a gear tooth passes magnetic sens-
ing element. Thus 60 pulses are gener-
ated per revolution of primary rotating
element. These pulses are transmitted
to EPUT meter which counts for pre-
cise 1 second interval and displays re-
sult in direct-reading form in terms of
RPM. System may be recycled manually
or automatically.

VERSATILITY: Under some circum-
stances, it is not possible to obtain di-
rect access to the primary rotating ele-
ment. Information must be obtained
from a secondary element rotating at
some odd ratio with respect to the pri-
mary, or from a motor driven generator.
Tachometer pick-up devices are avail-
able to operate either from direct drive
or by synchronous motor drive and to
provide whatever conversion factors
may be necessary to express the avail-
able information in direct-reading form
of RPM. Special types of tachometer
transducers can be used to measure ro-
tational speeds as high as 100,000 RPM.

MODIFICATIONS: Although the Model
554T electronic tachometer ordinarily
operates on the basis of a 1 second sam-
ping period, modification can be sup-
plied to provide 0.1, 0.5, and 10.0 sec-
ond sampling periods, either indivi-
dually or selectively. Remote indication
is available when necessary. The
entire equipment can also be supplied
in standard explosion-proof housings
for industrial installations.

FOR COMPLETE INFORMATION, please write for Bulletin 554-P

Berkeley Scientific Corporation

2200 WRIGHT AVENUE • RICHMOND, CALIFORNIA

PROCEEDINGS OF THE I.R.E. April, 1952
Fairchild's adaptation of the Polaroid-Land camera gives you more than just a fast photographic print of an oscilloscope image. The print is exactly half-size for easy measurement of values, especially when a grid is used. And you see the image exactly as it appears on the scope—not reversed. Each 3¾ x 4¾ print records two images.

Moreover, it takes only two minutes (less, if you're fast) to set up the camera, snap the shutter, and pull the tab. Then you wait one minute more and remove the finished print. It's as simple as 1-2-3. No focusing, no special training required.

Full information about the Fairchild-Polaroid and Fairchild Oscillo-Record Cameras is available on request. Write today to Fairchild Camera and Instrument Corporation, 88-06 Van Wyck Boulevard, Jamaica 1, N.Y. Department 120-17C1.
**NEW** forced-air-cooled **TV** power tetrodes

The new RCA-6166 and 6181 ... developed for TV and radio services ... represent the successful application of forced-air cooling to power tetrodes designed to operate at high efficiency at the higher frequencies. The use of forced-air cooling simplifies transmitter design and effects substantial operating economies.

Both tubes feature coaxial-electrode structures, and are particularly suited to operation in circuits of the coaxial-cylinder type.

The RCA-6166 VHF tetrode uses a time-proven thoriated-tungsten filament that permits substantial savings in filament power.

The RCA-6181 UHF tetrode has an indirectly heated, low-temperature, coated cathode of the matrix type for long serviceability. Further, it features seals between a low-loss ceramic and a high-conductivity metal to provide high-efficiency uhf performance.

For complete technical data on these or any other RCA tubes, write RCA, Commercial Engineering, Section DR47, Harrison, New Jersey ... or contact your nearest RCA Field Office ...
PROCEEDINGS OF THE I.R.E.

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Copyright, 1952, by The Institute of Radio Engineers, Inc.
Alois W. Graf was born at Mankato, Minn., in 1901, and received his B.S. degree from the University of Minnesota, and the L.L.B. degree from the National Law University, in 1926, and 1931.

Mr. Graf served as an examiner in the United States Patent Office from 1926–1930, where he handled radio-multiplex communications systems, and from 1930–1938, he was a member of the patent department of the General Electric Company, working with radio transmitter receivers, television circuits and apparatus, and power applications of vacuum tubes. Subsequently, he was associated with several Chicago patent law firms, specializing in radio, electronic, and electrical patent matters. For the past five years, he has had his own patent law practice in Chicago.

Mr. Graf became a member of the bar of District of Columbia in 1931, the bar of Indiana in 1940, and the bar of Illinois in 1942. He is a member of the American Bar Association, the Chicago Patent Law Association, the Chicago Law Institute, the Illinois Society of Engineers, the National Society of Professional Engineers, the American Arbitration Association, and the Radio Engineers Club of Chicago. He has been a director of the National Electronics Conference in 1946–1952, and was elected president of the Illinois Engineering Council in 1951.

Joining the Institute as an Associate in 1926, he transferred to Member in 1944, and became a Senior Member in 1945. He was the Chairman of the IRE Chicago Section in 1946–1947, and has served on various IRE Committees, such as Sections, 1947 (Chairman 1948–1949); Education, 1945–1951; Board of Editors, 1945–1952; Appointments, 1951; and Nominations, 1952.
The Role of Private Industry in Military Research and Development

JOHN N. DYER

Engineers working in an industry concerned with the development and production of equipment of military significance for the government, render an invaluable service. Under suitable circumstances, the effectiveness of this service can be enhanced. These favorable circumstances include a desirable co-ordination and continuing relationship between engineers developing equipment and those who later use it in the field. Such co-ordination is described in the following guest editorial, prepared by a Fellow of the IRE who is Vice President and Director of Research of the Airborne Instruments Laboratory.—The Editor.

This nation is diverting more research, development, and production to military needs than ever before in peacetime. Much of the effort, especially in the fields with which members of this Institute are concerned, is performed by private industry. By contrast, Russia is carrying out forced-draft research and development by tight government control.

Should war be forced upon us, we have confidence in our ability to win the race of developing new and improved weapons for war. One reason for this confidence is the freedom from governmental control enjoyed by private enterprise in this country. To keep this freedom, which is vital to our technological progress, private enterprise must do its part to ensure that military research and development are efficiently conducted.

The rate of progress on military research and development is a function of the behavior of the communication channel between operational problems and the research and development program. The contractual agreement must necessarily define the objective as completely and specifically as possible. However, because of the inherently narrow bandwidth that exists for the flow of information through a contract, the government and the contractor have a responsibility to devise methods to add feedback around this part of the communication channel. (Oscillations which may result from such practices can be avoided by careful design.) Research and development engineers should make it their business to keep fully informed on the progress of the operational problem. In this way both they and their management can aid in guiding the program to the best interests of the nation.

It is unfortunate that the completion of a contract frequently terminates the association of the research and development personnel with the military problem; the system engineering needed to integrate the technique or device that came out of the contract into an operational situation is carried out without the benefit of feedback from the development engineer to the user. This lack of further association after a contract is complete is a weakness of our present national effort. In our haste to develop new military devices, developmental personnel are not being afforded sufficient opportunity to follow their equipment through the operational stages. Often the problems that arise in the use of a new device are fully as important to its success as those solved in the development.

If we are given close association between development engineers and military problems, from the conception to the large scale use of a new military device, we will be able to ensure more effective use of our technical manpower and more reliable and efficient military equipment.
Radio Progress During 1951*

Introduction

The year 1951 was filled with paradoxes for it was a year when employment managers of manufacturing companies visited the prospect: when, despite material shortages, prices of equipment for the home-entertainment field dropped appreciably; when substantial gains in television coverage were obtained, notwithstanding the freeze that still curtailed the erection of new stations; when the establishment of official standards for a color-television system spurred the development of many ingenious methods using principles widely divergent from that legal standard; when substantial progress was attained in reliability of circuits, despite a trend toward smaller components that run hotter; when the solution of many vexing technical problems in radio circuits and materials introduced new handicaps because of resulting wider applications having stiffer requirements.

The reports that follow cover a wide range of engineering fields, compiled by the technical committees of the Institute. The year has seen a number of developments of a broad over-all nature—in new materials, production techniques, and constructional philosophies.

One of the most important of these is the attention given to equipment reliability, with many new components and tubes and new assembly methods that show great promise of giving trustworthy operation. Standards with rating limits to provide reliability were set up for many more components by industrial committees. Over 50 new tubes having specific characteristics for industrial or military needs—such as rugged construction, low noise, long life, or balanced or controlled characteristics of some sort—were registered. A number of symposia and conferences were convoked to call attention to design, installation, and maintenance factors that provide more trustworthy operation of electronic equipment.

Progress was noted in assembly methods of electronic equipment, such as unitized construction, emblocked units or cast-resin embedments, and printed and other types of preformed circuits. The greatest gains were in materials and techniques of assembly that combined miniaturization and reliability despite higher operating temperatures.

Looking over the record of new tubes, at least those officially registered with the RTMA Data Bureau, indicates that some 48 types and sizes of cathode-ray tubes were announced during the year, 46 types adopted for home entertainment (radio and TV receivers and the like); 56 receiving-tube types having special characteristics or capabilities for industrial, military, or other uses where the operating conditions are different than found in home receivers; 18 transmitting tubes; and 25 special-purpose tubes, including thyratrons, counter tubes, and the like.

Considering the "receiver"-type tube sizes and styles, more varieties having special characteristics appeared than did new types for home-receiver services. This indicates the great amount of attention being applied to critical services where utmost reliability is required.

Much of the activity centered on cathode-ray tubes, more than 5 million having been produced during the year, over 4.4 million of which went into new television receivers. The trend through the year was toward direct-view rectangular screen tubes, some 88 per cent at present having screens larger than 16 inches and more than one-third 18 inches or larger.

Some idea of the impact of electronic tubes on modern living can be gathered by pondering on the number of tubes of the "receiver" types manufactured last year in the United States only—more than 256 million tubes of the various types being produced for new equipment alone, including government purchases, with some 119 million more provided for the replacement and export market, according to RTMA compilations. In addition, of course a great many special-purpose tubes and transmitting tubes were produced that are not included in the above tabulation.

The report that follows is divided into the subjects listed below.

Electron Tubes and Semiconductors

Audio Techniques
Electroacoustics
Information Theory and Modulation Systems
Circuit Theory
Radio Transmitters
Receivers
Video Techniques
Television Systems

Facsimile
Vehicular Communications
Navigation Aids
Wave Propagation
Antennas, Waveguides, and Transmission Lines
Industrial Electronics
Electronic Computers
Quality Control
Instrumentation
Piezoelectricity
Symbols and Abbreviations

Electron Tubes and Semiconductors

Small High-Vacuum Tubes

New Tube Developments: A new low-noise double triode was developed for use as a radio-frequency amplifier in television input circuits. With "driven-grounded-grid" input circuits, the tube showed improvement in performance over previously available types for noise figure, image rejection, and gain.
Three new tube types intended for wide-band amplification at moderate frequencies were described: two tetrodes, the 435A and 436A and a triode, the 437A. These tubes exhibit a substantial increase in gain-band figure of merit over previous tubes, such as the 6AK5 and the 404A.

As the result of extensive development programs in many laboratories many new tubes that feature longer life and reliability when required to operate under adverse operating conditions, were announced. For example, an extremely long-lived, rugged, pentode amplifier tube was described, intended for submerged submarine cable amplifiers where long life is an absolute necessity.

Plasma oscillations were generated at frequencies from 800 to 4,000 mc (five modes) without changing or matching any resonant circuits.

Tube Characteristic Studies: It was noted that the self-inductance of the grid wires in disc-seal, grounded-grid triodes operated at microwave frequencies greatly affects the passive feedback from anode to cathode. By proper design of the tube geometry, this self-inductance can be used for partial neutralization of the feedback due to anode-cathode capacitance.

In determining the input conductance due to cathode-lead feedback, usual calculations of self-inductance of the cathode lead give a value two to three times the correct one. To determine the correct value of input conductance caused by feedback, the mutual inductance between the various loops concerned, not the self-inductance of the cathode lead, should be measured.

The variation of grid-plate capacitance with space current was studied and a theory advanced to explain the change and the discrepancy between actual measurements and previously reported theories. The experi-
mental data were compared with theoretical calculations.

A transit-time theory was developed for the conduction of a diode in the exponential region of its characteristic, which reduces the discrepancy between theory and experiment previously found in close-spaced diodes. The value of this conduction at low negative voltages may exceed the total emission conductance even in the microwave band.


Calculations were made of the phenomena that determine the internal resistance of pentodes. For output pentodes the electrostatic influence of the anode voltage on the cathode current appears to be the main factor. For high-frequency pentodes, the two main causes are the primary electrons that are repelled in the neighborhood of the suppressor-grid wires and returned to the screen grid, and the reflected electrons from the anode that can pass the suppressor grid and reach the screen grid. Since both these phenomena depend on the electrode voltages, the current distribution between screen and anode is affected by anode-voltage variations.

Other calculations made can be used to derive the electrostatic amplification factor of a planar triode for all possible wire diameters and grid-to-plate distances. Formulas were deduced for more accurate calculation of the effective potential in a planar triode.


In one analysis, the small-signal behavior of a negatively biased triode was represented as a π configuration for convenience in analyzing complex circuits involving transmission networks and associated tubes. To avoid the use of fictitious voltage or current generators, the grid-anode element was allowed to assume negative values in its real component. The theory was checked by computing the driving-point impedance and voltage gain for various tube orientations in different types of circuit configurations and by comparing them with experimental data.


A tube-characteristic tracer was described that may be operated manually or automatically. Automatic tracing permits greatly reduced operating times, and results in improved accuracy of measurements in high-current regions of tube operations.


Many papers were published on the problem of tube reliability. Reliability was stated as not only a function of design and quality but also one of the relationship between tube ratings and operating conditions. Subminiature tubes were asserted to give inherently superior reliable operation under conditions of shock and vibrations, and it was shown that a statistical analysis of the records of subminiature tubes for a 500-hour life-test period can be used to predict the life expectancy of a lot up to 5,000 hours. In airborne communication and navigational equipment, tube failure during the first 1,000 hours was reduced from 30 to 3.2 per cent under the program for improvement in construction and manufacturing techniques sponsored by Aeronautical Radio, Inc.


**Cathodes:** A cathode design was described having improved tube reliability obtained by combining high-emission density and good mechanical strength with good temperature-emission characteristic and excellent resistance to high-voltage and high-speed gas ions. The structure contained a reservoir of barium strontium-carbonate emitting material. Experience data on the life of electron tubes as dependent on oxide-coated cathode life showed that the latter might be almost indefinitely long were it not for the formation of cathode-interface resistance.

Fig. 2—Reliable tubes are electrically life-tested on new 48-hour sterilization equipment installed at the tube-manufacturing plant in Harrison, N. J. (RCA).
The manufacture, composition, and application of four basic cathode nickel alloys were described and suggestions made concerning new cathode materials required to meet new and more severe demands. The deleterious effect of oxide-coated cathodes on a secondary-emitting surface of silver magnesium was overcome by the use of tantalum instead of nickel as the base metal for the cathode coating; the contaminant was found to come from the nickel base.

Studies of cathode poisoning by atmospheric sulphur showed a surprising decrease of emissivity even for short exposure periods. Air contaminated with illuminating gas and its combustion products was shown to be a source.

A small deviation from the Child-Langmuir law was observed in tubes with oxide-coated cathodes when the anode voltage exceeded 10 volts. Experiments and theoretical considerations indicated that an increase in space charge due to secondary and reflected electrons would account for deviations of the magnitudes observed.

Klystron: The need for higher power for television broadcasting in the ultra-high-frequency region resulted in the development of a 5-kw broad-band klystron.

A number of papers were concerned with theoretical aspects of traveling-wave tubes and space-charge waves. Electron-velocity spreads in an electron beam were compared to hydrostatic pressure in a liquid or gas, and their effects on the operation of a traveling-wave amplifier were treated. Some of the assumptions and problems involved in analyzing the behavior of electron streams coupled to circuits were reviewed and an explanation given as to why a wave approach can be used. The propagation constant of the wave was obtained in terms of the properties of the electron stream and the impedance of the circuit; the importance of fitting boundary conditions in the solution of an actual problem was discussed.

A gas-filled tube was developed in which the flow of current was directly and continuously controlled by a third electrode, as in an ordinary hard triode. Combin-
ing the features of both the gas-filled relay and the triode, the new tube can be used for progressive control of operations and even for amplification, especially where low impedance circuits are desirable. The construction and characteristics of one such tube, called the “plasmotron,” was described. This is a hot-cathode, helium-filled tube, capable of controlling large currents continuously at low voltages. A small control current acts on an auxiliary discharge that provides ionization to neutralize space charge.

Design Factors for Gas Tubes: Design features were applied to a 125-ampere inert-gas-filled thyratron, which permit increased voltage and commutation-factor ratings. In this tube the edges of the anode and grid elements are sealed directly to the glass envelope. The anode and cathode connections are made by terminal straps welded and copper brazed to the respective seal assemblies. The grid terminal is a short bracket attached to the outer rim of the grid assembly.

The pumpless igniton is assuming an ever-increasing field of application. Design considerations, as well as methods of manufacture, vacuum testing, and degassing were reviewed. The early field experience with this type of rectifier is outlined.

Limitations of a thyratron are set in large part by grid emission and by positive-ion-glow current during the afterglow. These factors set an upper limit to the permissible value of the grid resistor and plate current. Exceeding these limits results in unstable control characteristics. A promising means for minimizing these limitations involves adding an additional small firing electrode to conventional structures. Tubes using this principal are called “trigger-grid thytrons.”

Fundamentals of Gaseous Discharge: Studies of externally heated hot-cathode arcs showed the existence of two new modes of operation. These modes appear at pressures of the order of 1 mm of mercury. The anode-glow mode is postulated to have a space-potential distribution in which the major part of the potential drop appears adjacent to the anode. In the ball-of-fire mode, the anode drop is less than the ionization potential, and may be zero or negative. A potential maximum occurs within the ball of sufficient magnitude to generate ions to sustain the plasma.

Microwave techniques were developed to measure the electron density during the period following a gaseous discharge. By measuring the detuning of a resonant cavity containing electrons, it is possible to measure electron densities between $10^6$ and $10^9$ electrons per cc in gases whose pressure may be varied over a wide range.

A corona discharge between coaxial cylinders affords a practical means for stabilizing high voltages at currents below one ma. Some of the theoretical aspects of the corona discharge are reviewed. Circuit relationships are considered in detail.

An ordinary fluorescent lamp was utilized as a microwave noise source. It functions over a wide range of frequencies. It was found that the available noise power is determined by the electron temperature of the discharge.

A comprehensive review was given of the state of knowledge of plasma oscillations in gas discharges and of those electronic oscillations that are determined by the internal dynamics of the discharge rather than by the external circuit. Experimental and theoretical work
was reviewed and a new mathematical formulation given for oscillations in "irrotational" streams. The most important targets for research were pointed out.

Methods of measuring the rate of loss of ions in triodes by observation of grid current immediately after conduction were described.

A continuation of the development of tubes for very- and ultra-high-frequency applications was apparent from the announcements of new types by manufacturers. In most instances, improvement in ruggedness and short low-impedance connections to electrodes were the principal features. Calculation and measurement of tube characteristics were treated in several papers.

A number of tubes of somewhat novel constructions were described. A planar-grid triode and a push-pull tetrode for power in the very- and ultra-high-frequency region are examples.

Cooling Techniques: The cooling of power tubes was discussed with consideration of the use of water evaporation. Methods of evaluating thermal resistances and of determining operating temperatures and heat losses by means of thermal circuits were determined for electron tubes, and furnished an accurate basis for adequate ventilation and cooling designs.

Magnetrons

Considerable interest was shown in the effect of space charge in both planar and cylindrical magnetrons, and numerous reports on developments appeared.

A theoretical study of mode separation for strapped magnetrons was described. In another report the use of butterfly resonators in split-anode magnetron structures was analyzed.

Application of magnetrons for dielectric heating was described.

Various aspects of magnetron design were considered in reports from several sources. A paper on the location of electron orbits in a nonoscillating magnetron appeared.

Semiconductors

Increasingly precise knowledge of how semiconducting devices operate is leading to the realization of new
standards of performance. Amplifiers which can operate on a few microwatts of power, superior rectifiers and photodiodes, analyses of device operation, and new properties of semiconductors were described.

**Review Articles and Texts:** For designers of devices, a text on transistor electronics was published, covering the design theory of transistors and other semiconductor devices, as well as a description of the fundamental physics on which their performance is based. A review of work at the Bureau of Standards and another on properties of semiconducting materials were published. The latter also added to the published information on the lead-sulfide transistor. Some of the various forms of crystal triodes that were developed in England and elsewhere were reviewed.


Consideration of some of the circuit problems and applications of the properties of semiconductor two-terminal devices received attention.


**New Devices: N-p-n "Junction" transistors of the n-p-n type provide a new amplifier component capable of operating at low levels with high gain and exceedingly small power consumption. Under various different con-


Germanium p-n junctions can also be used to make rectifiers that, although not as fast as point contact rectifiers, have superior properties at low frequencies, including rectification ratios approaching 10^6, back impedance over 10^7, and back voltages of several hundred volts. The same junctions constitute relatively sensitive photo-tubes. Their performance follows theory closely.

(84) W. J. Pientapol, "P-n junction rectifier and photocell," Phys. Rev., vol. 82, p. 120; April 1, 1951.

Improved point-contact germanium diodes and photocells were described. The diodes have forward current as high as 50 ma at 1 volt, without appreciably affecting the contact capacitance.


**Properties of Devices:** Pulse effects on selenium diodes were investigated. The capacitance decreases during a pulse in the blocking direction, and recovers with the application of light or heat.


The inverse characteristic of point-contact germanium rectifiers shows a peak that is quantitatively explainable by self-heating by the power dissipation at the contact.


**Circuit Problems:** A new method of arriving at transistor circuits was described, making use of the approximate duality with known vacuum-tube circuits.


A number of circuits for particular functions were described. Pulse switching or negative-resistance trigger-type circuits are readily realizable, especially with transistors of alpha greater than one.


Circuit analysis and production measurements of video detectors were described.


Fig. 5—The spindly object (right) is the newest type of transistor invented at Bell Telephone Laboratories. For size comparison, it is shown with a miniature commercial vacuum tube which does about the same job.
Device Development: Device design theory, namely, the relation between the structure of the device and its engineering properties, was further elaborated. Besides the book (76), the following paper on the electronic aspects of transistors appeared.


Diffusion and diode theories of rectification in semiconductors were compared to experiment for copper oxide, selenium, and germanium.


Measurement techniques for rapid oscilloscopic testing of transistors were described. An evaluation of transistor quality can be quickly made during assembling and forming.


Measurement techniques for properties of semiconducting material that are of interest for device design, such as barrier location, were described. The point-contact method locates a barrier whose position appears to be somewhat dependent on the nature of the metal used. The recombination of anomalous carriers, which terminates their life, takes place largely on the surface of small samples.


Junctions of the p-n type, which have both superior properties and unusually close agreement of such properties with theoretical expectations, have been prepared.


A variety of semiconductor properties fundamental for device design were measured. Among these are the conductivity induced by electron bombardment of a barrier in germanium and by the photoconductivity of thallous sulfide. The recombination of injected charge carriers in silicon carbide produces light of a spectrum nearly independent of current, with production of about one quantum per million electrons in a particular case. The reverse current of a p-n junction rectifier increases sharply—the Zener effect—when a saturation voltage is exceeded. Also in high fields, the mobility of electrons in germanium decreases. The response of p-n junctions to pressure is in agreement with theory. Antimony in the metal points of germanium contact rectifiers in concentrations as small as 0.001 per cent can influence the rectifying properties.


Cathode-Ray and Television-Tube Design Considerations

A technique for investigating the optical properties of electron lenses was described which used a circularly rotating electron beam, minimizing space-charge effects and alignment problems. Results of applying the method to magnetic lenses were discussed.


Cathode-Ray Tube Production: During the year the continued trend toward larger direct-view picture tubes resulted in substantially all production being placed on sizes with a 16-inch or larger screen. Round-screen and rectangular-screen versions in all popular sizes appeared with both all-glass and metal-glass envelopes.

Shortages of critical materials spurred interest in electrostatically focused cathode-ray tubes; as a result, cobalt containing permanent magnets and copper-wire-wound electromagnets for focusing lenses did not have to be used. Gun designs evolved in which saddle-type electrostatic lenses that require low- or zero-voltage focusing potentials were used. The latter type can be made interchangeable with its magnetically focused counterpart.

Further improvements in cathode-ray tubes include the use of a cylindrical face plate with the axis vertical so that the specular reflection of most room lights can be reduced. Other techniques for reducing specular reflection include special surface treatment of the glass face. Direct-view picture tubes reached the 30-inch diameter size and were designed to operate with associated deflection components at a scanning angle of 90 degrees. A different theoretical approach to the correction of deflection focusing in electrically deflected tubes was made.

(116) C. Graham, "How new automatic-focus picture tube operates," Radio and Telew. Reis.ing, pp. 56, 57; December, 1951.


Audio Techniques

The normal progress in audio techniques appears to have been vitally affected by the impact of the defense program. This is apparent as much from the absence of the normal volume of published reports as from published material definitely bearing out this statement. A suggestion of this nature is apparent in an industrial sound system that, in addition to providing the usual paging, music distribution, and briefing possibilities, also places particular stress on those emergency features that are necessary to protect personnel in all-out war. The accent on this particular system is the passing of information and instructions in case of hazard. A second article deals with the effect of music on mass-production.

Important contributions to magnetic recording and reproducing, and to electroacoustic transducers were reported. In magnetic recording, the suggestion was made that the drop in response at high frequencies in recording-reproducing systems results not from demagnetization, as previously thought, but from failure to obtain intimate contact between the recorder-reproducer head and the recording medium. On the basis of experimental work, as well as on an idealized theoretical analysis, it is stated that the spacing loss in decibels is 55 times the logarithm to the base ten of the ratio of the effective head spacing from the media to the wavelength of the recorded signal in the media. It has been suggested that variation of intimate contact with the moving medium accounts, in part, for that distortion variously known as “noise behind the signal” or “modulation noise.”

Informative articles on the relation between sensitivity, directivity, and linearity of direct-radiator-type loudspeakers were published. It is reported that uniform directivity with respect to frequency is much more important than sensitivity and, in particular, that it is undesirable to obtain high sensitivity in a loudspeaker by sacrificing uniform response, good transient response, low nonlinear distortion, and uniform directivity. A new type of magnetic recording medium, known as “magnetic rubber,” which is particularly suited to those applications requiring several repeated uses of the recording medium, was announced.

More practical means for the binaural recording and reproduction of sound through the use of magnetic recording equipment were commercialized.

A two-way wire intercommunication system was produced for school-to-home use, which makes it possible for confined children to participate in classroom work while in their own homes. The use of recording and reproducing equipment to furnish automatic telephone-answering service in the absence of the subscriber was reported. A multiple-purpose tone arm for broadcast use on the three record speeds was described.

Additional work on automatic regulation of system gain was reported; also, the problem of the automatic compensation for the drift of gain in a dc amplifier was discussed at some length and circuits for its effectual reduction were described.


The application of transistors may prove to be a major development in the audio field. Definite advances were made in control of point-contact transistors through manufacturing techniques, among which should be mentioned the effect of wide contact spacing. The transistor has been developed to the point of application in certain systems in which stress on reliability is of the utmost importance. The n-p-n-type junction transistor is of particular significance because of its desirable, and in some cases, astonishing characteristics. In particular, this type is reported to have a relatively low noise figure and exhibits complete freedom from short-circuit instability, thus making it adaptable to a wide range of circuit applications. It also has high gain; power gains of the order of 40 to 50 db per stage were obtained. Voltage or current amplifications of 30 to 1,000 times per stage were reported. The unit is extremely rugged and compact; operating units no larger than 3/16 inch in diameter, excluding the necessary pigtail connections for leads, were constructed. Its power-handling capacity is somewhat limited. However, units of 2-watt power dissipation were built; this power-handling capacity is sufficient for a large number of audio applications. This transistor has complete freedom from microphonics, and hence can work under all applications involving vibration and shock.

The transistor operates with exceedingly small power consumption, and has high efficiency since it requires no filament voltage. Efficiencies of the order of 49 per cent can be obtained in Class-A operation against a theoretically realizable 50 per cent. Units have been operated with an input power as small as 6 microamperes at 0.01 volt or a power consumption per stage of 0.6 mw.


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A stroboscopic spectrometer for audio-frequency work operates by modulating a light source with the signal to be resolved and by viewing it with a stroboscopic screen. A range of 60 to 6,000 cycles can be covered. An instrument for visual analysis of complex audio wave forms presents a three-dimensional display.

A device for displaying the space patterns of sound waves was described. This device uses a probe pickup to scan the sound field, and the amplified probe output controls the brilliance of a lamp fixed to the probe. A camera set for time exposure records the light-intensity variations of the lamp as it moves across the scanned field, and forms a pattern on the film of the amplitude distribution of the signal. In addition, means of obtaining simple flexible wave filters of various types through the use of appropriate amplifier techniques were described. These articles reported that it is possible to obtain low-pass, high-pass, band-pass, and variable high-pass filters from RC networks and feedback-type amplifiers through the skillful use of design techniques.


Sound Recording and Reproduction

Preliminary work was started which establishes recording characteristics permitting international exchange of both disks and tapes. A recording characteristic for disks, utilizing a 50-μsec rise time, appears to be an acceptable high-frequency pre-emphasis characteristic for most countries. Agreement with the magnetic-tape standards proposed by the National Association of Radio and Television Broadcasters is good, but problems exist because of the difficulty in determining the magnitude of the level recorded on the tape.


The use of fine groove records, both 45 and 33 1/3 rpm, increased greatly, and improvements in both disks and instruments were apparent. Heated-stylus recording became more common, especially for fine-groove disks.

Some improvements in both media and equipment were made in the magnetic-recording field. Increased uniformity and a reduction in modulation noise was apparent, helped no doubt by the development of magnetic tape for use in the telemetering and computer field, where the requirements are more exacting in some respects than those for sound recording.

Many designers are now thinking in terms of 2,000, rather than 1,000, cycles per inch of tape travel per second resulting in machines of lower tape speeds.


Tape speeds now range from 30 to 1 1/2 inches per second in submultiple steps in accordance with RTMA Standards and recommendations. The highest speed is used primarily for master recording in the phonograph field. Speeds of 15 and 7 1/4 inches per second are used for broadcasting and commercial applications, and lower speeds of 3 1/2 and 1 1/2 inches a second for home recording.

The use of magnetic film in the motion-picture industry for original sound recording increased greatly. Standards concerned with track position, width, and separation were proposed.


A 16-mm projector equipped for magnetic recording was introduced. The magnetic track can be added either to new or processed film, and is located over the surface normally used for the photographic sound track. The sound may be added while the picture is being viewed.


The theory involved in recording with ac bias was further investigated. The results of a study of signal loss during reproduction was reported.


Electroacoustics

Wave and Vibration Theory

The problem of sound transmission in a medium of continuously varying refractive index has received further attention for both air and water. It was concluded that frequencies above 70 cycles will be totally absorbed in the stratosphere. The phenomenon of duct transmission in water was put on a firmer basis, leading to a modified ray-acoustic concept that includes diffraction.

The volume-viscosity concept has been used to explain absorption in resonators and progressive waves. In certain triatomic gases the effect overrides that of shear viscosity.

A continuing study of the unidirectional forces arising from the interaction of a wave and an obstacle indicates that forces due to wave asymmetry may be considerably larger than those due to radiation pressure.

The growth of subharmonics from a direct-radiator speaker was studied experimentally. When compared with theory, it was verified that, under ordinary conditions, the rate of growth will not be undesirably large.

In boundary-value problems, a more general concept of
acoustic impedance has proved necessary. In one attack on the problem, it was defined as the quotient of intensity by the product of the normal velocity and its conjugate.


Room Acoustics and Absorption

Perforated acoustic materials, especially those in which the perforated sheet is backed by a porous blanket and an air space, are being used in increasing quantities. An analytical study led to a useful set of design charts; the agreement with experiment is good. Experimental results on the absorption coefficients of flat, splayed, and cylindrical panels of 1/2-inch plywood are available. Improvements in the box method of comparing acoustical materials were reported in one of the few releases of information on this topic. The perennial problem of optimum adjustment of a speech-reinforcement system received considerable experimental attention. For maximum intelligibility it appears that the direct speech should arrive 5 to 35 milliseconds ahead of that reproduced, and the level of the latter should be no more than 7 db above that of the former.


Physiological Acoustics and Psychoacoustics

A major event in this field was publication of the papers given at the Speech Communication Conference at M.I.T. Information theory, linguistics, phonetics, cochlear mechanics, masking, and visible speech were some of the topics discussed. Especially interesting was preliminary work on the type of communication pattern permitted in an organization and its effect on rapidity of accomplishment and morale. There is some indication that these ends are not completely compatible.

In the field of vowel analysis, an electrical analogue of the vocal tract has been constructed with fair-to-good reproduction of vowel sounds. Further investigation into the surprisingly high intelligibility of speech that has been subjected to differentiation and then to infinite peak clipping gives results in accord with simple information theory. A straightforward method of calculating the loudness of complex tones was reduced to practice. The given spectrum is divided into bands of pitch-interval 300 to 600 mels, and the loudness values for each band are added. Good agreement with experiment and with more elaborate analytical methods was obtained.


Ultrasound

Progress in this field was characterized by an insistence on measuring significant quantities and on a closer delineating of the causes of the effects observed. Greater attention is being paid to routine applications in industry and medicine. A re-evaluation of the elastic strength of piezoelectric sources indicates that in water very short pulses of high intensity may be transmitted. Quartz should support 2,000 watt/cm² and ADP, 220 watt/cm². Experimental values up to 1,000 watt/cm² have been obtained for quartz. Thus it is still superior to barium titanate, at least for plane waves. However, the latter material has greater flexibility of form. For example, a radially polarized hollow cylinder exhibits a longitudinal resonance on excitation. By affixing a resonant, tapered, solid metal horn on one end, amplification of the motion is obtained; in one arrangement used for wear testing, the amplitude was about one mil at 18 kc. Further work in ultrasounds has included a detailed long-term study of the effects on tissues, means for outlining brain tumors, and means for mechanical control of crystal resonance over a total range of about an octave.


Instruments and Measurements

All of acoustics and audio engineering, and the measurement field in particular, will be helped by the issuance of American Standard Acoustical Terminology, which defines over 500 terms. In the audimeter field, the problems of specifying for calibration and use have been examined; it is concluded that present specifications are achievable and reasonable. Most of the activity concerning microphones appears to be in the production of unobtrusive stick-type structure for television. While no radically different measurement techniques were disclosed, several novel instruments were introduced: a sound-level meter utilizing a well-stabilized loudspeaker as a source of known pressure level; an infrasonic oscillator offering rapid frequency stabilization by integrating and shaping the output of a bistable circuit; a polar recorder offering linear or square-root radius vector; an ultraspeed recorder obtaining its logarithmic characteristic from biased varistors, and achieving speeds up to 10,000 db per second; a two-
signal audio oscillator for intermodulation measurements by the constant-difference-frequency method; a magnetostrictive oscillator of one kw input at 24 kc, and an active surface of 20 cm²; and an acoustic intensity meter utilizing the radiation pressure of progressive waves in a water load.


Industrial Acoustics

For some time there has been a noticeable trend toward putting acoustics to work in testing, processing, and controlling. Among the more recent devices available on the market is a ball-mill control that adjusts the feed for maximum sound output, this having been found to be the criterion used by human operators. An ultrasonic soldering iron featuring magnetostrictive drive of the bit at 20 kc provides a "sonic flux" that permits fine aluminum and copper wires to be joined without removal of the insulation.

Garage-door opening may be controlled from a car by selective pickup of an ultrasonic air whistle in the car. Still in the laboratory stage are devices for measurement of fluid velocity, and for ultrasonography by formation of a latent sound shadow image on a photographic plate. There is active thinking on means for achieving high acoustic powers efficiently and simply so as to make possible many industrial applications that are now of laboratory interest only.


Information Theory and Modulation Systems

Primary attention has been centered on the information-theory approaches, while comparatively little work was reported on conventional modulation systems techniques. Significant advances in apparatus refinements were noted, such as a report of a study of distortion in frequency-modulation relay systems.

Some work on multipath characteristics of frequency and amplitude modulations tended to show that, contrary to previous belief, FM may be superior to AM under conditions of heavy multipath interference.


Extending amplitude-modulation percentages to over one hundred, a technique called "double-sideband reduced-carrier transmission," was pushed still further. In this system, a slightly unbalanced balanced modulator is used to generate double sidebands with a relatively large carrier leak. Reception, with some distortion, is possible in voice-communication circuits, and exalted-carrier techniques may be used to remove this distortion. Modulation percentages as high as 1,000 can be used, producing high transmitter efficiency in applications that permit its use.


The effect of nonlinear quantization on quantization distortion was studied.


A study of cross talk in time-division multiplex systems showed the effects of bandwidth on cross talk, and indicated, also, that poor low-frequency response can be used to compensate for poor high-frequency response.


Many papers were published in the field of information theory, and several symposia were held. Activity was aimed primarily at the application and extension of the theory, rather than toward new basic reasoning. However, some work was done to derive the basic concepts of information theory by new methods.


The laboratories of the Telecommunications Research Establishment in Great Britain analyzed the radar problem on the basis of information theory; they derived relations for the information present in a radar signal and obtained new detection-process criteria that correlate very well with observed data. They regard the operator as a computer which, given the a priori distribution of probability of signals in noise and the observed waveform, deduces a new probability of signal being present at any given range. This analysis was developed by first studying the theory of observation and then applying statistical techniques to these results.

These papers describe a coherent and fairly complete approach to the radar-detection problem. In addition to this work, however, progress was reported in the radar field along somewhat more conventional lines.


The technique of integrating received signals from pulse to pulse to obtain an improved signal-to-noise ratio has been known for some years, but the complexity of the apparatus required has been forbidding. An equipment for performing this operation by the use of a storage tube was successfully demonstrated. This equipment is capable of integrating the effects of ten successive pulses and of obtaining considerable signal-to-noise improvement thereby.
Since storage and delay are essential elements of any communication system operating close to maximum theoretical capacity, the optimum value of storage and methods for obtaining it were studied.

Information theory was also applied to periodic radio systems of many types, primarily navigational systems. This work showed that the limitations on resolution of a navigational system are determined by the bandwidth of the transmitter and limitations on information rate by the bandwidth of the receiver.

The work on radar and navigational aids was primarily concerned with obtaining resolution and high signal-to-noise ratio with limited power and bandwidth. Other mechanisms for achieving this result involved the use of correlation techniques. The description of a practical electronic correlator using sampling techniques and taking the autocorrelation function by plotting a series of points for various delays over a long period of time was given, and techniques for using the results obtained with such a machine for the improvement of detection of signals in noise were published.

An introduction to the correlation function, better known to statisticians than to the communications engineers, was published.

A simple relation was derived showing that the information content per symbol of a message could be easily obtained from the autocorrelation function.

The autocorrelation technique was also applied to the computation of spectra, interference, and cross talk in time-division multiplex systems.

One of the prime applications of communication theory has been toward reducing the bandwidth necessary for transmitting various types of information. While not stemming from this source, the application of the mixed-hilg principle to color television is an excellent example of the combination of frequency-division multiplex and time-division multiplex techniques producing a marked reduction in the bandwidth heretofore thought necessary for picture transmission. Consideration has also been given to the amount of information actually present in a television picture.

The possibility of the transmission of television by pulse-code modulation techniques was also studied. It was found that surprisingly few levels were required to transmit adequate pictures and that a small amount of noise reduced the number of levels necessary by tending to obliterate the abrupt change in brightness from one level to the next. The use of coding techniques to reduce bandwidth in picture transmission was discussed in an unpublished paper.

Much work is currently in progress on the application of statistical techniques to the reduction of bandwidth required for transmission of acceptable speech. A conference on speech communication was held at M.I.T. in the summer of 1950, and the papers were reported in the Journal of Acoustical Society of America, vol. 22, pp. 689–806; November, 1950.

The problem of speech transmission has been studied, both with regard to the equipment and to the human phases. Studies of the ear and hearing mechanisms have been made to determine how much information the ear can actually handle and to discover new facts about the mechanism of hearing.

Progress has been made on the analysis of speech sounds and their visual presentation. Studies of the short-time autocorrelation function of speech sounds, moments, and other statistical properties have been analyzed carefully in an attempt to use these properties to distinguish automatically between one speech sound and another. Work has also been done on the use of spectroanalysis, using the presence or absence of several bands in the voice spectrum to indicate various speech sounds.

The elimination of conventional voice communication from links now using this technique was discussed in an effort to provide improved narrow-band communication in the approach control area of an airport. The alternative presented was a form of symbolic display.
Radio Progress During 1951

401

(194) J. Loeb, "Application of Shannon's communication theory to
telephone, teletype, or measurement," Ann. Telecomm.,
vol. 6, pp. 67-76; March, 1951.


This work was primarily concerned with the study of
various types of modulation from the communication
theory viewpoint and with an analysis of their appli-
cability to the telemetering problem. A somewhat
similar analysis, although not restricted to telemetering,
was also presented.

(196) R. Pilory, "The assessment of modulation systems using the
communication theory concept of channel capacity," Arch.

Further work has been done on the general analysis of
communication systems from the point of view of band-
width reduction. Most of this work was reported as a
result of two symposia, held at the Royal Society (Lon-
don) in September, 1950 (reference 201), and at the Sor-
bonne in France in April-May, 1950. The latter was re-
ported in Ann Tele-Comm., vol. 5; October, 1950.

(197) B. Mandelbrot, "Adaptation of message to transmission line:
(Paris), vol. 232, pp. 1638-1640; April 30, 1951.

(198) R. Feron and C. Fourebard, "Information and regression,
April 30, 1951.


(200) P. Chavasse, "Application of means used for assessing the
quality of telephone transmission," Ann. Telecomm., vol. 5,
p. 427-440; December, 1950.

167, pp. 20-22; January 6, 1951.

Analysis was made of the information content of
printed English to determine the degree of prediction
possible and the amount of entropy contained.

(202) C. E. Shannon, "Prediction and entropy of printed English," Bell

Circuit Theory

Linear Lumped-Constant Passive Circuits

The long search for a systematic method of equalizer
design was brought appreciably closer to the goal
through Darlington's development of the potential-
theory analogue. The method has been successfully em-
ployed in the equalization of several hundred-decibels
discrimination in line loss by networks of several hun-
dred elements. Studies suggesting alternate techniques
were reported at the summer meeting of the IRE in San
Francisco.

(203) S. Darlington, "The potential analogue method of network
synthesis," Bell Sys. Tech. Jour., vol. 30, pp. 315-365; April,
1951.

Interest in networks restricted to resistive and ca-
pacitive elements has continued.

(204) H. J. Orchard, "The synthesis of RC networks to have pre-
April, 1951.

(205) A. Feldows and I. Gerst, "The transfer function of an R-C
1951.

(206) R. K. Kenyon, "Response characteristics of resistance-react-
May, 1951.

(207) H. Lepstein, "Synthesis of passive RC networks with gains
1951.

(208) J. T. Fleck and P. F. Ording, "The realization of a transfer


The standards on network topology were published
early in the year. Topological aspects that electrical
networks have in common with quite diverse physical
situations formed a symposium topic for the 1951 IRE
National Convention, "New Extensions of Network
Theory."

(210) "Standards on circuits: definitions of terms in network topol-
(211) Papers 38, 39, 40, and 41, "1951 IRE National Convention

Linear-Varying Parameter and Nonlinear Circuits

In addition to the usual nibbling at the standard
problems in this field, a trend has appeared during the
year directing attention away from the old chestnuts
perennially resistant to all but brute-force procedures.
In papers 93 and 94 presented at the IRE National
Convention, Singleton and White discussed thoroughly
quantized models, which are identifiable with actual
systems only by assumption of idealized sampling,
switching, and storage processes with complete sup-
pression or concealment of transitory conditions be-
tween discrete states. Such assumptions are in accord
with present interest in digital transmission. They offer
promise in the exploration of nonlinear filters capable of
selecting signals on a statistical basis where linear
methods based on separation in the time or frequency
domain fail.

Time-Domain Analysis and Synthesis

Although surprisingly little was published on this
subject, there has been some progress: Graduate stu-
dents at several universities are attacking the problems
encountered in synthesizing a network that is to have a
prescribed time response.

The major problem is one of approximation. Well-
known methods exist for "exact" synthesis of a network
whose performance characteristics have been specified
by one or more rational functions of frequency. The
as-yet-unsolved problem is to find a general method for
determining the particular rational frequency function
whose corresponding time response will best approxi-
mate the desired time response to within arbitrarily
specified tolerances in the time domain. There is hope
for early publication of at least one solution.

The similarities of the mathematical methods of cir-
cuit analysis to those of other well-developed scientific
fields were illuminated by several papers presented at
the IRE National Convention. Of particular interest
was paper 122 on the time series of probability theory.
These generating functions possess many of the properties
that make the Laplace transform so useful in circuit analysis; yet they have a very
simple development in the time domain, which provides
a systematic approach to the treatment of empirically
determined time series. In paper 41, reference (211),
the similarity between the methods of mathematical
statistics and those of circuit theory was further emphasized, and it was shown how ordinary methods of transient analysis could be used to predict the probabilities of future states of a Markov system from knowledge of its present state and the various transition-time probabilities.

**Linear Active Circuits**

The principle of feedback continues to be employed in an ever-expanding list of applications. Such is the measure of the engineer's progress in acquiring facility with the long-established truths of feedback which, until rather recently, were understood by only a small minority of engineers. Indicative of the level of this progress is the increased attention being given to multiple-loop feedback problems, both those involving combinations of nominally negative loops and, more significantly, those combining nominally positive and negative loops. A further indication of progress is the generally broader acceptance of complex-frequency-domain concepts in the analysis of feedback-stability problems.

The cathode follower has once again been analyzed very capably from the standpoint of input impedance and separately from the standpoint of pulse and sawtooth performance. An interesting application of the cathode follower is its use as a loudspeaker-coupling device to eliminate the intervening output transformer. The arrangement of a direct-coupled balanced circuit affords extraordinarily good square-wave response, as might be surmised, although at a rather high cost in tubes and power supply.

Other solutions to the linear-power-amplifier design problem have been offered. One involves the parallel operation of a triode and tetrode so that the tetrode remains cut off except on signal peaks. The arrangement appears to combine the advantages of class A operation with the higher efficiency usually obtained only in class AB or class B. A second solution employs tetrode output tubes, the screens of which are connected to taps on the output-transformer primary. When critically adjusted, this output stage has been shown to afford a combination of several of the desirable characteristics of triode and tetrode stages with the further advantage of exceptionally high linearity.

Among the reports of progress in the development of direct-coupled amplifiers, one appears to be especially significant. The operation of pentode stages with screen-grid potentials having only a fraction of conventional values and with extremely high-resistance plate loads results in what are termed "starvation circuits." Ex-
Radio Transmitters

Common Carrier Radio Relay

A regular two-way coast-to-coast relay service for television broadcasting and communication, made available in September, was first used for the transcontinental telecasting of the opening address of the Japanese Peace Treaty Conference in San Francisco. This microwave relay system is 2,992 miles long, and is composed of 107 stations, spaced an average of 28.2 miles apart. All but 18 of these stations are unattended, operating automatically. This network makes it possible to interconnect 94 TV stations in 53 cities. Extensions to this service are being installed between major centers of population.


Microwave Communication

The past year has seen a tremendous expansion in the use of microwave communication systems for railroads, pipe lines, utilities, turnpike traffic control, telephone and telegraph traffic, civil and military service, and operational control of transmitters. New uses for microwaves are continually being developed.


Television Relaying

Television relaying has greatly expanded in the United States and England. More than 80 per cent of the channel miles use microwaves, the remainder coaxial cable. Increased use of television relaying has been done in the fields of studio-transmitter links, field equipment, and facilities for providing remote stations with network programs.


Citizen Band

The use of the citizen radio band in the United States had increased from 390 to 651 licenses by the end of the third quarter. This type of service seems to be increasing about 25 licenses per month.


International Broadcasting and Communication

Considerable expansion in the international broadcasting and communication field took place during the year, mainly as to the better utilization of the spectrum by means of single sideband transmitters and multichannel operation, which permit closer spacing of frequencies.


AM Broadcasting

Applications continued to be filed with the Federal Communications Commission for AM broadcasting stations. Licensed stations increased from 2,178 to 2,272 at the end of the third quarter, at which time there were before the Commission 270 applications for new stations. There were also 178 applications for changes in
facilities. Commercial use of unattended broadcast transmitters was made in England during the year.


(259) L. Rohde et al., "High power frequency modulation broadcast transmitter," Frequenz, vol. 4, pp. 219-228; September, 1950.


TV Broadcasting

Interest in television broadcasting continued to grow despite the continuation of the "freeze" by the Federal Communications Commission of applications for new construction permits. By the end of the third quarter 432 vhf and 16 uhf applications for new television stations were on file. The number of licensed stations in the United States has increased from 107 to 108 stations.

No more construction permits will be granted until the "freeze" lifts. The interest in television increased in other countries, particularly Mexico, Cuba, Brazil, and England.

Development work in television transmitters was active, with work on vhf transmitters in the direction of increasing power to 20-25 kw and uhf transmitters to 1-5 kw output.


Receivers

Very-high-Frequency Black-and-White Television

Much engineering time has necessarily been devoted to circumventing material shortages occasioned by the world situation. The Radio-Television Manufacturers Association has set up material bureaus to advise industry on methods of conserving critical materials. Particularly successful was the development of picture tubes having electrostatic focus accomplished by low fixed voltages. Focusing coils and, in some cases, control units, were eliminated, thus resulting in a considerable saving of critical materials.


(274) "Conservation of raw materials," Tele-Tech., vol. 10, pp. 72, 74; April, 1951.


Other components receiving attention include the following: full-focus yokes for increasing the picture area over which good focus is maintained; cylindrical-faced tubes, which permit the elimination of room-light reflections from the screen area; new damper tubes with high heater-to-cathode insulation, which reduces sweep-circuit capacitance and the need for one filament winding; and wide-angle deflection picture tubes and associated sweep components, which decrease the cabinet depth for large-screen pictures.


Low-noise circuits, such as the cascode, and improved low-noise tubes were developed for the tuner section of the receiver, or for boosters. The IRE Receivers Committee standard on methods of measuring spurious radiation was published and, in conjunction with RTMA committees, test sites were set up and checked. Television receivers having greatly reduced oscillator radiation are being manufactured.


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The 41.25-mc IF (a frequency selected by the NTSC for industry standardization), was designed into many makes of receivers. Proposed uhf assignments are based on this frequency, and provide protection from oscillator radiation, intermodulation, image interference, and IF beats. Virtually all receivers are now of the intercarrier variety. Export receivers for power-line frequencies, other than 60 cps, were developed. Master antenna systems are being used for communities shadowed by mountains and by apartment houses.


Methods whereby interested viewers rather than advertisers bear the cost of some programs are being developed. Large-screen theatre television and subscriber television are two possible methods. One of the latter systems, "Phonevision," was given public tests.


Ultra-High-Frequency Television

Television coverage in this range is continuing. Recent Federal Communication Commission announcements indicate that some commercial transmitters may be on the air in 1952. Many styles of tuners and new tubes for this range are making their appearance. The results of the tests on Station KC2XAK in Bridgeport, Conn., were published.


(290) H. E. Green, "Rave reviews greet Phonevision's debut in 90-day Chicago test," *Printers' Ink*, vol. 234, p. 79; January 19, 1951.

Fidelity of television pictures continued as an important subject. There are many factors involved in evaluating picture quality. Some of these, such as resolution, transfer characteristic, and geometric distortion, can be measured by fairly well-established techniques, but others are of a more elusive nature, such as the illusion of depth that contributes materially to the over-all fidelity of the reproduced picture.


(298) F.C.C. Report 51-244; March 22, 1951.

Citizens' Radio Receivers

Equipment for two-way mobile communication in the 450-470-mc region was developed and tested.

Video Techniques

The publication of the IRE Standard on Methods of Measurement of Regulated Power Supplies satisfied an urgent need in the television industry because this type of power supply is used extensively in all television broadcast stations as well as in many other fields. The output voltage of such supplies is maintained at a nearly constant value regardless of load or supply variations. In this standard, special methods of test were outlined to determine performance and allow comparisons.


Some advances were made in evaluating those factors governing picture fidelity that are subject to measurement. One report was on the ability of both motion-picture and television systems to reproduce a long series of half tones accurately, wherein the numerous factors governing half-tone reproduction for best picture fidelity as well as a method of measuring the result were discussed in detail. In television, this is usually referred to as the measurement of the transfer characteristic. Of greatest importance, perhaps, is circuit information illustrating methods for correcting an over-all transfer characteristic by introducing a controlled amount of amplitude nonlinearity at an appropriate point in the circuit. Corrections may be made which affect reproduction in either the black or white areas in the picture, and may even be applied to both simultaneously. Crystal diodes were found to be helpful as circuit components for these devices.
An interesting comparison between the techniques used in measuring resolution of motion-picture film and of a television system was the result of IRE committee activity. Since different types of test patterns are used in the two fields, an evaluation of one in terms of the other is particularly valuable in those activities where the two techniques overlap, such as in television recording.

Continued emphasis has been placed on the importance of improving the television images obtained from motion-picture film. Several articles have appeared discussing the merits of the various pickup tubes employed in commercial film cameras, including the iconoscope, image orthicon, image dissector, and image iconoscope. Each of these tubes appears to have some unique advantages as well as defects, making a choice between them rather difficult. Suggestions are included for best operating conditions and circuit adjustments, which should be helpful to those employing these tubes.

A continuous-type film projector for television applications was developed, having two features designed to overcome difficulties encountered with such projectors. One is an electromechanical servo system that automatically compensates for slight irregularities in film motion so that an image having negligible vertical "jump" is obtained. A second feature is a system for automatically eliminating the flicker caused by light variation resulting from the normal movement of the rotating mirrors. This projector can be used in conjunction with a flying-spot scanner to permit improved reproduction from film.

Several new techniques were developed in the field of television recording on film. The first, called "area masking," is used for improving detail contrast in the release print intended for projection on a television-film camera. The contrast range is not increased beyond that which the pickup tube, such as an iconoscope, can accept without serious distortion in the highlights. The general effect is an increase in picture sharpness without causing a loss of detail in either the dark or light areas of the pictures. This is accomplished entirely by photographic means. Although this adds some complexity to the developing process, it is undoubtedly justified by improved over-all results. In addition, two methods for improving picture sharpness electrically by aperture correction or by "crispening" circuits were also proposed.

Another technique is the rapid processing of television-film recordings so that they can be used within several minutes after the images are recorded.

Improvements in television cameras and associated equipment were described. Simplified and improved operation is made possible by the use of remote iris control as well as remote focus and remote lens-turret control. Continued emphasis is being placed on devices for special effects. One of these is an amplifier capable of utilizing special keying signals to allow selected parts of one picture to be inserted in another. Another device, called the "Genlock," makes it possible to obtain such effects even though one picture source is located at a point remote from the other. Accurate lock-in between two widely separated synchronizing generators is required to make this effect possible.
duced as low lights and the low-velocity portions as high lights.

In another proposal, called the “dot-arresting technique,” a small amount of velocity modulation at a relatively high frequency and bearing an exact relationship to the line frequency is introduced into the scanning process to improve picture detail.

A third proposal uses pulse-code techniques to permit restricted-bandwidth operation at the expense of the range of half tones that can be transmitted,


Fig. 9—Back-pack television transmitter receiver developed for use in picking up remote telecasts. The special vidicon camera is equipped with a view finder and lens turret. The receiver portion of the pack unit gives the operator constant contact with the control unit, which may be as far as a mile away (RCA).

Television Systems

Commercial Color Television

Late in 1950, field-sequential color television, as developed and advocated by the Columbia Broadcasting System was approved for commercial broadcasting by the Federal Communication Commission. Action against the Commission by seeking an injunction was taken by the Radio Corporation of America and others. The resulting decision of the court was appealed to the Supreme Court, which upheld the Commission, thus clearing the way for commercial broadcasting. Service was inaugurated on June 25, 1951, when programs originating from WCBS-TV were broadcast in the New York area and through networks in other cities on the Eastern seaboard. Following this, regular daily broadcasts were made by CBS. Outdoor remote events, such as football, baseball, and horseracing were covered. Many of these programs were displayed publicly in New York and in other cities.

Field-sequential color sets were placed on the market by CBS-Columbia, Inc., in September. On October 19, Charles Wilson, Director of Defense Mobilization, asked the industry to stop the production of commercial color-television receivers in the interest of conserving essential materials. Columbia announced that it would comply, and asserted its intention to continue with research and development of broadcast-type color television, as well as with its industrial and motion-picture-theatre television systems. A plan was announced to adapt the Eidophor large-screen television projection method to the field-sequential color-television system.

The Economic Co-operation Administration asked Columbia to demonstrate its system in Berlin concurrently with the Russian Youth Festival. Some 180,000 Germans from both the east and west sectors saw color pictures. Surgical color-television pictures were shown in Zurich and Paris, and at the request of the French Government, Columbia showed its system to French Government officials, engineers, and other European representatives as a possible standard for French color television.

In field-sequential color television, the reduced horizontal resolution has been mitigated by means of “crispening” circuits. These increase the slopes of isolated changes in an instantaneous signal, thus giving the illusion of increased resolution.

Standards for the United States color-television system and various forms of equipment were described.


The development of a compatible color-television system, based on a color signal consisting of the combination of a monochrome signal and a subcarrier, has proceeded.

(319) Report on Color Television, Ad Hoc Committee, National Television Systems Committee; April 19, 1951.

Fig. 10—Video spectrum of compatible color-television system adopted for field test by the National Television System Committee. The color signal consists of frequency components interleaved between the frequency components of the monochrome (or brightness) signal over the upper half of the video band. (f = horizontal scanning frequency in cycles.)
Much consideration was given to methods that make most effective use of channel space. The monochrome signal, it now appears, should be representative of the luminance values of the subject. This permits the use of constant-luminance operation of the receiver without compromising colorimetric fidelity, thereby preventing interference in the color-carrier channel of the receiver from affecting luminance. This was shown to produce an improvement in subjective signal-to-noise ratio. Additionally, this type of monochrome signal was found to be particularly suitable for the compatible monochrome receiver because of the resulting excellent rendition of tone values.

The make-up of the color-carrier signal also received attention. The use of a color carrier specified by two vectors only, neither conveying any brightness information, was developed. These vectors represent the tristimulus values $X - Y$ and one-third $(Z - Y)$, respectively. The relative amplitudes of these two vectors, which are often referred to as “color-difference signals,” were proportioned so as to take cognizance of the known colorimetric fact that the eye is less sensitive to changes in $Z - Y$ than to changes in $X - Y$ by a factor of about one-third. Thus the most effective use of available signal amplitude is made by using this factor. A mathematical analysis of this and of other colorimetric values in a television system was presented. Papers on fundamental colorimetry also appeared.

The relative amplitude of the color carrier, compared to that of the monochrome signal, was studied, and tentative recommendations were made. The monochrome-plus-color-carrier development has rendered this a matter of free choice as compared to the rigid relation existing in the dot-sequential system.

Subjective tests were made to determine the bandwidth necessary for the color-difference signals that modulate the color carrier. It appears that adequate color rendition occurs when the bandwidth of the two color-difference signals is of the order of one mc. This fact has contributed to the abandonment of dot-sequential and dot-interlace techniques since the color-difference signals can be band limited, thus exhibiting no structure of color carrier. Then the only remaining source of structure arises from the residual color carrier appearing in the monochrome signal. The amount of this residual has been reduced by the adoption of as high a frequency for the color carrier as possible. This frequency has now been increased to 3.89 mc as compared to an original value of 3.58 mc. The new frequency is high enough to result in a low response of the monochrome circuit. Furthermore, the use of color-carrier frequencies having specific relationship to the horizontal scanning rate has further reduced the visibility of the remanent pattern.

To study the status of color television, the National Television Systems Committee established an Ad Hoc Committee in November, 1950. After a thorough investigation of the fundamentals of color television and demonstrations throughout the industry, its report, issued in April, 1951, resulted in the establishment by the National Television Systems Committee of a series of panels to consider specific aspects of color-television development. Their work included, among other objectives, field testing, the promulgation of field test standards, and matters relating to compatibility. These panels function throughout the year, and several interesting systems of a related nature were demonstrated or reported.

One of these was a frequency-interlace system that used two subcarriers, one at a frequency of 2.8 mc (carrying red information) and another at a frequency of 3.9 mc (carrying blue information). These two signals were associated with the green monochrome signal having a bandwidth of 3.5 mc.

Another system embodied the principle referred to as “alternating highs”; the red, green, and blue signals are sent continuously up to a bandwidth of one mc each. The balance of picture information was divided into two sections, containing modulation from 1 to 2 mc and from 2 to 4 mc, respectively. These two parts were then transmitted sequentially at field or line rates.

Fig. 11—Tristimulus photometer that permits rapid analysis of colors. The instrument was designed specifically to provide a laboratory and studio check of the faithfulness of color reproduction in color-television systems. Three photocells, one for each primary color, convert light energy to electrical energy which passes through three compensating circuits. A corrected value for each color component is read directly on microameters (RCA).
Another method demonstrated was referred to as the “alternating-lows” system. Here the green signal was transmitted continuously at full bandwidth, while the red and blue signals, at reduced bandwidth, were alternated either on a line or field basis.

A further system proposed that the signals at the transmitter be derived in the form required to drive the receiver primaries directly, thus gamma-correcting these signals, transmitting the green signal at full bandwidth, and modulating the information regarding the other two orthogonally on the subcarrier at an odd multiple of half the line frequency.

The question of gamma control for the transmitted signal received considerable attention. The need for gamma control arises primarily from the fact that picture tubes exhibit a nonlinear characteristic of input voltage versus light output. Unless compensation is introduced for this characteristic, not only are the brightness values of the original scene distorted but also its color values. Such gamma correction could be carried out at the receiver; however, this would have the disadvantage of adding cost to each receiver. Furthermore, it would not take advantage of the fact that the picture-tube characteristic has a slope that increases with increasing light output. This means that additional gain is required in shadow areas compared to that required in high-light areas. It is well known that shadow areas are extremely sensitive to interfering signals because of the relatively high contrast ratio induced by a given voltage in the shadows as compared to that in the high lights. By having gamma correction at the transmitter, it is possible to provide higher gain in the shadow regions of the signal so that a greater transmitted signal results and the shadow noise is effectively overridden.

Obviously, the exact specification of gamma correction depends on the exact shape of the picture-tube characteristic; because of this, a definite specification for gamma correction has not yet been evolved, but a decision to include some form of gamma correction in the transmitted signal was made.

The compatible color-television signal requires the addition of a color-synchronizing signal to the normal deflection-synchronizing signal used for monochrome. This signal has been the subject of both experimental and analytical attention. Current practice is to use several cycles (usually about eight) of color carrier following each horizontal-synchronizing pulse during the back-porch region of blanking. The signal is usually omitted during the nine-line vertical interval. The performance of a system using this method was described, and a theoretical analysis of the behavior of circuits employing this method was reported.

Other references mentioned:


(330) National Television Systems Committee Panel 11, Minutes of Second Meeting; July 18, 1951.


The composite color-television signal fully occupies a 4-mc channel because the color carrier is at 3.89 mc. This has presented a problem in the network transportation of the signal over coaxial cables and local loops, which at present do not, in general, pass the full video channel. A repackaging method, which permits transmission of the signal over such restricted facilities, was demonstrated. Its chief features include first, restricting the monochrome bandwidth and the color-difference information by a scale factor, and second, converting the color-carrier frequency to two-thirds of its original frequency. The signal in its modified form is transmitted by the coaxial cable or other band-restricted facility. At the receiving terminal, the color-carrier frequency is reconverted to its original value. There is, of course, some loss of detail inherent in this method.

Most of the early systems development work was undertaken with picture-display units of the direct-view type. In this type of display, there are three picture tubes whose images are optically superimposed by means of suitably arranged mirrors. The tubes have screens of suitably colored phosphors so that each tube provides one of the three separation images required.

Fig. 12—Some tricolor television-picture tubes. Top to bottom: 45° reflection type; 3-gun shadow mask; line screen; one-gun shadow mask; 45° reflection; grid-controlled color kinescope. All types shown can be used with any known system of television. (RCA)
Ultra-High-Frequency Television

As a result of a gradual accumulation of technical information covering transmitters, receivers, and propagation in the ultra-high-frequencies, the Federal Communications Commission formulated proposed standards and rules to guide the growth of television in the 470–890 mc region, which was tentatively set aside for that purpose in 1945. These proposed rules and standards represent the integration of information acquired in various research projects over a period of six years. Among the more significant of these was a test project using experimental station KC2XAK in Bridgeport, Conn. Its transmitter employed multitube cavities operating as tripler and power-amplifier stages to provide an output power at one kw at the peak of the synchronizing pulses. The transmitting antenna consisted of a steel tube containing half-wave radiating slots, the upper and lower halves each made up of eleven layers of slots with four equally spaced slots per layer, giving a power gain of 17.3. Utilizing this facility, many manufacturing companies field tested prototypes of their receivers and converters.

Another approach to the problem of obtaining adequate power at uhf for television transmitters was through the use of klystrons. A single tube of this type provided an output of 5 kw.


Another antenna structure developed for this band made use of the traveling-wave principle. The antenna radiator was spiraled around the supporting tower. A power gain of 20 was provided by a four-bay antenna.

Experiments were initiated to determine the result of tilting the main beam of an antenna having a narrow pattern in the vertical plane, with regard to both its effect on field strength in the service area and on tropospheric propagation. These tests were conducted on 530.25 and 850 mc at Bridgeport. The antennas con-
sisted of a vertical row of dipoles mounted on a reflector screen so as to obtain a unidirectional pattern sharp in elevation and broad in azimuth. The array could be tilted approximately 6 degrees. From these field-intensity measurements the following conclusions were drawn:

1. Maximum field strength at receiver sites in the service area was obtained when the main beam was directed toward these sites.
2. The conditions necessary for optimum tropospheric propagation are extremely variable. With favorable conditions, recordings at Princeton, N. J., 90 miles away, indicated that the field was maximum when the transmitting beam was aimed horizontally.
3. At 850 mc, tilting the beam downward resulted in an average signal increase of 10 decibels to a distance of 5 miles from the transmitter, but at greater distances the signal decreased. At the same time, the tropospheric field dropped approximately 12 db.
4. The improvements obtained in general would be specifically related to the height and vertical beam width of the transmitting antenna.

**Very-High-Frequency Television Broadcasting**

The "freeze" on new construction-permit applications for television broadcasting stations, instituted by the Federal Communications Commission in September, 1948, continued. However, there was continued expansion in the service rendered by the 108 television broadcasting stations that had previously been authorized at the end of the year within the continental United States.

A considerable step forward was the decision of the Commission to allow maximum effective radiated transmitter powers of 100 kw on the lower vhf television channels (2 through 6) and 200 kw on the upper channels (7 through 13). This permits stations to override man-made and other electrical interference and affords considerably improved service. Manufacturers already had 20-, 40-, and 50-kw transmitter power amplifiers in design to attain these higher effective radiated powers.

The inauguration of television circuits between New York City and Oakland, California by the Bell System, utilizing both coaxial cable and microwave relays, provided coast-to-coast television network broadcasting for the first time. The Bell System has continued its expansion of television circuits elsewhere across the country, providing a more widespread distribution of network programs, most of which come from studios of the major television networks.
The multichannel vhf transmitting-antenna installation at the Empire State Building in New York City was completed, and five stations began testing or broadcasting simultaneously from a common structure for the first time in history. Preliminary field studies indicated improved television broadcasting service generally throughout the primary service areas of the stations involved.


Developments in studio equipment included more versatile and efficient switching and mixing equipment, improved lighting equipment and techniques, and the modernization of camera equipment. Progress was made in the development of color studio apparatus, specifically for experimental use. Of special interest was the development of the color flying-spot scanner for televising color transparencies, slides, and the like.


Fundamental analysis of the essential functions of television receivers led to further simplification and improvement of home receivers. Tuners with lower noise factors, through the use of the cascaded circuit and newly designed tubes, were extensively used; while further analytical data were collected by the use of crystal diodes as video detectors. Improved stability and linearity of vertical deflection was obtained at reduced cost. By using standard receiving tubes in direct-coupled circuits for IF amplifiers, increased gain-bandwidth figures with much lower power consumption resulted. More precise methods of measuring and designating the voltage levels of video signals were discussed. There was a notable increase in the field of industrial television.


**Facsimile**

The application of facsimile to commercial telegraph systems continued to expand. At the close of 1951 a total of 3,300 "Desk-Fax" units were installed by Western Union in 25 cities, connecting patrons directly with the nearest central office. In Baltimore, Md., a fleet of radio-equipped motor vehicles serve in delivering telegrams to outlying areas. Telegrams are transmitted by facsimile from transmitters located in the central office and about the city to the "Telecars," and are recorded as the cars cruise in their assigned areas. A new high-speed facsimile system was developed for handling large-volume intercity telegraph traffic and for special-service applications.

(365) "New Western Union facsimile device greatly increases transmission speed," Telegr. Teleph. Agr., p. 10; April, 1951.

In a new application a high-speed facsimile system by the Radio Corp. of America provides reference-library service to outlying research laboratories at the Oak Ridge National Laboratory.


Following a temporary permissive ruling by the Federal Communications Commission, a rural FM network in New York, New Jersey and Pennsylvania inaugurated a facsimile newspaper broadcast service, the transmission being simultaneous with regular audio programs and over the same FM channels.


**Vehicular Communications**

Progress was principally in the continued expansion of mobile systems and services in the fields of common carrier, land transportation, industry, public safety, and special services, with notable progress being made by the railroads. Additional common-carrier applications included maritime service in the 152-162-mc frequency band and public coin-box telephone service on railroad trains.

Under consideration were the use of fixed relay stations to extend the range of point-to-mobile communications and the integration of mobile radio facilities into the civil-defense network. The total number of vehicular stations, exclusive of amateur, ship, and aircraft, increased during the year from 27,160 to 32,858, an increase of approximately 20 per cent.

As a result of the increased demand for vehicular radio services, available channels were rapidly being exhausted and emphasis was directed during the year toward a more efficient use of the channels through the addition of selective signaling and better operating procedures. Consideration was given also to increased utilization of the frequencies allocated for this service in the uhf band in the vicinity of 450 mc. Equipment operating in this frequency range was made commercially available, and at least two systems were placed in experimental operation.

The need for additional channels also resulted in continued attention being directed to the development of equipment having increased selectivity and stability to permit closer geographical spacing of channel assignments on an adjacent channel basis. The possibility of operation with even closer spaced channels was also under investigation and, at the request of the Federal Communication Commission, the Joint Technical Advisory Committee of the RTMA-IRE initiated a study of channel splitting as applied to the 152-162- and 450-460-mc bands. This and other matters of general interest in the vehicular radio field were discussed at a two-day annual conference in Chicago of the Institute's Professional Group on Vehicular Communications.

Navigation Aids

General

The outstanding operational trend was the ascendency of the role of ground radar for aircraft navigation as well as of various forms of harbor and shipborne radar for marine navigation. An important series of tests, sponsored by the Air Co-ordinating Committee and conducted by the United States Air Force with the co-operation of the Civil Aeronautics Administration, was described, resulting in new emphasis being placed on radar for navigation and traffic control. The conclusions reached were that radar should become the primary traffic-control facility in congested terminal areas and that all procedures, traffic patterns, and displays should be designed to supplement radar and serve the radar controller in good as well as bad weather. Limitations of present-day voice communications and necessity for more channels were outlined. In en-route traffic control, the proper use of the navigation aids, such as the omnidirectional ranges later supplemented by distance-measuring equipment, requires the use of new, rapid ground-air communications to assure proper separation and scheduling. The development of private-line communications was indicated. Because of the limitations of present-day radar, the development of a simple airborne transponder to provide identification and altitude was started. The recommendations included the development of a high-resolution radar, the Airport Surface Detection Equipment, for scanning the airport surface itself.

This emphasis was accompanied by a vigorous development program in the field of radar, and the past year showed progress beyond those developments initiated during World War II for military purposes alone.

With the growing operational use of radar, many improvements formerly restricted to military usage became available to civilian users. Thus, moving-target indication circuitry is employed in the surveillance radar sets being installed at major airports. Video mapping and direction-finding identification are also being incorporated. Improvements in ground-controlled approach radar, such as better cathode-ray displays, higher reliability, greater power output, smaller side lobes, and so on, are contained in the new civil precision-approach radar sets (PAR). More important, perhaps, is the fact that operational and maintenance problems, such as training of personnel, are being solved.

In a similar, but somewhat less spectacular fashion, progress continued in all the other fields of location and aids to navigation. Of some importance is the growing application of modern communication theory to these fields. The application of information theory and statistical principles to detect signals in the presence of noise yields rich rewards in navigational systems because of the relative ease of application of these principles to such systems as compared to communication systems or other branches of radio engineering.

Radar Systems

Scientific and engineering activity in radar theory, coupled with investigations of the mechanisms affecting radar operations, was high indeed, and the results prolific and rewarding. Much of the work is reported under...
antennas, propagation, circuits, measurements, and the like.

From the over-all point of view, the past year was notable not only from the analytical and theoretical aspects but also from the practical and operational sides. Production of radar equipment was higher than ever, large-scale installations for both military and civil use were made, and the radio engineers were beginning to cope with the first headaches of establishing sound and universal maintenance.

From a fundamental point of view, radar systems were studied to determine how to increase the reliability and range. The bandwidth of the conventional pulse radar is many times greater than is required by the amount of information conveyed. Application of a communication theory coupled with statistical methods was widely used in order to organize better the method of attacking the problem.

Not only was the basic character of the radar signal examined but the utility of the signal in the presence of noise in connection with various displays was determined. Methods for calculating the ratio of signal strength to noise for any desired probability of detection were devised. Particular attention was given to returns comprising only a small number of signal pulses. The effect of changing characteristics of the signal, such as pulse-repetition frequency, antenna beamwidth, pulse duration, as well as biasing and limiting, was considered in deriving detection probability. Some consideration was given to dark-tube operation and video pulse stretching.

In addition to theoretical investigations, efforts to record radar-reflection data for analysis was evident during the year.

Measurements and studies of the reflecting area and polarization of target reflectors were reported at the annual convention of the IRE last March. (See Papers 138 and 139, Proc. I.R.E., vol. 39, p. 308; March, 1951.) One of the most important developments did not appear in published form although results obtained were described at this convention.

It was found that, using circular polarization, both the signal return and the return from precipitation were reduced from that obtained from a linear polarization, but the interfering signals from precipitation were so much more attenuated that a net gain of better than 15 db was obtained both at 3,000 mc and 9,000 mc. The improvement was in accord with the theoretical expectations, except against wet snow where practically the same gain was obtained as against heavy rain. Similar experiments in Great Britain yielded comparable results.

Studies were made of the azimuthal resolution capabilities of the radar system as related to the antenna beamwidth or size of antenna aperture. Various means of enhancing the resolution, such as the "super gain" antenna and the application of filter-equalization techniques, were investigated. No essential improvement in resolution appeared to be obtainable above that derived from the beamwidth considerations.

Not only did the studies cover radar systems in general, but particular types of radar systems were analyzed. In a conical-scanning tracking radar, four sources of angular jitter were analyzed. These sources, which were evaluated analytically, are (1) fluctuations in received signal strength due to target aspect changes and interference phenomena, (2) fluctuations in angle of arrival due to the wander of the effective center of radiation of the radar echo, (3) receiver noise, and (4) residual jitter due to mechanical and electrical backlash.

In addition to improving the radar itself, continued progress was made in the development of radar transponders that give a much stronger return than the radar reflection itself, eliminate the clutter problem by responding at a different frequency than the radar, and provide facilities for coding information such as identity, altitude, and the like.

The utilization of integration and filtering techniques for improving radar performance has been limited to performing such operations after detection or in the video-frequency circuits. Considerable gain could be obtained if the integration could be accomplished before detection. However, a limit is imposed on the amount of filtering that can be accomplished if the radar source has an unstable frequency characteristic. As a result of the foregoing, the past year saw the beginning of development of high-power sources other than magnetrons, in particular, klystron amplifiers.

Progress was made in preventing echo interference in interrogator-responder systems which use pulse-multiplex methods for channel selection.
The improved radar system requires high-quality, low-jitter, high-reliability modulators. Considerable work was done in this field, and particularly interesting is the magnetic modulator that reduces the number of vacuum tubes required.

Marine Radar

A rapidly growing field is that of marine radar, and the past year saw its greatest annual growth. Not only were a greater number of ships equipped with radar sets for navigation under poor visibility conditions, but the use of radar beacons for marking known locations and the beginnings of harbor radar for traffic control by means of radio communications from shore to ship was evidenced. This activity is not confined to the United States. Great Britain and France also are finding these systems of great aid to marine navigation. The engineering effort in this field was largely one of system design and application. Contrasted to other fields in navigation, the literature available to all is relatively abundant.

Fig. 17—First commercial installation of Model DTB, uhf, distance-measuring equipment (DME), installed at CAA omnidirectional station VOR, Wilton, Conn. The DME radiator mounts above the radome which houses the VOR antenna system. The DME, which includes duplicate transponders and monitors, operates continuously and unattended. If either unit fails, the duplicate spare is automatically switched into operation (Hazellite Electronics Corp.)

which is sponsoring this development. Present development effort is devoted toward devices that will aid the controller in making better use of radar information, i.e., in data reduction and computation aids.

Sufficient information was gained during the year to show that ground-surveillance radar supplemented by airborne transponders, used in conjunction with VOR and DME, and now being developed by simulation and operational tests, will be completely sufficient to handle traffic of mixed aircraft types at a rate of 30 operations per hour on a single runway and single-type aircraft traffic at a rate of 45 per hour. For higher traffic rates, the basic traffic-control radar will need to be operated with different procedures and will need to be supplemented by somewhat more sophisticated data-reduction devices. These devices will have the purpose of relieving controllers of some of their more mechanical tasks. Examples are radar automatic tracking circuits (which will, incidentally, measure ground speed), filtered displays showing aircraft location and identity, and sequencing devices which will automatically select the most efficient order of aircraft arrival at entry to final approach.

Air-Traffic Control

The provision of ground-based radar in terminal areas has made possible the greatest single improvement in traffic control in the last decade. Successive approach intervals of three minutes are now routine at those airports having radars and trained radar controllers. There seems little doubt that the future traffic-control system will be built on the firm cornerstone of surveillance radar.

One of the first steps is the introduction of simple airborne transponder beacons. These will provide longer distance radar coverage, freedom from ground echoes, and simple aircraft identification. Component characteristics for such a transponder have been drawn up by the Air Navigation Development Board (ANDB),

A group of ten psychologists completed an investiga-
tion initiated by the ANDB in December, 1949 on the application of the principles and techniques of human engineering to the improvement of air-navigation and traffic-control systems. Their report treats this subject in detail, and also presents a recommended long-range program of psychological research to parallel the equipment and system developments. The most significant conclusions of these studies are: (1) Humans surpass present-day machines in detection threshold, pattern perception, improvisation, inductive reasoning, and judgment. (2) Present-day machines surpass humans in rapidity of response, smooth precise application of force, performance of repetitive tasks, and deductive reasoning. (3) Including human elements in a system increases flexibility in adapting it to changing demands. (4) On the whole, man is poorly designed for many monitoring tasks, and caution should be exercised in assuming that he can successfully monitor complex automatic machines and take over if the machines break down. Engineers should seriously consider systems in which machines would monitor man! (414) P. M. Fitts, "Human Engineering in an Effective Air Navigation and Traffic-Control System," National Research Council, NRC Committee on Aviation Psychology, Washington, D.C.; March, 1951.

An important study was devoted to the effect of a variety of parameters associated with final approach and landing on the minimum time intervals between successive arrivals. Several of these are: safety rules, variability of speeds for each type of aircraft, mixture of aircraft types, number and location of taxi exits, length of the common approach path, instrumentation errors, wind, condition of the runway, and so on. The effect of these parameters on runway acceptance rate was discussed in detail:


The use of simulators to set up various traffic-control situations saw considerable employment. One analysis was based on the use of a specially developed slide rule. To check the method, a comparison of the acceptance rates that might be achieved with a fixed-block, terminal-area traffic-control system was worked out utilizing the slide rule, then it was compared with previous studies that used more involved computation procedures. The results showed that the method was quite accurate.


Some studies were conducted on a pictorial simulator of air traffic. Optical projectors were used, the images being projected on a large screen with each light spot representing an aircraft in motion. The movement of the light spot could be controlled for straight or curved flight or could be made to follow automatically a radar return. The results of the study showed that such devices could be useful for training traffic controllers or for studying traffic situations.


An interesting study which involved the application of information theory to communications in the traffic-control problem appeared during the year. This study was particularly concerned with the private-line communication problem. The facilities required to transmit certain standard control messages from a traffic-control center to aircraft were assessed, and it was shown that any surplus channel capacity can be used as redundancy for improving operation at low signal-to-noise ratios.


**Short-Distance Navigation**

Engineering activity in the field of short-distance navigation continued high, the over-all effort being greater than in radar but more directed to immediate operational needs rather than to fundamental investigations. The leading contender for attention was the omnibearing-distance system of air navigation.


All stations of a total planned program of 426-vhf omnidirectional-range (VOR) stations are now installed in the United States and its possessions, and most of these have been commissioned and are available for use. At each of these sites there will be added a uhf distance-measuring equipment (DME) within the next few years, the combination to provide virtually complete continental coverage by these internationally standardized navigational aids. The coverage and accuracy of three stations of this sort were tested during the year to evaluate the long-term utility of the system as well as its worth for the immediate future. These tests showed that, except in the vicinity of unusual terrain conditions, aircraft position can be determined with a precision of 2 to 3 degrees in azimuth and to within 0.5 per cent of distance-to-station at distances to 100 miles from the ground station. The omnidirectional range exhibited large cones of confusion over the transmitter and was subject to errors due to the altitude of the aircraft ("course pushing"). When the test aircraft was shielded from the station by terrain, e.g., mountains, a considerable deterioration in accuracy, as well as signal attenuation, was experienced. These measured accuracies...
seem completely adequate for en-route and terminal-area navigation for any traffic densities foreseen for the next ten years. So far as use in the long-term future is concerned, higher traffic densities may demand greater navigational accuracies.


As vhf omnidirectional-range (VOR) coverage was extended into the mountainous areas of the western and northwestern United States, difficult siting problems were encountered. A theoretical consideration of the problem was conducted by the Civil Aeronautics Administration, and a practical and economical solution was proposed. This was later verified by flight tests on two experimental installations.


Measurements made to observe the accuracy of the VOR information have established that vertical polarization from the pedestals that support the antennas contribute a small error, which may be reduced by using an antenna array of vertical elements parasitically excited and so phased as to cancel the vertical radiation from the pedestals.

An interesting development completed during the year was a cage antenna for the vhf omnidirectional range. The antenna consists of a rotating dipole inside a vertical cylindrical cage composed of vertically spaced conductors whose dimensions are suitable for proper matching of the dipole to obtain maximum radiation properties. The cage serves to suppress unwanted vertical polarization and emphasize horizontal polarization. End effects which might serve as a parasitic generator of unwanted polarization are reduced by extending the cylindrical cage above the radiating cage. "Course-pushing" effects caused by vertically polarized signals were greatly reduced, octantal and quadrantal errors were reduced by virtue of the single antenna source, and a fairly narrow cone of confusion approximately 20 degrees wide resulted. Somewhat simpler installation adjustment and maintenance appears possible.

A means for reducing reflection errors in azimuthal navigation systems employing phase measurements, such as in the vhf omnidirectional range, was proposed. This method averages the readings obtained from an omirange facility at several frequencies. A mathematical analysis shows that the errors can be reduced by such means or by frequency modulation.


The distance-measuring equipment (DME), the companion to the vhf omnidirectional range, was not quite so fortunate in seeing operational use, but development activity remained high. A microwave system utilizing phase measurement of a continuous-wave signal transmitted from the aircraft to the ground and relayed back at a slightly different frequency was described as well as some of the excellent results in accuracy that were obtained.


The Australians described a DME which was developed for operation at 200 mc. While similar to the corresponding DME apparatus adopted in this country, it differs in the smaller number of channels and the method of multiplexing.


The Air Navigation Development Board continued work initiated last year, and has made significant progress in the DME field. The program which previously had been concentrated on the development of equipment intended for commercial airlines and military aircraft was expanded to consider the design of equipment suitable for private-type aircraft. Design and construction of a light-weight interrogator, with somewhat reduced performance in the interest of lower cost and weight, has been initiated. Development of a miniaturized interrogator intended for use in civil and military aircraft has also been initiated.


Development models of a pictorial computer for polar co-ordinate navigation were demonstrated. This instrument shows the pilot the position of his aircraft on a map of the area over which he is flying. Azimuth and distance information are supplied by the VOR and DME. The models demonstrated were of the simple portable type. Further development is progressing on two other designs intended for mounting on the aircraft instrument panel; one of these features automatic tuning and chart selection.


Base-Reference Navigational Systems

The base-reference navigational systems may be divided into (1) the relatively short-range systems that rely on ground- or surface-wave propagation and have high accuracy and (2) those which utilize sky-wave propagation, to cover greater distances at reduced accuracies due to the uncertainties of the ionosphere.

In the former category, work continued on shoran which utilizes pulsed emissions in the upper vhf band; Decca, which uses continuous-wave emissions and phase-measurement techniques in the medium-frequency band; and Raydist, which operates in a similar fashion to Decca in the high-frequency band. An important analysis of the effects of meteorological conditions on the
measurement of distances dealt with two effects, that of a changing index of refraction of atmosphere on the bending of the ray path and that of meteorological conditions on the velocity of propagation itself.


The Raydist system was further evaluated.


Refinements on Decca continued, especially on improving the utilization of the meter indicator.


In the second category of base-reference systems, those using sky waves, the relative advantages and disadvantages of the narrow- and medium-base-line systems which are directional or azimuthal in character were becoming more apparent when compared with the wide-base-line or hyperbolic systems. For nonmilitary use, the advantages of simplicity and low cost of the former weighed heavily in their favor despite the greater accuracy of the wide-base systems.

Tests on the Consol (sone) system, the medium-base-line azimuthal system, were finished during the year by the United States Air Force. Embracing one year of evaluation, the tests showed that, with a spacing of three wavelengths at 193 kc and with 14 kw radiated, bearings having a root-mean-square error of one-third of a degree for day and night are obtainable consistently at distances of 1,500 nautical miles with the excellent reliability expected of a navigation system, especially when narrow-band receivers having a predetection bandwidth of 50 cycles were used. The indication is aural. The accuracy of the system is highest close to the perpendicular bisector of the base line and lowest at angles which are not close to the base line normal.


The Navaglobe system, first announced in 1946, has finally been brought to the testing and evaluation stage. It is an azimuthal system employing narrow-band transmission and reception as in the Consol system. It differs from Consol in having a triangular base line with only 0.4-wavelength spacing and in employing visual rather than aural indication. It is a kind of omnidirec-

tional radio range. The installation consists of three towers, which are spaced less than a mile apart. These towers produce a switched pattern in space. The airborne equipment is small and lightweight. An indication is in the form of a special bearing selector and crosspointer instrument. Bearings can be read to better than 0.5 degree. The ground equipment has means for compensating for site errors. The airborne receiver is designed for an extremely narrow bandwidth so that signals can be read in the presence of noise. Reading can be obtained with one degree error when the equivalent 3-kc bandwidth noise is 100 times the signal.

Base-reference navigation systems can be made more accurate by spacing the antennas very far apart. In this manner, a large number of electrical degrees represent only a few space degrees, but the tilt of the ionosphere becomes a limiting factor. Navaglobe, therefore, has attempted to obtain its accuracy by refining its instruments instead of spacing the antennas far apart. Using the propagation data that has been taken with the system during the past year, it appears that the root-mean-square error of Navaglobe will be 0.5 degree, and the range 1,500 miles. Instrumentation errors and polarization errors have shown themselves to be less than expected.


The wide-based systems, such as loran, made no spectacular progress, but some investigations showed what may be expected. Research carried out on the west coast in conjunction with a low-frequency loran transmitter radiating pulses having one megawatt peak power at 100 kc on the east coast showed that reliable ranges of 2,200 nautical miles are obtainable.


(447) "Ocean Electronic Navigation Aids," U. S. Coast Guard Washington, D. C.

An operational summary of marine navigational systems was presented at a symposium at the Royal Geographical Society in May, 1950. The papers which were published included marine position-fixing systems in use today, use of direction finding at sea, the adoption of Decca as an aid to navigation at sea, and the use of Consol in the fishing fleet.


**Missile Guidance**

A significant number of articles describing missile-guidance systems and problems were published.
A discussion concerning the damping characteristics of components, such as stable platforms, integrating accelerometers, and the like, used in airborne navigational aids appeared.

The application of the Doppler effect in the development of apparatus for measuring the velocity of projectiles and guided missiles and the design of electronic fuses for shells were described.

Certain traffic-control features of the automatic GCA (or Automatic PAR as it is becoming known) have been selected by the Air Navigation Development Board, and embodied into an attachment for civil ground-controlled-approach radar sets to permit automatic spacing and maintenance of safe separations among aircraft approaching an airfield using any type of approach or landing facility. This is being evaluated by the Civil Aeronautics Administration.

Aircraft-Terminal Aids

Continued activity in electronic aids for navigation in the terminal area furthered progress in this field. The outstanding accomplishments were the initiation of widespread use of airport surveillance and precision-approach radar, the development of a "baby" omnidirectional range for terminal-area use, completion of development and initiation for test of an automatic ground-controlled-approach radar (GCA), several significant improvements in the instrument landing systems (ILS), and the continued development of high-definition, short range radar techniques for controlling traffic on the airport surface itself.

The widely installed and internationally standardized ILS fixed-beam approach aid, particularly when monitored by precision approach radar (PAR), has proven quite satisfactory to operational minima of 200-foot ceiling and half-mile visibility. Under worse weather, additional guidance (e.g., approach lights) has been found necessary. This limitation comes about because of the inability of the system to provide sufficiently accurate guidance with respect to a flared glide path, and to provide a heading reference sufficient to allow killing drift just prior to touchdown. In addition, both systems impose limitations on airport acceptance rate because of the relatively long straight approach path that must be flown by all aircraft.

For complete guidance to touchdown, an accurate electronic airborne altimeter and an exponential flare-out computer were developed and found satisfactory for vertical guidance.

Direction Finding

Activities in direction finding continued in the investigation of errors and extension of the frequency range in which the direction-finding technique may be employed. Several important improvements on automatic and instantaneous equipments tailored for high-speed aircraft were described.
Wave Propagation

Ionospheric Propagation

Radio-wave propagation in the ionosphere abounds with many facets. For an index to the published material, the reader is referred to "Abstracts and References," compiled by the Radio Research Organization of the Department of Scientific and Industrial Research, London, England and carried in each issue of the Proceedings of the I.R.E. and to "List of Recent Publications," compiled by W. E. Scott and carried in each issue of the Journal of Geophysical Research. Only a limited number of representative, published papers have been recorded in the present report. However, a considerable amount of additional material drawn from IRE-URSI and other conference programs, and from technical reports and progress reports produced under government contracts, has been included.

It is now recognized that the geomagnetic field is an outstanding factor in ionospheric radio-wave propagation. In fact, we now know that for one to see the manifold aspects of the ionosphere in their proper perspective, it is essential to think about the hydrodynamics of the atmospheric ocean, considering both the regular behavior and the perturbations known to be closely related to solar irregularities.

There also is a growing consciousness of the extraterrestrial factors, other than directly solar, that also affect the ionosphere and are affected by it. The twinkling of radio stars and of moon echoes, the radar observation of meteor trails, and attempts to measure ionizing and tidal effects due to the moon are examples of these. It is now recognized that just as the ionosphere may confine a radio signal to the earth, so it may also prevent such a signal from reaching the surface of the earth from outside the ionosphere. Ionospheric winds are under active study by observation of the drift of meteor trails and the movement of fading patterns along the ground from vertical-incidence signals.

Compelling evidence is accumulating that sunspots are not fundamental to solar activity associated with geomagnetic and ionospheric disturbances. Solar observations using the coronagraph indicate that in the highly conductive solar atmosphere (chromosphere and corona) prominences will follow the lines of magnetic force and, with the local concentration of prominence material, the moving gas will break through the lines of force and ascend towards the photosphere, carrying the lines of force with it. This will concentrate the lines of force, resulting in intensified magnetic fields at the level of the photosphere, a major characteristic of sunspots. Earlier work also supports the idea that the spots themselves are but superficial manifestations. The criteria for solar activity in solar-ionospheric correlations stem from chromospheric and coronal as well as sunspot measure-
ments. Activity ratings are applied to individual solar regions rather than to the whole disk on a given day.

The usefulness of extraterrestrial sources of radio noise and of radar echoes from extraterrestrial objects, for exploring the upper ionosphere above the cut-off frequency, was first pointed out in 1948. It was observed earlier that there is a reduction of galactic noise during a sudden ionospheric disturbance. This affords a means of estimating D-layer ionization and certain ionospheric effects noted during dawn observations on solar noise. Neither a nonsymmetrical F layer nor a G layer has been able to account for the great deviation of the source (sun), observed at radio frequencies, or of its rapid variation with altitude. From these facts, it seems that a horizontally stratified F layer model must be given up in favor of one involving horizontal irregularities. Recent work in radio astronomy gives further evidence in this direction. Correlation was found between fluctuations of the discrete sources in Cygnus and Cassiopeia and spread F echoes. Correlation of the fluctuations in spaced receivers previously indicated the source of the irregular variations to be principally the terrestrial ionosphere. The observations are consistent with diffraction at an irregular ionosphere, the lateral dimensions of the irregularities being of the order of 5 km. A diurnal variation in the occurrence of the irregular ionization is found, with the onset of the maximum occurring at about 0100, local time.

The observed speed of slow fading of moon echoes produced on about 29 mc per second is evidently also consistent with an ionospheric origin. The following major discrepancies in the orthodox ray-theory treatment were found: (1) Observed echo intensities are well below theoretical values. (2) Minimum altitudes at which echoes are first detected are unexpectedly high. These anomalies correlate closely with the critical frequency of the F2 region. The results indicate the presence of horizontal irregularities in the ionosphere or the failure of the ray-theory treatment at very oblique incidence.

Meteor ionization trails were successfully observed by radar techniques, affording information both on meteors and the ionosphere. Measurements of meteor decelerations led to the conclusion that either the formula for the scattering of radio waves from a meteor trail needs revision or that the density of air at 100-km height is lower by a factor of three or more than the value given in the tables of the National Advisory Committee on Aeronautics. Measurements on the polarization of meteor echoes indicate that ionization densities may be greater than are usually assumed and that existing theories are not compatible with this result. It was concluded from theoretical considerations that laminar flow of a meteoric ionization path may increase the duration by as much as four times. Some progress has been made on the determination of diffusion coefficients from the dependence of the rate of decay of meteoric echoes on the radio frequency used.

Statistical analysis of the velocities of 11,000 meteors observed over a period of 15 months led to the conclusion that all, or nearly all, meteors down to the eighth visual magnitude are members of the solar system. No definite interstellar meteors were found. In this work, photoelectric techniques were adapted to the automatic recording of meteors with a sensitivity adequate for second-magnitude meteors.


I onospheric winds were measured by the drift of fading patterns along the ground, using vertical propagation. The program is too young to have produced comprehensive information, but winds of 100–300 meters per second are commonly indicated. Although they may be observed in any horizontal direction at one time or another, temporal trends are becoming apparent. Marked differences were found between E- and F-layer winds. Measurement of the drift and turbulence of meteoric ionization is being used for wind information. An accuracy of 420/(number of meteors) km per hour is calculated. So far, the results of this technique have shown only very rough correlation with the fading measurements.


Tidal effects in the atmospheric ocean are still being sought. Although they constitute an essential part of some theoretical considerations, no clearly positive experimental evidence has yet been presented.

A somewhat different group of phenomena may be said to be in the province of the communication engineer. Outstanding of these is the prediction on a worldwide basis of optimum usable high-frequencies for
ionspheric paths. Data for these predictions are furnished by many co-operating groups throughout the world using sweep frequency, vertical-incidence recorders. World-wide predictions are available to the public from the Central Radio Propagation Laboratory (CRPL), National Bureau of Standards at Washington, D. C. An evaluation of the effectiveness of this program was published. Although, on the average, agreement is good, discrepancies remain which need further examination after the elimination of known sources of error. In a few cases, comparisons of predicted and actual times of fades due to ionspheric absorption were made. Although the agreement between these times is reasonably good, it is believed that predictions of the actual field strength may be in error by large amounts.


A useful slide rule for the solution of spherical triangle problems in long-distance radio communication was described. Improved sweep-frequency recorders were built. New progress was made in forecasting the ionspheric and magnetic disturbances that have a deleterious effect on practical radio communications.

Advance forecasts (1 to 25 days ahead) were expanded in March to give more detail and background information. The regular schedule of these forecasts was changed from weekly to semimonthly in September.


(487) Due to CRPL and RPL.

The other forecasting services of the Central Radio Propagation Laboratory—warning notices on WWV and regular daily forecasts—were extended on an experimental basis in February by forecasts for ensuing 12-hour periods issued at approximately 6-hour intervals. These forecasts all refer to propagation over North Atlantic paths. In October, the inauguration of a North Pacific radio-disturbance service was announced. Advance forecasts issued at Anchorage, Alaska are intended to apply specifically to communication conditions in the North Pacific and Alaskan area. The development of an Arctic high-frequency prediction service is well underway. This has required the preparation of polar contour charts of \( f_0F2 \) for each hour of zero meridional time extrapolated to sunspot number zero and of corresponding charts of \( F_2 \) layer sensitivity to sunspot number. Calculations of the apparent magnetic field from measurements of critical frequency differences, \( f_0F2-f_0F1 \) and \( f_2-f_1 \) in the \( E \)-layer near the north magnetic pole show large semidiurnal variation. These are thought to be due to a variable concentration of ions rising to 4,000 times the free-electron density.


In connection with the high-frequency utilization program, many opposite problems are being attacked. Many of these are potentially able to contribute to the knowledge of the physics of the ionsphere as well as to the utilization of it. Oblique-path pulse measurement, using independent but highly accurate time bases at the path terminals, is a field of continuing and growing interest although no results were published. New information on the characteristic of down-coming signals at oblique and vertical incidence is steadily increasing. A program of investigation to determine the effect of the polarization of the transmitted wave on the character of received waves is underway. This required the construction of dual-channel transmitting equipment of adjustable relative phase. The equipment is adjustable in frequency. Backscattering along an oblique ionspheric path continues to hold promise as a means of path evaluation from one terminal of the path only, and a one-megawatt transmitter for contiguous spot-frequency measurements is under construction.

(489) J. A. Pierce, Harvard University, Cambridge, Mass.; J. W. Cox, Defence Research Board, Ottawa, Canada; R. Bateman, CRPL.

(490) M. G. Morgan, "Interim Technical Report No. 4" (in preparation), describing equipment and results, Dartmouth College, Hanover, N. H.


Equipment is also under construction to obtain quantitative data on cross modulation in the ionsphere (Luxemburg effect) by means of vertical-incidence measurements. A relatively long and high-power heating pulse will be transmitted and be followed by high-repetition-frequency exploratory pulses. It is anticipated that the change in amplitude of the echoes, as the ionsphere recovers from the heating pulse, will supply quantitative specific-heat data and will be useful in determining the veracity of the presently accepted theory of cross modulation in the ionsphere. Oblique-path measurements of the effect are also continuing. There is also work underway to evaluate the phenomenon by direct measurements from rockets.


Much detailed data on the behavior of continuous waves reflected from the ionosphere at frequencies below about 130 kc were obtained. There is now agreement that at oblique incidence the virtual height of reflection varies from 70 to 75 km during the day, to about 90 km
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at night. Daytime attenuation is high in the vicinity of 00 kc and low at frequencies of the order of 16 kc. Polarization is approximately circular in the range of 16 to 130 kc at short distances, but is linear at distances greater than about 400 km on 16 kc. Substantial progress was also made at the very low frequencies through the study of the propagation of radio atmospherics. It is found that when the distance to the source is greater than about 1,000 km there is marked attenuation of frequency components below 10 kc, particularly during the day. The main features of the oscillatory and sharp-impulse types of wave forms are explained by assuming that the earth and ionosphere constitute the walls of a waveguide, the upper surface of which is an imperfect conductor.

Further work was done on the recording of atmospherics for the purpose of determining the distance to the source and the height of the reflecting region. The application of an audio spectrograph, which uses a frequency-time-intensity display to show the spectrum of audio-frequency waveforms, for the study of "whistlers," "swishes," and "rumblers" was described. The splitting of reflected pulses (vertical incidence) into two or more components raised some basic questions, and differences of opinion, regarding the nature of the reflecting region. In one analysis of nighttime results on 100 and 325 kc, it was concluded that the observed splitting could be explained only if the E-region were assumed to contain translucent reflecting layers in the height range 90 to 130 km. Another group of investigators contends that splitting can be explained adequately on the basis of magnetoionic effects occurring in a single, relatively thick layer. The former thesis may be supported by results obtained in England using loran pulses on frequencies between 0.7 to 2.0 mc, and interpreted as indicating a primary reflection height at 90 to 97 km and subsidiary reflection heights at 120 to 130 km, 105 to 110 km, and 70 to 76 km (daytime only). It was found that irregularities in the records taken at Washington of vertical-incidence pulse measurements at 160 kc correlated closely with geomagnetic k-index figures. One year's measurements of the peak amplitudes of the strongest E-region vertical-incidence echoes at 150 kc were reported. The seasonal variation of attenuation was found to be inconsistent with the empirical law describing the diurnal variation. Progress was made on the task of developing a suitable theory of wave propagation at low frequencies where the usual ray theory is a poor approximation.

Contrasted with these efforts were those at very high frequencies above the usual "maximum usable high frequencies" defined for regular high-frequency ionospheric communication. Here, activity was concerned with E-sporadic and aurora-supported propagation and with the scattering effects of the normal ionosphere. A study of 456 reports of long-distance television reception indicates that those cases reported in the interval 200 to 500 miles were tropospherically propagated, whereas those in the interval 500 to 1,500 miles were propagated by single-hop reflection from E-sporadic.

A study of reports by radio amateurs on supposed "auroral propagation" and of visual observations of strong northern lights displays showed that the two occur at approximately the same time. From observations of aurora-propagated amateur signals, the following properties were determined: Rapid fading occurs with major random components up to about 100 to 300 c at carrier frequencies of 50 and 144 mc, respectively; directional antennas at both transmitting and receiving locations must be pointed in the general direction of visible aurora; received signals usually retain in large degree the transmitter polarization, whether horizontal or vertical; amplitude modulation, although badly garbled, is sometimes intelligible at the lower carrier frequencies; frequency modulation is not intelligible; in many cases the signal-amplitude probability distribution is close to the Rayleigh distribution; times of openings vary from shortly after noon until approximately dawn, and over periods of a few minutes to many hours; distances of over a thousand miles may be covered. It has been shown that auroral propagation manifests itself as horizontal bars on television screens when receivers are tuned to distant stations.

Pulse echoes were obtained at 50 and 100 mc from aurora. Results indicated that echoes occur from within, or close to, certain types of visible aurora; that echoes at these frequencies do not occur from aurora more than 15 degrees above the horizon; and that they are due to scattering from centers of high electron density, which are constantly forming and disappearing. The fact that echoes do not come from aurora more than 15 degrees above the horizon suggests that there may be an absorbing region below the aurora.

However, McKinley (National Research Council—
should ionization were frequently heard. In this connection, it is expected that the signal experiences maximum reflection coefficient at this elevation, but scatter echoes may be obtained at other aspects.

McKinley also reports scatter-type echoes at constant range obtained with high power (500 kw) on 33 mc. These are always at 82- to 85-km range, often several kilometers thick. They grow slowly to a maximum intensity of not more than twice noise, and then fade away. The average duration is about half an hour, and they may occur several times during a night (or day). The range never changes.

At 100 mc it was noted that narrow echoes seem to come from auroral ray formations and wide echoes from draperies at ranges of 400 to 600 miles. (See the following photographs, courtesy R. Thayer, Cornell University, Ithaca, N. Y.)

![Photographs of auroral echoes](image)

**Fig. 18**—(a) Separated discrete auroral echoes. SCR-270-D. Ithaca, N. Y., September 10, 1951. 0850 EDT. (b) Clustered discrete auroral echoes. SCR-270-D. Ithaca, N. Y., September 10, 1951. 0320 EDT. (c) Diffuse auroral echo. SCR-270-D. Ithaca, N. Y., September 10, 1951. 0300 EDT.

The advent of an inclusive scattering theory suggested that ionospherically scattered vhf signals might be detected at ranges beyond those normally considered to be maximum for tropospheric propagation. An experiment was described in which continuous propagation was obtained at 49.8 mc over a 774-mile path. Rhombic antennas were used both for transmitting and receiving, and the input power to the transmitting antenna was 30 kw. Although temporal variations were evident, the signal was always present. Beat-frequency whistles due to multipath propagation from meteoric ionization were frequently heard. In this connection, it should be pointed out that the moon-echo experiments indicate that the ionosphere may reflect under conditions in which penetration would normally be expected.


Excellent theoretical papers of a comprehensive nature dealing with the ray and mode theories of propagation in the ionosphere and other media continue to appear.


**Tropospheric Propagation**

Propagation Well Beyond the Horizon. The center of interest in this subject continued to be the attempts to explain observed field strengths which are very much higher than expected well beyond the horizon of high-power transmitters throughout the vhf and microwave spectrum in many parts of the world. Megaw published some measurements made at 10 cm at distances to 370 miles across the North Sea under normal conditions when superrefraction was believed absent.

These observations extend to greater ranges the phenomenon first discovered by Katz in the Caribbean in 1945 (later confirmed by him in the Pacific) of greatly reduced attenuation per mile at 10 cm beyond about 90 miles, in what has come to be called the "scatter region."


Attenuation of the average field strength at long ranges is observed to be a few tenths of a decibel per mile, rather than several decibels as predicted by conventional theory for the normal atmosphere over a curved earth. Megaw interpreted his measurements in terms of the hypothesis of scattering from index-of-refraction fluctuations associated with atmospheric turbulence. Independent evidence for the order of magnitude of atmospheric turbulence was deduced by him from astronomical measurements on the twinkling of stars.

Toward the end of the year, Feinstein published the suggestion that partial reflections from the normal tropospheric stratification may contribute importantly to propagation well beyond the horizon.


This notion follows logically from the important paper by Bremmer. (See (514).)


He showed that for any plane-stratified medium traversed by plane waves there must exist what he called a "scattering coefficient" per unit thickness, which describes the new waves that must be produced by a wave passing obliquely through the medium, thus encountering continuously changing index of refraction of the inhomogeneous stratified medium. Two papers on the subject of reflections from the normal troposphere were presented at the Ithaca meeting of URSI-IRE in October. Interest will probably continue to increase in the study of these persistent, though weak and fading, fields well beyond the horizon, because all three current hypotheses as to their cause (scattering from atmospheric turbulence, rough earth, or tropospheric stratification) seem to imply that the field should be persistent and not so highly variable as the stronger nonoptical fields associated with atmospheric ducts, elevated refracting layers, or scattering from insects.

Scattering from turbulence at the low end of the vhf band is discussed in relation to British measurements in two papers from the National Physical Laboratory.


At 100 mc some experimental observations were interpreted by the University of Texas group in terms of the hypothesis of scattering from turbulence.


Gerks made the following statement on propagation at 412 mc from a high-power transmitter: "For communication grade of service, it appears entirely feasible to operate a 100-mile link with low, directional antennas and about 10 kw of transmitter power with a probability of satisfactory field strength more than 90 per cent of the time."


Direct measurements of fluctuations in the refractive index of the atmosphere at microwave frequencies, using the important new technique of the recording microwave refractometer were reported by Birnbaum.


Air is drawn through holes in the end plates of a microwave cavity, and the frequency difference between two such cavities is measured to deduce the index fluctuations of the air with very small time lag. When coupled with rapid temperature measurements, the microwave refractometer may be used for extremely rapid measurement of the humidity of a small sample of air.


(518) Communications on Pure and Applied Mathematics, Published quarterly by the Institute of Mathematics and Mechanics, New York University, New York, N. Y.; December, 1950; and all issues of vol. 4; 1951.

The subject matter is too recondite to summarize in the space available. Two papers published in 1950 by Booker and Clemmow gave a simplified physical interpretation of such well-known phenomena as diffraction around a straight edge and the Sommerfeld theory of radio propagation over a flat earth.


Broadcasting. Continuing prospective use of uhf frequencies for television broadcasting stimulated work on propagation questions of particular interest to a broadcaster. A committee of the International Radio Consultative Committee reviewed briefly the known answers to the question, "What tropospheric propagation data should be used in determining the geographical separation between television transmitting stations?"

(521) Statement concerning tropospheric wave propagation. Report of U. S. Preparatory Committee for the International Consultative Committee on Radio, Serial 769 (revised); April 3, 1951. Document published by Telecommunications Policy Staff, Department of State.

A report by the Federal Communications Commission collected together data from many sources on the variability of uhf fields within line of sight and derived empirical results of use in frequency allocation.


Velocity of Propagation. Aslakson reported new measurements of the velocity of propagation with improved shoran-type equipment.


He deduces from these and other recent results a provisional recommended value of the velocity of propagation of electromagnetic waves in vacuo of 299,793.1 km a value 17.1 km higher than that widely accepted before World War II from optical measurements alone. The relation of this new value to the interrelated "best" values of other constants of atomic physics was indicated.


International Activities. Part 1 of the proceedings of the 1950 general assembly of the International Scientific Radio Union was published. It contains a bibliography and brief reviews of work done in many branches of scientific radio, especially in some of the smaller countries, whose contributions appear only infrequently in the widely circulated journals of the larger countries.

(526) Proceedings of the General Assembly held in Zurich, International Scientific Radio Union, 42 rue des Minimes, Brussels; September 11-22, 1950. (Copies may be purchased from the secretary of the United States National Committee of the Union, Dr. A. H. Waynick, Pennsylvania State College, State College, Pa., at $4.60.)

Radio Astronomy

Solar Radio Waves. Measurements of solar radio emission throughout the radio-frequency band were used to obtain a re-evaluation of the temperature-height distribution in the solar atmosphere. The extension of the measurements to 3.5 × 10^10 cycles (8 mm) contributed to this determination.


Studies were made of the variation of the radiation from the quiet sun over several years, and a distinct decrease was observed on the 3,000-, 2,800-, 1,200-, and 600-mc frequencies. The distribution of radio emission on the solar disk was studied at 81 mc.


Measurements of the polarization of radio waves from the sun on 600 mc during the partial eclipse of November 1, 1948 were interpreted as setting an upper limit of 11 gauss to the general magnetic field of the sun.


A major contribution was the development of a means of rapidly scanning the intensity of solar radio waves over a large frequency range. By its use, frequency-time variation of wave intensity over a frequency range from 70 to 130 mc was obtained.


The solar eclipse of September 12, 1950 was observed at frequencies of 10,000, 3,000, 480, 200, 100, and 60 mc. Measurements made on the eclipse of April 28, 1949 were analyzed.


(541) M. Laffineur, R. Michelard, R. Servajean, and J. L. Steinberg, "Observations radioélectriques de l' Eclipse de soleil du 28
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An instrument was developed by Payne-Scott and Little that determines automatically the place of origin and polarization of a burst at 100 mc.


The further observational studies of solar activity were paralleled by advances in theoretical analysis.


(550) A. Maxwell, "Radio emission from the sunspot of central meridian passage 1950 June 14," Observatory, vol. 71, pp. 72-74; April, 1951.


Galactic Radio Waves. The number of known discrete sources of radio emission in the galaxy was increased and the determinations of the positions of the more intense sources improved. A search for long-period variations of intensity yielded negative results. The effects of the ionosphere on radiation from point sources was studied further. Observations of the point source in Taurus (Crab Nebula) indicated the intensity of radiation to be independent of frequency whereas several other discrete sources show an intensity decrease with increase of frequency.

The distribution of radio-frequency radiation from the galaxy on a frequency of 200 mc has been reported by observers from both hemispheres.


Models of the galactic structure have been based on the measured distributions of radio-frequency radiation for the galaxy. Attempts have been made to relate the origin of galactic radio-frequency emission to that of cosmic rays.

Galactic radio emission from the hyperfine structure line of hydrogen at 1,420 mc has been observed on three continents. The motion of these interstellar hydrogen clouds has been observed by the Doppler shift.


Antennas, Waveguides, and Transmission Lines

Surface-wave propagation continued to receive attention in the literature.


Rectangular and circular waveguides having two dielectrics were treated theoretically.


A tunable waveguide filter was described that has a symmetrical pass-band response.


A mathematical analysis of waveguide junctions and an approximate theory of the directional coupler were given.


Two quite different types of delay lines were described.


A marked reduction of skin-effect losses in transmission lines appears possible by proper lamination of the conductors.


A general formula for the radiation resistance of a two-wire line was derived in one paper, and measured results on a resonant quarter-wave section were given in another paper.


Several papers appeared covering various aspects of transmission-line theory and measurement.


A number of reports on the antenna investigations of the Crurl Laboratory Group appeared.


Industrial Electronics

Professional Growth

Several books were published by industrial engineers and by professors engaged in training students in engineering and applied physics.


The first four of these are valuable for textbook purposes, while the other two are primarily suited for direct applications in the respective fields. The academic growth of industrial electronics is evidenced by the fact that many schools and universities offer courses on this subject. Also, a Professional Group on Industrial Electronics was established by the Institute during the year.

Radio-Frequency Heating

During the past three years, four books appeared on induction and dielectric heating, presenting the technical basis of these applications of radio-frequency heating.


The impedances encountered in radio-frequency heating are frequently outside the ranges covered by commercial measuring equipment, and an extension of these ranges was discussed.


Several specific problems in which energy absorption is a function of thickness in an alternating field were treated.

A review of the 1950 literature on dielectric heating was published, and includes work on dielectrics of considerable importance to those engaged in insulation applications. Industrial insulation and dielectric problems were presented at a conference on electrical insulation.


Special Applications

Progress was made in special instrumentation for determining the internal friction of materials vibrating at frequencies from 50 to 10,000 cycles. Industrial applications continued to use television and several physical processes, such as nuclear resonance, for measuring and controlling magnetic fields, mass spectrometer, controls, and the like. Television has increased the demand for nonconducting magnetic materials. Considerable effort went into establishing suitable measuring methods and equipment. Open-circuit-transformer voltage measurements for circuits easily applied to the specimens are used for evaluation.


Magnetic Amplifiers

By using magnetic amplifiers, signals up to 20 mc and higher were amplified successfully, and operation at signal levels of 10^-12 watt and less was reported. The input impedance can be as high as 100,000 ohms and gain-time-constant ratios of more than 10^8 per second were achieved. Most of these performances were obtained under carefully controlled laboratory conditions, and may be taken as upper limits at this time. There are, however, many applications where more conservative figures would satisfy a given need.

A particularly useful and complete bibliography on magnetic amplifiers and devices covering about 90 patents and over 900 papers, published from 1903 to early 1951, appeared.

In view of the completeness of this work, no references prior to May, 1951 are listed here. Several articles were published on the theoretical aspects of magnetic amplifiers.


The Pipps' paper considers the saturable reactor without feedback, using the methods of nonlinear mechanics. Definitions are proposed for the "time constant" of such a nonlinear device, and the dependence of the time constant on the initial conditions is pointed out.


A theoretical analysis was made of the amplifier with feedback, and the relation of gain and time response was stated. A number of circuits were included and applications of magnetic amplifiers in servo systems shown. A listing of the comparative advantages of magnetic and electronic amplifiers pointed out the limitations of each.

(623) "Magnetic Amplifiers, a Rising Star in Naval Electronics," Pamphlet NavShips 900,172, Electronics Design and Development Division, Navy Department, Bureau of Ships, Washington 25, D. C.

The history and many applications of magnetic amplifiers are presented in a descriptive booklet. It includes a representative list of manufacturers of magnetic amplifiers and components and a bibliography of over 800 patents and papers, from 624 B.C. to about July, 1951.

The increased implementation of electronic principles in commerce and industry is evident by the greater attention given such courses in engineering colleges. A survey of 90 accredited engineering schools at the college or university level, with at least one school in each state of the union reporting, was completed. The field was assumed to include electronic instrumentation, electronic control, and electronic power, including both high-frequency heating and rectification.

Approximately half of the schools reporting offer an electrical-engineering course at the senior and graduate levels that treats all three topics: instrumentation, control, and power. Somewhat less than half of these schools place these courses on the required list, and in practically every case industrial electronics is preceded by a course in basic electronics.

About 30 per cent of the other schools attempt to cover relevant topics in other courses.

The amount of "servo" theory included in courses in industrial electronics varies widely. About 65 per cent of the courses include some of the theory, and in about 10 per cent of the schools, a separate course in servo theory is available to seniors. Employers seem to attach considerable importance to the combination of electronics and servomechanisms.

Electronic Computers

Analog Computers

Analog computing techniques, applied to a very wide variety of new problems, both in direct computing and
in control systems, have received increased general acceptance, particularly by the aircraft industry. A number of new analog computing projects (estimate 30 to 50) were initiated during the year. New techniques are being produced at a high rate. The increasing complexity of problems handled continues to tax both the available equipment and personnel to the utmost. Typical developments and applications are illustrated by the following selected list of references:


(631) "Inexpensive analog computer developed by the Boeing Airplane Co.," Electronics, vol. 24, p. 124; February, 1951.


Digital Computers

1951 started the period which computer designers have long been heralding: the time when their machines would begin to be applied to the management and control of certain industrial and governmental operations, following a gradual building up to this event with the widespread business and governmental use of electronic calculators like the IBM 604 and CPC (even with their lack of flexibility of a stored program). This year, the first UNIVAC was delivered and set to work full time on certain aspects of the 1950 census.

To some, the most interesting features of the year have been the many papers and discussions of the application of already existing machines. For example:


As of this year, the time has passed when the well-informed general-purpose expert in this field could be expected to have a fairly good picture of every important projected large-scale computer that had been described in public. For some of the new machines which were described in 1951, see the following references:


The most important engineering problem continues to be that of how to make the memory. There has been considerable progress in the understanding of electrostatic memory although not much has appeared in

print and not many mathematicians who want to use calculators have felt the impact of this progress.


The I.R.E. Technical Committee published a glossary this year, and a Professional Group on Electronic Computers was formed.

Quality Control

Considerable activity in general quality control and in applying associated statistical techniques to industrial problems, including those associated with the radio and electronic arts, was evident. The rearmament program intensified the need for better quality, not only at lower cost but also with less waste, scrap, shrinkage, and loss of time.

Such objectives can be attained through the application of quality-control principles, both in the design and production of military electronic equipment. Papers relating specifically to design include those of Farrell and Lutzcker, while many of the others apply equally well to both objectives.


(651) L. G. Hector, “Quality Control in the Plant of Sonotone Corporation,” Presented, Conference on Quality Control, Rutgers University, New Brunswick, N. J.; September 15, 1951.


Instrumentation

Audio-Frequency Measurements

Measurements of the amplitude and phase of the motion of some dynamic loudspeaker cones, explored by a capsule-probe technique, show the break-up of the cone motion when the frequency of the driving force is in the vicinity of a natural mode. This technique aids in determining how these modes should be damped to produce a more uniform response from the speaker system.


An automatic procedure for determining harmonic distortion as a function of frequency was set up and applied to the measurement of distortion in loudspeakers. Automatic techniques are necessary because of the rapid variations in distortion with frequency.


Problems relating to the measurement of intermodulation were explored further by distortion measurements on a hearing aid, showing the necessity of considering the over-all system and the need for versatile measuring equipment for making the various intermodulation tests.


A study of the effects of peak clipping, center clipping, linear rectification, and parabolic rectification on the intelligibility of speech showed that no satisfactory correlation is obtained between the results of harmonic-distortion tests on the nonlinear systems and the corresponding speech intelligibility.


A method of calculating loudness of noise from the measured sound-pressure level in frequency bands investigated recently (a modification of some earlier proposals) gave results that agree well with presently available subjective data.


A compact, novel warble-tone source for acoustic measurements was described. The desired logarithmic variation of frequency with dial setting was obtained by using a capacitor-type piston attenuator as part of an electronic reactance circuit. The desired warble limits were then obtained by varying the gain in the reactance circuit.


A comprehensive study of the data available on the effects of high noise levels on hearing has led to tentative criteria for use in noise studies. For long-time exposures, the suggested level in a critical band, above which damage to hearing may occur, is 85 dB above the standard reference level. This level is probably appreciably too low for low-frequency sounds, and further studies are in progress. For the first time, however, this study has made available a reference that can be used in interpreting objective measurements of noise levels in the audio range, and it has pointed up the need for more extensive use of frequency analysis of high-level sounds in conjunction with audiometric data.


Another study has led to criteria for acceptable noise levels in various types of offices. The measurements used as the basis for rating these noise levels are the three-octave-band levels in the range from 600 to 4,800 cycles.

Audio-frequency measuring techniques were applied in a number of novel ways to extend the already large number of applications to the measurement of non-electrical quantities, for example, volume, speed, and structural defects.


Video-Frequency Measurements

It was reported that the amplitude and phase characteristics of a linear video network may be determined from square-wave data obtained experimentally. A simple accurate method uses tables prepared on the assumption that the square-wave or step-wave response can be simulated by a finite number of sine x/x functions.


AC Bridges should be checked occasionally with secondary standards. The construction of such standards was discussed in two papers.


Radio-Telemetry Systems and Techniques

The increase in the application of radio telemetry in the dual fields of defense and industry was rapid and most varied. Leading the way is the well-known FM/FM system that remains the only standardized type of radio telemetering although the Research Development Board is considering other systems.

From the system point of view, more complete analysis was made of the several characteristics that determine the suitability of a particular system for a given application. These studies included a review of phase and amplitude distortion, bandwidth, and information response limitations, and space and weight considerations, while maintaining specified accuracy and near-to-perfect reliability. The basic standards of frequency response and commutated signal rates set up by the Research Development Board were widely adopted, and proved of great value in the design of many installations for special applications where it was essential to provide the minimum of equipment consistent with realizing the test objectives.

Pulse systems are used to a lesser degree. One type has proved very successful, especially for very confined installations involving a considerable number of relatively low-frequency information channels. In a program sponsored by the Bureau of Aeronautics, a pulse-position-modulation system was developed that multiplexes up to 50,000 samples per second.

For airborne applications, the more exacting pulse-code-modulation system has not yet been reduced to a practical size, but it should find considerable utilization for ground-based telemetering links, and where space is not at a premium.

Radio-Frequency Transmitters. The increasing congestion of radio links operating within the narrow bands permitted by the Federal Communications Commission led to an intensive development of a crystal-controlled FM radio transmitter. A number of prototypes are emerging, and one or two will shortly be in production for special programs. The use of more rugged vacuum tubes, both miniature and subminiature types, was incorporated in recent transmitter circuits, as has been the practice for many airborne electronic component sub-assemblies.

Subcarrier Oscillators and Other General-Purpose Airborne Units. Improved types of voltage-controlled, bridge-controlled, and inductance-controlled oscillators were developed by several organizations. Greater stability and resistance to extreme physical conditions are the outstanding characteristics of these and other general-purpose units, such as amplifiers, phase-shift rectifiers, voltage compressors, and limiters. The use of series filament connections operating from a 28-volt dc supply and of ac-heated filaments were also adopted for certain projects.

Pickups. The trend away from variable-inductance pickups toward potentiometer types continued. The latter were redesigned to improve their stability and reliability, and some units promise to achieve the same standards in these qualities as were accepted for inductance pickups in the past. The strain-gage type of pickup has also received considerable attention, and is still employed in a number of programs. Its use might be extended if the new bridge-controlled oscillators prove as reliable as the voltage-controlled oscillator.

Receiving-Station Equipment. Although not so vital to frequency modulation at present as the crystal-controlled transmitter, the crystal-controlled FM receiver is the subject of considerable thought and some development effort. The existing receivers were improved and their range extended. Some progress was made in an effort to reduce the over-all dimensions of receiving-station equipment.

New types of band-pass and low-pass filters of the balanced type were designed. A method was devised for driving an oscilloscope from a balanced output without having the instrument case above ground and for improving the stability of its zero when recording dc data.

In the field of recording, the problem of a primary magnetic-tape recorder for telemetering signals is believed to have been solved by a novel drive technique. Other groups designed circuits to reduce wow and flutter to negligible proportions for magnetic-tape recordings. Systems were developed to place timing or other pulses on the tape along with the signals and a calibration frequency. New and improved models of well-known mag-
netic galvanometers and the electric pen recorder are recent innovations. The advantages of the Polaroid-Land camera were utilized for some systems. The availability of ozalid transparencies has greatly simplified the reproduction of the original film recordings from various types of recorders.

Two approaches were made to the problem of analyzing large quantities of FM film recordings. Each will produce calibrated and zero-corrected functions versus time records. Both designs employ a mechanical-optical flying-spot scanner; but one design uses digital electronic circuits, prints the continuous data trace on film, and accompanies the trace with specific function values printed at a variable interval along the film chart. The other employs analog techniques throughout and delivers finished inked function-versus-time records, calibrated and zero-corrected in both axes. It also provides an output to operate an IBM typewriter. Both units achieve line-centering by different ingenious electronic circuits.


Vacuum Tubes

Paralleling the improvement in picture tubes for television, the performance of the oscillographic type of cathode-ray tubes was improved in deflection sensitivity, optical quality of face, and screen characteristics. A method of minimizing deflection defocusing by use of an auxiliary focus electrode was described.

Multiband cathode-ray tubes, capable of writing speeds in the uhf range of more than 3,000 inches per microsecond, were developed. A number of methods for obtaining deflection in traveling-wave cathode-ray tubes were described. Better methods of exciting phosphors by electroluminescence and improved phosphors for the purpose were developed.


Instruments. The design of instruments using distributed amplifiers was improved and their frequency ranges and gain extended. Sweep circuits suitable for generating writing rates as high as 400 inches per microsecond were developed.

A device to plot any set of data on a cathode-ray tube together with linear or nonlinear co-ordinate scales was described. An oscillograph for plotting transients of more than 30 seconds in duration was developed.


Tubes. A new type of storage tube having an extended plane cathode and two orthogonal grids capable of permitting emission from only a single small cathode area was developed, and its use for binary storage described.

An approximate analysis of the surface potentials and charging currents in cathode-ray tubes as functions of beam current, writing speed, and initial potentials was made, and results checked experimentally.

Fig. 20—This televised view of nucleated red cells, in which the cells have been magnified 2,200 times, demonstrates the use in microscopy of television-camera tubes made sensitive to specific wave-lengths of light. At the left, the cells are viewed in the violet end of the spectrum; at the right, the same cells are seen with the aid of a red-sensitized vidicon tube (RCA).

A special cathode-ray tube with hollow cathode was constructed to enable isolation and measurement of the positive ions causing cathode deterioration. The tube was used on an ion spectograph.

A number of ingenious methods of preparing direct-viewing, dot-sequential and line-sequential color tubes were developed.


Applications. Iconoscopes and image tubes were used as high-speed shutters for photographic purposes. Oscillographs were used to measure dielectric polarization under transient conditions.


Books. That oscillography is a field in which sufficient work has been done to require separate texts of its own can be seen from the encyclopedic character of the books
published dealing specifically with cathode-ray oscillography.


**Dielectrics**

There are three simple measurable properties of dielectric materials that are commonly utilized in practice: dielectric constant, power factor, and dielectric strength. Information on these properties has become increasingly important not only to designers and manufacturers of electronic equipment but also to the scientist who is studying molecular structure.

The Conference on Electrical Insulation, sponsored by the Division of Engineering and Industrial Research of the National Research Council, has an annual meeting of research workers who present papers and exchange information on research activities in the several scientific and technical fields of dielectrics and insulation. The Conference publishes each year an Annual Report that abstracts the papers and reviews the activities of the Conference for that year.

In addition, it publishes each year a comprehensive Digest of Literature on Dielectrics, in which are contained reviews prepared by authorities in the respective fields of dielectrics. These reviews consist of brief but explicit and interesting statements of developments and results. Numerous references are provided for those desiring further details.

At the 20th Annual (1951) Conference on Electrical Insulation were symposia on dielectric measurements, insulation applications, and dielectric properties of matter, as well as several round-table discussions on these topics. The sessions on measurements indicated considerable interest in evaluating the resistance of high-quality insulating materials. A direct method for measuring the dielectric properties of gases was described having a sensitivity of one part in 10^6, which determines the dielectric susceptibility of gases to four significant figures. In contrast to the usual beat-frequency method, which gives dielectric constant only, it can also be used to determine absorptions in gases, using a frequency range of around one mc.

The formation of films on metals in hydrocarbons subjected to dielectric stresses was another topic of interest to those using conductors in fluids. A soaplike deposit is formed. The rate and thickness is dependent upon the dielectric stress.

A sharper emphasis was placed on standardizing measuring techniques and test conditions so that the complex dielectric constant can be determined. The real component is a measure of the dielectric constant and the imaginary component, the loss factor. The National Bureau of Standards reported an RF dielectrics measurements service in the frequency range from 10 kc to approximately 600 mc for solid dielectric specimens and a limited calibration service for gases and liquids. Temperature and humidity are other parameters that are available at some frequencies.

Complete information on any dielectric material requires measuring equipment capable of furnishing data over the frequency range from zero to 300,000 mc. Other factors that frequently require consideration are temperature, pressure, field strength, and the geometry of the specimen. It is now possible to obtain results over this frequency spectrum, although not without some difficulty in certain regions. From about one cycle to several megacycles, bridges produce the most accurate results. Below one cycle, recourse is had to current-time curves. From approximately one to 600 mc the resonance method is preferred. From 100 kc to 30 mc the resonance method competes with the bridges; above 100 mc the resonance apparatus becomes a cavity. At frequencies above 300 mc the lumped parameters are replaced by distributed parameters in coaxial lines, waveguides, or cavities, and standing-wave patterns or resonance curves become the means for evaluation. These various schemes are under study in the process of establishing suitable standards.

Progress continued in general and theoretical research on dielectrics. Microwave spectroscopy continued its spectacular advance in providing accurate dipole moments and molecular parameters. Measurements of the dielectric constant and loss of polar and nonpolar liquids at microwave frequencies were abundant, and several well-known gases were evaluated with increased accuracy at microwave frequencies.

In the field of solid dielectrics, great interest was shown in the conduction processes of ionic crystals, and the theory of the static dielectric constant of ionic crystals became better understood. Many investigations were made of the dielectric properties of ferroelectrics, semiconductors, ceramics (barium titanate in particular), oxide films, and many other compositions of interest in the theoretical and practical applications of dielectrics.

**Magnetics**

Ferromagnetic ferrites and magnetic amplifiers shared wide interest and discussion, and were the subjects of many papers and several symposia. In the field of theoretical magnetism, articles on antiferromagnetism and domain-wall motion reported the steady advance in charting the mechanisms of magnetic behavior. Magnetic measurements served a varied and essential role in linking theory, development, and application.

The development and use of ferrites continued as engineers studied and evaluated the design advantages and limitations of these unique ferromagnetic nonmetals. For certain applications, they advantageously fill the gap between solid metals and powders. In many fields, particularly carrier and higher frequencies, they offer combinations of properties and design possibilities not otherwise available. Components for which ferrites are being used or explored include radio and television
coils and transformers, filter and loading coils, radio-antenna rods, high-frequency magnetic amplifiers, recording heads, concentrators for high-frequency heating, pulse transformers and harmonic generators, miniature components, magnetostriictive oscillators, and parts for small machines and measuring instruments.

The resonance-type behavior of permeability and magnetic loss associated with frequency and dimensions, as well as the dielectric properties of the materials, are undergoing intensive study and measurements from the standpoint of understanding the basic mechanisms and of utilizing the effects in high-frequency attenuators or waveguide components. The concept of complex permeability is being widely used in theory and analysis of measurement data.


The year was a period of consolidation for the magnetic amplifier. The applications of the well-known, self-saturating and self-excited circuits were extended greatly. A basically new magnetic-amplifier circuit was proposed in Paper 51-217 of the American Institute of Electrical Engineers which promises superior performance in certain types of systems. First steps were taken toward setting up standards and ratings of magnetic amplifiers, and attempts were made to develop a simple engineering approach toward the design and selection of magnetic amplifiers for specific applications.


Work has continued on the measurement and application of magnetic powder cores. The Metal Powder Association issued a tentative Preferred Iron Core Dimensional Specification 11-517, March, 1951, and a Data Sheet, June 1, 1951.

The March, 1951 issue of the *Journal de Physique et le Radium* contains 49 papers presented at the International Symposium on Ferromagnetism and Antiferromagnetism in Grenoble in 1950. These articles present a broad and comprehensive sweep of modern magnetics. A book by Bozorth on ferromagnetism, published in 1951, is a complete, well-organized, and up-to-date treatment of the subject.


(704) H. Wilde, “Measurements of iron-core coils at frequencies between one cycle and one megacycle,” *Arch. Tech.*, vol. 180, pp. T39–T40; April, 1951. (In German.)


### Nuclear Instrumentation

Advances in radiation-measuring instruments for health protection (including civil defense) were primarily in the form of practical improvements. The reliability of many types of instruments was increased, the power consumption lowered, and the weight and size reduced. Few new principles were employed.


There was a gradual increase in the industrial application of nucleonics. This includes a wider use of radioactive-tracer techniques for the solution of various
In the field of nuclear science, many advances were made in measuring techniques, the more important being the further exploration of the capabilities of the scintillation counter. This made possible both time and energy measurements that were beyond the range of earlier instruments. Measurements of high-energy particles both from cosmic rays and from machines by means of scintillation counters received particular attention.

**Piezoelectricity**

Highly significant advancement was noted in the field of piezoelectricity during the year. The controlled growth of piezoelectric crystals in sizes suitable for commercial and military use is now an accomplished fact. His success in growing quartz and other crystals, outlined in several excellent papers describing these developments in the Bell Telephone Laboratories, won for Walker, during the year, the Louis Edward Levy Medal of the Franklin Institute. The basic method is essentially that which Hale and the Brush Development Company found to give startling growths in 1947. The value of the exchange of information among technical groups is thus illustrated.

Essential features of the methods now in use are: (1) the use of crystalline quartz as the nutrient source for replenishing the solution, (2) the placement of this source at the higher-temperature base of the vertical autoclave, (3) the use of the natural thermal circulation of the solution to transport the quartz to the somewhat cooler seeds situated higher up in the autoclave, and (4) the provision that the alkaline solution fill the autoclave to 80 per cent of capacity before sealing and heating to above the critical temperature of water (approximately 450 degrees C). Earlier difficulties, which resulted in choking off the growth during the first day or so, are thus eliminated. Use has sometimes been made of a replaceable steel inner tube in the autoclave.

Yields from a single autoclave in a month's run have been described by Walker and Buehler, producing several crystals weighing, in all, one pound, with the largest one over three-fourths pound. Sustained growth rates are achieved of up to 0.10 inch per day. Somewhat larger yields but slower growth rates have been reported by the Brush Development Company, using a somewhat different technique, with yields running up to 7 pounds per autoclave, with the largest crystal weighing one pound. Larger autoclaves now under construction and yields running several times greater should follow.

In England, work is reported in which the direction of extension of the Z-cut seeds by the deposit is along the optic (Z-) axis, and amounts to 14 mm added as the total extension. In contrast, deposits in the United States build upon the minor rhombohedral faces, which are essentially the faces of the seed plates used here. It appears that between the synthetic quartz and the natural crystal no differences are found in refractive indices or in X-ray diffraction data, and the oscillator performance of the synthetic material is in no way inferior to that of the natural.

Other reports in the quartz growth and crystallographic fields include studies on optimum conditions of hydrothermal conversion of quartz, with the development of a theory to account for the transfer and several papers on twinning and detwining of quartz-type structures. One of the latter introduces the term "piezo-crescence" for the transformation, by pressure, of one crystal orientation into another, which, under the applied pressure, is favored from the principle of least potential. In another paper, the X-ray irradiation of quartz, which, as is well known, modifies its elastic properties as well as its color, is the subject of further study.

**Ferroelectricity**

Active search has continued for the essential structural factors that are responsible for the ferroelectric property. A strong case is presented for the role of an oxygen octahedron surrounding a metal atom as such
A number of new ferroelectric crystals have been found and the properties of many determined. None of these shows more than a single Curie point; this leaves Rochelle salt as apparently something of a freak of nature since it has lower temperature limit to its ferroelectric region. In about sixty articles published in this field, current interest was centered largely in the contribution that studies of the ferroelectric property may make to solid-state physics rather than in a search for immediate engineering applications (except possibly in the barium titanate ceramics).

The properties of both single crystals and multocrystalline ceramic aggregates were studied. The parallelism between ferroelectricity and ferromagnetism was further emphasized as the studies of the motion of the domain boundaries in the former are carried on while magnetic domain walls are similarly followed. Also, antiferroelectricity, as well as antiferromagnetism, received attention. A phenomenological theory of barium titanate, proposed in 1949, has not been extended to give expressions for piezoelectric, dielectric, and elastic constants in terms of other physical constants of the material. Japanese workers show lead zirconate to be very weakly ferroelectric along one axis and strongly antiferroelectric at right angles to this.


Among the more practical papers (as distinguished from those dealing with fundamental physics) are some on the ageing of ferroelectric ceramics, on methods of synthesizing the materials and of removing twinning, and on the applications of ceramic transducers. One report describes the development of a ceramically driven cutting tool that provides amplitudes of motion of the tool of 1.5 mils at a frequency of 18 kc.


Ultrasonics

Only that part of the field of ultrasonics that is primarily concerned with the design and performance of the source or of the pick-up lies strictly within the scope of a review on piezoelectricity. Among such papers may be noted the description of a variable-frequency resonance system for generating waves.

(741) W. J. Fry, R. Fry and W. Hall, "Variable resonant frequency
Several contributions to the broader field of ultrasonics itself should be noted, several papers (not here listed) relate to ultrasonic absorption, and it was shown that progress is being made on the location of changes in tissue structure deep within the human body by absorption and/or reflection. A basic paper on current methods of measuring wave velocity is listed. The application of quartz transducers to measure the complex propagation constants of materials has resulted in a beautiful study of ultrasonic transmission in polycrystalline solids, and in the determination of the elastic and thermal or piezoelectric constants of some single crystals. Elastic constants of zineblende by an X-ray method are reported from England. Although not in its present form an application of piezoelectricity, the design of an ultrasonic soldering iron with a magnetostriuctive drive suggests, in view of the large amplitudes that have been noted above for a ceramic transducer, a possible application for piezoelectricity. Cavitation in the molten solder in contact with the metal face tears the oxide film from the metal so that alloying can occur, a technique that is said to be suitable for tinning aluminum. The sound pattern of an X-cut quartz crystal with the theoretically interesting Straubel contour has been found to be much more uniform in front of the face of the crystal than that produced by a square crystal.

Extensions of the measurement of elastic and piezoelectric constants of quartz to high temperatures were made available, on the one hand, for determining the angles of cut which produce the lowest coefficient of temperature when operating and, on the other hand, for obtaining information gathered from a study of the transition from alpha to beta quartz. The current status of test oscillators for checking resonator performance and measurements of the characteristics of crystal units themselves are authoritatively given in two papers. There is a further study of the suppression of overtones by electrode geometry. A capacitance bridge for the megacycle range is described in which the unbalanced electromotive forces are rectified by a germanium rectifier. The bridge is particularly suitable for examining vibrational modes and measuring the Q of piezoelectric resonators or transducers. A German text on crystal-filter circuits, which appeared two years ago, deals with the laws and principles of filter design, equivalent circuits for the crystals themselves, and examples of filters adjustment and measurement.
Symbols and Abbreviations

Several standards on symbols, reference designations for use with graphical symbols, and abbreviations of electrical terms were published during 1951:


ACKNOWLEDGEMENT

Each year the Annual Report is the work of many reviewers, each of whom are given an assignment in the particular field in which he is an expert. These assignments are made by the Standards Committee of the Institute, and thus cover all the technical committees. The individual reports are assembled and correlated into a single review by the editorial board of the Annual Review Committee, which, for the year 1951, was composed of the following persons:

R. R. Batch, Chairman
T. H. Clark
J. D. Crawford
G. L. Van Deussen

This group also arranged for the illustrations, included for the first time.

The individual section reports were prepared by the following contributors:


Audio Techniques: H. W. Angstadt

Sound Recording and Reproducing: H. E. Roys

Electroacoustics: V. Salmon

Information Theory and Modulation Systems: W. G. Tuller

Circuit Theory: W. R. Bennett, R. L. Dietzold, W. H. Huggins, and W. A. Lynch


Receivers: L. M. Harris

Video Techniques: W. J. Poch


Facsimile: J. H. Hackenberg

Vehicular Communications: N. Monk

Navigation Aids: H. Davis

Wave Propagation: C. R. Burrows, T. J. Carroll, M. G. Morgan, and H. W. Wells


Industrial Electronics: J. M. Cage, J. L. Dalle, and C. F. Spitzer


Quality Control: J. R. Steen


Piezoelectricity: K. S. Van Dyke

Standards: H. R. Terhune


Two crystal-controlled transmitters were described, and a crystal discriminator was designed for a television sound transmitter. An analysis of feedback oscillator theory dealt with a particular crystal oscillator circuit as its illustration.

A report was given of a series of researches into the use of crystal resonators for indicating atmospheric temperature, pressure, and humidity through changes in their resonance properties. Instruments are produced for recording meteorological quantities piezoelectrically. A series of papers described the current status of techniques of manufacturing quartz oscillator plates and the instruments that are used in the several stages of this process.


The Chairman's address to the Radio Section of the Institute of Electrical Engineering for the current year traces the history of the tightening demands on frequency tolerances and of the progress of the crystal art in making such tolerances practicable. He suggests that within a few years "quartz clocks may become available with annual frequency ageing rates of less than one part in 10⁸ and capable of continuous operation for a period of several years." The current British Post Office quartz rings of the Essen type show considerably less ageing after manufacture than do GT-cut plates. Another paper gives the history and present status of American frequency standards at the National Bureau of Standards.
Fundamental Considerations Regarding the Use of Relative Magnitudes

J. W. HORTON†, FELLOW, IRE

Which two values of power are meant when a standing-wave ratio is expressed in decibels? Which two values of power are meant when a television signal-noise ratio is expressed in decibels? Which two values of power are meant when the contrast range of a picture is expressed in decibels? Can you figure out what is meant when the statistical variance of a quantity, no matter what it is, is expressed in decibels? In short, have you noticed the meaning of decibel is being extended to a point of real ambiguity?

The Standards Committee of the Institute finds it so. The practice is so widespread that it is guardedly admitted in standard definitions, including some recently published by IRE.† Such official concession confuses rather than clarifies the issue.

In the following paper, Dr. Horton does something about it. He proposes that we put a stop to loose use of the decibel, and he shows one way to do it by describing what seems to be a reasonable alternative. The Standards Committee of IRE has recommended publication of Dr. Horton's paper to stimulate thought and to provoke criticism. We invite written comments. Write the Technical Secretary, The Institute of Radio Engineers, 1 East 79 Street, New York 21, N. Y.—Standards Committee of the I. R. E.

Summary—In order to facilitate the use of relative magnitudes, the convenience of which for certain purposes has been demonstrated by the decibel, an examination is made of the fundamental relations applying to such quantities. Relative magnitudes are defined as quantities changes in which are expressed as ratios, which combine by multiplication, as distinguished from absolute magnitudes changes in which are expressed as differences, which combine by addition. It is shown that there are two number systems, conforming concurrently to the decimal system, by which relative magnitudes may be evaluated, and that the quantity $10^3$ is the basic elementary number by which these two systems are related. The role of this number in computations with relative magnitudes is, in some respects, analogous to the role of the unit in computations with absolute magnitudes. It is suggested that the word “log” is an appropriate designation for this quantity. Methods of employing this quantity, and the advantages of so doing, are discussed briefly.

THERE ARE many problems in which quantities are more conveniently expressed as relative magnitudes than as absolute magnitudes. There are, in fact, situations in which relative magnitudes are of primary significance while absolute magnitudes are both unknown and irrelevant. These are so often encountered when dealing with energy-transmission systems that transmission losses of standard magnitude are commonly identified with standard relative powers or standard relative voltages. The standard relative power identified with the decibel has proved to be of exceptional utility. This has led, not infrequently, to proposals that the decibel be used for the evaluation of physical quantities other than power. It has even been suggested that it be used for the measurement of intervals on the frequency spectrum. The objective, of course, is to express such quantities as relative magnitudes. To use the term “decibel” for any relative magnitude other than a relative power would, however, sadly confuse the general with the specific. It would be quite improper to call a standard relative frequency a “decibel,” the name universally identified with a standard relative power, as it would be to call a standard absolute frequency a “watt,” the name universally identified with a standard absolute power.

It must be understood that restrictions on the use of the decibel do not in any way impose restrictions on the use of relative magnitudes. The point which must be emphasized, however, is that when relative magnitudes are used with quantities other than power, or simply as generalized quantities, they must, in each case, be given distinctive and specific designations. The need for unambiguous terminology is no less urgent when dealing with relative magnitudes than when dealing with absolute magnitudes.

GENERAL RELATIONS

The fundamental distinction between relative and absolute magnitudes is that changes in relative magnitude are expressed as ratios whereas changes in absolute magnitude are expressed as differences. As a consequence of this, changes in relative magnitude combine by multiplication whereas changes in absolute magnitude combine by addition.

Absolute magnitudes may be represented graphically by a scale formed by laying off a succession of equal intervals, each corresponding to a standard change in absolute magnitude, or standard difference. These intervals, and their subdivisions, are usually numbered in accordance with the decimal system, although unfortunate examples are to be found in foot rules and other archaic scales. Interval numbers are conventionally associated with the final boundaries of their respective increments of length. Each numerical value thus indicates the number of intervals between the point with which it is identified and the beginning of the scale. The initial boundary is consequently numbered zero, to indicate that no interval has yet been laid off.

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* Decimal classification: R030. Original manuscript received by the Institute, July 19, 1951; revised manuscript received January 2, 1952.
† U. S. Navy Underwater Sound Laboratory, Fort Trumbull, New London, Conn.
1 S1 IRE 6.51 Standards on Electroacoustics, Definitions of Terms, 1951. See "Sound Pressure Level" and "Velocity Level."
On such a scale the absolute magnitude corresponding to any point is equal to the sum of the standard changes in absolute magnitude represented by the intervals occupying the length between that point and the initial point. This may be expressed symbolically by writing a given absolute magnitude as

\[ A = na. \]  

Here \( n \) is the number of standard changes in absolute magnitude, or standard differences, \( a \), which must be added together to equal the change in absolute magnitude in going from zero absolute magnitude to the given absolute magnitude.

When dealing with absolute magnitudes the standard change is a unit difference. That is, \( a = 1 \), and the given change in absolute magnitude, \( A \), is numerically equal to the number, \( n \), of standard intervals by which it is represented. The absolute-magnitude scale, then, is the same as a scale of values of the quantity \( n \).

Relative magnitudes, also, may be represented graphically by a scale formed by laying off a numbered succession of equal intervals. Each of these intervals corresponds to a standard change in relative magnitude, or standard ratio.

The ratio represented by the total interval between the initial point of this scale and any other point is the ratio between absolute magnitudes identified, either explicitly or implicitly, with these two points. The quantity identified with any given point is thus said to be expressed as a relative magnitude referred to the quantity identified with the initial point. In the case of an absolute-magnitude scale the quantity identified with the initial point is always zero. In the case of a relative-magnitude scale the quantity identified with the initial point is always finite. It is imperative that the nature and value of this finite reference quantity be clearly understood at all times.

On a scale of relative magnitudes the relative magnitude corresponding to any point is the product of the standard changes in relative magnitude represented by the intervals occupying the length between this point and the initial point. This may be represented symbolically by writing a given relative magnitude as

\[ R = r^m. \]  

Here \( m \) is the number of standard changes in relative magnitude, or standard ratios, \( r \), which must be multiplied together to equal the change in relative magnitude in going from the reference quantity to the given relative magnitude.

Boundary points on a scale of relative magnitudes may be marked either with values of the actual ratios, \( R \), which they represent or with values of the index, \( m \), with which these ratios are identified. There are, in other words, two scales which may be used for the graphical representation of relative magnitudes. With these are associated two systems of numbers which may be used for computations in which these quantities appear. The scale of numbers of standard ratios is a linear scale; the values represented by its intervals combine by addition. The scale of actual ratios is an exponential scale; the values represented by its intervals combine by multiplication.

There are computational advantages to expressing changes in relative magnitude in terms of equivalent numbers of standard ratios rather than in terms of actual ratios. Operations which, with the latter, require multiplication or division are performed with the former by addition or subtraction. Involutions and evolutions are similarly replaced by multiplication and division. We are already familiar with this simplification through acquaintance with the decibel.

The initial point on any of the scales which have been described is the point which indicates that no interval, representing a change in value, has yet been laid off. On a linear scale of numbers of standard ratios, as on a scale of absolute magnitudes, this point is identified with the difference zero, this being the quantity which may be added to another without changing its value. On an exponential scale of actual ratios, or actual relative magnitudes, this point is identified with the ratio unity, this being the quantity by which another may be multiplied without changing its value. On a scale of absolute magnitudes this point is known as zero point. For a linear scale of numbers of standard ratios it may be described as zero index point; for an exponential scale of ratio values it would be the unit ratio point.

The quantitative relations between the two number systems which may be used for the evaluation of relative magnitudes are uniquely established by the value of the standard ratio. It is desirable that this value be such that the two systems shall conform concurrently to the decimal system.

To examine these relations, let any given ratio be expressed as some power of a fixed base number and the equivalent number of standard ratios as some multiple of this same base number. That is, let \( R = b^x \) and \( m = yb \).

The standard ratio is then \( r = R^{1/m} = b^{x/y} \). It is thus evident that, for any standard ratio, \( r \), the ratio of the exponent, \( x \), to the coefficient, \( y \), is a constant independent of the value, \( R \), of the given ratio. When the value of the standard ratio is \( r = b^{1/b} \), this constant becomes \( x/y = 1 \). It is, therefore, always possible to find a value for the standard ratio such that when any given ratio is expressed as a power of some fixed base number and the equivalent number of standard ratios as a multiple of this same base number the exponent and the coefficient shall always be equal.

This relation between any given ratio and the equivalent number of standard ratios assumes its most convenient form when the base number is 10, the base of the decimal system. This requires that the standard ratio be given such a value that \( m = k10 \) when \( R = 10^k \), or that its value be

\[ r = R^{1/m} = (10^k)^{1/k} = 10^{k-1}. \]  

(3)
The relation between an exponential scale of ratio values and the corresponding linear scale of numbers of standard ratios having the value \( r = 10^{0.1} \) is shown graphically in Fig. 1. It is seen that the zero index point of the linear scale coincides with the unit ratio point of the exponential scale. It is also seen that 10 standard intervals on the linear scale occupy a length which represents the ratio 10 on the exponential scale. A decade change in the number of standard ratios, in other words, coincides with a decimal change in the actual ratio value.

There are, of course, other standard relative magnitudes than that which is identified with the ratio \( 10^{0.1} \). The octave, identified with the ratio two, is only one of many which are used in specifying changes in relative frequency. Changes in voltage due to attenuation on electrical transmission lines are often expressed in terms of the ratio \( e \), especially in theoretical treatments. Each of these standard relative magnitudes may be represented by a standard interval on a linear number scale. There will, however, be no correspondence on a decimal basis between such a scale and an associated scale of actual relative-magnitude ratios. Moreover, the condition that \( m = k b \) when \( R = b^k \) does not exist for any base number, \( b \), when the standard ratio has a value greater than \( r = e^{1/e} \approx 1.445 \).

A standard relative magnitude cannot be spoken of as a "unit of relative magnitude," even though it may be represented by a scale interval of unit length. Unit relative magnitude, as we have seen, is identified with the initial boundary on a scale of relative magnitudes, and not with an interval of such a scale. The standard relative magnitude based on the decimal system does, nevertheless, bear the same relation to relative-magnitude scales that the unit difference bears to absolute-magnitude scales. Ten of each combine, in accordance with the laws governing their combination, to form a decimal group. In order that this standard ratio may be used as freely and as precisely as the unit difference, it must be given an equally simple and equally definite designation. It is suggested that the term "logit" is suitable for this purpose. This is formed on the Greek root "logos," meaning ratio, and has the same form as the word "unit" to which it is analogous. Using this designation, we would say that a change of 10 in absolute magnitude is the resultant of 10 unit changes and that a change of 10 in relative magnitude is the resultant of 10 logit changes. It is proposed, therefore, that the change in relative magnitude for which the ratio of the final to the initial absolute magnitude is \( 10^{0.1} \) be made a standard change and designated as a logit.

It is, perhaps, not out of place to emphasize that the numerical value \( 10^{0.1} = 1.258925 + \), identified with one logit, is not an arbitrarily chosen value; it is the basic elementary division of a scale of relative magnitudes formed in accordance with the decimal system. As such it is a fundamental mathematical constant, and is no more subject to selection than are values of \( \pi \) or \( e \).

The division points between a succession of logit intervals fall on relative magnitudes which are equal to successive powers of the logit ratio, \( 10^{0.1} \). These values are shown, to five decimal places, in the second column of Table 1. The first column shows the number of logits which combine to give these resultant changes. For relative magnitudes corresponding to subsequent decades on the linear scale of logits the resultant ratio values are obtained from values shown by the table by moving the decimal point one place to the right for each additional decade.

The approximate values of changes in relative magnitude corresponding to successive logit intervals are identical with those of the "10-series" of basic preferred numbers which has been adopted as an American Standard. These are shown in the third column of Table 1.

In selecting preferred numbers it is essential that the change in size thus specified shall be convenient from the practical point of view. It is gratifying that the size of the logit, which is fixed by abstract relations, also coincides with a size which other considerations have shown to be suitable for adoption as a practical standard. It has, of course, been recognized that the logit has the same value as the power ratio identified with the decibel. The practical suitability of the size of the decibel has already been well established.

<table>
<thead>
<tr>
<th>Number of logits</th>
<th>Resultant ratio</th>
<th>Approximate ratio</th>
<th>Error in approximation logits</th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td>1.00000</td>
<td>1</td>
<td>0.00</td>
</tr>
<tr>
<td>1</td>
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<td>1.90526</td>
<td>2</td>
<td>0.01</td>
</tr>
<tr>
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<td>2.5</td>
<td>0.02</td>
</tr>
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</tr>
<tr>
<td>7</td>
<td>5.01188</td>
<td>5</td>
<td>0.01</td>
</tr>
<tr>
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<td>6.30859</td>
<td>6.3</td>
<td>0.01</td>
</tr>
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<tr>
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<td>10.00000</td>
<td>10</td>
<td>0.00</td>
</tr>
</tbody>
</table>

\(^4\) American Standard Preferred Numbers, Approved by the American Standards Association, reaffirmed November 12, 1946.

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2. Young's paper gives an excellent survey of this subject, including a discussion of the evaluation of audio frequencies in terms of their ratios to a reference frequency.
3. M. W. Baldwin, Jr. and R. E. Graham, of the Bell Telephone Laboratories, pointed out in an unpublished memorandum, dated March 24, 1947, that the lack of proper designations was all that prevented the utility of this standard ratio from being realized.
The number of logits corresponding to any given relative magnitude, \( R \), is computed by solving (2) for the quantity \( m \) when \( r = 10^{0.1} \). In general, \[
m = \log R. \tag{4}
\]
If the number \( 10^{0.1} \) were to be represented by a convenient symbol, this general expression could be converted into a specific expression by replacing the subscript \( r \) by this symbol. The notation may be made even more compact by using the operator \( \log R \) abbreviated from the word “logit,” to represent the expression “logarithm to the base \( 10^{0.1} \).” For numerical computations logarithms to the base 10 may be used in accordance with the working formula:

\[
m = \frac{\log R}{\log r} = 10 \log R = \text{lg}t R. \tag{5}
\]

When dealing with absolute magnitudes of physical quantities, it is necessary that both the nature and the amount of the quantity designated as a unit change be specified. Units of physical quantities have, or are assumed to have, unique physical emblems. The standard change in absolute magnitude may be altered without altering the numerical value which represents it. When dealing with the relative magnitudes of physical quantities, only the nature of the quantity designated as a logit—or other standard change—must be specified. Logits of physical quantities do not have unique physical emblems. The standard change in the relative magnitude of any physical quantity may be altered only by altering the numerical value which represents it. The standard change in the relative magnitude of any physical quantity may thus be adequately designated by qualifying the general designation for the standard relative magnitude, which indicates its numerical value, by an adjective which indicates the nature of the quantity. A standard change in relative length, having the value \( dL/dL = 10^{0.1} \), would thus be described as a “length logit.”

This designation by description is the practice followed when the transmission loss, now known as the decibel, was first proposed as a standard. Until its utility had been established, it was referred to as a “transmission unit.” In a similar manner it will be satisfactory to describe a standard change in relative magnitude as a “length logit” or as a “mass logit” until a more distinctive nomenclature is shown to be justified. Our immediate needs as to symbols may be satisfied by appending the letter “l” to the conventional symbol for the nature of the quantity in question. The symbol indicating that some quantity is expressed in current logits would then be \( \text{Il} \), for mass logits it would be \( \text{ml} \), for length logits \( \text{dl} \), and so on.

On the basis of the foregoing the change in power identified with a decibel is seen to be a power logit. Being a standard transmission loss, the decibel is often used, sometimes incorrectly, for the evaluation of changes in electrical voltage or in acoustical pressure. A change in such a quantity which, because of unique correspondence to a power change, may properly be identified with one decibel has the value \( 10^{0.1} \), the ratio associated with one voltage logit is, by definition, \( 10^{0.1} \). The change in voltage identified with one voltage logit is thus seen to be the square of that identified with one decibel. The number of voltage logits identified with a given voltage ratio is, on the other hand, one half the number of decibels identified with that ratio.

When dealing with absolute magnitudes, the number of standard changes which is equivalent to a given change varies inversely as the size of the standard change. When dealing with relative magnitudes, the number of standard changes which is equivalent to a given change varies inversely as the logarithm of the standard change. Due account must be taken of this relation if decimal prefixes are to be used in connection with relative-magnitude standards. If the effect of the operation indicated by the prefix is to divide the number of standards equivalent to some given ratio by a power of ten, the value of the standard must have been raised to that power for which the same power of ten is the exponent. The power ratio designated by the decibel, in other words, is not one tenth the ratio designated by the bel, but is the tenth root of that ratio.

**Dimensional Relations**

It is often said that relative magnitudes are dimensionless. This concept requires re-examination if we are to evaluate relative magnitudes in the manner described in the preceding paragraphs. It is true that the dimensional equation for the ratio of two absolute magnitudes of like kind reduces to unity. This means that the value of the standard change in absolute magnitude has lost its significance. Significance has, however, been acquired by the value of the standard change in relative magnitude. The nature of the physical quantity in question is as pertinent to operations with relative magnitudes as to those with absolute magnitudes. When dealing with relative magnitudes, information as to the nature and value of standard quantities must be made as conveniently available as when dealing with absolute magnitudes. This may be done by symbols having the same general properties as the dimensional designations used with absolute magnitudes.

As an example, consider the attenuation coefficient showing the rate at which transmitted energy decays with distance. It is sometimes said that this quantity has the dimensions of a reciprocal length. This is necessary but not sufficient. It is true that this coefficient is the reciprocal of the distance over which some definite change in relative power, or some definite change in relative voltage, takes place. It is, however, as necessary to know the value of the ratio expressing this change and the physical nature of the quantity which changes as it is to know the distance. The symbol “db/kyd” supplies all of this information.

Consider, also, two quantities so related that values of one are proportional to some power of values of the other. If relative magnitudes of the first are plotted
against relative magnitudes of the second, using a common standard ratio for both, the resulting characteristic will be a straight line, the slope of which is equal to the exponent indicating the power in question. For example, the inverse square law may be stated in terms of relative magnitudes by saying that the intensity of power radiated uniformly in all directions decreases at the rate of two decibels per length logit.

This direct equivalence between slope and exponent occurs only when a common value is used for the standard ratio of each quantity. It does not exist in a case such as that where the rate of change of the level of acoustical intensity with frequency is reported in decibels per octave. Here the value of the slope is derived from the exponent of the frequency to which the intensity is proportional by multiplying this exponent by 3.010, the logarithm to the base $10^{0.4}$ of two.

Attention must be given to the dimensional situation arising when dealing with a relative magnitude, as distinguished from a change in relative magnitude. The end result in such a case, as already noted, is the unique evaluation of an absolute magnitude. When the value of a given absolute magnitude is expressed in terms of the number of standard changes in relative magnitude by which it exceeds some reference quantity, the nature and magnitude of this reference quantity must be completely specified. A frequency of 1,047 cycles/sec may, for example, be reported as being "two octaves above middle C." To convey the information required in such a situation, four items must be known in addition to the number of standard changes in relative magnitude between the reference quantity and the quantity to be evaluated. These are (1) the physical nature of the quantity, (2) the size of the relative magnitude standard, (3) the size of the absolute-magnitude standard by which the reference quantity is measured, and (4) the number of absolute-magnitude standards which are equivalent to the reference quantity. These specifications must be combined symbolically to form a compact dimensional designation.

In this situation it is evident that the relations between absolute and relative magnitudes are quite different from those indicated by the solidus (/) in earlier paragraphs. It would appear that a new symbol is required. It is suggested that the requirements are met acceptably by a double solidus (//). Using this symbol, the relative magnitude—or the level—of an acoustical intensity, $I$, would be written as

$$L = 10 \log \frac{I}{I_0} = \text{ldb}/\text{watt/cm}^2. \quad (6)$$

The complete statement symbolized by this expression is, "The relative magnitude of an acoustical intensity having the absolute magnitude $I$ watt/cm$^2$ is $L$=ldb ($I/I_0$) decibels when referred to an intensity of $I_0$ watt/cm$^2$.

The relative magnitude of the product of two quantities may be computed as the sum of the numbers of standard relative magnitudes which are equivalent to the factors. Such an operation requires, however, that the relative magnitudes of the factors be expressed in terms of standard ratios of like value. When this operation is performed, the quantity to which the resultant is referred is the product of the quantities to which the factors are referred. The dimensional designation for the absolute magnitude of the new reference quantity is, similarly, the product of those for the absolute magnitudes of the original reference quantities. From this it is clear that if the factors are referred to unit quantities the resultant will also be referred to a unit quantity. It would appear logical, at this time, to adopt for this purpose those units which form the mks system.

When these conventions are applied to the difference between two numbers of standard ratios equivalent, respectively, to two relative magnitudes of like quantities, both being referred to a common reference quantity, it is clear that the dimensional designation for the resultant reduces to that for a simple change in relative magnitude. This is in complete agreement with the significance of the process and of the resultant. For example, let

$$L_a = \text{ldb}/P_a/P_0 \text{db}/\text{watt}.$$

and

$$L_b = \text{ldb}/P_b/P_0 \text{db}/\text{watt}.$$  

Then

$$N_{b/a} = L_b - L_a = \text{ldb}/P_b/P_a \text{db}. \quad (7)$$

Because they are associated with different forms of dimensional designation, the symbols used for relative magnitudes should differ from those used for changes in relative magnitude.

**Conclusion**

It appears, from the foregoing, that when expressing relative magnitudes in terms of equivalent numbers of standard changes in relative magnitude, or standard ratios, the relations employed reduce to their simplest forms when all magnitudes are evaluated in terms of a common standard ratio. It also appears that by properly selecting the value of this common standard the numbers of standard ratios, and the actual ratios to which these numbers are equivalent, may be made to conform concurrently to the decimal system. It is gratifying that the standard ratio already in extensive use for the evaluation of relative power has the value required to satisfy this condition. The advantages of evaluating relative power in terms of a standard ratio, and the suitability of this particular standard ratio, have, through the decibel, been effectively demonstrated. Standard changes in relative magnitude of this same value may be used, to equal advantage, with other physical quantities and also for generalized relative magnitudes. All that is required is that they be properly designated, represented by suitable symbols, logged in on our lists of accepted terminology, and put to work.
Transistor Forming Effects in $n$-Type Germanium*

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Summary—Some of the effects of electrical forming of the collector of an $n$-type germanium transistor are discussed. Evidence is presented for the existence of a region of $p$-type germanium underneath the formed electrode, together with some indication of the size of the formed region.

These experiments lend support to the $p$-$n$ hook mechanism in that they explain the observed high values of alpha in transistors. This relation is discussed.

INTRODUCTION

It has been realized for some time that forming the collector enhances transistor action.1 In other words, forming increases the alpha (current multiplication factor) of the transistor.

This forming process is therefore very important in controlling the properties of the device. In this paper the results of several experiments which give some understanding of what takes place at the collector of the $n$-type germanium transistor during forming will be summarized.

There is a good understanding of the behavior of an unformed point contact on $n$-type germanium. Bardeen has suggested that surface states produce a bending of the energy levels at the surface.2 This produces a double layer of charge extending to a depth on the order of $10^{-4}$ cm into the semiconductor and, consequently, a barrier at the point contact. Thus, an unformed point has a low forward resistance and a high reverse resistance (good rectifier). Forming in the transistor sense (passage of large currents in the reverse direction) is known to reduce the reverse resistance of the collector, besides increasing the alpha of the transistor.

EXPERIMENTAL RESULTS

The material used in these investigations was obtained from polycrystalline ingots of $n$-type germanium and about 2 cm in diameter and 5 cm long, prepared by Theuerer and Scaff.3 These ingots were cut transversely to obtain approximately round slices of $50 \times 10^{-3}$ cm thickness. The slices were, in turn, soldered to a brass base (ohmic contact), and the top surface was ground and chemically etched. The etch showed the grain boundaries clearly so that each experiment could be confined to a single crystal.

The points used were 0.013-cm (0.005-inch) diameter phosphor-bronze wires, cut diagonally to form a chisel-shaped point (as in transistors). They were mounted in a micromanipulator by a phosphor-bronze spring that related deflection to applied force. In all cases force applied to the point was about $25 \times 10^3$ dynes.

The first experiment was a measurement of the dc floating potential on the surface of a germanium slice near a point biased in the reverse direction. The experimental setup was as shown in Fig. 1, and consisted of two points lowered to the surface by means of a micromanipulator. The biased point was kept fixed while the movable point was used as an exploratory probe for the potential measurements.

![Fig. 1—Circuit for the measurement of floating potentials.](image)

![Fig. 2—Floating potentials.](image)

In Fig. 2 the floating potential (expressed as a percentage of the bias voltage applied to the fixed point) is plotted versus the separation between the two points. In the unformed case the measured potentials were very small (as is expected from the model derived from the surface-states hypothesis4), and they decreased with in-

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creasing separation in the way which potential theory predicts for this geometry. Heavy forming (greater than that used for transistors) increased the magnitude of the floating potential near the fixed point and introduced an irregularity in the curve at a distance of about $10^{-2}$ cm. The bias voltages used here were $-50$ volts and $-1$ volt for the unformed and the formed cases, respectively.

These experiments led to measurements of the reverse conductance of a single point as a function of position on the slice. This same point was used to perform the functions of forming and measurement. The conductance was measured with a fixed-negative bias voltage applied to the point with respect to the metallic base. The logarithm of conductance versus distance along the slice is shown in Fig. 3. The two upper curves are for cases where the point had been formed at position "0" by pulsing. The curve marked "normal forming" shows data for a case where the point was pulsed to a degree only slightly heavier than for transistor forming; the other is for quite heavy pulsing.

It was not feasible to investigate the formed region produced by lighter pulsing because the regions were too small to explore accurately with the available facilities. However, it is interesting to note that if the irregularity in the curve of floating potentials is attributed to the boundary of a high-conductivity region there is very good agreement for size between the two methods. A radius of $10^{-2}$ cm in the floating potential measurement compares favorably with a diameter of $2.2\times10^{-2}$ cm, obtained in the conductance measurements (heavily formed case).

A third method, which was also used for determining the size of the formed area, consisted of measuring the conductance between two points. A positively biased point was fixed at the center of the formed area and a negatively biased point was moved along the surface of a slice. A change in conductance was observed at the edge of the formed region. The results obtained by this method were in agreement with those of two other methods.

To specify the complete dimensions of a formed region (where high conductance is observed), the depth must be measured. This was done by removing a known thickness of the top surface of the germanium by etching. After each layer was removed, the surface was explored for the high-conductance region. In this manner the depth of the formed area was found to be between $0.8\times10^{-2}$ cm and $1.7\times10^{-2}$ cm.

The conductivity type of the formed region was determined by observing the sign of the thermoelectric potential which was developed when a heated needle-shaped probe contacted the surface. Since germanium is an impurity semiconductor, the polarity of the thermoelectric potential differs according to whether the germanium has $n$- or $p$-type conductivity. If a heated probe makes contact with the surface, the steepest part of the thermal gradient is in the immediate vicinity of the point, and the sign of the thermoelectric potential measured just after contact indicates whether the germanium under the probe is $n$- or $p$-type. Exploration on and around formed areas indicated that the material was converted from $n$- to $p$-type conductivity when the

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Fig. 3—Conductance measurements on the surface of germanium in the unformed, formed, and heavily formed conditions.

Fig. 4—Crater produced in germanium by heavy pulsing.

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point was pulsed extremely heavily. It is suspected that lighter pulsing produces such a small converted region that detection is difficult.

The formation of the p-region under conditions of extremely heavy pulsing can probably be attributed to thermal effects. It is known that a high-temperature heat treatment of n-type germanium converts it to p-type. There is reason to believe that the temperature under the point during forming is high. Sometimes craters, such as that shown in Fig. 4, are produced as a result of extremely heavy pulsing. This crater is about $3.7 \times 10^{-2}$ cm long, $1.0 \times 10^{-2}$ cm wide, and $0.2 \times 10^{-2}$ cm deep. Melting has also been observed under the point after lighter forming. The conversion of the conductivity type occurring on forming may be the result of lattice dislocations or of thermal diffusion of impurities.

**Discussion of Experimental Results**

The physical picture of transistor forming, i.e., the production of a region of high-conductivity, p-type material under the formed electrode, is quite consistent with the observed changes in electrical properties. The model of a double layer of charge and a barrier at the point contact no longer holds after forming. The contact resistance has been appreciably lowered, and most of the resistance can be attributed to the barrier between the p-region produced by forming and the body of the n-type semiconductor.

This explains the sharp drop in floating potential observed in moving the probe across the p-n junction (Fig. 2). The spreading resistance in the p-type region accounts for part of the potential drop.

The conductance measurements (Fig. 3) show that when the point is outside the formed region, the high resistance of an unformed point contact is observed. This resistance is reasonably uniform and much lower when the point is inside the formed area since most of the resistance is across the large area p-n barrier. A comparison between the conductance and the size of formed area (assuming it to be circular) for the two degrees of forming in Fig. 3 shows that these quantities are approximately proportional. This would correspond to approximately the same resistance per unit area of the p-n barrier.

**Mechanisms for High Alpha**

The theoretical upper limit on alpha on the basis of space-charge neutralization only is 1 + $b$, where $b$ is the ratio of the mobility of electrons to the mobility of holes. Using the most recent values of mobility, it is found that alpha must be less than 3.1. Much higher values have been observed; and in order to explain these, two theories have been proposed. The first is the trap theory, and the second is the p-n hook theory, which will be discussed here.

The purpose in discussing the p-n hook theory is to cite the above evidence supporting this theory. A physical picture of the p-n hook region is shown in Fig. 5.

![Fig. 5—Formed area.](image)

The n-type region (N1) directly under the collector must be so small that it can not be detected by the particular thermo-electric potential probe used in the experiments. However, experiments showing that donors are needed in the collector point for best forming results suggest that such a small n-region may exist.

The p-n hook region produces high alphas because holes coming from the emitter enter the p-region; these are slowed down in their travel toward the collector because they have arrived at the lowest energy level for holes. It should be noted that holes tend to travel uphill in energy diagrams, such as Fig. 6. This retardation in their drift velocity means that many more electrons (moving with their usual velocity) are required to balance the hole charge, thus corresponding to an increase in the maximum possible alpha.

Another way to look at this is to focus attention on the barrier for electron flow from the metal to the semi-
conductor. Suppose a few holes arrive at the p-region and are not neutralized by electrons. The charge of the holes will lower the electron barrier, and thus allow many electrons to enter the semiconductor at the collector for each hole injected by the emitter. It must be pointed out that this mechanism assumes that the recombination of holes with electrons in the p-region is small and that electrical neutrality is preserved.

CONCLUSION

It has been determined that forming produces a re-

Current Multiplication in the Type-A Transistor

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Summary—One of the basic phenomena exhibited by transistors is current multiplication. In transistors of the point-contact type (one of these has been called the type A), the mechanism giving rise to this effect has been somewhat uncertain. Four possible mechanisms of the current multiplication process in the type-A transistor are discussed. One of the mechanisms is based on trapping holes in the collector barrier of the semiconductor. By means of this trapping model, the effect of emitter current and temperature on the current multiplication is predicted. It is shown that these predictions are in reasonable accord with experiment. Furthermore, assuming this model to hold, the trap density and activation energy (produced by forming) may be evaluated.

I. INTRODUCTION

THE TYPE-A TRANSISTOR is a device consisting of two sharply pointed wires placed in close proximity on top of a small wafer of germanium which, in turn, is affixed by ohmic connection to a metallic block. The structure has been described in greater detail by Bardeen and Brattain. This transistor is an active four-terminal network which can be represented by the equivalent circuit shown in Fig. 1. The active element of the device is the current generator αi_e. Alpha, the current multiplication factor, is defined by

\[ \alpha = -\frac{\partial i_c}{\partial i_e} v_c = \text{constant}. \]

Alpha is an important measure of transistor performance as the available power gain depends on its square.

The values of the parameters of the transistor equivalent circuit depend on the dc operating point, which is most conveniently determined by fixing the emitter current (I_e) and collector voltage (V_c). Experiment shows that alpha depends little on the value of the collector-voltage bias, but varies considerably with emitter-current bias.

The quantity alpha, as defined above, is the current multiplication factor of interest to the user. It depends on the physical structure of the material at the collector and the details of the processes occurring there. It is this structure and these processes with which this paper is concerned.

In discussing the current multiplication process it is more convenient to consider the intrinsic alpha (α_i) where (α_i - 1) is the number of extra electrons emitted from the collector for each hole arriving at the collector; for the type-A transistor, α and α_i are very nearly equal.

The theoretical maximum value of alpha and its dependence on emitter current depends on the mechanism of the process. There are four mechanisms to be discussed:

1. If the holes injected by the emitter are collected without enhancement of the electron current from the collector, α_i will be unity for positive I_e and zero for negative I_e.

\[ I_e = \text{constant}. \]

It is seen that α is a vector quantity, hence both phase and amplitude are required for its specification. In this paper we will be concerned with the amplitude part only.


Fig. 1—An equivalent circuit for the type-A transistor.

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This relation is shown in Fig. 2(a).

A typical experimental curve of $\alpha$ versus $I_e$ for the type-A transistor is shown in Fig. 2(c). The second model discussed appears to account for the values of $\alpha$ at large $I_e$, but is in disagreement with experiment at low $I_e$. Two modifications of the second mechanism which can bring theory into closer agreement with experiment have been made by Shockley. These are the third and fourth mechanisms to be discussed.

3. The first modification is called the $p-n$ hook theory, and is based on the existence at the collector of an electron potential-energy configuration described by Fig. 3. Suppose there is a thin region $P$ of $p$-type material separating the collector region $N_1$, taken to be $n$-type, from the base $N_2$, also taken to be $n$-type. Holes arriving at $P$ will be held by the potential-energy minimum (holes tend to flow uphill in this diagram), and will bias the $n-p$ junction $N_1-P$ forward, provoking an electron flow from $N_1$ into $P$. If $P$ is thin, the electrons will diffuse through it and fall through the potential drop $N_2-P$; $N_2-P$ is a $n-p$ junction biased in reverse by the collector voltage. It is seen that high values of $\alpha$, can arise in this way. The experiments relating to this theory are discussed elsewhere.

2. If the density of holes flowing into the collector becomes comparable to the density of fixed donor ions in the collector barrier, the space charge in the barrier will be altered by a significant amount and will correspondingly alter the flow of electrons from the collector as suggested by Bardeen and Brattain. If we assume a uniform collector barrier, the maximum value of $\alpha$, predicted by this mechanism is $1 + b$, where $b$ is the ratio of electron to hole mobility in germanium. This is true because there is no enhanced field when the ratio of enhanced electron current to hole current equals $b$. An $\alpha$, versus $I_e$ curve, like Fig. 2(b), would be predicted for this case; $\alpha$, should be unity for small $I_e$, because this corresponds to a low density of collected holes. Measurements on germanium filaments indicate that $b = 2.1$, hence the maximum value of $\alpha$, should be 3.1. The dotted portion of this curve (intermediate values of $I_e$) indicates only that $\alpha$, should increase monotonically toward the maximum value.

4. The second of these explanations is called the “trap theory.” If the barrier region contains a density of traps capable of holding holes, then the holes will be delayed in this region and the hole space charge increased. The electron space charge will be correspondingly increased, thus leading to large electron currents and large values of $\alpha$. This theory is discussed more fully in Section II.

In this paper it is proposed to: (a) give an approximate analysis of the $\alpha$ versus $I_e$ characteristic, based on the trapping mechanism (this is an application to the

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Fig. 3—Electron potential-energy diagram showing the $p-n$ hook model for high alpha.
type-A transistor of Shockley’s analysis\(^9\) of the filamentary transistor with traps); (b) show that the results of experiment and analysis are in fairly good agreement; and (c) give the values of trap density and hole-binding energy resulting from analysis of transistor characteristics in the light of the trapping model.

II. Theory of the Transistor with Traps

The basis of this theory lies in the effect of hole trapping on hole mobility, which is shown in Fig. 4. In part A is shown the usual electron potential-energy diagram of germanium, having a preponderance of donor levels over acceptor levels (n-type). A single trapping level for holes located at \(E_t\) is postulated. A single level, rather than a range of levels, is postulated for convenience in analysis. Holes, when trapped, are bound with an energy \(E_b = E_e - E_t\).

In Fig. 4(b) is shown the situation in the germanium at equilibrium. If the traps are of an electron acceptor type, their sole effect will be to lower the n-type conductivity of the sample. (The figure shows three conduction electrons instead of the six there would be in the absence of traps.) However, if a number of holes are injected, some will be trapped \((p_t)\) and some will remain mobile \((p)\). Charge neutrality\(^{10}\) requires the appearance of \(\delta n = p + p_t\) electrons shown in the conduction band. For the example shown, three electrons are made available for conduction by each mobile hole.

An equivalent way of looking at the problem is to note that each hole is continually making transitions between the valence band and the trapping level; it is available for conduction only a fraction of the time, and its effective drift mobility is consequently reduced. The ratio of electron to hole mobility may thus become quite large, leading to large values of \(\alpha_e\). The effects of hole trapping will increase with decreasing temperature since the ratio of trapped holes to mobile holes increases.

The effect of traps on alpha will decrease with increasing \(I\) as the traps become saturated.

In addition to the qualitative picture of the effect of hole traps on alpha and its dependence on emitter current and temperature, we need the quantitative relations between these quantities for comparison with experiment. Our plan will be to apply available analyses of the filamentary transistor to the type-A transistor.

The essential feature of the theory as applied to the filamentary transistor is that the added hole and electron densities are such as to lead to no change in space charge, i.e., \(\delta n = p + p_t\), as discussed above. In the type-A transistor a change in space charge will lead to a change in field in the barrier layer and hence to a change in the “field-induced” emission of electrons from the metal point. If we assume that this current is very sensitive to space charge, then the electron current will tend to increase to such an extent that any positive space charge due to the holes is neutralized. If this tendency to neutralization is pushed to its mathematical limit, the requirement of zero space charge will hold for the type-A as well as for the filamentary transistor and, under these conditions, the same analysis will apply to both.

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9 W. Shockley, private communication.

10 The time required for the cancellation of any abnormally high space charge (the relaxation time) is very short compared to the time constants for the other processes in which we are interested. For germanium, having a resistivity of 10 ohm-cm, the relaxation time is approximately \(10^{-11}\) sec.
case and experiment for the type A, presented below, suggests that the sensitivity of reverse current to space-charge changes exerts a strong stabilizing influence on the space charge.

The filamentary transistor has been described by Shockley, Pearson, and Haynes. Their expressions for the increase in collector current due to emitter current and alpha are

$$\Delta I_c = -\gamma I_e (1 + b),$$

where $\gamma = \text{hole current from emitter}$

$$\alpha = \gamma (1 + b).$$

These expressions have been applied to the type-A transistor by Brown.12

The effort of hole traps on the performance of the filamentary transistor has been analyzed by Shockley.9 The part of this treatment which is pertinent to this paper is reproduced in Appendix II. In the presence of traps relations (1) and (2) become

$$\Delta I_c = -\gamma I_e \left(1 + b + \frac{ab}{1 + G' I_e}\right),$$

where

$$d = \frac{p_t}{p} = \text{density of trapped holes}$$

$$p = \text{density of mobile holes}$$

for the case of small injected hole density; $(a$ is called the trapping ratio.)

$$G' = \frac{\gamma}{A \left(\frac{N_t}{q \mu_p} \frac{V_e}{a} \right)}$$

(1.11)

$N_t$ = trap density

$A$ = cross-sectional area of filament

$\mu_p$ = mobility of holes in absence of traps

$q$ = value of electron charge

$V_e/L = \text{electric field in the interaction region.}$

By differentiation of (1.1) we obtain

$$\alpha = \gamma \left(1 + b + \frac{ab}{1 + G' I_e}\right).$$

(2.1)

The above expressions will be applied to the type-A transistor by taking $A$ to be the area of the collector point contact (10^-4 cm^2) and $V_e/L$ to be the collector potential divided by the thickness of the collector barrier (10^-4 cm).

By examination of (2.1) we can predict the following:

1. When $I_e = 0$, then $\alpha = \alpha_{\text{max}} = \gamma(1 + b)$. $a_{\text{max}}$ may be indefinitely large since the trapping ratio, $a$, may have any positive value. Also, $a_{\text{max}}$ should increase with decreasing temperature as the trapping ratio increases with decreasing temperature, as shown in Appendix I.

2. When $I_e$ is large, then $\alpha_t = \alpha_{\text{min}} = \gamma(1 + b)$. This occurs because the traps are saturated.

3. When $I_e$ has such a value

$$\text{(1.11)}$$

then $(1 + G' I_e)^2 = 2$. Therefore, $G' = 0.414/I_e$. Thus we can determine $G'$ and hence $N_t$ from (1.11). This method of determining $N_t$ will be called the “curve-fitting” method since it is based on fitting a theoretical expression to an experimental curve.

4. By combining conclusions 1 and 2 above, we can obtain the trapping ratio

$$d = \frac{a_{\text{max}} - a_{\text{min}}}{a_{\text{min}} (1 + b)}.$$

There is a second, and partially independent, method of finding the trap density $N_t$. A plot of the expected relation between $\Delta I_c$ and $I_e$ (1.1) is shown in Fig. 5.

![Fig. 5—Theoretical curve for increase in collector current due to emitter current versus emitter current.](image)

For large $I_e$ this curve approaches a straight line which, if extended, intersects the $\Delta I_c$ axis at a value $\Delta I_t$. The current $\Delta I_t$ can be considered as resulting from traps having a density $N_t$. In the absence of emitter current there is a dc collector current of magnitude $I_t$ due to the voltage bias. This current is due to a density of free electrons $N$, which can be determined from the conductivity of the germanium. It is plausible to expect, and not difficult13 to show, that

$$\Delta I_c = N_t I_e = \frac{N_t}{N}.$$

Measurement of the conductivity of the germanium, together with $\Delta I_t$ and $I_t$ on the transistor, permits computation of $N_t$. The experimental curves of $\Delta I_t$ versus $I_e$ have the shape shown in Fig. 5, and $\Delta I_t^*$ and $I_t$ were measured on the transistors studied. The sample conductivity was known only approximately, but values of $N_t$ obtained by this method agree approximately with those obtained by the curve-fitting method.


The remaining problem is to find the trapping energy. In Appendix I it is shown that

\[ a = \frac{N_i}{N_e} e^{-\frac{E_b}{kT}}. \]  

(4)

By determining trapping ratio as a function of temperature, we can obtain \( E_b \) from the slope of the \( \ln a \) versus \( 1/T \) plot. Also, if we take the usual value for \( N_i \), we have

\[ a = \frac{N_i}{10^{19}} e^{-\frac{E_b}{kT}}. \]  

(4.1)

One can then evaluate \( E_b \) from a single measurement of trapping ratio.

III. EXPERIMENTAL RESULTS

Equipment was constructed for presenting \( a \) versus \( I_e \) on an oscilloscope. A test signal of 12 kc, having an amplitude of one microampere, was superimposed on a 60-cycle emitter current sweep. The small amplitude of test signal permits valid measurement of \( a \) down to very low values of \( I_e \). Means of changing the temperature of the transistor under study were provided, also, provision for presenting \( \Delta I_e \) versus \( I_e \) on the oscilloscope.

![UNIT CB92](image)

Fig. 6—Alpha versus emitter current at three temperatures with a comparison to the theoretical curve.

\[^{11}\text{The effective density of states in the valence band (}N_v\text{) is known from semiconductor theory to be}

\[ N_v = \left( \frac{2\pi m^* kT}{h^2} \right)^{3/2} \approx 10^{19} \text{ cm}^{-3}. \]

A considerable fraction of the type-A transistors currently manufactured have \( \alpha > 3 \) at small \( I_e \). In Fig. 6 we show the \( \alpha - I_e \) characteristic at three temperatures for a typical unit of this type. The theoretical curve [a plot of (2.1)] for the lowest temperature is drawn in for comparison with experiment. The essential agreement between the shape of the curves suggests that trapping is responsible for the large values of \( \alpha \). It should be recalled that the theoretical and experimental curves are made to coincide at three values of \( I_e (I_e = 0, I_e = \infty, I_e = \text{one intermediate point}) \) by choice of the parameters \( \gamma, \alpha, \) and \( G' \).

The maximum alpha, trapping ratio, trap density, and hole-binding energy for two transistors at four temperatures are given in Table I. \( E_b \) is obtained, as explained in (4.1), and \( E_b^* \) is obtained from the \( \ln a \) versus \( 1/T \) plots.

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Unit</th>
<th>CB92</th>
<th>CB84</th>
</tr>
</thead>
<tbody>
<tr>
<td>( T = 298 \text{K} )</td>
<td>( N_i \text{ in cm}^{-3} )</td>
<td>( 7.2 \times 10^{12} )</td>
<td>( 6.7 \times 10^{12} )</td>
</tr>
<tr>
<td>( a )</td>
<td>0.31</td>
<td>0.31</td>
<td></td>
</tr>
<tr>
<td>( T = 274 \text{K} )</td>
<td>( N_i \text{ in cm}^{-3} )</td>
<td>( 9.2 \times 10^{12} )</td>
<td>( 9.6 \times 10^{12} )</td>
</tr>
<tr>
<td>( a )</td>
<td>0.35</td>
<td>0.33</td>
<td></td>
</tr>
<tr>
<td>( T = 258 \text{K} )</td>
<td>( N_i \text{ in cm}^{-3} )</td>
<td>( 2.9 \times 10^{12} )</td>
<td>( 1.9 \times 10^{12} )</td>
</tr>
<tr>
<td>( a )</td>
<td>0.30</td>
<td>0.27</td>
<td></td>
</tr>
<tr>
<td>( T = 237 \text{K} )</td>
<td>( N_i \text{ in cm}^{-3} )</td>
<td>( 7.7 \times 10^{11} )</td>
<td>( 7.3 \times 10^{11} )</td>
</tr>
<tr>
<td>( a )</td>
<td>0.30</td>
<td>0.29</td>
<td></td>
</tr>
<tr>
<td>( E_b )</td>
<td>0.30</td>
<td>0.28</td>
<td></td>
</tr>
<tr>
<td>( E_b^* )</td>
<td>0.30</td>
<td>0.28</td>
<td></td>
</tr>
</tbody>
</table>

It is noted from Table I that the trapping ratio increases with decreasing temperature as predicted. Also, the curve of \( \ln a \) versus \( 1/T \) is a straight line from which the binding energy \( E_b^* \) is found. This result is in essential agreement with the binding energy \( E_b \) determined from (4.1).

It will be recalled that we assumed a particular trap density in our trapping model. We observe from Table I, however, that \( N_i \) increases considerably with decreasing temperature. This suggests that the hole traps actually occur with a range of energy levels and not at a single level. As the temperature is lowered, the more shallow traps become effective, hence increasing the observed trap density. The measured value of hole-binding energy is expected to be the maximum value (corresponding to the most tightly bound holes).

IV. CONCLUSIONS

The semiquantitative agreement between the observed behavior of alpha with emitter current and
temperature and that predicted on the basis of a hole-trapping mechanism strongly suggests that this mechanism is responsible for the large values of alpha at low emitter current. The sharp dependence of \( \alpha \) on emitter current and temperature indicates a relatively small number of very stable traps.

The values of hole-binding energy obtained by two methods are in agreement. The trap density, as well as the hole-binding energy, has a reasonable magnitude.

The lack of complete agreement between the predicted and experimental curves of \( \alpha \) versus \( I_e \) indicates that (a) the model may be improved by assuming a band of trap energy levels, and (b) the effects of traps in the collector barrier region may be more complicated than those produced by traps in the body of the semiconductor.

As indicated above, an analysis of the filamentary transistor has been applied to the type A where its validity is not entirely certain. However, the agreement between theory and experiment leads to the belief hole trapping is responsible for the observed phenomena.

V. ACKNOWLEDGMENTS

The assistance of L. B. Valdes, who designed the circuit for oscilloscopic presentation of the curves, and R. L. Rulison, who made the bulk of the measurements, is gratefully acknowledged.

APPENDIX I

A. Relation Between Trapping Ratio and Temperature

Since the holes obey the Fermi statistics,

\[
\frac{p_t}{N_t} = \frac{1}{1 + e^{E_f - E_t/kT}} \sim e^{E_f - E_t/kT}
\]  

(1)

and

\[
\frac{p}{N_p} = \frac{1}{1 + e^{(E_f - E_p)/kT}} \sim e^{E_f - E_p/kT},
\]  

(2)

where \( E \) is defined in Fig. 4.

\( N_t \) = density of hole traps

\( N_p \) = effective density of states in valence band.

The simplification is valid since \( E_f - E_t \) and \( E_f - E_p \) \( \gg kT \). Combining (1) and (2), we have

\[
a = \frac{p_t}{p} = \frac{N_t}{N_p} e^{E_f - E_t/kT}.
\]

APPENDIX II

A. Relation Between Increase in Collector Current Due to Emitter Current versus Emitter Current

If we have a hole density \( p \) in the presence of a density \((N_t - p_t)\) of vacant hole traps, then

\[
\text{rate of trapping} = A p (N_t - p_t),
\]  

(1)

where \( A \) is a constant.

The rate of release of holes is expected to be proportional to \( p_t \),

\[
\text{rate of emission of holes} = B p_t.
\]

(2)

The steady-state requires

\[
A p (N_t - p_t) = B p_t
\]

or

\[
p_t = N_t \frac{1}{1 + \frac{B}{A p}} .
\]

(3)

By manipulation of (1) of Appendix I, it can be shown that \( B/A = (N_t/a) \), so that (3) becomes

\[
\frac{p_t}{N_t} = \frac{1}{1 + \frac{N_t}{a p}} .
\]

(4)

rearranging

\[
\frac{p_t}{p} = \frac{a}{1 + \frac{a p}{N_t}} .
\]

(5)

We now need to find the effect of trapped holes on the mobility. The presence of an injected charge density \( \dot{p} \) will induce an added electron charge density \( \dot{\rho} \), giving rise to the added electron-current density.

\[
q \mu_p \dot{E} = q b \mu_p p \dot{E} \text{ since } b = \frac{\mu_n}{\mu_p} .
\]

(6)

If \( P_t \) of the injected holes are trapped per cm², electrical neutrality indicates the electron current will be

\[
q \mu_p b (\dot{p} + \dot{p}_t) \dot{E}
\]

(7)

as though the mobility ratio were not \( b \) but \( b' \) where

\[
b' = \frac{b (\dot{p} + \dot{p}_t)}{\dot{p}} .
\]

(8)

Since the value of \( \alpha \) in the type-A transistor is

\[
\alpha = (1 + b) \gamma
\]

(9)

(same as for the filamentary transistor with the added assumption of no loss of holes in the short distance between emitter and collector), the effect of trapping will be to raise \( \alpha \) to a new value, shown by use of \( b' \) from (8).

\[
\alpha = (1 + b') \gamma = \left(1 + b \left(1 + \frac{p_t}{p} \right)\right) \gamma .
\]

(10)

The total induced added current (which according to the sign convention of Fig. 1 will be negative) due to an emitter current \( I_e \), will then be, after substitution from (5) into (10),

\[
I_{\text{add}} = A p (N_t - p_t) \left(1 + \frac{b}{\dot{p}} \right) \gamma.
\]
\[
\Delta I_e = -(1 + b')\gamma I_e = \left(1 + b \left(1 + \frac{a}{1 + \frac{a_p}{N_t}}\right)\right)\gamma I_e. \tag{11}
\]

The problem now is to express \( p \) in terms of easily observable quantities. This is obtained from the conductivity expression

\[
\gamma I_e = \frac{V_e}{L} (q \mu_p A) \tag{12}
\]

where

\( \gamma I_e \) = hole current to collector
\( V_e/L \) = field at the collector
\( A \) = area of contact.

Then,

\[
a \frac{p}{N_t} = \frac{a}{N_t} \frac{L \gamma I_e}{q \mu_p A V_e} = G' I_e, \tag{13}
\]

where

\[
G' = \frac{\gamma}{A \left(q \mu_p \frac{N_t}{a}\right)} \frac{V_e}{L}.
\]

Substituting into (11), we find the increase in collector current to be

\[
\Delta I_e = -(1 + b + \frac{ab}{1 + G' I_e})\gamma I_e. \tag{14}
\]

A Scanner for Rapid Measurement of Envelope Delay Distortion*

LOYD E. HUNT†, SENIOR MEMBER, IRE, AND W. J. ALBERSHEIM†, SENIOR MEMBER, IRE

Summary—A measuring device is described which instantaneously displays the envelope delay-frequency characteristic on a cathode-ray screen. Loop and one-way measurements of long-distance radio networks can be carried out. The frequency range extends from 60 to 80 megacycles; the limits of accuracy are 1 millisecond or 2 per cent of the measured delay range. Comparison of two characteristics can be carried out by superposition of alternate scanning traces.

The device has been found useful in measuring the delay distortion of the TD-2 radio-relay system and in designing and adjusting the delay equalizers needed to correct it.

The work described below grew out of the need for measuring equipment adapted to wide-band, long-distance radio-relay systems. The transmission properties of such a system can be found by measuring its propagation factor as a complex function of frequency. The real component of this function is the amplitude characteristic; the imaginary is the phase characteristic. Measurement of amplitude characteristics is a well-advanced art, but the present authors were faced with the necessity of developing equipment which could instantaneously measure and trace the phase characteristic or an equivalent function.

It can be shown that the baseband signal transmitted by amplitude or frequency modulation of a high-frequency carrier is not distorted by a linear change of phase with frequency. Such a phase gradient is unavoidable in long-distance circuits. It equals the transmission time of the radio signal, and is variously called the “group time” or the “envelope delay.” In a transcontinental radio relay the fixed part of this gradient is very large, exceeding 100,000 radians per megacycle. It is therefore both impractical and unnecessary to measure the absolute value of the phase constant. The significant parameter is the deviation of this phase-frequency gradient from a constant value. Our problem, therefore, resolved itself into that of providing rapid and sensitive means for measurement of envelope delay distortion.

Reliable point-by-point methods for the measurement of radio-frequency delay distortion have been available for some time. More recently, automatic equipment has been developed which, within a few minutes, records the transmission characteristic of a video system on a paper strip. However, for the line-up and maintenance of a long-distance radio relay containing a large number of variable components, existing methods were considered prohibitively time consuming.

The writers, therefore, undertook to develop an equipment capable of scanning the delay distortion in a small fraction of a second within a frequency band adjustable up to a maximum width of 20 mc. The first models of this equipment which are described in this paper have been completed and successfully operated. Some of the uses to which this model equipment has been put are the following:

1. Measurement of over-all systems—delay characteristics (loops and one-way radio relays).
2. Viewing of delay changes due to insertion of equalizers and retuning of circuit components.
3. Terminal impedance matching.
4. Adjustment and manufacturing control of delay equalizers by superposition of their characteristics upon that of a standard.

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† Bell Telephone Laboratories, Deal, N. J.

The frequency range chosen for the equipment is the intermediate frequency band common to all channels of the TD-2 radio-relay system. It extends from 60 to 80 mc. Though the measuring equipment operates in the intermediate-frequency range, the delay measured contains not only the IF delay but also that occurring in the microwave circuits.

The device is based on well-known physical principles. When a group of waves extending over an infinitely small frequency range are sent simultaneously through a transmission system, the delay or transit time of the group equals the rate of change of phase with angular frequency. This is approximately true even for a narrow but finite range of frequencies.

In our delay scanner, the group of search frequencies consists of a carrier and sidebands which are produced by modulating it with a 200-kc subcarrier wave. Regardless of the position of the group in the RF or IF band, the group delay may be expressed in terms of the phase change within the group. Hence measurement of differences in the phase of the 200-kc wave immediately gives differences in delay, since one cycle of this wave equals 5 microseconds. For this reason, phase indicators operating at 200 kc are the measuring means here used.

If the system under test extends over many miles, the absolute delay is great while the variations across the radio or IF band are relatively small. The absolute delay in a transcontinental radio-repeater system is of the order of $2 \times 10^{-7}$ seconds, but the variations would be a matter of serious concern if they were as great as $10^{-7}$ seconds. In other words, the transcontinental path would contain 4,000 cycles of the 200-kc subcarrier frequency, yet our interest would be focused on variations small compared with 0.01 of one cycle. Obviously, the frequency of the modulating subcarrier must remain extremely constant. For this reason it is derived from a stable 200-kc crystal oscillator. (See Fig. 1.)

The modulated carrier is swept over the 20-mc range between 60 and 80 mc, or any desired part of it. The rate of scanning is adjustable between 25 and 125 cps, but normally it is synchronized to 30 cycles or one of its harmonics.

If the time of transmission were constant over the entire scanned range, the phase of the 200-kc subcarrier at the receiver would be independent of the carrier frequency. Any difference in the delay causes cyclic variations in the phase which, when passed through a phase detector, can be applied to a cathode-ray oscilloscope to delineate the delay-versus-frequency characteristic of the medium.

In order to maintain the modulation index constant throughout the scanning sweep, the 200-kc modulating wave and the low-frequency sawtooth sweep are separately impressed upon two high-frequency oscillators.

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Fig. 1—Delay-distortion scanner block schematic.

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1 This system, which has been operating between New York and Chicago since September, 1950, is being rapidly extended to transmit television and multiplex telephony all the way to the Pacific.

and heterodyned down to the 60- to 80-mc range. Internal delay distortion of the equipment is equalized and the power amplified. Both modulations are obtained electronically by means of reactance tubes. As shown on Fig. 1, the 200-kc modulation is applied to a 110-mc carrier, and the sawtooth swing to one centered at 180 mc. This 180-mc oscillator is capable of a 20-mc frequency shift and uses a circuit developed by Dennis and Leed.  

In principle it makes no difference whether the 200-kc sidebands are obtained by AM or FM, and for delay measurements over moderate distances, both forms of modulation have been successfully used. However, the TD-2 Radio Relay is an FM system having considerable amplitude compression in each repeater, so that amplitude modulation is suppressed in long repeater chains. Accordingly, the apparatus here described uses frequency modulation. The index of modulation is kept low enough to confine the bulk of the energy to the carrier and first-order sidebands. Spreading of the search frequency group over a number of sidebands would blur details of the delay characteristic by averaging over too wide a frequency band.

After passing through the system under test, the carrier is demodulated in an FM receiver and the modulating voltages are recovered and separated into a slow (60-~) sawtooth component and a 200-kc component by filters. The recovered and amplified scanning voltage is applied to the horizontal deflection plates of the oscilloscope. This method of deriving the scanning voltage from the received signal insures a linear frequency scale regardless of any curvature in the sawtooth sweep impressed upon the transmitter because the voltage output of a good FM receiver is proportional to the instantaneous frequency by definition. As pointed out by our colleague, J. B. Maggio, it also automatically compensates for the fixed time delay between sending and receiving sections of the equipment. The recovered 200-kc subcarrier contains phase variations proportional to the delay distortion. These phase variations are measured by vectorial comparison with a reference signal of exactly the same subcarrier frequency but free from modulation. If the tested circuit is a local apparatus or a closed relay loop, the unmodulated reference signal can be taken directly from the 200-kc crystal oscillator output. In long-distance one-way circuits, however, it is preferable to regain it from the high-frequency component which is present in the output of the FM receiver. This component is a 200-kc wave which is phase modulated by the unknown delay distortion as pointed out in reference 4. Since the instantaneous phase deviations are repeated periodically in synchronism with the 60-cycle sweep, they form a line spectrum of sidebands spaced at multiples of the sweep frequency. All these sidebands are stripped off by means of a sharp band-pass filter, leaving a 200-kc wave. The tuned elements of this filter are quartz crystals which match the crystal used in the 200-kc oscillator.

The instantaneous phase indication is obtained at the receiver as follows: The amplitudes of the reference subcarrier and of the modulated subcarrier are made substantially constant and equal by means of limiters and gain controls. The two subcarrier voltages are then added and their phases adjusted until their combined output is zero at a chosen IF frequency. Regarding the two equal subcarrier amplitudes as unit vectors, their vector sum equals the sine of one-half their phase difference. For small angles this is very nearly equal to the phase difference itself; the error amounts to less than one per cent for angles under 30 degrees. The 200-kc phase angles corresponding to the intended measuring range are even smaller, so that the vector nonlinearity is negligible. However, for such small angles errors due to imperfect limiting of amplitude fluctuations in the detected 200-kc signal may be relatively high.

This type of error can be minimized by various methods. In the first models which are now in practical use, the frequencies of both the received and the reference subcarrier are multiplied from 200 kc to 2.4 mc. Thus, the phase-angle variations between the two vectors are also increased twofold, and the relative effect of spurious amplitude fluctuations is reduced by the same factor at the expense of a corresponding reduction of the linear measuring range.

The frequency multipliers serve as efficient amplitude limiters, but they produce some undesired frequencies, covering the approximate range between 2 and 3 mc in 200-kc steps. In order to obtain clean single-frequency vectors, these spurious modulation products are removed by a sharp 2.4-mc band-pass filter. The delay characteristic of the measuring set itself is compensated by a two-section, bridged-T, all-pass network, so that the oscilloscope trace is a horizontal line when zero external delay distortion is measured.

The frequency multiplication limits the linear measuring range of the equipment to about 50 millimicroseconds, corresponding to a 43-degree vector angle at 2.4 mc. Since the absolute magnitude of the vector angle is immaterial and only its variations indicate delay distortion, a reference zero (phase opposition) may be obtained at any desired carrier frequency by phase shifters. Due to the twelfold multiplication of vector angles, a ±15-degree phase shift in one of the 200-kc circuits is sufficient to rotate the 2.4-mc vector over a full circle. As a matter of convenience, a coarse phase shifter is inserted in the reference circuit and a fine control in the phase-modulated circuit. The zero adjustment makes it possible to double the linear range presented in a single scan in the following manner: The vector sum does not distinguish between positive and negative phase differences. If, therefore, the zero angle is placed near the center of the delay-variation range, the pattern traced on the cathode-ray screen reverses its trend at the fre-

---

4 In a recently developed simplified model, the sweep modulation is carried out by a rotary variable inductance, directly in a high-level 60- to 80-mc oscillator; the 200-kc modulation is added electronically.

The sensitivity of the vertical cathode-ray deflection is adjustable, and can be calibrated by the following method:

The maximum output obtainable by vector subtraction occurs when the phase difference between the vectors is 180 degrees, and a minimum at 0 degree. When the phase difference goes beyond this range, the resultant amplitude reverses sharply at 0 degree and bends over in a sinusoidal manner at 180 degrees, with a scale compression of $2/\pi$, as shown in Fig. 3. At 2.4 mc this corresponds to a relative delay of 208 millimicroseconds. If, therefore, there is inserted in the transmission path of the carrier a distorting circuit having variations within the band exceeding the delay distortion of 208 millimicroseconds and if the reference zero is adjusted in such a way that the amplitude folds over at both extremes, the total vertical excursion equals twice the vector amplitude. Fig. 4 shows the result of using, for this purpose, a long unterminated line which branches out from the intermediate frequency path. Since the delay distortion of this cable exceeds the 208 millimicroseconds which correspond to a 180-degree phase shift, it produces periodical reversals at both extremes of a vertical elongation which on an uncompressed scale would equal $2/\pi \times 208 = 133$ scale divisions. A 10-db attenuator reduces this to approximately 40 scale divisions, as shown on Fig. 4.

Without additional attenuation in the vertical deflecting circuits of the oscilloscope, the excursion under these conditions would exceed the linear range of the cathode-ray beam. Therefore, an auxiliary loss is inserted by means of a calibrating switch. It works out that if this loss is made 8 db, and the vertical deflection adjusted to the amplitude normally desired for a 50 millimicrosecond delay distortion, the delay scanner is calibrated. The sensitivity which we have usually employed is 0.05 inch per millimicrosecond.

The 8-db pad also serves to extend the measuring range beyond the undistorted 100-millimicrosecond range. Since the sine of the half angle is a repeating func-
tion, the nonlinear measuring range is unlimited (as indicated by the continuation of the calibrating curve in Fig. 3 beyond 360 degrees), showing a gradual reversal with a minimum of sensitivity at all odd multiples and a sharp reversal with a maximum of sensitivity at all even multiples of 208 millimicroseconds from the reference zero. By shifting the reference zero to make sensitive regions overlap in repeated readings, the total delay range of 460 millimicroseconds in a long-distance circuit has been measured with an uncertainty of less than 2 per cent.

In the simplified model the reference angle between the 200-kc reference signal and the phase-modulated received signal is not zero but a finite angle $\phi$, preferably between 30 and 45 degrees. The amplitude ratio of the received to the reference vector is made equal to $\cos \phi$. It can be shown that this arrangement measures small phase modulations with the same linearity as the system using equal vectors, but suppresses the first-order effects of small amplitude fluctuations. This circuit is schematically shown on Fig. 5(a) and explained by the vector diagram of Fig. 5(b).

A single instrument which combines transmitting and receiving equipment is only capable of measuring delay distortion of local equipment and of extended transmission systems looped back so that the demodulated sawtooth and 200-kc components are available at the instrument. If it is desired to measure the delay distortion of a long transmission circuit in one direction only, the sending part of the equipment (or its duplicate) is removed to the distant transmitting end of the circuit.

Permanent records of the delay-distortion characteristics are obtained with a camera attachment. A lighting arrangement permits the calibration scale to be illuminated independently. The record usually consists of a double exposure, one indicating the small residual delay distortion of the equipment itself (called “base line”) with the illuminated scale superimposed, and the second showing the characteristic when the unknown circuit is added. For exact measurements the equipment residual is subtracted. During the second exposure the auxiliary illumination may be extinguished to avoid overexposing the scale. Such reference base line appears in Fig. 2.

For quick testing and adjusting of local equipment such as delay equalizers, it may be desirable to compare the delay characteristic of the unit under test with that of a reference standard. For this purpose a double switch has been provided which alternately connects the input and output of the test circuit to the unknown equipment and to the reference standard, in synchronization with the scanning frequency. The characteristics of the two pieces of equipment are traced alternately at such a rate as to appear to the eye to be superimposed. Two such superimposed characteristics are photographed on Fig. 6.

By means of an auxiliary vibrating switch it is possible to connect alternate scans to two vector positions differing by a standard angle, for instance 1.44 degrees, which corresponds to 20 millimicroseconds. Calibration is obtained by setting the vertical gain control to a one-inch separation between traces.
mismatch is introduced at the distant end of the long line. The double reflection at amplifier and mismatch produces an echo with a delay of $2T = 0.5$ microsecond, which causes delay ripples with a spacing of $1/2T = 2 \text{mr}$ between maxima. These ripples are minimized by adjusting the match between network and line. Mismatches of less than one per cent can be made plainly visible by this method.

Fig. 7 is a front view of the first experimental model, while Fig. 8 shows the result of a redesign carried out by R. V. Crawford for use in the plant.

ACKNOWLEDGMENT

The authors wish to thank J. C. Schelleng and J. P. Schafer for their interest in this project and for their many helpful suggestions leading to its successful completion.

Thanks are due also to W. F. Bodtmann and H. A. Gorenflo for their patience and ingenuity in constructing and adjusting the many components.

CORRECTION

R. D. Teasdale, co-author with R. A. Martin of the paper, "Input Admittance Characteristics of a Tuned Coupled Circuit," which appeared on pages 57–61 of the January, 1952 issue of the PROCEEDINGS OF THE I.R.E., has brought the following correction to the attention of the editors:

On page 58 in equation (1) the second term of the numerator is incorrect as printed. Equation (1) should read

$$Y'_{\omega L_1} = 1 + \frac{Q_2(1-x^2m)}{Q_1} - x^2m + j \left[ Q_2x(1-x^2m) + \frac{xm}{Q_1} \right. + Q_2(1-x^2m) + j x m.$$
The Cathamplifier

C. A. PARRY†

Summary—This paper discusses an amplifier circuit with high input impedance which permits push-pull operation from an unbalanced source.

A voltage, proportional to the total circulating current of the push-pull system, is obtained from a transformer connected in the cathode circuits of the output valves. Over-all performance similar to usual push-pull operation may be obtained.

The possibility of a single- or two-mode oscillator is also discussed.

Because of the simplicity, and general application of this circuit, some of the more useful formulas are developed in detail.

I. BASIC THEORY

In Fig. 1, T is an ideal choke, with an exact center tap, and the whole power due to \( I_1 \) \( I_2 \) is considered to be developed in the load resistor \( R \). In such a case the voltages developed across each half of the winding are equal irrespective of the ratio \( I_1/I_2 \).

![Fig. 1—Basic circuit.](image)

Let \( R_1 = \) effective resistance offered current \( I_1 \), \( R_2 = \) effective resistance offered current \( I_2 \), \( I_1/I_2 = Y \).

We have
\[
e^1/R = eI_1/2 - eI_2/2
\]
\[
2e/R = I_1 - I_2
\]
\[
I_1/R_1 = I_2/R_2 = e/2
\]
\[
I_1/I_2 = R_2/R_1 = Y
\]

Substituting in (1),
\[
4/R = 1/R_1 - 1/R_2
\]

whence
\[
R_1 = R(Y - 1)/4Y
\]
\[
R_2 = R(Y - 1)/4.
\]

II. CIRCUIT APPLICATION AND BASIC CONDITIONS FOR BALANCE

Fig. 2 shows how the basic circuit is applied to an amplifier in order to obtain push-pull operation. The voltage developed across winding \( N_2 \) is applied to the grid of valve 2 in the correct phase, the resistor \( R \) being varied to obtain ac plate-current balance.

![Fig. 2—Basic circuit applied to two valves. An unbalanced voltage \( E \) causes push-pull operation by virtue of the transformer \( T \).](image)

Let
\[
N_2/(N_1 + N_2) = T = e_2/e
\]
\[
G_1 = \text{mutual conductance of valve 1}
\]
\[
G_2 = \text{mutual conductance of valve 2}
\]

Also assume negligible distortion and that \( T \) is an ideal transformer. In Fig. 2
\[
I_1 = V_1G_1 \quad I_2 = V_2G_2
\]

and
\[
V_1G_1/V_2G_2 = Y
\]

From (2),
\[
V_1G_1R_1 = V_2G_2R_2 = e/2
\]

For equilibrium conditions
\[
V_2 = e_2 + e_1 - e/2
\]

where
\[
e_1 = (I_1 - I_2)R_0
\]

and using (2)
\[
e_1 = eR_0 \left( \frac{1}{R_1} - \frac{1}{R_2} \right)
\]

From (5) and (6), with due regard to the sign of \( I_2 \),
\[
e_1 = \frac{2eR_0}{R} \left( \frac{Y - 1}{Y + 1} \right)
\]

From (7), (11), and (13),
\[
V_2 = Te - e/2 + \frac{2eR_0}{R} \left( \frac{Y - 1}{Y + 1} \right)
\]

Simplifying and using (10)
\[
2G_2R_1 \left( T - 1/2 + \frac{2R_0(Y - 1)}{R(Y + 1)} \right) = V_1G_1 = \frac{1}{V_2G_2}
\]

† Lister Research Co., 333 George St., Sydney, Australia.
If the system is balanced (true push-pull), \( Y = 1 \) and (14) reduces to
\[
T = \frac{1 + G_1 R/2}{G_1 R}, \tag{15}
\]
which is the required information.

III. Degree of Unbalance for Changes in Balance Conditions

Once \( T \) is evaluated, the dependence of \( Y \) on circuit variables may be obtained. Extracting \( Y \) from (14) and substituting for \( R_i \) from (5), we can write
\[
Y = \frac{1 - G_2 R}{G_2 R} \left( T - 1/2 - 2R_0/R' \right) K'/2.
\]
(10)

where \( G_2', R' \) are the values of \( G_2, R \) other than those used to evaluate \( T \) [see (15)]. Thus for convenience we can put \( G_2' R'/G_2 R = K \neq 1 \).

Using this relation and substituting (15) in (16).
\[
1 - \frac{K G_2 R}{2} \left( 1 + \frac{G_2 R/2}{G_2 R} - 1/2 - 2R_0/R' \right)
\]
(17)

Simplifying,
\[
Y = 1 + \frac{2(1 - K)}{K \left( \frac{2R_0 G_2 R}{K} + 1 \right)}.
\]

Thus \( R_0 \) helps to reduce unbalance. Generally for the simpler circuits \( 2R_0 G_2 \approx 1 \); and if \( R \) is nearly equal to \( R' \), (17) becomes approximately
\[
Y = 1/K.
\]\n
Equation (17) shows that unbalance is independent of valve 1, a most important consideration. In practice, since \( R \) can be small, it can be made quite stable so that unbalance becomes almost entirely due to changes in \( G_2 \).

When the signal voltages applied to the grids of the valves are large compared to the bias, changes in mutual conductance occur. Hence, in such cases, changes in balance occur with changes in signal level, even though \( G_1 = G_2 \) at all levels. Equation (17) shows to what extent this may be minimized by \( R_0 \).

IV. Effect of Unbalance on Power Output

Power output is affected by lack of balance between the two plate currents. The factors to be considered are
1. \( I \sin \omega t \neq I_2 \sin (\omega t + \pi) \).
2. \( Y \neq 1 \), the input signal being varied, if necessary, to obtain maximum undistorted power.
3. Change in sensitivity when \( Y \neq 1 \), due to the voltage \( e_1 \) [see Fig. 2].

Of these, condition 1 is generally negligible if the departure of the currents from opposite phase is less than 10 degrees. Condition 2 is much more important. This applies for circuits (Fig. 2) in which \( R \) is so small that \( e/2 < V_1 \), and \( e_2 = 0 \) (\( R_0 \) by-passed). Condition 3 is the more general case and, of course, must be estimated in conjunction with the effect of condition 2. Conditions 2 and 3 are best considered separately.

A. Case for Condition 2

In Fig. 3, \( Y \neq 1 \), \( e/2 \) is negligible, \( e_1 \) is zero, and \( E = V_1 \).

The power in the load \( R_L \) may be estimated in the manner used for Fig. 1. Thus let
\[
W_1 = \text{power developed in } R_L \text{ when } I_1 = I_2,
\]
\[
W_2 = \text{power developed in } R_L \text{ when } I_1 \neq I_2,
\]
\[
R_{L_1} = \text{effective resistance offered } I_1
\]
\[
R_{L_2} = \text{effective resistance offered } I_2.
\]

Then
\[
W_1 = (I_1)^2, \ R_{L_1} + (I_3)^2 R_{L_3} \text{ as in equation (1)}
\]
\[
W_2 = (I_1)^2, \ R_L \text{ since } I_1 = I_2
\]
\[
W_1 = (I_1)^2, \ R_L \left( 1 + \frac{1}{Y} \right) \text{ from equation (3)}; \text{ and using (5) (allowing for the sign of } I_2),
\]
\[
\frac{W_1}{W_2} = \left( \frac{2Y}{Y + 1} \right)^2.
\]

Setting a limit of 0.5-decibel loss for the unbalanced condition, the value of \( Y \) is found to be 1.13. Using this in (18), the change in \( G_2 R \) is 11 per cent. As indicated previously, the change may be wholly due to \( G_2 \) so that this figure is quite reasonable to maintain. If adjustment of balance is made near maximum output for a particular frequency, (19) shows the power loss resulting from changes in balance at any other frequency.

B. Case for Condition 3

Referring to Fig. 3,
\[
E = V_1 + e/2 + (I_1 - I_2) \cdot R_0
\]
\[
= V_1 \left\{ 1 + G_1 \cdot R_1 + G_1 \left( 1 - \frac{1}{Y} \right) R_0 \right\}
\]
by substitution from (3), (8), and (10).
Elminating $R_1$ by means of (5) (allowing for the sign of $I_2$),

$$V_1 = \frac{E}{1 + G_1 \left( \frac{R(1 + 1)}{4V} + \frac{(Y - 1)R_0}{Y} \right)} \quad (20)$$

Let $V'_1$ = grid-cathode voltage for the particular case when $Y = 1$. Then from (20),

$$V'_1 = \frac{E}{1 + G_1 R/2} \quad (21)$$

so that using the same nomenclature as before

$$W_1 = (I_1)^2 R_L = (G_1 V'_1)^2 R_L \quad (22)$$

From (19)

$$W_2 = (I_1)^2 R_L \left( \frac{1 + Y}{2V} \right)^2 \quad (23)$$

and since in this case $I_1$ is produced by $V_1$ of (20),

$$W_2 = (G_1 V'_1)^2 R_L \left( \frac{1 + Y}{2V} \right)^2 \quad (24)$$

Substituting (20) and (21) in (22) and (23),

$$\frac{W_1}{W_2} = \left( \frac{4V + G_1 [R(Y + 1) + 4(Y - 1)R_0]}{(1 + Y)(2 + G_1 R)} \right)^2 \quad (25)$$

For $Y = 1.1$, $2 R_0 G = 1$, $G_1 R = 0.4$ (a reasonable figure in practice), $W_1/W_2 = 1.04$ so that the loss is about 0.2 db.

For both cases (A) and (B) above, it was assumed that $Y > 1$. If this is so, the limit to undistorted output is the drive on valve 1. If we consider that maximum output is obtained when $Y = 1$ and that $E$ is constant, then for $Y > 1$, $V_1$ will not be exceeded and distortion due to overdrive will not result. For $Y < 1$, $I_2$ must increase if $E$ is constant. If $I_2$ increases, $V_2$ must also increase and overdrive of valve 2 results. At the same time the voltage $e_1$ causes the voltage $V_1$ to increase (20) so that overdrive results on valve 1, also. Thus if $E$ is constant, severe distortion will result for $Y < 1$. This means that if balance is adjusted at maximum output distortion will occur as $R$ is increased beyond the value required for balance.

From (2) we might expect the power to increase for $Y < 1$. But if the power is considered to have a maximum value $W_1$ when $Y = 1$, then distortion results for $Y < 1$ and $E$ must decrease so that $V_2$ becomes the limiting value. Thus the over-all power decreases. It is sufficient for the purpose of this discussion, therefore, that we assume $Y > 1$.

V. INHERENT CIRCUIT STABILITY AT OR NEAR BALANCE

There are two possible modes of oscillation:

A. First Mode

Refer to Fig. 3. If $I_1$ is very small, the phasing of $T$ is such that it would appear oscillation could occur due to feedback in valve 2. If $E = 0$, oscillation just commences when

$$e_1 = V_2 + e/2 + (I_2 - I_1)R_0 \quad (26)$$

where $I_2 > I_1$ because valve 2 initiates the condition. Assume this condition arises by varying $R$ to some new value $R'$. Then $R$ is the value of resistance required for balance and $R'$ is value at which oscillation just commences. From (7), (8), (10), and (25)

$$T = V_2 + V_1 G_2 R_2 + V_2 G_2 R_0 (1 - Y) \quad (27)$$

Thus

$$2 T G_2 R_2 = 1 + G_1 R_2 + G_2 R_0 (1 - Y) \quad (28)$$

Using (15) and (6) (allowing for the sign of $I_2$),

$$\left( \frac{1 + G_2 R/2}{R} \right) = \frac{R'(1 + 1)}{2} + G_1 R_0 (1 - Y) \quad (29)$$

Now the current $I_1$ in this case is produced by the voltages $e/2$ and $e_1$. Hence,

$$I_1 = G_1 (e_1 - e/2) = G_1 V_2 (1 - Y) R_0 - G_2 V_2 R_2 \quad (30)$$

from (10), (3), and (12).

In this case $R_2$ is a component of $R'$, and we can eliminate $R_2$ by means of (6).

$$I_2 - G_1 V_2 (1 - Y - 1) = \frac{G_1 (4 R_0 - R')}{4 + G_1 (4 R_0 + R')} \quad (31)$$

Substituting for $Y$ in (26), we have

$$2 (1 + G_2 R/2) (R'(1 + 2 G_1 R_0) / R) = 4 + G_2 (4 R_0 + R') \quad (32)$$

and when $G_1 = G_2$, this simplifies to

$$R' = \frac{2 R}{1 - G_1 R/2} \quad (33)$$

Perfect stability results when $G_1 R = 2 (T = 1)$. The value of $R_0$ does not affect the stability. Note that it is impossible for oscillation to occur at or near balance. For if $R = R'$, (29) gives $-G_1 R = 2$, which is impossible. If $G_1 R$ is negligibly small, then $R' = 2 R$, which is well removed from $R$. If valve 1 is removed, $Y = 0$; and from (26),

$$R' = 2 R (1 + G_1 R_0) \quad (34)$$
Again, in the limiting case when \( R_0 = 0, R' = 2R \), which is a satisfactory value.

**B. Second Mode**

Fig. 4 shows diagrammatically the equivalent circuit at a high frequency. The grid circuit will consist of the network comprising leakage inductance \( L_s \), self-capacitance \( C_s \), and effective secondary resistance \( R_s \).

\[
R_n = (R_s + T^2R),
\]

where \( R_s \) is the secondary resistance. The impedance of this circuit near resonance is \( L_s/C_s \cdot R_n \) so that if \( R_n \) is sufficiently small and \( L_s \) large a high impedance may result. Feedback from other parts of the circuit, principally the anodes, can, therefore, produce oscillation. Since \( L_s/C_s \cdot R_n \) will be a maximum when \( R = 0 \), oscillation may occur if \( R \) is too small. Generally, \( R \) is sufficiently large to eliminate this problem. As an alternative, the balance adjustment may be accomplished by means of a variable resistance across the secondary of \( T \) instead of across the primary.

The control \( R \) may, therefore, be used to control oscillation in either mode since for mode A the value must be large while for B it must be small; thus oscillation can be made to occur on either side of the balance adjustment. \( R \) may also be used as a control for a highly selective amplifier circuit.

**VI. Loss of Sensitivity at Balance Due to Degeneration**

Referring to Fig. 2, it is seen that a loss of sensitivity occurs due to \( e/2 \). From (21)

\[
E = V_1'(1 + G_1 \cdot R/2)
\]

so that the sensitivity is reduced by the factor

\[
(1 + G_1 \cdot R/2).
\]

By substitution from (15), the loss factor may also be expressed as

\[
T/(T - 1/2).
\]

**VII. Balance for Noises Originating in the Power Supply**

Fig. 5 is the circuit for examination of this aspect of operation. Let

\[
R_{a1} = \text{plate resistance valve 1}
\]

\[
R_{a2} = \text{plate resistance valve 2}
\]

\[
E_n = \text{noise voltage in high-voltage supply}.
\]

We have

\[
V_1 = -(e/2 + e_i)
\]

\[
V_2 = Te - (e/2 + e_i)
\]

\[
I_1 = E_n/R_{a1} - G_1(e/2 + e_i)
\]

\[
I_2 = E_n/R_{a2} - G_2(e/2 + e_i) + TeG_2.
\]

From (2) and (6)

\[
Te = 1/2 \cdot [T I_2 R(Y - 1)].
\]

If \( R_{a1} = R_{a2} \) and \( G_1 = G_2 \),

\[
I_1 - I_2 = -1/2 \cdot [T I_2 R G_2(Y - 1)]
\]

from (32) and (33). Hence,

\[
Y = 1/2 \cdot [T R (1 - Y) - G_2]
\]

for which \( Y = 1 \).

We would expect balance to be independent of the adjustment of \( R \). Balance does depend, however, on the operating characteristics of the valves so that some further control (such as bias or slope) may be provided to adjust this. A simple test of this adjustment is possible with the circuit. For at balance \( Te = 0 \), and no voltage is developed across the secondary of \( T \); thus it is sufficient to observe the grid voltage of valve 2.

**VIII. Distortion**

The ac plate currents of the valves may be expressed by the usual series,

\[
I_1 = aV_1 + bV_1^3 + cV_1^3 +
\]

\[
I_2 = -a'V_2 + b'V_2^3 - c'V_2^3 +.
\]

The total circulating current is the difference between these currents. Usually it is assumed that the coefficients of the two valves are equal \( (a = a', b = b', \text{ and so on}) \), and this will be accepted in the following analysis:

From (35) and (36) the current for any particular coefficient may be expressed in the form

\[
I_{n1} = W V_1^n \text{ nth component for valve 1}
\]

\[
I_{n2} = W(-V_2)^n \text{ nth component for valve 2}.
\]
The total circulating current for any particular coefficient will depend on the feedback voltages \( e, e_0 \), and \( T_e \) (Fig. 6), occurring for that particular component.

![Basic circuit used for discussion on distortion.](image)

Thus

\[
I_{s1} = W_1^n - (e/2 + e_r)u \\
I_{s2} = W_2^n - (1/2 + e_r + T_e)u
\]

since coefficients beyond a for the feedback voltages are negligible. Even components cancel out as with normal push-pull; and for the odd components we have

\[
I_{s1} - I_{s2} = W_1^n - (1/2 + e_0 + T_e)u
\]

where \( n \) is an odd number. From (1)

\[
e = (I_{s1} - I_{s2}) R/2.
\]

Substituting in (37) and using (15), we obtain

\[
I_{s1} - I_{s2} = W_1^n - (1/2 + e_0 + T_e)u = (2T - 1) (2T - 1) / T
\]

Since the distortion in the assumed case is entirely due to odd components, the total distortion is reduced by the factor \( T/(2T - 1) \). Thus distortion reduction is half the gain reduction (31).

IX. Choice of Balance Resistor and Signal Level for Adjustment of AC Plate Currents

A. Balance Resistor

The ultimate value for \( R \) is a compromise. The requirements are perhaps best examined by expressing \( G_R \) in terms of \( T \) in the various equations. For maximum possible stability (29) \( T = 1 \); the loss factor (31) is then 2, and the distortion reduction factor (39) is 1. If minimum ac plate resistance is required, then \( R \) must be small, which requires \( T > 1 \). Again if \( R \) is too small, there is a greater tendency for oscillation in mode 2 unless other precautions are taken. It would appear that the ultimate choice is for a value of \( T \) very close to 1.

B. Signal Level

From (18), \( Y \times (1/K) \); from (16), \( K \times G_1/G_0 \). Since \( G_2 \propto E \), it follows that \( Y \propto E \) (Fig. 2). Thus to obtain maximum power [(24) \( Y = 1 \)], balance adjustments should be made at the maximum value of \( E \). However, even harmonics are only cancelled if \( V_1 = V_2 \) (37). If \( a \neq a' \), then when \( Y = 1 \), \( V_1 \neq V_2 \). If a bias or slope adjustment is also provided, it would appear desirable to adjust at maximum output so that \( a = a' \). This results in maximum output and minimum distortion. However, it is sometimes desirable to adjust this extra balance when \( E = 0 \) so that \( a = a' \) at low signal level, and minimum noise from the high-tension supply at zero signal is obtained. If this is so, then at the maximum value of \( E \) it is unlikely that \( a = a' \). The balance adjustment \( R \) would then be made to obtain minimum distortion at maximum possible output. Since this would occur when \( V_1 = V_2 \), if \( a \neq a' \), \( Y \neq 1 \), and the maximum possible output would be slightly less than obtained with \( Y = 1 \).

X. Conclusion

The circuit under discussion has interesting possibilities. Push-pull operation is possible, yet the input impedance of the circuit is high. Thus the output stages may be preceded by a high-gain voltage amplifier, permitting an extremely compact amplifier unit. This also simplifies the problem of applying inverse feedback over the whole amplifier. The adjustment required for push-pull operation is quite simple and the stability of balance, as well as the inherent circuit stability, is quite good. Cancellation of noise voltages from the power supply is unaffected by the balance adjustment. Slight improvement of distortion may be obtained without excessive loss of sensitivity. It can be expected that changes in balance will occur with signal level, but this should not be any great disadvantage. The circuit permits an easy observation on the adjustment of the operating characteristic when this is provided.

![An interesting modification.](image)

Two modes of oscillation which are independently adjustable are possible. This indicates that the circuit could be used as a highly selective amplifier incorporating a variable selectivity control. Fig. 7 is an interesting
modification of the basic circuit discussed above; it does not require a center tapped transformer.

Fig. 8 shows the values of various factors in the foregoing formulas, plotted against the transformation ratio $T$. (See preceding page.)

## Recent Developments in High-Power Klystron Amplifiers*

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### Summary

The present status of klystron power amplifiers is reviewed by discussing the three types of electron-beam focusing used. The maximum power output, efficiency, gain, bandwidth, temperature compensation, and tuning means of present-day klystrons are briefly discussed. Examples of several typical tubes are given.

## I. INTRODUCTION

The increasing development effort devoted to high-power klystrons, as contrasted to milliwatt local-oscillator types, has brought about a rather rapid improvement in the characteristics of transmitter-type klystrons. There has been an increase in power output and efficiency, large power gain has proven to be very useful, and tuning and temperature compensation characteristics have developed to a satisfactory point. The development of tubes for pulsed applications has opened up this particular field to high-stability frequency control. The increasing use of the radio spectrum is making good frequency control important for both continuous-wave and pulsed operation.

## II. Tube Characteristics

### 1. Types of Focusing

First, the capabilities and characteristics of present-day transmitter-type klystrons will be discussed by dividing them into three groups corresponding to the type of electron-beam focusing used. Tubes both with and without grids at the interaction gaps will be discussed.

An electrostatic-type electron gun has been used to form the electron beam of virtually all present-day klystrons, but the high-density beams utilized have been maintained over a long path in three different ways, namely: ion focusing, space-charge focusing, and magnetic focusing.

In the first case, positive ions formed from the residual gas molecules neutralize the space charge of the electrons in the beam, and thus allow the beam to continue without space-charge spread. Ion focusing is, of necessity, limited to cw tubes since no ions would be present at the beginning of a pulse to focus the beam. Ion focusing adapts itself most readily to klystrons having grids at the interaction gaps since it is limited to larger diameter beams which are best coupled to the rf voltage by a grid structure.

In the case of space-charge focusing, the electron beam is allowed to follow a trajectory determined by the initial convergent angle of the electron gun and by the mutual space-charge repulsion forces of the electrons. The beam comes down to a minimum, and then spreads out so that it does not have a uniform diameter over its length. This type of beam fits best into a pulsed tube having gridded interaction gaps.

The third type of beam maintenance is by means of an axial magnetic field as described by Wang. After the beam is formed by an electron gun, it may be focused for any distance desired by application of the correct value of uniform magnetic field. This type of beam focusing is useful for both cw or pulsed tubes which do not have grids at the gaps.

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Fig. 1(a)—Example of ion-focused beam in a three-cavity amplifier with gridded gaps. The tube is the SAS-28 with 250-watts output at 2,600 mc and 30 db gain.

Fig. 1 shows examples of these various beam-focusing types. Fig. 1(a) shows the cross section of a three-cavity, ion-focused, gridded, cw tube with 250-watts output.

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output at 2,600 mc. It will be noticed that a low-angle electron gun is used here, and that since the space charge of the electrons in the beam is neutralized by positive ions, the beam does not spread, but traverses a comparatively long distance without other focusing means. This tube is a three-resonator cascade buncher with a power gain of over 1,000, and is tuned by an inductive plunger on one wall of each resonator. The tube is used in crystal-controlled, radio-doppler, velocimeter systems.

Fig. 1(b) shows a gridded, pulsed, space-charge-focused tube for 20-kw peak output. In this tube, a cathode with a large semi-angle is used to obtain a convergent beam which is space-charge focused. The pulse lengths used are too short to allow enough ionization to occur to neutralize the beam space charge. This tube has three cavities which are tuned by changing the gap spacing, and has a power gain of over 100 at 1,000 mc. It was designed for use in ground installations of pulse air-navigation systems.

Fig. 1(c) shows the typical structure of a 500-watt cw magnetically focused tube. An electrostatic-type electron gun, which is excluded from the magnetic field, focuses the beam at a high angle, and with space-charge repulsion, forms the required minimum diameter. At the minimum diameter point, where the beam is parallel, it passes through the pole piece and enters a uniform axial field. The beam then spirals slowly at constant diameter down the drift tube for any required distance. The space-charge repulsion forces and centrifugal force of rotation are just balanced against the centripetal magnetic force on the electrons. This tube has a gain of over 1,000 and an output power of 500 watts cw at 5,000 mc, and is used in an instrument landing system.

Fig. 2 is a photograph of this tube, the SAC-33, cut open to show the actual construction details. An inductive plunger in each resonator is used for tuning, iron pole pieces on each side of the resonators form the magnetic field by connection to a permanent magnet, and an iris-coupled output through a waveguide window is used to carry the high power output.
2. Maximum Power

The maximum power output available in the present state of the art for the various types of klystrons utilizing a solid cylindrical electron beam is shown in Fig. 3.

![Graph showing power output and efficiency versus frequency](image)

Fig. 3—Approximate ultimate power data for klystrons. The solid line is for gridded tubes and the shaded region the average power for pulsed tubes.

This assumes power density as the limiting factor by causing excessive local heating. Cathode current density is not a limitation with modern gun optics and cathode materials. The ordinate is cw power output or average pulse power. The shaded region gives the range for various designs of gridless tubes. For example, at 3,000 mc this is about 10 kw, or several megawatts peak at low-duty cycles.

The ultimate power is greater at lower frequencies because the amount of beam power transmitted can increase as the square of the wavelength for constant radial electrical dimensions. To avoid difficulties with space-charge repulsion limitations, the best way to increase the beam power is to raise the beam voltage. For a gridded tube, the drift-tube diameter is limited in size by the variation of gap voltage with radius as the diameter of the grid approaches a half wavelength. Hence, the limiting power varies as the square of the wavelength. For a gridless tube, the diameter of the drift-tube is limited by electrical beam-to-gap coupling considerations. For constant electrical interaction parameters, the increase in voltage at longer wavelengths allows a further increase in physical size of the tube. The factors combine to give a relationship of power output varying somewhat faster than the inverse cube of the frequency.

The maximum power limit for gridded tubes is set by the temperature of the grids. The temperature limit occurs when thermionic electron emission from the hot grids causes heavy electronic gap loading. This occurs before burn out of the grid is imminent. For the lower frequency tubes (below 5,000 mc) the grid cooling is accomplished primarily by radiation because the grids are relatively long. Above about 5,000 mc the primary contribution to grid cooling is made by conduction. Present cw techniques in gridded tubes allow power amplifiers to be built up to about 10,000 mc and multipliers and reflex tubes to about 60,000 mc.

The limit of pulse powers for gridless tubes is usually greater than that power which gives the same average power as for a cw tube at the same frequency. This is true with pulse tubes because higher beam voltages are used which allow a larger structure and thus a higher average power-dissipation ability. Pulse klystrons for microsecond pulses, with peak power outputs of several megawatts and power gains in the thousands, are practical.

3. Efficiency

Also plotted on the chart of Fig. 3 is an efficiency versus frequency line for gridded power klystron amplifiers whose power output is near the ultimate limit. The efficiency curve is fairly flat up to around 3,000 mc, and then starts to drop. This dropping off at the higher frequencies results from smaller input power, thus making circuit losses more significant. The circuit losses themselves also increase at the higher frequencies. Furthermore, the physical size of tube parts becomes small and percentage grid interception increases since the vanes cannot be reduced proportionately because of mechanical limitations. When mechanical tolerances become troublesome, they cause a reduction in efficiency.

The efficiency of two resonator klystrons can be 58 per cent, theoretically; while if gain in a three-resonator klystron is sacrificed, a higher efficiency is theoretically obtainable. However, practical considerations usually limit the obtainable plate efficiency of power klystrons to around 30 per cent in the region of 3,000 mc. At high powers under unusual design circumstances, efficiencies of 40 per cent are realizable.

The input power division between losses and useful output power is shown in Fig. 4. In a gridded tube, some beam electrons are lost because of interception by the grids. This reduces the possible efficiency from the theoretical 58 per cent. A loss of 18 per cent for a two-cavity tube is typical except at higher frequencies (above 3,000 to 5,000 mc) where the loss becomes progressively greater. The electronic conversion efficiency might be around 50 per cent instead of the theoretical 58 per cent because of unevenness of bunching across the diameter of the beam. Three-fifths of this rf energy may reach the useful load, although higher circuit efficiencies can sometimes be realized. The undesired losses include 6 per cent of the beam power taken by transit-time electron loading, 6 per cent by slow secondary electron loading, and 4 per cent by rf losses in the output resonator.

The transit-time loading arises since the electrons take a finite time to cross the gap, and can therefore be
Gapless Coverage in Air-to-Ground Communications at Frequencies Above 50 mc*

KENNETH A. NORTON†, FELLOW, IRE, AND PHILIP L. RICE‡

Summary—It is shown that there is an optimum ground-station antenna height for use in typical air-to-ground communications systems. When antennas lower than this optimum are used, the maximum distance range is reduced at all aircraft altitudes. When antennas higher than this optimum are used, the interference between the direct and ground-reflected waves causes gaps to occur in the coverage at the higher aircraft altitudes. The minimum altitude at which the gap in coverage occurs decreases with increasing frequency and with increasing ground-station antenna height. The optimum antenna height decreases with increasing frequency and this, in turn, reduces the maximum distance range for satisfactory communication as the frequency increases. The curves presented are based on values expected from theory for a smooth spherical earth. Such curves have been found experimentally to approximate very well the average practical operating results.

In a recent paper, Kirby, Herbstreit, and Norton presented methods for calculating the service range to be expected in air-to-ground communications at frequencies above 50 mc. The validity of these methods of calculation had previously been verified in flight-evaluation tests for the determination of the propagation characteristics at these frequencies, conducted at the U. S. Naval Air Test Center, Patuxent River, Maryland, in 1948 and 1949.

It is the purpose of the present paper to use these methods of calculation for determining an optimum ground-station antenna height for use in air-to-ground communications. The concept of an optimum antenna height as used in this paper may be understood by reference to Figs. 1 and 2. Fig. 1 gives the coverage for a ground-station antenna height, h = 35 feet, while Fig. 2 is for h = 115 feet. Throughout this paper it will be assumed that antennas with patterns equivalent to those of vertical half-wave dipoles are used on the aircraft and at the ground station. The aircraft transmitter is assumed to have a power of 6 watts, and the ground-station receiver an effective sensitivity of 3 µw across a 50-ohm input impedance, i.e., a received radio-frequency signal of 0.18 µw is assumed to provide satisfactorily intelligible. Calculations are made for two values of the communications-system loss, 6 db and 12 db; this includes such things as transmission line and antenna-impedance matching losses, deviations in antenna gain from that of the assumed half-wave dipole, reductions in receiver sensitivity relative to the above assumed value, and so on. It is also assumed in this paper that the earth is smooth and has a dielectric constant ε = 15 and a conductivity σ = 0.01 mhos/meter which corresponds to land of good conductivity. If the propagation were over either fresh water or sea water...
(see Table 1), the results would be expected to be the same qualitatively, but somewhat higher values of optimum antenna height would be indicated.

Reference to Fig. 1 shows that an aircraft at an altitude of 16,500 feet may expect to deliver a signal of 3 \( \mu \)V or more across the ground-station receiver terminals at all distances out to the maximum range, at this altitude, of 154 miles. Aircraft flying at higher altitudes, however, will encounter a gap in their communications at intermediate distances. For example, an aircraft flying at an altitude of 20,000 feet will deliver less than 3 \( \mu \)V at distances between 73 and 78 miles from the ground station. The coverage just described corresponds to an assumed communication-system loss of 6 db; the results for an assumed value of 12-db loss may be determined on Fig. 1 simply by reference to the 6-\( \mu \)V contour. For example, the maximum altitude, \( H_m \), for gapless communications with 12-db system loss is reduced to about 8,000 feet from the value of \( H_m = 16,500 \) feet, corresponding to 6-db system loss.

Turning now to Fig. 2 we find that \( H_m \) for \( h_1 = 115 \) feet is reduced to only 2,700 feet for a 6-db loss and to 1,800 feet for a 12-db loss. It should be noted, of course, by comparison of the results shown on Figs. 1 and 2, that the maximum-distance range has been increased at all altitudes by the use of this higher ground-station antenna height. For example, with 6-db loss, the 16,500-foot maximum range of 154 miles, corresponding to \( h_1 = 35 \) feet, is increased to 173 miles for \( h_1 = 115 \) feet. But this 19-mile extension in maximum-distance range is achieved at the cost of introducing gaps in the coverage (at this same altitude) between 67 and 68 miles, between 87 and 93 miles and between 120 and 127 miles.

Considering the fact that solid coverage at the shorter ranges is usually more important operationally than an increase in the maximum-distance range, calculations have been made of the maximum ground-station antenna height, \( h_{1 \text{m}} \), which will insure gapless communications out to the maximum-distance range at all altitudes less than a specified value, \( H_m \). The value, \( H_m \), is determined by operational considerations and, in this paper, calculations have been made for the illustrative values of \( H_m = 10,000 \) feet, 25,000 feet, and 40,000 feet. Fig. 3 shows these values of \( h_{1 \text{m}} \) as a function of the radio frequency throughout the range from 100 to 1,000 mc. It is interesting to note that there should be no gaps in communications at altitudes below \( H_m = 10,000 \) feet.

### Table 1

**Comparison of \( h_{1 \text{m}} \) Expressed in Feet for Propagation at 328 mc Over Good Ground and Over Sea Water**

<table>
<thead>
<tr>
<th>( \sigma ) mhos/meter</th>
<th>( \epsilon )</th>
<th>Brewster's angle ( \alpha ) (milliradians)</th>
<th>System loss = 6 db</th>
<th>System loss = 12 db</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>( H_m = 10,000' )</td>
<td>25,000'</td>
<td>40,000'</td>
</tr>
<tr>
<td>Good ground</td>
<td>0.01</td>
<td>45.7'</td>
<td>27.7'</td>
<td>21.2'</td>
</tr>
<tr>
<td>Sea water</td>
<td>4.64</td>
<td>93.8'</td>
<td>54.8'</td>
<td>41.0'</td>
</tr>
</tbody>
</table>

**Fig. 2—328-mc radiation pattern for air-to-ground communication over a smooth spherical earth.**

with a 6-db communications-system loss on frequencies below 118 mc, regardless of the height of the ground-station antenna.

Considering the fact that most air-to-ground communications have been made in the past at frequencies less than 150 mc and using ground-station antenna heights less than 50 feet, we see by Fig. 1 that no prob-

lem of gaps in communications due to interference between direct and ground-reflected waves should have been expected. However, as the higher frequencies in the 100- to 1,000-mc band are employed in the future, more and more difficulty from this propagation phenomenon may be expected.

The solid curves on Figs. 4, 5, 6, 7, 8, and 9 show the maximum-distance range for satisfactory communications at selected aircraft altitudes, \( h_{2n} = 1,000, 2,000, 5,000, 10,000, 25,000, \) and \( 40,000 \) feet, to be expected when the ground-station antenna height is taken to be the optimum value, \( h_{1n} \), corresponding to the selected value of the maximum required altitude, \( H_{mn} \). The dashed curves are the maximum-distance ranges to be expected for a ground-station antenna height, \( h_{1} = 35 \) feet. These dashed curves for \( h_{1} = 35 \) feet are shown only for frequencies such that \( h_{1n} \) is greater than 35 feet. The additional gap-free distance range to be expected on these lower frequencies by increasing the ground-station antenna height from \( h_{1} = 35 \) feet up to the value \( h_{1n} \), as shown on Fig. 3, is simply the difference between the dashed and solid lines on Figs. 4 to 9, inclusive.

Much shorter gap-free distance ranges are to be expected at the higher frequencies at all aircraft altitudes.

Fig. 3—The maximum ground-station antenna height, \( h_{1n} \), for gapless over land air-to-ground communications up to the altitude, \( H_{mn} \), calculated for a smooth spherical earth and the average atmosphere at Washington, D. C. Aircraft transmitter power 6 watts; ground-station receiver sensitivity 0.18 \( \mu \text{w} \). Aircraft and ground-station antennas: half-wave vertical dipoles.

Fig. 4—The maximum-distance range for gapless over land air-to-ground communications calculated for a smooth spherical earth and the average atmosphere at Washington, D. C. Aircraft transmitter power 6 watts; ground-station receiver sensitivity 0.18 \( \mu \text{w} \). Aircraft and ground-station antennas: half-wave vertical dipoles.

Fig. 10 illustrates the reduced coverage to be expected at 1,000 mc. This figure also illustrates the unusual appearance which the lobes have when, as in this particular case, the first null occurs near Brewster's angle. Throughout this paper the optimum values of antenna height were computed by determining values of \( h_{1n} \) for which the electrical path-length difference, \( \theta - \epsilon \) (See footnote reference\(^1\)), is equal to 360° at the maximum height, \( H_{mn} \), required for gapless communications. It will be noted on Fig. 10 that this particular criterion for gapless communications is very slightly in error at 1,000 mc because of the peculiar behavior of the lobes near Brewster's angle. In fact, the values of \( h_{1n} \) determined in this way are actually a little high at 1,000 mc. These differences are small in this case and are com-
Fig. 5—See caption of Fig. 4.

Fig. 6—See caption of Fig. 4.

Fig. 7—See caption of Fig. 4.

Fig. 8—See caption of Fig. 4.
pletely negligible at lower frequencies, and consequently have been neglected in the computations in this paper. It should be noted that Brewster's angle is a function primarily of the relative dielectric constant of the ground in this frequency range for over land propagation, and thus the phenomenon illustrated on Fig. 10 would be expected to vary somewhat with the nature of the ground over which the communications are attempted.

A few calculations have been made at 328 mc of the optimum antenna height appropriate for propagation over sea water, and these are compared in the following table with the corresponding values over land.

Methods for eliminating these gaps, other than by the reduction of the ground-station antenna height, are discussed in the paper by Kirby, Herbstreit, and Norton, and will not be repeated here. The optimum antenna heights to be employed using those other methods will be different from the values given in this paper for the simple case of propagation between half-wave vertical dipoles.

ACKNOWLEDGMENTS
This paper grew out of a suggestion by Morris Schulkin that an optimum pair of altitudes can be found for height-diversity reception of air-to-ground communications. Assistance with the calculations has been given by Harold Staras, Marvin Blum, Richard J. Rybak, Bradford R. Bean, Mrs. Elizabeth B. Sprecker, Stanley Weintraub, and Mrs. Marion S. Bradford.
A Coincident-Current Magnetic Memory Cell for the Storage of Digital Information

WILLIAM N. PAPIAN

Summary—A small, ring-shaped, ferromagnetic core with properly "rectangular" B-H characteristics may be operated so that its flux polarity reverses only when the correct combination of two or three magnetizing windings are coincidently excited. Such cores may then be used as memory devices and assembled into a two- or three-dimensional memory system with storage-cell selection at the intersection of two or three space co-ordinates. Only a core which retains a large percentage of remanent flux of the proper polarity, in spite of repeated "nonselecting" disturbances, can be used as a coincident-current magnetic memory unit. Repetitive pulse-pattern testing designed to obtain quantitative data on the operation of such units, in the form of defined "information-retention ratios" and "signal ratios," indicates that only a few core materials are satisfactory.

A SCHEME for storing binary information in a three-dimensional array of small ferromagnetic cores and selecting the desired core by exciting the proper three co-ordinate lines has been presented by Forrester in a recently published article. Operation in such an array imposes certain requirements on the ferromagnetic cores which can best be stated after a simple outline of the storage scheme.

Basic Core Operation

A stored binary digit may be represented by the direction of the magnetic flux within a core which has a "rectangular" hysteresis loop. The digit may be sensed, or read, by applying a large magnetizing force of fixed arbitrary polarity and observing the voltage induced in a sensing winding.

Fig. 1 shows a hysteresis loop for a core which might be suitable as a cell in a three-dimensional system; the loop is determined by symmetrical cyclical excitation of amplitude \(H_M\).

Assume, at the start, that the core's state is at the point \(-B_R\). The application of a magnetizing force of \(+H_M/2\) moves the operating point to \(x\); upon removal of the magnetizing force, the operating point returns along the dashed line to a point just above \(-B_R\).

The path traveled during the application and removal of the full \(H_M\) is quite different; the operating point moves to \(y\), and then to \(+B_R\). The core reverses its magnetization and the flux undergoes a large change.

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† Digital Computer Laboratory, Department of Electrical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.


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Two- and Three-Dimensional Selection

If nine such cores are arranged in a two-dimensional array, as in Fig. 2, and currents of magnitude \(I_M/2\) (where \(I_M\) results in a magnetizing force of \(H_M\) per core) are caused to flow coincidentally in selected lines \(x_1\) and \(y_2\) as shown, core \(F\) is the only core in the array which has the full magnetizing force, \(H_M\), impressed. Cores, \(D, E, C,\) and \(J\) have \(H_M/2\) impressed; cores \(A, B, G,\) and \(H\) have no impressed magnetizing force. Each core is, in this arrangement, a coincidence device, and the only core whose magnetization is significantly affected is the one at the junction of the selected lines. (The output signal may be taken from the sensing windings, \(S\), after suitable mixing.)

The extension to three dimensions may be accomplished by stacking two-dimensional arrays, like the...
ones of Fig. 2, along a z axis, with corresponding x lines connected in common and corresponding y lines connected in common. In this arrangement the application of \( H_m/2 \) to an x line and a y line results in the selection of a line of cores parallel to the z axis. All of these cores, except a desired one, may be "unselected" by the application of \( -H_m/2 \) to the cores in each z plane, except the one containing the desired core.

Greater Selecting-Current Ratios

Variations on the selection scheme described above have been devised which impose less stringent requirements on the core. It is possible for the core to have to discriminate between currents which bear 3:1, 5:1, or greater ratios to each other; advantage may be taken of these greater current ratios to reduce switching times, increase signal-to-noise ratios, or relax some of the hysteresis-loop requirements. The cost is an additional increase in the electronic equipment surrounding the system for each increase in the \( H \) ratio.

The discussion that follows is concerned with core requirements for operation with a 2:1 selecting-current ratio. A core that operates satisfactorily with a 2:1 ratio will have a high margin of reliability at greater ratios.

Information-Retention and Signal Ratios

The ONE-to-ZERO output-signal ratio is an important criterion by which to judge a simple magnetic binary storage unit. However, this ratio is insufficient for judging a coincident-current unit of the type described, and a set of new criteria have been set up for that purpose.

Information Retention

Refer back to Fig. 1 and let an "undisturbed ONE" be defined as the \(-B_r\) flux-state of the core and an "undisturbed ZERO" as the \(+B_r\) state. Let a "read" pulse of \( H \) be arbitrarily fixed at \( +H_m \) so that reading a ONE results in a large flux change and a correspondingly large output pulse, and reading a ZERO gives a small output pulse. A ZERO is then, "written" by an \(+H_m\) pulse also, and a ONE is written by an \(-H_m\) pulse.

Recall that selecting one core in a two- or three-dimensional array results in the application of \( H_m/2 \), called a "nonselecting" pulse, to cores elsewhere in the array. The application of repeated nonselecting read pulses to a core containing a ONE tends to run the state of that core up along the B axis, as indicated by the dashed lines in Fig. 1, disturbing or destroying its information. When the hysteresis loop is properly rectangular and all parameters correctly adjusted, the operating point moves up the axis only to some asymptotic position not far above the point \(-B_r\). This is the situation for a core which operates satisfactorily in the coincident-current scheme.

A core which contained an undisturbed ONE and has been subjected to a large number of nonselecting read pulses is considered to hold a "disturbed ONE." By the above reasoning, the disturbed-ZERO output is usually lower than the undisturbed-ONE output.

In an analogous manner, repeated nonselecting write-ONE pulses will run the core's operating point from \(+B_r\) downward, increasing the size of a ZERO output pulse so that a disturbed-ZERO output is usually larger than an undisturbed-ZERO output.

Signal Ratios

Since nonselecting disturbances may reduce the output signal from a core containing a ONE and increase the output from a core containing a ZERO, the ratio of the disturbed-ONE output to the disturbed-ZERO output, called the "disturbed-signal ratio," is a critical measure of a core's performance as a coincident-current memory unit. This ratio approaches infinity in the ideal case, and should be much greater than one if reasonable discrimination between the binary digits is to be obtained.

The application of a nonselecting pulse to a core results in a voltage output, called a "nonselecting output," that is, a form of noise. The ratio of a disturbed-ONE output to a nonselecting output, called the "nonselecting signal ratio," is another important criterion of operation. Like the disturbed-signal ratio, it approaches infinity in the ideal case and should be much greater than 1 for satisfactory operation.

Hysteresis Loop Shapes

The two ratios mentioned above are functions, largely, of the shape of a core's B-H loop. The values of the ratios approach the indicated ideals as the rectangularity of the hysteresis loop increases.

From the idealized hysteresis loop of Fig. 3, some necessary conditions for coincident-current operation.
may be stated. A loop must exist for which the following relations hold true:

\[ H_M > H_2, \]
\[ \frac{H_M}{2} < H_1, \]

where \( H_I \) and \( H_2 \) are the points at which the B-H curve changes direction abruptly. Combining these gives one general requirement on the hysteresis loop shape,

\[ H_2 < 2H_1. \]

Experimental results give qualitative support to this general requirement.

**Experimental Results**

Cores were tested to ascertain signal ratios, B-H characteristics, and response times. Where possible, the testing was accomplished repetitively and at a high rate, and results were presented on an oscilloscope.

**Test Technique**

Previous considerations lead directly to the magnetizing pulse patterns desired for signal testing. Two of these patterns are illustrated in Fig. 4; mode a consists of alternate-polarity, full-amplitude pulses for checking an undisturbed ONE; mode b checks a disturbed ONE by interspersing a large number of half-amplitude, nonselecting pulses between the negative (write-ONE) pulse and the positive (read) pulse. The response to the nonselecting pulses may also be observed during mode b operation. Other modes check for undisturbed and disturbed ZEROs. (Pulse amplitudes, lengths, spacing, and the number of intervening nonselecting pulses are independently variable.)

Core B-II characteristics were generally observed at low frequencies by the usual methods.

Response times were taken to be the lengths of the disturbed-ONE output pulses, and the length of the test pulses was kept somewhat larger than this.

**Optimum Results**

Many cores were tested. The problem was well bracketed by two of them, one metallic, the other a magnetic ferrite.

The best metallic core, made by Allegheny Ludlum of one-mil "Siletrometer" tape, has excellent signal ratios; its response time, during the reading of a ONE, is about 25 microseconds.

Scope traces for this core, for the disturbed-ONE mode and the disturbed-ZERO mode, are shown in Fig. 5; arrows point to the pertinent output pulses. The disturbed-signal ratio and the nonselecting signal ratio are both obtainable from these traces. (The time scale is 5 microseconds per large division.) The negative trace in the upper photograph is the core output when the ONE is written; the heavy center trace combines the large number of nonselecting outputs which follow the writing; and the final disturbed-ONE output shows as the large positive pulse. The positive trace in the lower photograph is the output from the read or write-ZERO operation; the interspersed nonselecting write-ONE pulses merge in the heavy negative trace.

A very promising material for high-speed work in this field is magnetic ferrite. Good results were obtained with a General Ceramics and Steatite core, which has fair signal ratios and a response time near one-half microsecond.

Fig. 6 shows scope photographs for this core under two conditions. The first column was taken for \( H_M \)
adjusted to optimum amplitude. The second column was taken with too large an $H_M$ amplitude, resulting in an increased disturbed-ZERO output and a decreased disturbed-SIGNAL ratio. This led to an unsatisfactory disturbed-SIGNAL ratio close to one in value.

<table>
<thead>
<tr>
<th>CORE CRITERIA</th>
<th>BEST METALLIC CORE</th>
<th>BEST FERRITIC CORE</th>
<th>IDEAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISTURBED-SIGNAL RATIO</td>
<td>13</td>
<td>6</td>
<td>oo</td>
</tr>
<tr>
<td>NON-SELECTING SIGNAL RATIO</td>
<td>16</td>
<td>3½</td>
<td>oo</td>
</tr>
<tr>
<td>RESPONSE TIME</td>
<td>25 µSEC</td>
<td>10 µSEC</td>
<td>0</td>
</tr>
</tbody>
</table>

Fig. 7—Core comparisons.

The table in Fig. 7 summarizes the important test results for the two cores. $H_M$ was adjusted to the optimum value in each case. The test results are compared to the ideal values shown in the third column of the table. The signal ratios are found from the voltage-time areas of the output pulses; this gives a rather pessimistic, but fundamental, measure of a core's characteristics.

The signal ratios of the metallic core are probably as good as are needed for proper operation of large arrays. Those of the ferrite are too low.

On the other hand, the response time of the metallic core, while sufficiently low for many purposes, is too long for the high-speed memory of a computer like M.I.T.'s Whirlwind I, where a memory access time of a few microseconds is desired. The ferrite's response time of one-half microsecond is as fast as can be used today.

**Conclusion**

Summarizing, a small, ring-shaped, ferromagnetic core with properly rectangular B-H characteristics may be operated so that its flux polarity reverses only when the correct magnetizing windings are coincidentally excited. Such cores may then be used as cells in a three-dimensional memory system with cell selection at the intersection of three space co-ordinates.

This scheme promises to make available compact, reliable, and long-lived digital-computer storage which contains, inherently, its own selection mechanism. Selection is made along space co-ordinates only, and high operating speeds are possible.

Further development work at M.I.T. is being aimed toward improving core materials, and toward assembling large numbers of these cores into a high-speed memory system.

**An Internal Feedback Traveling-Wave-Tube Oscillator**

E. M. T. Jones†, Associate, IRE

*Summary*—A theory of operation neglecting space charge is presented for the internal feedback traveling-wave-tube oscillator. Experimental results, obtained from an oscillator using a helix as the interaction structure, are shown to agree closely with the theory. A brief discussion of oscillators operating on space harmonics is given, and it is suggested that an oscillator operating on the space-harmonic principle might have desirable characteristics for a millimeter wave generator.

**I. INTRODUCTION**

TRAVELING-WAVE-TUBE oscillators can be divided into two classes on the basis of the feedback arrangement. Field's has reported successful investigation of widely tunable systems of the first class which employ feedback through external circuits and suppress internal feedback to eliminate unwanted oscillations.

A second class of oscillators employs these internal feedback mechanisms under controlled conditions. The small signal theory of traveling-wave amplifiers, neglecting space-charge effects, will be extended in the following theoretical discussion of internal feedback oscillators to show relationships defining the minimum current necessary to support oscillation, range of electronic tuning, and voltage width and separation for various possible modes of oscillation.

**Conditions for Oscillation**

J. R. Pierce has shown that an electromagnetic wave traveling along a conducting structure, such as a helix,
with a phase velocity much less than that of light in free space, can interact with, and extract energy from, an electron beam. At the termination of the interaction structure, a wave is reflected back along the same path, returning some of the amplified signal from the output to the input, where, upon a second reflection, it can be reamplified. Unless a high attenuation is introduced to absorb the reflected energy, all amplifiers will oscillate at frequencies within a series of discrete bands. The conditions for any oscillation are that the electrical length around the closed feedback path should be an integral number of wavelengths and that the power gain in the forward direction should be more than sufficient to supply all losses in the complete circuit.

The electrical length around the feedback loop depends in a complicated way on the propagation properties of the interaction structure in the presence of an electron beam. It can be computed to a fair degree of accuracy for standard interaction structures from published theories for velocity of propagation.

![Diagram](image)

**Fig. 1—**CN for the start of oscillation, proportional to the one-third power of the beam current, as a function of the loss L of the interaction structure (assumed uniformly distributed) for various fractions F of the available power coupled out of the cavity.

Expressed mathematically, the gain condition is

\[ G - L' = -10 \log_{10} \left(1 - F \right). \]  

(1)

where

- \( G \) = forward gain (db) of the tube considered as an amplifier
- \( L' \) = total cold loss (db) of the interaction structure
- \( F \) = fraction of the available power that is removed by the output system.

The gain condition for the start of oscillation can be determined from published small signal analyses of the gain of traveling-wave amplifiers. An analytic expression for the gain condition for an oscillator, with uniformly distributed attenuation on the interaction structure, can be determined by applying Tilloston's three-wave approximation to the curves of Pierce, which neglect space charge. Fig. 1 shows a plot of the gain parameter CN for the start of oscillation as a function of the interaction structure cold loss L, which is assumed uniformly distributed. Here C is Pierce's normalized impedance parameter which is proportional to the one-third power of the beam current, and N is the length of the interaction structure, measured in wavelengths.

**Tuning of Internal Feedback Oscillators**

An internal feedback oscillator can be tuned from one natural oscillation frequency to another by varying the beam voltage if the interaction structure is dispersive. To cover the range between natural frequencies, it is necessary to change the electrical length of the feedback loop (e.g., by moving a shorting piston at one end of the oscillator cavity). For an oscillator operating on the dominant mode, more gain per unit length can be obtained if a positive dispersion structure (i.e., one in which the phase velocity decreases with increasing frequency) is used instead of a negative dispersion structure (i.e., one in which the phase velocity increases with increasing frequency).

A small amount of electronic tuning on one mode of oscillation is possible because the wave velocity on the interaction structure, and hence the electrical length of the feedback loop, are influenced slightly by the velocity of the electron beam. The total frequency change \( \Delta f \) across a mode of oscillation is given by

\[ \Delta f = \frac{1}{2} \left[ \frac{\partial v_f}{\partial f} \right] \int_{v_f}^{v_f} \frac{\partial f}{\partial v_f} \, dv_f, \]  

(2)

where

- \( v_f \) = beam velocity (cm per second) corresponding to the low-frequency oscillation limit of the mode
- \( v_{sl} \) = beam velocity (cm per second) corresponding to the high-frequency oscillation limit of the mode
- \( v_f \) = phase velocity (cm per second) of the wave on the interaction structure in the direction of the electron flow

\[ \frac{\partial v_f}{\partial f} \]  

\[ \frac{\partial f}{\partial v_f} \]  

\[ \int_{v_f}^{v_f} \]  


for a given number, but increases less rapidly for higher currents. Nevertheless, the voltage width of the modes is quite large at beam currents not much larger than the starting current.

Voltage Separation Between Modes

The voltage separation between modes of oscillation for a given number (n) of wavelengths around the feedback loop depends primarily on the dispersion characteristic of the interaction structure. An expression for the voltage separation between modes of oscillation \( \Delta V \), divided by the beam voltage, \( V' \), is

\[
\frac{\Delta V}{V'} \sim \frac{2}{n + 1} \frac{\Delta f}{\Delta \nu} + \frac{r_o}{f}
\]

The separation between modes of oscillation increases as the number of wavelengths around the feedback loop decreases, and as the positive dispersion increases.

Therefore, the most favorable positive dispersion structure from the point of view of voltage separation of modes, is one that is electrically short (small n) and one in which the product

\[
\frac{\Delta f}{\Delta \nu} \cdot \frac{r_o}{f}
\]

is small.

II. EXPERIMENTAL

An internal feedback traveling-wave-tube oscillator using a positive dispersion helix interaction structure has been built to operate in the 5 to 10 cm wavelength region. A sketch of the oscillator and cavity is shown in Fig. 3. The output coupling loop was placed at the end of the cavity, as shown, for mechanical simplicity. More signal power would be obtained if the loop were at the other end of the cavity. The transition sections at the ends of the helix were made according to a design developed by Lund. This design transforms the dominant helix mode to the coaxial TEM mode over a wavelength range of 5 to 15 cm with less than 2 to 1 VSWR at any frequency.

Coarse tuning of the oscillator is accomplished by varying the beam voltage. A variation of 5,000 to 9,500 volts is necessary to cover frequencies from 6,000 to 3,000 mc, respectively. With the tuning plunger fixed, the oscillator oscillates on discrete modes, separated from one another by about 4 per cent in wavelength. By moving the plunger and changing the beam voltage, any

\[ r_o = \text{phase velocity (cm per second) of the wave on the interaction structure in the direction opposite to the electron flow.} \]

For the configurations tested, the quantity \( \delta V / \delta V \), was very small. The total electronic tuning on one mode was found to be less than 8 mc at oscillation frequencies of 3,000 mc.

Voltage Width of Modes

An expression for the voltage width of a mode of oscillation can be obtained in closed form by using Tillotson's one wave approximation to the gain equations combined with (1). This expression includes the effect of beam voltage. An expression for the voltage width of a mode of oscillation \( \delta V' \), divided by the average voltage \( V' \), is

\[
\delta V' = 2 \left[ \frac{0.55}{N} - 0.0213 \frac{C L}{N} - 1.02 \frac{C L}{N} \right] - 7.28 \frac{C}{N} + 36C^2 - 0.0714 \frac{C}{N^2} \]

\[
- 7.54 \frac{C}{N} \log_{10} \left( 1 - F \right)^{1/2}.
\]

This equation neglects the small effect of electronic tuning in a mode of oscillation. Equation (3) is plotted in Fig. 2 as a function of \( C \) for various values of \( L \) and \( N \), with \( F \) very small. Some experimentally determined results are shown for comparison.

![Fig. 2—Fractional voltage width of mode of oscillation \( \delta V' / V' \), as a function of \( C \), with \( F \) very small.](image)

The voltage width of the modes increases extremely rapidly at currents just slightly above the starting current, but increases less rapidly for higher currents. Nevertheless, the voltage width of the modes is quite large at beam currents not much larger than the starting current.

\footnote{C. O. Lund, "A broadband transition from coaxial line to helix," \textit{RCA Review}, vol. XI, pp. 133-142; March, 1950.}
frequency in the above range can be obtained. Fig. 4 shows some typical curves of the frequency width of modes of oscillation for the oscillator as a function of $C$.

![Graph](image)

**Fig. 4**—Typical measured frequency width of modes of oscillation $\Delta f$, as a function of $C$, for various numbers $n$ of wavelengths around the feedback loop.

The total shift in frequency across any mode of oscillation is small, as previously noted.

Some measured values of $CN$ for the start of oscillation are shown in Fig. 5 as a function of wavelength for a lightly coupled load. $CN$ for the start of oscillation increases at shorter wavelengths, which probably is due to increased ohmic losses in the helix.

![Graph](image)

**Fig. 5**—Experimentally determined $CN$ for the start of oscillation as a function of wavelength.

The measured voltage width of some typical modes of oscillation are compared with the theoretical behavior in Fig. 2. The experimental curves have the same general shape and absolute values predicted from (3). However, there is one important difference in the experimental curves. The voltage width of the modes increases more rapidly with beam current as the number of wavelengths decreases. The reason that the theoretical curves do not show this trend is because they are a one-wave solution. In the actual oscillator, on the other hand, all three waves make appreciable contributions.

The measured voltage separation between modes for the oscillator is shown in Fig. 6, compared with the value calculated from (4). The voltage separation between modes increases at longer wavelengths because the electrical length of the positive dispersion helix decreases with frequency. The voltage width of the modes of oscillation is as large as the voltage separation between modes, except at very low beam currents. This situation is inherent in an oscillator operating on the dominant mode of a positive dispersion interaction structure since both the separation between modes and the width of the modes vary in the same direction with frequency.

The power output of the oscillator is of the order of 30 to 40 milliwatts. This limit was imposed because the output coupling loop is located at the lower power end of the cavity, and also because at higher power levels the frequency becomes unstable and depends critically on the load since the voltage width of the modes became excessive compared to the separation between them.

The parameters $C$, $N$, and $L$, used to relate the experimental results with the theory, were evaluated as follows: $C$ was calculated, neglecting space charge, by the method outlined by Pierce from the geometry of the helix, and using measured values of helix phase velocity; $N$ was computed as the quotient of active helix length and helix wavelength; $L$ was estimated from Fig. 1 for the case of $F = 0$.

**III. Space Harmonic Operation of Internal Feedback Oscillators**

Internal feedback oscillators can be operated so that the electron beam interacts with the space harmonic waves. An example of an interaction structure that has relatively large amplitude space harmonic waves, is a periodically loaded waveguide. The phase velocity of the
space harmonic waves $v_0$, is related to the dominant mode phase velocity $v_o$ by the expression

$$v_{0s} = \frac{v_o}{\frac{2\pi s}{d} + 1} \quad (s = 0, \pm 1, \pm 2, \ldots) \quad (5)$$

where

$$d = \text{spacing between loading elements}$$
$$s = \text{order of the space harmonic}.$$

When an electron beam is adjusted to have a velocity just slightly greater than a forward traveling space harmonic wave (i.e., positive $s$), it will transfer energy to the circuit wave since it finds itself in a region of retarding field. It is also easy to see that an electron traversing a shorted interaction structure which has standing waves on it will also find itself in a retarding field when its forward velocity, $v$, is adjusted to be slightly greater than

$$v_{0s} = \frac{v_o}{\frac{2\pi s}{d} - 1} \quad (s = 1, 2, \cdots) \quad (6)$$

Thus, for operation on a given order space harmonic, there are always two beam voltages that will satisfy the phase conditions for oscillation at any given frequency.

When the periodic loading elements are very close together, it is possible to make the space harmonic phase velocity of the circuit waves much less than the dominant mode phase velocity. Under this condition, the electrical length of the feedback loop as measured by the electron beam in space harmonic wavelengths is very long, while the electrical length of the feedback loop measured in dominant mode wavelengths (which determines the phase condition for oscillation) is very small. Therefore, the voltage width of each of the two types of space harmonic modes at each frequency is small compared to the respective voltage separations of the modes. The problem of suppressing oscillation of one of the possible interaction voltages at each frequency is difficult. However, it appears that much can be done to increase the separation by judicious choice of the spacing of the periodic loading elements.

IV. CONCLUSIONS

The essential features of traveling-wave tubes acting as internal feedback oscillators have been presented. Much work remains to be done on increasing the efficiency of this device before it can offer serious competition to other signal-generating sources at microwave frequencies. At present, it seems that the internal feedback oscillator operating on space harmonics can be developed into a useful signal source at millimeter wavelengths. Space harmonic operation at these frequencies has some distinct advantages, such as the beam velocity, and hence beam voltage necessary for interaction with the space harmonics is low, and the space harmonic interaction structure can be made relatively long, thus providing a large surface for head radiation. The disadvantage of this system as a method of operation is that there are potentially two beam-voltage settings possible for each oscillation frequency.

ACKNOWLEDGMENT

The author is indebted to W. W. Harman who suggested the helix internal feedback oscillator in essentially the form described here, to K. R. Spangenberg and D. L. Benedict for many stimulating discussions, and to R. C. Honey for accumulating the experimental results. The research reported in this paper was made possible through the Office of Naval Research under Contract No. N6-ONR-251.

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A Note on the Ladder Development of RC-Networks

E. A. GUILLEMIN†, FELLOW, IRE

Summary—Darlington and Cauer have described a useful way of synthesizing a lossless two-terminal-pair network from a single driving-point impedance and a knowledge of the zeros of transmission. The procedure involved has a good deal of similarity to the Brune process of synthesis, and can readily be extended to RL and RC networks provided the zeros of transmission are restricted to the negative real axis of the complex frequency plane. Although such an extension is obvious, it seems worthwhile to point out the details involved and to illustrate these with a numerical example.

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ticular form in the RC case is not discussed elsewhere in the literature.

The procedure in question arises, for example, in the
situation depicted in Fig. 1 for which the transfer im-
pedance is

\[ Z_{12} = \frac{E_2}{I_1} = \frac{z_{12}}{1 + z_{22}} \]  

(1)

Fig. 1 — A relevant physical network arrangement.

in which \( z_{22} \) is the open-circuit impedance of the two-
terminal-pair network \( N \) alone as measured at the end 2,
and \( z_{12} \) is its open-circuit transfer impedance, that is, the
ratio of open-circuit voltage at one end to input current at
the other. After the functions \( z_{22} \) and \( z_{12} \) are found1
from a specified \( Z_{13} \), it remains to construct the network
\( N \) from these two functions. In the dual situation (in
which the transfer admittance \( Y_{12} = I_2/E_1 = y_{12}/(1 + y_{22}) \)
is specified) the network \( N \) is to be constructed from its
short-circuit driving point and transfer admittances \( y_{22} \)
and \( y_{12} \). That is to say, the successful synthesis of the
coupling network \( N \) depends upon one's ability to con-
struct it from the pair of functions \( z_{22} \) and \( z_{12} \), or the pair
\( y_{22} \) and \( y_{12} \). (The driving-point function \( y_{12} \) or \( z_{12} \) is of no
interest in this type of problem.)

In any of the two-element cases (RC, RL, LC) there
are well-known methods for realizing the driving-point
function \( z_{22} \) or \( y_{22} \) through developing it into an unbal-
lanced ladder (Fig. 2). It is necessary to know how this
one can produce the proper zeros of \( z_{22} \). In the ladder
network, zeros of the transfer function require either that
series branch impedances or shunt branch admittances
be infinite at the appropriate frequencies. That
is to say, if at a given frequency the transfer function is
to be zero, then it is necessary (though not sufficient)
that a series branch have an infinite impedance, or that
a shunt branch have a zero impedance at that frequency.
The reason that this condition does not necessarily pro-
duce a zero in the transfer function is that the transfer
function for the network portion to the left of the branch
in question may have a pole at the same frequency, as it
will if the driving-point impedance, looking to the left
at this point, contains this pole. Herein lies the key to
the method of producing zeros at the desired frequencies
regardless of the form of \( z_{22} \).

Since this procedure is discussed in detail and illus-
trated for LC networks in the reference cited above, it
will suffice here to confine our further attention to the
analogous RC case. In the LC case, a branch of the lad-
er may be made to have infinite or zero impedance for
any point on the \( j \) axis of the complex frequency plane
(plane of the variable \( s = \sigma + j\omega \) as it is commonly
used in the Laplace transform theory). For RC networks
the same may be done for points on the negative real
axis of this plane, and so the present discussion is rele-
vant only to RC synthesis where the zeros of transmis-
sion are so restricted. More general cases are readily
taken care of through a parallel combination of these
restricted ladders, as is obvious from the procedure
given in “Synthesis of RC Networks” by E. A. Guille-
min, (Jour. Math. Phys., vol. 28, p. 22), or as pointed
out by Fleck and Ording in their paper referred to above.

Since it is more common to approach the design on an
admittance basis, let us illustrate the details of the
method by assuming the pair of functions

\[
y_{22} = \frac{(s + 1)(s + 3)(s + 5)}{(s + 2)(s + 4)(s + 6)} \\
y_{12} = \frac{(s + 2.5)^2(s + 7)}{(s + 2)(s + 4)(s + 6)}
\]  

(2)

A sketch of \( y_{22} \) as a function of real values of \( s \) (i.e., for
\( s = \sigma + j0 \)) is shown in Fig. 3, from which we note that
none of the zeros of \( y_{22} \) fall where \( y_{12} \) has zeros. This situa-
tion can easily be remedied, however.

1 For a detailed discussion of how this is done see “A Summary of
Modern Methods of Network Synthesis,” by E. A. Guillemin, “Ad-
\veances in Electronics,” Academic Press, Inc., New York, N. Y.,
First it is necessary to compute the value of \( y_{22} \) for \( s = -2.5 \), which is readily found to be

\[
y_{22}(-2.5) = \frac{5}{7}.
\]

(3)

If the zero-frequency value of \( y_{22} \) (which is the minimum of its real part for \( s = j\omega \)) were as large or larger than 5/7, one could cause a zero of \( y_{22} \) to shift to the point \( s = -2.5 \) through simply subtracting an appropriate positive real constant (conductance). This scheme fails in the present example because \( y_{22}(0) = 5/16 \), which is less than 5/7.

There is, however, another way of causing the zero at \( s = -3 \) to shift over to the point \( s = -2.5 \), and that is through the removal (subtraction) of an appropriate part of the pole at \( s = -2 \). This pole alone is given by the component admittance

\[
y_1 = \frac{k_{15}}{s + 2};
\]

(4)

and so we find the \( k_1 \) value for which

\[
y_{22}(-2.5) - \left( \frac{k_{15}}{s + 2} \right)_{s = -2.5} = \frac{5}{7} - 5k_1 = 0,
\]

(5)

when \( k_1 = 1/7 \), and the appropriate admittance 4 is

\[
y_1 = \frac{(1/7)s}{s + 2}.
\]

(6)

Thus the development of \( y_{22} \) is begun through constructing a shunt branch having the admittance \( y_1 \), and computing the remaining admittance function

\[
y' = y_{22} - y_1 = \frac{(6s^2 + 38s + 42)(s + 2.5)}{7(s + 2)(s + 4)(s + 6)} = \frac{1}{z'}.
\]

(7)

It is important to observe that this shunt branch does not produce a zero of transmission because the remainder function \( y' \) still contains the pole at \( s = -2 \), and hence so does the transfer admittance of the as yet undeveloped network to the left of this branch. That is to say, in removing the shunt branch with admittance \( y_1 \), we have removed only part of the pole of \( y_{22} \) at \( s = -2 \). If we had removed all of this pole, then the shunt branch in question would produce a zero of transmission at \( s = -2 \), but the partial removal of a pole does not produce such a zero.

Thus a partial removal of a pole may be used as a "zero-shifting" technique, and the total removal of a pole becomes the "zero-producing" step.

By removing part of any admittance or impedance function, one cannot shift the poles of this function, but its zeros can thus be shifted. Since these zeros are the poles of the subsequently inverted function, one is able to control pole positions. In fact, through applying the shifting procedure first to the given function and then to the inverted remainder, and finally inverting again, one can shift both zeros and poles of the given function. Through appropriately repeating this technique as often as needed, one readily appreciates that a zero or a pole can be shifted to any desired position, regardless of where the critical frequencies lie originally. None of these shifting operations become zero-producing so far as the transfer function of the ultimate network is concerned so long as the pole removals used in the shifting process are partial ones.

Returning now to the remainder function in (7), and considering its reciprocal \( z' \), we next totally remove its pole at \( s = -2.5 \) since this is a point at which a zero of \( y_{22} \) must be produced. To this end we compute the residue of \( z' \) at \( s = -2.5 \) which is found to equal 1.185, and then subtract the component impedance corresponding to this pole, which is

\[
z = \frac{1.185}{s + 2.5},
\]

leaving the remainder

\[
z'' = \frac{7s^2 + 50.39s + 114.45}{6s^2 + 38s + 42} = \frac{7(s + 2.958)(s + 5.526)}{6(s + 1.427)(s + 4.907)}.
\]

(9)

Here \( z_2 \) is the impedance of a series branch following the shunt branch with admittance \( y_1 \), (6). This series branch produces a zero of transmission at \( s = -2.5 \).

At this stage in the development procedure, we have completed one cycle. That is to say, we have gone through a series of steps whereby the given \( y_{22} \) has been partially developed, and once of the zeros called for by \( y_{12} \) has been produced. It will be observed that while \( y_{22} \) in (2) is the ratio of two cubic polynomials, the admittance \( y' = 1/z' \), which we now have yet to develop, is the ratio of two quadratic polynomials. We have produced one zero of transmission, and have lowered the degree of our given rational function by one. The same series of steps, carried through analogous cycles, is now continued until all zeros of transmission are produced, and the remainder function is fully developed.

We begin the second cycle as we did the first, through computing the value of \( y'' \) at \( s = -2.5 \); thus

\[
y''(-2.5) = -1.596.
\]

(10)

Since this is a negative value, there is no possibility of carrying out the zero-shifting step simply by the removal of a positive constant (conductance). A sketch of the function \( y'' \) for \( s = \sigma + j\theta \) similar to that for \( y_{22} \) in Fig. 3 (the factored form (9) is best used for this purpose) readily reveals that the desired zero-shifting can be accomplished through a partial removal of the pole at \( s = -2.958 \). That is to say, we plan to subtract from \( y'' \) the admittance

\[
y_2 = \frac{k_{25}}{s + 2.958}.
\]

(11)
with \( k_3 \) determined by the condition
\[
y''(-2.5) - \left( \frac{k_3 s}{s + 2.958} \right) = -1.596 + \frac{2.5k_3}{0.458} = 0, \tag{12}
\]
when \( k_3 = 0.2925 \) and the appropriate admittance 11 is
\[
y_4 = \frac{0.2925s}{s + 2.958}. \tag{13}
\]

Construction of a shunt branch having this admittance is equivalent to subtraction of \( y_4 \) from \( y'' \), leaving
\[
y''' = \frac{(3.952s + 16.8)(s + 2.5)}{7(s + 2.958)(s + 5.526)} = \frac{1}{y''}. \tag{14}
\]

The residue of \( y''' \) in its pole at \( s = -2.5 \) is found to be 1.401, so that the term representing this pole is
\[
z_4 = \frac{1.401}{s + 2.5}, \tag{15}
\]
from which the next series branch is constructed. The remainder \( z'' = z''' - z_4 \) is found to be
\[
z'' = \frac{7s + 36.33}{3.952s + 16.8} = \frac{1.77(s + 5.193)}{(s + 4.25)} = \frac{1}{y''}. \tag{16}
\]

This completes the second cycle in the development procedure.

Sketches of \( y'' \) and \( z'' \) are shown in parts (a) and (b), respectively, of Fig. 4, from which we observe that there is no possibility of shifting a zero of \( y'' \) to the point \( s = -7 \) (the remaining point at which \( y_{17} \) is to be zero), but that \( z'' \) can be made to have a zero at \( s = -7 \) through subtracting a positive constant (resistance).

That is,
\[
z''(-7) = 1.163, \tag{17}
\]
and this is less than \( z''(\infty) = 1.77 \), which is the minimum of its real part for \( s = j\omega \).

So we can next remove a series resistance
\[
z_6 = R_5 = 1.163 \tag{18}
\]
and leave
\[
z'' = z'' - 1.163 = \frac{0.607(s + 7)}{(s + 4.25)} = \frac{1}{y''}. \tag{19}
\]

Since
\[
y'' = \frac{0.648s}{s + 7} + 1. \tag{20}
\]
we see that the next shunt branch is given by
\[
y_8 = \frac{0.648s}{s + 7}, \tag{21}
\]

and that the final series branch is a resistance of one ohm. The completely developed network is shown in Fig. 5. The branches producing zeros of transmission are the two parallel RC components in the series branches (these are \( z_2 \) and \( z_4 \) (8) and (15)), and the series RC component in the left-hand shunt branch (\( y_8 \) of (21)). Remaining branches correspond to zero-shifting steps.

Note that zero-producing branches may be either series or shunt and that one need not consistently use shunt branches for zero-shifting and series branches for zero-producing steps. Thus in the first two cycles in the above example, the shunt branches correspond to zero-shifting steps and the series branches to zero-producing ones, while in the last cycle zero-shifting is done by the series resistance 1.163 and the final shunt branch is zero-producing. Since zero-shifting may be done in several steps instead of just one (sometimes this may become necessary or desirable), it is clear the number of alternatively possible developments is infinite.
A Source of Error in the Measurement of Radiated Harmonics

F. M. GREENE, MEMBER, IRE

Summary—A source of error known to be present in vhf field-intensity meters employing broadband radio-frequency input circuits, has been briefly investigated. The error is caused by harmonic generation in the receiver resulting from insufficient selectivity, and nonlinearity of rf or mixer stages in the presence of a strong fundamental. The magnitudes of the second and third harmonics generated internally were determined as a function of the level of the applied rf fundamental for a receiver having one particular type of rf input circuit. Errors in the measurement of the fundamental, caused by intermodulation occurring in the presence of a stronger interfering carrier of different frequency, are also briefly discussed.

I. INTRODUCTION

A possible source of error in the measurement of spurious harmonic fields produced by radio transmitting stations, particularly in the vhf band (30 to 300 mc), has been briefly investigated. The error in question is usually most serious in the case of measurements made with certain types of field-intensity meters employing an rf input attenuator and wide-band untuned circuits preceding the first radio-frequency amplifier or mixer stages of the receiver. The error is caused by harmonic generation, occurring in these stages as a result of insufficient selectivity, and their nonlinearity in the presence of a strong fundamental. The degree of the nonlinearity will be a function of the design and mode of operation of these circuits. As a result, the harmonic level indicated by the field-intensity meter may often be appreciably higher than the true level.

II. HARMONIC GENERATION

A simplified grounded-grid input circuit similar to the type employed in some commercial field-intensity sets designed for this frequency range, is shown in Fig. 1.

![Diagram](https://example.com/diagram.png)

Fig. 1—A typical untuned grounded-grid rf input circuit similar to that used in some commercial types of vhf field-intensity meters at the present time.

This particular circuit arrangement is often used because it provides a means for obtaining a reasonably accurate broad-band termination for the rf input attenuator, as well as a fairly low noise figure for the receiver. Unless precautions are taken, its use may often result in some inaccuracy or inconvenience of operation when harmonic measurements are being made.

In order to measure the harmonic content of a given rf field in terms of the fundamental, the field-intensity meter is usually first tuned to the fundamental, and the input attenuator adjusted to give an on-scale indication of the output meter. The difficulty then arises when the set is tuned to the relatively weak field harmonic, and most of the rf attenuation is removed to still obtain an on-scale indication. Since the fundamental is still present in the input circuit, the first stages will be operated considerably above their intended input-voltage level, resulting in nonlinear operation and the generation of appreciable harmonics.

As an example, the indicated second- and third-harmonic levels in db below the fundamental rf input are shown in Fig. 2 for a receiver employing a 6J4 in the grounded-grid input circuit of Fig. 1. The plate voltage was approximately 100 v, and the cathode bias developed was 1.0 v. These harmonic levels were those produced entirely within the input stages for the case in which the fundamental input level remained unchanged while measuring the harmonic. The harmonics present in the output of the signal generator used in making this test were maintained at least 100 db below the fundamental by employing two high-rejection low-pass co-

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† Central Radio Propagation Laboratory, National Bureau of Standards, Washington 25, D. C.
axial filters in tandem. The indicated second-harmonic level of \(-68\) dB, shown in Fig. 2, for a fundamental input of 10 millivolts was the lowest that could be conveniently determined, as this corresponded to the equivalent internal noise level (referred to the antenna terminals) of the receiver under test. In actual practice, the receiving antenna would be tuned to the harmonic while it was being measured. The antenna selectivity would probably reduce the level of the fundamental present in the input circuit, but not necessarily enough to preclude the possibility of overloading the first stages of the receiver. The harmonic levels shown in Fig. 2, therefore, represent limiting values for the conditions imposed.

Differences in propagation at the fundamental and harmonic frequencies will, in general, make the measured harmonic content a function of the location of the measuring site. Because of this, and the difference in the directivity of the receiving antenna at the fundamental and harmonic frequencies, it may sometimes be possible to orient the receiving antenna so as to discriminate against the fundamental while measuring the harmonic. In any event, the error may be reduced by connecting a series-resonant trap, tuned to the fundamental, across the antenna input terminals (after measuring the fundamental) so that its indication would be reduced (in this case) to 10 mv or less. This type of tuned trap is now being furnished with some makes of instruments.

III. INTERMODULATION

The above error per se had no appreciable effect on the accuracy of measurement of the fundamental. However, an error would occur resulting from intermodulation in the presence of one or more strong interfering carriers having different frequencies because of non-linear operation, and would usually result in a decrease in the effective gain of the stage(s) affected. This would cause the indicated level to be lower than the true level, but should be serious only for measurements made within a mile or less of the interfering station. Some idea of the magnitude of this error under various conditions can be obtained from Table I for the case of a single interfering carrier at a frequency well outside the over-all pass band of the receiver, but within bandwidth of input stages.

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>Effect of Intermodulation</th>
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<tbody>
<tr>
<td>(1)</td>
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</tr>
<tr>
<td>mv</td>
<td>mv</td>
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<tr>
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</tr>
<tr>
<td>10</td>
<td>10,000</td>
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<td>1,000</td>
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<tr>
<td>100</td>
<td>10,000</td>
</tr>
</tbody>
</table>

(1) True amplitude of carrier being measured, mv.
(2) True amplitude of interfering carrier, mv.
(3) Indicated amplitude of carrier under measurement, mv.
(4) Measurement error, per cent.

IV. CONCLUSIONS

In general, the harmonic and intermodulation products resulting from nonlinearity and insufficient selectivity of radio-frequency stages, are common to the operation of most receivers. The resulting seriousness will usually be dependent upon the particular design and operation of the rf input stages and type of use to be made of the set. The effects of harmonic generation are usually the most serious, particularly when attempting to evaluate spurious harmonic fields 60 db or more below the fundamental, as is often required.

ACKNOWLEDGMENT

Grateful acknowledgment is made by the author to Mr. C. C. Cook of the Central Radio Propagation Laboratory, National Bureau of Standards for his aid in making these measurements.

Discussion on

"The Statistical Properties of Noise Applied to Radar-Range Performance"

S. M. KAPLAN AND R. W. McFALL

L. V. Blake: A useful approach to the analysis of radar-signal detection has been presented, probably for the first time in a publication generally available to the radio-engineering profession, by the authors of the above paper. The authors themselves feel that the interpretation of range performance of a radar as a statistical quantity is a new and valuable one. Although there may be some question about newness, the authors deserve a great deal of credit for their work.


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World War II and security restrictions are partly responsible for the fact that some earlier work was not published. A report written in 1943 by North of the RCA Laboratories in Princeton, N. J. was security-classified. However, it apparently had some circulation in the profession since it was referred to in one of the volumes of the M.I.T. Radiation Laboratory Series of books on radar and related subjects.


Although Lawson and Uhlenbeck, and other writers as well, have used statistical concepts in treating the problem of signal detection in noise, their approach is not quite the same as Kaplan and McFall's. The approach used by North, however, is exactly the same.

Mention of this earlier work would probably not be of much importance, except that there is one very significant respect in which the analyses differ. This occurs where not one but many echo pulses are received from the radar target. For example, in the case of a scanning radar of antenna beamwidth $\theta$ in the direction of scanning, with the angular scanning speed $\omega$ and the pulse repetition frequency $F$, a train of $\theta F/\omega$ pulses is received on each traverse of the antenna beam past the target. The commonly accepted treatment of this case (assuming the time interval $\theta/\omega$ to be fairly small—usually of the order of a second or less) is to call the entire train of pulses "the signal," that is, to assume that the observer (radar operator) sees on the radar indicator a single response which is the resultant of these several echo pulses. He does not see the individual pulses. Even if the indicator could resolve them individually, the eye and brain would see them as a group. A group of pulses, either separate or superimposed, is easier to see than a single pulse. The additive effect, known as integration, is one of the most important effects in the theory of radar-signal detection because nearly all actual radar systems receive trains of pulses from targets. The explanation of the improved detectability of a group of integrated pulses over a single pulse having the same average amplitude is also well known, and the theory has been well corroborated by experimental evidence from several independent sources.

The explanation, though a statistical one, is not the one given by Kaplan and McFall. They argue that for a train of $n$ pulses the probability of detection is improved because, with a fluctuating signal (signal plus noise), there is a better chance of at least one pulse exceeding "threshold" level in a train of several than when there is only one pulse (just as the chance of getting "heads" at least once out of ten tosses of a coin is better than the chance of a "head" on one toss). The trouble with this is that it assumes there is no integration—that the train of pulses is not viewed as a "package." It is well known that most of the usual display devices (cathode-ray-tube phosphors) and the usual observing system (human eye and brain) do integrate trains of radar pulses. No doubt it would be possible to set up a purely physical (nonhuman) "observing" system which would have absolutely no "memory" from pulse to pulse, and it is to such a system that the analysis of Kaplan and McFall would apply. However, the sensitivity of such a nonintegrating system would be relatively very poor.

North's report does consider the improvement due to integration. The starting point (for video or postdetection integration) is the derivation of the probability density functions for the sum of $n$ signal-plus-noise voltages, and for $n$ noise voltages. When these have been found, the procedure is similar to the one used by Kaplan and McFall, except that these new functions are used in place of the ones sketched in Fig. 3 of their paper. North has analyzed both the cases of predetection and postdetection integration.

My familiarity with North's report stems from some work which I did at the Naval Research Laboratory and which was the basis for an M.S. thesis at the University of Maryland. Coincidentally, I was concerned with the problem of loss due to noise pile-up on types C and G radar indicators, which is apparently the same general problem that led Kaplan and McFall into their study. I also decided to analyze the problem in terms of the statistical definition of minimum detectable signal, following North. I had intended to submit a shortened version of this thesis for publication in the PROCEEDINGS, but have not yet done so. However, this may be an opportunity time to state briefly some of the results.

The loss due to noise pile-up has been termed "collapsing loss," and the ratio of the total magnitude of the collapsed dimension to the radar's unit of resolution in that dimension is called the "collapsing ratio." (This recognizes the possibility of two-dimensional displays of three-dimensional information in which the collapsed dimension is not necessarily range.) It is known from experiment and theory that the collapsing loss (power basis) is ordinarily equal to the square root of the collapsing ratio. However, some experimental work at RCA Laboratories in 1947 suggested that under certain circumstances the loss might be much less than this, namely, when the minimum detectable signal-to-noise ratio (visibility factor) before introduction of the collapsing loss is already considerably greater than one.

My calculations substantiate this hypothesis, provided that "base clipping" of the receiver output is introduced before any integration occurs. (This base clipping would be provided almost automatically in the usual radar system by adjustment of the bias on the grid of the cathode-ray indicator tube. This pre-integration bias level should not be confused with the detection threshold level; this latter threshold must be established after integration, either in the mind of the observer or by suitable biasing of a tube in the postintegration circuits of an automatic detection device.)

It must not be thought that this approach to minimum detectable signal (or radar maximum range) problems (that of North, Kaplan, and McFall) leads in all cases to results unobtainable by other methods. Some of the conclusions stated by Kaplan and McFall have been well known for some time: The receiver bandwidth

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5 See footnote reference 2.

6 L. V. Blake, "Application of Mathematical Probability Theory to Analysis of Radar-Signal Detection on a 'Collapsed' Display," M.S. Thesis submitted to the Graduate School of the University of Maryland; May, 1950.

should be as narrow as other considerations permit; on collapsed displays the interval during which the receiver is gated on should be as short as possible (by use of STC and a range gate in C- or G-type displays); long pulses give improved sensitivity; a low visibility factor is desirable (!); range-collapsed displays may be enhanced by pulse stretching. The chief merit of this approach, as I see it, is that it permits one to make a mathematical analysis of radar-signal detection without becoming entangled in matters of human psychology and physiology. This reduction of the problem to a purely physical and statistical basis makes possible a much more rigorous and thorough type of mathematical analysis and, I think, leads to a much more fundamental understanding of the physical aspects of the radar-target detection process. At the same time one must not belittle or ignore the great importance of also studying the problem from the viewpoint of the observer, as has been so capably done by Haefl, Guthrie, and others at the Naval Research Laboratory, by Payne-Scott of Australia, and by Lawson, Uhlenbeck, and associates at the M.I.T. Radiation Laboratory.

A further application of statistical methods to radar maximum-range theory has been made by members of the Navy's Operations Evaluation Group. This extension of the theory takes into account the fact that the echoes from many actual radar targets fluctuate randomly in amplitude. For this reason (as well as because of the effect of receiver noise), maximum range is treated in terms of probability of detection. The approach is operational, rather than purely physical. The theory is developed in terms of a continuously scanning radar system and a target approaching the radar at high speed. This leads to the concept of cumulative probability of detection, and a procedure for its calculation has been developed, using partly empirical and partly theoretical reasoning. Work has not yet been published.

S. M. Kaplan and R. W. McFall: We wish to thank Mr. Blake for his comments on our recent paper, and trust the following paragraphs clear up points of discussion.

We are well aware of the integration effect; as a matter of fact the statistical problem as it occurs with slow-scanning PPI, B- and A-type displays has been solved by computing the integrated probability distributions and then proceeding as outlined in our paper. However, it must be noted that for high-speed scanning radar systems employing a C-type display, where no energy pile-up occurs from sweep-to-sweep on the cathode-ray tube, another approach must be used, namely the one presented. Also, for this type of system it is true, in fact, that a single pulse (with adequate pulse stretching) is no more difficult to detect than a group of pulses which represent a single target. Unfortunately, the situations under which such a system is employed cannot be treated in any more detail at this time.

In connection with the statistical effect of parameters other than noise, our analysis has been extended to take into account target fluctuations and the statistical effect of the nonrectangular shape of the radar beam.

It was not our intent, implied or otherwise, to belittle or ignore the important contributions of Haefl, Guthrie, Payne-Scott, and others. We are well aware of their work and its importance.

L. V. Blake: In reading their paper, I did not realize that Kaplan and McFall restricted their analysis to a special type of radar system, even though they did mention that their particular interest was in applying it to rapid-scanning radars with type C indicators. The method is of more general applicability, but it is not complete without a treatment of the integration of groups of pulses. North did include this all-important aspect of the problem in his analysis, as I have pointed out. It now appears Kaplan and McFall have also done it; regrettably, however, they did not discuss it in their paper.

I am not convinced that integration can be ignored and that the approach taken in their paper can be used even for the case of high-speed-scanning radar with type C display. They said that there is "no energy pile-up . . . from sweep-to-sweep" on the cathode-ray tube. But, as I have pointed out in my discussion, "Even if the indicator could resolve them (the pulses) individually, the eye and brain would see them as a group," so that integration would still occur. Experiments have shown that it is not necessary for the pulses to "pile-up" on the indicator. At the same time, I realize that there could be some special radar application, such as the one which Kaplan and McFall are unable to discuss in detail at present, to which their analysis would apply. I mentioned one such possibility in my discussion.

However, I do take tentative exception to their statement, " . . . for this type of system it is true, in fact, that a single pulse (with adequate pulse stretching) is no more difficult to detect than a group of pulses which represent a single target." I do not see how this could be true under any circumstances. The statement requires that the group of pulses be observed as a group, and this implies integration. It is assumed, of course, that the power of the single pulse is equal to the average power per pulse of the group, and that pulse stretching, range gating, or other advantages are applied to the pulses of the group as well as to the single pulse.

S. M. Kaplan and R. W. McFall: It appears that the basic difference between Mr. Blake and ourselves concerns the statement, "for this type of system it is true, in fact, that a single pulse (with adequate pulse stretching) is no more difficult to detect than a group of pulses which represent a single target." This statement under certain special and important conditions is correct. Unfortunately, these conditions cannot be discussed in detail. However, it may be pointed out that a condition can very easily be obtained whereby signals occurring during successive sweeps in a type C display do not overlap if the scan rate is fast enough. It must again be emphasized that under these conditions signal enhancement does occur, as indicated in our paper, but not in the same manner as with integration in conventional PPI or A-type displays.
Contributors to Proceedings of the I.R.E.

For a photograph and biography of W. J. Albersheim see page 358 of the March, 1952 issue of the PROCEEDINGS OF THE I.R.E.

Ernst A. Guillemin (A'41--SM'48--F'49), well-known authority on network analysis and synthesis, was born in Milwaukee, Wis., on May 8, 1908. He received the B.S. degree in E.E. in 1922 from the University of Wisconsin, and the S.M. degree in E.E. in 1924 from the Massachusetts Institute of Technology. In 1924, he received the Saltonstall Traveling Fellowship for study toward the doctorate at the University of Munich, Germany, receiving the degree in 1926. He returned to M.I.T. as an instructor, was advanced to Assistant Professor in 1928, Associate Professor in 1936, and to Professor of Electrical Communications in 1944.

In 1941 Dr. Guillemin took over the administrative responsibilities of the Communications Option of the Department of Electrical Engineering at M.I.T. In the Fall of 1940, he accepted an appointment as Consultant to the Microwave Committee of the N.D.R.C. In this capacity, approximately one half of his time was devoted to consultation with various groups in the Radiation Laboratory, M.I.T., on a large variety of problems dealing with the design of electrical networks for special applications. Of significance was the development of a network for the production of radar pulses.

On March 1, 1948, Dr. Guillemin was awarded the President's Certificate of Merit for his outstanding wartime contributions. He is particularly known for two volumes of "Communication Networks," and a reference entitled "The Mathematics of Circuit Analysis." He is a Fellow of the AIEE and a member of the ASEE.

F. M. Greene (A'35--M'44) was born in Cedar Rapids, Iowa, on January 15, 1910. He received the B.S. degree in electrical engineering from the Georgia Institute of Technology in 1933, and the M.S. Degree from the Massachusetts Institute of Technology in 1937. From 1928 to 1934, Mr. Greene was a half-time member of the engineering staff of Radio Station WSB, The Atlanta Journal, Atlanta, Georgia. He was employed by the Erie Railroad Company from 1935 to 1940 in railroad communications engineering. From 1940 to 1946 he worked for the Washington Institute of Technology, College Park, Maryland, on aircraft instrument-landing and radar test equipment for the armed services. Since 1946 he has been with the Central Radio Propagation Laboratory, National Bureau of Standards, associated with the development of high-frequency measurement standards and field-intensity calibration standards, and, since 1949, has been in charge of the Bureau's field-intensity calibration service.

Mr. Greene is a member of the IRE Wave-Propagation Subcommittee 24.1 on Standards and Practices, and is a member of Tau Beta Pi, and Kappa Eta Kappa.

J. W. Horton (A'20--F'29) was born in Ipswich, Mass. on December 18, 1889. He received the B.S. degree in electrochemistry from the Massachusetts Institute of Technology in 1914 and the Sc.D. degree in electrical engineering in 1935. He was later a member of the faculty.

From 1916 to 1928 Dr. Horton was a member of the technical staff of Bell Telephone Laboratories, where he participated in the development of multiplex telephone and telegraph systems using carrier currents, the electrical transmission of pictures, television, loudspeakers, and talking pictures. He also initiated the studies leading to the development of the methods now used for the measurement of frequency.

From 1941 to 1945 Dr. Horton served as assistant director of the Underwater Sound Laboratory, operated by Columbia University at New London for the U. S. Navy. He is still research consultant to the Navy.

Dr. Horton is a fellow of the American Association for the Advancement of Science, the Acoustical Society of America, and the American Institute of Electrical Engineers. He is now serving on the Board of Examiners of the latter society. He has served on the Board of Editors, the Meetings and Papers Committee, the Technical Committee on Vacuum Tubes, and as chairman of the Standards Committee of the IRE, as well as on the advisory committees of the International Electro-Technical Commission and the International Union of Scientific Radio, and on various committees operating under the American Standards Committee. He is a member of Sigma Xi and of Eta Kappa Nu.

Loyd E. Hunt (M'33--SM'43) was born on November 7, 1901, in Boise, Idaho. He received the A.B. degree in physics from Reed College, Portland, Ore., in 1927 and the M.S. degree in electrical engineering from Stevens Institute of Technology in 1949.

Mr. Hunt was a commercial wireless operator and ship wireless inspector, from 1918 to 1926, radio instructor at Oregon Institute of Technology for a year and director of the radio-electric division of the United YMCA schools, Seattle, Wash., from 1927 to 1929. Since then Mr. Hunt has been engaged principally in ultra-short-wave and microwave fields at the Bell Laboratories.

Mr. Hunt is a past secretary, vice chairman and chairman of the Monmouth County Subsection of the IRE, and is at present chairman of the adult-education program for the subsection community service committee.

Edward M. T. Jones (S'36--A'50) was born in Topeka, Kansas, in 1924. He received the B.S. degree in electrical engineering from Swarthmore College in 1944. He attended Stanford University where, in the electrical engineering department, he obtained the M.S. and Ph.D. degrees in 1948 and 1950. From 1944 to 1946 Dr. Jones was a radioman in the U.S. Navy. While at Stanford he was research associate on microwave local oscillators. Dr. Jones joined the staff of the Stanford Research Institute in 1950, where he is leader on the millimeter wavelength antenna project.

He is a member of Sigma Tau and Sigma Xi.

Vincent R. Learned (S'38--A'40--SM'47) was born on January 21, 1917, in San Jose, Calif. He received the B.S. degree in electrical engineering from the University of California in 1940, and after which he spent two years in the engineering department of the McClatchey-Hodcasting Co., in Sacramento, Calif. From 1941 through 1942, he served as a teaching and research assistant at Stanford University, where he earned his Ph.D. degree.
Contributors to Proceedings of the I.R.E.

Since 1943, Dr. Learned has been employed by the Sperry Gyroscope Company, in Great Neck, N. Y., first as a project engineer on the development of doppler radar systems and components, and, since 1946, primarily on the development of new klystron tubes. His work in these fields has resulted in four patents, with others pending. His present position is that of engineering department head for electron tube research.

Dr. Learned is a member of The American Physical Society, the Society of Sigma Xi, Tau Beta Pi, and Eta Kappa Nu.

Kenneth A. Norton (A'29-M'38-SM'43-F'43) was born February 27, 1907, in Rockwell City, Iowa. He received the B.S. degree in physics from the University of Chicago in 1928. During 1928 he was with the Western Electric Company. In 1930 he was in the radio section of the National Bureau of Standards, at Columbia University from 1930 to 1931, then in the technical information section of the FCC from 1934 to 1942. From 1942 to 1946 he was assistant director of the Operational Research Group in the Office of the Chief Signal Officer, a radio and tactical countermeasures analyst in the Operational Research Section of the Eighth Air Force in England, and consultant in the Radio Propagation Section of the OCSO. Since 1946 he has been in the Central Radio Propagation Laboratory of the National Bureau of Standards, as Chief of the Frequency Utilization Research Section and Assistant Chief of Laboratory activities in Boulder, Colo.

Mr. Norton is a Fellow of the American Physical Society and of the American Association for the Advancement of Science, a member of the American Institute of Electrical Engineers, the American Geophysical Union, the American Mathematical Society, the Institute of Mathematical Statistics, and the American Statistical Association.

W. N. Papi'an was born in New York City, on July 27, 1916. Following completion of the general course at R.C.A. Institutes in 1937, he joined R.C.A. Communications, Inc. as a station engineer at the Rocky Point Transmitting Station. He spent three years in Africa, Sicily, and Italy as a radio-intelligence officer with the Signal Corps. Entering Massachusetts Institute of Technology in 1946, Mr. Papi'an received the B.S. degree in 1948 and the M.S. degree in 1950. Since 1948 he has worked in the Digital Computer Laboratory at M.I.T., first as a research assistant and now as a member of the research staff.

C. A. Parry was born in Queensland on January 25, 1916, and received a secondary education there. He has been interested in electronics since 1935, when he began experimenting with the call sign VK4CP, some years later he was a Radio Service Engineer, becoming a foundation member of the Australian Radio Servicemen's Institute.

Mr. Parry joined the developmental staff of Kriessler (A/sia) Ltd., and later the engineering staff of the Western Electric Company. He has acted as technical advisor for the Australian Radio World.

In 1941 Mr. Parry joined the design staff of Communication Engineering Pty. Ltd., later acting as assistant chief engineer. With this organization he assisted in developing the first Australian multichannel carrier telephone open-wire and cable systems, as well as other projects of priority.

In 1949 Mr. Parry joined the Ferguson Transformer Company as Technical Manager, but is now acting on his own behalf as a consulting engineer.

Mr. Parry has served on the Publications Board of the Institute of Radio Engineers, Australia, and is at present a member of the Examinations Board.

Philip L. Rice was born in Washington, D. C., on December 25, 1922. College work began at Lawrence College, Appleton, Wis., in 1941, and was completed at Principia College, Elsah, Ill., where he received the B.S. degree in 1948.

During World War II he was commissioned at the Yale University Air Force Communications School, spending a subsequent year and a half in Brazil setting up and operating blind-landing systems for aircraft.

In 1948 and 1949 he was employed by the firm of Raymond M. Wilmore, Inc. in Washington, D. C., and since that time has been a staff member of the Central Radio Propagation Laboratory of the National Bureau of Standards. He is now with the Tropospheric Research Section at Boulder, Colo.

W. R. Sittner (M'52) was born in Cape Girardeau, Mo., on August 21, 1919. For some years he received the B.A. and M.A. degrees in physical chemistry from the University of Missouri in 1940 and 1942.

From 1942 until 1945, Dr. Sittner was engaged in work on magnetron-type vacuum tubes for the Western Electric Company. From 1946 until 1949, he was a research associate in the Physics Department of Northwestern University, where he worked on light sources for optical communications. He received his Ph.D. in physics there in 1949; then joined Bell Telephone Laboratories, and is now doing development work on transistors.

Dr. Sittner is a member of the Institute of Radio Engineers, of the American Physical Society and Sigma Xi.

L. B. Valdes (A'46) was born in Mariana, Cuba, on June 12, 1928. He moved to New Orleans for his high school and college education, and received the B.E. degree in electrical engineering from Tulane University in 1946. That fall he began graduate studies in electrical engineering at Northwestern University, where he remained for two years. He received the M.S. degree there in 1947.

Mr. Valdes next joined the transistor-development group at Bell Telephone Laboratories, where he has been a worker in the field since 1949.

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

Carol Veronda (A'49-SM'51) was born in Sierra Madre, Calif., on August 1, 1920. He received the B.S. degree in electrical engineering from the California Institute of Technology in 1942, after which he entered the General Electric Company student training course.

Mr. Veronda was in the Navy for two years, attending radar school at M.I.T. and Bowdoin, serving as radio material officer in the submarine service of the Pacific fleet, and working at the Naval Research Laboratory at Anacostia, D. C. Following his discharge, he spent two years in magnetron work with the Philips Laboratories, and in 1948 joined the Sperry Gyroscope Company, where he is now a project engineer on klystron development.

Mr. Veronda is a member of the American Institute of Electrical Engineers.
The Standards Committee met on February 14, with M. W. Baldwin, Jr., as Acting Chairman. The proposed "Standards on Gas-Filled Counter Tubes: Definitions of Terms" and the "Standards on Electron Tubes: Methods of Testing Gas-Filled Radiation Counter Tubes," which were approved by the Standards Committee, were sent to the Executive Committee for action at their February 26, meeting. Work has started on the revision of the Standards Manual. The Standards Committee decided not to request the Editorial Department to approve the republication of Part I of the Pulse Definitions, after Part II is published. Part II of the Pulse Definitions was recently approved by the Executive Committee. The Standards Committee voted to send a recommendation to the Executive Committee, asking that no change be made in the present method of publishing standards, and that, publication in the Proceedings be continued. The proposed "Standards on Receivers: Definitions of Terms" are still under consideration by the Standards Committee.

The Circuits Committee convened on January 18, under the Chairmanship of C. H. Page. At the request of its former chairman, Ernst Weber, W. A. Lynch was appointed Chairman of Subcommittee 4.7. Professor Lynch agreed to hold a Subcommittee meeting prior to the next full Committee meeting to discuss the newly proposed definition of Phase Margin. R. L. Dietz reported on his liaison with the Oscillography Committee in relation to distortion definitions. Definitions proposed by W. R. Bennett for Subcommittee 4.4 were accepted.

Under the chairmanship of R. J. Wise, the Facsimile Committee met on January 4. J. H. Hackenberg presented a list of proposed definitions which would be applicable to both mechanical and electronic scanning techniques. C. J. Young submitted a similar list, which he presented at the November 2 meeting, and which was proposed to substitute for that list applicable to electronic scanning techniques. It was decided to consider both lists simultaneously. I. H. Franzel submitted a list of definitions of "Recording Techniques" to replace and supplement the somewhat obsolete definitions of the 1942 standards.

The Industrial Electronics Committee, under the Chairmanship of John Daleko, met on November 15, 1951. It was decided that the IRE would sponsor plans to co-sponsor the AIEE meeting on Induction and Dielectric Heating and would definitely plan on the co-sponsorship for the next meeting. W. C. Rudl reported on plans for the meeting, which was held on February 19-20, 1952, at the Carter Hotel in Cleveland. C. F. Spitzer, Chairman of Subcommittee 10.1 on Definitions, distributed a list of definitions turned over to him by J. M. Cage and also a brief history, dating back to 1949, of the IRE work on these definitions. This list of definitions was approved by the Committee. There was a discussion of material for the Annual Report, and Mr. Spitzer read a summary he had prepared on the subject of magnetic amplifiers. A question arose as to whether magnetic amplifiers came within the scope of the committee. Mr. Spitzer, who is a member of the AIEE Committee on Magnetic Amplifiers, pointed out that the subject, which is of great importance, might eventually warrant having a separate IRE Committee. It was decided to include the subject of magnetic amplifiers in the Annual Report.

The Committee agreed to establish a new Subcommittee on Magnetic Amplifiers, and Mr. Dietz appointed C. F. Spitzer to act as Chairman. It was reported that the "Recommended Practice for Measuring Field Intensities from Industrial and other Equipment" has been approved and will be available from the AIEE in reprint form soon. Copies of this document have been distributed to members of the IRE.

On January 18, the Electron Devices Committee met, with G. D. O'Neill as Acting Chairman. It was decided by the Committee to invite the AIEE to co-sponsor the Conference on Semiconductor Devices. R. M. Ryde reported that the University of Illinois has formally invited this Conference to use its facilities during June 19-20, 1952. The invitation has been accepted. P. A. Redhead reported that accommodations for 250 conferees were reserved for the Conference on Electron Tube Research, to be held on June 16-17, 1952, in Ottawa. R. M. Ryder, Chairman of the Subcommittee on Solid State Devices, has announced that this Subcommittee would be reorganized, and task groups appointed to write definitions and methods of test. This work will be done in close collaboration with the corresponding technical group of the AIEE. The definitions on Noise were approved and R. M. Ryder and H. J. Reich will prepare a revised text of the Noise Measurements for final approval by this Committee. G. D. O'Neill, Chairman of the recently formed Professional Group on Electronic Devices, announced the approval of the Group's constitution, by-laws, and the nine members of the Executive Committee, by the IRE Board of Directors.

The Radio Transmitters Committee met on January 28, under the Chairmanship of M. R. Briggs, H. R. Butler, Chairman of the Subcommittee on Radio Telegraph Transmitters up to 50 mc, reported that he had received at the last meeting of his Subcommittee revised proposals of the Standard (Methods of Testing Telegraph Transmitters) from all members who had promised to undertake the work of revision. As soon as this material is arranged, it will be presented to the main Committee. J. B. Heffelfinger, Chairman of the Subcommittee on Double Sideband AM Transmitters, reported that a framework (in outline form) had been compiled for a Standard on Double Sideband Transmitters: Methods of Testing, which he presented to the Committee for comments. Mr. Briggs asked Committee members to review the outline and forward comments to Mr. Heffelfinger. Harold Goldberg, Chairman of the Subcommittee on Pulse-Modulated Transmitters, announced that his Subcommittee had completed the first draft of its proposed Standards on Methods of Measurement of Pulse Quantities. He asked for comments from Committee members.

A. E. Kerwien, Chairman of the Subcommittee on Single Sideband Radio Communication Transmitters, announced the reorganizing of his Subcommittee. Mr. Kerwien said that the Subcommittee had previously adopted some definitions for submission to the main Committee, but that it was believed that these should now be reviewed by the re-established Subcommittee. A draft of methods for testing such conditions as radio-power output of transmitters and spurious outputs, applicable to single sideband transmitters had been prepared, although more work remains to be done.

The Electroacoustics Committee, under the Chairmanship of W. D. Goodale, decided to draft Standards on Methods of Testing Loudspeakers.

Calendar of COMING EVENTS

IRE Cincinnati Section, Spring Technical Conference, Cincinnati Engineering Societies Building, Cincinnati, Ohio, April 10

URSI-IRE Spring Meeting, National Bureau of Standards, Washington, D. C., April 21-24

IRE Television Convention, London, England, April 28-May 3

Association for Computing Machinery Meeting, Mellon Institute, Pittsburgh, Pa., May 2-3


IRE New England Radio Engineering Conference, Copley-Plaza Hotel, Boston, Mass., May 10

IRE National Conference on Airborne Electronics, Hotel Biltmore, Dayton, Ohio, May 12-14

The Society for Experimental Stress Analysis Meeting, Indianapolis, Ind., May 14-16

4th Southwestern IRE Conference and Radio Engineering Show, Rice Hotel, Houston, Tex., May 16-17

Radio Parts and Electronic Equipment Show, Conrad Hilton Hotel, Chicago, Ill., May 19-22

IRE-AIEE Conference on Semiconductor Devices, University of Illinois, Urbana, Ill., June 10-20

1952 IRE Western Convention, Municipal Auditorium, Long Beach, Calif., August 27-29

National Electronics Conference, Sherman Hotel, Chicago, Ill., September 24-October 1

IRE-RTMA Radio Fall Meeting, Syracuse, N. Y., October 20-22
Professional Group News

AERBORNE ELECTRONICS

The National Conference on Airborne Electronics will be held on May 12-14, in Dayton, Ohio. Subjects of the technical sessions will be outstanding, and it is expected that the conference will surpass last year's. A successful one-day meeting was held by the Airborne Electronics Group on January 30, as part of the five day Convention of the Institute of Aeronautical Sciences.

ANTENNAS AND PROPAGATION

The first and second issues of the Transactions by the Antennas and Propagation Group have been collected and mailed to its members. Additional copies may be obtained by applying to the IRE Headquarters.

The Group on Antennas and Propagation will hold a joint Spring Technical Meeting with the USA National Committee of the URSI, at the National Bureau of Standards, April 21-24, Washington, D.C.

AUDIO

The Papers Study Committee, under the Chairmanship of Hugh Knowles, will study for content and publication medium all papers and technical editorials published heretofore by the Audio Group.

J. K. Hilliard, Chairman of the Committee on Advertising, has announced that any organization, corporation, or person, for the amount of $25.00 annually, is eligible for listing in the six consecutive issues of the IEEE-PCA Transactions. The listing will consist of two lines, one giving the name and street address of the advertiser and one indicating the product of service. Each line is to be not in excess of 72 characters. To date, six advertisers have submitted material.

The Boston Chapter of the Audio Group held a conference at the Massachusetts Institute of Technology, on January 15, under the Chairmanship of E. C. Dyett. The paper, "A Low-Cost Loudspeaker Assembly," by J. J. Baruch, was presented.

ELECTRONIC COMPUTERS

The Constitution of the recently formed Group on Electronic Computers has been approved by the Professional Groups Committee.

The Los Angeles Chapter of the Group on Electronic Computers is sponsoring an Electronic Computers Symposium, April 30-May 1, on the campus of the University of California. Included in the two-day meeting will be two panel discussions, on Utilization of Germanium Diodes, and Designing for Maximum Reliability. Papers will be presented on Magnetic Devices, Analog Devices, Input-Output Devices, and Programmers and Computers. The keynote of the symposium, "Engineering Tomorrow's Computers," will be offered by H. D. Huskey of the Institute for Numerical Analysis, National Bureau of Standards, University of California.

ENGINEERING MANAGEMENT

A dinner meeting was held by the Group on Engineering Management in Syracuse, N.Y., with Ralph Galbraith, of Syracuse University, as the principal speaker. Dr. Galbraith's subject was "Management of Research in Engineering Laboratories."

GROUP CONVENTION SYMPOSIUM


INDUSTRIAL ELECTRONICS

The Group on Industrial Electronics will hold a Symposium on "Electronics and Machines," May 22-23, at the Palmer House, in Chicago, Ill.

INFORMATION THEORY

A bibliography on Information Theory has been published by this group and mailed to all its members.

INSTRUMENTATION

A symposium on Progress in Quality Electronic Components, under the sponsorship of AIEE-IRE-RTMA, has been scheduled for May 5-7, in Washington, D.C. The Group on Instrumentation has also approved acting as co-sponsors to the West Coast Symposium on Components, which is planned for next year.

NEW GROUPS

The petition for the formation of a Group on Medical Electronics has been approved by the Professional Groups Committee. Also approved by the Committee was the petition for the formation of a Group on Microwave Electronics. This petition will be acted upon by the Executive Committee.

A Planning Committee held a meeting in February, with representatives of the United States Army, Navy, and Air Force, International Telephone and Telegraph, American Telephone and Telegraph, Western Union, Press Services, and others, who are interested in forming a new Wire Communications (Point-to-Point) Professional Group.

NUCLEAR SCIENCE

The Group on Nuclear Science is planning a conference in the United States, the latter part of this year, equivalent to that of the Nuclear Instrumentation Conference held in England.

The Nuclear Science Group participated in a joint symposium with the AIEE in February, at Washington, D.C. The symposium was on "Scintillation Counters."

PROFESSIONAL GROUPS COMMITTEE

A "Task Force" on publication procedure has been appointed by the Professional Groups Committee, to work on new policies for establishing a uniform Group Publication Policy.

The Professional Groups Committee held a get-together meeting at the IRE National Convention. Special tables were arranged for the Professional Groups at the President's Luncheon during the Convention.

QUALITY CONTROL

E. K. Wimpy, of CBS, has been appointed Chairman to the Paper-Control Committee of the Quality Control Group.

SOUTHWESTERN IRE CONFERENCE PROMISES RECORD SUCCESS

The Fourth Southwestern IRE Conference and Radio Engineering Show, scheduled for May 16-17, 1952, at the Rice Hotel, Houston, Tex., promises to be the largest and most comprehensive IRE Conference and Show yet held in that district.

The Houston IRE Section, host and sponsor of the Conference, has made record strides in the planning of both the technical and social program. A wide variety of radiotechnological products and services will be on display at the Radio Engineering Show, and early figures indicate that 40 or more national manufacturers will participate.

The companies who will supply speakers and authorities on technical sessions are among the following:

Microwave and VHF Communication: Federal Telephone & Radio Corporation; General Electric Corporation; Motorola, Incorporated; Philco Corporation; and RCA Victor.

Audio: Paul Klipsch Company.


Airborne Electronics: FCC, Colonel E. White; Bendix Aviation Corporation, Mr. Meecham; and ANDB, Frank White.

Components: Thomas and Skinner Steel Company, James Ireland, "Permanent Magnets"; Bell Telephone Laboratories, J. Campbell, Jr., "Transistors."

Horn Engineering: Eimac Company, John Reirntz, "TV."

Broadcast and Television: A Earl Cullum and Associates.

IRE President D. B. Sinclair, of the General Radio Company will address the Conference, and Commander T. A. M. Craven, consulting engineer, of Washington, D.C., will speak at the banquet Saturday evening, May 17. Commander Craven's topic will be, "Television Spectrum Allocations."

A new feature of the Conference this year will be a program of entertainment for the wives which will include a tea, luncheon, fashion shows, and a tour of the Houston beauty spots.
IRE-AIEE-RTMA Symposium on Progress in Quality Electronic Components

ROGER SMITH HOTEL, WASHINGTON, D. C., May 5-7, 1952

A Components Symposium to be held in Washington, D. C., May 5-7, will be sponsored by the Institute of Radio Engineers, the American Institute of Electrical Engineers, and the Radio-Television Manufacturers Association, with active participation by the Research and Development Board and other agencies of the United States Department of Defense, and the National Bureau of Standards. Headquarters will be at the Roger Smith Hotel, where registration facilities will be available beginning Sunday evening, May 4. Technical sessions will be held in the Department of Interior auditorium. The following program will be presented:

Monday, 10:00 A.M., May 5

WELCOME


Session I

ELECTRONICS TODAY

Chairman, A. V. Astrin, Acting Director, National Bureau of Standards, Washington, D. C.


"Reliability of Military Electronics," E. A. Speaksman, Vice Chairman, Research and Development Board, Department of Defense, Washington, D. C.


Monday Afternoon, May 5

Session II—Part A

BASIC MATERIALS

Chairman, J. N. Koenig, Rutgers University, New Brunswick, N. J.

"Recent Developments in Ceramic Dielectrics," E. J. Smoke, Rutgers University, New Brunswick, N. J.


"Expected Performance of Glass Capacitors," Gail Smith, Corning Glass Works, Corning, N. Y.

"Tantalitic Capacitors," L. W. Foster, General Electric Co., Hudson Falls, N. Y.

Session III—Part C

COILS, INDUCTORS, AND TRANSFORMERS

Chairman, R. C. Sprague


"Ferrite Inductor Cores," W. W. Stifler, Jr., Ferroxube Corp. of America, Saugetties, N. Y.

Tuesday Afternoon, May 6

Session IV—Part A

MISCELLANEOUS COMPONENTS

Chairman, J. H. Miller, Weston Electrical Instrument Corp., Newark, N. J.


"Vibrators for the Armed Services," K. M. Schafer, P. R. Mallory and Co., Inc., Indianapolis, Ind.

"Indicating Instruments for Use Under Severe Conditions," F. X. Lamb, Weston Electrical Instrument Corp., Newark, N. J.

"Influence of Wire and Cable on Improved Components," P. M. Overlander, RCA, Camden, N. J.


Session IV—Part B

DESIGN AND PRODUCTION METHODS


"Unitized Packaging by the Laminar Method," D. G. Heifert, Emerson Electric Manufacturing Co., St. Louis, Mo.

"Heat Transfer from Electronic Components," Walter Robinson, Ohio State University Research Foundation, Columbus, Ohio.

Session VI—Part A

AN EVENING WITH TRANSISTORS

Chairman, (to be announced)


Wednesday Morning, May 7

Session VI

IRE People

George H. Brown (A'30-VA'39-F'41) has been appointed director of the systems research laboratory at the RCA Laboratories Division, Princeton, N. J.

Dr. Brown, a native of Wisconsin, received the B.S. degree at the University of Wisconsin in 1930, the M.S. and Ph.D. degrees in 1931, and 1933, and his professional degree of E.E. in 1942. From 1930 until 1933, he was a research fellow in the electrical engineering department at the University of Wisconsin, and from 1933 to 1942, he was with the research division of the RCA Manufacturing Company, at Camden, N. J. He has been associated with the RCA Laboratories at Princeton since 1942.

Dr. Brown has served on the IRE Committees of, Annual Review, Antennas, and Papers Procurement, and received the IRE Fellow Award for his "studies and publications in the field of radio antennas." He is a member of Sigma Xi, and a Fellow of the American Institute of Electrical Engineers.

G. H. BROWN

Albert Axelrod (S'49-A'50) has been appointed senior engineer in the advanced development laboratories of CBS-Columbia Inc., a manufacturing subsidiary of the Columbia Broadcasting System.

Prior to joining CBS-Columbia, Mr. Axelrod was connected with Loral Electronics Corporation, for three years as project engineer. He holds a B.E.E. degree from the College of the City of New York, and is a member of the American Institute of Electrical Engineers and Eta Kappa Nu engineering fraternity.

Leslie McMichael (M'20-F'25), chairman and managing director of McMichael Radio Ltd., London, Eng., died recently. His age was 67.

Known for his many contributions to the British radio industry, Mr. McMichael began his experimental radio work as early as 1903. In 1913, in association with R. H. Klein, he organized the Wireless Society of London, which later became the Radio Society of Great Britain. He spent many years in close association with the Society, holding the office of vice president and later honorary secretary.

Mr. McMichael was born in Birkenhead, Eng., on November 17, 1884, and received his technical training at Mason College in Birmingham, and as an apprentice at several noted electrical companies. During World War I, he served with the Royal Airforce in the Wireless Telegraphy Section. His early years were spent in wireless research with various companies, and in 1911-1920, he owned and operated his own radio station in the London district. In 1921, he opened his first factory for radio equipment at Slough, Bucks, Eng. In the course of Mr. McMichael's professional career, he brought out several radio patents, and did useful research work in relation to synthetic crystal, being responsible for a crystal known as "radicro," a manufactured all-sensitive galena.

Mr. McMichael was the chairman for the Council of Radio Manufacturer's Association in England, in 1932, and President of the British IRE, in 1944-1946. He was a Fellow of the IRE, Australia, and a member of the Institute of Electrical Engineers.

Max J. O. Strutt (SM'46) has been elected director of the Institute of High Electro-technics at the Swiss Federal Institute of Technology, Zurich, Switzerland.

His work will largely be connected with electronic tubes, transistors, magnetic amplifiers, and gas discharges, including their applications for illumination purposes.

M. J. O. STRU TT

Dr. Strutt, who was born in 1903, received his formal education at the University and Institute of Technology of Munich, from 1921-1924, and the E.E. and D.Tech.Sc. degrees from the Institute of Technology, Delft, Holland, in 1926, and 1927, respectively. In 1927, he became the consulting research engineer of the Philips Company Ltd., at Eindhoven, Holland, and in 1948, was appointed professor in the faculty of electricity at the Swiss Federal Institute of Technology.

Since taking up his duties as professor of electrical engineering at the Swiss Institute, Dr. Strutt has delivered several series of lectures in the University of London and in the Instituto Nacional de Electronica at Madrid, Spain, as well as at several institutes of technology in Western Germany. He was awarded a honorary doctorate in electrical engineering by the Institute of Technology at Karlsruhe, Western Germany, at its 125th jubilee, for his achievements in the field of technical and physical applications of the high and ultra-high frequencies. He is the author of numerous publications in this field.

Dr. Strutt is a member of the Royal Institute of Engineers at the Hague, the Dutch Physical Society, the Swiss Electro-technical Society at Zurich, the Physical Society of Zurich, and the Swiss Society of Sciences at Berne.
A. G. Jensen (A'23–N'26–F'42) has been promoted to Director of Television Research at the Bell Telephone Laboratories. Until his recent appointment he was the engineer in charge of television research at the Bell Telephone Laboratories.

Mr. Jensen, who was born in Copenhagen, Denmark, received the E.E. degree from the Royal Technical College in Copenhagen in 1920, and remained there for a year as instructor before coming to the United States. In 1921–1922, he took postgraduate work at Columbia University, and then joined what is now the research department of the Bell Telephone Laboratories. Until 1926 he was at the field Laboratory in Clifton, N. J., engaged in radio receiving studies and in the design of field-strength measuring sets. He then went to London to initiate short-wave reception from the United States, and remained there four years in charge of the test station during the development of transatlantic short-wave service. In 1930 he returned to this country to work on the development of the coaxial system, taking charge of the development of terminal and measuring equipment. Since 1938, he has been engaged in research work in television equipment and systems.


He has been the IRE Representative for various technical committees, and received the IRE Fellow Award for his "constructive participation in the development of the short-wave transatlantic telephone, the development of broad-band, multi-channel telephony, and the art of television."

Edward W. Herold (A'30–N'38–SM'43–F'48) has been promoted to director of the radio tube research laboratory of the RCA Laboratory Division in Princeton, N. J.

Mr. Herold, who was born in 1907, in New York, N. Y., received the B.S. degree from the University of Virginia in 1930, and the M.S. degree from the Polytechnic Institute of Brooklyn, in 1924. From 1924 to 1926, he was associated with the Bell Telephone Laboratories, Inc., and from 1927 to 1929 with E. T. Cunningham Inc. In 1930 he entered the research and development laboratory of the RCA Manufacturing Company at Harrison, N. J., and since 1942, has been with the RCA Laboratory Division at Princeton.

Mr. Herold has been active on various IRE Committees including: Board of Editors, 1946–1951; Editorial Administrative, 1946–1951; Membership, 1942, Papers, 1944, 1945; and Winter Technical Meeting, 1945. He was the Vice-Chairman of the IRE Princeton Section in 1948 and Chairman in 1949.

Mr. Herold is a member of Phi Beta Kappa and Sigma Xi.

Edward C. Homer (A'28–SM'45), electronics research engineer of the Western Union Telegraph Company, died recently of a heart attack. His age was 58.

During World War II, Mr. Homer supervised the development of the Navy's first night-fighter radar trainer. He also directed the development of a portable carrier telegraph system for the Army Signal Corps and other advances in modern telegraphy. He was a technical representative for the National Defense Research Committee.

A native of River Forest, Ill., Mr. Homer was graduated from Cornell University in 1917. In World War I, he served with the Signal Corps in France, supervising the installation and operation of automatic telegraph apparatus. After the war he was employed in the electrical department of Worthington Steel Company in Coatesville, Pa., and later by the Commonwealth Edison Company in Chicago, and the Public Service Company of Northern Illinois.

He joined Western Union as division inspector of automatic equipment and became electronics research engineer in charge of the laboratories. Mr. Homer was a member of the IRE Committees on Electronics, 1944–1945; Electron Tubes, 1946–1948; Vacuum Tubes, 1945–1946; and Electron Tubes and Solid State Devices, 1949–1952. He was also a member of the Radio Technical Planning Board.

Michael C. Turkish (A'46) has been appointed chief engineer of the coil spring department of the Eaton Manufacturing Company. He has been associated with the Eaton organization as a designer and mathematician since 1938.

Mr. Turkish was born in Bayonne, N. J., in 1916, and received the B.S. degree from Wayne University in 1938. He later studied at the University of Michigan, from 1939–1940. Joining the Eaton Company, he spent several years on the design and testing of the various component parts of the valve gear in an engine, including cam design and analysis. During World War II, he worked on special projects in connection with sodium-cooled aircraft valves, and from 1947–1950, he was in charge of engineering for the Sagnac Dynamic Devices Division, for Eaton. He has recently been engaged in work on hydraulic lifters and turbine blades in Detroit.

Mr. Turkish is a member of the Society of Automotive Engineers, and Tau Beta Pi. He operates an amateur radio station V8MGK.

Merril F. Distad (F'31–A'31–SM'45) formerly of the Naval Research Laboratory, has joined the staff of the Ordinance Development Division of the National Bureau of Standards to work on an electronic ordnance.

At the Naval Research Laboratory, from 1946 to 1950, Dr. Distad was head of the Electrical Contact Phenomena Research Section, supervising research on sliding contacts, particularly the high-altitude carbon brush problem. Prior to this, he directed the Chesapeake Bay annex section of the radio division of the NRL, and was responsible for all work of the scientific personnel stationed there. Previously he was head of a radar oscillator research group of NRL, supervising research and development on oscillators in the 100 to 700-mc frequency range. He also has taught courses in physics, trignometry, and electrical engineering.

A native of North Dakota, Dr. Distad received his B.A. degree in physics from Concordia College, in 1931, and his M.S. and Ph.D. degrees from the University of Minnesota, in 1934 and 1938, respectively. He is the author of several papers on semiconductors and is a member of the American Physical Society, the Physical Society of London, the American Institute of Electrical Engineers, the Philosophical Society of Washington, the Research Society of America, and Sigma Xi.
Abstracts and References


NOTE: The Institute of Radio Engineers does not have available copies of the publications mentioned in these pages, nor does it have reprints of the articles abstracted. Correspondence regarding these articles and requests for their procurement should be addressed to the individual publications, not to the IRE.

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ACOUSTICS AND AUDIO FREQUENCIES

534.321.9 Making Ultrasonic Waves Visible—R. Hanel. (Radio Tech. (Vienna), vol. 27, pp. 325–329; August, 1951.) Description of simple ultrasonic equipment developed at the Technische Hochschule, Vienna.


534.41:534.78 The Sound-Film Spectrograph—an Instrument for the Acoustic Analysis of Speech and Other Rapidly Changing Sounds—B. H. Edgardard. (IVA (Stockholm), vol. 22, no. 5, pp. 134–153; 1951. In German.) The sound to be analysed is recorded either on film or magnetic tape in a number of parallel tracks, each corresponding to the frequency range of a particular bandpass filter. The equipment is compared with the Bell Telephone visible-speech spectrograph.

534.84 The Acoustics of Ancient Theatres—F. Canac. (Rev. Sci. (Paris), vol. 89, pp. 151–166; May/June, 1951.) Investigation of the design and acoustic properties of historical open-air theatres, many photographs of which are reproduced, and discussion of the results of particular tests made using logatomes and by a spherocyclic tank method for the theatres at Orange and Vaison, France.

534.844.5 The Use of Artificial Reverberation in the Theatre—A. Molé. (Ann. Télécommun., vol. 6, pp. 245–249; August/September, 1951.) The introduction of artificial reverberation, produced by means of an auxiliary echo room, enables artistic requirements to be satisfied, without impairing the intelligibility of speech. The relation between intelligibility and the slope of the sound-decay curve is given in a simple form and is verified experimentally.

534.846 Acoustics of the Royal Festival Hall, London—P. H. Parkin. (Nature (London), vol. 168, no. 4268, pp. 264–266; August 18, 1951.) A brief discussion of considerations taken into account in the design of the hall. The difficulty in meeting the subjective criteria of the musician in terms of physical quantities is stressed. Data are given for reverberation time and noise level due to external sources, and comments of eminent musicians on the high quality of the hall are included.

534.861.1 Recording Studio Design—P. A. Shears. (Wireless World, vol. 57, pp. 355–360; September, 1951.) Various types of frequency distortion which may be caused by unsuitable studio design are discussed and the two typical defects of excessive reverberation time at low frequencies and “flutter echo” at high frequencies are illustrated in a three-dimensional characteristic. An empirical relation between optimum reverberation time and hall volume is extrapolated to give guidance in the design of small studios. In large halls any natural resonances are usually at frequencies too low to give trouble, but in studios with volumes of the order of 3,000 feet4 such resonances may occur in the range 30 to 150 c.p.s. Wall constructions and treatments for absorbing excess energy over various frequency ranges are described, with numerical detail.

534.861.1 Broadcasting Studios with Sound-Diffusing Walls—C. Tutino and G. Sacerdote. (Ponte e Telecom., vol. 19, pp. 5–15; January, 1951.) An account of work recently carried out on studios in Milan and Turin. The walls and ceilings were lined with plaster moulded into semi-cylindrical shapes of uniform length but varying diameter, the moulds being arranged in groups disposed alternately horizontally and vertically so that the wall surface was as irregular as possible. Typical dimensions were: length, 90 cm; diameter, 16 to 32 cm. With this arrangement no resonance effects were detectable at frequencies within the combined range of violin and cello. Measurements were made on models and in the studios themselves to determine the effect of the arrangement on the acoustic properties of the rooms; experiments are still in progress.

534.874.1+621.396.621:519.241.1 Perturbation and Correlation Methods for Enhancing the Resolution of Directional Receivers—Hunt. (See 790.)


541.305.623.8 Speech-Reinforcement System Evaluation—L. L. Beranek, W. H. Radford, J. A. Kessler and J. B. Wiesmer. (Proc. I.R.E., vol. 39, pp. 1113–1123; November, 1951.) Results of measurements for six auditoria using subjective rating tests, word-articulation tests and a new “terminal-word” test. A graphical method is presented for calculating the effect of the frequency response of the system, the reverberation time of the room, directivity of the loudspeaker and room noise. A flat response from 400 to 4,000 cps is needed for good intelligibility; room reverberation has little effect if the loudspeaker system is sufficiently directive.

541.305.623.8 The Universal Radiator, a New Development in Radiator-Group Technique—K. Feik. (Elektrotech. (Berlin), vol. 5, pp. 365–372; August, 1951.) Formulas are given from which the directional characteristics of radiator groups, their power and amplification factor, can be determined. Results are presented for various types including (a) circular groups, (b) linear groups, (c) circular groups and (d) combinations of circular and twin groups. Practical combinations for directional and all-round transmission are discussed.

541.306.611.21:621.317.382 Power Measurements on Ultrasonic Quartz Oscillators—Schmitz and Waldick. (See 734.)

安东NAS AND TRANSMISSION LINES

541.315.212.011.2/.3 Effective Resistance and Effective Inductance of Current-Carrying Conductors at High Frequencies—W. Taeger. (Punk u. Ton, vol. 22, pp. 422–429; August, 1951.) Consideration of a straight conductor such as the inner conductor of a coaxial cable, shows that at hf the current distribution is not the same at all points of the cross-section, but that between the center and the surface of the conductor there is a great difference of both current magnitude and phase. The resulting increase of effective resistance and decrease of inductance, as dependent on the frequency and on the diameter of the conductor, is calculated and shown graphically.

561.392+621.396.67:621.307.5 Practical TV Antenna and Transmission-Line Considerations—(Radiotronics, vol. 16, pp. 155–179; August, 1951.) An account is given in simple terms of the fundamentals of
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radio emission and propagation and of the manner of operation of antennas and transmission lines. Various types of antenna and array useful for television are described and illustrated; performance is discussed, with numerical examples.

621.392.017.13:621.3.011.22 577
Radiation Resistance of a Two-Wire Line—J. E. Storer and R. King. (Proc. I.R.E., vol. 39, pp. 1088-112; November, 1951.) A general formula for the radiation resistance is derived by integration of the normal component of the Poynting vector over a large sphere surrounding the line. The result is in agreement with that computed by other methods. Formulas are presented for the special cases of a lossless system and a nonresonant line.

621.392.018.78 578
Pulse Distortion in RC and LG Lines—K. Steinbuch. (Arch. elek. Übertragung, vol. 5, pp. 354-360; August, 1951.) The symbols R, C, L and G denote respectively the series resistance, shunt capacitance, series inductance and shunt conductance of a line. Thin-wire cables consisting of individual wire are not correctly represented by ordinary RC lines. Lines characterized mainly by L and G are of little practical importance, but are nevertheless of interest since coils and transformers with B/H characteristics have an LC line circuit equivalent. Use of the error integral in conjunction with operational calculus enables formulas to be derived permitting numerical calculation of signal transmission characteristics of line. Undistorted transmission and reflection effects are discussed. The theory is applied to the transmission of a broadcasting program on the phantom circuit of a telephone system, which can be regarded as an RC line.

621.392.09 579

621.392.201:621.317.320 580
Determination of Aperture Parameters by Electrolytic-Tank Measurements—Cohn. (See 725.)

621.392.261:621.390.09 581

621.392.261:621.390.11 582
Directional-Coupler Errors—P. A. Benson. (Wireless Eng., vol. 28, pp. 371-372; December, 1951.) In the type of coupler using two windings of a 3/4 apart, errors in measurements of voltage and current at a given range are a reflection of the differences at the windows. The errors depend on the relative phase of the transmitted and reflected waves, and on the phases of the reflections at the windows.

621.390.07 583
Distribution of Radiation Resistance along a Rod Aerial: As Coil Line with Transformer Coupling—O. Zinke. (Funk u. Ton, vol. 30, pp. 392-397; December, 1951.) An equivalent circuit is considered in which the antenna is represented by an iterative network of coils and capacitors whose values differ along the line. This circuit enables the distribution of the radiation resistance along the antenna to be determined. The analysis also gives a simple explanation of the frequency dependence of the radiation resistance. This agrees, for antennas with current maximum at the foot (electrically short antennas or those excited in odd harmonics), with the frequency dependence determined by integration of the radiation intensity in the distant field.

621.390.067 584
Plane Aerials of Small Width—S. Zinier. (Ann. Telecommun., vol. 6, pp. 214-222; August/September, 1951.) Theory is developed by considering the plane antenna as a system of parallel linear conductors whose number tends to infinity. Kirchhoff's equations are applied with simple expressions are derived for the current distribution and input impedance; results are in good agreement with values found by experiment. Radiation characteristics are also calculated.

621.390.667:621.317.330 585
The Measurement of Antenna Impedance Using a Receiving Antenna—E. O. Hartig, R. King, T. Morita and D. G. Wilson. (Proc. I.R.E., vol. 39, pp. 1458-1460; November, 1951.) Energy from a remote transmitter excites a receiving antenna erected vertically over a large conducting plane and base-loaded by a vertical slotted coxial cable of variable length. Measurements enable the antenna impedance to be determined. Curves of the measured impedance as a function of the electrical length of the antenna are given. Explanation is obtained with the impedance values for the same antenna when base-driven through the slotted conductors. Both sets of measurements are in good agreement with the King-Midderton-second-order theory.

621.390.607.11.21 586
The Impedance of an Antenna over a Large Circular Screen—J. E. Storer. (Jour. Appl. Phys., vol. 22, pp. 1058-1066; August, 1951.) A theoretical problem of an antenna erected vertically in the plane of a screen. An integral equation is obtained for the electric field in the plane of the screen, outside the screen. This equation is solved approximately by the use of a variational principle, and a formula is obtained for the change of antenna impedance as a function of the diameter of the screen.

621.390.607.11.21 587
Influence of a Plane Reflector on the Input Impedance of a Thick Circular Cylinder—S. Zinier. (Ann. Telecommun., vol. 6, pp. 205-212; July, 1951.) Data are presented in tables and graphs for facilitating the calculation of the input impedance of a cylindrical antenna with a plane reflector, using the double-line theory previously developed (2645 of 1951).

621.390.607.11.21 588
Mutual Impedance of Wire Aerials—L. Lewin. (Wireless Eng., vol. 28, pp. 352-355; December, 1951.) For the general case of two straight wire aerials carrying sinusoidal currents it is possible to evaluate the mutual impedance in terms of the Si and CI functions. A demonstration of this expression in the case of two coplanar X/2 wires is given. The special cases of dipoles parallel or forming an X or V are also considered (below) (Mediumhurst, 1932 "Abstracts," p. 285 (Carter) and 1933 "Abstracts," p. 214 (Murray)).

621.390.607.11.21 589
Dipole Aerials in Close Proximity—R. G. Mediumhurst. (Wireless Eng., vol. 28, pp. 355-358; December, 1951.) A treatment of the problem of mutual impedance of crossed half-wave dipoles, leading to a solution in terms of Si and CI functions. Owing to the assumption of zero thickness of the wires, the limiting cases of the two-dimensional X and V arrangements when the included angle becomes zero, and of the parallel arrangement when the distance becomes zero, give different values for the mutual reactance. See also 588 above (Lewin, 1932 "Abstracts," p. 585 (Carter) and 1943 "Abstracts," p. 214 (Murray)).

621.390.607.018.2417 590
The Folded Fan as a Broad-Band Antenna—R. L. Linton, Jr. (Proc. I.R.E. (London), vol. 39, pp. 1436-1444; November, 1951.) The results of the numerical calculations in the frequency range 100 to 1,350 mc are used to design a naval antenna operating within the communication band of 2 to 27 mc, having a 4 to 1 frequency ratio and a maximum power loss of 18.5 per cent, due to mismatch when connected to a 52-Ω line.

621.390.671+621.390.11 591

621.390.671 592
Current and Charge Distributions on Antennas and Open-Wire Lines—D. J. Angelakis. (Jour. Appl. Phys., vol. 22, pp. 910-915; July, 1951.) Results of measurements on cylindrical antennas and their feeders with iron, glass and Bakelite become graphs. The presence of a stub support modifies the distributions on the antenna only near the junction of the antenna, feeder and stub, but for antenna loads near antiresonance the distributions on the feeder as well as the impedances of the system are altered considerably. A corrective network for the region of the junction is discussed.

621.390.675 593

621.390.607.500.017:621.371.336 594

621.390.607.500.017:621.371.336 595
A Vertical Nonrotating Directional Aerial System—J. H. Chapman (QST, vol. 35, pp. 20-23; July, 1951.) A receiving antenna system for amateur use on 6, 10 and 20 m. Three vertical dipoles are arranged equidistantly. Any two are fed in antiphase to give coverage over a 120° sector. The main beam in the vertical plane covers all useful elevation angles on all three working frequency bands. A considerable saving in mast height relative to a horizontal antenna is claimed.
Artificial Dielectrics for Microwave Circuits. — Sharpless. (See 727.)


Recent Developments in Rectangular and Cylindrical Waveguides. — G. F. Clark. (Jour. Franklin Inst., vol. 252, p. 1-22; July, 1951.) A comprehensive treatise of an introductory character, but not over-simplified; vector analysis is used as the basis of the treatment.

CIRCUITS AND CIRCUIT ELEMENTS

Electrical-Equivalent Circuits.—K. Klippel. (Ferrneldtech. Z., vol. 4, pp. 337-346; August, 1951.) Detailed review of their application in the representation of electromagnetic, physical and physico-chemical phenomena.

The Calculation of the Magnetic Field of Rectangular Loaded Slot, and its Application to the Reactance of Transformer Windings.—E. Billig. (Proc. I.E.E. (London), Part IV, vol. 98, pp. 55-64; October, 1951.) "The magnetic vector potential of current-carrying conductors in a rectangular slot is the same as that due to an infinite number of images of these conductors from all the boundaries. The solution of this problem can thus be obtained in the form of a Fourier series, periodic in both the x and y directions, the constants of the solution being determined for the boundary conditions, i.e., by the dimensions of the slot and of the conductors, and by the currents passing through them. Expressions for the magnetic vector potential due to any conductor arrangement can thus be developed, and these lend themselves to consideration with simplification without undue loss of accuracy."

A Sweep-Type Differential and Integral Discriminator.—E. Feistain. (Rev. Sci. Instr., vol. 22, pp. 761-765; October, 1951.) A circuit is described for determining the pulse-height distributions from scintillation counters, proportional counters, parallel-plate counters and other pulse sources. It will operate with any positive-output amplifier, with rise time ≥ 0.1 μs and output limited to 100V.

A High-Precision Pulse-Height Analyzer of Moderately High Speed—G. W. Hutchinson and G. G. Scarratt. (Phil. Mag., vol. 42, pp. 792-806; June, 1951.) Designed for nuclear research work. Information is stored in an ultrasonic delay line and displayed on a CRT screen. The accuracy of channel width and the linearity of response are both within 1 part in 1,000. The storage capacity may be varied to give 60 channels of up to 104 pulses each, 80 channels of up to 3X105 pulses each, or 120 channels of up to 103 pulses each, with a maximum sampling rate of 1,600 per second.

Winding Space Determination—N. H. Crowhurst. (Electronic Engr. (London), vol. 23, pp. 302-306; August, 1951.) The factors controlling the choice of winding space and winding methods for transformers and chokes are briefly summarized. The use of abacs for simplifying the calculations involved is described with examples.

Calculation of Small Transformers.—E. Donauer. (Funk u. Ton, vol. 5, pp. 369-374; July, 1951.) Design formulas and curves are given which are applicable to multi-winding transformers suitable for power packs and using either M or E110 amperages. A numerical example is worked out.


Transient Response of a Narrow-Band Automatic Frequency-Control System—T. Miller. (Proc. I.R.E., vol. 39, pp. 1433-1436; November, 1951.) Description of a method of analyzing the response of acf systems operating in conjunction with narrow-band-pass filters. A time lag, equivalent to the reciprocal of the bandwidth, is assigned to the filter. Circuit parameters are determined for the case of operation at near resonance. The equations of the system are derived by means of the Laplace transform, and the transient response of the system to a step change of input frequency is evaluated by the method of residues.

The Response of Round-Wire Single-Layer Inductance Coils—A. H. M. Arnold. (Proc. I.E.E., Part IV, vol. 98, pp. 94-100; October, 1951.) "Butterworth's two formulas for the resistance of short coils with a finite number of turns are merged into a single formula valid for coils of any length and having any number of turns. Numerical values of the functions of the resistance for short coils are given in tabulated form. The formula is shown to give results in reasonable agreement with the experimental figures of Medhurst (1694 of 1947) and Hickman (Bureau of Standards Scientific Paper No. 472)."

A Comprehensive Counting System for Nuclear Physics Research.—N. F. Moody, W. D. Howell, W. J. Battrell and R. H. Taplin. (Rev. Sci. Instr., vol. 22, pp. 439-461; July, 1951.) A method of constructing counting systems from a number of standardised sub-units is described. Details of the design of these sub-units are given, the aim being to attain versatility of function and reliability in performance. A discussion of the choices of various components used in these sub-units is described. Further sections of the paper to be published later will deal with the details of the amplifiers.

The Controlled Tripping of High-Voltage Impulse Generators.—A. S. Hough and J. J. Crowhurst. (Jour. Franklin Inst., vol. 242-245; August, 1951.) A triggered spark-gap and associated circuit is described which enables a generator to be discharged in a single-stage procedure with measuring equipment such as a counter or rotating-mirror camera. A tripping pulse of only about 5 kV is required; the tripping of a single-stage generator can be performed within 0.1 μs of a predetermined short delay time.


The One-Sided Green's Function—Miller. (See 711.)

Double Return for Null Measurement at High Frequency—Samal. (See 724.)

High-Frequency Matching Transformer.—F. Steiner. (On. Z. Telegr. Teleph. Funk Fernruecktech., vol. 5, pp. 93-100; July/August, 1951.) In a tuned wide-band matching transformer developed in the damped parallel-tuned secondary circuit at frequencies away from resonance gives rise to large variations of apparent input impedance. Design formulae are derived in which the series-tuned primary circuit partially compensates for these variations.

Application of Matrices to Four-Terminal Network Problems—H. F. Biggar. (Electronic Eng. (London), vol. 23, pp. 307-311; August, 1951.) The relation of matrices to network equations is explained and simple matrix algebra is applied to the derivation of a constant-resistance equalizer with balanced input and unbalanced output.

Transient Response, Conditions for Monotonic Characteristics—F. Macdiarmid. (Wireless Engr., vol. 28, pp. 330-334; November, 1951.) The necessary and sufficient conditions for a monotonic transient response are derived for the case of a network to which is applied a unit current-step is applied. The location of the zeros of the impedance function on the complex-frequency plane is shown to be impossible as the location of the poles. Conditions for monotonic transient response are derived for networks having two poles and two zeros in the complex-frequency plane; the results are applied in discussion a compensated anode load fed by a triode valve.
Pulse Distortion—S. II. Moms (Proc. I.R.E., Part IV, vol. 98, pp. 37–42; October, 1951.) For "wave forms of simple shapes certain features may be defined: content, epoch, spread, shape, and form, etc., which are affected in a very simple way by passing through a linear system (which is regular at low frequencies). In fact, by proper definition, they are affected only additively by constants which are independent of the applied wave form, and characteristic only of the system. These invariances for the pulses and for the system correspond to the cumulants used to describe statistical distributions.

A Design of an Ultrasonic Delay-Line T. Gold (Phil. Mag., vol. 42, pp. 787–791; July, 1951.) Design and construction details of a vertical folded Helig delay line, for use in an electronic memory unit, giving a delay of 1.2 ms with a bandwidth of several mc.

Linear Electromechanical Quadrupoles W. E. John. (Freqques, vol. 5, pp. 166–173 and 190–192; June and July, 1951.) Analysis of the applicability of electrical circuit theory to electromechanical phenomena. General equations for the forward and backward dynamic impedances and over-all damping of a passive transducing circuit are derived and developed for application to specific circuits. A detailed mathematical treatment is given for an electrostriction process.

Design of Electric Wave Filters with the Aid of the Electrolytic Tank—A. R. Boothroyd. (Proc IRE (London), Part IV, vol. 98, pp. 65–93; October, 1951.) New analogue representation (in terms of complex frequency) of the properties of image-parameter transfer functions of the Zobel type by current flow in an electrolyte tank provides a convenient method for determining filter insertion-loss characteristics. The tanks used are developments of the double-layer tank described by Boothroyd, Chinery and Mackay (1949) of 1949). A transformation is developed by means of which the approximation problem can be avoided for the specific low-pass filter insertion loss, the poles and zeros of the approximation function of the filter being accurately determined by simple measurements in the electrolyte tank.

The Multisection RC Filter Network Problem—L. Storch. (Proc. IRE, vol. 39, pp. 1456–1458; November, 1951.) Two methods for deriving the filter characteristics from the basic circuit equations are described. The methods, unlike that of Tuchodi (1950), take nothing for granted but Ohm's and Kirchhoff's laws. The first, a finite-difference method, leads to the solution almost immediately. The second method makes use of image parameters suitable for cascade connection of symmetrical structures.

Ferrites as Magnetostriective Resonators and their Application as Electrical Filter Elements — W. H. Weile. (Tech. Mitt. Siemens-Telef. Teleph-Verk., vol. 28, pp. 1 and August 1, 1951, in German, with French summary.) Methods of production and magnetic properties of MgZn, CoZn and NiZn mixed ferrites are discussed. Measurements show that NiZn ferrite with Zn ferrite content 0 to 40 per cent exhibits a strong magnetostriective effect, and practically high permeability is obtained practically no eddy-current losses. Q-factor lies between 1,000 and 3,000. Two bridge-type filter circuits with a 4-kc pass band at 40 and 80 kc respectively are described. The power transmitted in the pass band is about 1 mw.

Microstrip Filters employing a Single Cavity Exposed More than One Mode—Wei-Guan Lin. (Jour. Appl. Phys., vol. 22, pp. 989–1001; August, 1951.) A cavity resonator with input and output couplings constitutes a network with two pairs of poles and zeros in a characteristic with an infinite number of possible modes of oscillation. In some cavities of special shape, several degenerate modes with identical natural frequency can occur. In a single cavity these degenerate modes can be coupled together to form a chain of coupled cavities by perturbation of the otherwise ideal geometrical configuration of the cavity. The characteristic of such devices are analyzed and applied to the design of multi-mode filters. Experimental models of 2-, 3-, and 5-mode filters are described, with insertion-loss curves.

The Vestigial-Sideband Filter for the Sutton Coldfield Television Station—E. C. Cook. (Proc. IRE (London), Part III, vol. 98, pp. 460–464. Discussion, pp. 465–470; November, 1951.) The specificity of the filter is outlined and the theory of the complimentary constant-resistance network filters of the Norton type is explained. The basic design formulas relevant to the chosen network are given, in which interconnections of lumped elements by coaxial lines. The results of measurements on the performance of the adopted practical circuit show agreement with that of the idealized network.

Alignment and Adjustment by Synchronously Coupled RC-Coupling Networks—M. Dishal. (Proc. IRE, vol. 39, pp. 144–145; November, 1951.) The method described for rapidly tuning a filter is to couple very loosely a detector to the first resonator and then to tune consecutively all odd-numbered resonators for maximum detector output and all even-numbered resonators for minimum detector output, ensuring that all resonators following the one being tuned are completely detuned. The theory of the method is given and the technique of adjustment of circuit constants in the filter is considered.


Practical Assembly of Printed Circuits—R. Singer. (Électronique (Paris), pp. 18–20; 17 and May, and June, 1951.)

Some Sawtooth Oscillations—V. Vogel. (Ann. Télécomm., vol. 6, pp. 182–190; July, 1951.) An analytical study is made of circuit systems in which abrupt alternations between two states occur. Approximate solutions are found by applying Poincaré's method of trajectories. The trajectories on the phase plane being represented by a mathematical construction in the form of a winding of order 5. Starting with the multivibrator as a particular example, generalized equations are developed; the periodic solutions through those satisfactorily represent the operation of the circuit.


On the Influence of Circular Holes in Electrolytic Tank—A. R. Boothroyd and W. Keen (Z. angew. Phys., vol. 3, pp. 253–259; July, 1951.) Experimental investigation at wavelength of 10 and 25 cm of the alteration of resonator frequency due to the damping due to apertures in a cavity wall. The theoretical calculation of the frequency dependence of losses are described in detail for the determination of coupling factors. As in coupled circuits for medium frequencies, there is a critical value of coupling above which the wave form in the secondary cavity is of the double-hump type.

Arrangement for Division and Multiplication of Frequencies and Frequency Bands—H. Wüsten (Funk u. Ton, vol. 5, pp. 374–376; July, 1951.) Short description of a method (patent applied for) by which the multiplication or division can be effected without the occurrence of harmonics or combination frequencies. A tuned circuit is used in conjunction with either a rectifier or valve input circuit.

Synchronizer for 100-kc Square Wave Generator—L. C. Hedrick (Proc. IRE, vol. 22, p. 357; July, 1951.) The synchronizer previously described (1950) have been found defective owing to lack of stability in the synchronizer, a new synchronized circuit described which has proved entirely satisfactory, one unit having been run continuously for a week without loss of synchronization.

A Generator for Pulses of Variable Length—N. G. Giariddi (Poste e Telecomunicazioni, vol. 1, pp. 5–9; May, 1951.) Analysis of May's circuit (1950) and a modified modification by connection of one of the diodes of a 6AL5 valve across the terminals of the grid circuit of one of the diode being applied to the input of the following amplifier as standard dc restorer. This results in perfect linearity of the pulse length characteristics, and constant pulse amplitude as the pulse length is varied.

Harmonic Generation in the U.H.F. Region by Means of Germanium Crystal Diodes—F. D. Lewis (Gen. Rad. Exper., vol. 26, pp. 6–8; July, 1951.) Diodes were used to derive up to the second, third, fourth, fifth, sixth, and fourth-mc oscillators respectively. The available power starts from about 60 mw at 500 mc to about 2,000 mw at 1.34A. Harmonic mixers are used. Circuit data are given. The maximum power from 10 crystals is only about 30 per cent of that from Ge crystals in the range 400–1,000 mc.

Design of Input Circuit of a Capacitor-Microphon—"T. Kirschner. (Arch. ekt. Übertragungsw., vol. 5, pp. 383–391; August, 1951.) The reaction of the acoustical-mechanical system of a capacitor microphone on the electrical system due to changing in a complex internal impedance. Amplifier design for the condenser, with special reference to this and to polarization voltage, distortion and the input resistance of the valve used. See also 18 of February.
Wave Propagation on Helical Wires

W. Sollfrey. (Jour. appl. Phys., vol. 22, pp. 905-910, July, 1951.) The field equations and boundary conditions are formulated exactly and a general expression is obtained in terms of powers of the ratio of wire thickness to distance between turns. A new coordinate system is introduced in which a helical wire of circular cross-section appears as a surface with a coordinate constant. Maxwell's equations and the boundary conditions are expressed in terms of this system and a perturbation method is applied to obtain approximate solutions of the equations. The results indicate a principal mode which is propagated along the wire with the velocity of light. The theory also predicts transverse electric fields along the axis, of the same order of magnitude as the longitudinal fields. These transverse fields determine the minimum magnetic field required to maintain a stable electron beam along the axis.

Propagation in the Non-homogeneous Atmospheric Layer

J. W. Joyce and E. H. Kurihara. (Phys. Rev., vol. 87, pp. 945-951, July 15, 1952.) A new theory of the propagation of electromagnetic waves in the ionosphere has been developed. The theory is based on the assumption that the ionosphere consists of a stratified medium with a sharp transition from the conductive region above to the non-conductive region below. The analysis is carried out to determine the effective properties of the medium and to predict the behavior of electromagnetic waves propagating through it.

Reflection of Electromagnetic Waves from Slightly Rough Surfaces

S. O. Rice. (Comm. pure appl. Math., vol. 4, pp. 317-350, August, 1951.) A new theory of the reflection of electromagnetic waves from a slightly rough surface is developed. The theory is based on the idea that the surface can be regarded as a collection of random roughness elements. The reflection coefficient is calculated as a function of the surface roughness parameters and the frequency of the incident wave.

Reflection from a Perfectly Conducting Plane

P. P. Chen. (Proc. nat. Acad. Sci., vol. 38, pp. 510-513, March, 1952.) The theory of reflection from a perfectly conducting plane is extended to include the case of a plane with a rough surface. The reflection coefficient is calculated as a function of the surface roughness parameters and the frequency of the incident wave.

The Possible Nature and Electromagnetic Origin of the Observed Pulsa
tions of the Diameter of the Sun—L. Galiwan. (Rev. Acad. nat. Lincei, vol. 11, pp. 60-62, July, 1951.) A new theory of the origin of the observed pulsations of the diameter of the Sun is proposed. The theory is based on the idea that the observed pulsations are due to the presence of a duct, and the solution is expressed in terms of Hankel functions of order one-quarter.

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Field Representations in Spherically Stratified Regions—N. Marcuvitz. (Commun. pure appl. Math., vol. 4, pp. 263-315, August, 1951.) A general method is given whereby a representation may be obtained of the field produced by point charges in a spherically stratified medium. The field is expressed by a superposition of mode functions chosen to permit a simple evaluation of the associated amplitude. The method of separation of the field into a product of a spherical wave function and a coordinate constant. Maxwell's equations and the boundary conditions are expressed in terms of this system and a perturbation method is applied to obtain approximate solutions of the equations. The results indicate a principal mode which is propagated along the wire with the velocity of light. The theory also predicts transverse electric fields along the axis, of the same order of magnitude as the longitudinal fields. These transverse fields determine the minimum magnetic field required to maintain a stable electron beam along the axis.

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551.619.0:551.578.1/4

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increase in current carriers, but to an increase in their apparent mobility owing to modification of the intergranular barriers. The conductivity of specimens of the same dimensions prepared under different crystallizing conditions is shown to increase with increasing size of microcrystals. Carrier concentration decreases with increasing temperature, in agreement with X-ray diffraction evidence of greater crystal perfection at higher temperatures.


54.23: 548.55: 537.311.33 698 Electrical Properties of Selenium: Part I—Single Crystals—H. W. Henkel. (Jour. Appl. Phys., vol. 22, pp. 916-925; July, 1951.) The dark resistivity of crystals grown in a melt was studied as a function of axis orientation, temperature, field, and time of annealing. A high field. The large values found for thermoelectric power indicate hole conduction with a hole density of the order of 10¹³ cm⁻³, the density decreasing with temperature increase above room temperature. Mobilities and activation energies were also determined.


54.48-31 + 54.74-31 700 Some Conduction Properties of the Oxides of Cadmium and Nickel—C. A. Hogarth. (Proc. Phys. Soc., vol. 64, pp. 691-700; August 1, 1951.) Results of measurements of electrical conductivity, thermoelectric power of CdO and NiO at temperatures up to 500°C and at various pressures of the surrounding oxygen are shown graphically; they are in general agreement with theory.


54.817.221: 535.61 + 535.345.1 703 Infrared Transmission of Galena—W. Paul, D. A. E. Sugden and R. V. Adams. (Phys. Soc., vol. 64, pp. 528-529; June 1, 1951.) Single crystals of galena were found to be semi-transparent in the infra-red. A measure of about 3μm, beyond which the transmission falls off. The transmittance, as measured by a spectral range of about 4.5μm, then falling more slowly to a low value at 10μm. The rise of transmission beyond 3μm coincides with the sharp fall in the photoconductivity of thin films of PbS at room temperature and also in the photovoltaic effect shown by crystals with point contacts.

54.80: 537.228.1 704 Piezoelectric Behaviour of Partially Plated Square Plates Vibrating in Contour Modes—H. G. Williams. (Proc. Phys. Soc., vol. 64, pp. 706-712; August 1, 1951.) A continuation of work described previously [2208 of 1951 (Bechmann)]. Measurements on square plates are used to check the theoretical solution for the motion. For the long-titudinal mode-2 described by Ekstein (423 of 1945) a particularly sensitive test of the theory is possible. Experiment confirms that with a critical value of electrodes the piezoelectric excitation vanishes.

54.80: 504.514.51: 530.37 705 Piezoelectricity—the Growth of Dauphiné Twinning in Quartz under Stress—L. A. Thomas and W. A. Wooster. (Proc. Roy. Soc. A, vol. 208, pp. 43-62; August 7, 1951.) The behavior of plates and bars of quartz, held at about 400°C while they were twisted or bent by external means, or while strained by means of a tensometric network. The growth of one crystallographic orientation out of another under the influence of stress, for which the term 'piezoelectric' is proposed. Piezoelectricity may also be expected in other crystals such as titanates, felspars and boracites.

621.314.63 706 Effect of Temperature on the Height of Potential Barriers and on the Breakdown Voltage of Rectifiers—E. Billing. (Proc. Phys. Soc., vol. 64, pp. 732-753; August 1, 1951.) Measurements of the contact resistance of standard Se, Ge and Si rectifiers indicate a barrier height for temperatures above room temperature. The decrease observed at lower temperatures suggests that the barrier disappears at absolute zero. In some rectifiers (e.g. Ge contact rectifiers) the turnover voltage is lowered by a decrease in temperature, and in others (e.g. Ge contact rectifiers) the turnover voltage increases at low temperatures, at least down to the temperature of liquid air.

621.315.61 707 On High Frequency Power Loss of Dielectrics—K. Higasi and Y. Ozawa. (Proc. Phys. Soc. Japan, vol. 6, pp. 280-281; July/August, 1951.) Power loss in a dielectric is not determined directly by the loss tangent but is related to the hf conductivity e. Thus a maximum value of tan δ can occur at some frequency without resonance absorption. It is suggested that the frequency curve be used as a criterion of resonance.

621.315.62.4 708 Properties of Beryllium-Barium Titanate Dielectrics—E. N. Bunting, G. R. Shelton, A. S. Creeamer and B. Jaffe. (Bw. Stand. J. Res., vol. 47, pp. 15-24; July, 1951.) Dielectrics having compositions in the system Be₂TiO₃-TiO₂ were matured at 1,240°-1,525°C. Data are given for the composition, heat treatment, absorption and shrinkage. The dielectric constant (K) and tan δ of the products were measured. The power factor (Q) were determined at various temperatures from -60° to 200°C; measurement frequencies used were 50 k, 130 k, 1 m, 20 m and 3 kmc. The linear thermal expansion over the range 25°-700°C was found to vary from 0.58 to 0.77 per cent. The resistivity at 200°C was increased by a factor of 10° over a few days; for specimens of some compositions K and Q changed with time. Results are tabulated.

nominal frequency, actual accuracy even greater. The frequency stability of the B.B.C.'s ordinary transmissions is also discussed briefly.

621.3.087.4: 551.510.355 719
A 16-kw Panoramic Ionospheric Receiver—R. Lindeborg (Electro-Techn. Z., Stockholm, No. 85, 41 pp.; 1951.) For another account see 1425 of 1951.

621.3.087.6: [621-526]: 613.396.015 720
A Servo Drive for Heterodyne Oscillators—T. Slonczewski. (Electr. Eng., vol. 70, p. 583; August, 1951). A summary of A.I.E.E. Summer General Meeting paper. A method for sweeping a test oscillator through its frequency range while some characteristic of the device under test is noted. The frequency varies linearly with time, which simplifies the analysis of the records.

621.316.8: 621.396.822 721
A Low-Frequency Noise-Voltage Generator—H. Schneider. (Funk u. Tov, vol. 5, pp. 337–341; July, 1951.) Equipment is described which gives, in the frequency range 1–20kc, an effective voltage of 5V across a 600-Ω matched load. Peak noise voltages are about three times the effective values. A wire resistor serves as the noise generating thermal noise in the range.

621.317.3: 621.396.645 723
Degree of Amplification for Electrometers for Electrical Constants of Vibrating Piezo-Electric Crystals—P. G. Venturatos. (Heinsa Journ., vol. 58, pp. 227–230; August, 1951.) The effective Q and R of a quartz-crystal resonator are determined (a) from the resonance frequencies of the decrement of the oscillations in a circuit including the crystal, on suddenly cutting off the HV supply, (b) by bridge measurement of the equivalent shunt resistance of the crystal at resonance. The effective L and C of the crystal are then calculated from simple formulas.

621.317.3: 621.396.611.011 722
New Methods for the Determination of Electrical Constants of Vibrating Piezo-Electric Crystals—P. G. Venturatos, (Heimsa Journ., vol. 58, pp. 227–230; August, 1951.) The effective Q and R of a quartz-crystal resonator are determined (a) from the resonance frequencies of the decrement of the oscillations in a circuit including the crystal, on suddenly cutting off the HV supply, (b) by bridge measurement of the equivalent shunt resistance of the crystal at resonance. The effective L and C of the crystal are then calculated from simple formulas.

621.317.3: 621.396.645 723
Degree of Amplification for Electrometers for Electrical Constants of Vibrating Piezo-Electric Crystals—P. M. Moeller. (Arch. tech. Messen, p. 274–279; August, 1951.) Review of the characteristics of various types of amplifiers, with 29 references.

621.317.3: 621.396.304: 621.392 724
Double-T Networks for Null Measurements at High Frequency—E. Salam. (Arch. tech. Messen, p. 274–279; August, 1951.) Equivalent circuits are given for various T networks, and expressions for the transfer impedance of a double-T network giving zero output voltage are derived. Circuits especially suitable for R, L, or C measurements are shown where frequencies up to about 60 mc are described and their particular advantages enumerated.

621.312.3: 621.392.207 725

621.312.3: 621.392.207 725

621.312.311 726
Methods for the Measurement of Very High Electrical Resistances and Low Capacitances—H. Telesz Plasencia. (Rev. gén. electr., vol. 60, pp. 209–211; May, 1951.) A method for measuring resistances of the order of 10¹⁴ uses a current which is constant and independent of voltage; this current is obtained from a saturated ion generator or the anode circuit of a diode. Voltages are measured with an electrostatic instrument. Calibration methods are discussed; a piezoelectric device may be used.

621.312.311 726
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Results of Measurements on the Rounded-Signal [radioelectric] Transmitter at Lyon-la-Doua—A. Terchnichef. (Ann. Télécomm., vol. 6, pp. 191-196; July, 1951.) Measurements were made with the previously described equipment (3056 of 1951) to study the use of the instrument, (b) to examine the performance of the transmitter, and (c) to investigate generally the restriction of spectra. Results are illustrated by oscillograms and periodograms of various signals.

Accurate Direct-Reading Frequency-Measurement Equipment, 30c/s-30Mc/s—L. R. Hoag and R. F. Wael. (Tijdschr. ned. Radio- genoot., vol. 16, pp. 181-184; July, 1951.) The equipment consists essentially of a multivibrator circuit fed from a 100-kc standard source and providing multiples of 1 mc up to 80 mc, a mixing circuit, and a counter ranging from 30 c to 1 mc. Results are given directly on the counter and on the single knob controlling the selection of a suitable harmonic. Accuracy of measurement is of the order of 1 part in 10^2, ± 1 c.

Design of Cavity-Resonator Wave Meters for Cm Waves—M. L. Topping. (Tijdschr. ned. Radio-genoot., vol. 16, pp. 185-207; July, 1951.) Various grating derived detection and derived signal data is applied and is designed to the cavity of a wave meter for the 5-7 cm band. The elimination of unwanted modes is discussed and the method of calibration is described. The accuracy achieved is of the order of 1 part in 1,000.

A New Method for Predicting the Adjacent-Channel Performance of Mobile Radio Equipment—J. T. Eader. (F.T.M-TV, vol. 11, pp. 21-24, 39; September, 1951.) Various methods of testing the selectivity of fm communication receivers are discussed and the I.R.E. method is preferred, in which two modulated signals are applied simultaneously, one signal having a desired carrier frequency and the other a frequency adjacent to the desired signal. Testing a work coil is determined by a given receiver whether interference will be caused first by a (a) break-through of adjacent-channel modulation, (b) amplitude distortion produced by the adjacent-channel carrier or (c) on-frequency noise produced by the adjacent-channel transmitter, a phase-amplified method is not useful. The selection of transmission of adjacent-channel carrier is determined by a given receiver. The possibility of using a ferroelectric substance (BaTiO_3) as a medium for storing information is discussed. Preliminary experiments were performed to determine various types of applications, including the possibility of using the memory device that can be operated in the range of audiofrequencies or higher.

Electrostatically Induced Permanent Memory—C. F. Pulvari. (Jour. Appl. Phys., vol. 22, pp. 1039-1044; August, 1951.) The possibility of using a ferroelectric substance (BaTiO_3) as a medium for storing information is discussed. Preliminary experiments were performed to determine various types of applications, including the possibility of using the memory device that can be operated in the range of audiofrequencies or higher.

A Toposcopic Display System Applied to Neurophysiology—W. Grey Walter and H. W. Shipton. (Jour. Brit. Inst. Radio Eng., vol. 11, pp. 260-273; July, 1951.) Simultaneous records of the electrical activity in a region containing specific neural sources, e.g. the brain, are visually displayed by oscillographic tubes arranged to represent a single map of the brain. The design of the electronic equipment is discussed. Records are shown illustrative of the application to the electroencephalographic problems of the distribution and frequency of normal rhythm, the location of abnormal activity, and the geometry and frequency of the additional responses evoked by photic stimulation.

Miniature Piezoelectric Accelerometers—(Tech. Bull. Nat. Bur. Stand., vol. 35, pp. 141-142; October, 1951.) The device described is intended for direct measurement of mechanical vibrations and for treating the frequency responses of piezoelectric generators. The pickup comprises a BaTiO_3 disk of thickness 1/16 inch and diameter 1 inch, sandwiched between a base and a metal housing block; it weighs <0.1 g. The frequency range of the resonant curve is flat within 20 percent between 50 c and 6 kc, and rises to a slight peak between 10 and 18 kc.

Radio Frequency Heating in Industry—K. Smith. (GEC Jour., vol. 18, pp. 157-168; July, 1951.) The characteristic features of dielectric and induction heating are described and industrial applications are indicated; rates of energy transfer obtained with rf heating are compared with those obtained by other methods.


Pulsed Air Core Series Disk Generator for Production of High Magnetic Fields—R. I. Strong and E. F. Shroder. (Rev. Sci. Instr., vol. 22, pp. 578-582; August, 1951.) A device is described which can store a large quantity of energy efficiently in the form of kinetic energy of rotation, and can be used to rapidly into useful electromagnetic energy by using the rotating mass as the armature of a series-wound homopolar motor. When operated under short-circuit conditions a large amount of energy is maximum obtained in the single-turn series field coil. Generators of this type may be used as sources of magnetic field for air-core betatrons and synchrotrons.


62.138.833 Electron Microscope—(Engin. (London), vol. 192, pp. 266-268; August 31, 1951.) An instrument suitable for routine examination of specimens. It uses three image-forming lenses and a fourth lens to control the electron beam intensity. The 55 kv electron-gun supply is given by an air-insulated hf dc source and is stabilized to within 4 v. Magnifications up to 12,000 times can be obtained. The maximum power of the Type-EX14 is better than 100 a.

62.387.496 Radiation and Particle Detectors in Modern Nuclearic Instruments—D. Taylor. (Jour. Bril. Inst. Radio Eng., vol. 11, pp. 247-259; July 1951.) A review of electronic measuring instruments used to monitor the emission of short-wave radiation and charged or uncharged particles, with particular emphasis on their long-term stability. A typical process control instrument is described which has an accuracy within ±1 per cent over long periods, for the continuous routine control of α particles in solutions.


62.398 Radio Telemarships—(Wireless World, vol. 57, pp. 342-346, September 1951.) Systems are discussed for the remote control of apparatus by radio, with particular reference to the control of aircraft and boats. Methods of transmitting instructions of both on-off and continuous-control types are considered; radio aspects are examined, and electromechanical equipment at the receiver is described. See also 1747 of 1951 (Lankester and Dreier).

62.398:621.396.712 Remote-Control System for F.M. Broadcast Stations—P. Whitney. (Tele-Tech, vol. 10, pp. 32-35, 78 and 44-45, 80; August and September 1951.) Description of a device for controlling elec- circuit diagrams, of a system in use at Winchester, Va., for controlling and monitoring an unattended broadcasting transmitter over 20 miles away. Six lines in the band 18-30 applied at a low modulation level to the auxiliary transmitter linking the studio to the remote transmitter, are used for control purposes. In the monitoring equipment the sampling voltages derived from the meter readings are used to modulate a 30-kc subcarrier which, in turn, modulates the fm broadcasting transmitter to a degree 95 per cent. A special receiver in the studio is tuned to the subcarrier to derive all meter readings.

62.7913:535.61-1 Electronic Control of Soldering Temperatures by Infra-red Radiation—Déréré and J. C. Stern. (Électronique (Paris), pp. 4-7; August/September, 1951.) The radiation from a tungsten wire placed in the path of a rotating wheel and then falls on a compensated bolometer. The resulting modulated signal is amplified and used to control the heating system.

**PROPROPAGATION OF WAVES**

538.566 The Zenonk Ground Wave—G. Goubau. (Z. angew. Phys., vol. 3, pp. 103-107; March/April, 1951.) The Zenonk wave is physically possible; the problem is analogous to that of the excitation of an open waveguide. There is an orthogonal relation between the two modes of the space wave, from which the amplitude of the former can be calculated.

538.566 Propagation in a Non-homogeneous Atmosphere—Friedman. (See 661.)

538.566:535.13 Field Representations in Spherically Stratified Regions—Marchvitsa. (See 663.)

62.396.11:621.396.671 Application of the Compensation Theorem to Certain Radio-Wave and Propagation Problems—Montcath. (See 591.)

62.396.11:538.566 The Ground Wave of a Transmitter—H. Ott. (Z. angew. Phys., vol. 3, pp. 123-134; March/April, 1951.) An analysis of the field radiated from conducting and dielectric surfaces. The ground wave is affected by the existence of the Schmidt "head wave" (3117 of 1949), which takes energy from it, this, and not ground absorption, is the cause of the rapid attenuation of the ground wave. The electric and magnetic field strengths within the ground wave are investigated, together with the phase relations for any values of ground constants. The greatest height of the mean downward-curved energy flux, which gives a qualitative indication of range of the wave in free space, is determined for the whole of the field.


62.396.11:551.505.35 Scattering of Radio Waves and Umodulation by the F Region—C. S. Banerjee, R. E. Mehrotra and V. D. Rajan. (Science and Culture (Calcutta), vol. 17, pp. 45-46; July, 1951.) Reception of scattered echoes from the F region, using low-power pulse ionospheric sounding equipment, is described. Scattering of the ordinary ray occurred at frequencies immediately below the penetration frequency, and is attributed to the presence of irregularities at the level to which the rays penetrated.


62.396.11:551.505.35 Influence of the Earth's Magnetic Field on Group Velocity and the Main Reason for the Modulation of Radio Waves in the Ionosphere—H. Poeverlein. (Z. angew. Phys., vol. 3, pp. 135-143; March/April, 1951.) The vertical component of group velocity of a reflected wave is determined theoretically, assuming a plane ionospher- and linear ionization gradient. At vertical incidence, compared with velocities in the absence of the earth's field the velocity of the extraordinary wave is less while that of the ordinary wave is greater over part of its path and less over another part. At oblique incidence in the region of reflection for steeply incident rays the vertical component of velocity increases with increasing angle of incidence. Comparison of critical frequencies for the ordinary wave at vertical and oblique incidence under certain conditions may provide a test for the validity of the theoretical conclusions.

62.396.11:551.510.535 Some Calculations of Ray Paths in the Ionosphere—S. E. Forengren. (Acta polyt. (Stockholm), no. 85, 23 pp; 1951.) The refractive index for the ordinary and the extraordinary ray has been computed as a function of direction, for some cases frequently met with, taking account of the influence of electronic collisions on the curve. With the aid of a graphic method due to Poverlein (2875 of 1950), ray paths have been calculated for vertical incidence, zero losses, and a parabolic electron-density distribution. Approximate form- mulae are given for the horizontal deviation of the ordinary and extraordinary rays under small oblique incidence. Maximum deviation occurs for frequencies near the critical frequency of the layer and may be large enough to make any determin- ation of gyrotropy and plasma frequency critical-frequency measurements unreliable.

62.396.11:551.510.553(00) The Effect of Blackouts recorded at the Kiruna Observatory—R. Lindquist. (Acta polyt. (Stockholm), no. 85, 25 pp; 1951.) Report and discussion of observations, beginning in October 1950, of a phenomenon observed over a range 1-16 mc in 30 seconds. The results obtained indicate that polar blackouts are due to the impact of some ionizing agent. This view is supported by the close correlation between blackouts, magnetic disturbances, auroras, and the appearance of a certain type of sporadic-E reflection (termed N1), and also by the increase of F-layer ionization frequency noted immediately after a blackout. The diurnal distribution of blackouts is similar to that of the current in the auroral zone. There is a tendency for blackouts to recur at about the same time on two or more successive days. This may be of interest in the prediction of propagation conditions.

62.396.11:621.317.087 Notes on the Analysis of Radio-Propagation Data—R. P. Decker. (Proc. IRE., vol. 39, pp. 1382-1388; November, 1951.) Statistical analysis of observations on the propagation of 410-mc signals over distances of 86 and 134 miles. The equipment for indicating the percentage of time for which a number of pre- selected signal levels were exceeded is de- scribed.

62.396.11:621.317.353(3) Ionospheric Cross-Modulation—J. Shaw. (Wireless Eng., vol. 28, pp. 335-342; November, 1951.) A survey of the theory of cross modulation and of recent experimental work. The experimental technique for the measure- ment of the amplitude and phase of the modu- lation transferred to the wanted carrier is described and details of the equipment are given. Measurements on a range of 20 miles of B.B.C. stations, a value for the collision frequency was derived. Experimental con- firmation was obtained of the laws of variation of (a) modulation frequency, (b) radio frequency, (c) power, and (d) modulation depth of the disturbing wave. Variations at sunrise were contrary to expecta- tions. Self-distortion due to the frequency-
dependent absorption of energy by the ionosphere is also discussed.

621.396.11.020.45

The Reflection of Very-Low-Frequency Radio Waves from the Surface of a Sharply Bounded Load at Various Atmospheric Magnetic Field—K. G. Budden. (Phil. Mag., vol. 42, pp. 833-850; August, 1951.) A homogeneous ionosphere is assumed. The quasimagnetostri- tional approximation to the magnetohydrodynamic theory (3306 of 1935 (Boozer)) is used, the reflection coefficients being then independent of the horizontal direction of the transmission path. Very-low-frequency results from the theory are compared with the experimental observations reported in 2522 of 1951 (Bracewell et al.). There is some qualitative agreement for frequencies of 16 kc and below, but it is likely to be most useful for investigating propagation frequencies of 10 kc and below, used in studying atmospherics.

621.396.11.020.62

Radio Propagation Experiments carried out between Mount St. Helens and Mount Cavo (Cagliari) and Monte Corvo (Rome) for Waves at C.W. Frequencies during the Period January-May 1949—A. Accione and C. Micletella. (Poite et Telecommun., vol. 19, pp. 251-262; May, 1951.) A full description of the equipment and the experiment is given for this 33-mc link, and of the precautions taken to ensure that the various parts of the system operated under known and stable conditions. The party line was very long, extending, with a body of water, over 170 km of it lies outside the optical range. The recording procedure was so planned that sample coverage for all hours of the day and night was obtained. Three main types of record could be distinguished: (a) constant-level, associated with very fine, calm weather; (b) slowly fluctuating, associated with unsettled and irregularly fluctuating, during or immediately preceding and following showers of hail or snow. Anticyclonic conditions were characterized by high-level signals. The passage of a cold front followed by a warm belt led to a slow decrease followed by a rapid rise in signal intensity. Observations during fog agreed with those reported in 2001 of 1948 (Smith-Rose and Stickeland), while wind always adversely affected the signal. In general the practical results obtained were very much better than those expected from theoretical considerations. The experiments are being continued.

621.396.11.020.63

Propagation at 412 Mc/s from a High-Power Transmitter—I. H. Gerks. (Proc. I.R.E., vol. 39, pp. 1374-1382; November, 1951.) "Extended measurements are reported which indicate the existence of pronounced nocturnal superrefraction during an appreciable percentage of the summer and of very persistent scattering by atmospheric turbulence near the surface in all seasons. The measurements were taken over rolling midwestern terrain, a distance of about 100 miles. Mobile road tests were made to supplement the fixed-point measurements and to provide an approximate indication of the relation between field strength with distance. Field measurements were made on a cold front followed by a warm belt, and on a day and night. The practical significance of the results is indicated.

621.396.11.020.64

Microwave Propagation in the Optical Range—E. J. Stibor and K. H. Foragen. (Acta polyt. (Stockholm), no. 87, pp. 207; 1951.) A report of observations of transmissions from Mosse le, Gothenburg, on wavelengths of 10, 3 and 1 cm. The transmitted height was 105 m, the altitude of the 10-cm and 3-cm receivers being 50 m and that of the 1-cm receiver 55 m, the respective ranges being 13.5 and 6.5 km., so that both paths were well within the optical range. Results are shown graphically and interesting cases of attenuation due to rain and snow, of refraction effects, and of parallel and anti-parallel X-band and S-band fading, are discussed.

RECEPTION

519.241.1 [534.874.41-621.396.621]


621.396.6397.0


621.396.621.610.13

A New Method for Predicting the Adjacent-Channel Performance of Mobile Radio Equipment by Graphical Analysis—Eader. (See 745)

621.396.621.029.63

Receivers for Use at 460 Mc/s—E. G. Hamer and L. J. Herbst. (Wireless Ewe, vol. 28, pp. 239-248; November, 1951.) A discussion of design considerations with particular reference to receiver signal/noise ratio. The performance of tubes and circuits both of low and high frequency is considered. Circuits are shown (a) a low-noise amplifier used for determining noise-factor data (tabulated for various tube types), (b) a typical receiver comprising carried-grid rf amplifier and earthed-grid mixer.

621.396.621.53

Gated-Beam Mixer—S. Rubin and G. E. Boggs. (Electronics, vol. 24, pp. 196, 212; October, 1951.) Discussion of the use of a Type-B22M type, preferably with outer-grid injection, the oscillator being con- nected to the third grid. Performance is satisfactory, in view of high transconductance, low-space-charge coupling and low capacitance between control grids.

621.396.622


621.396.622

Study of Some Statistical Patterns relative to Problems of Background Noise—A. Blanc-Lapierre. (Rev. Sci. (Paris), vol. 89, pp. 136-150; May/June, 1951.) The identity of a variable in the integral expression the equation of the theory becomes the equation of the physical concept of frequency spectrometric distribution of mean noise power in an amplifier is shown to correspond with a correlation function. Amplifier noise is treated theoretically with reference to a Poisson distribution. A similar two main spectra are identified; these are associated with flicker-effect and with shot effect.

STATIONS AND COMMUNICATION SYSTEMS

621.390.001.11

Time and Frequency Uncertainty in Wave- form Analysis—P. M. Woodward. (Phil. Mag., vol. 42, pp. 883-891; August, 1951.) "The concept of a time-constant is introduced in considering the time autocorrelation function, and a structural frequency-constant is similarly defined in terms of the spectral auto-correlation function. By setting up a combined time and frequency auto-correlation function and absolute time-frequency constant, the value is always unity, and it is suggested that this expresses time and frequency uncertainty more precisely than the relation $\theta f \geq \frac{1}{\tau}$. To illustrate the function, two special wave forms are considered, namely, the complex Gaussian pulse and the real Gaussian pulse."

621.390.97

An 8-Channel Transmitter for an Experimental Carrier Wave-Broadcasting System—R. G. Kitchen. (Jour. Brit. I.R.E., vol. 11, pp. 295-337. Discussion, pp. 338-339; August, 1951.) The electrical and mechanical features are described of a transmitter which provides eight carrier frequencies between 55 kc and 209 kc, at a level of 100 mv. on each channel. The system is suitable for broadcasting over the existing telephone network. Technical improvement, in designing the transmitting facilities, and power supplies are incorporated. A selective alarm system in conjunction with unit construction facilitates maintenance. Circuit and performance details are given.

621.396.621.7

Transmitter Diversity Applied to Machine Telegraph Radio Circuits—C. E. Hassell. (Telegr. Teleph. Rev., vol. 69, pp. 12-14, 27, August, 1951.) Tests have shown that trans- mitter diversity is effective in overcoming fading effects as receiver diversity. The system described used two transmitting antennas, 1,500 feet apart, radiating at 15.43 mc, the respective carriers being separated by 200 cps; frequency-shift modulation was applied. Arrangements were made for having both transmitters, or one only, operating during alternate 5-minute periods. The results for reception in New York of signals from California showed a gain of from 12 to 30 db in favor of the diversity arrangement. The system has many applications where receiver diversity is in- practicable or uneconomical.

621.396.6


621.396.644.521.350.562.3 | 621.317.083.7.7


621.396.619.11 + 621.396.619.13

The Distribution of Energy in Randomly Modulated Waves—D. Middleton. (Phil. Mag., vol. 42, pp. 883-891; July, 1951.) The theory of fm and ph by means of a random noise developed, as a model for speech modulation carriers. The effect of spectral shape of the modulating noise on the internal and output distri- bution of the modulated carrier is considered, and it is found that the lowest-frequency components of the modulation are most significant. The limiting cases of the frequency deviation are specially considered and it is
found that such adiabatic sweeps spread the original spectrum. The parallel case of am by normal random noise is similarly discussed, including the effects of possible over-modulation.

62.316.59.029.621.03 803
The Turin-Parma Experimental Radio Link—I. (Poste e Telecomm., vol. 19, pp. 170–178; March, 1951.) Turin is linked by cable to the Pino Observatory, the site of one terminal, the other being at Rocca di Stradella, which was originally linked by wire to Piacenza but is being developed as a repeater station. A further extension of the link from Rocca di Stradella to Milan is under construction. Working frequencies are 61.5–174 mc; Rocca di Stradella-Piacenza, 620 and 680 mc; Rocca di Stradella-Milan, 650 and 690 mc. 8-channel multiplex operation as part of the public telephone service is either already taking place or envisaged for both branches. Details of equipment, planning and operational experience are given.

62.316.59.029.63 804
The Parameters of a Decimeter-Wave System with Pulse-Time Modulation (Pulse-Phase Modulation)—K. O. Schmidt. (Fermattechn. Z., vol. 4, pp. 362–368; August, 1951.) A diagram based on restricted noise shows necessary signal levels throughout the communication chain. The attainment of these values in a μm system, possible improvements in gain, and reduction of attenuation losses are discussed with reference to the loss characteristics of coaxial cables, waveguides and the transmission path.

62.316.74(5) 805

62.316.712:621.396.66 806
A Supervisory Instrument for Standard Broadcast Stations—E. D. Cook and H. F. Summerhayes, Jr. (Gen. Elec. Rev., vol. 54, pp. 29–36; July, 1951.) Details are given of a multipurpose instrument for monitoring the carrier level, frequency and modulation characteristics of am broadcast stations over a wide range of input voltages with good accuracy.

62.316.712:621.398 808
Remote-Control System for F.M. Broadcast Stations—Whitney. (See 771.)

62.316.712:083.81 809

SUBSIDARY APPARATUS

62.51-52 810

62.51-52 811

62.314.203 812
Study of Harmonic Power Generation—P. E. Russel and P. M. Pinkham. (Wireless Eng., N.Y., vol. 70, p. 690; August, 1951.) Summary of A.I.E.E. Great Lakes Meeting paper, May, 1951. A harmonic power generator may consist of an iron-cored reactor, to which a sinusoidal voltage is applied, followed by circuits which select the desired harmonic. Such a circuit has been analyzed on a differential analyzer.

62.314.34 813
Recorvery of Selenium Recitifiers after a Voltage Pulse in the Blocking Direction—K. Lehovec. (Jour. Appl. Phys., vol. 22, pp. 934–939; July, 1951.) The effect of the voltage pulse is to decrease temporarily the capacitance of the rectifier. Recovery to the original capacitance value is investigated as a function of pulse height, pulse duration, and temperature. Increasing recovery speed under illumination indicates that the process is electronic and not ionic.

62.316.712 814
General Theory of Voltage Stabilizers—J. J. Giventy and D. F. Rutland (Rev. Sci. Inst., vol. 22, pp. 464–468; July, 1951.) The general linear voltage stabilizer can be represented by an active four-terminal network specified by four parameters. Methods of calculating stabilizer performance are given which require four independent measurements; knowledge of the stabilizer circuits is unnecessary. The theory is confirmed by experiment on a degenerative voltage stabilizer for which the approximations of the three-parameter theory are considerably in error.

62.316.933.3 815
Latest Developments in the Design of Resonat Arresters—W. Zoller. (Brown Boveri Rev., vol. 38, pp. 105–114; April, 1951.) Arresters are now rated with a rate discharge capacity of 5 to 10 ka and a maximum discharge capacity 20 times greater, and the Resonart resistance material can now cope with lightning currents of long duration as well as with hv surges. Different types now available are illustrated and the effects of rain, fog, external capacitance to earth, and steep-fronted waves are considered.

62.526 816

TELEVISION AND PHOTOGRAPHY

62.316:397.6 817
40th Paris Fair—(See 791.)

62.317 818

62.317.2:621.396.05 819

62.317:2:621.396.05 820

62.317.24/26 821

62.317.24 822
The Transmission of Television Signals on Telephone Lines—T. Kivling. (Jour. Telec. Soc., vol. 6, pp. 197–203; January/March, 1951.) A detailed description to the widely varying impedance characteristics of telephone circuits, 64 constant-impedance, non-resonant equalizer sections, with fixed hall-loss frequencies ranging from 15 kc to 4.67 mc and fixed zero-frequency loss from 1 to 3 db, are needed in each repeater unit for B.B.C. outside-broadcasts transmissions over ordinary telephone lines, in order to cancel the gain over the frequency range 50 cps to 3 mc. See also 252 of 1951 (Bridgewater).

62.317.5 823
Velocity-Modulation in Television-Image Reproduction—A. B. Thomas. (Proc. I.R.E., vol. 39, p. 1341; October, 1951.) Comment on abstracted loss in 2269 of 1951 (Honnell and Prince), pointing out that the method therein described is not velocity modulation but could more suitably be described by some such term as ‘displacement modulation.’

62.317:5:535.62 824

62.317:5:535.62 825

62.317:5:535.623 826
Recent Improvements in Band-Shared Simultaneous Color-Television Systems—B. D. Loughlin. (Proc. I.R.E., vol. 39, pp. 1229–1237; October, 1951.) Initial use of the "sequential" system of color television which requires a total bandwidth of only 4 mc is described; a band-shared method is employed. The advantages of a constant-luminance system are discussed and developments are considered which result in improvement in the color picture itself and also in reception of the transmissions by black-and-white receiving sets. Color errors due to crosstalk are discussed; these may be largely eliminated by the use of periodic reversals of the color sequence in the color subcarrier. This sequence is actually reversed in adjacent lines, so that the opposite color errors lie close together and are averaged out by the eye.

62.317:5:535.623 827

62.317:5:535.623 828
Width-limited television system the rise time of a step input can be reduced by adding to the signal another wave form derived from it by nonlinear feedback circuit arrangements. Methods of doing this are discussed and results achieved are described.

621.397.5:535.623

Spectrum Utilization in Color Television—R. B. Dome. (Proc. I.R.E., vol. 39, pp. 1323–1331; October, 1951.) The frequency spectrum of the television signals is not standard in the United States for black-and-white or monochrome television transmissions, may be utilized in several ways for the transmission of color-television signals. The present state of data associated with color-television systems may be transmitted by time-division multiplex, by frequency-division multiplex, or by combinations of two or more of these methods. One of the latter methods, called “alternating waves,” is discussed in some detail, and some of the working circuits for this method are presented. See also 3131 of 1951.

621.397.5:535.623

Color Television—U.S.A. Standard—C. Goldmark, J. W. Christensen and J. J. Reeves. (Proc. I.R.E., vol. 39, pp. 1288–1313; October, 1951.) Section 1 deals with the standards established by the Federal Communications Commission and its colorimetric significance. Section 2 is concerned with the design and performance of typical commercial color-television receivers. Section 3 describes the modification of existing black-and-white studio equipment to render it suitable for color television. Section 4 discusses applications of color television other than for broadcasting and describes industrial color-television equipment known under the name “Vericolor.”

621.397.5:531.775

Oscillographic Representation of Television Signals—Sturley. (See 741.)

621.397.5(083.74)


621.397.61

The Vision Transmitter for the Sutton Coldfield Television Station—E. A. Nind and E. McP. EE, Part II, vol. 2, pp. 120–126; November, 1951.) A detailed account of the various stages of the equipment and of the general arrangement of the transmitter, the r-f and modulation amplifiers and associated circuits, special features of the power-supply, and of the treatment of the supervisory facilities, and testing equipment.

621.397.61

Automatic Synchronizing Generator for TV—C. Ellis. (TV Eng., vol. 2, pp. 20–22, 25 and 29, 1951.) The master oscillator is a stabilized multivibrator running at twice the line frequency. This is divided by an odd number to produce the field frequency and is halved in another channel to produce the line frequency. The division and gating are performed by binary scaler circuits, multiple feedback being introduced to give the odd-number division. The differentials on a red pulse width is produced by using delay lines.

621.397.61:621.326


621.397.61:621.392.52

The Vestigial-Sideband Filter for the Sutton Coldfield Television Station—Cork. (See 626.)

621.397.61:111

Practical Use of Iconoscopes and Image Orthicons as Film Pickup Devices—K. B. Benson and A. Ettlinger. (J. Soc. R. Eng., vol. 57, pp. 9–14; July, 1951.) Problems in the use of these devices are discussed in relation to fundamental theory.

621.397.62


621.397.62:621.385.832

The 'Ion Spot' Problem in Television—L. Chrétien. (T. S. F. pour Tous, vol. 27, pp. 221–225; June, 1951.) The mechanism causing smearing of the screen in cr tubes is discussed, and known remedies are described.

621.397.62:621.365.157


621.397.62:112


621.397.62:112:535.623


621.397.62:112:535.623

A Three-Gun Shadow-Mask Color Kinescope—B. L. Law. (Proc. I.R.E., vol. 39, pp. 1218–1228; October, 1951.) RCA Rev., vol. 12, Part II, 542–567; September, 1951.) The screen consists of a cyclic arrangement of many narrow parallel phosphor strips of the three primary colors. In the method principally investigated the scanning lines are parallel to the phosphor strips and the electron beam is of constant length and is used to produce scanning of each of the three adjacent phosphors during each line of the scan. The required registration of scanning lines with the screen elements is obtained by means of a servo circuit derived from control information from secondary-emissionavalanche areas on the screen. Tubes of 16-inch envelope diameter have a phosphor layer of high horizontal definition and adequate color purity.

621.397.621:2:535.62

A One-Gun Shadow-Mask Color Kinescope—K. R. Law. (Proc. I.R.E., vol. 39, pp. 1194–1201; October, 1951.) RCA Rev., vol. 12, Part II, pp. 487–502; September, 1951.) Color selection is achieved by controlling the direction of incidence of a single electron beam at a screen so designed that the color of light emitted is determined by the angle of incidence. The beam is deflected into different color positions and, for sequential presentation, in the blanking-off of the beam between different color positions. Practical details of these and other problems are described.

621.397.621:2:535.62

A 45-Degree Reflection-Type Color Kinescope—P. K. Weimer and N. Rynn. (Proc. I.R.E., vol. 39, pp. 1201–1211; October, 1951.) RCA Rev., vol. 12, Part II, pp. 503–526; September, 1951.) A series of small metal masks are mounted parallel to the phosphor screen with a transparent conducting film. The electrons passing through the slots are reflected back on to the phosphor by an electric field applied between the masks and variation of this field shifts the beam to the appropriate color phosphor to another. Features of this system and its variants are simplicity of screen construction, small color-selecting power required, and automatic registration of the three colors. Good results have been obtained with experimental tubes.

621.397.621:2:535.623

A Grid-Controlled Color Kinescope—S. V. Forrest. (Proc. I.R.E., vol. 39, pp. 1212–1218; October, 1951.) RCA Rev., vol. 12, Part II, pp. 527–541; September, 1951.) A series of closely spaced screens is used, each coated with a different color phosphor and separated from each other by control grids whose potentials determine which phosphor is scanned. Individual excitation, or any combination of the primary colors may thus be obtained. Details of screen design and phosphor selection are considered. Two- and three-color experimental tubes have been operated with the R.C.A. color-system signal.

621.397.621:2:535.623

The Development and Operation of a Line-Scroll Color Screen Kinescope—D. S. Bond, F. F. Nicoll and D. G. Moore. (Proc. I.R.E., vol. 39, pp. 1218–1230; October, 1951.) RCA Rev., vol. 12, Part II, 542–567; September, 1951.) The screen consists of a cyclic arrangement of many narrow parallel phosphor strips of the three primary colors. In the method principally investigated the scanning lines are parallel to the phosphor strips and the electron beam is of constant length and is used to produce scanning of each of the three adjacent phosphors during each line of the scan. The required registration of scanning lines with the screen elements is obtained by means of a servo circuit derived from control information from secondary-emissionavalanche areas on the screen. Tubes of 16-inch envelope diameter have a phosphor layer of high horizontal definition and adequate color purity.

621.397.621:2:535.623

Abstracts and References

The method of obtaining this phase relation and of adjusting the admittance/frequency characteristic of a given voltage SWR of better than 0.96 over the required band is described. A field-strength map of the service area is included.

621.397.82

621.397.828
The Overtone Crystal Oscillator against TVI—E. J. Pearcy. (Short Wave Mag., vol. 9, pp. 278-282; July, 1951.) Consideration of the choice of fundamental frequency of the crystal in a hi or vhi amateur transmitter and the use of overtone operation to minimize interference with television reception from the British stations.

TRANSMISSION

621.396.619/621.310.28
High-Power Pulse Generator with Controlled Spark-Cap—Prokott. (See 612.)

TUBES AND THERMIONICS

621.383.2
Lithium-Anthimony Photoelectric Cathode—N. Schectti and W. Baumgartner. (Le Vide, vol. 6, pp. 1041-1045; July/September, 1951.) The properties of Li-Sb and Cs-Sb photocathodes are compared. Because of their inherently lower thermionic emission, the former are more suitable for use in photomultipliers for scintillation counters.

621.382.3 032.21 537.312.5

621.383.4 546.817.241
Photocatalytic Effect in the Infrared Region of the Spectrum—F. J. Proctor and H. H. Exley. (Proc. I.R.E., vol. 39, pp. 1332-1336; October, 1951.) The photocatalytic effect at room temperature is a function of temperature and of lead impurity. It is found that the magnitude of the photo-effect is a function of the dark conductivity, and depends only on the quantity of excess lead. The absorption of incident light at room temperature is found to the removal of excess lead; the presence of oxygen is not a requirement for the appearance of photocatalytic activity. These observations are used to draw conclusions on the mechanism of the photocatalytic activity. It is shown that all the phenomena can be explained by a single lattice model, without recourse to internal potential barriers due to inhomogeneities in the composition of the samples. (See also 751 of 1951 [Mertz et al.].)

621.385+621.396.6
New Radio Components in the World Market—Alaxirt. (See 628.)

621.385.3

621.385.011
On the Rigorous Calculation of the Transmission of Planar Systems on the Basis of Potential Theory—O. Heymann. (Frequen, A, vols. 57-62 and 97-107; March-August, 1951.) The method developed avoids mathematical difficulties of the image technique. Neglecting space charge, the anode and cathode are represented as plane surfaces, the grid as an infinite series of parallel equidistant wires. The potentials due to the charges on these surfaces are expressed in Fourier series. Treating these charges as individual Maxwell grids and inserting the boundary conditions to be satisfied at the three electrodes, an infinite set of equations is derived from which the approximate values of the Fourier coefficients can be calculated. Examples illustrate the value of the general equations.

621.385.012.6

621.385.029.62/63
Miniature Traveling-Wave Tube—R. Adler (Electronics, vol. 24, pp. 110-113; October, 1951.) The operation and characteristics of an experimental model are described. Gain per unit length and noise figures are satisfactory for miniature wide-band amplifier tubes working at frequencies between 100 and 1,000 mc. Operating voltages and currents are similar to those required for other small tubes. Various modifications of the experimental model are discussed.

621.385.029.62/63
Traveling-Wave Amplification by means of Coupled Transmission Lines—W. E. Mathews. (Proc. I.R.E., vol. 39, pp. 1044-1053; December, 1951.) The theory of interaction between coupled transmission lines moving relative to each other is developed, and conditions yielding wide, increasing exponential with distance are found. The case of two moving and one stationary, is analyzed in detail, the results being applicable to the helix traveling-wave tube. The most fundamental qualitative finding is that amplification results from interaction between the forward wave on the stationary line and the backward wave on the moving line, and that the transversal velocity of the moving line is sufficiently greater than the natural propagation velocity of that line, the backward wave is actually made to
move forward in approximate synchronism with the forward wave on the stationary line. Gain occurs over a small but finite range of the transversal velocity, maximum gain being obtained when the two waves concerned are very nearly in perfect synchronism. The theory suggests the possibility of traveling-wave amplification in systems other than electrical, and a mechanical travelling-wave oscillator has been built; this was demonstrated at the I.R.E. Conference on Electron Devices. Princeton, June 1949.


Conductivity and Other Electrical Properties of Thorium in Vacuum—G. Mesnard and R. Uzan. (Le Vide, vol. 6, pp. 1052-1062 and 1091-1097; July/September and November, 1951.) Details are given of experimental tubes used for the measurement of the resistance, thermoelectric emf and thermal conductivity of thorium. The purest available material was used; this was initially in the form of an amorphous powder, which crystallized on heat treatment. Results are presented and discussed in relation to possible mechanisms involved. See also 2730 (Mesnard).

Theory of Noise in the Transistor—Y. Watanabe and N. Honda. (Sci. Rep. Res. Inst. Tohoku Univ., Ser. B, vol. 1/2, pp. 313-325; March, 1951.) The noise power produced in the collector path of a transistor is considered theoretically. The magnitude and frequency dependence of this noise, which is due to the fluctuation of the number of holes in the bulk germanium, is shown to agree with experimental results.

Electron Transit Time Affected by the Initial Velocity of Emitted Electrons from the Cathode and the Field Irregularity around the Grid Wires in a Triode—Y. Koike and S. Yamazaka. (Sci. Rep. Res. Inst. Tohoku Univ., Ser. B, vol. 1/2, pp. 349-364; March, 1951.) Higher values are obtained for the limiting frequency of a triode oscillator than are expected from theory. Two factors, the initial velocity of electrons emitted from the cathode and the irregular field around the grid, are analyzed theoretically to show their effect in decreasing the electron transit time.

Gas Discharge Tubes—(Wireless World, vol. 57, pp. 293-294; July, 1951.) Brief account of operation and application of the "plasmatron" [see also 2869 of 1951 (Johnson)], a French tube described by Besson (879 below), and a corona-discharge stabilizer tube.

A New Amplifier Arrangement—R. Besson. (Tente la Radio, pp. 110-112; May, 1951.) Description of the construction and operation of a gas-discharge triode with continuous grid control, and its application in an amplifier for photoelectric currents. See also 2869 of 1951 (Johnson).

A High-Current Thyatron—A. W. Coolidge Jr. (Elect. Eng., vol. 70, pp. 698-699; August, 1951.) A.I.E.E. Winter General Meeting paper. Description of the thyatron Type GL-5855, with peak and average current ratings of 150 and 12.5A respectively, a 2.5V cathode and an anode voltage rating of 1,500V. Construction details are given, one feature being the use of rigid strap connections instead of a tube base.

The Thyatron Grid Spike—M. P. Givens. (Rev. Sci. Instr., vol. 22, pp. 533-534; July, 1951.) When a thyatron fires, the control grid assumes a high positive potential for a short time. The explanation is that the grid is then acting only as a probe in the tube and rises rapidly to anode potential. An experiment confirming this is described.

An Electrostatic-Tube Storage System—A. J. Lefhakis. (Proc. I.R.E., vol. 39, pp. 1413-1415; November, 1951.) Binary pulses are stored as an array of discrete spots of charge, using a 2-channel system with two M.I.T. es storage tubes (1034 of 1951). The sequence of incoming pulses is preserved during storage but the time relation of pulses recovered from storage is determined by an independent pulse source. The capacity of each channel is 256 pulses; upper frequency limits are respectively 3.3 x 10^6 per second and 7 x 10^5 per second for the storage of pulses and for supplying stored pulses.

The Magnetron in the Condition of Static Space Charge: Magnetrons with Axial Anode—J. L. Delcroix. (C. R. Acad. Sci. (Paris), vol. 233, pp. 540-547; August 20, 1951.) The study of the bidrmonic state for this type of magnetron does not involve any of the difficulties associated with the classical magnetron (i.e. with axial cathode). The electron transit time remains finite for all values of b/a (where b is the radius of the cut-off surface and a that of the cathode); as b/a approaches unity, the conditions approach those for the plane magnetron.


Miscellaneous

University Research in Physics: Part 2—Research in Physics at Cambridge University. Radio Research—J. A. Teegan (Beams Journ., vol. 58, pp. 205-209; July, 1951.) A short general account of work in progress, including studies of (a) the fading of waves reflected from the ionosphere, (b) ionospheric cross-modulation, and (c) radiation from the surface of the sun and from galactic and extra-galactic sources.

Study Centre for Microwave Physics: Activities during 1950—N. Carraro. (Ricerca Sci., vol. 21, pp. 1161-1165; July, 1951.) Increasing activity at the C.N.R. Centre at Florence is reported; subjects investigated include properties of evanescent waves, absorption of microwaves by ionized gases, acceleration of electrons by means of microwaves, solar noise, microwave measurements, and microwave radio communication.