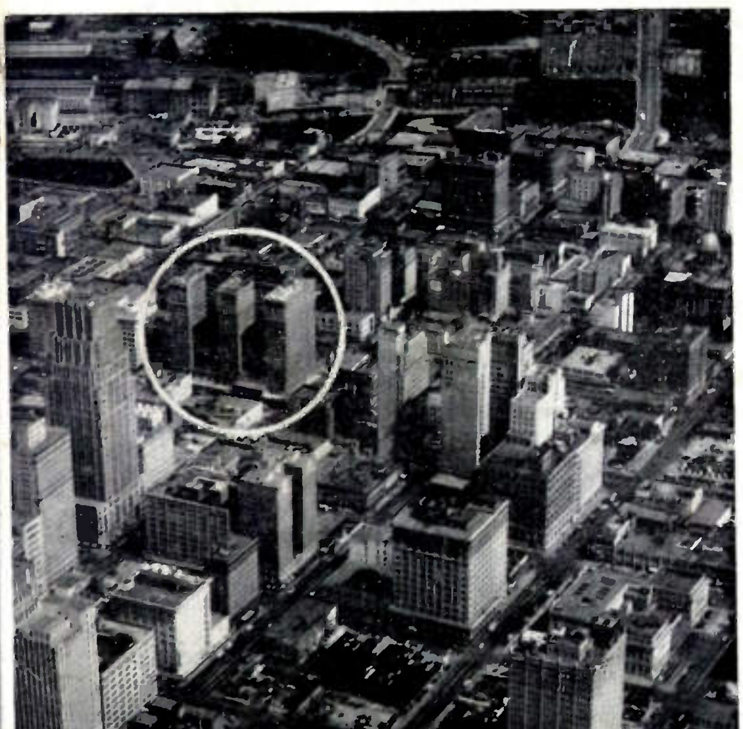
Proceedings of the I·R·E

A Journal of Communications and Electronic Engineering

April, 1952

Volume 40 Number 4



Houston Chamber of Commerce

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.

PROCEEDINGS OF THE I.R.E.

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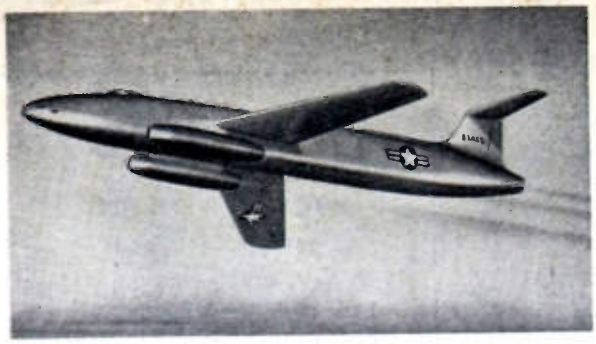
The Institute of Radio Engineers



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.

May 16, 17, 1952
Rice Hotel, Houston, Texas

The Southwestern IRE Conference will feature technical papers on eight major radio subjects:

- Microwave and V.H.F. Communications
- Audio
- Instruments
- Geophysics
- Airborne Electronics
- Components
- Broadcast & T.V.
- "Ham" Engineering

A wide variety of radio-electronic products and services will be on display at the Show to be held in conjunction with the Conference. About 40 firms are exhibiting, and special emphasis will be on their products in the fields of Audio, Geophysics and Instrumentation.

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!

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

Table of Contents will be found following page 64A

Meetings with Exhibits

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

Δ

Spring Technical Conference on Television
April 19, 1952
Cincinnati Engineering Society Building, Cincinnati, Ohio
Adv. & Exhibits: Wynne W. Gulden
3272 Dayton Avenue
Cincinnati 11, Ohio

Δ

NEREM, Saturday, May 10, 1952
Copley Plaza Hotel, Boston, Mass.
New England Radio Engineering Meeting
Gen. Chairman: Alfred J. Pote
71 West Sqauntum St.
N. Quincy, Mass.

Δ

National Conference on Airborne Electronics
May 12, 13 & 14, 1952
Hotel Biltmore, Dayton, Ohio
Exhibits: Paul D. Hauser
1430 Gascho Drive, Dayton 3

Δ

4th Southwestern IRE Conference
May 16, 17, 1952
Rice Hotel, Houston, Texas
Exhibits: Gerald L. K. Miller
1622 W. Alabama
Houston 6, Texas

Δ

Radio Parts Show
Chicago
May 19-24, 1952

Δ

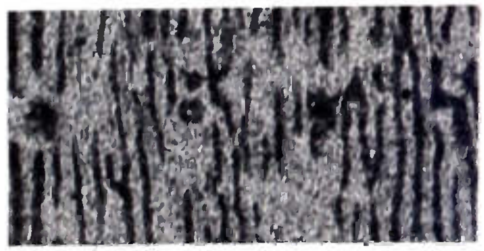
Western Electronic Show and IRE Regional Convention
August 27, 28 & 29, 1952
Municipal Auditorium
Exhibits: Heckert Parker
215 American Avenue
Long Beach, Calif.

Δ

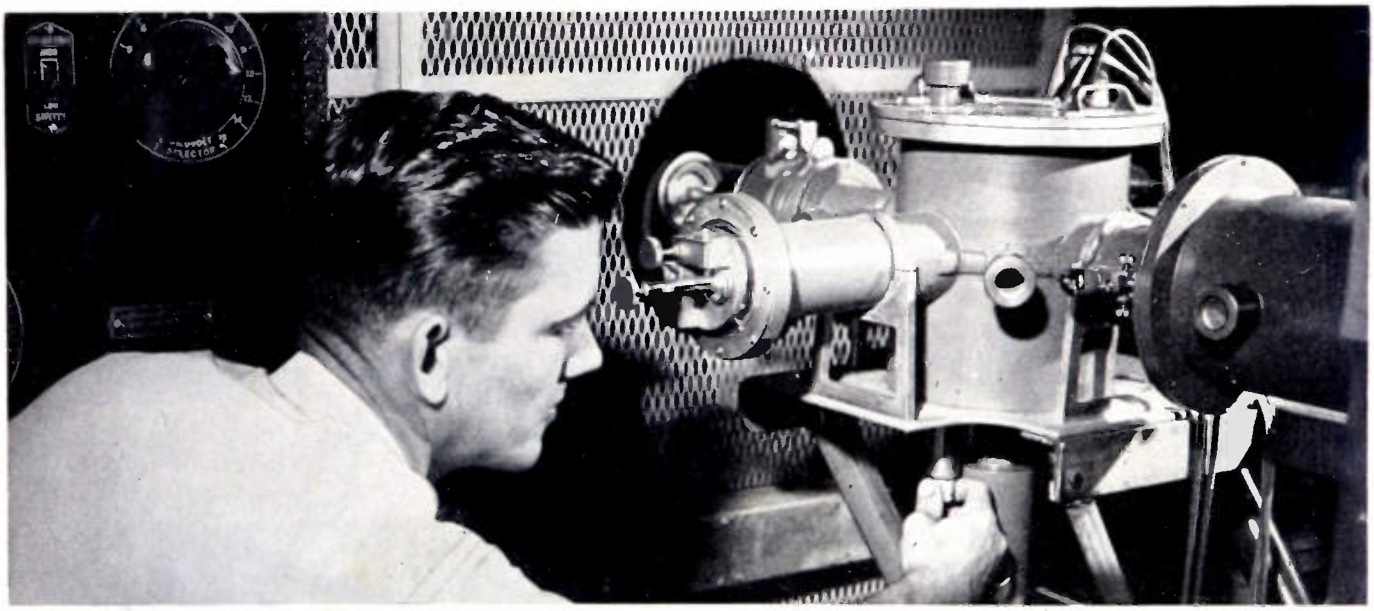
National Electronic Conference
Sept. 29, 30, Oct. 1, 1952
Hotel Sherman, Chicago, Ill.
Exhibits Manager: Mr. R. M. Krueger,
c/o Amphenol, 1830 South 54th Ave.,
Chicago 50, Ill.

Electrons probe the future

1 Electron micrograph of an alloy of aluminum, nickel, cobalt and iron. Magnification 20,000 diameters.



2 Cooled from high temperature in a magnetic field, the alloy becomes a powerful, permanent magnet. Note changed structure. Black bars reveal formation of precipitate parallel to the applied field. Each bar is a permanent magnet.



3 A Bell scientist adjusts electron diffraction camera. Electrons are projected on the specimen at glancing angles. They rebound in patterns which tell the arrangement of the atoms . . . help show how telephone materials can be improved.

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 ringers 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.

4 Diffraction pattern of polished germanium reveals minute impurities which would degrade the performance of a Transistor.

BELL TELEPHONE LABORATORIES

Improving telephone service for America provides careers for creative men in scientific and technical fields.

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

Proportional Automatic Control Equipment

Fielden Instrument Corp., 2920 N. Fourth St., Philadelphia 33, Pa., has a new ARC-1 automatic control which provides a continuous indication and record of the process variable, and automatically controls the machine to correct for any deviation from the desired control point.

The control may be set up to ignore momentary deviations, then make corrections which are proportional to the deviation from the desired control point at time intervals automatically adjusted to suit machine or process speed.

This equipment is simple to install. Push buttons for manual control are provided on the instrument panel and additional push buttons may be installed elsewhere when required. Pilot lights indicate when the process variable is within tolerance limits or above or below the control point, also when a correction is being made.

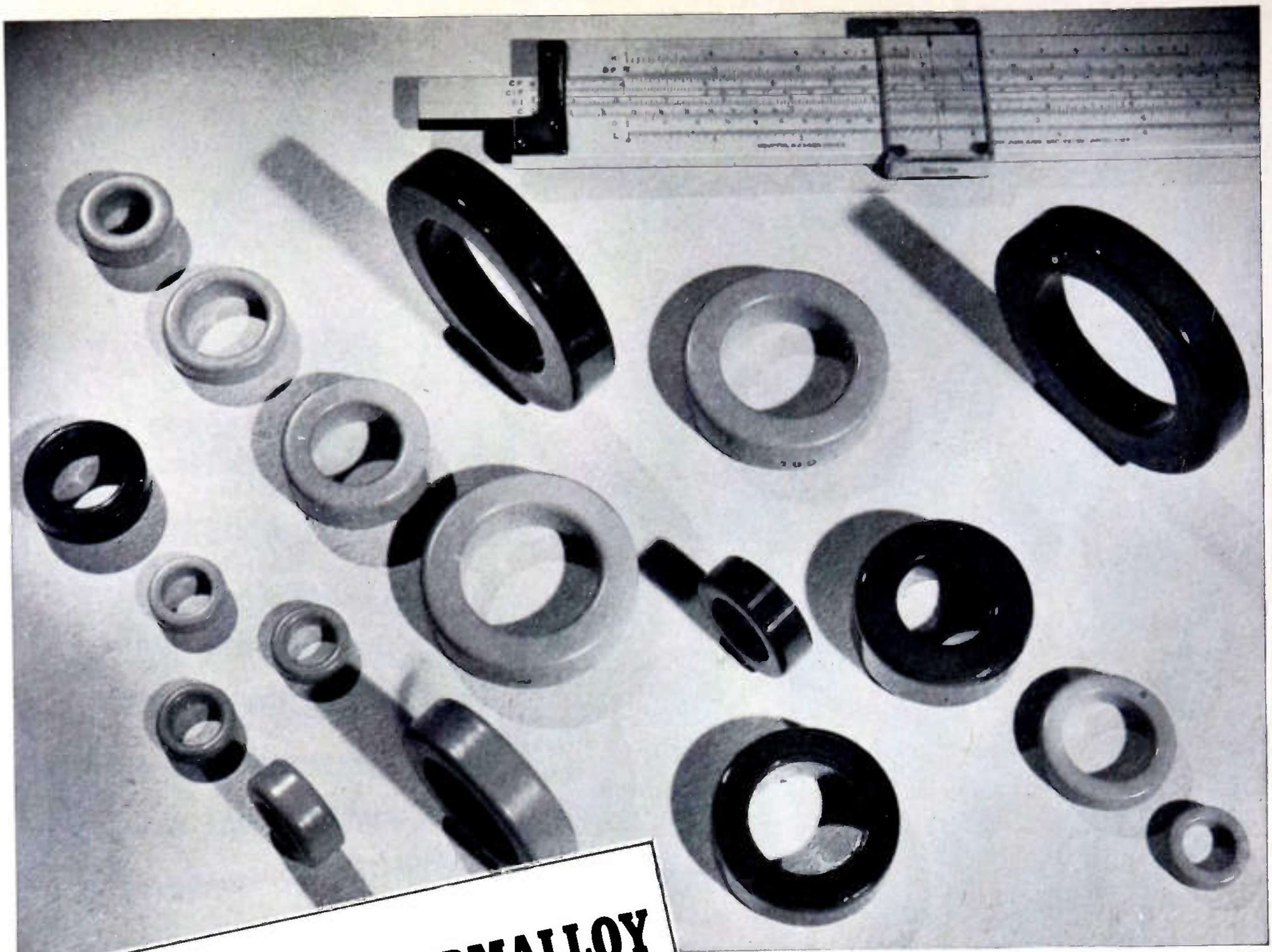
Price for equipment consisting of recorder, timing panel, tachometer, and control relay is $1,250.00.

Galvanometer System

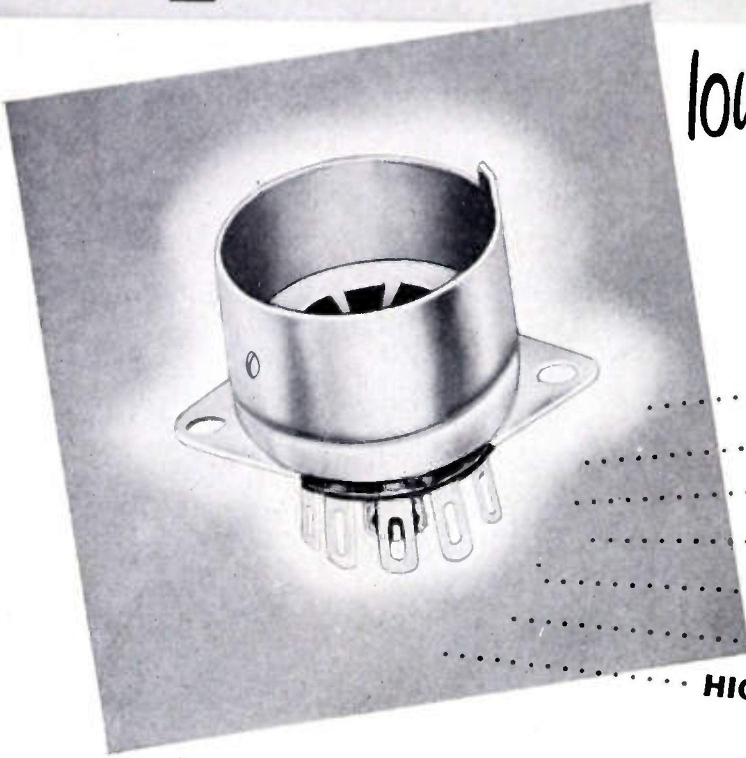
An improved Type 1951 dc galvanometer system just introduced by the **Shallcross Manufacturing Co.**, Collingdale, Pa., features simplified construction, lighter weight, and lower cost.

Instead of being supported in a large phenolic base as in conventional designs, the coil and its mechanism are mounted on rod supports and protected by a removable aluminum cover, 23/32 inch in

(Continued on page 22A)



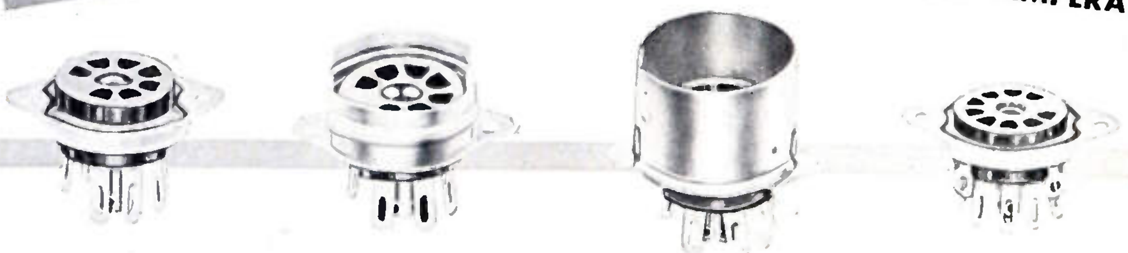
MYCALEX



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-I-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.

SINCE 1919 MYCALEX THE INSULATOR TRADE MARK REG US PAT OFF

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**

30 pulses per second

more than 900 cars per minute!

Relays

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

AN-3320-1 D.C.

AN-3324-1 D.C.

Series 595 D.C.

Series 610 A.C.—615 D.C.

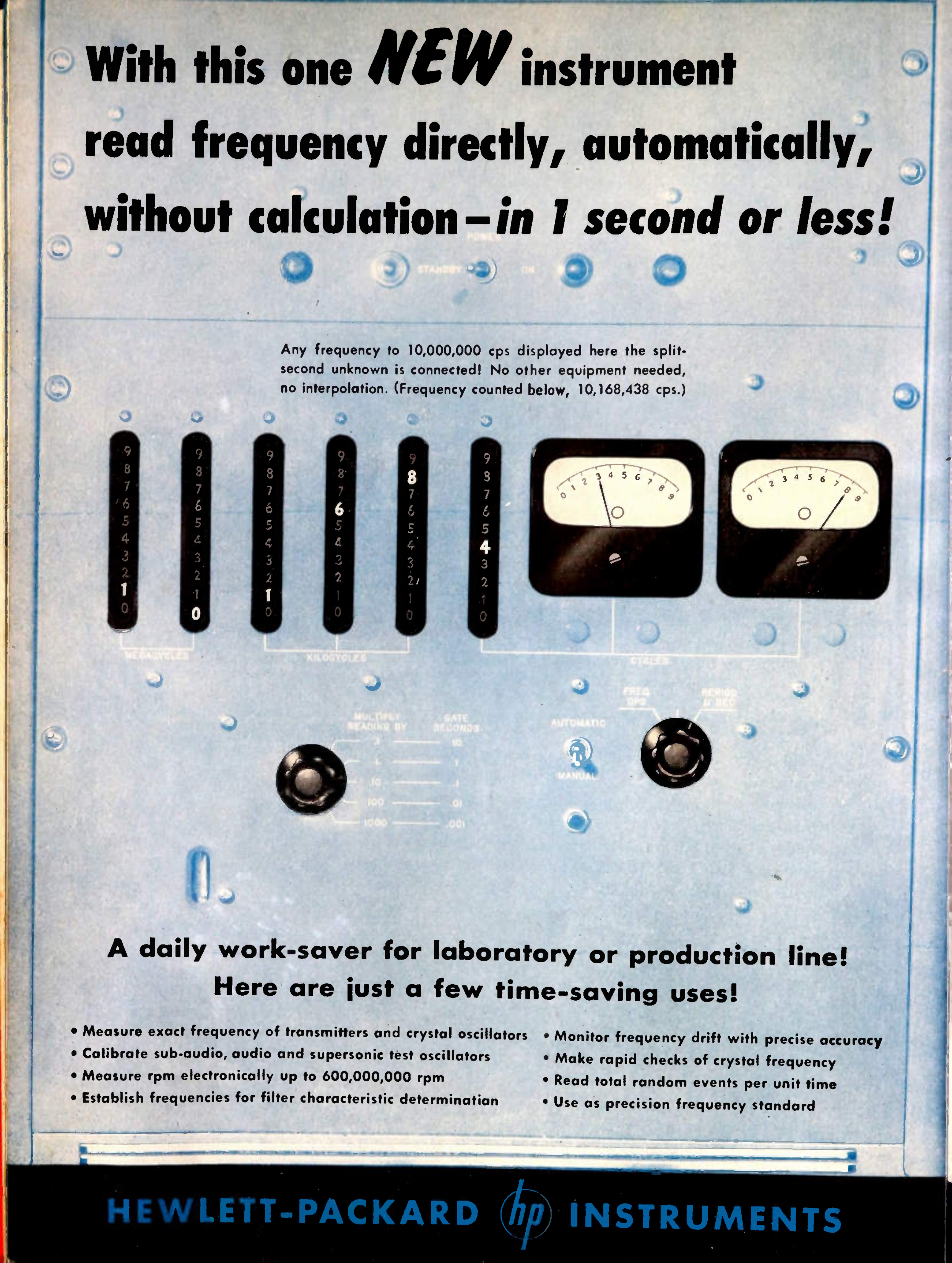
Series 695 D.C.

WRITE — WIRE — TELETYPE — PHONE NOW!

GUARDIAN ELECTRIC

1628-D W. WALNUT STREET CHICAGO 12, ILLINOIS

A COMPLETE LINE OF RELAYS SERVING AMERICAN INDUSTRY


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 determinatian
• Monitor frequency drift with precise accuracy
• Make rapid checks of crystal frequency
• Read total random events per unit time
• Use as precision frequency standard
HEWLETT-PACKARD hp INSTRUMENTS

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.

BRIEF SPECIFICATIONS

-*hp*- 524A Frequency Counter

COUNTING RATE: 10 mc maximum.

PRESENTATION: 8 places, direct reading.

COUNT PERIOD: 0.001, 0.01, 0.1, 1, 10 secs.

LOW FREQUENCIES: Permits low frequencies to operate as time base. Duration of one cycle is displayed in microseconds.

ACCURACY: ± 1 count ± 2/1,000,000 per week. (Higher accuracy external standard may be employed.)

PERIOD MEASUREMENT: Within 0.03% up to 300 cps; within 1 μsec between 300 cps and 10 kc.

EXTERNAL 100 KC TIMING CIRCUIT: For higher accuracy. Requires 1 v across 50,000 ohms shunted by 30 μμfd.

INPUT VOLTAGE: 1 v peak minimum.

INPUT IMPEDANCE: Approx. 100,000 ohms, 30 μμfd shunt.

CONNECTORS: Standard BNC type.

POWER SOURCE: 115 v, 50/60 cps, 400 watts.

SIZE: Approx. 28" high, 21¾" wide, 14" deep. Weight 115 lbs. Shipping weight 175 lbs.

PRICE: $2,000.00 f.o.b. factory.

Data Subject to Change Without Notice

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, 0.1, 0.01, and 0.001 seconds. Counting and display periods are equal and automatically cycled. The count is displayed repetitively; or, by merely pressing the "manual" button, can be "held" any length of time.

2. *Period Measurement for Low Frequencies* • The equipment measures the duration of one low frequency cycle in microseconds. A 10 cps sample is taken to determine this period. Periods may be 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 Scaler 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. Scaler delivers 1 output pulse per 100 received, and displays residual count on two panel meters. Instrument may be used with conventional 10^5 pps scalers to increase count capacity. $600.00 f.o.b. factory.

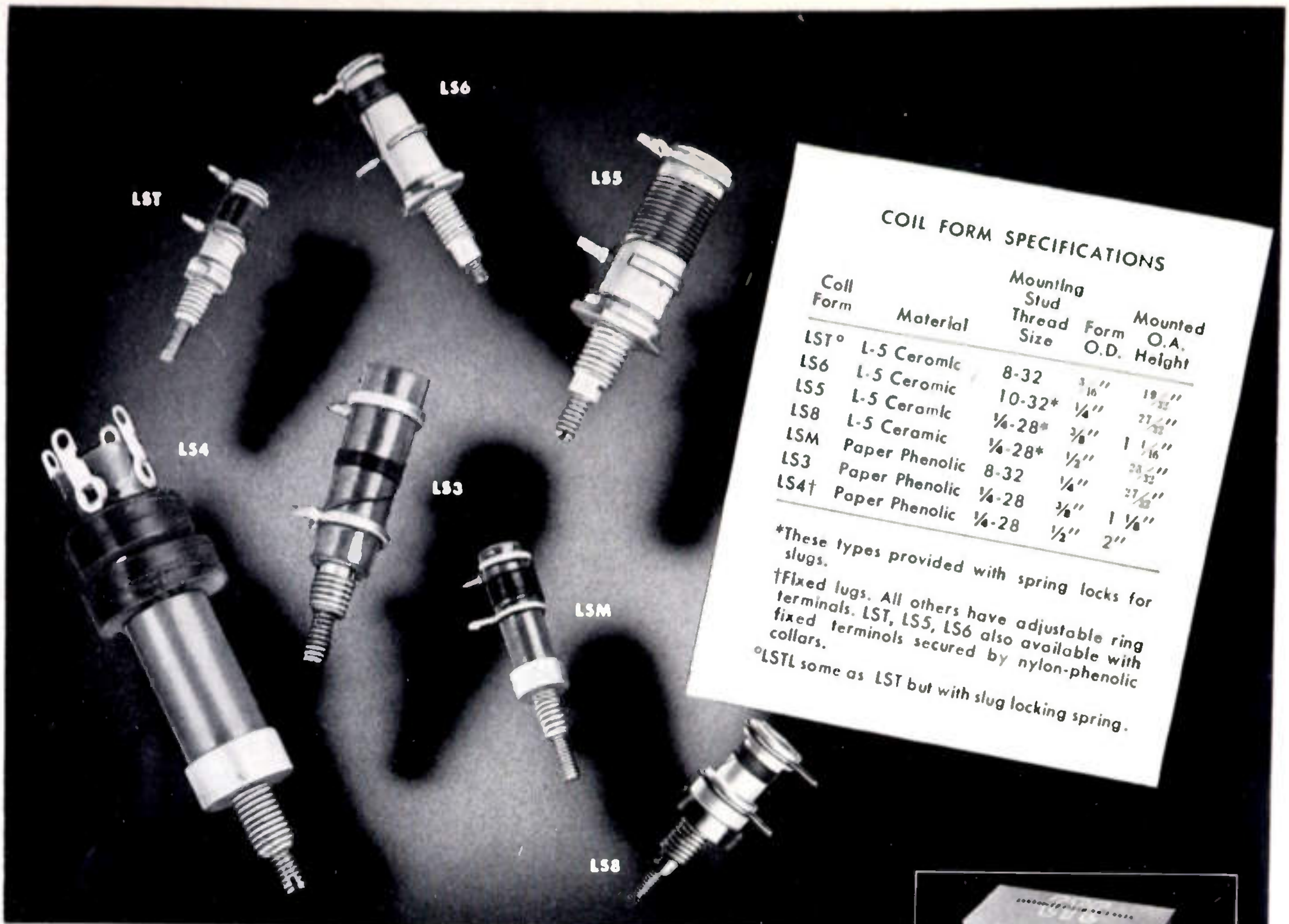
See your -hp- field engineer or write direct for complete details.

HEWLETT-PACKARD COMPANY

2322D PAGE MILL ROAD • PALO ALTO, CALIFORNIA, U.S.A.

Export: Frazar & Hansen, Ltd., San Francisco, Los Angeles, New York

THE COMPLETE COVERAGE LINE



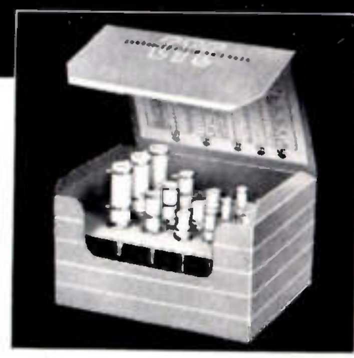
COIL FORM SPECIFICATIONS

Coil Form	Material	Mounting Stud Thread Size	Form O.D.	Mounted O.A. Height
LST°	L-5 Ceramic	8-32	3/16″	19/32″
LS6	L-5 Ceramic	10-32*	¼″	27/32″
LS5	L-5 Ceramic	¼-28*	⅜″	1 1/16″
LS8	L-5 Ceramic	¼-28*	½″	28/32″
LSM	Paper Phenolic	8-32	¼″	27/32″
LS3	Paper Phenolic	¼-28	⅜″	1 ⅛″
LS4†	Paper Phenolic	¼-28	½″	2″

*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.

°LSTL same as LST but with slug locking spring.



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.

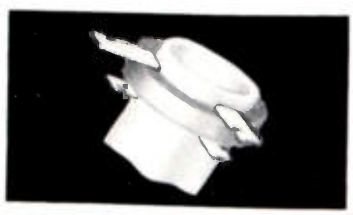
Here are the coils you want ...*the way you want them!*

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 Thermionic Corporation, 456 Concord Avenue, Cambridge 38, Mass. West Coast manufacturers, contact: E. V. Roberts, 5014 Venice Blvd., Los Angeles, and 988 Market Street, San Francisco, California.



NEW NYLON-PHENOLIC COLLARS. Terminals held securely; soldering spaces doubled; excellent for both bifilar and single pie windings. Show on 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.

CAMBRIDGE THERMIONIC CORPORATION

custom or standard . . . the guaranteed components

RAYTHEON

Ready for YOU now!

... this reliable source of Reliable Tubes

CK 5654 the high Gm RF pentode

CK 5686 the all purpose power output tube, good from audio to 150 mc.

CK 5725 the gating or mixer pentode (dual control grids)

CK 5726 the high perveonce twin diode

CK 5749 the remote-cutoff RF amplifier pentode

CK 5751 the high Mu dual triode

CK 5814 the medium Mu dual triode

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.

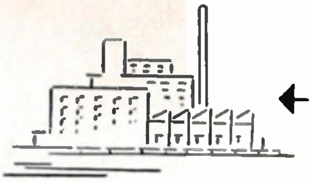
Close to 400 Raytheon distributors are at your service on these tubes. Application information is yours for the asking from Raytheon at Newton, Chicago, Los Angeles.

RAYTHEON

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

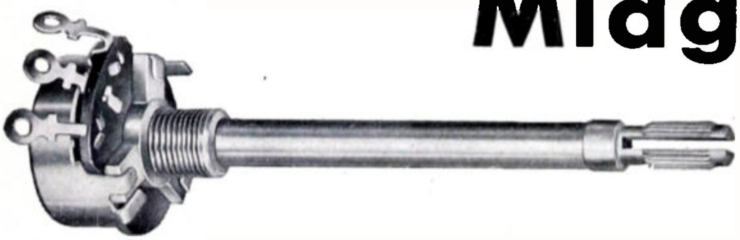
Excellence in Electronics

RELIABLE SUBMINIATURE AND MINIATURE TUBES • GERMANIUM DIODES AND TRANSISTORS • RADIAC TUBES • RECEIVING AND PICTURE TUBES • MICROWAVE TUBES

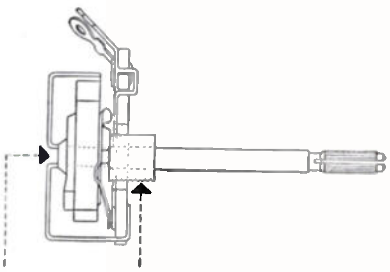


here and here

MALLORY Midgetrols®



do a trouble-free job for you



Two-Point Suspension

Only with Mallory Midgetrols do you get two-point suspension—the feature which gives more stable resistance values and longer control life. It also permits specification of longer shafts and makes it possible to use shorter shaft bushings.

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

P. R. MALLORY & CO. Inc.
MALLORY

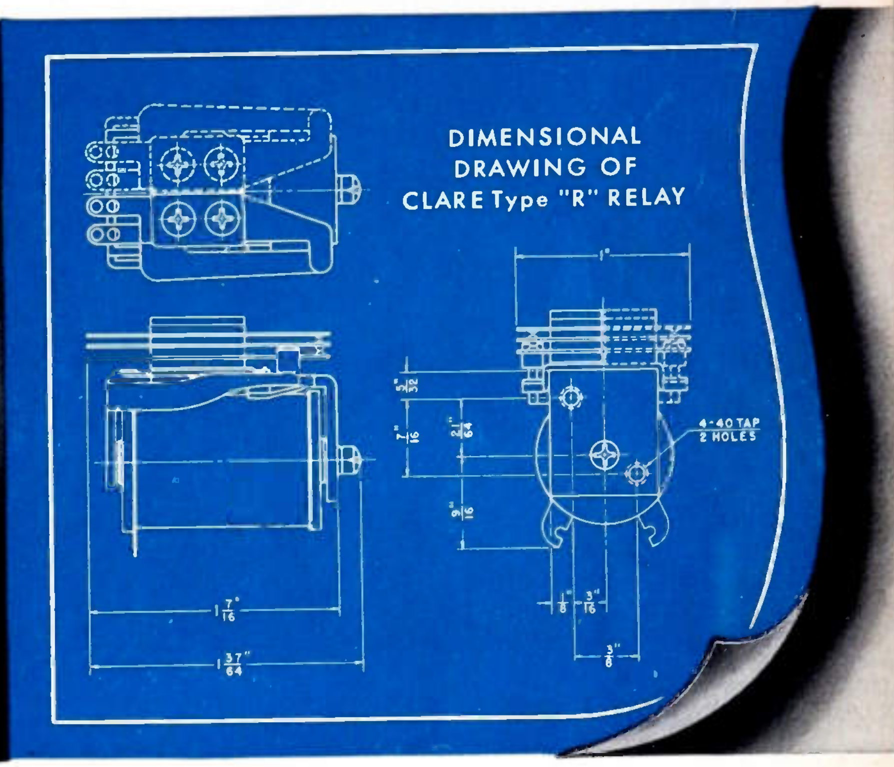
SERVING INDUSTRY WITH
Electromechanical Products—Resistors • Switches • TV Tuners • Vibrators
Electrochemical Products—Capacitors • Rectifiers • Mercury Dry Batteries
Metallurgical Products—Contacts • Special Metals • Welding Materials

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

A NEW CLARE RELAY...

the Type "R" combines extremely small size with unusual sensitivity and long life

Approximately Actual Size



SPECIFICATIONS

SIZE
Length: 1 7/16"—Height: 1 3/64"—Width: 1"

WEIGHT
Approximately 2 ounces

COIL
Single or double-wound

OPERATING VOLTAGE
Up to 230 volts d-c

ARMATURE
Single or double arm

CONTACT ASSEMBLY
Form A to C. Maximum of 10 springs in each pileup.

MOUNTING
Two #4-40 tapped holes in end of heelpiece

● 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

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:

TEXTILE BROADCASTING COMPANY
Radio WMRC Station
GREENVILLE, S. C.

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 watts; this means an input of 10,5000 watts which in my opinion is pushing any pair of tubes for FM service.

This tube had to operate at a plate current of 1.35 amps. at 3900 volts.

We are highly pleased with this tube.

Very truly yours,

Radio Station WMRC-WMRC-FM

George D. Tate
Chief Engineer

GEORGE D. TATE
Chief Engineer
WMRC

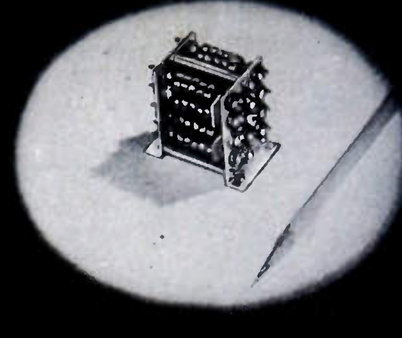
FOLLOW THE LEADERS TO
Eimac TUBES
THE POWER FOR R-F

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

EITEL-McCULLOUGH, INC.
SAN BRUNO, CALIFORNIA

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

MUST YOUR EQUIPMENT BE RADIO INTERFERENCE FREE?



8 circuit miniaturized filter for wide band RF Interference Suppression.

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

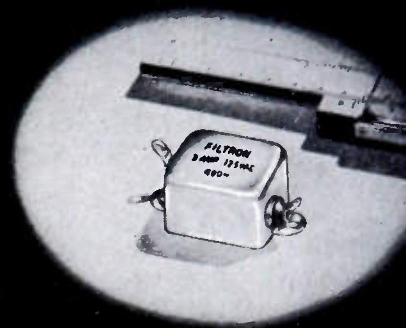
FILTRON'S engineering department, cooperating with engineers of leading companies, has solved RF Interference Suppression problems throughout the country.

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.

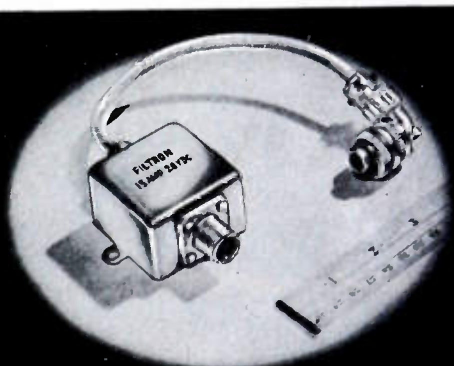
FILTRON has custom *designed* over 1000 different types of RF Interference Suppression Filters for equipment that meets military RF Interference Suppression limits and specifications.

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.



Miniature 3 amp.—125 VAC-400~ filter—hermetically sealed—size 1 1/8" x 1" x 11/16"



15 amp.—28 VDC filter, size 2" x 2" x 1 1/4", with pressurized AN connectors—high attenuation from 150 KC to 400 MC.

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!

RF INTERFERENCE SUPPRESSION FILTERS FOR:

Motors	Dynamotors
Generators	Power Plants
Inverters	Actuators
Electronic Controls	Gasoline Engines

And other RF Interference producing equipment

filtered by ***FILTRON***

LOCKHEED XF-90

THE FILTRON CO., INC.
FLUSHING, LONG ISLAND, NEW YORK
LARGEST EXCLUSIVE MANUFACTURERS OF RF INTERFERENCE FILTERS

...GIVE EXTRA DEPENDABILITY

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 44, Illinois.

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

OHMITE

First in **WIRE-WOUND RHEOSTATS and RESISTORS**

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 6A)

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

The Type 1951 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 potentiometer 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, **Aerovox 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 uuf.

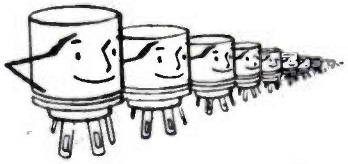
Capacitor for Low-Voltage Distribution

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 16½ inches long and 4½ 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...

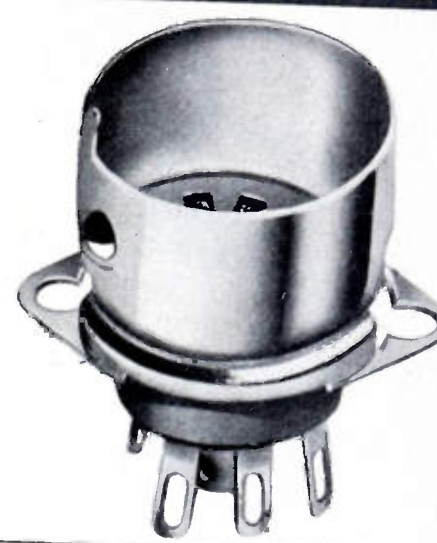


report for Active Duty!

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.


2.


3.


4.


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**

For regular commercial use, Sylvania makes RMA 7- and 9-Pin Miniature, Turret, Octal, Duo-Decal, etc., sockets. Available in General Purpose and Low Loss Phenolics with any combination of contact materials. Write for new illustrated catalog giving complete descriptions: Sylvania Electric Products Inc., Dept. A-1304, Parts Sales Division, Warren, Pa.

SYLVANIA

RADIO TUBES; TELEVISION PICTURE TUBES; ELECTRONIC PRODUCTS; ELECTRONIC TEST EQUIPMENT; FLUORESCENT TUBES, FIXTURES, SIGN TUBING, WIRING DEVICES; LIGHT BULBS; PHOTOLAMPS; TELEVISION SETS

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

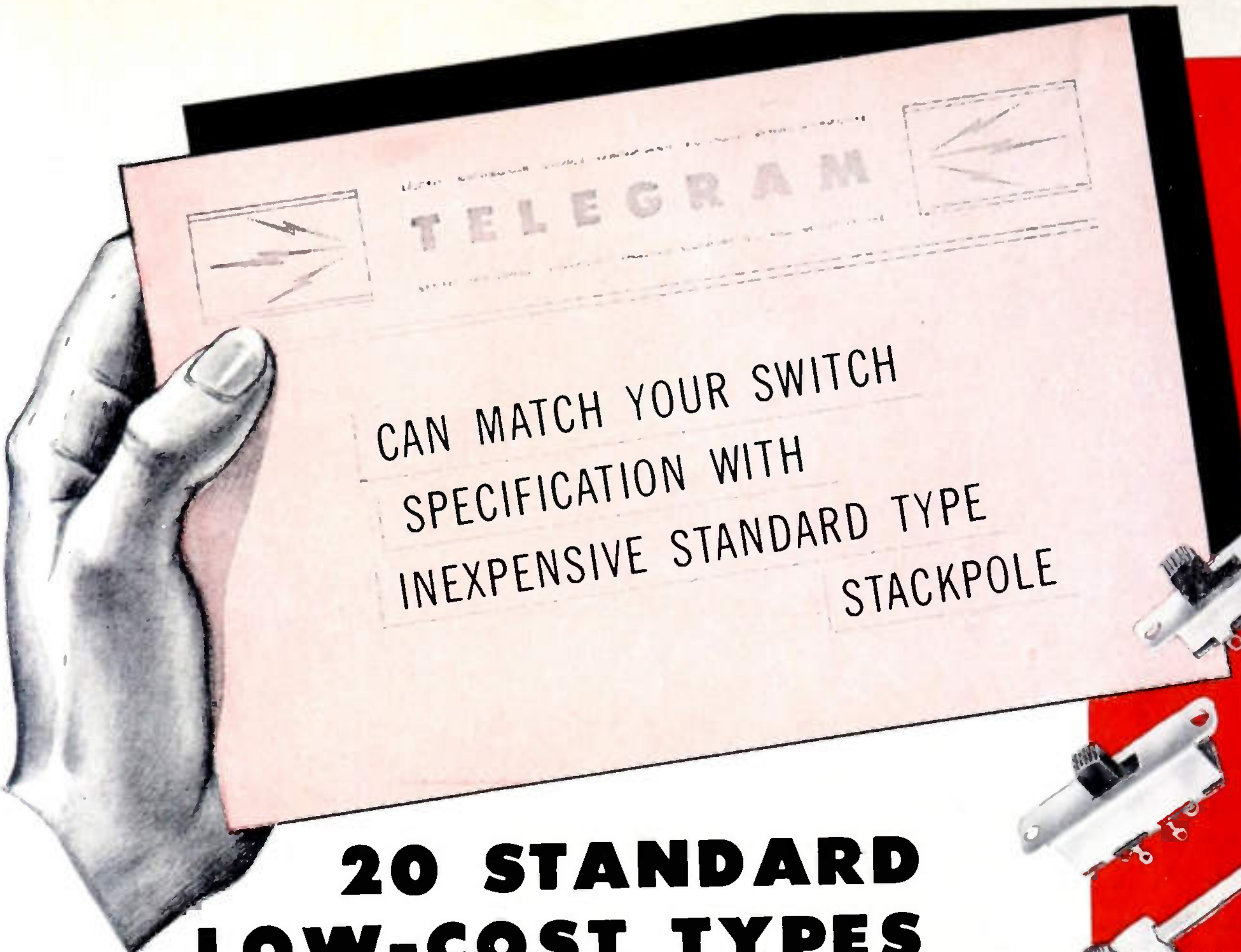
Tru-Ohm Products, Division of Model Engineering and Manufacturing Co., 2800 Milwaukee Ave., Chicago 18, Ill. announces the development of the Tru-Ohm Power Rheostat. This item augments the firm's line of resistors, which include variable, fixed, "Econohm," "Ribohm" resistors, etc.

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.

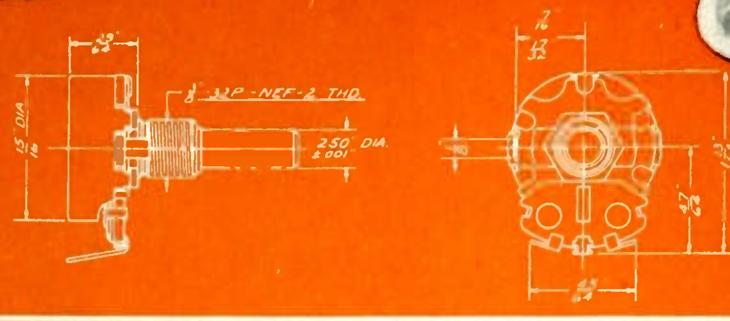
(Continued on page 52A)


TELEGRAM
CAN MATCH YOUR SWITCH
SPECIFICATION WITH
INEXPENSIVE STANDARD TYPE
STACKPOLE

A Complete Line

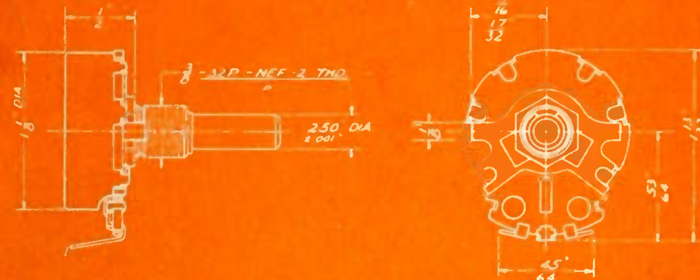
that

TYPE 45
(JAN-R-94, Type RV2)



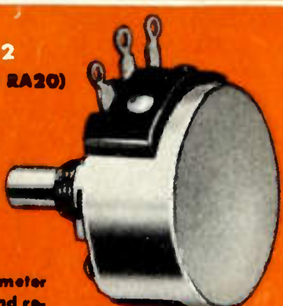
¼ watt, 15⁄16" diameter variable composition resistor.
Also available with other special military features not covered by JAN-R-94. Attached Switch can be supplied.

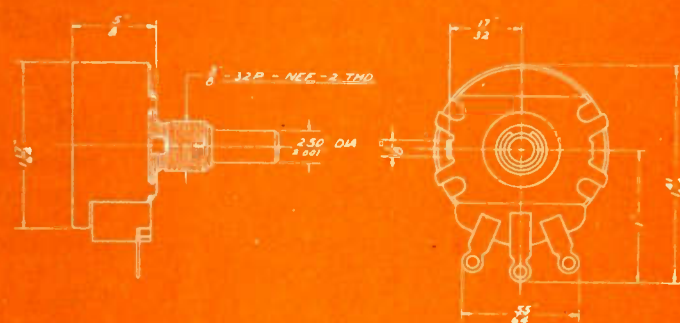
TYPE 35
(JAN-R-94, Type RV3)



½ watt, 1⅛" diameter variable composition resistor.
Also available with other special military features not covered by JAN-R-94. Attached Switch can be supplied.

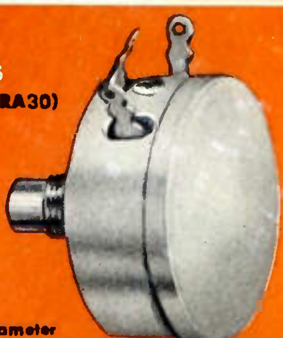
TYPE 252
(JAN-R-19, Type RA20)

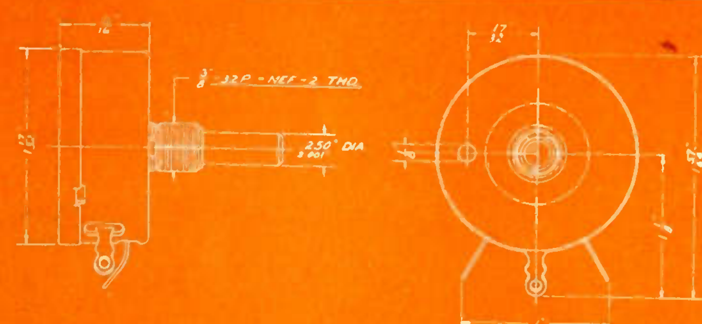




2 watt, 1¹³⁄₆₄" diameter variable wirewound resistor. Also available with other special military features not covered by JAN-R-19. Attached Switch can be supplied.

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





4 watt, 1¹⁷⁄₃₂" diameter variable wirewound resistor. Also available with other special military features not covered by JAN-R-19. Attached Switch can be supplied.

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

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.

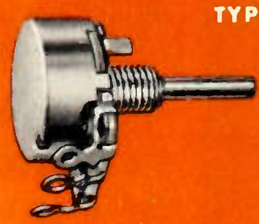
NEW COMPLETE CTS CATALOG. Write for your copy today.

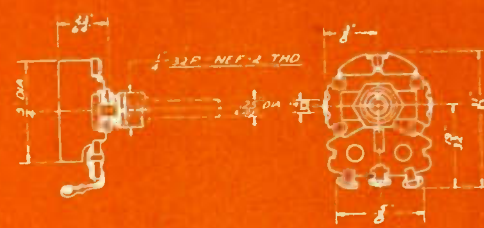
...of Variable Resistors

MEETS MILITARY SPECIFICATIONS

−55°C to + 150°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.

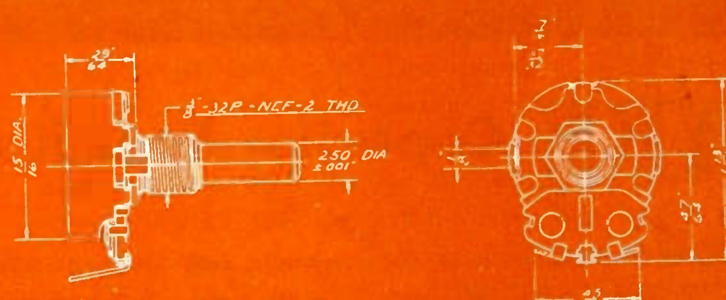
TYPE 65





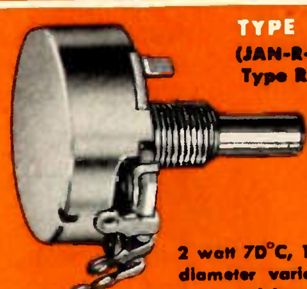
½ watt 70°C, ⅝" diameter miniaturized variable composition resistor.

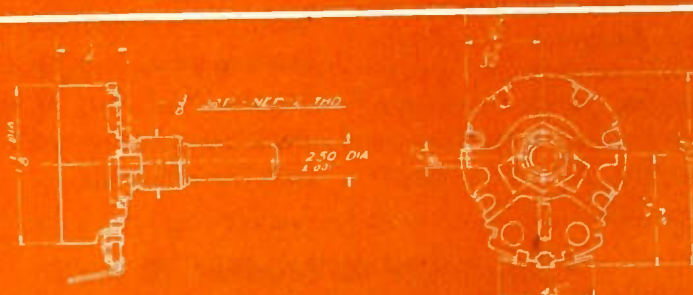
TYPE 90



1 watt 70°C, 1$\frac{5}{16}$" diameter variable composition resistor. Attached Switch can be supplied.

TYPE 95 (JAN-R-94, Type RV4)





2 watt 70°C, 1⅛" diameter variable composition resistor. Also available with other special military features not covered by JAN-R-94. Attached Switch can be supplied.

Specialists in Precision Mass Production of Variable Resistors

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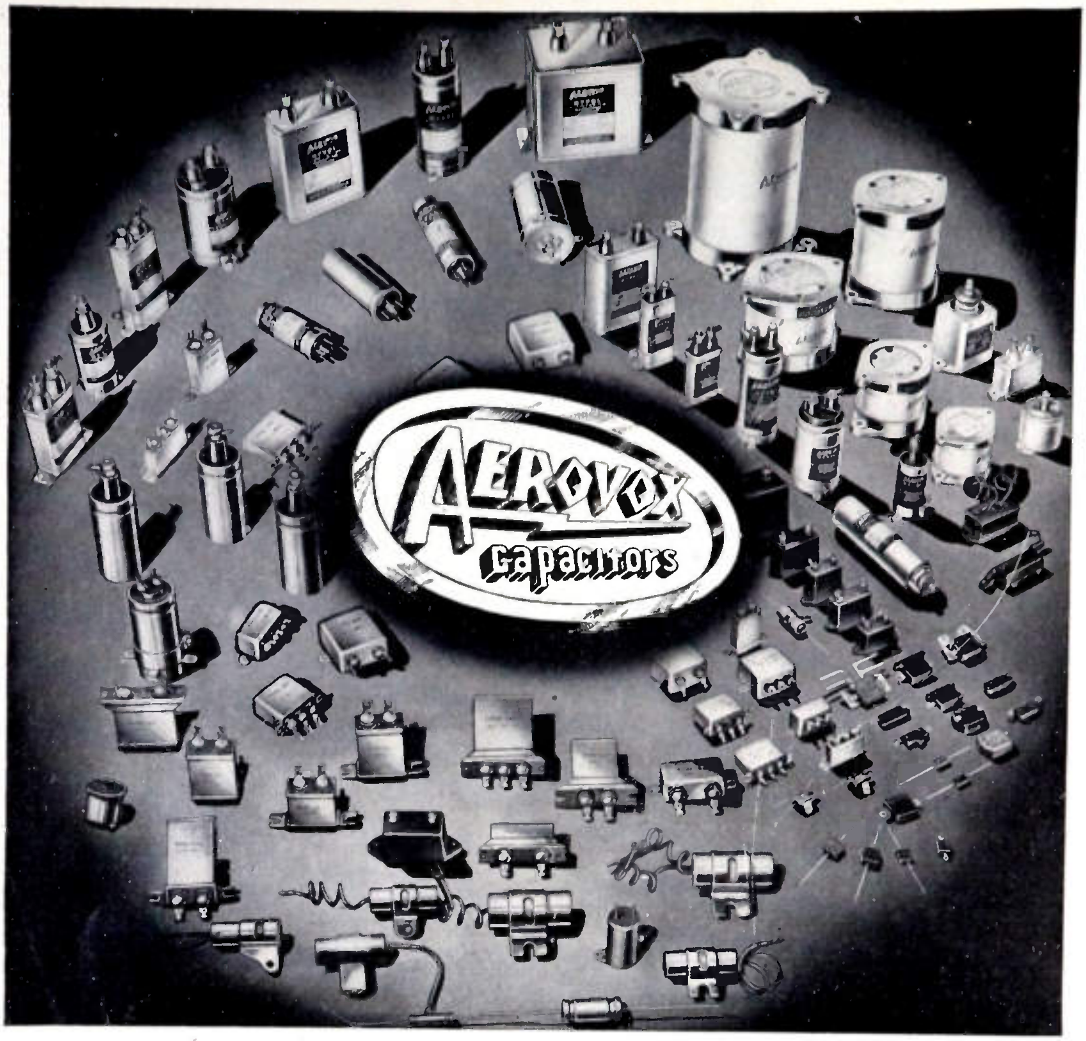


INTERFERENCE FILTERS

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.

OIL CAPACITORS

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

HIGH-TEMPERATURE MINIATURES

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.; ¼" d. x 9/16" l.

ELECTROLYTICS

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

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.

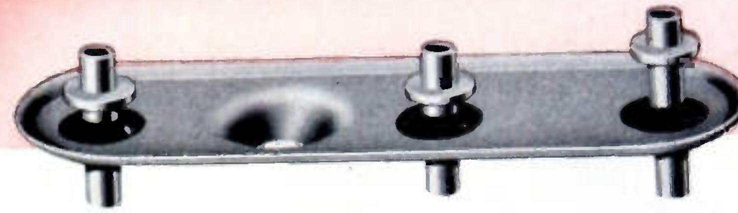
THE HOME OF CAPACITOR CRAFTSMANSHIP

AEROVOX CORPORATION, NEW BEDFORD, MASS., U. S. A.

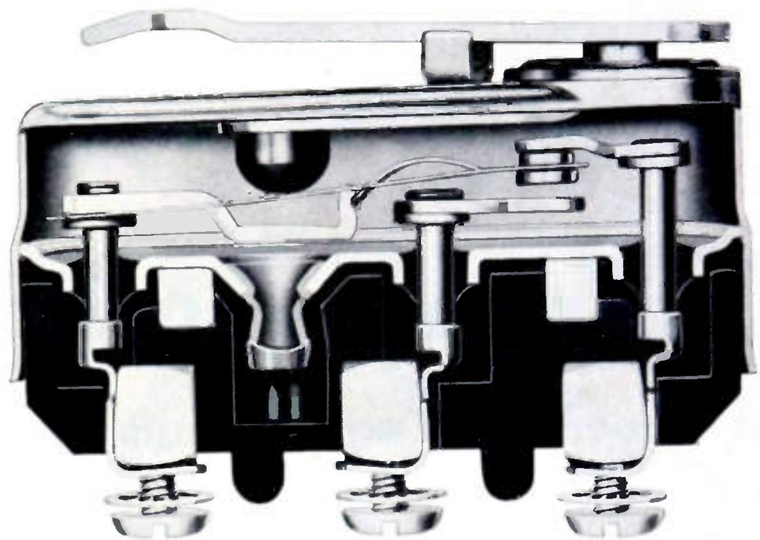
Export: 41 E. 42nd St., New York 17, N. Y. • Cable: AEROCAP, N. Y. • In Canada: AEROVOX CANADA LTD., Hamilton, Ont.

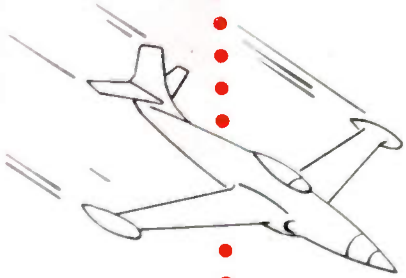
SALES OFFICES IN ALL PRINCIPAL CITIES

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.

INSULATE ELECTRICALLY
GLASS TO METAL
FUSITE
TERMINALS
PROTECT PRODUCT PERFORMANCE
SEAL HERMETICALLY

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

THE FUSITE CORPORATION

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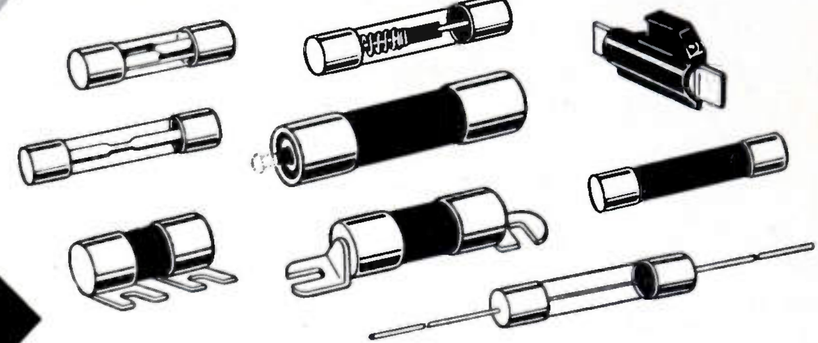
MANUFACTURERS OF A COMPLETE LINE OF FUSES

For

TELEVISION • RADIO • RADAR

INSTRUMENTS • CONTROLS • AVIONICS

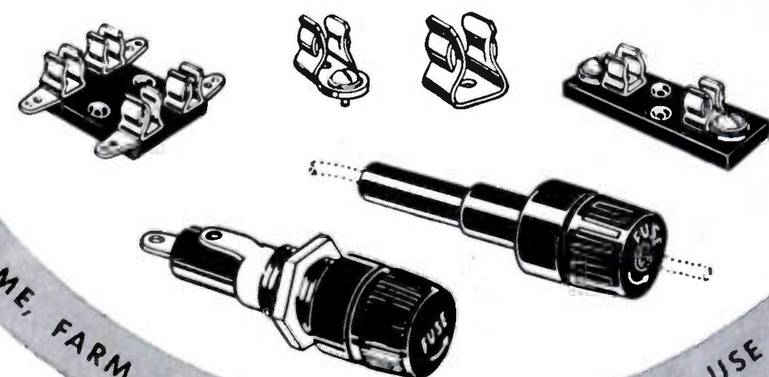


Let

BUSS FUSES

Help Protect Your Reputation

plus companion lines of BUSS Fuse Clips, Blocks and Fuse Holders. Made in many types to make it easy to select the fuse and fuse mounting needed to give required protection.



FOR HOME, FARM, COMMERCIAL AND INDUSTRIAL USE

As a User of High Quality Materials

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 . . .*

BUSSMANN Mfg. Co. (Division of McGraw Electric Co.)
University at Jefferson, St. Louis 7, Mo.

Please send me bulletin IRE containing complete facts on BUSS small dimension fuses and fuse holders.

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Title ______________________

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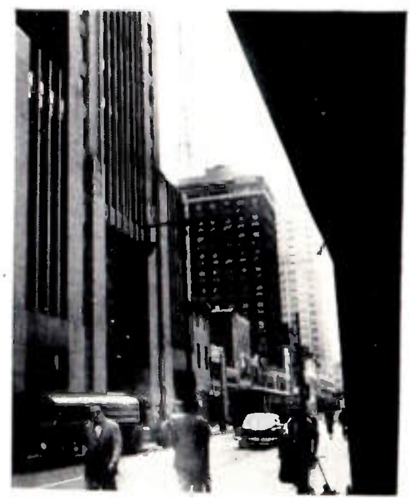
494 feet above Philadelphia's busiest streets

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

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



BLAW-KNOX ANTENNA TOWERS

Distributed by Graybar


Supplying the NERVE SYSTEM
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SPECIAL HARNESSES,
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FASTER, ECONOMICAL
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Constructed of Wires
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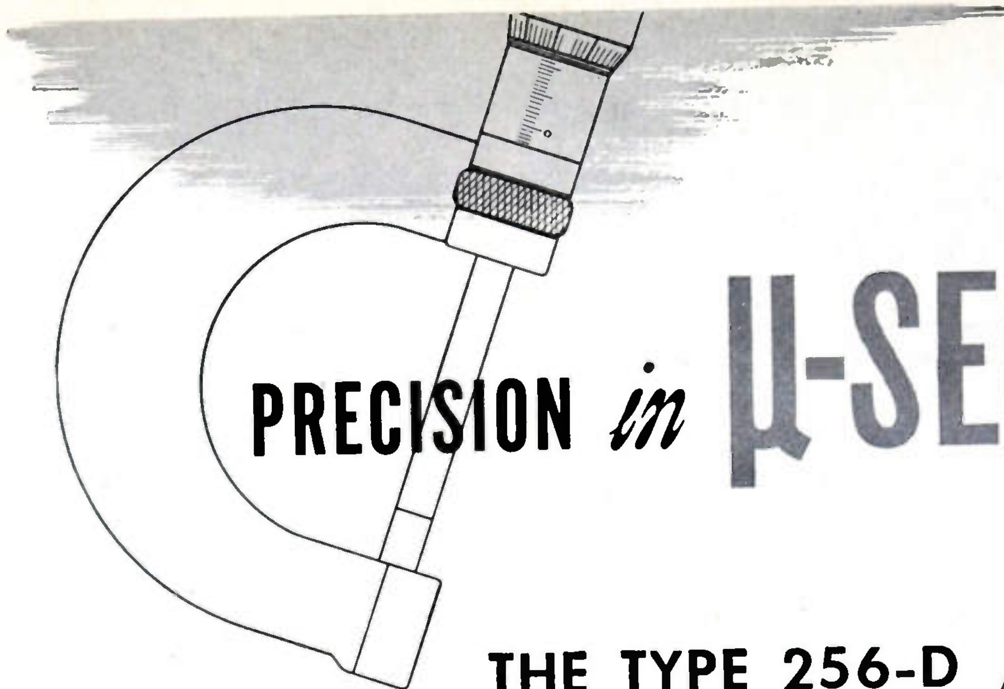


PRECISION *in* µ-SECS

THE TYPE 256-D

and for PRECISION IN YARDS

THE TYPE 256-E

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.

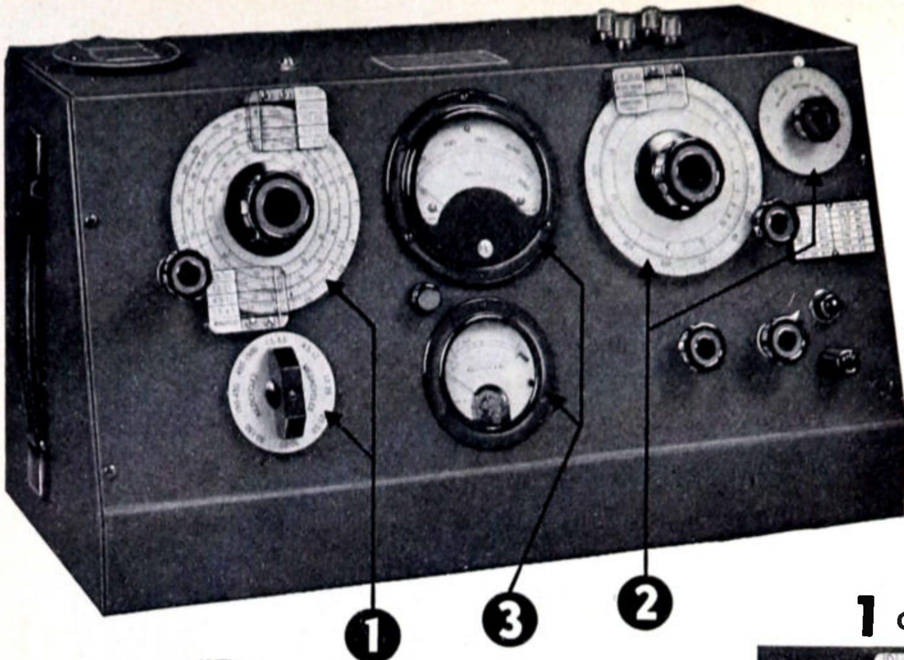
Electrically similar to the Type 256-D. Calibrations in yards instead of microseconds. Designed especially as test equipment for electronic ranging systems, or as an accessory unit for radar systems.

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.

DU MONT

for Oscillography

Instrument Division, **ALLEN B. DU MONT LABORATORIES, Inc.**, 1500 Main Ave., Clifton, N. J.



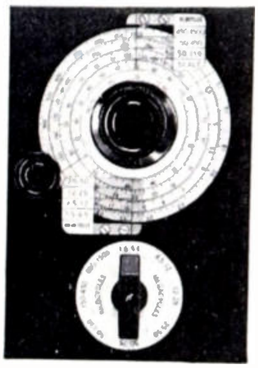
EXAMINE THESE *Direct Reading Features* WHICH SIMPLIFY ACCURATE MEASUREMENTS

The Q METER

TYPE 160-A

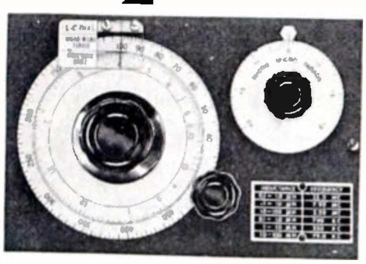
50 kc. to 75 mc.

1 OSCILLATOR FREQUENCY DIAL.



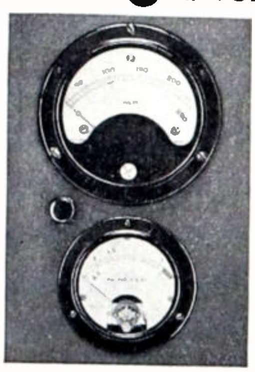
This large 4½" open faced dial has eight overlapping frequency ranges, each calibrated *directly* in kilocycles or megacycles, with scales conveniently divided for maximum readability. A vernier dial drive enables fine settings to be made with ease. All frequency ranges are accurate to within ±1% except 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 enables 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.

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 part 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.

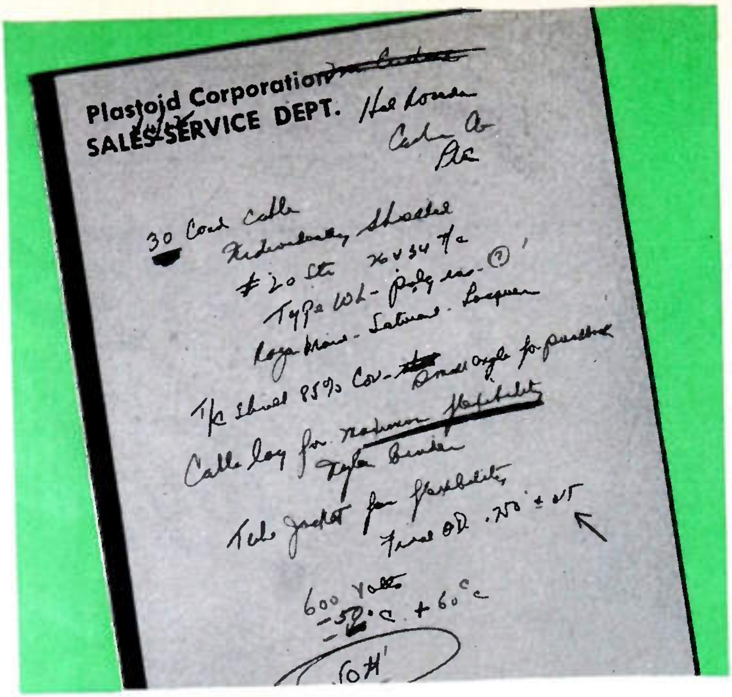
Q Measurement Accuracy: Approximately 5% for direct reading measurement, for frequencies up to 30 mc. Accuracy less at higher frequencies.

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.)

DESIGNERS AND MANUFACTURERS OF THE Q METER · QX CHECKER
FREQUENCY MODULATED SIGNAL GENERATOR · BEAT FREQUENCY
GENERATOR AND OTHER DIRECT READING INSTRUMENTS

BOONTON RADIO *Corporation*
BOONTON·N·J·U·S·A·



Make it?

Certainly!

—WE KNOW HOW!

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.*

The finished job . . . a custom-engineered SYNKOTE ¾" cable with 30 individually-shielded conductors, fungus-resistant, flexible, designed to "take it" at −50°C or +60°C!

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DEPENDABLE
Multi-Conductor Cables

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HOOK-UP WIRE • AIRCRAFT CABLE • TV WIRE • COAXIAL CABLE •
NYLON JACKETING • HIGH TEMPERATURE WIRE • MULTI-CONDUCTOR CABLES

Test data are *in resistors too!*

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.

ACTUAL SIZE

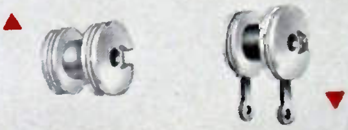
ALL NEW Type WW Wire Wound Resistors for JAN Equipment—Industrial Applications—Miniaturization

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 characteristic & Specifications! High stability suits them to a multitude of industrial uses, and compactness and small size make them ideal for miniaturization.

important

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 strains. 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.

	Original Resist.	1st Cycle % Chge	2nd Cycle % Chge	3rd Cycle % Chge	4th Cycle % Chge	Resist. at End of 100 hrs. load	Total % Chge	% Chge from Last Temp. Cycle to End of 100 hrs. load %	Resistance Chge at End of 100 Hrs. Load only % (no cycling)	
1	100,010	+.04	+.04	+.05	+.05	100,050	+.04	—.01	100,040	—.02
2	100,000	+.03	+.04	+.03	+.05	100,060	+.06	+.01	100,000	0
3	100,000	+.01	+.02	+.02	+.05	100,000	0	+.05	100,050	—.02
4	100,000	+.02	0	+.02	+.02	100,000	0	—.02	100,040	—.01
5	100,010	+.03	+.04	+.04	+.05	100,000	0	—.05	100,030	—.03
6	100,000	0	+.03	+.04	+.04	100,100	+.1	+.06	99,980	0
7	100,000	+.04	+.05	+.04	+.04	100,070	+.07	+.03	100,000	0
8	100,000	+.03	+.05	+.05	+.05	100,050	+.05	0	100,000	0
9	100,000	+.04	+.03	+.05	+.04	100,010	+.01	—.03	100,050	0
10	100,000	+.02	+.02	+.02	+.04	100,010	+.01	—.03	100,000	0
11	100,000	0	+.01	+.01	+.03	100,000	0	—.03		

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.

SIZES AND RANGES

JAN-R-93	1 5/32" Max.	29/32" Max.	27/32" Max.	13/16" Max.		3/4" Max.	Dia.
	2 1/8" ± 1/16"	1 1/8" ± 3/16"	1" Max. 7/8" Min.	5/8" ± 1/16"		13/32" Max.	Length
	4.00 Meg.	750,000	300,000	300,000		185,000	Max. Range
Style	RB14	RB13	RB12	RB11	RB11	RB10	None
New IRC Style #	WW2J	WW5J	WW4J	WW11J	WW3J	WW8J	WW10J
Dia.	7/8" D	3/4" D	9/16" D	9/16" D	9/16" D	9/16" D	9/32" D
Length	2 1/8" L	1 1/4" L	1" L	21/32" L	9/16" L	29/64" L	13/32" L
No. of Pies	8	4	4	2	2	1	1
J. A. N. .0015" Dia.	4.250 Meg.	1.5 Meg.	0.5 Meg.	0.300 Meg.	0.185 Meg.	0.185 Meg.	40,000 Ohms.
Commercial .0013" Dia.	6.00 Meg.	2.7 Meg.	0.9 Meg.	0.450 Meg.	0.225 Meg.	0.225 Meg.	80,000 Ohms.
.0013" Dia. 1000 Alloy							100,000 Ohms.

Power Resistors • Voltmeter Multipliers • Insulated Composition Resistors • Low Wattage Wire Wounds • Volume Controls • Voltage Dividers • Precision Wire Wounds • Deposited Carbon Precistors • Ultra-HF and High Voltage Resistors • Insulated Chokes.

IRC

Wherever the Circuit Says —/\/\/\/—

INTERNATIONAL RESISTANCE COMPANY

401 N. Broad Street, Philadelphia 8, Pa.

In Canada: International Resistance Co., Ltd., Toronto, Licensee

Mail Coupon today for Full Details of New IRC Precision Wire Wounds in Technical Data Bulletin 00

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

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

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TITLE ______________________

COMPANY ______________________

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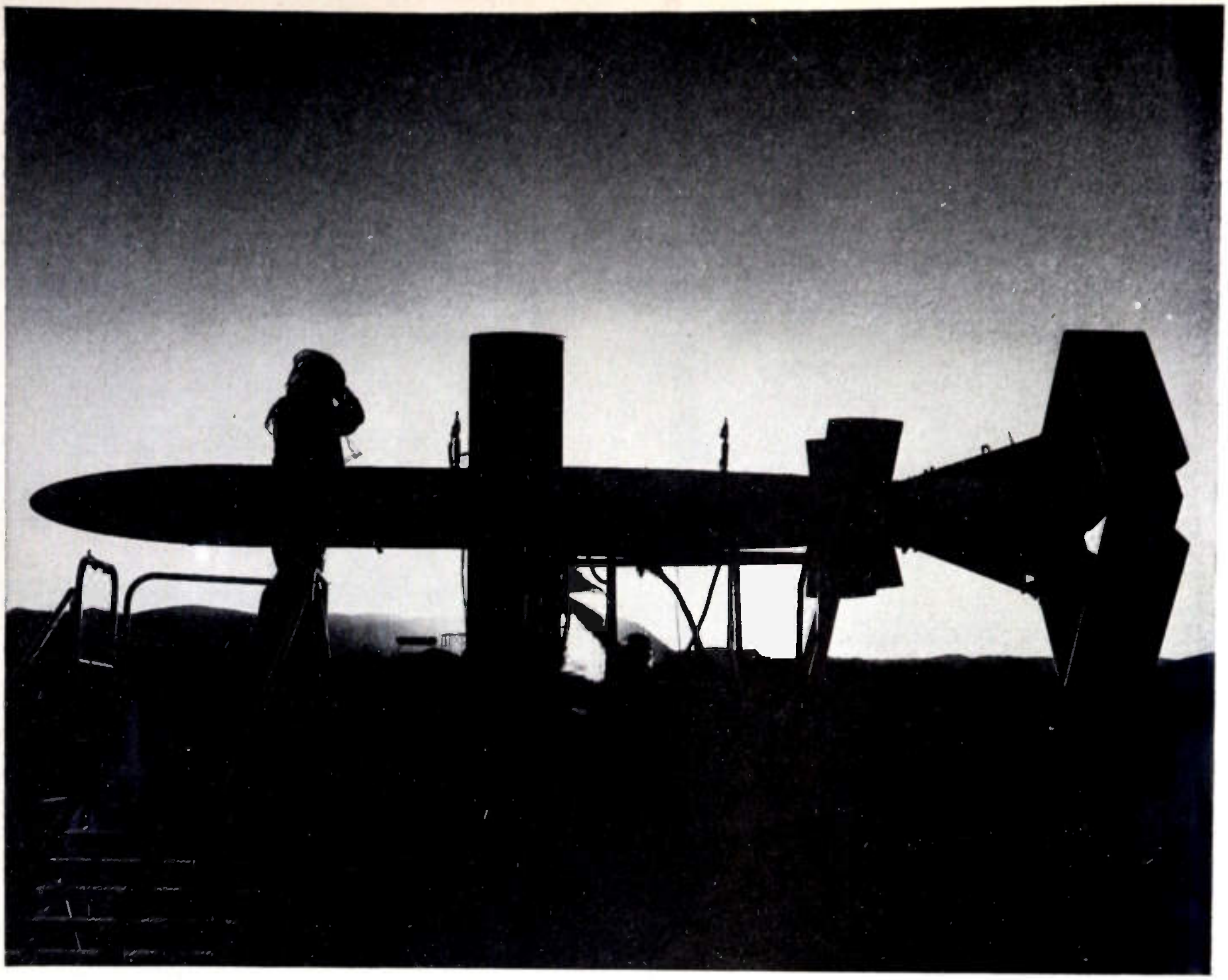
CITY ______________ ZONE ______ STATE ______



If you

want to **get tough**

in your assemblies,

In the heavy-weight division — fixed and adjustable Greenohms — up to 200 watt.

specify

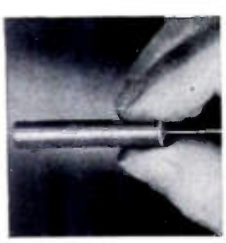
greenohm*

power resistors

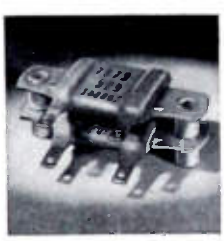
*The green-colored power resistors so conspicuous these days in dependable radio-electronic and electrical assemblies, are GREENOHMS. *No tougher resistors made.* That statement is sustained by laboratory tests. Likewise by countless case histories out in the field.

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

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



Greenohm Jr. — point-to-point wired power resistor sealed in ceramic tubular casing. 4, 7 and 8 watt.



Flat Greenohms for flat mounting individually, or for stacked arrays. 30 to 75 watt.

In the bantam-weight division — 5 and 10 watt fixed Greenohms.

Standecs — convenient above-chassis mounting Greenohms in ceramic casings. 10 to 25 watt.

What is the ideal resistance value? That's easy. With the Clarostat Power Resistor Decade Box inserted in actual circuit, handling actual load, you try the six knobs for anything from 1 to 999,999 ohms. When right operating conditions are attained, read resistance directly off dials. Quick, simple, positive, economical.

you can **stand pat** *with* **clarostat**

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

CLAROSTAT

Controls and Resistors

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

In Canada: Canadian Marconi Co., Ltd., Toronto, Ontario

ELECTRONIC **ELECOM** COMPUTER

DECADE DELAY LINE

An entirely New laboratory unit

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

DELAY LINES

PULSE TRANSFORMER

D.C. AMPLIFIER

PULSE TRANSFORMER

DUAL MAGNETIC HEAD

ELECTRONIC COMPUTER CORPORATION

DESIGNERS AND MANUFACTURERS OF ELECTRONIC DIGITAL COMPUTERS AND DATA HANDLING SYSTEMS AND EQUIPMENT

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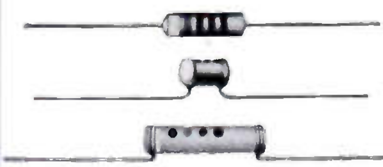
ERIE RESISTOR COMPONENTS

For Easy Assembly
Dependable Performance

ERIE TUBULAR CERAMICONS*



Erie "GP"* Molded Insulated Ceramicons
5 MMF—5,000 MMF

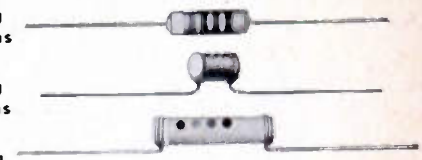
Erie "GP" Dipped Insulated Ceramicons
5 MMF—5,000 MMF

Erie "GP" Non-Insulated Ceramicons
5 MMF—5,000 MMF

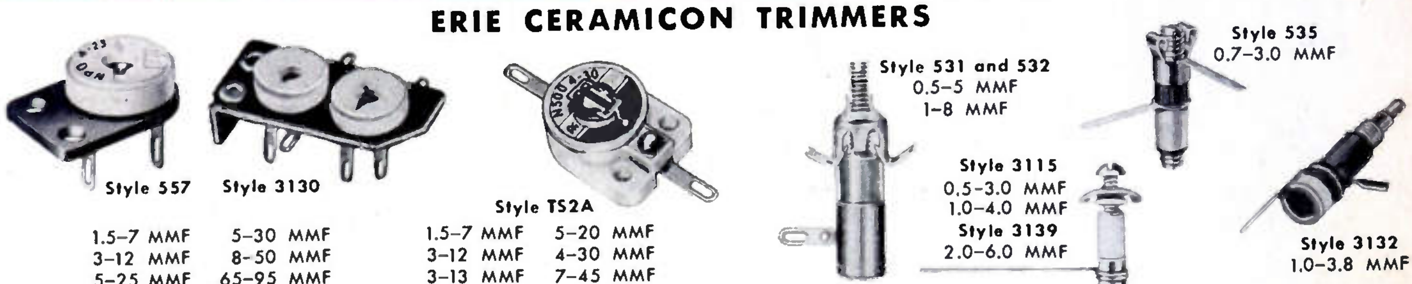
Temperature Compensating
Molded Insulated Ceramicons
0.5 MMF—550 MMF

Temperature Compensating
Dipped Insulated Ceramicons
0.5 MMF—1,800 MMF

Temperature Compensating
Non-Insulated Ceramicons
0.5 MMF—1,800 MMF



ERIE CERAMICON TRIMMERS



Style 557 Style 3130

1.5–7 MMF 5–30 MMF
3–12 MMF 8–50 MMF
5–25 MMF 65–95 MMF
150–190 MMF

Style TS2A

1.5–7 MMF 5–20 MMF
3–12 MMF 4–30 MMF
3–13 MMF 7–45 MMF

Style 531 and 532
0.5–5 MMF
1–8 MMF

Style 3115
0.5–3.0 MMF
1.0–4.0 MMF

Style 3139
2.0–6.0 MMF

Style 535
0.7–3.0 MMF

Style 3132
1.0–3.8 MMF

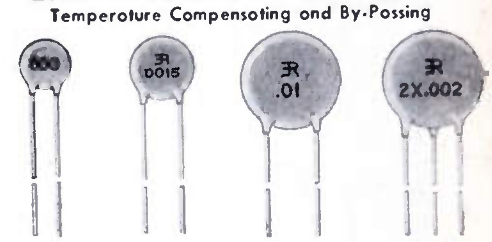
ERIE FEED-THRU CERAMICONS

Style 327, Style 2404, Style 2405, Style 357, Style 362, Style 321, Style 2416, Style 2418

5 MMF—1,000 MMF
5 MMF—1,500 MMF

ERIE DISC CERAMICONS

Temperature Compensating and By-Passing



Style 831, Style 801, Style 811, Style 812

Up to .01 MFD

ERIE STAND-OFF CERAMICONS

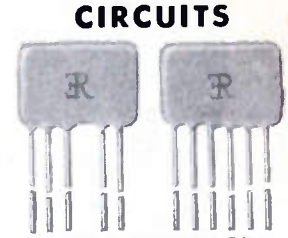
Style 2322, Style 2336, Style 318, Style 319, Style 325, Style 326, Style 323 and 324

5 MMF—5,000 MMF

ERIE BUTTON MICA CONDENSERS

15 MMF—6,000 MMF

ERIE PRINTED CIRCUITS



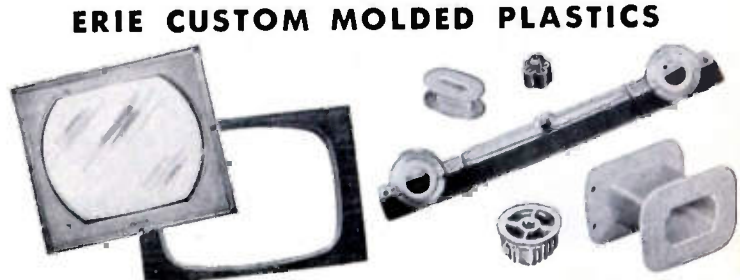
Standard, Integrator, Filter, and Coupling Circuits

ERIE HIGH VOLTAGE CERAMICONS

Style 412, Style 414

10 and 20 KV.—500 MMF

ERIE CUSTOM MOLDED PLASTICS



Custom Injection Molded Plastic Knobs, Dials, Bezels, Name Plates, Coil Forms, etc.

*Ceramicon, Hi-K, GP, and Plexicon are registered trade names of Erie Resistor Corporation.

Electronics Division

ERIE RESISTOR CORP., ERIE, PA.

LONDON, ENGLAND · TORONTO, CANADA

with

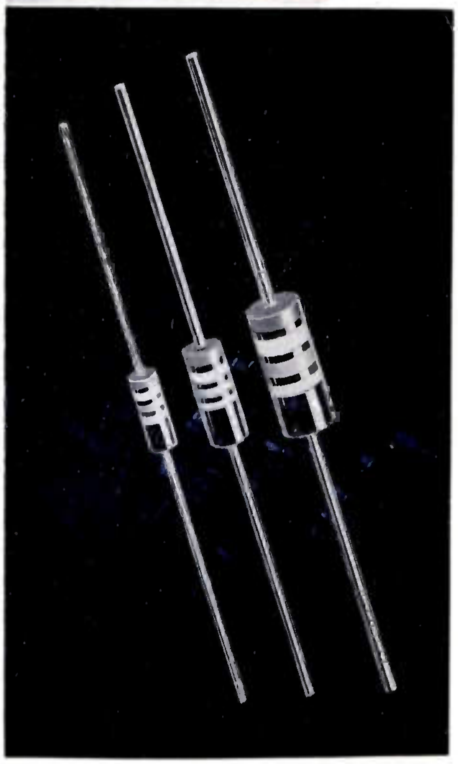
Permanent Characteristics

The solid molded construction gives Bradleyunits a wide safety factor. They are not crowded for performance because they are rated at 70C . . . not at the usual 40C. 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 Bradleyunits require no wax impregnation to pass salt water immersion tests.

Bradleyunits 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.



SIZES OF BRADLEYUNITS

Rating	Length	Diameter
½-w	3/8"	9/64"
1-w	9/16"	7/32"
2-w	11/16"	5/16"

A-B Quality

ALLEN-BRADLEY

FIXED & ADJUSTABLE RADIO RESISTORS

Sold exclusively to manufacturers QUALITY of radio and electronic equipment

TUNG-SOL

5881

AVAILABLE NOW IN QUANTITIES

BEAM POWER AMPLIFIER

for the ultimate in reliability where the 6L6 is called for . .

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 micanol 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.

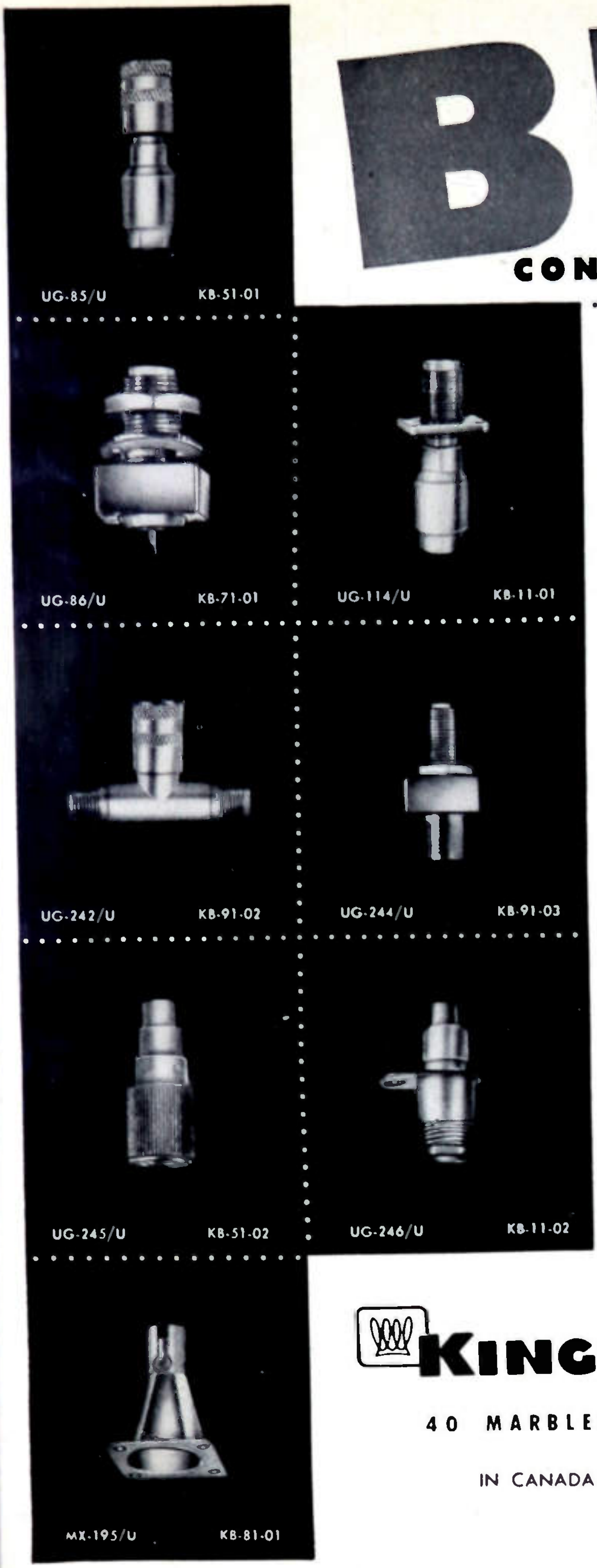
TUNG-SOL ELECTRON TUBES

The TUNG-SOL engineering which has produced the 5881 is constantly at work on a multitude of special electron tube developments for industry. Many exceptionally efficient general and special purpose tubes have resulted. Information about these and other types are available on request to TUNG-SOL Commercial Engineering Department.

TUNG-SOL ELECTRIC INC., NEWARK 4, NEW JERSEY

Sales Offices: Atlanta • Chicago • Culver City (Calif.) • Dallas • Denver • Detroit • Newark

Tung-Sol makes All-Glass Sealed Beam Lamps, Miniature Lamps, Signal Flashers, Picture Tubes, Radio, TV and Special Purpose Electron Tubes.



BN

CONNECTORS BY KINGS

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.

Our fully-staffed engineering department is ready to serve you promptly and skillfully. You'll be glad you called on Kings first.

KINGS Electronics CO., INC.

40 MARBLEDALE ROAD, TUCKAHOE, N. Y.

IN CANADA: ATLAS RADIO CORP., LTD., TORONTO

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 24A)

High-Mu Power Triode

Lewis & Kaufman, Inc., Los Gatos, Calif., announce the type 100TH high-mu power triode. This tube may be used as a Class-AB af power amplifier and modulator, and as a Class-C power amplifier and oscillator.

The filament is thoriated tungsten; voltage, 5.0; current, 6.3 amperes.

The direct interelectrode capacitances are: grid to plate, 2.0 $\mu\mu$f; grid to filament, 2.9 $\mu\mu$f; plate to filament, 0.3 $\mu\mu$f.

Transconductance is 4,500 μmho. The frequency for maximum ratings is 40 mc. A data sheet, available from the firm, on which the tube is illustrated, gives physical dimensions, operating curves, and detailed electrical characteristics.

Plant Expansion

Kepco Laboratories, Inc., 131-38 Sanford Avenue, Flushing 55, N. Y., manufacturers of voltage regulated power supplies and specialized electronic equipment, will house its production, research and development facilities in a new plant, specifically designed to handle the production of electronic equipment for research and industrial needs.

This one story brick and steel building will have modern business offices, and research laboratories, in addition to a large production area.

Noise and Field Intensity Meter

A new model, NF-105, noise and field intensity meter, covering the range from 20 to 400 mc, has been developed by **Empire Devices, Inc.,** 38-25 Bell Blvd., Bayside, L. I., N. Y.

The frequency range is covered by means of two plug-in heads, housing the rf and I.F. circuits. The bandwidth is 70 kc from 20 to 200 mc, and 200 kc from 200 to 400 mc. The range, as a two-terminal rf voltmeter, is 1 to 100,000 microvolts for carrier intensity measurements, and 1 to 100,000 microvolts for noise measurements. The VSWR is below 1.2 to 1. Two calibrating standards are used; a spot-frequency sine-wave generator, and a broad band impulse generator. The im-

(Continued on page 58A)

KOLLSMAN

for products of precision and dependability

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

Today, Kollsman works without pause toward the fulfillment of America's defense needs. And to our nation's research scientists, the skill, ingenuity and creative drive of Kollsman Research Laboratories are available for the solution of instrumentation and control problems.

KOLLSMAN INSTRUMENT CORPORATION

ELMHURST, NEW YORK — GLENDALE, CALIFORNIA

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ASSOCIATED ILIFFE PUBLICATIONS

Up-to-date news of every British development

WIRELESS WORLD. Britain's chief technical magazine in the general field of radio, television and electronics. Founded over 40 years ago, it provides a complete and accurate survey of the newest British techniques in design and manufacture. Articles of a high standard cover every phase of radio and allied technical practice, with news items on the wider aspects of international radio. Theoretical articles by recognised experts deal with new developments, while design data and circuits for every application are published. Wireless World is indispensable to technicians of all grades and is read in all parts of the world.

Published monthly, $4.50 *a year.*

WIRELESS ENGINEER—the magazine of radio research and progress—is produced for research engineers, designers and students in the fields of radio, television and electronics. Its editorial policy is to publish only original work, and its highly specialized content is accepted as the authoritative source of information for advanced workers everywhere. The magazine's Editorial Advisory Board contains representatives of the National Physical Laboratory, the British Broadcasting Corporation, and the British Post Office. Regular features include an Abstracts and References Section compiled by the Radio Research Organization of the Department of Scientific and Industrial Research.

Published monthly, $7.00 *a year.*

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Speech Reinforcement in Reverberant Auditoria: Use of Time Delays and Line-source Loudspeakers. Magnetic Recording: Mechanism of Asymmetrical Hysteresis. Valve Voltmeter without Calibration Drift: "Infinite-input, Zero-output-resistance" Adaptor for D.C. Voltmeters.

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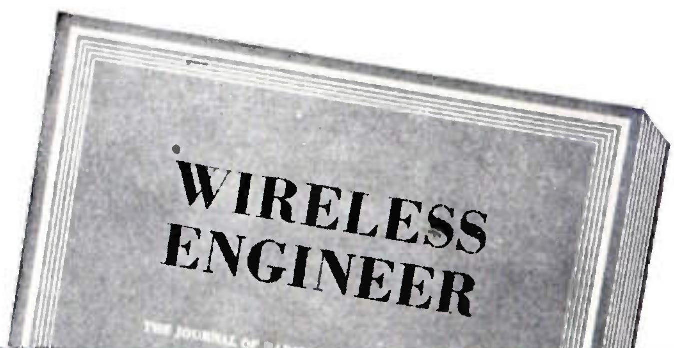

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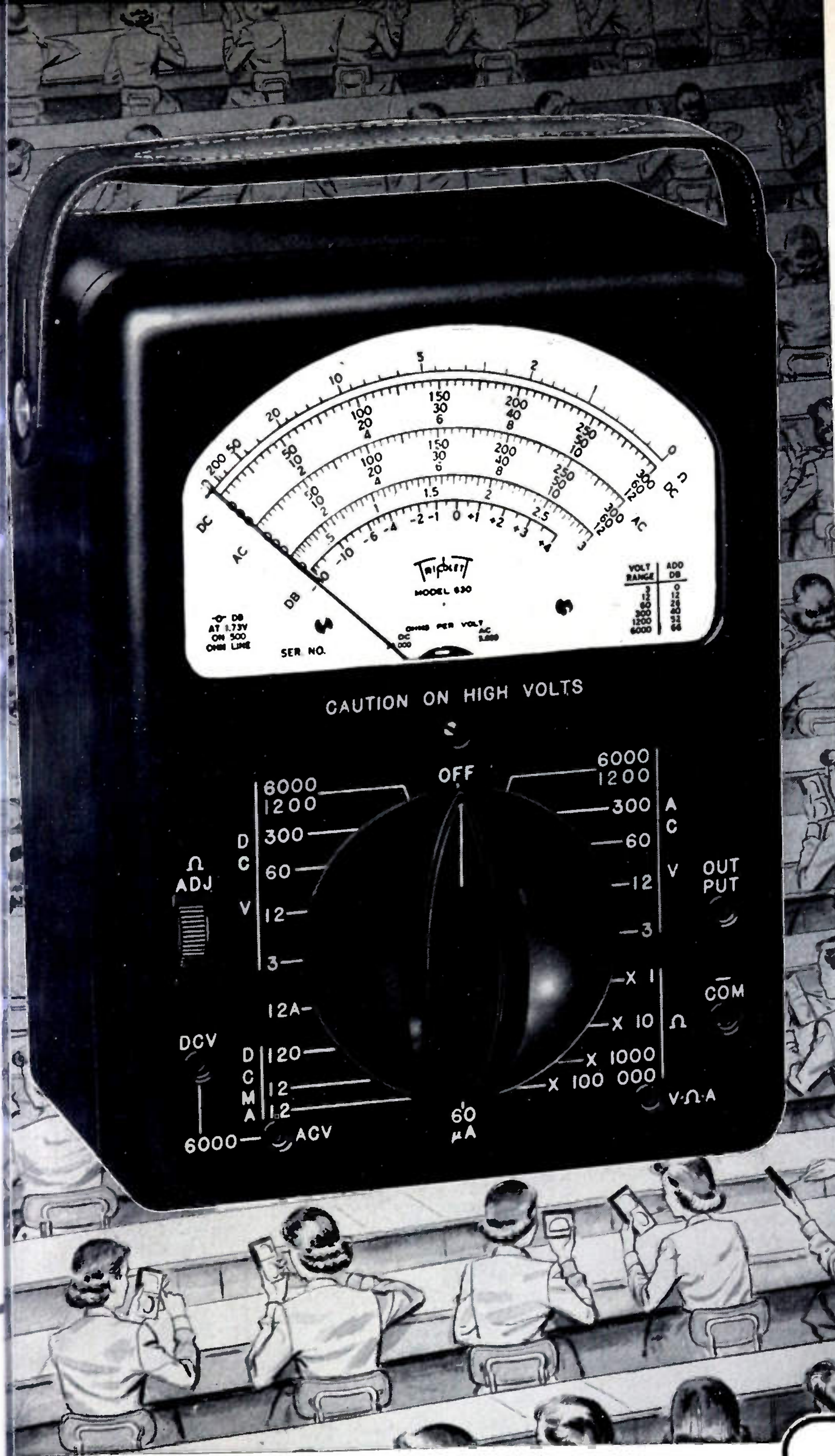

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by R. L. Triplett
PRESIDENT

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 dependence 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: 3-12-60-300-1200-6000 (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 "Triplett" stand for better construction and more service for your test equipment dollar.

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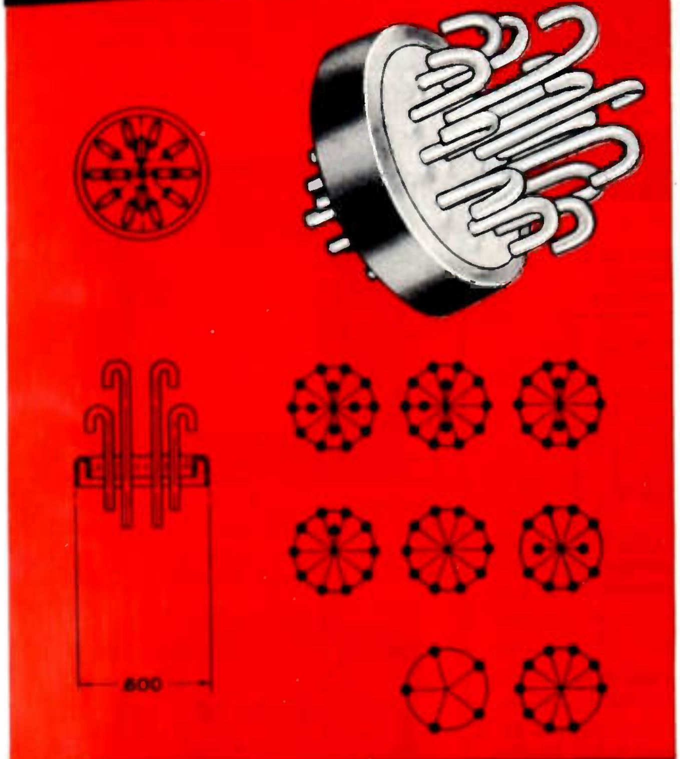
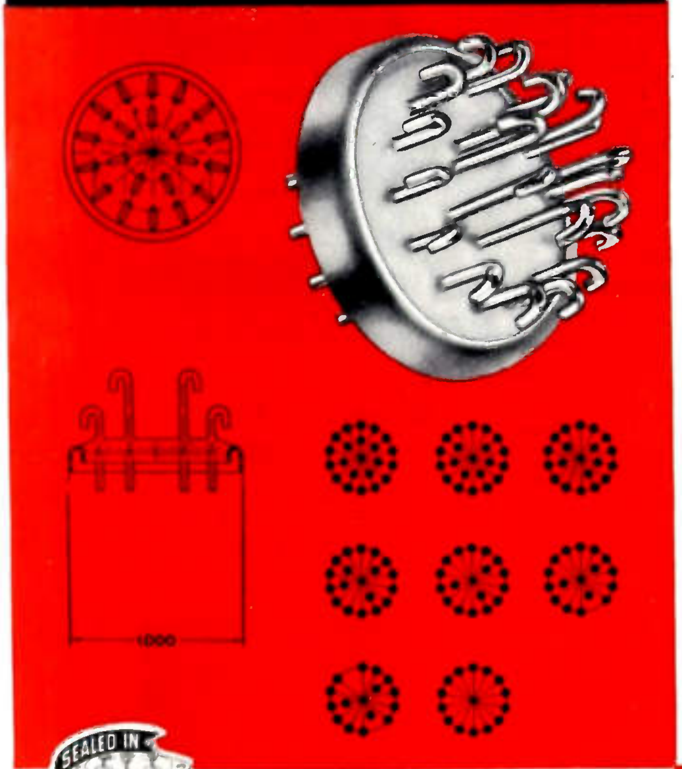
HERMETIC Leads the Field in its Miniaturization Program



Terminals and Headers are Available in RMA Color Code.



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 und 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 megohms.

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Submit your own problems in this highly exacting field to our specialist-engineers. They are eager to be of help. Write for your copy of our new 32-page brochure, the most complete and informative presentation ever made on hermetic seals.

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News—New Products

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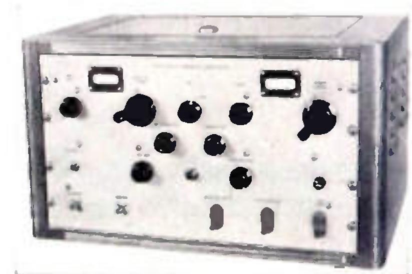
(Continued from page 52A)

pulse generator, whose output can be made externally, produces pulses 5×10^{10} seconds wide (0.0005). The pulse spectrum is flat to 1,000 mc within ±0.5 db.

UHF Sweep-Marker Generator

Tube Dept., Radio Corp. of America, 415 S. Fifth St., Harrison, N. J., has two new uhf sweep generators, the WR-40A and the WR-41A. Both instruments feature continuous tuning from 470 to 890 mc and operate entirely on fundamental frequencies; no beat notes or harmonics are used. They have a continuously variable sweep width from 0 to 45 mc with an amplitude variation of 0.1 db per mc or less throughout the swept range. The maximum output level of the sweep oscillator is 0.5 volt across a 50-ohm load. Facilities are also provided for matching to either a 72- or a 300-ohm load.

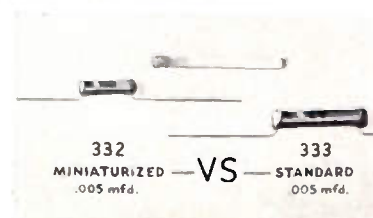


This instrument has a built-in crystal calibrator and variable-frequency-marker oscillator. Both the sweep-frequency oscillator and the variable-frequency-marker oscillator employ an RCA-5675 pencil triode.

The WR-41A has the same sweep-generator mechanism used in the WR-40A but does not include the laboratory-type calibrator or marker circuit. This instrument is most useful in factory operations.

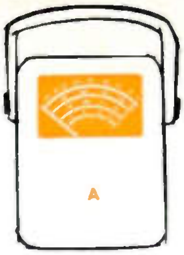
Miniature Tubular Ceramic Capacitors

A new line of miniaturized ceramic capacitors, under the trade name "GP3 Ceramicons," is announced by **Erie Resistor Corp.**, Erie, Pa.



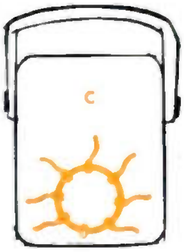
These capacitors employ a high dielectric-constant ceramic material especially developed by Erie. With this material, capacitance values as high as 0.002 ufd are available on a basic $\frac{1}{8}\times\frac{3}{8}$ inch long

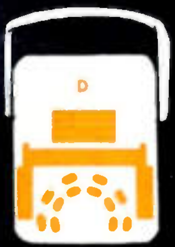
(Continued on page 60A)

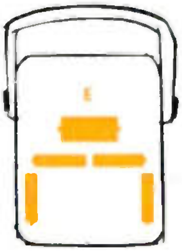


THE SIMPSON MODEL 260 VOLT-OHM-MILLIAMMETER OUTSELLS ALL OTHERS COMBINED BECAUSE

- 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 Instruments That Stay Accurate Are Available From All Leading Electronic Distributors

SIMPSON ELECTRIC COMPANY
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In Canada: Bach-Simpson, Ltd., London, Ont.

News—New Products

These manufacturers have invited PROCEEDINGS readers to write for literature and further technical information. Please mention your I.R.E. affiliation.

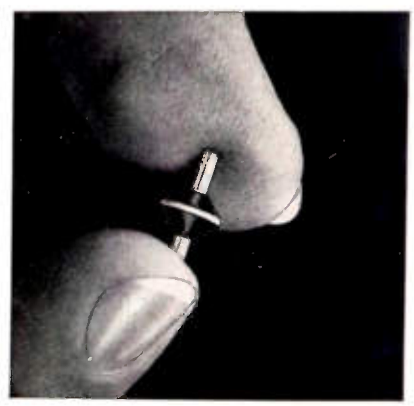
(Continued from page 58A)

tube, and 0.005 ufd on a $\frac{1}{8}\times\frac{5}{8}$ inch long tube. These GP3 Ceramicons 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 Ceramicons 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

The "Shirt-stud" capacitor, a new design for coupling circuits in TV receivers and other electronic equipment, is the latest product of the **Sprague Electric Co.**, North Adams, Mass.



Known as Type 502C, this $\frac{1}{4}$-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 $\mu\mu$f at 500 volts dc working. Performance characteristics are similar to

(Continued on page 62A)

See New IRE Directory Questionnaire
Pages 131-3A

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 62A)

those of Sprague *Cera-Mite* disk capacitors. Complete engineering information is available in Engineering Bulletin 605 available on letterhead request only.

Laboratory Amplifier

A new relay-rack Type 221-A Laboratory Amplifier which features extended frequency response, high power output, and negligible hum and distortion has been developed by **Hermon Hosmer Scott, Inc.**, 385 Putnam Ave., Cambridge 39, Mass. Inexpensively priced, the unit is a versatile electronic tool for industrial and scientific laboratories.

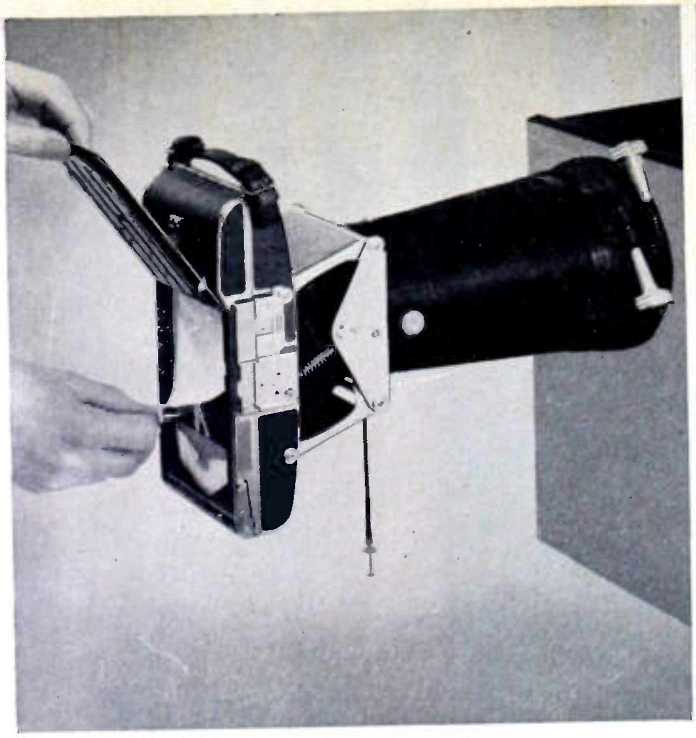
Specifications are: Rated power output, 20 watts; frequency response flat from 12,000 to 55,000 cps; first-order difference-tone intermodulation component less than 0.1 per cent at full rated peak output; harmonic distortion less than 0.5 per cent at full 20 watts output; hum level—90 db below full output; input for full rated 20 watt output, 0.5 volt on low level input, 1.5 volts on high level input; input impedance 0.5 megohm for low level input, 1.5 megohms for high level input. Free bulletin on reauest.

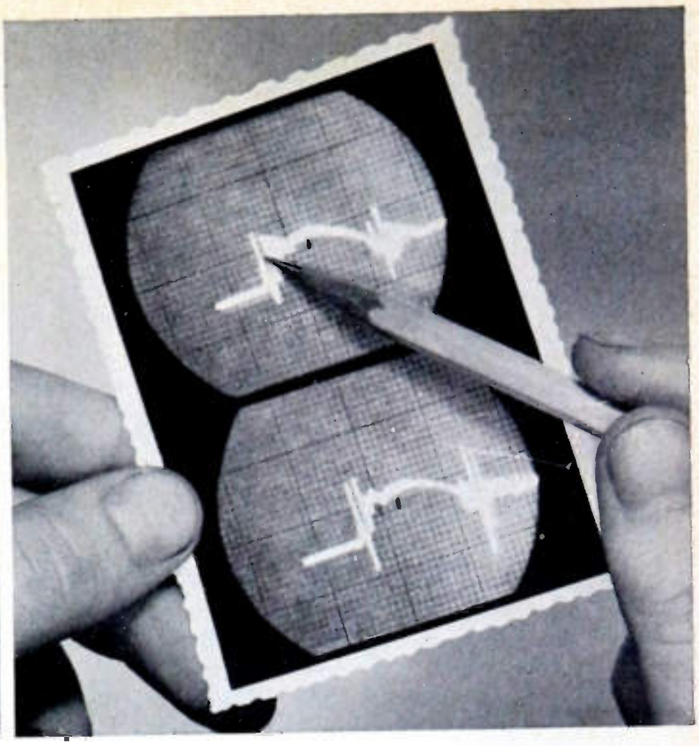
Miniature Power Resistors

Miniature power resistors are now available in two, five, and ten watt sizes from **Dale Products, Inc.**, Columbus, Neb. The 2-, 5-, and 10-watt sizes (like the 25- and 50- made by Dale) offer completely welded construction from terminal to terminal for trouble free performance. A special silicone material seals the resistance element, making it impervious to moisture.

The Dalohm's standard tolerance is 1 per cent, but tolerances as high as 0.05 per cent can be furnished if necessary. The temperature co-efficient is practically flat. The resistance shift is less than 0.00002 per cent per degree centigrade. New illustrated price sheets are available on request.

(Continued on page 110A)





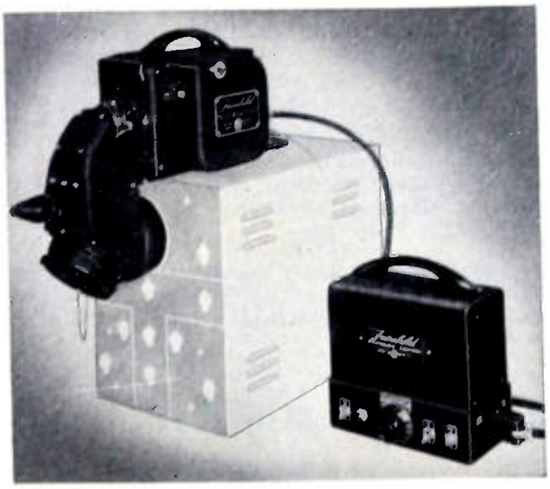
EASY TO TAKE...EASY TO READ

with the Fairchild-Polaroid® Oscilloscope Camera

ELECTRONIC CONTROL GIVES INFINITE SPEED VARIATION

with the Fairchild Oscillo-Record Camera

For both still and continuous-motion recording on 35-mm film or paper, the Fairchild Oscillo-Record Camera is ideal. Continuously variable speed control is provided through electronic regulation. There are no belts or pulleys. Film is sprocket-driven so there is no slippage. Top-of-scope mounting eliminates need for tripod and keeps scope controls easily accessible. There is provision for three film lengths—100, 400, or 1000 feet.



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 3¼ x 4¼ 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.*

FAIRCHILD
OSCILLOSCOPE RECORDING CAMERAS

VHF-TV-UHF

RCA-6166

RCA-6166

(Typical Operation in Class B or Grid-Modulated Class C Television Service, Grid-Drive Circuit, 54 to 216 Mc)

DC Plate Voltage	5800 volts
DC Grid-No. 2 Voltage	1200 volts
DC Grid-No. 1 Voltage*	—130 volts
Peak RF Grid-No. 1 Voltage	375 volts
DC Plate Current*	3.45 amp
Driver Power Output (Approx.)*	800 watts
Power Output (Approx.)*	12,000 watts

RCA-6181

(Typical Operation in Class B or Bias-Modulated Class C Television Service, Cathode-Drive Circuit at 900 Mc)

DC Plate Voltage	1800 volts
DC Grid-No. 2 Voltage	475 volts
DC Cathode-to-Grid-No. 1 Voltage*	75 volts
Peak RF Grid-No. 1 Voltage	120 volts
DC Plate Current*	1.7 amp
Driver Power Output (Approx.)*	200 watts
Useful Power Output (Approx.)*	1200 watts

*At synchronizing level

RCA-6181

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-proved 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 . . .

FIELD OFFICES: (East) Humboldt 5-3900, 415 S. 5th St., Harrison, N. J. (Midwest) Whitehall 4-2900, 589 E. Illinois St., Chicago, Ill. (West) Madison 9-3671, 420 S. San Pedro St., Los Angeles, Calif.

RADIO CORPORATION of AMERICA

ELECTRON TUBES — **HARRISON, N. J.**

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PROCEEDINGS OF THE I.R.E.

Published Monthly by

The Institute of Radio Engineers, Inc.

VOLUME 40 — *April, 1952* — NUMBER 4

PROCEEDINGS OF THE I.R.E.

INSTITUTE NEWS AND RADIO NOTES

Alois W. Graf

DIRECTOR, 1952–1953

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.

(1) A. W. Rogers and B. A. Diebold, "Improved components and materials for reliable electronic equipment," *Elec. Mfg.*, vol. 48, pp. 114–119; December, 1951.
(2) G. E. Devey, "Reliable electronic equipment," *Elec. Mfg.*, vol. 48, pp. 107–109, 216; January, 1951.
(3) "Application of Tubes in Guided Missiles for Maximum Reliability," Symposium, Panel on Electron Tubes, Research and Development Board, 139 Center Street, New York, N. Y.
(4) A. E. Javitz, "Cast resin embedments," *Elec. Mfg.*, vol. 48, pp. 103–118; September, 1951.

* Decimal classification: R090.1. Original manuscript received by the Institute, February 7, 1952. This report is based on material from the 1951 Annual Review Committee of The Institute of Radio Engineers, as co-ordinated by the Chairman.

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

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.

(5) R. M. Cohen, "Use of low-noise twin triode in television tuners," *RCA Rev.*, vol. 12, pp. 3–25; March, 1951.

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.

(6) G. T. Ford and E. J. Walsh, "The development of electron tubes for a new coaxial transmission system," *Bell Sys. Tech. Jour.*, vol. 30, pp. 1103–1128; October, 1951.

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.

(7) L. A. Veazie, "The Key West-Havana cable: an electron tube for submarine repeaters," *Bell Lab. Rec.*, vol. 29, pp. 449–451; October, 1951.

Two new contact or relay tubes utilizing secondary emission and a central grid were described: one, the unilateral contact type, the other bilateral. The advantages are high operating speeds, absence of phase shift, and trouble-free contacts. Contact resistance in the bilateral type is reduced to about 1,000 ohms.

(8) J. L. H. Jonker and Z. Van Gilder, "New electronic tubes employed as switches in communication engineering," *Philips Tech. Rev.*, vol. 13, pp. 49–54; September, 1951.

Previously experienced difficulties with the life of secondary-emission tubes can be overcome by employing a layer of cesium oxide, kept at a temperature less than 180 degrees centigrade. Characteristics and constructions of several types, including a high-mutual-conductance tube with four stages of multiplication and a variable mu-tube, were described. The use of grid-shaped secondary-emission electrodes enhances performances. Several circuits using such tubes were also described.

(9) A. J. W. M. Van Overbeek, "Voltage-controlled secondary emission multipliers," *Wireless Eng.*, vol. 28, pp. 114–125; April, 1951.

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

(10) G. Wehner, "Electron plasma oscillations," *Jour. Appl. Phys.*, vol. 22, pp. 761–765; June, 1951.

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.

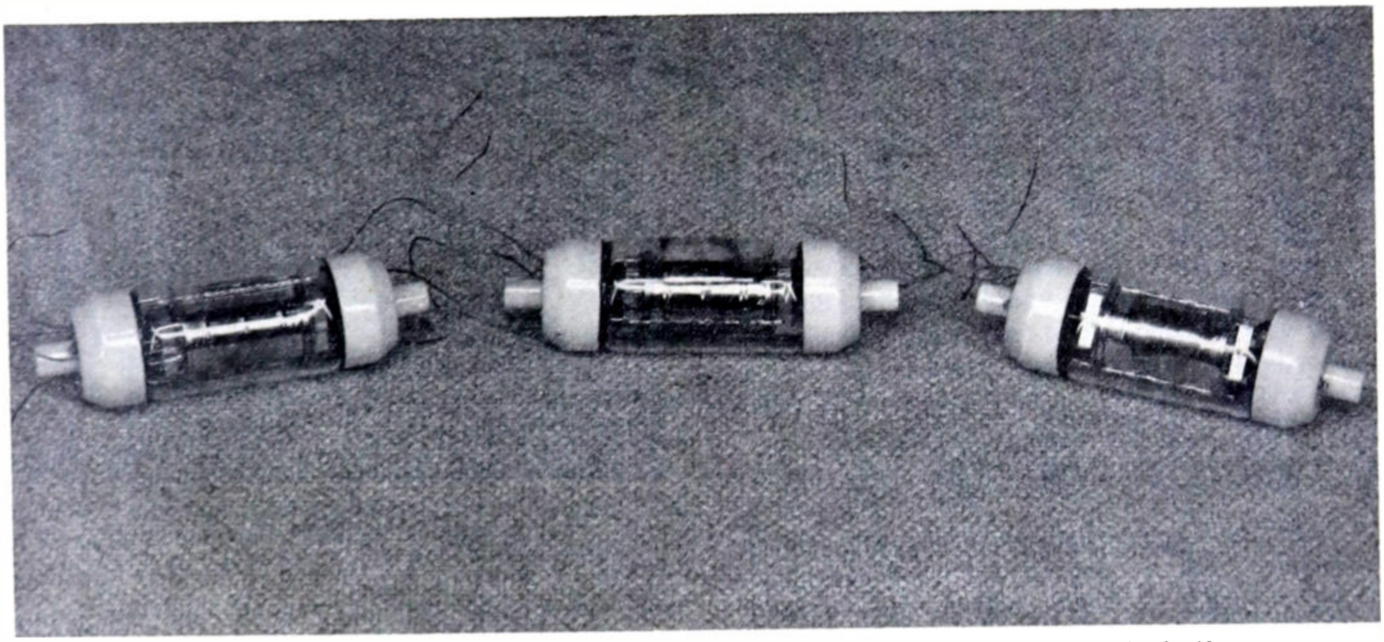

Fig. 1—Electron tubes developed at Bell Telephone Laboratories for use in submerged repeaters in the Key West-Havana submarine cable.

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.

(11) G. Diemer, "Passive feedback admittance of disc-seal triodes," *Philips Res. Rep.*, vol. 5, pp. 423–434; December, 1950.
(12) E. E. Zepler, "Valve input conductance at V.H.F.," *Wireless Eng.*, vol. 28, pp. 51–53; February, 1951.

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 experimental data were compared with theoretical calculations.

A transit-time theory was developed for the conductance 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 conductance at low negative voltages may exceed the total emission conductance even in the microwave band.

(13) E. E. Zepler and S. S. Srivastava, "Interelectrode impedances in triodes and pentodes," *Wireless Eng.*, vol. 28, pp. 146–150; May, 1951.
(14) G. Diemer, "Microwave diode conductance in the exponential region of the characteristic," *Philips Res. Rep.*, vol. 6, pp. 211–223; June, 1951.

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.

(15) J. L. H. Jonker, "The internal resistance of a pentode," *Philips Res. Rep.*, vol. 6, pp. 1–13; February, 1951.
(16) P. H. J. A. Kleijnen, "The penetration factor and the potential field of a planar triode," *Philips Res. Rep.*, vol. 6, pp. 15–33; February, 1951.

In one analysis, the small-signal behavior of a negatively biased triode was represented as a π configuration for convenience in analyzing complex circuitry 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.

(17) A. W. Keen, "Triode transmission networks," *Wireless Eng.*, vol. 28, pp. 56–66; February, 1951.

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.

(18) J. Arnold, "Electronic tracing of tube characteristics," *Sylvania Tech.*, vol. 4, pp. 14–17; January, 1951.

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.

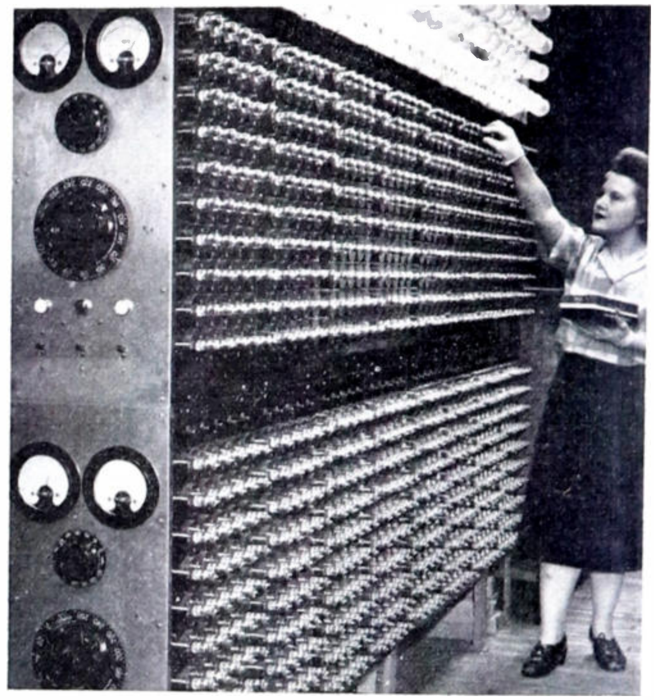

Fig. 2—Reliable tubes are electrically life-tested on new 48-hour stabilization equipment installed at the tube-manufacturing plant in Harrison, N. J. (RCA).

(19) M. A. Acheson and E. M. McElwee, "Concerning the reliability of electron tubes," *Sylvania Tech.*, vol. 4, pp. 38–40; April, 1951.
(20) J. R. Steen, "The JETEC approach to the tube reliability problem," Proc. I.R.E., vol. 39, pp. 998–1000; September, 1951.
(21) P. T. Weeks, "Reliability in miniature and subminiature tubes," Proc. I.R.E., vol. 39, pp. 499–503; May, 1951.
(22) E. M. McElwee, "Statistical evaluation of life expectancy of vacuum tubes designed for long-life operation," Proc. I.R.E., vol. 39, pp. 137–141; February, 1951.
(23) G. Gage, "High reliability miniature tubes," *Electronics*, vol. 23, pp. 66–68; December, 1950.
(24) J. D. Fahnestock, "Military requirements for subminiature tubes," *Electronics*, vol. 24, pp. 108–109; April, 1951.

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 almostly indefinitely long were it not for the formation of cathode-interface resistance.

(25) D. R. Hill, "New cathode design improves tube reliability," *Electronics*, vol. 24, pp. 104–106; August, 1951.
(26) C. C. Eaglesfield, "Life of valves with oxide-coated cathodes," *Elec. Commun.* (London), vol. 28, pp. 95–102; June, 1951.

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.

(27) A. M. Bounds and T. H. Briggs, "Nickel alloys for oxide-coated cathodes," PROC. I.R.E., vol. 39, pp. 788–799; July, 1951.
(28) S. Nevin and H. Salinger, "Secondary-emitting surfaces in the presence of oxide-coated cathodes," PROC. I.R.E., vol. 39, pp. 191–193; February, 1951; see also, *Elec. Commun.* (London), vol. 28, pp. 103–105; June, 1951.

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.

(29) H. A. Stahl, "On poisoning of oxide cathodes by atmospheric sulphur," PROC. I.R.E., vol. 39, p. 193; February, 1951.

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.

(30) R. M. Matheson and L. S. Nergaard, "High-speed ten-volt effect," *RCA Rev.*, vol. 12, pp. 258–268; June, 1951.

Klystrons: 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.

(31) H. M. Crosby, "5 kw. klystron UHF television transmitter," *Electronics*, vol. 24, pp. 108–112; June, 1951.
(32) Engineering Staff of Varian Associates, "High-power UHF-TV klystron," *Electronics*, vol. 24, pp. 117–119; October, 1951.

Traveling-Wave Tubes

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.

(33) P. Parzen, "Theory of space-charge waves in cylindrical waveguides with many beams," *Elec. Commun.* (London), vol. 28, pp. 217–219; September, 1951.
(34) P. Parzen and L. Goldstein, "Effect of hydrostatic pressure in an electron beam on the operation of traveling-wave devices," *Jour. Appl. Phys.*, vol. 22, pp. 398–401; April, 1951; see also, *Elec. Commun.* (London), vol. 28, pp. 228–232; September, 1951.
(35) J. R. Pierce, "Waves in electron streams and circuits," *Bell Sys. Tech. Jour.*, vol. 30, pp. 626–651; July, 1951.

Gain, noise factor, and attenuation in conventional traveling-wave tubes were investigated. A dispersive travelling-wave tube was described and experimental results given. It was shown that with useful gain at 3,000 mc a noise figure of no more than 11 decibels can be attained. The essential information for the calculation of traveling-wave-tube gain was given, and the accuracy of the information verified by experimental measurements.

(36) B. Friedman, "Amplification of the traveling-wave tube," *Jour. Appl. Phys.*, vol. 22, pp. 443–447; April, 1951.
(37) F. N. Robinson and R. Kompfner, "Noise in traveling-wave tubes," PROC. I.R.E., vol. 39, pp. 918–926; August, 1951.
(38) C. C. Cutler, "The calculation of traveling-wave-tube gain," PROC. I.R.E., vol. 39, pp. 914–917; August, 1951.

Miniature broad-band amplifier tubes operating at frequencies of 100 and 1,000 mc were described. Operating voltages and currents are no greater than those required for other small tubes.

(39) R. Adler, "Miniature traveling wave tube," *Electronics*, vol. 24, pp. 110–113; October, 1951.

Theoretical and experimental studies were made of a single-corrugated waveguide as used in a medium-power traveling-wave amplifier. A medium-power traveling-wave tube was described having 20-decibel gain with 10-watts power output operating over the frequency range 4,400–5,000 mc. The tube uses waveguide input and output circuits, and has a useful bandwidth of about 1,000 mc.

(40) G. C. Dewey, P. Parzen, and T. J. Marchese, "Periodic waveguide traveling-wave amplifier for medium powers," PROC. I.R.E., vol. 39, pp. 153–159; February, 1951; see also, *Elec. Commun.* (London), vol. 28, pp. 220–227; September, 1951.
(41) J. H. Bryant, "Medium-power traveling-wave tube type 5929," *Elec. Commun.* (London), vol. 27, pp. 277–279; December, 1950.

Traveling-wave tubes operating at 6 mm were described. One such tube has a helix wound with 0.003-inch wire on a 0.020-inch mandrel, and operates at 1,000 volts with a beam current of 1 ma. This tube has a measured gain between 1.3 and 3.8 decibels between 6.1 and 6.4 mm. The present methods of generating millimeter waves were reviewed, and new techniques suggested.

(42) J. B. Little, "Amplification at 6 mm. wavelength," *Bell Lab. Rec.*, vol. 29, pp. 14–17; January, 1951.
(43) J. D. Fahnestock, "Amplification at 50,000 megacycles," *Electronics*, vol. 24, pp. 140–141; April, 1951.
(44) J. R. Pierce, "Millimeter waves," *Electronics*, vol. 24, pp. 67–69; January, 1951.

A general study of noise in electron beams was made, with special attention given to the problem of noise in traveling-wave tubes.

(45) C. C. Cutler and C. F. Quate, "Experimental verification of space charge and transit time reduction of noise in electron beams," *Phys. Rev.*, vol. 80, pp. 875–878; December, 1950.

Gas-filled Tubes

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. Combining 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 "plasmatron," 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.

(46) "Gas discharge tubes," *Wireless World*, vol. 57, pp. 293–294; July, 1951.
(47) E. O. Johnson, "Controllable gas diode," *Electronics*, vol. 24, pp. 107–109; May, 1951.

Design Factors for Gas Tubes: Design features were applied to a 12.5-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.

(48) A. W. Coolidge, "A high current thyratron," *Elec. Eng.*, vol. 70, pp. 698-699; August, 1951.

The pumpless ignitron 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.

(49) C. C. Herskind and E. J. Remscheid, "Development of a pumpless ignitron," *Elec. Eng.*, vol. 70, pp. 855–858; October, 1951.

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 thyratrons."

(50) L. Malter and M. R. Boyd, "Grid current and grid emission studies in thyratrons—the trigger grid thyratron," PROC. I.R.E., vol. 39, pp. 636–642; June, 1951.

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.

(51) L. Malter, E. O. Johnson, and W. M. Webster, "Studies of externally heated hot cathode arcs," *RCA Rev.*, vol. 12, p. 415; September, 1951.

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^{10} electrons per cc in gases whose pressure may be varied over a wide range.

(52) M. A. Biondi, "Measurement of the electron density in ionized gases by microwave techniques," *Rev. Sci. Instr.*, vol. 22, p. 500; July, 1951.

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.

(53) S. W. Lichtman, "High-voltage stabilization by means of the corona discharge between coaxial cylinders," PROC. I.R.E., vol. 39, pp. 419–424; April, 1951.

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.

(54) W. W. Mumford, "A microwave noise source," *Bell Lab. Rec.*, vol. 29, pp. 116–120; February, 1951.
K. S. Knol, "Determination of the electron temperature in gas discharges by noise measurements," *Philips Res. Rep.*, vol. 6, pp. 288–302; August, 1951.

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

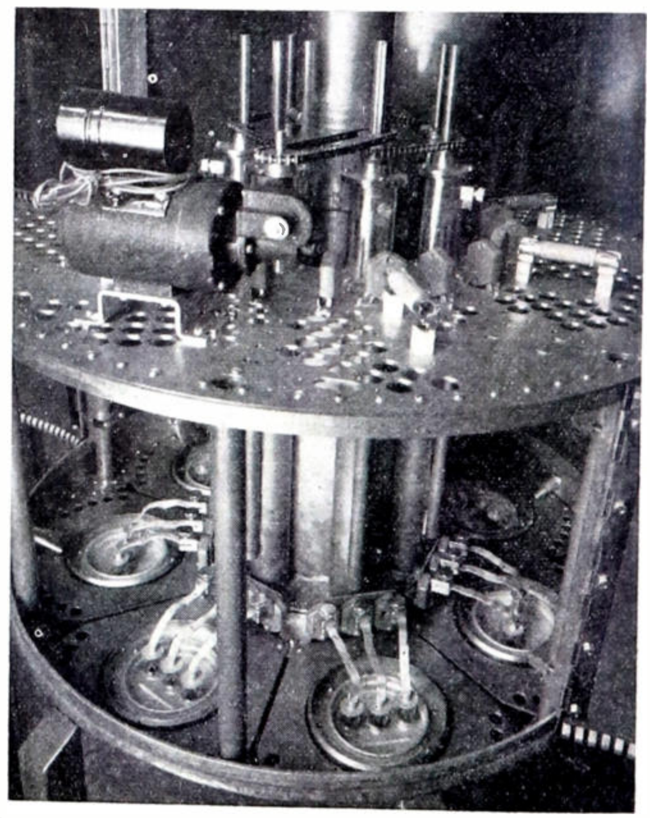

Fig. 3—Amplifier for 20-kw air-cooled transmitter for vhf, showing cluster of 5762 triodes in the output stage. Grounded-grid circuits are used (RCA).

was reviewed and a new mathematical formulation given for oscillations in "irrotational" streams. The most important targets for research were pointed out.

(55) D. Gabor, "Plasma oscillations," *Brit. Jour. Appl. Phys.*, vol. 2, pp. 209–218; August, 1951.

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

(56) K. W. Hess, "Measuring the deionization time of gas-filled diodes and triodes," *Philips Tech. Rev.*, vol. 12, pp. 178–184; December, 1950.

High-Frequency Tubes

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.

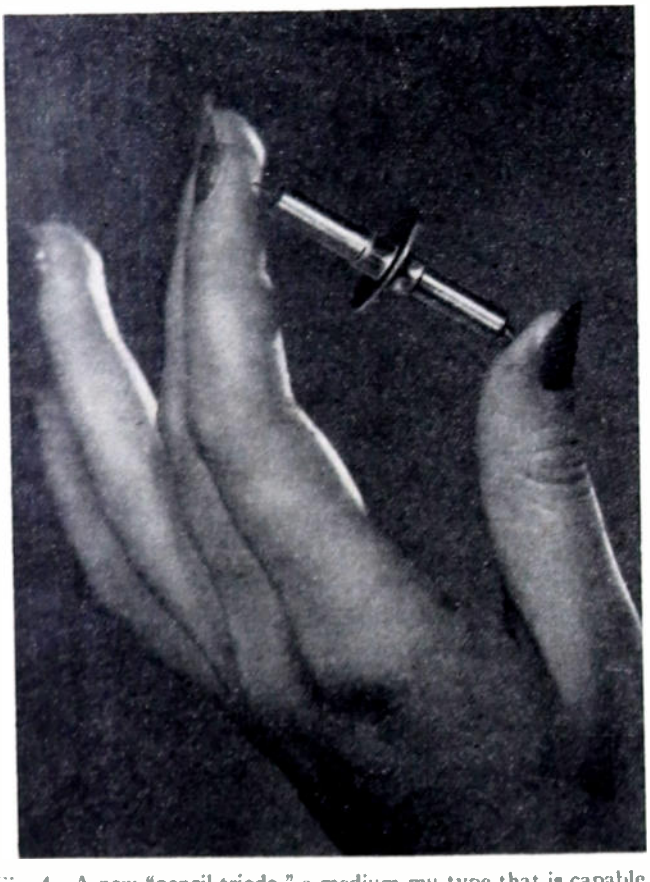

Fig. 4—A new "pencil triode," a medium-mu type that is capable of producing peak output of more than 1,000 watts in plate-pulsed service at frequencies up to 3,300 mc (RCA).

(57) A. M. Hardie, "Pulse technique in high-power valve development," *Metrop. Vick. Gaz.*, vol. 23, pp. 350–360; April, 1951.
(58) H. M. Wagner, "Tube characteristic tracer using pulse techniques," *Electronics*, vol. 24, pp. 110–114; April, 1951.
(59) E. E. Spitzer, "Principles of the electrical rating of high-vacuum power tubes," PROC. I.R.E., vol. 39, pp. 60–69; January, 1951.
(60) Abd El-Samie Mostafa, "Electron tube performance with large applied voltages," PROC. I.R.E., vol. 39, pp. 70–73; January, 1951.

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.

(61) C. E. Fay, D. A. S. Hale, and R. J. Kircher, "A 1.5 kw. 500 mc. grounded-grid triode," PROC. I.R.E., vol. 39, pp. 800–803; July, 1951.
(62) E. G. Dorgelo and P. Zijlstra, "Two transmitting valves for use in mobile installations," *Philips Tech. Rev.*, vol. 12, pp. 157–165; December, 1950.

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.

(63) C. Beurtheret, "Cooling of electron tubes by vaporization of water," *Onde Elect.*, vol. 31, pp. 271–276; June, 1951.
(64) B. O. Buckland, "Electron-tube heat-transfer data," *Elec. Eng.*, vol. 70, pp. 962–966; November, 1951.

Magnetrons

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

(65) G. A. Boutry and J. L. Delcroix, "The space-charge in a magnetron under static cut-off conditions: planar or quasiplanar magnetron," *Compt. Rend.* (Paris), vol. 232, pp. 1413–1415; April 9, 1951.
(66) J. L. Delcroix and G. A. Boutry, "The space-charge in a magnetron under static cut-off conditions: cylindrical magnetron," *Compt. Rend.* (Paris), vol. 232, pp. 1653–1655; April 30, 1951.
(67) D. L. Reverdin, "Electron optical exploration of space-charge in a cut-off magnetron," *Jour. Appl. Phys.*, vol. 22, pp. 257–262; March, 1951.
(68) H. W. Welch, Jr., "Effects of space charge on frequency characteristics of magnetrons," PROC. I.R.E., vol. 38, pp. 1434–1449; December, 1950.
(69) H. W. Welch, Jr. and W. G. Dow, "Analysis of synchronous conditions in the cylindrical magnetron space-charge," *Jour. Appl. Phys.*, vol. 22, pp. 433–438; April, 1951.

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.

(70) A. W. Aikin, "A mode-separation theory for heavily-strapped magnetrons," *Brit. Res. Rep.*, Ref. 12/51. (*Science Abstracts* B, vol. 54, p. 515, 3864; 1951.)
(71) H. J. Reich, J. C. May, J. G. Skalnik, and R. L. Ungvary, "Some aspects of split-anode magnetron operation," PROC. I.R.E., vol. 38, pp. 1428–1433; December, 1950.

Application of magnetrons for dielectric heating was described.

(72) R. B. Nelson, "Magnetrons for dielectric heating," *Elec. Eng.*, vol. 70, pp. 627–633; July, 1951.

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.

(73) G. A. Espersen and B. Arfin, "Low-voltage tunable X-band magnetron development," *Tele-Tech*, vol. 10, pp. 50–51; June, 1951; and pp. 30–31; July, 1951.
(74) A. W. Aikin, "Magnetron design. The hole and slot resonator," *Brit. Res. Rep.*, Ref. 11/51. (*Science Abstracts* B, vol. 54, p. 515, 3865; 1951.)
(75) R. Svensson, "Experimental investigation of the electron orbits in a magnetron," PROC. I.R.E., vol. 39, p. 838; July, 1951.

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.

(76) W. Shockley, "Electrons and holes in semiconductors," D. Van Nostrand Co., Inc., New York, N. Y.; 1950.
(77) R. Breckinridge, "Solid state electronics," *Phys. Today*, vol. 4, p. 6; September, 1951.
(78) H. K. Henisch (ed.), "Semiconducting Materials," Academic Press, New York, N. Y.; 1951.
(79) T. R. Scott, "Crystal triodes," *Elec Commun.* (London), vol. 28, pp. 195–208; September, 1951.

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

(80) F. R. Stansel, "The characteristics and some applications of varistors," PROC. I.R.E., vol. 39, pp. 342–358; April, 1951.

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 conditions, the following performance figures are separately attainable: gain up to 45 decibels or more per stage; frequency response up to a few megacycles; noise figure better than 15 decibels at one kc; operation, with reduced gain, at biases of a few tenths of a volt and a few microamperes; power output class A up to 50 mw, and class C to over one watt.

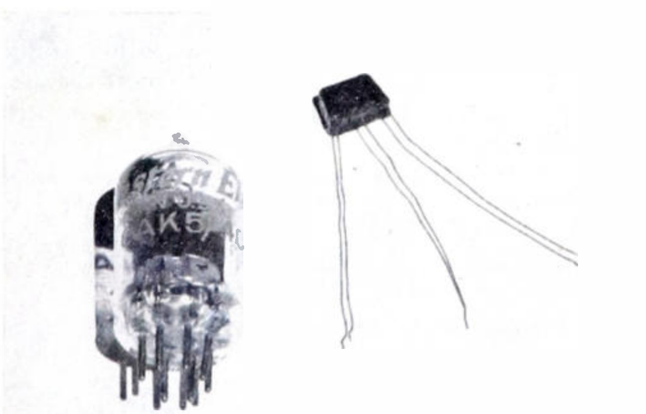

Fig. 5—The spidery object (right) is the newest type of transistor invented at Bell Telephone Laboratories. For size comparison, it is shown with a miniature commercial vacuum tube which does about the same job.

(81) R. L. Wallace, Jr. and W. J. Pietenpol, "Some circuit properties and applications of *n-p-n* transistors," PROC. I.R.E., vol. 39, pp. 753–767; July, 1951. Also published in *Bell Sys. Tech. Jour.*, vol. 30, pp. 530–563; July, 1951.
(82) W. Shockley, M. Sparks, and G. K. Teal, "*P-n* junction transistors," *Phys. Rev.*, vol. 83, pp. 151–162; July 1, 1951.

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 photocells. Their performance follows theory closely.

(83) R. N. Hall and W. C. Dunlap, "*P-n* junctions prepared by impurity diffusion," *Phys. Rev.*, vol. 80, p. 467; November 1, 1950.
(84) W. J. Pietenpol, "*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.

(85) B. J. Rothlein, "A new high-conductance crystal diode," *Sylvania Tech.*, vol. 4, p. 44; April, 1951.
(86) B. J. Rothlein, "A photovoltaic germanium cell," *Sylvania Tech.*, vol. 4, p. 86; October 1951.
(87) F. A. Stahl, "Germanium trigger photocells," *Elec. Eng.*, vol. 70, pp. 518–520; June, 1951.

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.

(88) K. Lehovec, "Recovery of selenium rectifiers after a voltage pulse in the blocking direction," *Jour. Appl. Phys.*, vol. 22, pp. 934–939; July, 1951.

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.

(89) L. P. Hunter, "Inverse voltage characteristic of a point contact on *n*-type germanium," *Phys. Rev.*, vol. 81, pp. 151–152; January 1, 1951.
(90) A. I. Bennett and L. P. Hunter, "Pulse measurement of the inverse voltage characteristic of germanium point contacts," *Phys. Rev.*, vol. 81, p. 152; January 1, 1951.

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

(91) R. L. Wallace, Jr., "Duality, a new approach to transistor circuit design," PROC. I.R.E., vol. 39, p. 702; June, 1951.
(92) R. L. Wallace, Jr. and G. Raisbeck, "Duality as a guide in transistor circuit design," *Bell. Sys. Tech. Jour.*, vol. 30, pp. 381–417; April, 1951.

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.

(93) J. G. Skalnick, H. J. Reich, J. E. Gibson, and T. Flynn, "Auxiliary current alters transistor characteristics," *Electronics*, vol. 24, pp. 142, 228, 232, and 236; September, 1951.
(94) W. B. Bowers, "Transistor frequency-multiplying circuit," *Electronics*, vol. 24, pp. 140–141; March, 1951.
(95) L. L. Koros and R. F. Schwartz, "Transistor frequency-modulator circuit," *Electronics*, vol. 24, pp. 130–132, 134; July, 1951.
(96) P. M. Schultheiss and H. Reich, "Some transistor trigger circuits," PROC. I.R.E., vol. 39, pp. 627–632; June, 1951.

Circuit analysis and production measurements of video detectors were described.

(97) W. P. Whalley, C. Masucci, and N. P. Salz, "An analysis of the germanium diode as a video detector," *Sylvania Tech.*, vol. 4, p. 25; April, 1951.

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.

(98) R. C. Prim, "Some results concerning the partial differential equations describing the flow of holes and electrons in semiconductors," *Bell. Sys. Tech. Jour.*, vol. 30, pp. 1174–1213; October, 1951.

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

(99) E. Billig, "Application of the image force model to the theory of contact rectification and of rectifier breakdown," *Proc. Roy. Soc.*, vol. 207, p. 156; June 22, 1951.
(100) P. T. Landsberg, "The theory of direct-current characteristics of rectifiers," *Proc. Roy. Soc.*, vol. 206, p. 463; May 22, 1951.
(101) P. T. Landsberg, "Contributions to the theory of heterogeneous barrier-layer rectifiers," *Proc. Roy. Soc.*, vol. 206, p. 477; May 22, 1951.

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

(102) R. W. Haegele, "A visual transistor test method and its application to collector forming," *Sylvania Tech.*, vol. 4, p. 61; July, 1951.

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.

(103) F. A. Stahl, "Effect of the probe metal in locating a *p-n* barrier in germanium," *Sylvania Tech.*, vol. 4, p. 61; July, 1951.
(104) J. R. Haynes and W. Shockley, "The mobility and life of injected holes and electrons in germanium," *Phys. Rev.*, vol. 81, pp. 835–843; March 1, 1951.
(105) F. S. Goucher, "Measurement of hole diffusion in *n*-type germanium," *Phys. Rev.*, vol. 81, p. 475; February 1, 1951.

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

(106) G. K. Teal, M. Sparks, and E. Buehler, "Growth of germanium single crystals containing *p-n* junctions," *Phys. Rev.*, vol. 81, p. 637; February 15, 1951.
(107) F. S. Goucher, G. L. Pearson, M. Sparks, G. K. Teal, and W. Shockley, "Theory and experiment for a germanium *p-n* junction," *Phys. Rev.*, vol. 81, p. 637; February 15, 1951.

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.

(108) A. R. Moore and F. Herman, "Electron bombardment induced conductivity in germanium point-contact rectifiers," *Phys. Rev.*, vol. 81, pp. 472–473; February 1, 1951.
(109) A. W. Ewald, "On the photoconductivity of thallous sulfide cells," *Phys. Rev.*, vol. 81, pp. 607–611; February 15, 1951.
(110) K. Lehovec, C. A. Accardo, and E. Jamgochian, "Injected light emission of silicon carbide crystals," *Phys. Rev.*, vol. 83, pp. 603–607; August 1, 1951.
(111) K. B. McAfee, E. J. Ryder, W. Shockley, and M. Sparks, "Observations of Zener current in germanium *p-n* junctions," *Phys. Rev.*, vol. 83, pp. 650–651; August 1, 1951.
(112) W. Shockley, "Hot electrons in germanium and ohm's law," *Bell Sys. Tech. Jour.*, vol. 30, pp. 990–1034; October, 1951.
(113) H. H. Hall, J. Bardeen, and G. L. Pearson, "The effects of pressure and temperature on the resistance of *p-n* junctions in germanium," *Phys. Rev.*, vol. 84, pp. 129–132; October 1, 1951.
(114) W. G. Pfann, "Significance of composition of contact point in rectifying junctions on germanium," *Phys. Rev.*, vol. 81, p. 882; March 1, 1951.

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.

(115) D. E. George, R. G. E. Hutter, and H. Cooperstein, "The rotating beam method for investigating electron lenses," *Sylvania Tech.*, vol. 4, pp. 41–43; April, 1951.

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 defocusing in electrically deflected tubes was made.

(116) C. Graham, "How new automatic-focus picture tube operates," *Radio and Telev. Retailing*, pp. 56, 57; December, 1951.
(117) G. S. Szegho, M. E. Amdursky, and W. O. Reed, "Low-reflection picture tubes," *Electronics*, vol. 24, pp. 97–99; January, 1951.
(118) H. E. Thomas, "Wide angle picture tubes," *Radio and Telev. News*, vol. 16, pp. 3–6; September, 1951.
(119) J. E. Rosenthal, "Correction of deflection defocusing in cathode-ray tubes," Proc. I.R.E., vol. 39, pp. 10–15; January, 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.

(120) H. S. Morris, "Industrial survival of sound systems," *Audio Eng.*, vol. 35, pp. 24, 25, 37, 38, 39; May, 1951.
(121) J. Goodman, "Music and mass production," *Audio Eng.*, vol. 35, pp. 23, 44, 45, 46; September, 1951.

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.

(122) A. S. Windeler, "The junction transistor," *Bell Lab. Rec.*, vol. 24, pp. 378–381; August, 1951.
(123) B. N. Slade, "A high-performance transistor with wide spacing between contacts," *RCA Rev.*, vol. 11, pp. 517–526; December, 1950.
(124) R. L. Wallace, Jr. and W. J. Pietenpol, "Some circuit properties and applications of *n-p-n* transistors," *Bell Sys. Tech. Jour.*, vol. 30, pt. 3, pp. 530–563; July, 1951.

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 self-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.

(125) R. L. Wallace, Jr., "Reproduction of magnetic signals," *Bell Sys. Tech. Jour.*, vol. 30, pt. 2, pp. 1145–1173; October, 1951.
(126) H. F. Olson, "Sensitivity, directivity and linearity of direct radiator loudspeakers," *Audio Eng.*, vol. 34, pp. 15–17; October, 1950.
(127) "Magnetic Rubber," *Rev. Sci. Instr.*, vol. 23; November, 1951.

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.

(128) "BTL development benefits labs family," *Bell Lab. Rec.*, vol. 29, pt. 4, p. 173; April, 1951.
(129) L. J. Anderson and C. R. Johnson, "New broadcast light pick-up and tone arm," *Audio Eng.*, vol. 35, pp. 18, 20–21, 39; March, 1951.
(130) F. V. Welch, "Want to hire a 'telephone sitter'?," *Telephony*, vol. 140, pp. 13–14; February 17, 1951.

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.

(131) G. A. Singer, "Performance and operation of a new limiting amplifier," *Audio Eng.*, vol. 34, pp. 18–19, 69–70; November, 1950.
(132) F. R. Smith, "Automatic stabilization of high-impedance d-c amplifiers," *Electronics*, vol. 24, p. 124; February, 1951.

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.

(133) F. A. Fischer, "Stroboscopic audio frequency spectrometer," *Fermeldetech. Z*, vol. 3, pp. 74–180; May, 1950.
(134) H. R. Foster and E. E. Crump, "Methods and instruments for the visual analysis of complex audio waveforms," *Proc. NEC* (Chicago), vol. 5, pp. 564–572; 1949.
(135) W. E. Koch and F. K. Harvey, "A photographic method for displaying sound wave and microwave space patterns," *Bell Sys. Tech. Jour.*, vol. 30, pt. 3, pp. 564–587; July, 1951.
(136) A. Peterson, "Continuously adjustable low and high-pass filters for audio frequencies," *Proc. NEC* (Chicago), vol. 5, pp. 550–555; 1949.
(137) C. C. Shumard, "Design of high-pass, low-pass, and band-pass filters using R-C networks and direct current amplifiers with feed back," *RCA Rev.*, vol. 11, pp. 534–564; December, 1950.

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.

(138) "AES standard playback curve," *Audio Eng.*, vol. 35, p. 22; January, 1951.
(139) "NARTB Recording and Reproducing Standards," 1771 "N" St., N.W., Washington, D. C.; June, 1951.

The use of fine-groove records, both 45 and 33⅓ 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.

(140) *Audio Rec.*, vol. 7, pp. 3–10; August–September, 1951.

Tape speeds now range from 30 to 1⅞ 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 7½ inches per second are used for broadcasting and commercial applications, and lower speeds of 3¾ and 1⅞ 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.

(141) "Proposed American standards," *Jour. Soc. Mot. Pic. and Telev. Eng.*, vol. 57, pp. 71–74; July, 1951.
(142) G. Lewin, "Synchronous ¼-inch magnetic tape for motion picture productions," *Jour. Soc. Mot. Pic. and Telev. Eng.*, vol. 56, pp. 664–671; June, 1951.

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.

(143) E. E. Masterson, F. L. Putzrath, and H. E. Roys, "Magnetic sound on 16-mm edge-coated film," *Jour. Soc. Mot. Pic. and Telev. Eng.*, vol. 57, pp. 559–566; December, 1951.

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

(144) R. E. Zenner, "Magnetic recording with ac bias," Proc. I.R.E., vol. 39, pp. 141–146; February, 1951.
(145) O. W. Muckenhirn, "Recording de-magnetization in magnetic recording," Proc. I.R.E., vol. 39, pp. 891–897; August, 1951.
(146) R. L. Wallace, Jr., "The reproduction of magnetically recorded signals," *Bell Sys. Tech. Jour.*, vol. 30, pp. 1145–1173; October, 1951.

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.

(147) N. A. Haskell, "Asymptotic approximation for normal modes in sound-channel propagation," *Jour. Appl. Phys.*, vol. 22, pp. 157–168; February, 1951.
(148) H. Lu, "Volume viscosities and compressibilities from acoustic phenomena," *Jour. Acous. Soc. Amer.*, vol. 23, pp. 12–15; January, 1951.
(149) P. J. Westervelt, "The theory of steady forces caused by sound waves," *Jour. Acous. Soc. Amer.*, vol. 23, pp. 312–315; May, 1951.
(150) O. K. Mawardi, "On the generalization of the concept of impedance in acoustics," *Jour. Acous. Soc. Amer.*, vol. 23, pp. 571–576; September, 1951.

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 ¼-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.

(151) U. Ingård and R. H. Bolt, "Absorption characteristics of acoustic materials with perforated facings," *Jour. Acous. Soc. Amer.*, vol. 23, pp. 533–540; September, 1951.
(152) R. W. Kenworthy and T. D. Burnham, "Absorption coefficients of fir plywood panels," *Jour. Acous. Soc. Amer.*, vol. 23, pp. 531–532; September, 1951.
(153) C. B. Boenning, S. F. Huber, and T. Mariner, "A modification of the box method of determining relative sound absorption coefficients," *Jour. Acous. Soc. Amer.*, vol. 23, pp. 114–115; January, 1951.
(154) P. H. Parkin and W. H. Scholes, "Recent developments in speech-reinforcement systems," *Wireless World*, vol. 57, pp. 44–50; February, 1951.

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.

(155) "Proceedings of the speech communications conference at M.I.T.," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 689–806; November, 1950.
(156) L. L. Beranek, J. L. Marshall, A. L. Cudworth, and E. P. G. Peterson, "Calculation and measurement of the loudness of sounds," *Jour. Acous. Soc. Amer.*, vol. 23, p. 261; May, 1951.

Ultrasonics

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 ultrasonics 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.

(157) G. M. Naimark, J. Klair, and W. A. Mosher, "A bibliography on sonic and ultrasonic vibration: biological, biochemical and biophysical application," *Jour. Frank. Inst.*, vol. 251, pp. 279–299; February, 1951; also pp. 402–408; March, 1951.
(158) B. E. Noltingk, "Ultrasonic generators for high powers," *Jour. Brit. I.R.E.*, vol. 11, pp. 11–19; January, 1951.
(159) American Society for Testing Materials, Symposium on Ultrasonic Testing, ASTM Special Publication 101; 1951.
(160) B. Curry, *et al.*, "Bibliography, Supersonics or Ultrasonics 1926 to 1945 with Supplement to 1950," Oklahoma A. and M. Research Foundation; 1951.

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 audiometer 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 magnetostriction 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.

(161) American Standards Association, "American Standard Acoustical Terminology," ASA Standard Z 24.1—1951. New York, N. Y.; 1951.

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.

(162) W. B. Hess, R. C. Swingal, and S. K. Waldorf, "Measuring water velocity by an ultrasonic method," *Elec. Eng.*, vol. 69, p. 983; November, 1950.
(163) G. S. Bennett, "A note on the activation of photographic emulsions by ultrasonic waves," *Jour. Acous. Soc. Amer.*, vol. 23, pp. 478–480; July, 1951.

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.

(164) L. E. Thompson, "Distortion in multichannel frequency modulation relay systems," *RCA Rev.*, vol. 11, pp. 453–464; December, 1950.

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.

(165) G. Grammer, "D. S. R. C. radio telephony," *QST*, vol. 35, pp. 1–16; May, 1951.

The effect of nonlinear quantization on quantization distortion was studied.

(166) P. F. Panter and W. Dite, "Quantization distortion in pulse-count modulation with nonuniform spacing of levels." Proc. I.R.E., vol. 39, pp. 44–48; January, 1951.

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.

(167) S. Moskowitz, L. Diven, and L. Feit, "Crosstalk considerations in time-division multiplex systems," Proc. I.R.E., vol. 38, pp. 1330–1336; November, 1950.

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 precepts of information theory by new methods.

(168) L. Brillouin, "Maxwell's demon cannot operate—information and entropy," *Jour. Appl. Phys.*, vol. 22, pp. 334–343; March, 1951.
(169) D. Gabor, "Communication theory and physics," *Phil. Mag.*, vol. 41, pp. 1161–1187; November, 1950.
(170) E. Reich, "Definition of information," Proc. I.R.E., vol. 39, p. 290; March, 1951.

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.

(171) P. M. Woodward and I. L. Davies, "A theory of radar information," *Phil. Mag.*, vol. 41, pp. 1001–1017; October, 1950.
(172) P. M. Woodward, "The decoding of radar information," *Telecommunication Research Establishment*, Tech. Note 76.
(173) I. L. Davies, "Theory of radar information—existence probabilities for signals in noise," *Telecommunication Research Establishment*, Tech. Note 109.
(174) S. M. Kaplan and R. W. McFall, "The statistical properties of noise applied to radar range performance," Proc. I.R.E., vol. 39, pp. 56–60; January, 1951.

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.

(175) J. V. Harrington and T. F. Rogers, "Signal-to-noise improvement through integration in a storage tube," PROC. I.R.E., vol. 38, pp. 1197–1203; October, 1950.

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.

(176) A. J. Lephakis, "Storage devices for communications," *Electronics*, vol. 23, pp. 69–73; December, 1950.

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.

(177) M. Leifer and N. Marchand, "The design of periodic radio systems," *Sylvania Tech.*, vol. 3, pp. 18–21; October, 1950.
(178) M. Leifer and N. Marchand, "Cross-Correlation and the Optimum Signal-to-Noise Ratio for Periodic Systems," Presented, I.R.E. National Convention, New York, N. Y.; March 19–22, 1951.
(179) M. Leifer and N. Marchand, "Cross-Correlation in Periodic Radio Systems," Presented, I.R.E. Conference on Airborne Electronics, Dayton, Ohio; May, 1951.

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.

(180) T. P. Cheatham, Jr., "An Electronic Correlator," Research Laboratory of Electronics, Massachusetts Institute of Technology Report 122; March 28, 1951.
(181) Y. W. Lee, T. P. Cheatham, Jr., and J. B. Wiesner, "Application of correlation analysis to the detection of periodic signals in noise," PROC. I.R.E., vol. 38, pp. 1165–1171; October, 1950.
(182) Y. W. Lee and L. G. Kraft, "Detection of Repetitive Signals in Noise by Correlation," Presented, I.R.E. National Convention, New York, N. Y.; March 19–22, 1951.

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

(183) D. A. Bell, "The auto-correlation function," *Wireless Eng.*, vol. 28, pp. 31–32; January, 1951.

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

(184) P. Elias, "A note on auto-correlation and entropy," PROC. I.R.E., vol. 39, p. 839; July, 1951.

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

(185) E. R. Kretzmer, "An application of auto-correlation analysis," *Jour. Math. Phys.*, vol. 29, pp. 179–190; October, 1950.
(186) L. A. Zadeh, "Correlation functions and spectra of phase and delay modulated signals," PROC. I.R.E., vol. 39, pp. 425–428; April, 1951.

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-highs 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.

(187) R. B. Dome, "Spectrum utilization in color television," PROC. I.R.E., vol. 39, pp. 1323–1331; October, 1951.
(188) Y. Delbord, "Television and the transmission of information," *Ann. Telecomm.*, vol. 6, pp. 11–22; January, 1951.

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.

(189) W. M. Goodall, "Television by pulse-code-modulation," *Bell Sys. Tech. Jour.*, vol. 30, pp. 33–49; January, 1951.
(190) A. E. Laemmel, "Coding Processes for Bandwidth Reduction in Picture Transmission," Presented, I.R.E. National Convention, New York, N. Y.; March 19–22, 1951.

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.

(191) A. R. Tunturi, "The Auditory Cortex and Information Theory," Presented, Western I.R.E. Convention, San Francisco, Calif.; August 22–24, 1951.

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.

(192) H. Seki and S. Muroga, "Some Considerations Regarding Encoding, Decoding, and Recording of Speech," Radio Regulatory Comm., Tokyo, Japan.

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.

(193) W. G. Tuller, "Application of the information theory to system design," *Elec. Eng.*, vol. 70, pp. 124–126; February, 1951.

(194) J. Loeb, "Application of Shannon's communication theory to telecontrol, telemetry, or measurement," *Ann. Telecomm.*, vol. 6, pp. 67–76; March, 1951.
(195) M. H. Nichols and L. L. Rauch, "Radio telemetry," *Rev. Sci. Instr.*, vol. 22, pp. 1–29; January, 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 applicability to the telemetering problem. A somewhat similar analysis, although not restricted to telemetering, was also presented.

(196) R. Piloty, "The assessment of modulation systems using the communication theory concept of channel capacity," *Arch. elekt. Übertragung*, vol. 4, pp. 493–508; December, 1950.

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

(197) B. Mandelbrot, "Adaptation of message to transmission line: part 1—quantity of information," *Compt. Rend. Acad. Sci.* (Paris), vol. 232, pp. 1638–1640; April 30, 1951.
(198) R. Feron and C. Fouregard, "Information and regression," *Compt. Rend. Acad. Sci.* (Paris), vol. 232, pp. 1636–1638; April 30, 1951.
(199) P. Marcon, "Frequency compression," *Ann. Telecomm.*, vol. 5, pp. 321–337; October, 1950.
(200) P. Chavasse, "Application of means used for assessing the quality of telephone transmission," *Ann. Telecomm.*, vol. 5, pp. 427–440; December, 1950.
(201) W. Jackson, "Information theory," *Nature* (London), vol. 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 Sys. Tech. Jour.*, vol. 30, pp. 50–64; January, 1951.

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 employed in the equalization of several hundred-decibels discrimination in line loss by networks of several hundred 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 capacitive elements has continued.

(204) H. J. Orchard, "The synthesis of RC networks to have prescribed transfer functions," Proc. I.R.E., vol. 39, pp. 428–432; April, 1951.
(205) A. Fialkow and I. Gerst, "The transfer function of an R-C ladder network," *Jour. Math. Phys.*, vol. 30, pp 49–72; July, 1951.
(206) R. R. Kenyon, "Response characteristics of resistance-reactance ladder networks," Proc. I.R.E., vol. 39, pp. 557–559; May, 1951.
(207) H. Epstein, "Synthesis of passive RC networks with gains greater than unity," Proc. I.R.E., vol. 39, pp. 833–835; July, 1951.
(208) J. T. Fleck and P. F. Ordung, "The realization of a transfer ratio by means of a resistor-capacitor ladder network," Proc. I.R.E., vol. 39, pp. 1069–1074; September, 1951.
(209) L. Storch, "The multisection RC filter network problem," Proc. I.R.E., vol. 39, pp. 1456–1458; November, 1951.

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 topology, 1950," Proc. I.R.E., vol. 39, pp. 27–29; January, 1951.
(211) Papers 38, 39, 40, and 41, "1951 IRE National Convention Program," Proc. I.R.E., vol. 39, pp. 292–315; March, 1951.

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 suppression or concealment of transitory conditions between 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 students 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 approximate 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 circuit 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 representation of time series by generating functions of the type commonly used in 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-

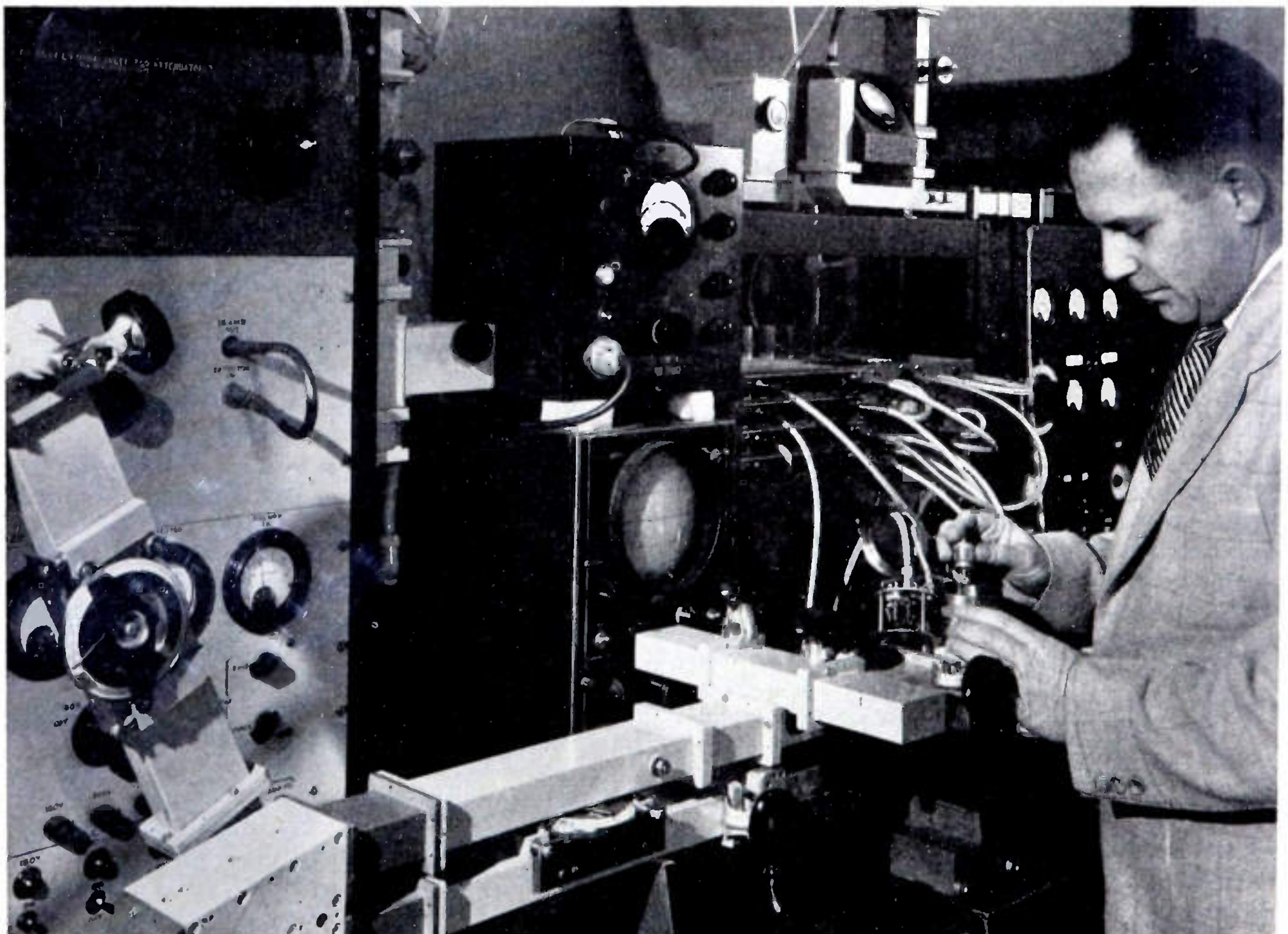

Fig. 6—A laboratory arrangement for testing the performance of the transmitter modulator and filter associated with the transcontinental microwave radio-relay system. The development engineer has removed the 416-A close-spaced triode electron tube (Bell Telephone Laboratories).

tremely high stage gains are possible with this mode of tube operation, and fewer circuit components are needed.

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.

(212) J. B. Maggie, "Terminals for the TD-2 radio relay system," *Bell Lab. Rec.*, vol. 29, pp. 314–317, 323; July, 1951.
(213) G. R. Frantz, "Repeaters for the TD-2 radio relay system," *Bell Lab. Rec.*, vol. 29, pp. 356–360; August, 1951.
(214) L. Espenschied, "Coast-to-coast radio relay system opens," *Bell Lab. Rec.*, vol. 29, pp. 427–428; September, 1951.
(215) T. J. Grieser and A. C. Peterson, "A broad-band transcontinental radio relay system," *Elec. Eng.*, vol. 70, pp. 810–815; September, 1951.
(216) A. A. Roetken, K. D. Smith, and R. W. Friis, "The TD-2 microwave relay system," *Bell Sys. Tech. Jour.*, vol. 30, p. 1041; October, 1951.

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.

(217) J. K. Kulansky, "Multiplex ringdown panel," *FM-TV*, vol. 10, pp. 21–22; November, 1950.
(218) F. B. Gunter, "Multiplex design," *FM-TV*, vol. 10, pp. 16–18; November, 1950.
(219) D. Samuelson, "Mid-valley microwave relay," *FM-TV*, vol. 11, pp. 23–25; February, 1951.
(220) Staff Paper, "High frequency, remote supervisory control, and communication engineering," *The Brown Boveri Rev.*, vol. 38, p. 77; January–March, 1951.
(221) R. V. Rector and W. E. Sutter, "Microwave systems for 960 and 2,000 MC," *Trans. AIEE*, vol. 69, pp. 1100–1109; June, 1950.
(222) R. F. Stevens and T. W. Stringfield, "Microwave applications to Bonneville Power Administration system," *Elec. Eng.*, vol. 70, pp. 29–33; January, 1951.
(223) S. J. Ross, "Very high frequency and ultra high frequency radio links in the Australian Post Office Communication Network," *Inst. Engrs.* (Australia), vol. 23, pp. 11–20; January–February, 1951.
(224) F. B. Gunter, "940–960 megacycle communications equipment for industrial application," *Elec. Eng.*, vol. 70, pp. 573–578; July, 1951.
(225) B. Lauterburg, "New high frequency telephone system for electric railways," *Techn. Mitteilungen*, vol. 29, pp. 137–144; April, 1951.
(226) F. A. Gunther, "Multiplex FM design," *FM-TV*, vol. 11, pp. 19–21; January, 1951.
(227) L. E. Thompson, "Distortion in multichannel frequency modulation relay systems," *RCA Rev.*, vol. 11, pp. 453–464; December, 1950.

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.

(228) Staff Paper, "Portable microwave television link," *Elec. Commun.* (London), vol. 27, pp. 295–297; December, 1950.
(229) A. H. Mumford, C. F. Booth and R. W. White, "The London/Castleton experimental radio-relay system," *P. O. Elec. Eng. Jour.*, vol. 43, pp. 93–99; July, 1950.
(230) V. Learned, "The klystron mixer applied to television relaying," Proc. I.R.E., vol. 38, pp. 1033–1035; September, 1950.
(231) M. J. L. Pulling, "Television from France, metre- and centimeter-wave radio links between London and Calais," *Wireless World*, vol. 56, pp. 353–354; October, 1950.
(232) M. Silver, *et al.*, "Video design considerations in a TV repeater link," *Tele-Tech.*, vol. 10, pp. 28–30, 61; January, 1951.
(233) B. W. Southwell, "Los Angeles to San Francisco microwave relay," *Tele.-Tech.*, vol. 10, pp. 44–45, 83; February, 1951.
(234) J. Packer, "Microwave television links," *Radio and Telev. News*, Radio-Electronic Dept., vol. 16, pp. 14A–15A, 29A–31A; April, 1951.
(235) R. J. Clayton, *et al.*, "London-Birmingham television radio-relay link," *Eng.*, vol. 171, pp. 447–449; April 13, 1951.
(236) R. J. Clayton, *et al.*, "London-Birmingham television radio-relay link," *Proc. IEE* (London), vol. 98, pp. 204–223, 224–227; July, 1951.
(237) H. G. Miller and L. Staschover, "Television-Link sound diplexer," *Elec. Commun.* (London), vol. 28, pp. 100–109; June, 1951.

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.

(238) Staff Paper, "Miniature walkie-talkie," *Wireless World*, vol. 57, pp. 323–324; August, 1951.

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.

(239) V. J. Tyler, "A general purpose remote control system for radio transmitters," *Marconi Rev.*, vol. 15, pp. 61–81; 2nd Quarter, 1951.
(240) G. E. Hansell, "Transmitter diversity applied to machine telegraph radio circuits," *RCA Rev.*, vol. 11, pp. 508–516; December, 1950.
(241) N. Lund, "Methods of measuring adjacent band radiation from radio transmitters," Proc. I.R.E., vol. 39, pp. 653–656; June, 1951.
(242) G. T. Royden, "Suppression of harmonics in radio transmitters," *Elec. Commun.* (London), vol. 28, pp. 112–120; June, 1951.
(243) G. T. Royden, "Transmission-line balance indicator for transmitters," *Elec. Commun.* (London), vol. 28, pp. 110–111; June, 1951.
(244) E. T. Wrathall and C. P. Beanland, "The single-sideband system of high frequency radio transmission," *Marconi Rev.*, vol. 14, pp. 2–22; 1st Quarter, 1951.
(245) F. Ellrodt, "The equipment of the Frankfort-on-the-Main radio station for transoceanic transmission," *FTZ*, vol. 3, pp. 346–355; September, 1950.
(246) G. Schwarzbeck, "Ultrashort wave transmitters," *Forts d. Radiotechnik*, vol. 12, pp. 176–192; 1950–51.
(247) R. Terlecki, *et al.*, "B.T.R. frequency-shift radiotelegraph equipment," *Strowger Jour.*, vol. 7, pp. 98–103; July, 1950.

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.

(248) Staff Paper, "The new Daventry transmitter," *Jour. Brit. I.R.E.*, vol. 11, pp. 136; April, 1951.
(249) R. G. Kitchen, "An 8 channel transmitter for an experimental carrier wire-broadcasting system," *Jour. Brit. I.R.E.*, vol. 11, pp. 295–339; August, 1951.
(250) N. D. Webster, "Economical 5 K.W. transmitter," *Electronics*, vol. 24, pp. 115–117; May, 1951.
(251) Staff Paper, "Daventry third programme transmitter," *Elec. Eng.*, vol. 23, p. 166; May, 1951.
(252) Staff Paper, "Broadcasting transmitters," *The Brown Boveri Rev.*, vol. 38, pp. 79–80; January–March, 1951.
(253) L. B. Petery, "Air-Cooled 5–10 K.W. A.M. Broadcast transmitter," *Tele-Tech.*, vol. 9, pp. 28–29, 64–65; November, 1950.
(254) E. S. Harris, "New 1 K.W. H.F. transmitter for communication or broadcast service," G. E. Co., *Telecommun.*, vol. 5, pp. 106–123; July, 1950.
(255) M. Beurtheret, "Justification of the improvement of quality standards of radio broadcasting transmitters," *Onde elec.*, vol. 31, pp. 184–187; April, 1951.
(256) R. J. Newman, "All new 250-watt transmitter," *Broadcast News*, vol. 63, pp. 8–13; March–April, 1951.
(257) Staff Paper, "150-K.W. medium-wave broadcast transmitter at Daventry," *Eng.*, vol. 171, pp. 506–507; April 27, 1951.
(258) R. W. Hallows, "New Daventry station; 200 K.W. transmitter design for unattended working," *Wireless World*, vol. 57, pp. 236–238; June, 1951.
(259) W. Bürck, "Recent developments in transmitter construction and its physical principles," *Forts d. Radiotechnik*, vol. 12, pp. 302–326; 1950–51.
(260) G. Stein, "New 150 K.W. radio broadcasting stations in Sundsvaal and Gothenburg," *Tele.* (Sweden), pp. 22–37; 1951.

FM Broadcasting

General activity in FM broadcasting was less than previous years. The number of licenses outstanding in the United States increased from 513 to 544, and special temporary authorizations were decreased from 163 to 96.

(261) J. Ruston, "A simple crystal discriminator for FM oscillator stabilization," Proc. I.R.E., vol. 39, pp. 783–788; July, 1951.
(262) H. Rakshit and N. L. Sarkar, "Simple method of producing wide-band frequency modulation," *Indian Jour. Phys.*, vol. 24, pp. 207–222; May, 1950.
(263) G. Brauer, "Lorenz 10 K.W. ultra short wave transmitter for frequency modulation broadcasting," *FTZ*, vol. 3, pp. 292–296; August, 1950.
(264) L. Rohde, *et al.*, "High power frequency modulation broadcast transmitter," *Frequenz*, vol. 4, pp. 219–228; September, 1950.
(265) A. A. Gerlach, "Distortion—band-pass considerations in angular modulation," Proc. I.R.E., vol. 38, pp. 1203–1207; October, 1950.
(266) F. A. Gunther, "Multiplex FM designs," *FM-TV*, vol. 11, pp. 19–21; January, 1951.
(267) H. Schutzendübel, "The new frequency-modulated 10 K.W. ultra-short wave radio broadcast transmitter in Hamburg," *Elec. Tech. Zeit.*, vol. 71, pp. 675–679; December, 1950.
(268) J. H. Kopp, "Comments about new frequency modulation circuits," *Funk-Technik* (Berlin), vol. 6, pp. 240–241; 1951.
(269) J. H. H. Merriman and R. W. White, "The application of frequency modulation to VHF multichannel radiotelephony," *Proc. IEE* (London), vol. 98, p. 56; January, 1951.

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.

(270) W. M. Goodall, "Television by pulse code modulation," *Bell Sys. Tech. Jour.*, vol. 30, pp. 33–49; January, 1951.
(271) H. M. Crosby, "Five-KW klystron UHF television transmitter," *Electronics*, vol. 24, pp. 108–112; June, 1951.
(272) J. Ruston, "Measuring TV transmitter amplitude characteristics," *Tele-Tech.*, vol. 10, pp. 30–31, 69–72; September, 1951.
(273) V. J. Cooper, "Shunt regulated amplifiers," *Wireless Eng.*, vol. 28, pp. 132–145; May, 1951.
(274) D. G. Fink, "Television broadcasting in the United States 1927–1950," Proc. I.R.E., vol. 39, pp. 116–123; February, 1951.
(275) E. T. Emmo and E. Jones, "The video output stage," *Elec. Eng.* (London), vol. 22, pp. 408–413, 454–460; October and November, 1950.
(276) R. G. Peters, "U.H.F. amplifier design," *Telev. Eng.*, vol. 2, pp. 10–11; July, 1951.

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.

(277) "Saving critical materials," *Elec. Mfg.*, vol. 48, pp. 102–105 256, 258, 260; December, 1951. Also, *Mater. Bur. Bull.* Radio-Telev. Mfg. Assoc.; 1951.
(278) "Conservation of raw materials," *Tele-Tech.*, vol. 10, pp.39, 72, 74; April, 1951.
(279) L. E. Swedlund and R. Saunders, "Material-saving picture tube," *Electronics*, vol. 24, pp. 118–120; 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.

(280) J. Pell, "The cosine defection yoke," *TV Eng.*, vol. 2, pp. 10–11; June, 1951.
(281) H. W. Grossbohlin, "The design of 90° deflection picture tubes," *Tele.-Tech.*, vol. 10, pp. 42–44; August, 1951.

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.

(282) G. Voyles, "A cascode type antenna-mounted TV booster," *Radio and Telev.*, vol. 46, pp. 54–55, 90–91; July, 1951.
(283) "Standards on radio receivers: Open field method of measurement of spurious radiation from frequency modulation and television broadcast receivers," Proc. I.R.E., vol. 39, pp. 803–806; July, 1951.
(284) J. Van Duyne, "Suppression of local oscillator radiation in television receivers," Presented, IRE-RTMA Fall Meeting, Toronto, Canada; October 29, 1951.

(285) C. G. Seright, "Open-field test facilities for measurement of incidental receiver radiation," *RCA Rev.*, vol. 12, pp. 45–52; March, 1951.

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.

(286) E. D. Lucas, "How TV came to Panther Valley," *Radio and Telev.*, vol. 45, pp. 31–34; March, 1951.
(287) D. W. Pugsley, "Production experience with a 40-mc. IF receiver," *Electronics*, vol. 23, pp. 98–100; November, 1950.

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.

(288) R. V. Little, "The RCA PT-100 theatre television equipment," *Jour. Soc. Mot. Pic. Eng.*, vol. 56, pp. 317–331; March, 1951.
(289) R. L. Garman and B. Foulds, "Some commercial aspects of a new 16-mm intermediate film television system," *Jour. Soc. Mot. Pic. Eng.*, vol. 56, pp. 219–226; February, 1951.
(290) H. E. Green, "Rave reviews greet Phonevisions's debut in 90-day Chicago test," *Printers' Ink*, vol. 234, p. 79; January 19, 1951.

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.

(291) "The FCC reports on television intermodulation tests," *Tele.-Tech.*, vol. 10, pp. 33, 86; June, 1951.
(292) F. Shunaman, "Miniature magnetron for UHF TV receivers," *Radio and Electronics*, vol. 22, pp. 32–33; August, 1951.
(293) K. E. Loofbourrow and C. M. Morris, "A new miniature triode for UHF TV tuners," Presented, IRE-TRMA Fall Meeting, Toronto, Canada, October 30; 1951.
(294) M. W. Slate, J. P. Van Duyne, and E. F. Mannerberg, "Modified butterfly UHF-TV converter," *Electronics*, vol. 24, pp. 92–96; October, 1951.
(295) H. R. Hesse, "A UHF television converter," Presented, IRE-RTMA Fall Meeting, Toronto, Canada; October 30, 1951.
(296) B. F. Tyson and J. G. Wiessman, "R-F amplifier for UHF television tuners," *Electronics*, vol. 24, pp. 106–109; October, 1951.
(297) R. F. Guy, "Investigation of ultra-high-frequency television transmission and reception in the Bridgeport, Connecticut area," *RCA Rev.*, vol. 12, pp. 98–142; March, 1951.
(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.

(299) "Methods of measurement of electronically regulated power supplies, 1950," Proc. I.R.E., vol. 39, pp. 29–35; January, 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.

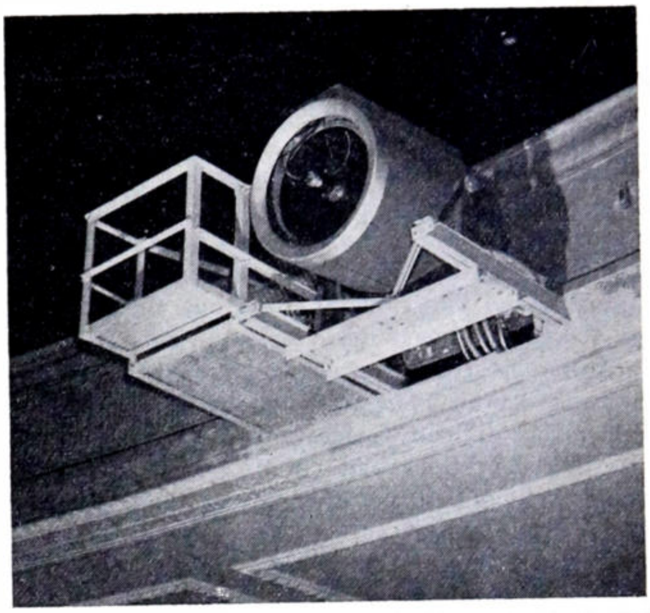

Fig. 7—Typical installation of theatre television system in the RKO Fordham Theatre in the Bronx, New York City. Photograph shows optical barrel mounted on front of balcony. This unit, housing the high-voltage projection-type kinescope, saucer-shaped reflecting mirror, and correcting lines, projects the image to the theatre screen (RCA).

(300) M. W. Baldwin, Jr., "Television picture fidelity," *Electronics*, vol. 24, pp. 106–107; January, 1951.

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.

(301) O. H. Schade, "Image gradation, graininess and sharpness in television and motion picture systems," *Jour. Soc. Mot. Pic. and Telev. Eng.*, vol. 56, pp. 137–177; February, 1951.
(302) R. Kuehn, "Crystal diodes in TV studio equipment," *Electronics*, vol. 23, pp. 114–116; December, 1950.

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.

(303) H. J. Schafly, "Some comparative factors of picture resolution in television and film industries," Proc. I.R.E., vol. 39, pp. 6–10; January, 1951.

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.

(304) K. B. Benson and A. Ettlinger, "Practical use of iconoscopes and image orthicons as film pickup devices," *Jour. Soc. Mot. Pic. and Telev. Eng.*, vol. 57, pp. 9–14; July, 1951.
(305) R. L. Garman and R. W. Lee, "Image tubes and techniques in TV film camera chains," *Jour. Soc. Mot. Pic. and Telev. Eng.*, vol. 56, pp. 52–64; January, 1951.
(306) R. Theile, "Image iconoscope for improved TV film scanning," *Tele.-Tech.*, pp. 44–46; November, 1951.

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.

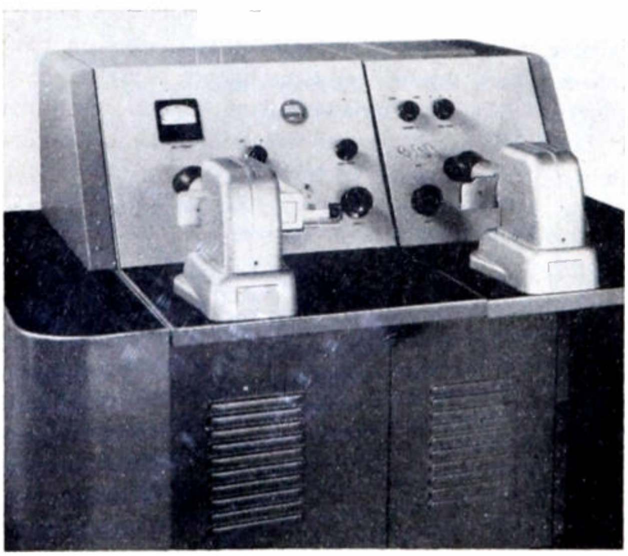

Fig. 8—Dual scanner. The FTL-82A television flying-spot scanner pictured above is used to convert slide information to a video signal suitable for television broadcasting. Developed by Federal Telecommunication Laboratories, Inc., it enables the effective and commercial handling of commercials, test patterns, spot news, and other television-slide information.

(307) D. G. Fink, "Continuous film scanner for TV," *Electronics*, vol. 24, pp. 114–116; July, 1951.

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.

(308) P. J. Herbst, R. O. Drew, and S. W. Johnson, "Electrical and photographic compensation in television film reproduction," *Jour. Soc. Mot. Pic. and Telev. Eng.*, pp. 289–307; October, 1951.
(309) P. C. Goldmark and J. M. Hollywood, "A new technique for improving the sharpness of television pictures," *Jour. Soc. Mot. Pic. and Telev. Eng.*, pp. 382–396; October, 1951.

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

(310) R. L. Garman and B. Foulds, "Some commercial aspects of a new 16 mm intermediate film television system," *Jour. Soc. Mot. Pic. and Telev. Eng.*, vol. 56, pp. 219–226; February, 1951.

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.

(311) R. L. Garman and J. E. Cope, "Simplified operation keynoted in new TV equipment," *Tele.-Tech.*, vol. 10, p. 48; October, 1951.
(312) W. L. Hurford, "Combined special effects amplifier for television," *Tele.-Tech.*, pp. 50–53; November, 1951.
(313) J. H. Roe, "The Genlock," *Jour. Soc. Mot. Pic. and Telev. Eng.*, vol. 56, pp. 232–234; February, 1951.

Several unconventional approaches to the television scanning process were proposed although their use may be confined largely to special applications. In one of these proposals, a scanning beam of constant current is velocity modulated by the video signal so that high-velocity portions of the scanning path will be reproduced 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.

(314) M. A. Honnell and M. D. Prince, "Television image reproduction by use of velocity modulation principle," Proc. I.R.E., vol. 39, pp. 265–268; March, 1951.
(315) K. Schlesinger, "Dot arresting improves TV picture quality," *Electronics*, vol. 24, pp. 96–101; September, 1951.
(316) W. M. Goodall, "Television by pulse code modulation," *Bell Sys. Tech. Jour.*, vol. 30, pp. 33–49; January, 1951.

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.

(317) P. C. Goldmark and J. M. Hollywood, "A new technique for improving the sharpness of television pictures," Proc. I.R.E., vol. 39, pp. 1314–1322; October, 1951.
(318) P. C. Goldmark, J. W. Christensen and J. J. Reeves, "Color television—U.S.A. standards," Proc. I.R.E., vol. 39, pp. 1288–1313; October, 1951.

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.

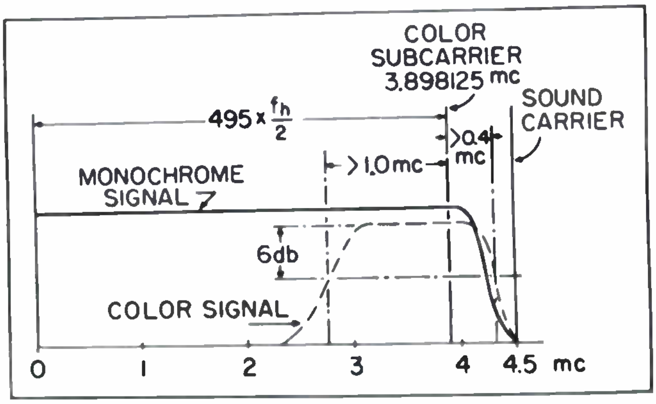

Fig. 10—Video spectrum of compatible color-television system adopted for field test by the National Television System Committee. The color signal consists of frequency components interleaved between the frequency components of the monochrome (or brightness) signal over the upper half of the video band. (f_h = horizontal scanning frequency in cycles.)

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

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.

(320) "Compatible Color Systems Using Wideband Brightness Transmission," Submitted, Ad Hoc Committee, National Television Systems Committee; February 8, 1951.
(321) "Plans for compatible color television," *Electronics*, vol. 24, pp. 80–81; February, 1951.
(322) Hazeltine Electronics Corp., Report 7113; December 11, 1950.
(323) Demonstration of various monochrome signals by RCA on compatible monochrome receivers; Radio Corporation of America, Washington, D. C.; July, 1951.

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

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 microammeters (RCA).

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.

(324) F. J. Bingley, "Colorimetry in Color Television," Presented IRE Convention, New York, N. Y.; March 20, 1951.
(325) D. L. MacAdam, "Quality of color reproduction," Proc. I.R.E., vol. 39, pp. 468–485; May, 1951.
(326) D. G. Fink, "Color fundamentals for TV engineers," *Electronics*, vol. 23, pt. I, pp. 89–95; December, 1950; vol. 24, pt. II, pp. 78–83; January, 1951; vol. 24, pt. III, pp. 104–109; February, 1951.
(327) W. T. Wintringham, "Color television and colorimetry," Proc. I.R.E., vol. 39, pp. 1135–1172; October, 1951.
(328) R. C. Moore, J. Fischer, and J. Chatten, Presented, IRE Convention, New York, N. Y.; March, 1951.

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.

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.

(329) National Television Systems Committee Panel 13, Report of Panel Actions; October 23, 1951.
(330) National Television Systems Committee Panel 11, Minutes of Second Meeting; July 18, 1951.
(331) E. M. Creamer and M. I. Burgett, "Performance of Carrier-Synchronizing Circuits for Color-Television Signals," Presented, IRE Convention, New York, N. Y.; March, 1951.
(332) T. S. George, "Analysis of synchronizing systems," PROC. I.R.E., vol. 39, pp. 123–131; February, 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.

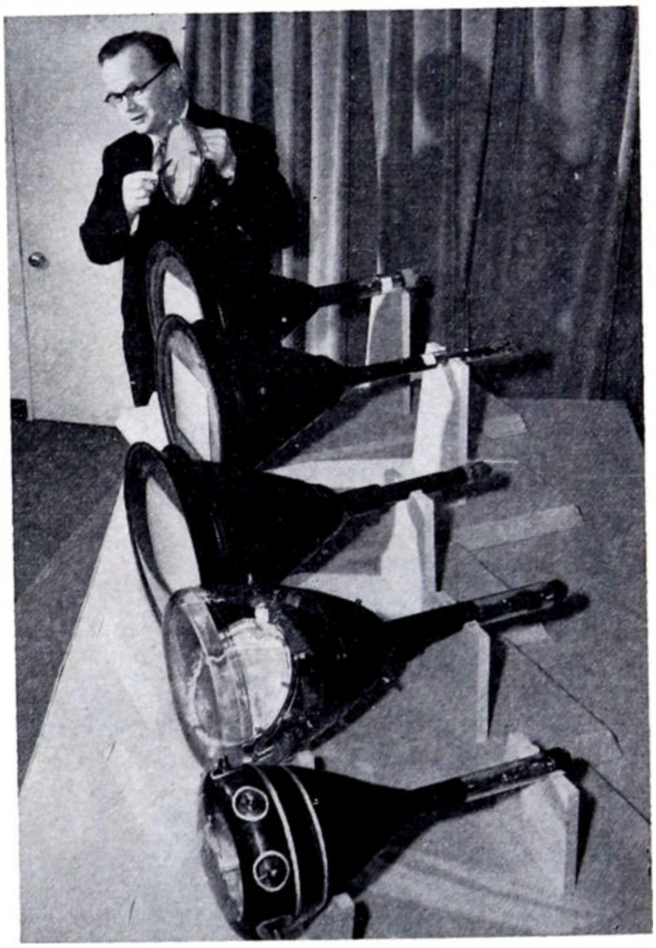

Fig. 12—Some tricolor television-picture tubes. Top to bottom: 45° reflection type; 3-gun shadow mask; line screen; one-gun shadow mask; 45° reflection; grid-controlled color kinescope. All types shown can be used with any known system of television. (RCA)

Several forms of single direct-view color-television tubes were described.

(333) Demonstration given by the Radio Corporation of America in Washington, D. C. of transmission of compatible color signals originating in New York, N. Y.; October, 1951.

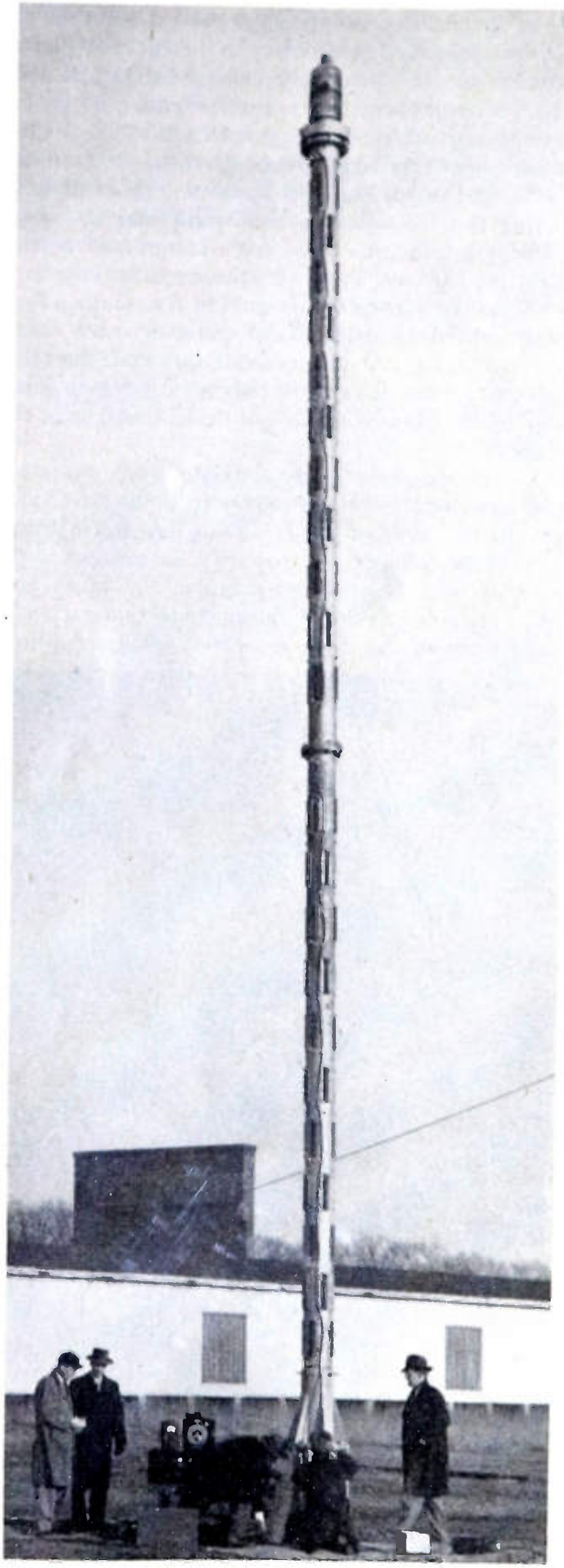

Fig. 13—Uhf antenna of the type installed at the experimental station, Stratford, Conn. Slots can be stacked in sufficient number to give the desired gain. The prototype shown operates in the 529–535-mc channel and has a gain of about 20. It is 40 feet high and 11 inches in diameter (NBC).

(334) A series of articles on color television, PROC. I.R.E.; October, 1951.
(335) R. Dressler, "The Chromatron," Presented, RTMA-IRE Radio Fall Meeting, Toronto, Canada; October, 1951.

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.

(336) D. G. Fink, "Television Broadcasting in the United States 1927–1950," PROC. I.R.E., vol. 39, pp. 116–123; February, 1951.
(337) R. F. Guy, "Investigation of ultra-high-frequency television transmission and reception in the Bridgeport, Connecticut area," *RCA Rev.*, vol. 12, pp. 98–142; March, 1951.
(338) H. M. Crosby, "Five-kw klystron uhf television transmitter," *Electronics*, vol. 24, pp. 108–112; June, 1951.
(339) L. O. Krause, "Sidefire helix uhf-TV transmitting antenna," *Electronics*, vol. 24, pp. 107–109; August, 1951.
(340) "Tilting of antenna increases uhf TV station signal strength," *Elec. Eng.*, vol. 70, p. 651; July, 1951.
(341) R. Guenther, "Radio relay design data 60 to 600 mc," PROC. I.R.E., vol. 39, pp. 1027–1034; September, 1951.
(342) K. H. Cook and R. G. Artman, "UHF-TV propagation measurements," *Tele.-Tech.*, vol. 10, pp. 50–51; March, 1951; pp. 52–54; April, 1951.
(343) R. G. Peters, "UHF-RF amplifier design," *Telev. Eng.*, vol. 2, pp. 10–11; July, 1951.
(344) J. H. Battison, "Day with uhf-TV at KC2XAK, Bridgeport, uhf conversion strips for use in TV tuners," *Tele-Tech.*, vol. 10, p. 32; July, 1951.
(345) W. H. Sayer, Jr. and E. Mehrbach, "Uhf transmitter uses beer-barrel cavity," *Electronics*, vol. 24, pp. 125–127; December, 1951.
(346) B. M. Ely, "Uhf transmission line problems," *Telev. Eng.*, vol. 2, pp. 12–27; November, 1951
(347) B. M. Ely, "Report on first I.R.E.-uhf symposium," *Telev. Eng.*, vol. 2, pp. 10–28; October, 1951.

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 consisted 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.

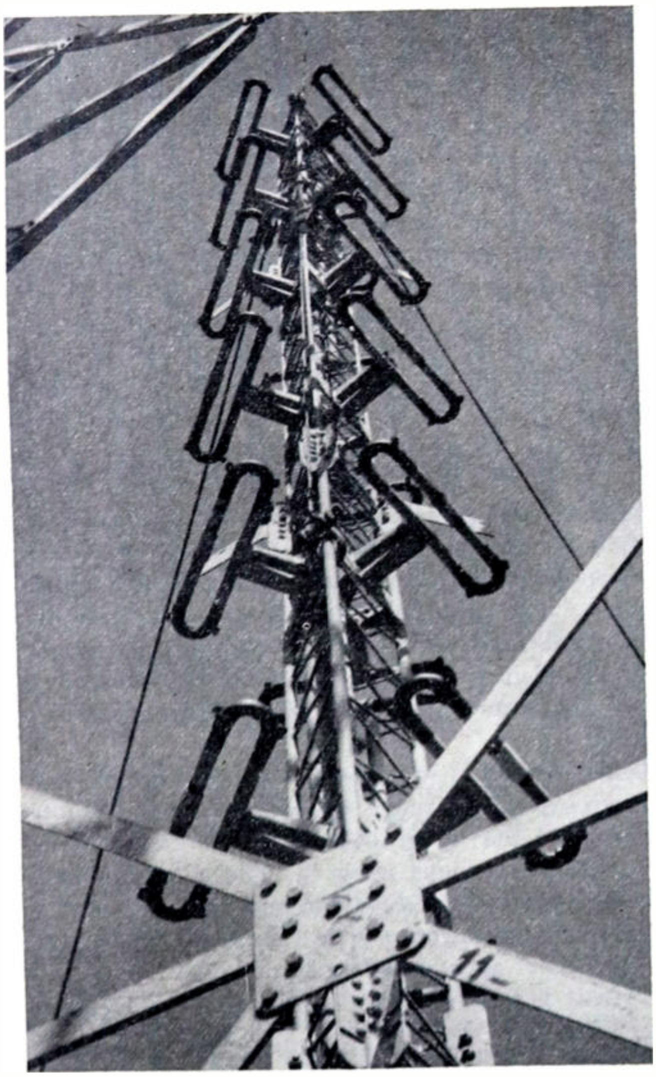

Fig. 14—TV antenna. The 8-bay triangular loop antenna shown being raised into position is one of the unique features of Station LR3-TV, Buenos Aires. Use of this antenna gives the new station an effective radiated power of 45 kw, the largest of any TV station in the Western Hemisphere. Owned and operated by Radio Belgrano y Primera Cadena Argentina de Broadcastings, the new station, which was officially inaugurated on October 17, was completely equipped by Federal Telecommunication Laboratories, Inc.

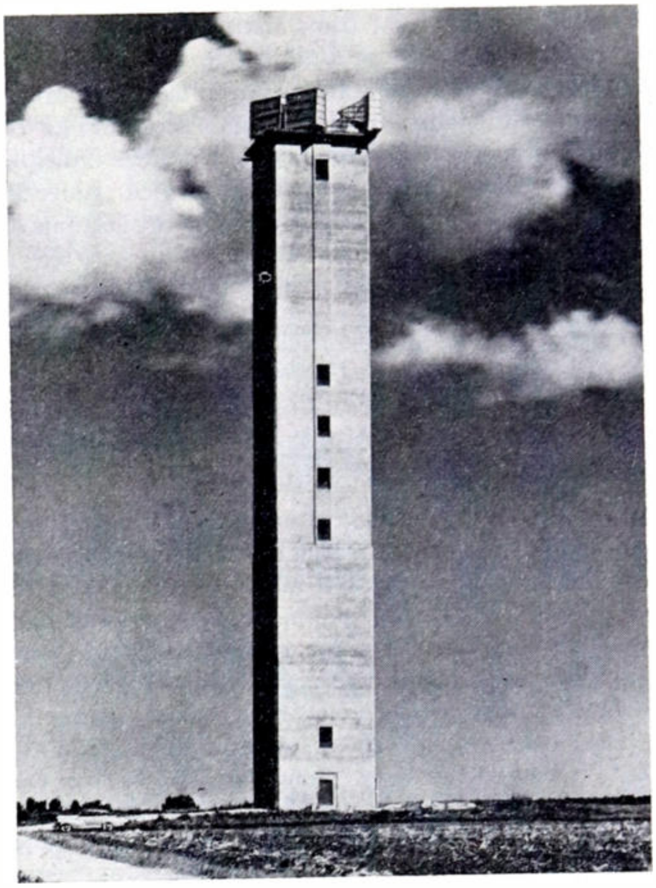

Fig. 15—A typical concrete station on the New York-San Francisco microwave radio-relay route. This station houses equipment developed at Bell Telephone Laboratories.

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.

(348) Federal Communications Commission, Report and Order 48-2182; September 30, 1948.
(349) Federal Communications Commission, Public Order 51-752; Adopted July 25, 1951.
(350) T. J. Grieser and A. C. Peterson, "Broad-band transcontinental radio relay system," *Elec. Eng.*, vol. 70, pp. 810–815; September, 1951.
(351) J. G. Chaffee and J. B. Maggio, "Frequency modulation terminal equipment for the transcontinental relay system," *Elec. Eng.*, vol. 70, pp. 880–883; October, 1951.

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.

(352) "The Empire State Story," Symposium, IRE National Convention, New York, N. Y.; March, 1951. Also, *Telev. Eng.*, vol. 2, pp. 8–9; April, 1951.
(353) J. M. Brush, "TV video switching," *Telev. Eng.*, vol. 2, pp. 12–15, 28, 29; July, 1951.
(354) R. D. Chipp, "Blue TV lamp design report," *Telev. Eng.*, vol. 2, pp. 16–17, 29; August, 1951.
(355) S. Helt, "Modern trends in TV camera design," *Telev.*, vol. 8, pp. 10, 49; January, 1951.

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 cascode 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.

(356) W. B. Whalley, "Simplification of television receivers," Proc. I.R.E., vol. 38, pp. 1404–1408; December, 1950.
(357) R. M. Cohen, "Use of new low-noise twin triode in television tuners," *RCA Rev.*, vol. 12, pp. 3–25; March, 1951.
(358) H. Kayner, "New types of TV tuners," *Tele.-Tech.*, vol. 10, pp. 39–41; March, 1951.
(359) W. B. Whalley, C. Masucci, and N. P. Salz, "Analysis of the germanium diode as a video detector," *Sylvania Tech.*, vol. 4, pp. 25–34; April, 1951.
(360) W. B. Whalley, C. Masucci, and K. Hillman, "Stabilized Vertical Deflection," Presented, RTMA-IRE Radio Fall Meeting, Toronto, Canada; October, 1951.
(361) E. L. Crosby, "The series amplifier," *Radio and Telev. News*, vol. 46, p. 12; October, 1951.
(362) J. E. Roe, "Video levels in television broadcasting," *Tele.-Tech.*, vol. 10, pp. 45–57, 60–62; August, 1951.
(363) V. K. Zworykin, "Industrial television," *Elec. Eng.* (London), vol. 23, pp. 8–11; January, 1951.

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.

(364) C. Jelinek and K. R. Jones, "Progress in radio-facsimile telegram delivery," *Western Union Tech. Rev.*, vol. 5, pp. 41–50; April, 1951.
(365) "New Western Union facsimile device greatly increases transmission speed," *Telegr. Teleph. Age.*, p. 10; April, 1951.
(366) "New high speed facsimile system," *Electronics*, vol. 24, p. 160; May, 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.

(367) "Facsimile reproduction for A.E.C. library service," *Electronics*, vol. 24, pp. 222, 224; March, 1951.
(368) "New facsimile system developed by R.C.A. for Oak Ridge Laboratory," *Elec. Eng.*, vol. 70, p. 177; February, 1951.

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.

(369) J. V. L. Hogan and J. W. Smith, "Multiplexed broadcast facsimile," *Electronics*, vol. 24, pp. 97–99; October, 1951.
(370) "Multiplex facsimile broadcasting," *Radio and Telev. News*, vol. 46, p. 120; July, 1951.

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.

(371) W. M. Phillips, "Use of FM communication by power utilities," *FM-TV*, vol. 11, pp. 17–18, 32, 34; January, 1951.
(372) R. E. Martin, "Radio communications for power systems," *Engineering* (London), vol. 171, pp. 114–116; January 26, 1951.
(363) "1540 miles of radio train communication on the Missouri Pacific," *Railway Signaling*, vol. 44, pp. 102–104, 116; February, 1951.
(374) R. F. Peterson, "New St. Paul mobile radio system," *FM-TV*, vol. 11, pp. 19–22, 38; February, 1951; pp. 19–21; March, 1951.
(375) H. A. Stowe, "Electronics in a large public utility," *Proc. I.R.E. (Australia)*, vol. 12, pp. 69–76; March, 1951.

(376) N. F. Harmon, "Community civil defense communications plan," *Electronics*, vol. 24, pp. 88–91; July, 1951.
(377) L. Geno, "Police and fire radio system at Buffalo," *FM-TV*, vol. 11, pp. 13–17; July, 1951.
(378) N. Monk, "Experimental radio telephone service for train passengers," Proc. I.R.E., vol. 39; pp. 873–881; August, 1951.
(379) "Train to dispatcher radio on the Northern Pacific," *Modern Railroads*, vol. 6, pp. 66–70; September, 1951.

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.

(380) L. P. Morris, "Equipment for 450 mc," *FM-TV*, vol. 11, pp. 26–28; March, 1951.
(381) L. A. Dorff, "Operational study of a highway mobile telephone system," *Elec. Eng.*, vol. 70; pp. 236–241; March, 1951.
(382) "450 mc mobile equipment," *FM-TV*, vol. 11, pp. 17, 38; May, 1951.
(383) "Electronic selective dispatcher permits private conversations," *Elec. Eng.*, vol. 70, p. 753; August, 1951.
(384) E. M. Webster, "Vehicular radio communication, Utilization and expansion," *Telegr. Teleph. Age.*, pp. 7–8, 10; December, 1951.

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.

(385) R. A. Beers, *et al.*, "Design of mobile two-way radio communication equipment at 152–174 mc," *Broadcast News*, pp. 56–65; January–February, 1951.
(386) D. E. Noble, "Improved communciation equipment for mobile use," *Tele.-Tech.*, vol. 10, pp. 36–39, 66–67; February, 1951.
(387) C. London, "Railway radio takes a new step," *Westinghouse Eng.*, vol. 11, pp. 47–49; March, 1951.
(388) H. H. Davids and T. J. Foster, "Crowded-band mobile equipment," *Electronics*, vol. 24, pp. 102–105; July, 1951.
(389) T. S. Eader, "Equipment performance specs.," *FM-TV*, vol. 11, pp. 22–24, 38–39; September, 1951.

Navigation Aids

General

The outstanding operational trend was the ascendance 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 aides, 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.

(390) "Air Traffic Control and the National Security," Air Co-ordinating Committee, Air Traffic Control and Navigation Panel, Superintendent of Documents, U. S. Gov't. Printing Office; December, 1950.
(391) D. W. Rentzel, "Air traffic control," *Aero. Eng. Rev.*, vol. 10, pp. 18, 21, 41; May 1951.

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.

(392) N. L. Harvey, "A new basis for the analysis of radio navigation and detection systems," *Sylvania Tech.*, vol. 3, pp. 15–18; October, 1950.

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.

(393) P. M. Woodward and I. L. Davies, "A theory of radar information," *Phil. Mag.*, vol. 41, pp. 1001–1017; October, 1950.
(394) C. E. Corum, "Signal-to-Noise Improvement by Pulse Integration," Report 3699, U. S. Naval Research Laboratory, Washington 25, D. C., 11 pp.; July, 1950.
(395) P. M. Woodward, "Information theory and the design of radar receivers," Proc. I.R.E., vol. 39, pp. 1521–1524; December, 1951.

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.

(396) S. M. Kaplan and R. W. McFall, "The statistical properties of noise applied to radar range performance," Proc. I.R.E., vol. 39, pp. 56–60; January, 1951.
(397) A. W. Ross, "Visibility of radar echoes," *Wireless Eng.*, vol. 28, pp. 79–92; March, 1951.

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

(398) V. C. Pineo and R. C. Peck, "A circuit for simultaneously recording the range, amplitude and duration of radar type reflections," *Rev. Sci. Instr.*, vol. 22, p. 112; February, 1951.

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.

(399) W. D. White, "The use of circular polarization as a means of reducing radar precipitation returns," Airborne Instrument Laboratory, Mineola, N. Y.

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.

(400) J. Freedman, "Resolution in radar systems," Proc. I.R.E., vol. 39, pp. 813–818; July, 1951.

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.

(401) C. E. Brockner, "Angular jitter in conventional conical-scanning, automatic-tracking radar systems," Proc. I.R.E., vol. 39, pp. 51–55; January, 1951.

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.

(402) J. W. Busby, "New crystal controlled radar beacon," *Tele.-Tech.*, vol. 10, pp. 24–26; January, 1951.
(403) R. S. Butts, "Miniature radar transponder beacon," *Electronics*, vol. 24, pp. 104–107; September, 1951.
(404) R. S. Styles, "Prevention of echo interference in double-pulse coded interrogator-responder systems," *Aust. Jour. Appl. Sci.*, vol. 2, pp. 26–42; March, 1951.

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.

(405) W. F. Marshall, "Microwave generators with crystal control," *Electronics*, vol. 24, pp. 92–95; November, 1951.

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.

(406) H. Tigler, "High voltage pulse modulators for radar pulse transmitters," *Arch. elekt.* (Ubertragung), vol. 5, pp. 47–51, 91–98; January-February, 1951.
(407) W. S. Melville, "The use of saturable reactors as discharge devices for pulse generators," *Proc. IEE* (London), vol. 98, pt. III, pp. 185–207; May, 1951.

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.

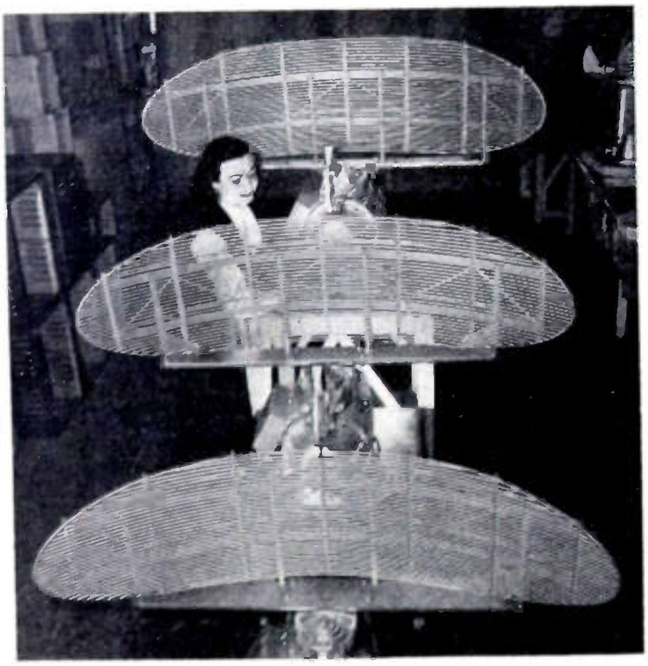

Fig. 16—Three shipboard radar antennas for 3.2-cm operation (RCA).

(408) E. J. Isbister and J. W. Busby, "Ramark beacons," *Navigation*, vol. 2, pp. 357–363; June, 1951.
(409) R. W. M. Braham, "Harbor radar systems," *Navigation*, vol. 2, pp. 371–374; June, 1951.
(410) C. E. Moore, "New developments in radar for merchant marine service," *RCA Rev.*, vol. 11, pp. 465–481; December, 1950.
(411) F. W. Garrett, "The design and application of a marine radar system," *Marconi Rev.*, vol. 14, pp. 23–38; 1st Quarter, 1951.
(412) J. A. Saxton and H. G. Hopkins, "Some adverse influences of meteorological factors on marine navigational radar," *Proc. IEE* (London), vol. 98, pt. III, pp. 26–36; January 1951.

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), 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.

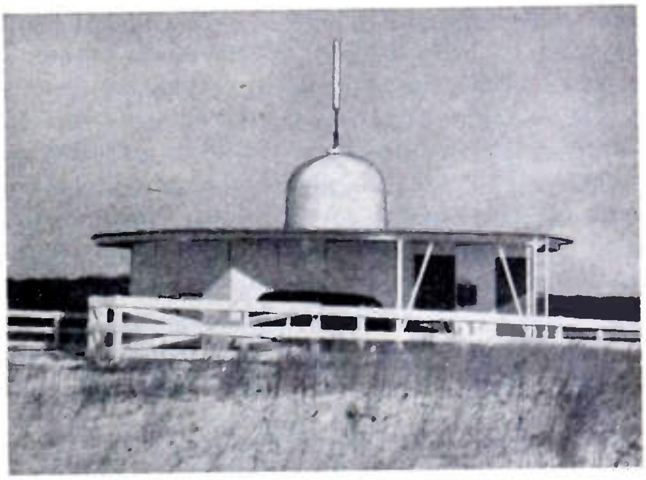

Fig. 17—First commercial installation of Model DTB, uhf, distance-measuring equipment (DME), installed at CAA omnidirectional station VOR, Wilton, Conn. The DME radiator mounts above the radome which houses the VOR antenna system. The DME, which includes duplicate transponders and monitors, operates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

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.

(413) "Summary Progress Report," Air Navigation Development Board, Washington, D. C., pp. 3, 4, 26, 27, 30, 31, 32; July, 1951.

A group of ten psychologists completed an investigation 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 men!

(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:

(415) L. R. Philpott, "The External Acceptance Rate of an Airport," ANDB Technical Memorandum 3; June 22, 1951.

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.

(416) S. M. Berkowitz, "Analysis of a Fixed-Block Terminal Area, Air Traffic Control System," Technical Report #F-2164-2, Franklin Institute, Philadelphia 3, Pa.; May 1, 1951.
(417) R. B. Coulson and V. D. Burgmann, "An investigation into air traffic control by a simulation method," *Jour. Inst. Nav.*, vol. 4, pp. 34–65; January, 1951.

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.

(418) "Evaluation of Navascreen," Report No. 145, Technical Development and Evaluation Center, Civil Aeronautics Administration, Indianapolis, Ind.; May 1951.

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.

(419) W. G. Tuller, "Application of the information theory to system design," *Elec. Eng.*, vol. 70, pp. 124–126; February, 1951.
(420) R. B. Adler and S. J. Fricker, "The Flow of Scheduled Air Traffic," Technical Report 198, Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, Mass.; May 2, 1951.
(421) "Evaluation of Proposed Air Traffic Control Procedures in the Washington Terminal Area by Simulation Techniques," Technical Development and Evaluation Center Report 147; July, 1951.

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.

(422) P. C. Sandretto, "Rho-theta system of air navigation," *Elec. Commun.* (London), vol. 27, pp. 268–276; December, 1950.
(423) D. O. Fraser, "The American plan for air traffic control," *Jour. Inst. Nav.*, vol. 4, pp. 214–231; July, 1951.
(424) R. C. Borden, C. C. Trout, and E. C. Williams, "Description and evaluation of 100-channel distance-measuring equipment," Proc. I.R.E., vol. 39, pp. 612–618; June, 1951.
(425) H. C. Hurley, S. R. Anderson, and H. F. Keary, "The Civil Aeronautics Administration omnirange," Proc. I.R.E., vol. 39, pp. 1506–1520; December, 1951.

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.

(426) W. R. Rambo, J. S. Prichard, D. P. Duffy, R. C. Wheeler, A. E. Dusseau, Jr., and S. Goldstein, "Final Report on Evaluation of Omni-bearing-Distance System of Air Navigation," Airborne Instruments Laboratory Reports 540-1 (Summary) and 540-2 (two volumes), Mineola, N. Y.; October, 1950.

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.

(427) "Mountain Top VOR Site Flight Tests," Technical Development and Evaluation Center Report 139, Civil Aeronautics Administration; March, 1951.

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 omnirange facility at several frequencies. A mathematical analysis shows that the errors can be reduced by such means or by frequency modulation.

(428) M. K. Goldstein, "Reduction of Reflection Errors in Certain Navigation Systems," Air Navigation Development Board Technical Memorandum 52, Washington 25, D. C.; May 15, 1951.

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.

(429) J. Lyman and G. B. Litchford, "Distance measuring equipment for the terminal area," *Aero. Eng. Rev.*, vol. 10, pp. 48–55; May, 1951.

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.

(430) D. G. Lindsay, J. P. Blom, and J. D. Gilchrist, "Distance-measuring equipment for civil aircraft," *Proc. I.R.E.* (Australia), vol. 11, pp. 307–315; December, 1950.

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.

(431) R. C. Borden, C. C. Trout, E. C. Williams, "Uhf Distance-Measuring Equipment for Air Navigation," TD-114, and "Evaluation of 100-Channel Distance-Measuring Equipment," TD-119, Civil Aeronautics Administration, Indianapolis, Ind.; 1951.

Development models of a pictorial computer for polar co-ordinate navigation were demonstrated. This instrument shows the pilot the position of his aircrart 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.

(432) "The TDEC Course Line and Pictorial Computer Programs," Technical Development and Evaluation Center Report 138, Civil Aeronautics Administration, Indianapolis, Ind.; May, 1951.

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.

(433) C. I. Aslakson and O. O. Fickeissen, "The effect of meteorological conditions on the measurement of long distances by electronics," *Trans. Amer. Geophys. Union*, vol. 31, pp. 816–826; December, 1950.

The Raydist system was further evaluated.

(434) F. S. Howell, "Experimental results of continuous-wave navigation systems," Proc. I.R.E., vol. 39, p. 841; July, 1951.
(435) W. D. Perrault, "Raydist traces planes path with pinpoint accuracy," *Amer. Aviation*, vol. 14, pp. 29–30; March 19, 1951.

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

(436) F. J. Hewitt, "A new method of testing the mark V Decca navigator receiver in high noise levels," *Trans. S. Afr. Inst. Elec. Eng.*, vol. 42, pp. 111–125; March, 1951.
(437) "Automatic course plotting," *Wireless World*, vol. 57, pp. 143–144; April, 1951.

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 (sonne) 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 band width 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.

(438) "Consol—a Radio Aid to Navigation," H.M. Stationery Office, London (MCAP 59); September-October, 1950.
(439) C. E. Ingalls, "Evaluation of Radio Set AN/FRN-5," A. F. Technical Report 6234, Rome Air Development Center, Rome, N. Y.; March, 1951.
(440) "Data Evaluation and Analysis of Radio Set AN/FRN-5," *Engineering School Bull.*, North Carolina State College, N. C., Contract W28-099 ac-434, Rome Air Development Center, Rome, N. Y.; July 15, 1951.
(441) "The Performance of the Consol System of Navigation in High Atmospheric Noise Levels," South African Council for Scientific and Industrial Research Report No. ETR-11, Telecommunications Research Laboratory, Pretoria, South Africa; March, 1951.

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 omnidirectional 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 cross-pointer 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.

(442) P. R. Adams and P. C. Sandretto, "Long Distance Navigation Requirements and the Navaglobe Developments," Presented, Institute of Navigation, Washington, D. C.; March 9, 1951.
(443) R. H. Woodward and O. Goldberg, "Radio Wave Propagation over Long Distances at 100 KC." Presented, Ithaca, N. Y.; September 9, 1951. Copies available from Rome Air Development Center, Rome, N. Y.

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.

(444) J. A. Blickensderfer, "Applications of Certain Statistical Concepts in Designing Selective Systems," Technical Report No. 7, Project on Low Frequency Navigation Systems, Electronics Research Laboratory, Stanford University, Calif.
(445) "Monthly Reports on Status of Research on Low Frequency Navigation Systems," Electronics Research Laboratory, Stanford University, Contract W28-099 ac-157, Rome Air Development Center, Rome, N. Y.; November, 1950–November, 1951.
(446) R. H. Myers, "Design of a loran transmitter," *Elec. Commun.* (London), vol. 28, pp. 31–45; March 1951.
(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.

(448) "Marine radio position fixing systems," *Jour. Inst. Nav.*, vol. 3, pp. 317–356; October, 1950.

Missile Guidance

A significant number of articles describing missile-guidance systems and problems were published.

(449) G. R. Urquhart, "Proportional radio control," *Aero Digest*, vol. 62, pp. 20, 21, 73, 74, 91; February, 1951.
(450) G. A. Long, "Missile guidance," *Navigation*, vol. 2, pp. 290–294; December, 1950.
(451) R. Drenick, "The perturbation calculus in missile ballistics," *Jour. Frank. Inst.*, vol. 251, pp. 423–436; April, 1951.
(452) S. Herrick, "Rocket Navigation," *Navigation*, vol. 2, pp. 259–272; December, 1950.
(453) J. C. Bellamy, "Instruments for upper atmosphere and interplanetary navigation," *Navigation*, vol. 2, pp. 272–275; December, 1950.

A discussion concerning the damping characteristics of components, such as stable platforms, integrating accelerometers, and the like, used in airborne navigational aids appeared.

(454) W. Wrigley, "Schuler tuning characteristics in navigational instruments," *Navigation*, vol. 2, pp. 282–290; December, 1950.

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.

(455) U. Tiberio, "Radar apparatus using the Doppler effect," *Elettroticnia*, vol. 38, pp. 266–278; June, 1951. (In Italian.)

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.

(456) "Summary Progress Report," Air Navigation Development Board, Washington, D. C., pp. 5, 12, 25; July 1, 1951.

The Civil Aeronautics Administration's Technical Development and Evaluation Center at Indianapolis explored the possibility of applying a vhf omnidirectional range as a terminal-area navigational aid by constructing a small, low-powered omnirange having its antenna array on the ground. A self-contained, battery-operated, crystal-controlled transmitter was developed to provide a marker signal for the terminal omnirange at points four or five miles from the airport. The marker signal is provided by heterodyning the omnirange carrier with a keyed signal from the transmitter. Tests were sufficiently successful so that additional installations are being planned.

A system for automatically tracking an aircraft in distance, azimuth, and elevation during its approach for a landing by utilizing the GCA radar outputs was completed and is being evaluated.

(457) J. T. McNaney, "Automatic GCA," *Electronics*, vol. 24, pp. 82–87; February, 1951.
(458) A. Moisson, "Blind landing control type A B," *Rev. tech. Comp. franc Thomson-Houston*, no. 15, pp. 5–18; 1951. (In French.)

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.

The first production unit of a new glide-slope transmitter was installed and tested at the Indianapolis Municipal Airport. This new equipment employs the null-reference antenna system developed at Technical Development and Evaluation Center. This improved antenna array provides a path in space that is only negligibly affected by heavy snowfall. With the null-reference antenna array, the response of the course-deviation indicator was found to be substantially improved, particularly when the airplane is below the glide path.

Substantial progress has been made in improving the performance of the vhf instrument-landing localizer through the use of antenna arrays with greatly increased directivity, thus minimizing the effects of spurious reflections. Apertures of the order of 80 to 100 feet are used. This results in a null pattern that has its maxima about 5 degrees either side of the central null. Three types of directive array have been used: (1) cylindrical paraboloid, one wavelength (or 9 feet high) with a quarter-wave rim and having a focal distance of 3/2 wavelength; (2) linear broadside array of 18 half-wave dipoles with back screen; (3) slotted waveguide broadside array with 18 probe-fed vertical slots.

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.

(459) J. H. Moon, "The development of the aircraft automatic radio compass," *Jour. Inst. Nav.*, vol. 3, pp. 393–403; October, 1950.

(460) J. Rhys Jones, "Instantaneous direction finding," *Electronic Eng.* (London), vol. 22, pp. 481–482; November, 1950.
(461) P. G. Hansel, "Polarization errors of radio direction finders; a proposed classification," PROC. I.R.E., vol. 39, p. 970; August, 1951.
(462) J. H. Moon, "Calibration of aircraft direction finders with particular reference to site selection," *Marconi Rev.*, pp. 101–112; 1951.
(463) W. Runge, M. Strohhacker, and A. Troost, "The 'Telegon' direction-finder," *Telefunken Ztg.*, vol. 24, pp. 75–81; June, 1951. (In German.)

Experiments with apparatus covering the band from 4 to 15 mc showed that with coaxial loops spaced 100 meters apart, each having a receiver carefully matched to the other, it was possible to measure the angle of arrival of radio waves reflected from the ionosphere to within one degree in the horizontal plane and to within one and a half degrees in the vertical plane so long as the arrival angle exceeded 30 degrees.

(464) W. Ross, E. N. Bramley, and G. E. Ashwell, "A phase-comparison method of measuring the direction of arrival of ionospheric radio waves," *Proc. IEE* (London), vol. 98, pt. III; pp. 294–302; July, 1951. (Paper 1134.)

Typical of the trend to extend direction-finding techniques to higher and higher frequencies was exploratory work in measuring the angle of arrival in the vertical plane of a complex wave in the microwave region. The arriving wave is a composite of the direct ray and the ground-reflected ray. Equipment used at 9,300 mc consisted of three separate antennas and receivers. The upper and lower antennas were separated at a vertical distance of 10 feet so that an angle of arrival of 0.01 degree gave a 6-degree phase difference. With the three separate sources, six parameters can be measured corresponding to the phase and amplitude at each point source. Since two must be used as reference, four relative quantities are measured so that sets of equations can be solved for angle of arrival and amplitude of direct and ground-reflected rays. This method gives promise of being able to measure low vertical angles of arrival with great precision, and may be useful for radar equipment.

(465) F. E. Brooks, Jr., "A receiver for measuring angle of arrival in a complex wave," PROC. I.R.E., vol. 39, pp. 407–411; April, 1951.
(466) K. Morita, "Direction finder and flow meter for centimeter waves," PROC. I.R.E., vol. 39, pp. 1529–1534; December, 1951.

Instruments

Considerable emphasis continued in the field of instrumentation of navigational and traffic-control devices. Most of the emphasis was on forms of display, arrangement of instruments, and comparison of meter-type pictorial displays for airborne use.

(467) O. W. Newmark, "Blind flying panels and instruments," *Jour. Inst. Nav.*, vol. 4, pp. 201–205; April, 1951.
(468) W. L. Webb, "Aircraft navigation instruments," *Elec. Eng.*, vol. 70, pp. 384–388; May, 1951.
(469) W. D. Perrault, "CAA to evaluate three pictorial computer designs," *Amer. Aviation*, vol. 14, pp. 30, 31, 33, 36; December 11, 1950.
(470) K. Witmer, "On modern radio navigation instruments," (in German), *Bull. schweiz. electrotech. Ver.*, vol. 42, pp. 125–135; March 10, 1951.

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.

(471) D. F. Martyn, "Theory of Magnetic Storms and Auroras," Presented, Ninth General Assembly, URSI, Zurich, Switzerland; September, 1950.

There also is a growing consciousness of the extraterrestrial factors, other than directly solar, that both 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 descend 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 measurements. 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.

(472) G. H. Munro, "Travelling disturbances in the ionosphere," *Proc. Roy. Soc. A*., vol. 202, pp. 208–223; 1950.
(473) M. Ryle and A. Hewish, "The effects of the terrestrial ionosphere on the radio waves from discrete sources in the galaxy," *Mon. Not. R. Astr. Soc.*, vol. 110, pp. 381–394; 1950.

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 F_2 region. The results indicate the presence of horizontal irregularities in the ionosphere or the failure of the ray-theory treatment at very oblique incidence.

(474) F. J. Kerr and C. A. Shain, "Moon echoes and transmission through the ionosphere," PROC. I.R.E., vol. 39, pp. 230–242; March, 1951.

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.

(475) A. Aspinall, J. A. Clegg, and G. S. Hawkins, "A radio echo apparatus for the delineation of meteor radiants," *Phil. Mag.*, vol. 42, pp. 504–514; 1951.
(476) D. W. R. McKinley, "Meteor velocities determined by radio observations," *Astrophys. Jour.*, vol. 113, pp. 225–227; March, 1951.
(477) J. Feinstein, "The interpretation of radar echoes from meteor trails," *Jour. Geophys. Res.*, vol. 56, pp. 37–51; March, 1951.
(478) L. A. Manning and M. E. Van Valkenberg, "The Polarization Characteristics of Meteoric Echoes," Presented, IRE-URSI Meetings, Cornell University, Ithaca, N. Y.; October 8–10, 1951.
(479) T. N. Gautier, "The Effect of Laminar Flow on the Duration of Meteor Echoes," Presented, IRE-URSI Meeting, Cornell University, Ithaca, N. Y., October 8–10, 1951.
(480) V. C. Pineo, "Experimental Determination of Rates of Decay of Meteoric Echoes as Functions of Wave Frequency and Height," Presented, IRE-URSI Meeting, Cornell University, Ithaca, N. Y.; October 8–10, 1951.

Ionospheric 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 $420/(\text{number of meteors})^{1/2}$ km per hour is calculated. So far, the results of this technique have shown only very rough correlation with the fading measurements.

(481) R. Greenstone, "Systematic Ionospheric Winds," Presented IRE-URSI Meeting, Cornell University, Ithaca, N. Y.; October 8–10, 1951; J. H. Chapman, "Fading of Radio Waves from the Ionosphere," Presented, IRE-URSI Meeting, Cornell University, Ithaca, N. Y.; October 8–10, 1951. Radio Physics Laboratory, Defence Research Board, Ottawa, Canada, Report 4; August 1, 1950.
(482) L. A. Manning and A. M. Peterson, "Meteoric Echo Measurement of Ionospheric Drift and Turbulence," Presented, IRE-URSI Meeting, Cornell University, Ithaca, N. Y.; October 8–10, 1951.

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 world-wide basis of optimum usable high-frequencies for ionospheric 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 ionospheric 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.

(483) T. N. Gautier, M. B. Harrington, and R. W. Knecht, "On the Question of the Magnitude of the Solar Lunal Variation in Radio Field Strength," Presented, IRE-URSI Meeting, Cornell University, Ithaca, N. Y.; October 8–10, 1951.
(484) A. F. Wilkins and C. M. Minnis, "Comparison of ionospheric radio transmission forecasts with practical results," *Proc. IEE* (London), vol. 98, pt. III, pp. 209–220; 1951.

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 ionospheric 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 semiweekly in September.

(485) D. V. Dickson, "Nomogram and slide-rule for solution of spherical triangle problems found in radio communications," *Jour. Geophys. Res.*, vol. 56, pp. 163–175; 1951.
(486) R. Naismith and R. Bailey, "An automatic ionospheric recorder for the frequency range 0.55-17 mc/s," *Proc. IEE* (London), vol. 98, pt. III, pp. 11–18; 1951. See also, R. Bailey, "Aperiodic aerials," *Wireless Eng.*, vol. 28, pp. 208–214; July, 1951. CRPL has now equipment designated Model C-3 and RPL has new equipment designated Model LG-17.
(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 *foF2* for each hour of zero meridian 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_o–f_z and f_x–f_o, 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.

(488) J. C. W. Scott, "The gyro-frequency in the arctic E-layer," *Jour. Geophys. Res.*, vol. 56, pp. 1–16; March, 1951.

In connection with the high-frequency utilization program, many apposite problems are being attacked. Many of these are potentially able to contribute to the knowledge of the physics of the ionosphere 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 character 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 ionospheric 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.
(491) W. G. Abel, "Use of Long-Distance Backscatter to Determine Skip Distance and Maximum Usable Frequency," Presented, IRE-URSI Meeting, Washington, D. C.; April 16–18, 1951.
(492) See, for example, W. Ross, E. N. Bramley, and G. E. Ashuell, "A phase comparison method of measuring the direction of arrival of ionospheric radio waves," *Proc. IEE* (London), vol. 98, pt. III, pp. 294–302; July, 1951. J. E. Hogarth, "Polarization of the Z-trace," *Nature* (London), vol. 167, p. 943; June 9, 1951. S. N. Mitra, "Anomalous behavior of multiply reflected echoes from the ionosphere," *Science and Culture* (Calcutta), vol. 16, pp. 425–426; 1951.

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

(493) I. J. Shaw, "Some further investigations of ionospheric cross-modulation," *Proc. Phys. Soc.*, (London), vol. 64, pp. 1–20; January, 1951.

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 at night. Daytime attenuation is high in the vicinity of 100 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.

(494) R. N. Bracewell, K. G. Budden, J. A. Ratcliffe, T. W. Straker, and K. Weekes, "The ionospheric propagation of low- and very-low-frequency radio waves over distances less than 1000 km," *Proc. IEE* (London), vol. 98, pt. III, pp. 221–236; May, 1951.
(495) C. Williams, "Low-frequency radio-wave propagation by the ionosphere, with particular reference to long-distance navigation," *Proc. IEE* (London), vol. 98, pt. III, pp. 81–103; 1951.
(496) F. F. Gardner, "The use of atmospherics to study the propagation of very long radio waves," *Phil. Mag.*, vol. 41, pp. 1259–1269; December, 1950. P. W. A. Bowe, "The waveforms of atmospherics and the propagation of very low frequency radio waves," *Phil. Mag.*, vol. 42, pp. 121–138; February, 1951.
(497) K. G. Budden, "The propagation of a radio atmospheric," *Phil. Mag.*, vol. 42, pp. 1–19; January, 1951.

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," "tweeks," 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.

(498) J. M. Watts and J. N. Brown, "Effects of ionosphere disturbances on low frequency propagation," *Jour. Geophys. Res.*, vol. 56, pp. 403–408; September, 1951.
(499) A. H. Benner, "Vertical-incidence ionosphere absorption at 150 kc," Proc. I.R.E., vol. 39, pp. 186–190; February, 1951.
(500) J. J. Gibbons and R. J. Nertney, "A method for obtaining the wave solutions of ionospherically reflected long waves, including all variables and their height variation," *Jour. Geophys. Res.*, vol. 56, pp. 355–371; September, 1951.

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.

(501) E. K. Smith, "The Effect of Sporadic E on Television Reception," Presented, IRE-URSI Meeting, Cornell University, Ithaca, N. Y.; October 8–10, 1951. Technical Report No. 7, Under Contract W36-039-sc-44518, Cornell University, Ithaca, N. Y.; October 1, 1951.

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—

Ottawa) reports auroral echoes at angles above 15 degrees on 56 mc and from overhead on 33 mc, and greater absorption should be expected on these frequencies. Because of the magnetic dip angle in southern Canada, a radio wave leaving at 15 degrees above the horizontal would be approximately normal to the auroral ray structure which aligns itself with the earth's magnetic field. Thus 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.)

indicate that the ionosphere may reflect under conditions in which penetration would normally be expected.

(502) H. G. Booker, J. A. Ratcliffe, and H. D. Shim, "Diffraction from an irregular screen with applications to ionospheric problems," *Phil. Trans. A*, vol. 242, pp. 579–607; September 12, 1950.

(503) H. G. Booker and W. E. Gordon, "A theory of radio scattering in the troposphere," Proc. I.R.E., vol. 38, pp. 401–412; April, 1950.

(504) A. H. LaGrone, W. H. Benson, Jr., and A. W. Straiton, "Attenuation of radio signals caused by scattering," *Jour. Appl. Phys.*, vol. 22, pp. 672–674; 1951.

(505) W. Dieminger, "The scattering of radio waves," *Proc. Phys. Soc.* (London), vol. 64, pp. 142–158; 1951.

(506) W. Pfister, "Magneto-ionic Multiple Splitting Determined with the Method of Phase Integration," Presented, IRE-URSI Meeting, Washington, D. C.; April 16–18, 1951.

(507) G. Millington, "The effect of the earth's magnetic field on short-wave communication by the ionosphere," *Proc. IEE* (London), vol. 98, pt. IV, pp. 1–14; October, 1951.

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.

(508) For example, C. O. Hines, "Wave packets, the poynting vector, and energy flow, Part I—non-dissipative (anisotropic) homogeneous media, Part II—Group propagation through dissipative isotropic media, Part III—packet propagation through dissipative anisotropic media," *Jour. Geophys. Res.*, vol. 56, pt. I, pp. 63–72; vol. 56, pts. II and III, pp. 197–220; 1951.

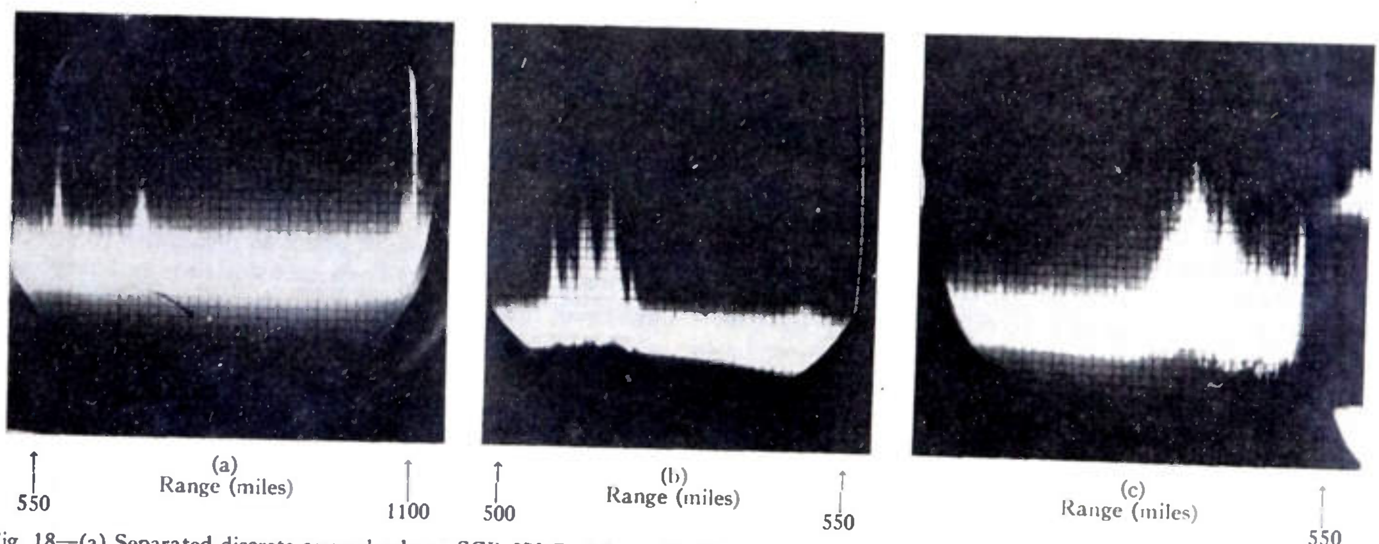

Fig. 18—(a) Separated discrete auroral echoes. SCR-270-D. Ithaca, N. Y., September 10, 1951. 0850 EDST. (b) Clustered discrete auroral echoes. SCR-270-D. Ithaca, N. Y., September 10, 1951. 0320 EDST. (c) Diffuse auroral echo. SCR-270-D. Ithaca, N. Y., September 10, 1951. 0300 EDST.

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

Tropospheric Propagation

Propagation Well Beyond the Horizon. The center of interest in this subject continued to be the attempts made 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.

(509) E. C. S. Megaw, "Scattering of electromagnetic waves by atmospheric turbulence," *Nature* (London), vol. 166, pp. 1100–1105; December 30, 1950.

These observations extend to greater ranges the phenomenon first discovered by Katzin 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."

(510) M. Katzin, "Signal Fluctuation in Long-Range Over-Water Propagation," Symposium on Tropospheric Wave Propagation, Naval Electronics Report 173, San Diego, Calif., pp. 94–97.

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.

(511) J. Feinstein, "Tropospheric propagation beyond the horizon," *Jour. Appl. Phys.*, vol. 22, pp. 1292–1293; October, 1951.

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

(512) H. Bremmer, "The propagation of electromagnetic waves through a stratified medium and its WKB approximation for oblique incidence," *Physica*, vol. 15, pp. 593–608; August, 1949.

(513) H. Bremmer, "WKB approximation as the first term of a geometric-optical series," *Commun. Pure and Appl. Math.*, vol. 4, pp. 105–115; June, 1951.

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.

(514) J. A. Saxton, "The propagation of metre radio waves beyond the normal horizon," *Jour. IEE* (London), vol. 98, pt. III, pp. 360–382; September, 1951.

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

(515) A. W. Straiton, D. F. Metcalf, and C. W. Tolbert, "A study of tropospheric scattering of radio waves," Proc. I.R.E., vol. 39, pp. 643–648; June, 1951.

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."

(516) I. H. Gerks, "Propagation at 412 megacycles from a high-power transmitter," Proc. I.R.E., vol. 39, pp. 1374–1382; November, 1951.

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.

(517) G. Birnbaum, "Fluctuations in the refractive index of the atmosphere at microwave frequencies," *Phys. Rev.*, vol. 82, pp. 110–111; April 1, 1951.

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.

Mathematical Theory. Volume 13 of the Radiation Laboratory series, "The Propagation of Short Radio Waves," a series of theoretical papers, originally presented at a symposium on electromagnetic waves at New York University in June, 1950, appeared in the quarterly, *Communications on Pure and Applied Mathematics*. The latter also carried more than 10 papers having application to the theory of tropospheric propagation.

(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.

(519) H. G. Booker and P. C. Clemmow, "The concept of an angular spectrum of plane waves, and its relation to that of polar diagram and aperture distribution," *Jour. IEE* (London), vol. 97, pt. III, pp. 11–17; January, 1950.

(520) H. G. Booker and P. C. Clemmow, "A relation between the Sommerfeld theory of radio propagation over a flat earth and the theory of diffraction at a straight edge," *Jour. IEE* (London), vol. 97, pt. III, pp. 18–27; January, 1950.

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.

(522) H. Fine, "UHF propagation within line of sight," Federal Communications Commission TRR Report 2.4.12; June 1, 1951. Gerks gave statistical summaries of space variability of fields at 412 mc in Iowa.

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

(523) C. I. Aslakson, "A new measurement of the velocity of radio waves," *Nature* (London), vol. 168, pp. 505–506; September 22, 1951.

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.

(524) J. A. Bearden and H. M. Watts, "A re-evaluation of the fundamental atomic constants," *Phys. Rev.*, vol. 81, pp. 73–81; January, 1951.

(525) J. W. M. DuMond and E. R. Cohen, "Least-squares adjusted values of the constants as of December, 1950," *Phys. Rev.*, vol. 82, pp. 555–556; May 15, 1951.

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.

(527) J. P. Hagen, "Temperature gradient in the sun's atmosphere measured at radio frequencies," *Ap. Jour.*, vol. 113, pp. 547–566; May, 1951.

(528) J. H. Piddington, "The derivation of a model solar chromosphere from radio data," *Proc. Roy. Soc. A.*, vol. 203, pp. 417–434; October 10, 1950.

(529) J. C. Jaeger and K. C. Westfold, "Equivalent path and absorption for electromagnetic radiation in the solar corona," *Aust. Jour. Sci. Res. A.*, vol. 3, pp. 376–386; September, 1950.

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.

(530) A. E. Covington, "Some characteristics of 10.7-centimetre solar noise," *Jour. Roy. Astron. Soc.* (Canada), vol. 45, pt. I, pp. 15–22; January–February, 1951; pt. II, pp. 49–61; March–April, 1951.

(531) W. N. Christiansen and J. V. Hindman, "A long-period change in radio-frequency radiation from the 'quiet' sun at decimetre wave-lengths," *Nature* (London), vol. 167, pp. 635–637; April 21, 1951.

(532) K. E. Machin, "Distribution of radiation across the solar disk at a frequency of 81.5 Mc/s," *Nature* (London), vol. 167, pp. 889–891; June 2, 1951.

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.

(533) S. F. Smerd, "The polarization of thermal 'solar noise' and a determination of the sun's general magnetic field," *Aust. Jour. Sci. Res. A.*, vol. 3, pp. 265–273; June, 1950.

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.

(534) "Meeting of the Royal Astronomical Society," *Observatory*, vol. 70, pp. 55–62; April, 1950.

(535) J. P. Wild and L. L. McCready, "Observations of the spectrum of high-intensity solar radiation at metre wavelengths," *Aust. Jour. Sci. Res. A.*, vol. 3, pts. 1 and 2, pp. 387–408; September, 1950; pt. 3, pp. 541–557; December, 1950; vol. 4, pt. 4, pp. 36–50; March, 1951.

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.

(536) F. T. Haddock, C. H. Mayer, T. P. McCullough, R. White, and R. M. Sloanaker, "The measurement of 3 and 10 centimeter radiation during the total solar eclipse of September 12, 1950," *Astron. Jour.*, vol. 56, pp. 38–39; April 1951.

(537) J. P. Hagen, "Naval Research Laboratory eclipse expedition to Attu, Alaska, September 12, 1950," *Astron. Jour.*, vol. 56, pp. 39–40; April, 1951.

(538) G. Reber and E. Beck, "The measurement of 65 centimeter radiation during the total eclipse of September 12, 1950," *Astron. Jour.*, vol. 56, p. 47; April, 1951.

(539) T. Hatanaka, S. Suzuki, and F. Moriyama, "Preliminary Report on the Observation of the Solar Radio Noise at the Partial Eclipse on September 12, 1950," Issued by Eclipse Committee, Science Council of Japan, 1951, Reprinted as Tokyo Astronomical Observatory Reprint 79.

(540) J. P. Hagen, F. T. Haddock, and G. Reber, "NRL Aleutian radio eclipse expedition," *Sky and Telescope*, vol. 10, pp. 109, 111–113; March, 1951.

(541) M. Laffineur, R. Michard, R. Servajean, and J. L. Steinberg, "Observations radioélectriques de l'éclipse de soleil du 28

Avril 1949," *Ann. d'Astrophys.*, vol. 13, pp. 337–342; July–September, 1950; Reprinted as a contribution to *I.A.P.B.* 53.

An instrument was developed by Payne-Scott and Little that determines automatically the place of origin and polarization of a burst at 100 mc.

(542) R. N. Bracewell, "An instrumental development in radio astronomy," *Observatory*, vol. 70, pp. 185–186; October, 1950.

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

(543) É. J. Blum and J. F. Denisse, "Comparaison des rayonnements radioélectriques reçus de soleil sur deux fréquences voisines," *Compt. Rend.* (Paris), vol. 231, pp. 1214–1216; November 27, 1950.
(544) É. J. Blum, J. F. Denisse, and J. L. Steinberg, "Étude des orages radioélectriques solaires de faible intensité," *Compt. Rend.* (Paris), vol. 232, pp. 387–389; January 29, 1951.
(545) É. J. Blum, J. F. Denisse, and J. L. Steinberg, "Sur l'intreprétation des sursauts radioélectriques solaires," *Compt. Rend.* (Paris), vol. 232, pp. 483–485; February 5, 1951.
(546) W. N. Christiansen, J. V. Hindman, A. G. Little, R. Payne-Scott, D. E. Yabsley, and C. W. Allen, "Radio observations of two large solar disturbances," *Aust. Jour. Sci. Res. A.*, vol. 4, pp. 51–61; March, 1951.
(547) J. H. Piddington and H. C. Minnett, "Solar radio-frequency emission from localized regions at very high temperatures," *Aust. Jour. Sci. Res. A.*, vol. 4, pp. 131–157; June, 1951.
(548) M. A. Ellison, "Source points of radio noise bursts associated with solar flares," *Nature* (London), vol. 167, pp. 941–942; June 9, 1951.
(549) A. E. Covington, "Circular polarization of 10.7-centimetre solar noise bursts," *Jour. Roy. Astron. Soc.* (Canada), vol. 45, pp. 157–161; July–August, 1951.
(550) A. Maxwell, "Radio emission from the sunspot of central meridian passage 1950 June 14," *Observatory*, vol. 71, pp. 72–74; April, 1951.
(551) G. Reber, "Motion in the solar atmosphere as deduced from radio measurements," *Science*, vol. 113, pp. 312–314; March 23, 1951.
(552) T. Hatanaka, Y. Sekido, Y. Miyazaki, and M. Wada, "Solar Radio Outburst and Increase of Cosmic-Ray Intensities on September 20, 1950," Report on Ionosphere Research in Japan, vol. 5; 1951; Reprinted, Tokyo Astronomical Observatory Reprint 80.
(553) J. F. Denisse, "Contribution á l'étude des émissions radio-électriques solaires," *Ann. d'Astrophys.*, vol. 13, pp. 181–202; April–June, 1950.
(554) B. Kwal, "Les ondes électromagnétiques émises par les protons rapides dans les champs magnétiques intenses, et la corrélation entre le rayonnement cosmique et les *bruits* radio-électriques du soleil et de la galaxie," *Compt. Rend.* (Paris), vol. 231, pp. 1057–1059; November 13, 1950.
(555) K. C. Westfold, "The interpretation of the magneto-ionic theory," *Jour. Atmos. Terr. Phys.*, vol. 1, pp. 152–186; 1951.
(556) B. Kwal, "Sur le rayonnement électromagnétique des protons cosmiques dans les champs magnétiques intenses des objets célestes," *Jour. Phys. Radium*, vol. 12, pp. 66–67; January, 1951.
(557) B. Kwal, "Sur une possibilité d'interpréter les 'bruits' radio-électriques du soleil et de la galaxie comme rayonnement des protons des radiations cosmiques dans les champs magnétiques intenses du soleil et des autres objects célestes," *Ann. d'Astrophys.*, vol. 14, pp. 189–198; May–June, 1951.
(558) V. A. Bailey, "The relativistic theory of electro-magneto-ionic waves," *Phys. Rev.*, vol. 83, pp. 439–454; July 15, 1951.
(559) J. Feinstein and H. K. Sen, "Radio wave generation by multi-stream charge interaction," *Phys. Rev.*, vol. 83, pp. 405–412; July 15, 1951.
(560) S. F. Smerd, "A radio-frequency representation of the solar atmosphere," *Proc. IEE* (London), vol. 97, pt. III, pp. 447–452; November, 1950.
(561) Y. Rocard, "Sur un mécanisme d'émission radioélectrique coronale," *Compt. Rend.* (Paris), vol. 232, pp. 598–600; February 12, 1951.
(562) S. A. Korff and Y. Beers, "The solar atmosphere and the origin of radiofrequency radiation," *Phys. Rev.*, vol. 80, pp. 489–490; November 1, 1950.
(563) U. C. Guha, "Reversal of polarization of microwaves from sun-spots," *Indian Jour. Phys.*, vol. 25, pp. 8–16; January, 1951. Also, *Proc. Indian Assoc. Cultivation Sci.*, no. 34.
(564) C. deJager, M. Minnaert, and C. A. Muller, "Absence of hydrogen radiation of wavelength 21 cm. in the sun," *Nature* (London), vol. 168, p. 391; September 1, 1951.
(565) J. F. Denisse, J. L. Steinberg, and S. Zisler, "Contrôle de l'activité géomagnétique par les centres d'activité solaires distingués par leurs propriétés radioélectriques," *Compt. Rend.* (Paris), vol. 232, pp. 2290–2292; June 18, 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.

(566) M. Ryle, F. G. Smith, and B. Elsmore, "A preliminary survey of the radio stars in the Northern Hemisphere," *Mon. Not. R. Astr. Soc.*, vol. 110, pp. 508–523; 1950.
(567) F. G. Smith, "An accurate determination of the positions of four radio stars," *Nature* (London), vol. 168, pp. 555; September 29, 1951.
(568) M. Ryle, "Radio astronomy," *Rep. Progr. Phys.* (London), vol. 13, pp. 184–246; 1950.
(569) M. Ryle and B. Elsmore, "A search for long-period variations in the intensity of radio stars," *Nature* (London), vol. 168, pp. 555–556; September 29, 1951.
(570) B. Y. Mills and A. B. Thomas, "Observations of the source of radio-frequency radiation in the constellation of Cygnus," *Aust. Jour. Sci. Res. A.*, vol. 4, pp. 158–171; June, 1951.
(571) M. Ryle and A. Hewish, "The effects of the terrestrial ionosphere on the radio waves from discrete sources in the galaxy," *Mon. Not. R. Astr. Soc.*, vol. 110, pp. 381–394; 1950.
(572) C. L. Seeger, "Some observations of the variable 205 mc/s radiation of Cygnus A," *Jour. Geophys. Res.*, vol. 56, pp. 239–258; June, 1951.
(573) G. J. Stanley and O. B. Slee, "Galactic radiation at radio frequencies, Part 2, The discrete sources," *Aust. Jour. Sci. Res. A.*, vol. 3, pp. 234–250; June, 1950.
(574) C. L. Seeger and R. E. Williamson, "The pole of the galaxy as determined from measurements at 205 mc.sec.," *Ap. Jour.*, vol. 113, pp. 21–49; January, 1951.
(575) C. W. Allen and C. S. Gum, "Survey of galactic radio-noise at 200 mc/s.," *Aust. Jour. Sci. Res. A.*, vol. 3, pp. 224–233; June, 1950.

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.

(576) J. G. Bolton and K. C. Westfold, "Galactic radiation at radio frequencies, Part 3. Galactic structure," *Aust. Jour. Sci. Res. A.*, vol. 3, pp. 251–264; June, 1950.
(577) G. Westerhout and J. H. Oort, "A comparison of the intensity distribution of radio-frequency radiation with a model of the galactic system," *B.A.N.*, vol. 11, pp. 323–333; August 26, 1951.
(578) A. Unsold, "Cosmic radiation and cosmic magnetic fields, Part 1. Origin and propagation of cosmic rays in our galaxy," *Phys. Rev.*, vol. 82, pp. 857–863; June 15, 1951.
(579) V. L. Ginzburg, "Cosmic rays as a source of galactic radio-radiation," *Doklady Akademiia Nauk S.S.S.R.*, vol. 76, pp. 377–380; 1951.
(580) H. I. Ewen, E. M. Purcell, C. A. Muller, J. H. Oort, and J. L. Pawsey, "Observation of a line in the galactic radio spectrum," *Nature* (London), vol. 168, pp. 356–358; September 1, 1951.

Antennas, Waveguides, and Transmission Lines

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

(581) S. S. Attwood, "Surface wave propagation over a coated plane conductor," *Jour. Appl. Phys.*, vol. 22, pp. 504–509; April, 1951.
(582) G. Goubau, "Single-conductor surface-wave transmission line," Proc. I.R.E., vol. 39, pp. 619–624; June, 1951.

Rectangular and circular waveguides having two dielectrics were treated theoretically.

(583) A. Banos, Jr., D. S. Saxon, and H. Gruen, "Propagation characteristics in a coaxial structure with two dielectrics," *Jour. Appl. Phys.*, vol. 22, pp. 117–123; February, 1951.
(584) J. van Bladel and T. J. Higgins, "Cut-off frequency in two-dielectric layered rectangular waveguides," *Jour. Appl. Phys.*, vol. 22, pp. 329–334; March, 1951.

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

(585) W. Sichak and H. Augenblick, "Tunable waveguide filter," Proc. I.R.E., vol. 39, pp. 1055–1059; September, 1951.

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

(586) D. M. Kearns, "Analysis of symmetrical waveguide junctions," *Jour. Res. Natl. Bur. Stand.*, vol. 46, pp. 267–282; April, 1951.
(587) F. Bolinder, "Approximate theory of the directional coupler," Proc. I.R.E., vol. 39, p. 291; March, 1951.

Two quite different types of delay lines were described.

(588) E. M. Bradburd, "Magnetostrictive delay line," *Elec. Commun.* (London), vol. 28, pp. 46–53; March, 1951.
(589) A. N. Wang, "Magnetic delay-line storage," Proc. I.R.E., vol. 39, pp. 401–407; April, 1951.

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

(590) A. M. Clogston, "Reduction of skin-effect losses by the use of laminated conductors," Proc. I.R.E., vol. 39, pp. 767–782; July, 1951.

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.

(591) J. E. Storer and R. King, "Radiation resistance of a two-wire line," Proc. I.R.E., vol. 39, pp. 1408–1412; November, 1951.
(592) F. M. Leslie, "Radiation from resonant quarter-wave transmission lines," *Wireless Eng.*, vol. 28, pp. 70–72; March, 1951.

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

(593) A. E. Laemmel, N. Marcuvitz, and A. A. Oliner, "Approximation methods in radial transmission-line theory with applications to horns," Proc. I.R.E., vol. 39, pp. 959–965; August, 1951.
(594) H. Meinke, "The behavior of electromagnetic waves in highly nonuniform lines," *Z. angew. Phys.*, vol. 22, pp. 473–478; December, 1950.
(595) H. A. Wheeler, "Transmission-line impedance curves," Proc. I.R.E., vol. 39, pp. 1400–1403; December, 1950.
(596) H. E. Sorrow, W. E. Ryan, and R. C. Ellenwood, "Evaluation of coaxial slotted-line impedance measurements," Proc. I.R.E., vol. 39, pp. 162–168; February, 1951.

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

(597) E. D. Hartig, R. King, T. Morita, D. G. Wilson, "The measurement of antenna impedance using a receiving antenna," Proc. I.R.E., vol. 39, p. 1459; November, 1951.
(598) T. Morita, "Theory of the Concentric-Slot Antenna," Presented, IRE National Convention, New York, N.Y.; March, 1951.
(599) J. V. N. Granger and T. Morita, "Radio-frequency current distribution on aircraft structures," Proc. I.R.E., vol. 39, pp. 932–938; August, 1951.
(600) R. King, "Theory of collinear antennas," *Jour. Appl. Phys.*, vol. 21, pp. 1232–1251; December, 1950.
(601) C. H. Papas and R. King, "Radiation from wide-angle conical antennas fed by a coaxial line," Proc. I.R.E., vol. 39, pp. 49–51; January, 1951.

Industrial Electronics

Professional Growth

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

(602) R. R. Benedict, "Introduction to Industrial Electronics," Prentice-Hall, New York, N. Y.; 1951.
(603) J. M. Cage, "Theory and Application of Industrial Electronics," McGraw-Hill Book Co., Inc., New York, N. Y.; 1951.
(604) D. P. Eckman, "Industrial Instrumentation," John Wiley and Sons, Inc., New York, N. Y.; 1951.
(605) J. D. Trimmer, "Response of Physical Systems," John Wiley and Sons, Inc., New York, N. Y.; 1951.
(606) R. C. Walker, "The Industrial Application of Gas-filled Triodes (Thyratrons)," Chapman and Hall, London; 1951.
(607) G. M. Chute, "Electronic Motor and Welder Controls," McGraw-Hill Book Co., Inc., New York, N. Y.; 1951.

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.

(608) L. Hartshorn, "Radio-Frequency Heating," George Allen and Unwin, Ltd., London; 1949.
(609) L. L. Langton, "Radio-Frequency Heating Equipment," Pitman Publishing Co., New York, N. Y.; 1949.
(610) F. W. Curtis, "High-Frequency Induction Heating," McGraw-Hill Book Co., Inc., New York, N. Y., 2nd Ed.; 1950.
(611) H. F. Trewman, ed., "Electronics in the Factory," Pitman Publishing Co., Ltd., London; 1949.

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.

(612) R. E. Lafferty, "Extended Q-meter measurements," *Electronics*, vol. 24, p. 125; November, 1951.
(613) A. Colombani, "Induction heating of a hollow sphere," *Jour. Phys. Radium*, vol. 12, pp. 26–30; January, 1951.

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.

(614) "Digest of the Literature on Dielectrics," vol. 14, National Academy of Sciences, National Research Council; March, 1951.
(615) "1950 Annual Report of the Conference on Electrical Insulation," National Research Council; March, 1951.

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.

(616) A. D. N. Smith, "An electronic instrument for the measurement of the damping capacity of materials," *Jour. Sci. Instr.*, vol. 28, pp. 106–108; April, 1951.
(617) M. Andrieux and M. Fraize, "Instrument for production test of permeability of magnetic circuits," *Onde Elect.*, vol. 31, pp. 65–69; February, 1951.

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 10^6 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.

(618) J. G. Miles, "Bibliography of Magnetic Amplifier Devices and the Saturable Reactor Art," Technical Paper 50-388; Presented, American Institute of Electrical Engineers Fall Meeting, Cleveland, Ohio; 1951.
(619) R. A. Ramey, "On the mechanics of Magnetic Amplifier Operation," Technical Paper 50-217, Presented, American Institute of Electrical Engineers Summer Meeting, Toronto, Canada; 1951.
(620) R. A. Ramey, "On the Control of Magnetic Amplifiers," Technical Paper 51-389, Presented, American Institute of Electrical Engineers Fall Meeting, Cleveland, Ohio; 1951.
(621) L. A. Pipes, "Steady-State and Transient Analysis of an Idealized Series Connected Magnetic Amplifier," Technical Paper 51-390, Presented, American Institute of Electrical Engineers, Fall Meeting, Cleveland, Ohio; 1951.

The Pipes' 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.

(622) S. B. Cohen, "Analysis and design of self-saturable magnetic amplifiers," Proc. I.R.E., vol. 39, pp. 1009–1020; September, 1951.

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 importance 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:

(624) R. H. Strotz, J. F. Calvert, and N. F. Morehouse, "Analog computing techniques applied to economics," AIEE Paper 51-93, *Trans. AIEE;* 1951.
(625) B. Lippel, "A High-Precision Analog to Digital Converter," Proceedings of National Electronic Conference; 1951.
(626) A. A. Gerlach, R. E. Zenner, and C. N. Pederson, "A Precise Electronic Function Generator," Proceedings of National Electronic Conference; 1951.
(627) J. F. Reintijes, "An Analogue Electronic Correlator," Proceedings of National Electronic Conference; 1951.
(628) J. H. Neher, "The determination of temperature transients in cable systems by means of an analog computer," AIEE Paper 51-253. *Trans. AIEE.;* 1951.
(629) W. Pagels, "A portable electronic pile simulator," AIEE Paper 51-262, *Trans. AIEE;* 1951.
(630) J. Winson, "Solution of aeroelastic problems by electronic analogue computation," *Jour. Aero. Sci.;* July, 1950; January, 1951.
(631) "Inexpensive analog computer developed by the Boeing Airplane Co.," *Electronics*, vol. 24, p. 124; February, 1951.
(632) W. B. Boost and J. D. Rector, "An electric analog method for the direct determination of power system stability swing curves," AIEE Paper 51-338, *Trans. AIEE;* 1951.
(633) S. Bosworth, "New analog computer; IDA" (for integro differential analyzer), *Electronics*, vol. 24, p. 216; August, 1951.
(634) F. R. Smith, "Automatic stabilization of high impedance d-c amplifiers," *Electronics*, vol. 24, p. 124; February, 1951.
(635) "Sixty second genius: Project typhoon," *Aero Digest;* January, 1951; *Electronics*, vol. 24, p. 138; April, 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:

(636) Staff of the (Harvard) Computation Laboratory, "Synthesis of Electronic Computing and Control Circuits," Harvard University Press, Cambridge, Mass., p. 278; 1951.

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:

(637) A. D. Booth, "The physical realization of an electronic digital computer," *Elec. Eng.* (London), vol. 22, pp. 492–498; December, 1950.
(638) F. C. Williams, T. Kilburn, and G. C. Tootill, "Universal high-speed digital computers: small scale experimental machine," *Proc. IEE* (London), vol. 98, pt. 2, pp. 13–28; February, 1951.
(639) D. H. Gridley and B. L. Sarahan, "Design of the naval research laboratory computer," *Elec. Eng.* (London), vol. 70, p. 111; February, 1951.
(640) M. Woodger, "Automatic computing engine of the national physical laboratory," *Nature* (London), vol. 167, pp. 270–271; February 17, 1951.
(641) R. Stuart-Williams, "Nimrod," *Elec. Eng.* (London), vol. 23, pp. 344–348; September, 1951.
(642) R. C. M. Barnes, E. H. Cooke-Yarborough, and D. G. A. Thomas, "An electronic digital computer, part 1," *Elec. Eng.* (London), vol. 23, pp. 286–291; August, 1951; part 2, pp. 341–343; September, 1951.
(643) G. Kjellberg and G. Neovius, "The BARK, a Swedish general-purpose relay computer," *Math. Tables and Aids to Calc.*, vol. 5, pp. 29–34; January, 1951.
(644) P. L. Morton, "The California digital computer," *Math. Tables and Aids to Calc.*, vol. 5, pp. 57–61; April, 1951.

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.

Fig. 19—The Graphechon, "visual memory tube," stores and amplifies weak but brief signal, such as oscilloscope traces or radar "pips" for as long as a minute (RCA).

(645) M. Kincaid, J. M. Adden, and R. B. Hanna, "Static magnetic memory for low-cost computers," *Electronics*, vol. 24, pp. 108–111; January, 1951.
(646) J. W. Forrester, "Digital information storage in three dimensions using magnetic cores," *Jour. Appl. Phys.*, vol. 22, pp. 44–48; January, 1951.
(647) An Wang, "Magnetic delay-line storage," Proc. I.R.E., vol. 39, pp. 401–407; April, 1951.

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

(648) "Standards on electronic computers: definitions of terms," Proc. I.R.E., vol. 39, pp. 271–277; March, 1951.

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 Lutzker, while many of the others apply equally well to both objectives.

(649) J. A. Davies, "Quality Evaluation of General Electric Company's ARINC Tubes," Quality Control Conference Papers 1951, Presented, Convention, American Society for Quality Control, Cleveland, Ohio, p. 89; May 23–24, 1951.

(650) E. B. Farrell, "The control chart as a tool for analyzing experimental data," Proc. I.R.E., vol. 39, pp. 132–137; February, 1951.

(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.

(652) E. M. Jeffery, "Quality control in tube and component or accessory manufacture," *Telev. Eng.*, vol. 1, p. 40; November, 1950.

(653) J. M. Juran, "Quality-Control Handbook," McGraw-Hill Book Co., Inc., New York, N. Y., Section 13, pp. 653–680.

(654) L. Lutzker, "Quality control in TV receiver production," *Telev. Eng.*, vol. 1, p. 6; February, 1950.

(655) L. Lutzker, "Statistical methods in research and development," Proc. I.R.E., vol. 38, p. 1253; November, 1950.

(656) E. M. McElwee, "Statistical evaluation of life expectancy of vacuum tubes designed for long-life operation," Proc. I.R.E., vol. 39, pp. 137–141; February, 1951.

Instrumentation

Audio-Frequency Measurements

Measurements of the amplitude and phase of the motion of some dynamic loudspeaker cones, explored by a capacitor-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.

(657) M. S. Corrington and M. C. Kidd, "Amplitude and pulse measurements on loudspeaker cones," Proc. I.R.E., vol. 39, pp. 1021–1026; September, 1951.

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.

(658) H. F. Olson and D. F. Pennie, "An automatic nonlinear distortion analyzer," *RCA Rev.*, vol. 12, pp. 35–44; March, 1951.

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.

(659) A. P. G. Peterson, "Intermodulation distortion," *Gen. Rad. Exper.*, vol. 25, pp. 1–8; March, 1951.

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.

(660) J. C. R. Licklider and R. Held, "Effects of various types of nonlinear distortion upon the intelligibility of speech," Presented, Acoustical Society of America, Chicago, Ill.; October 23, 1951.

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.

(661) L. L. Beranek, J. L. Marshall, A. L. Cudworth, and A. P. G. Peterson, "Calculation and measurement of the loudness of sounds," *Jour. Acous. Soc. Amer.*, vol. 23, pp. 261–260; May, 1951.

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.

(662) C. G. Mayo and D. G. Beadle, "Equipment for acoustic measurements," *Elec. Eng.* (London), vol. 23, pt. 2, pp. 368–373; October, 1951.

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.

(663) K. D. Kryter, "The effects of noise on man," *Jour. Speech and Hearing Disorders*, Monograph Supplement 1; September, 1950.

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.

(664) L. L. Beranek, "Noise Control in Office and Factory Spaces," Transactions of Chemical Engineering Conferences, Bulletin 18, Industrial Hygiene Foundation of America, Pittsburgh, Pa., pp. 26–33; 1951.

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.

(665) P. K. Jurgen, "Sound waves test cylinder heads," *Electronics*, vol. 24, pp. 90–91; October, 1951.
(666) O. V. Riley, "Precision measurement of shaft speeds," *Electronics*, vol. 24, pp. 104–105; October, 1951.
(667) R. D. Kodis and R. Shaw, "Crawler detects gun-barrel cracks," *Electronics*, vol. 24, pp. 92–95; October, 1951.

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.

(668) H. A. Samulon, "Spectrum analysis of transient response curves," Proc. I.R.E., vol. 39, pp. 175–186; February, 1951.

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

(669) W. H. Ward, M. H. Oliver, and S. J. Fray, "H.F. resistance standards and their use in the calibration of an admittance bridge up to 60 mc/s.," *Jour. IEE* (London), vol. 97, pt. 3, pp. 438–446; November, 1950.
(670) R. A. Kempf, "Coaxial impedance standards," *Bell Sys. Tech. Jour.*, vol. 30, pp. 689–705; July, 1951.

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 include 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 subassemblies.

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 magnetic 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.

(671) M. H. Nichols and L. L. Rauch, "Radio telemetry," *Rev. Sci. Instr.*, vol. 22, pp. 1–29; January, 1951.

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.

(672) H. E. Hollman, "The traveling-wave cathode-ray tube," Proc. I.R.E., vol. 39, pp. 194–195; February, 1951.
(673) W. B. Sell and J. V. Lebacqz, "A microwave oscillograph," Proc. I.R.E., vol. 39, p. 210; February, 1951.
(674) E. C. Payne, E. L. Mager, and C. W. Gerome, "Electroluminescence—a new light source," *Sylvania Tech.*, vol. 4, pp. 2–5; January, 1951.

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.

(675) Y. P. Yu, H. E. Kallman, and P. S. Christaldi, "Millimicrosecond oscillography," *Electronics*, vol. 24, pp. 106–111; July, 1951.
(676) A. L. Thomas, Jr., "The graph scope, an electronic graph plotter and graphical computer," *Elec. Eng.* (London), vol. 69, pp. 1097–1100; December, 1950.
(677) A. E. Ferguson, "An oscilloscope for the observation of long duration transients," *Jour. Sci. Instr.*, vol. 28, pp. 52–56; February, 1951.

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.

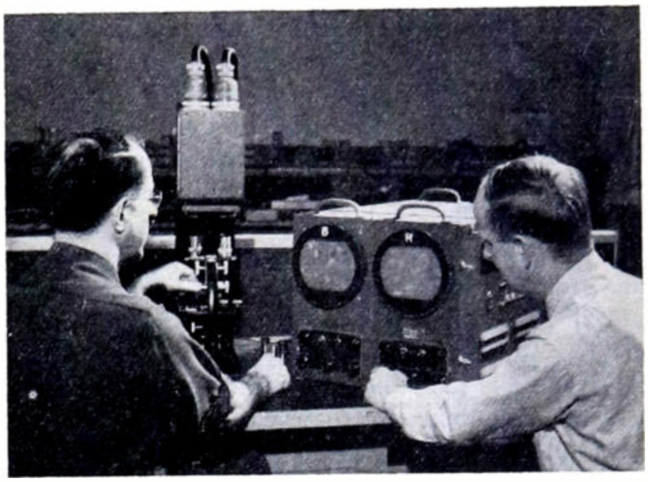

Fig. 20—This televised view of nucleated red cells, in which the cells have been magnified 2,200 times, demonstrates the use in microscopy of television-camera tubes made sensitive to specific wavelengths of light. At the left, the cells are viewed in the violet end of the spectrum; at the right, the 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 spectrograph.

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

(678) J. Rajchman, "The selective electrostatic storage tube," *RCA Rev.*, vol. 12, pp. 53–97; March, 1951.
(679) C. V. Parker, "Charge storage in cathode-ray tubes," Proc. I.R.E., vol. 39, pp. 900–908; August, 1951.
(680) C. H. Bachman, H. Eubank, and G. Hall, "Positive ion studies in cathode-ray tubes," *Jour. Appl. Phys.*, vol. 22, pp. 1208–1210; September, 1951.

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

(681) H. A. Prime and R. C. Rurnock, "An iconoscope electro-optica shutter for high speed photography," *Proc. IEE* (London) vol. 97, pt. 2, pp. 793–796; December, 1950.
(682) A. W. Hogan, "Use of image converter tube for high-speed shutter action," Proc. I.R.E., vol. 39, pp. 268–270; March, 1951.
(683) D. W. Davidson, R. Pauty, and R. H. Cole, "Transient method for the measurement of dielectric polarization," *Rev. Sci. Instr.*, vol. 22, pp. 678–682; September, 1951.

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.

(684) O. S. Puckle, "Time Bases," Chapman and Hall Ltd., London; 1951.

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 10^8, 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, magnetostrictive 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.

(685) R. L. Harvey, I. J. Hegyi, and H. W. Leverenz, "Ferromagnetic spinels for radio frequencies," *RCA Rev.*, vol. 11, pp. 321–363; September, 1950.
(686) M. J. O. Strutt, "Ferromagnetic materials and ferrites," *Wireless Eng.*, vol. 27, pp. 277–284; December, 1950.
(687) M. Kornetzki, "Test results obtained with ferrite cores of high permeability," *Z. angew. Phys.*, vol. 3, pp. 5–9; January, 1951 (In German.)
(688) R. Herr, "Mixed ferrites for recording heads," *Electronics*, vol. 24, pp. 124–125; April, 1951.
(689) H. A. Goldsmith, "Ferromagnetic ceramics," *Product Eng.*, vol. 22, pp. 97–102; April, 1951.
(690) V. E. Legg, "Ferrites: new magnetic material for communication engineering," *Bell Lab. Rec.*, vol. 29, pp. 203–208; May, 1951.
(691) F. G. Brockman, "Structure and properties of ferrites," *Electrical Eng.*, vol. 70, pp. 489–494; June, 1951.
(692) E. Both, "Ferrite materials permit improved designs of magnetic devices," *Materials and Methods*, vol. 34, pp. 76–79; July 1951.
(693) G. T. Rodo and A. Terris, "Magnetization processes in a ferrite," *Phys. Rev.*, vol. 83, p. 177; July 1, 1951.
(694) F. Wagenknecht, "Dielectric and magnetic properties of ferrites at high frequencies," *Frequenz*, vol. 5, pp. 145–155, 186–189; June–July, 1951. (In German.)

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.

(695) Progress Report of the AIEE Magnetic Amplifier Subcommittee, American Institute of Electrical Engineers, Paper 51-71.
(696) R. A. Ramey, "On the Mechanics of Magnetic Amplifier Operation," American Institute of Electrical Engineers, Paper 51-217.
(697) J. G. Miles, "Types of Magnetic Amplifiers—A Survey," Transcript of paper delivered at the Winter General Meeting of the American Institute of Electrical Engineers, New York, N. Y.; January 24, 1951. Available from Engineering Research Associates, Incorporated, St. Paul, Minn.
(698) W. J. Dornhoefer and V. H. Krummeuacher, "Applying magnetic amplifiers" (four parts), *Elec. Mfg.*, vol. 47, pp. 94–99, 232; March, 1951; vol. 47, pp. 112–117, 240; April, 1951; vol. 48, pp. 106–112, 244; August, 1951; vol. 48, pp. 92–97, 242; September, 1951.
(699) R. Feinberg, "High-gain magnetic amplifier—theory of the self-excited transductor," *Wireless Eng.*, vol. 28, pp. 151-155; May, 1951.
(700) J. M. Manley, "Some general properties of magnetic amplifiers," Proc. I.R.E., vol. 39, pp. 242–251; March, 1951.
(701) J. G. Miles, "Bibliography of Magnetic Amplifier Devices and Saturable Reactor Art," American Institute of Electrical Engineers, Paper 51-388.

Work has continued on the measurement and application of magnetic powder cores. The Metal Powder Association issued a tentative Preferred Iron Core Dimensional Specification 11-51T, 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.

(702) R. M. Bozorth, "Ferromagnetism," D. Van Nostrand Company, Inc., New York, N. Y.; 1st Ed., 968 pp.; 1951.
(703) V. G. Welsby, "Theory and Design of Inductance Coils," McDonald and Co., London, 180 pp.; 1951.
(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.)
(705) O. I. Butler and H. R. Chablani, "High-frequency magnetization of ferromagnetic laminae," *Wireless Eng.*, vol. 28, pp. 92–97; March, 1951.
(706) R. Millership and F. V. Webster, "High-frequency permeability of ferromagnetic materials," *Proc. Phys. Soc.* (London), vol. 63, pp. 783–795; October 1, 1950.
(707) R. Feldheller and H. Hettich, "Variation with frequency of the magnetic after-effect in powder cores," *Z. angew. Phys.*, vol. 2, pp. 494–499; December, 1950.
(708) A. von Engel, "Advances in the field of magnetic measuring methods for constant fields," *Arch. Tech.* (Messen), vol. 179, pp. T132–T133; December, 1950. (In German.)
(709) P. M. Prache and R. Cozenave, "Measurement of permeability and magnetic losses of straight samples," *Cables and Trans.* (Paris), vol. 4, pp. 216–233; July, 1950. "Cylindrical coil theory and calculation of reluctance or resistance between ends on straight core and infinity," *Cables and Trans.* (Paris), vol. 5, pp. 60–67; January, 1951.
(710) J. M. Kelly, "Magnetic field measurements with peaking strips," *Rev. Sci. Instr.*, vol. 22, pp. 256–258; April, 1951.
(711) E. G. Thurlby, "High permeability 'Sendust' powder core rings," *Metal Prog.*, vol. 60, pp. 83–87; October, 1951.
(712) H. J. Williams, W. Shockley, and C. Kittel, "Studies of the propagation velocity of a ferromagnetic domain boundary," *Phys. Rev.*, vol. 80, pp. 1090–1094; December 15, 1950.
(713) C. Kittel, "Ferromagnetic resonance," *Jour. Phys. Radium*, vol. 12, pp. 291–302; March, 1951.
(714) J. H. von Vleck, "Recent developments in the theory of antiferromagnetism," *Jour. Phys. Radium*, vol. 12, pp. 262–274; March, 1951.
(715) K. Hoselitz, "Recent progress in the field of permanent magnets," *Jour. Phys. Radium*, vol. 12, pp. 448–458; March, 1951.

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.

(716) W. C. Elmore, H. Kallman, C. E. Mandeville, W. J. Ladniak, and L. D. Marinelli, "Practical aspects of radioactivity instruments," *Nucleonics*, vol. 8, pp. S-2–S-32; June, 1951.
(717) R. L. Butenhoff, "Instrumentation in civil defense," *Elec. Eng.* (London), vol. 70, pp. 287–290; April, 1951.

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 problems and also beta-ray thickness measuring methods for control and other purposes.

(718) J. L. Putman, "Radioisotopes techniques conference—Oxford, 1951," *Nucleonics*, vol. 9, pp. 5–16; October, 1951.

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.

(719) A. C. Walker, "Growing piezoelectric crystals," *Jour. Frank. Inst.*, vol. 250, pp. 481–524; December, 1950.
(720) A. C. Walker, "Growing quartz crystals for military needs," *Electronics*, vol. 24, pp. 96–99; April, 1951.
(721) Brush Development Company, "Artificial Quartz Crystals," Ninth Quarterly Progress Report, U. S. Signal Corps under Contract W36-039-sc-38190; March 15, 1951.
(722) C. S. Brown, R. C. Kell, L. A. Thomas, N. Wooster, and W. A. Wooster, "Growth of large quartz crystals," *Nature* (London), vol. 167, pp. 940–941; June 9, 1951.

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 detwinning of quartz-type structures. One of the latter introduces the term "piezocrescence" for the transformation, by pressure, of one crystal orientation into another, which, under the applied pressure, is favored from the principle of le Chatelier. 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.

(723) J. F. Corwin and A. C. Swinnerton, "The growth of quartz in alkali halide solutions," *Jour. Amer. Chem. Soc.*, vol. 73, pp. 3598–3601; August, 1951.
(724) L. A. Thomas and W. A. Wooster, "Piezocrescence—The growth of Dauphine twinning in quartz under stress," *Proc. Roy. Soc. A.*, vol. 208, pp. 43–62; August 7, 1951.
(725) J. W. Gruner and L. Gardiner, "Twinning studies of quartz type structures," *Tech. Infor. Pilot*, U14900, pp. 2685; April 26, 1951. Quarterly Progress Report 19, University of Minnesota, on Contract W36-039-sc-32006; June 1–September 1, 1950.
(726) F. P. Phelps and W. J. Howard, "Detwinning quartz crystals," *Tech. Infor. Pilot*, U17181, pp. 3121; August 20, 1951. Quarterly Progress Report 8, National Bureau of Standards, on Contract PHIBP-50-6; January 31, 1951.
(727) G. Forman, "A study of color centers produced in quartz by X-radiation," *Jour. Opt. Soc. Amer.*, vol. 41, pp. 377–380; June, 1951.

The review article listed will be found to be interesting. With the extended interest in all crystals that may be piezoelectric, it is well to note the publication, during the year, of an index of crystal properties and angles and also a book on crystal growth.

(728) K. Lonsdale, "Facts about crystals," *Amer. Scien.*, vol. 39, pp. 577–589; 1951.
(729) T. V. Barker, "The Barker index of crystals," *Acta Cryst.*, vol. 4, pp. 191–192; 1951.
(730) H. E. Buckley, "Crystal Growth," John Wiley and Sons, Inc., New York, N. Y., and Chapman and Hall, London, 571 pp.; 1951. For review, see *Proc. Phys. Soc. A.*, vol. 64, p. 952; October, 1951.

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 key, in the case of those crystals that do not contain hydrogen.

(731) B. T. Matthias, "Ferroelectricity," *Sciences*, vol. 113, pp. 591–596; 1951.

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 multicrystalline 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.

(732) A. F. Devonshire, "Theory of barium titanate—Part II," *Phil. Mag.*, vol. 42, pp. 1065–1079; October, 1951.
(733) M. H. Cohen, "Ferroelectricity versus antiferroelectricity in barium titanate," *Phys. Rev.*, vol. 84, p. 369; 1951. Letter to Editor.
(734) K. H. Stewart, "Domain wall movement in a single crystal," *Proc. Phys. Soc. A.*, vol. 63, pp. 761–765; July, 1950.
(735) G. Shirane, E. Sawaguchi, and Y. Takagi, "Dielectric properties of lead zirconate," *Phys. Rev.*, vol. 84; 476–481; November 1, 1951.

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.

(736) W. R. Eubank and L. E. Schilberg, "Aging of $BaTiO^3$ ceramics," *Phys. Rev.*, vol. 81, p. 651; February 15, 1951.
(737) Glenco Corp., "Development and application of barium titanate ceramics as non-linear circuit elements," *Tech. Infor. Pilot*, U14829, p. 2688; April 18, 1951. Final Quarterly Report, Contract W36-039-sc-44606; August 15, 1950.
(738) Harshaw Chemical Co., "Barium titanate and related crystal growth," *Tech. Infor. Pilot*, U16875, p. 3055; August 2, 1951. First Quarterly Report, Contract DA36-039-sc-74; January 31, 1951.
(739) E. A. Wood, "Detwinning ferroelectric crystals," *Bell sys. Tech. Jour.*, vol. 30, pt. I, pp. 945–955; October, 1951.
(740) W. P. Mason and R. F. Wick, "A barium titanate transducer capable of large motion at an ultrasonic frequency," *Jour. Acous. Soc. Amer.*, vol. 23, pp. 209–214; March, 1951.

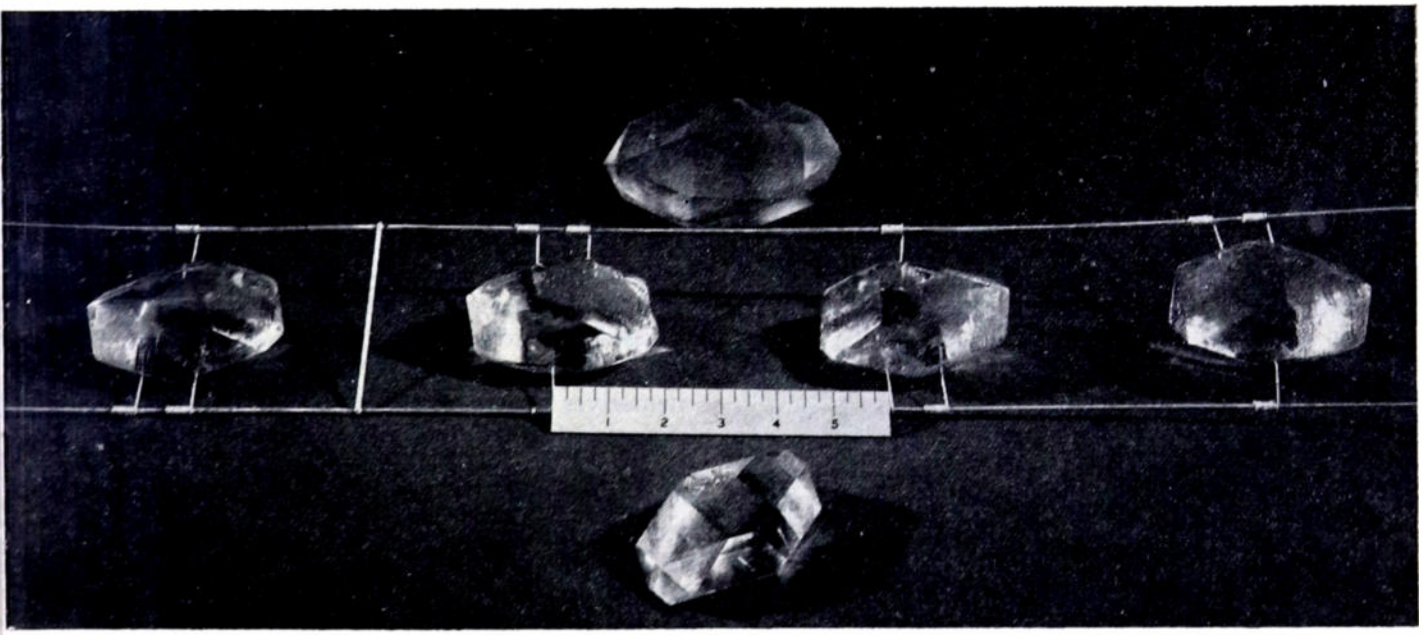

Fig. 21—Controlled growth of quartz crystals. Each of the four large and clear crystals on the horizontal frame weighs at least one-half pound. The very clear crystal in the foreground weighs three-fourths pound, and that in the background weighs over one pound (Bell Telephone Laboratories).

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

crystal systems," *Jour. Acous. Soc. Amer.*, vol. 23, pp. 94–100; January, 1951.
(742) W. L. Hall and W. J. Fry, "Design of variable resonant frequency crystal transducers," *Rev. Sci. Instr.*, vol. 22, pp. 155–161; March, 1951.
(743) G. Bolz, "Theoretische und experimentelle untersuchungen der schwingungen und des strahlungswiderstandes eines ultraschallquarzes," (Theoretical and experimental investigations of the vibration and radiation resistance of an ultrasonic quartz), *Z. angew. Phys.*, vol. 2, pp. 119–127; March, 1950.
(744) G. W. Swanson, Jr. and W. T. Thomson, "The design of resonant quartz-crystal ultrasonic transducers for research purposes," *Jour. Appl. Mech.*, pp. 427–430; December, 1950.

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 zincblende 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 magnetostrictive 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.

(745) G. W. Willard, "Improved methods for measuring ultrasonic velocity," *Jour. Acous. Soc. Amer.*, vol. 23, pp. 83–93; January 1951.
(746) H. J. McSkimin, W. L. Bond, E. Buehler, and C. K. Teal, "Measurement of the elastic constants of silicon single crystals and their thermal coefficients," *Phys. Rev.*, vol. 83, p. 1080; 1951.
(747) H. J. McSkimin, "A method for determining the propagation constants of plastics at ultrasonic frequencies," *Jour. Acous. Soc. Amer.*, vol. 23, pp. 429–434; July, 1951.
(748) W. L. Bond, W. P. Mason, and H. J. McSkimin, "Elastic and electromechanical coupling coefficients of single crystal barium titanate," *Phys. Rev.*, vol. 82, p. 442; 1951.
(749) E. Prince and W. A. Wooster, "The elastic constants of zincblende, determined from thermal diffuse scattering of X-rays," *Acta. Cryst.*, vol. 4, p. 191; 1951.
(750) B. E. Noltingk and E. A. Neppiras, "Ultrasonic soldering irons," *Jour. Sci. Instr.*, vol. 28, pp. 50–52; 1951.
(751) E. W. Samuel and R. S. Shankland, "The sound field of a Straubel X-cut crystal," *Jour. Acous. Soc. Amer.*, vol. 22, pp. 589–592; September, 1950.

Vigoureux has published a book (in English) on ultrasonics, containing many references. Also, a bibliography on ultrasonics, containing about 650 entries (copies of which are stated to have been deposited in a number of public and university libraries), was prepared. The general concept of radiation resistance has received renewed consideration, with a clarification of some basic confusions.

(752) P. Vigoureux, "Ultrasonics," John Wiley and Sons, Inc., New York, N. Y., 163 pp.; 1951. For review, see *Science*, vol. 114, p. 470; 1951.
(753) B. Curry and E. Hsi, "Bibliography on supersonics or ultrasonics," *Jour. Acous. Soc. Amer.*, vol. 23, p. 245; March, 1951
(754) F. E. Borgnis, "Theory of Acoustic Radiation Pressure," Technical Report 1, Contract Nonr-220(02), California Institute of Technology, Pasadena, Calif.; July 25, 1951. Submitted by W. G. Cady, Project Director.

Resonators, Oscillators, and Transmitters

Experimental studies of vibrating plates continue, and progress has been made in confirmation of the theory on contour modes. Stroboscopically illuminated interferometer patterns of the vibrations of a quartz plate were photographed in England. Attention is called to an important contribution to the theory of thickness-shear resonances of rectangular plates, with marked success in predicting the experimental frequencies for a long series of secondary modes.

(755) R. Bechmann, "Contour modes of square plates excited piezoelectrically and determination of elastic and piezoelectric coefficients," *Proc. Phys. Soc.* (London), vol. 64B, pp. 323–337; April 1, 1951.
(756) R. Bechmann and P. L. Parsons, "Piezoelectric behaviour of partially plated square plates vibrating in contour modes," *Proc. Phys. Soc.* (London), vol. 64B, pp. 706–712; August 1, 1951.
(757) S. Tolansky and W. Bardsley, "Interferometric studies on the vibration of piezoelectric plates," *Proc. Phys. Soc.* (London), vol. 64, pp. 224–230; March 1, 1951.
(758) R. D. Mindlin, "Thickness-sheer and flexural vibrations of crystal plates," *Jour. Appl. Phys.*, vol. 22, pp. 316–323; March, 1951.

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 themslves, and examples of filters adjustment and measurement.

(759) W. P. Mason, "Zero temperature coefficient quartz crystals for very high temperatures," *Bell Sys. Tech. Jour.*, vol. 30, pp. 366–380; April, 1951.
(760) R. K. Cook and P. G. Weissler, "Piezoelectric constants of alpha- and beta-quartz at various temperatures," *Phys. Rev.*, vol. 80, pp. 712–716; November 15, 1950.
(761) L. F. Koerner, "Progress in development of test oscillators for crystal units," Proc. I.R.E., vol. 39, pp. 16–26; January, 1951.
(762) L. F. Koerner, "Measurement of chracteristics of crystal units," Proc. I.R.E., vol. 39, p. 1115; September, 1951. Abstract 1958.
(763) J. J. Vormer, "Crystal plates without overtones," Proc. I.R.E., vol. 39, pp. 1086–1087; September, 1951.

(764) J. S. Mendouse, P. D. Goodman, and W. G. Cady, "A capacitance bridge for high frequencies," *Rev. Sci. Instr.*, vol., 21 pp. 1002–1009; December, 1950.
(765) W. Herzog, "Siebschaltungen mit Schwingkristallen," (Crystal Filter Circuits), Dieterichsche Verlagsbuchhandlung, Wiesbaden, pp. 361, 45 DM; 1949.

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.

(766) J. W. Busby, "New crystal controlled Radar beacon," *Tele.-Tech.*, vol. 10, pp. 24–26, 70; January, 1951.
(767) R. H. Myers, "Design of a loran transmitter," *Elec. Commu.* (London), vol. 28, pp. 31–45; March, 1951.
(768) J. Ruston, "A simple crystal discriminator for FM oscillator stabilization," Proc. I.R.E., vol. 39, pp. 783–788; July, 1951.
(769) E. J. Post and H. F. Pit, "Alternate ways in the analysis of a feedback oscillator and its application," Proc. I.R.E., vol. 39, pp. 169–174; February, 1951.

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.

(770) P. Goldsmith, *et al.*, "Investigations of use of crystals as meteorological elements for measurements of temperature, pressure, and humidity," *Tech. Infor. Pilot*, U13633, p. 2468; May 21, 1951. Quarterly Progress Report 9, Armour Research Foundation on Contract W36-039-sc-36852; September 1, 1950.
(771) W. Parrish, "The manufacture of quartz oscillator plates. I—How the required cuts are obtained," *Philips Tech. Rev.*, vol. 11, pp. 323–332; May, 1950.
(772) W. Parrish, "The manufacture of quartz oscillator plates. II—Control of the cutting angles by X-ray diffraction," *Philips Tech. Rev.*, vol. 11, pp. 351–360; June, 1950.
(773) W. Parrish, "The manufacture of quartz oscillator plates. III—Lapping and final frequency adjustment of the blanks," *Philips Tech. Rev.*, vol. 12, pp. 166–176; December, 1950.

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 10^8 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.

(774) C. F. Booth, "The evolution of frequency control," *Proc. IEE* (London), vol. 98, pt. 3, pp. 1–10; January, 1951.
(775) W. D. George, "Quartz-crystal frequency standards," Proc. I.R.E., vol. 39, pp. 1115; September, 1951. Abstract 1958.

Symbols and Abbreviations

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

(776) "Standards on Abbreviations of Radio Electronic Terms, 1951," Proc. I.R.E., vol. 39, pp. 397–400; April, 1951.
(777) RTMA Standard TR-115, "Symbols and Designations for Single Line Diagrams for Audio Facilities," Radio-Television Manufacturers Association, New York, N. Y.; June, 1951.
(778) MIL-STD-16, "Military Standard Reference Designations for Electrical and Electronic Symbols," Munitions Board Standards Agency, Department of Defense, Washington 25, D. C.; February, 1951.
(779) NEMA Publication ICI-1949, "Standards for Industrial Control," Part 21, "Terminal Markings" and Part 33, "Device Designations," Reissued in Revised Form. National Electrical Manufacturers Association, New York, N. Y.; October, 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. Batcher, *Chairman*
T. H. Clark
J. D. Crawford
R. T. Hamlett
H. P. Westman
L. E. Whittemore
G. L. Van Deusen

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

The individual section reports were prepared by the following contributors:

Electron Tubes and Semiconductors: E. M. Boone, C. E. Fay, T. J. Henry, R. C. Hergenrother, M. E. Hines, E. C. Homer, E. M. Hurlburt, I. Meth, W. T. Millis, G. O'Neill, R. M. Ryder, W. G. Shepherd, R. W. Slinkman, and H. L. Thorson
Audio Techniques: H. W. Angustadt
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
Radio Transmitters: T. J. Boerner, M. R. Briggs, H. R. Butler, H. Goldberg, P. J. Herbst, A. E. Kerwien, L. A. Looney, J. Ruston, and I. R. Weir
Receivers: L. M. Harris
Video Techniques: W. J. Poch
Television Systems: F. J. Bingley, R. M. Bowie, E. T. Dickey, P. Goldmark, S. Helt, and W. Whalley
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
Antennas, Waveguides, and Transmission Lines: E. C. Jordan
Industrial Electronics: J. M. Cage, J. L. Dalke, and C. F. Spitzer
Electronic Computers (Analog): E. L. Harder; (Digital): N. Rochester
Quality Control: J. R. Steen
Measurements: P. S. Christaldi, J. L. Dalke, G. L. Fredendall, T. J. Gaffney, W. J. Mayo-Wells, G. A. Morton, C. D. Owens, A. Peterson, J. R. Steen
Piezoelectricity: K. S. Van Dyke
Standards: H. R. Terhune

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.[1] 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 $10^{0.1}$ 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 "logit" 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 as 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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† U. S. Navy Underwater Sound Laboratory, Fort Trumbull, New London, Conn.

[1] 51 IRE 6.S1 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

$$A = na. \tag{1}$$

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

$$R = r^m. \tag{2}$$

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. Involution and evolution 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 $r=R^{1/m}=b^{x/yb}$. 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

$$r = R^{1/m} = (10^k)^{1/k10} = 10^{0.1}. \tag{3}$$

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.

Fig. 1—Scales of actual relative magnitudes, R, and of equivalent numbers, m, of standard relative magnitudes, r. The three quantities are related by the equation $R=r^m$, and the standard relative magnitude has logit value, $r=10^{0.1}$.

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.[2] 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 $m=kb$ when $R=b^k$ does not exist for any base number, b, when the standard ratio has a value greater than $r=e^{1/e}=1.445$.

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.[3] 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 magnitudes 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 π 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 I. 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 seen adopted as an American Standard.[4] These are shown in the third column of Table I. 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 I

Values of the Ratios Corresponding to Successive Powers of the Logit Ratio, $10^{0.1}$

Number of logits	Resultant ratio	Approximate ratio	Error in approximation logits
0	1.00000	1	0.00
1	1.25893	1.25	0.03
2	1.58489	1.6	0.04
3	1.99526	2	0.01
4	2.51189	2.5	0.02
5	3.16228	3.15	0.02
6	3.98108	4	0.02
7	5.01188	5	0.01
8	6.30959	6.3	0.01
9	7.94331	8	0.03
10	10.00000	10	0.00

[2] R. W. Young, "Terminology for logarithmic frequency units," *Jour. Acous. Soc. Amer.*, vol. 11, pp. 134–139; 1939.
Dr. 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.

[4] American Standard Preferred Numbers, Approved by the American Standards Association, reaffirmed November 12, 1946.

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,

$$m = \log_r R. \tag{4}$$

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 "lgt," 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

$$m = \frac{\log R}{\log r} = 10 \log R = \text{lgt } R. \tag{5}$$

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 embodiments. 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 embodiments. 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 $d_2/d_1=10^{0.1}$, 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 *il*, for mass logits it would be *ml*, for length logits *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 $10^{0.05}$; 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 $10^{0.1}$ 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

$$L = 10 \log \frac{I}{I_0} = \text{lgt} \frac{I}{I_0} \text{ db//watt/cm}^2. \tag{6}$$

The complete statement symbolized by this expression is, "The relative magnitude of an acoustical intensity having the absolute magnitude I watt/cm² is $L = \text{lgt}$ (I/I_0) decibels when referred to an intensity of I_0 watt/cm²."

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

$$L_a = \text{lgt } P_a/P_0 \text{ db//}P_0 \text{ watts.}$$

and

$$L_b = \text{lgt } P_b/P_0 \text{ db//}P_0 \text{ watts.}$$

Then

$$N_{b/a} = L_b - L_a = \text{lgt } P_b/P_a \text{ db.} \tag{7}$$

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 50×10^{-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 25×10^3 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

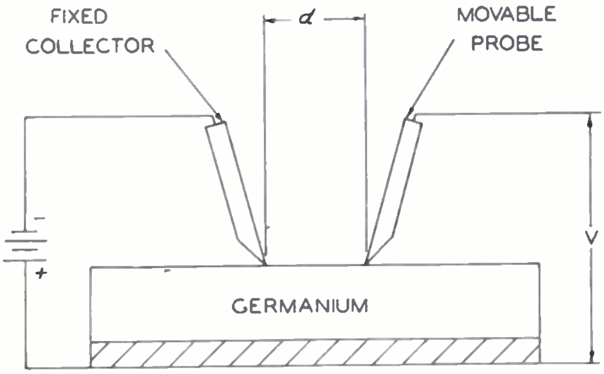

Fig. 1—Circuit for the measurement of floating potentials.

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.

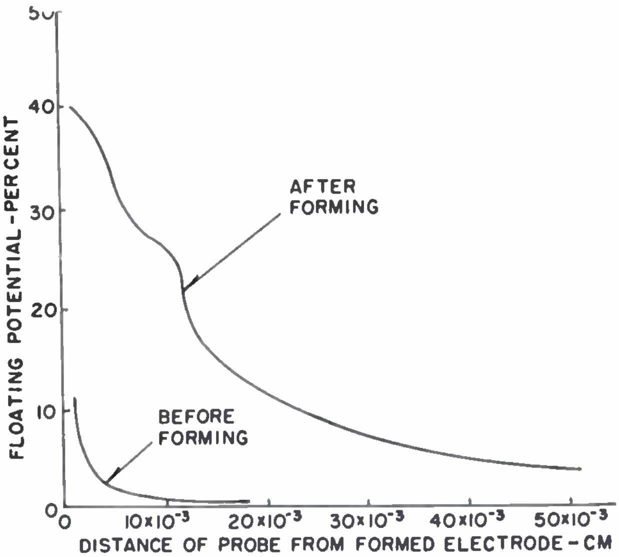

Fig. 2—Floating potentials.

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 hypothesis[2]), and they decreased with in-

* Decimal classification: R282.12. Original manuscript received by the Institute, June 18, 1951; revised manuscript received January 25, 1952.

† Bell Telephone Laboratories, Murray Hill Laboratory, Murray Hill, N. J.

[1] J. Bardeen and W. H. Brattain, "Physical principles of transistor action," *Bell Tel. Labs. Jour.*, vol. 28, pp. 239–277; April, 1949. J. Bardeen and W. G. Pfann, "Effects of electrical forming on the rectifying barriers of n- and p-germanium transistors," *Phys. Rev.*, vol. 77, p. 401; 1950.

[2] J. Bardeen, "Surface states and rectification at a metal semi-conductor contact," *Phys. Rev.*, vol. 71, pp. 717–727; May 15, 1947.

[3] H. C. Torrey and C. A. Whitmer, "Crystal rectifiers," McGraw-Hill Book Co., New York, N. Y., p. 304; 1948.

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 −one 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

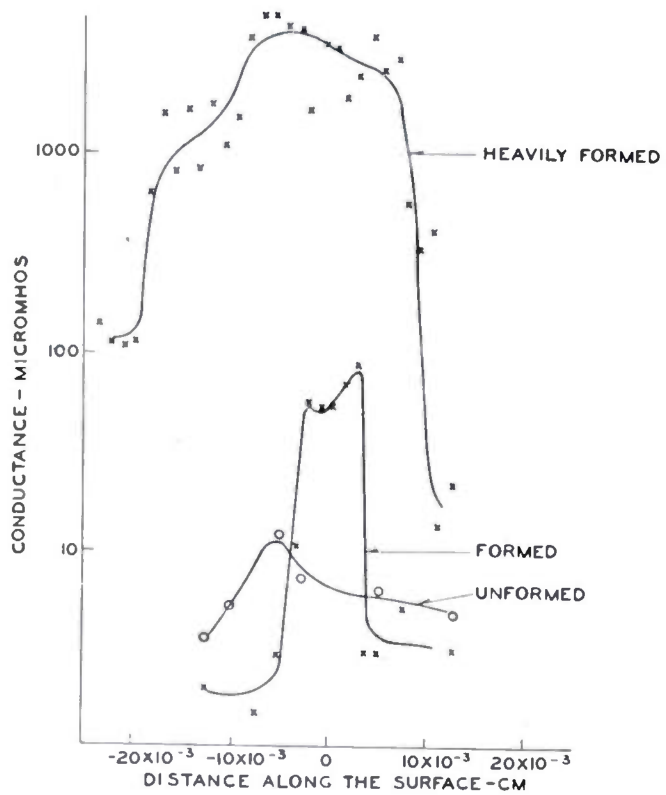

Fig. 3—Conductance measurements on the surface of germanium in the uniformed, formed, and heavily formed conditions.

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 ligher 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 2.2×10^{-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 0.8×10^{-3} cm and 1.7×10^{-3} 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.[4] 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

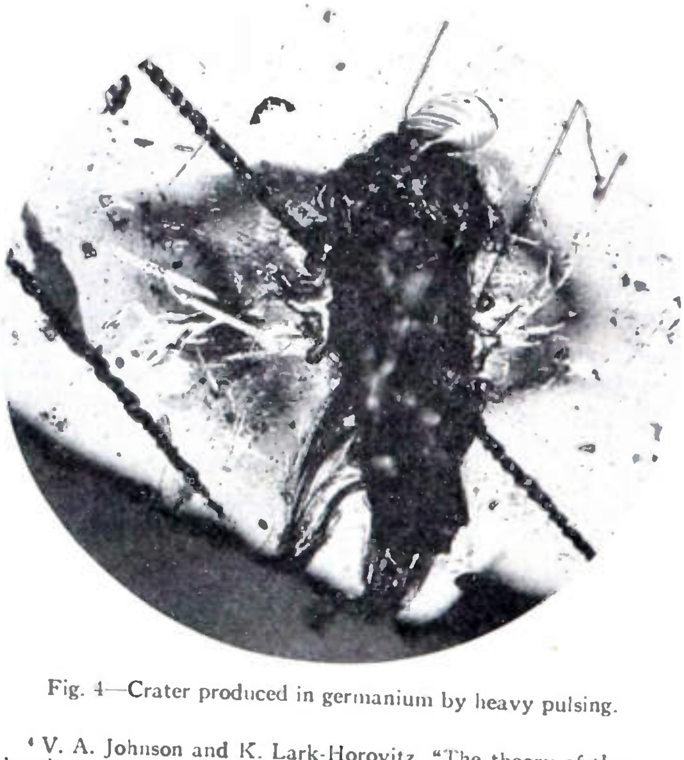

Fig. 4—Crater produced in germanium by heavy pulsing.

[4] V. A. Johnson and K. Lark-Horovitz, "The theory of thermoelectric power in germanium," *Phys. Rev.*, vol. 69, p. 259; 1946.

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[5] 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 3.7×10^{-2} cm long, 1.0×10^{-2} cm wide, and 0.2×10^{-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.[6]

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,[7] 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.[8] The first is the trap theory,[9] and the second is the *p-n* hook theory,[10] 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.

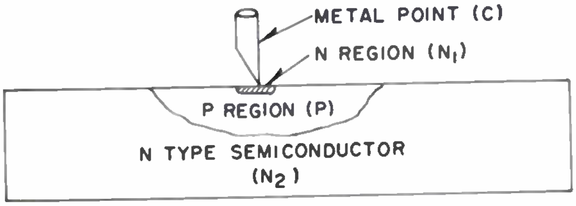

Fig. 5—Formed area.

The *n*-type region (N_1) 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.[11]

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

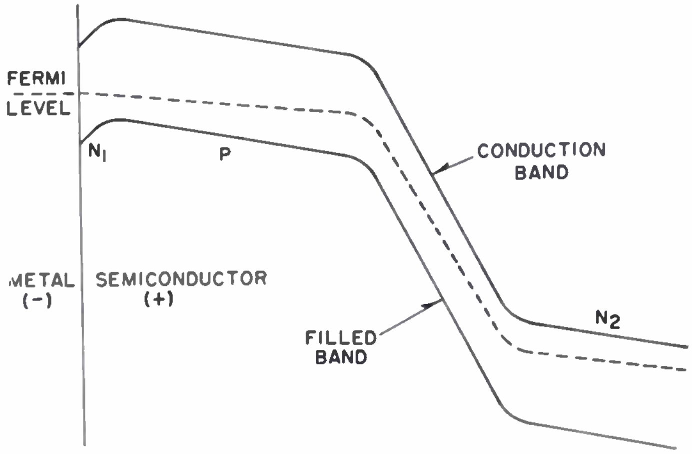

Fig. 6—Energy-band picture of a formed collector with the electric field applied.

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-

[5] Torrey and Whitmer "Crystal Rectifiers," McGraw-Hill Book Co., New York, N. Y., p. 365; 1946.

[6] The author, in collaboration with J. D. Struthers, studied the diffusion of copper into germanium from phosphor-bronze points. Results indicated that 5×10^{20} atoms/cm^3 of copper are introduced into the formed region of the germanium by extremely heavy pulsing.

[7] G. L. Pearson, J. R. Haynes, and W. Shockley, "Comment on mobility anomalies in germanium," *Phys. Rev.*, vol. 78, p. 295; 1950.

[8] W. Shockley, "Theories of high values of alpha for collector contacts on germanium," *Phys. Rev.*, vol. 78, p. 294; 1950. Also, W. Shockley, M. Sparks, and G. K. Teal, "*p−n* junction transistors," *Phys. Rev.*, vol. 83, p. 151; 1951.

[9] Evidence for the trap theory may be found in W. R. Sittner, "Current multiplication in the type-A transistor," Proc. I.R.E., pp. 448–454; this issue.

[10] W. Shockley, "Electrons and Holes in Semiconductors," D. Van Nostrand Co. Inc., New York, N. Y., p. 111; 1950.

[11] W. G. Pfann, "Significance of composition of contact point in rectifying junctions on germanium," *Phys. Rev.*, vol. 81, p. 882; 1951.

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 region of high-conductivity, p-type material underneath the formed electrode. The size of this region increases with heavier forming. The existence of a p-region suggests that the p-n hook theory may serve as an explanation for the high values of alpha observed in point-contact transistors.

Acknowledgment

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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.[1] This transistor is an active four-terminal network which can be represented by the equivalent circuit shown in Fig. 1.[2] The active element of the device is the current generator $\alpha_i i_e$. Alpha, the current multiplication factor, is defined by

$$\alpha = -\left(\frac{\partial i_c}{\partial i_e}\right)_{V_c} = \text{constant.}^3$$

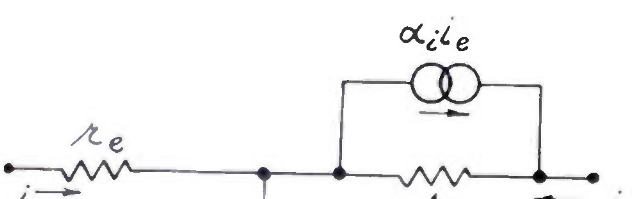

Fig. 1—An equivalent circuit for the type-A transistor.

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 ($\alpha_i - 1$) 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.[4]

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.

* Decimal classification: R282.12. Original manuscript received by the Institute, September 13, 1951; revised manuscript received January 30, 1952.

† Bell Telephone Laboratories, Allentown Laboratory, 555 Union Blvd., Allentown, Pa.

[1] J. Bardeen and W. H. Brattain, "Physical principles involved in transistor action," *Phys. Rev.*, vol. 75, p. 1208; 1949.

[2] R. M. Ryder and R. J. Kircher, "Some circuit aspects of the transistor," *Bell Sys. Tech. Jour.*, vol. 28, p. 367; 1949.

[3] 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.

[4] W. Shockley, "Electrons and Holes in Semiconductors," D. Van Nostrand Co., New York, N. Y., pp. 102–103; 1950.

This relation is shown in Fig. 2(a).

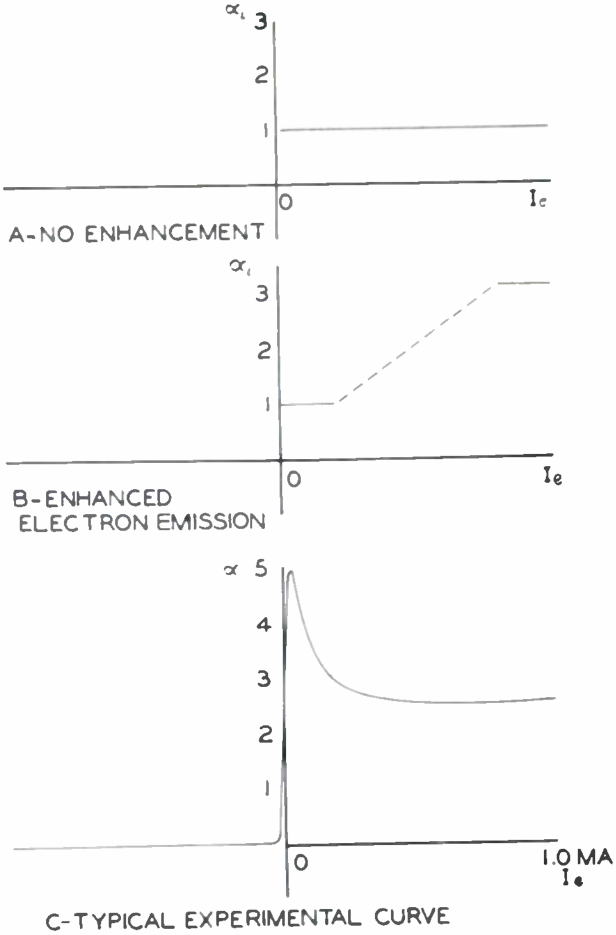

Fig. 2—(a) Predicted curve of alpha versus emitter current without enhancement. (b) Predicted curve with enhanced emission. (c) Typical experimental curve.

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.[1] If we assume a uniform collector barrier, the maximum value of α_i predicted by this mechanism is $1+b$, where b is the ratio of electron to hole mobility in germanium.[5] This is true because there is no enhanced field when the ratio of enhanced electron current to hole current equals b. An α_i versus I_e curve, like Fig. 2(b), would be predicted for this case; α_i should be unity for small I_e because this corresponds to a low density of collected holes. Measurements[6] on germanium filaments indicate that $b=2.1$, hence the maximum value of α_i should be 3.1. The dotted portion of this curve (intermediate values of I_e) indicates only that α_i should increase monotonically toward the maximum value.

A typical experimental curve of α 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 α 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.[5] 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 α_i can arise in this way. The experiments relating to this theory are discussed elsewhere.[7,8]

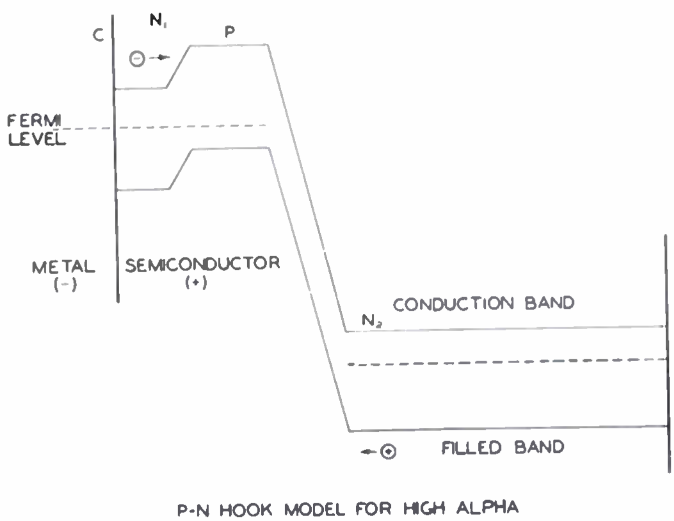

Fig. 3—Electron potential-energy diagram showing the $p-n$ hook model for high alpha.

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 α_i.

This theory is discussed more fully in Section II.

In this paper it is proposed to: (a) give an approximate analysis of the α versus I_e characteristic, based on the trapping mechanism (this is an application to the

[5] W. Shockley, "Theories of high values of alpha for collector contacts on germanium," *Phys. Rev.*, vol. 78, p. 294; 1950.
[6] G. L. Pearson, J. R. Haynes, and W. Shockley, "Comment on mobility anomalies in germanium," *Phys. Rev.*, vol. 78, p. 295; 1950.
[7] L. B. Valdes, "Transistor forming effects in *n*-type germanium," Proc. I.R.E., pp. 445–448; this issue.
[8] W. G. Pfann, "Significance of composition of contact-point in rectifying junctions on germanium," *Phys. Rec.*, vol. 81, p. 882; 1951.

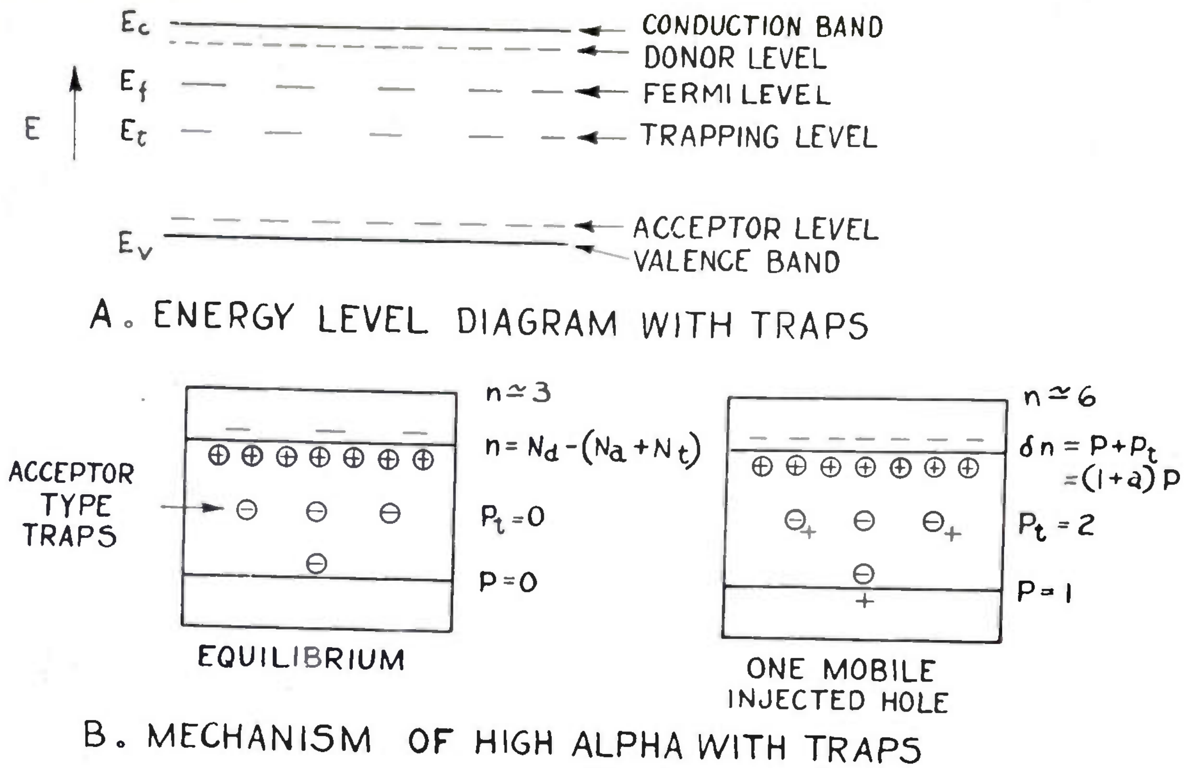

Fig. 4—The trapping model.

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 $E_b = E_v - E_t$.

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.

[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.

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 α_i. 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_e 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. The agreement between theory for the filamentary 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.[11] Their expressions for the increase in collector current due to emitter current and alpha are

$$\Delta I_c = -\gamma I_e(1 + b), \tag{1}$$

where γI_e = hole current from emitter

$$\alpha_i = \gamma(1 + b). \tag{2}$$

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

$$\Delta I_c = -\gamma I_e\left(1 + b + \frac{ab}{1 + G'I_e}\right), \tag{1.1}$$

where

$$a = \frac{p_t}{p} = \frac{\text{density of trapped holes}}{\text{density of mobile holes}}$$

for the case of small injected hole density; (a is called the trapping ratio.)

$$G' = \frac{\gamma}{A\left(q\mu_p \dfrac{N_t}{a}\right)\dfrac{V_c}{L}} \tag{1.11}$$

N_t = trap density
A = cross-sectional area of filament
μ_p = mobility of holes in absence of traps
q = value of electron charge
V_c/L = electric field in the interaction region.

By differentiation of (1.1) we obtain

$$\alpha_i = \gamma\left(1 + b + \frac{ab}{(1 + G'I_e)^2}\right). \tag{2.1}$$

The above expressions will be applied to the type-A transistor by taking A to be the area of the collector point contact (10^{-6} cm²) and V_c/L to be the collector potential divided by the thickness of the collector barrier (10^{-3} cm).

By examination of (2.1) we can predict the following:

1. When $I_e = 0$, then $\alpha_i = \alpha_{max} = \gamma(1 + b + ba)$; α_{max} may be indefinitely large since the trapping ratio, a, may have any positive value. Also, α_{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 $\alpha_i = \alpha_{min} = \gamma(1 + b)$. This occurs because the traps are saturated.
3. When I_e has such a value

   $$(I_e') \quad \text{that} \quad \alpha_i = \frac{\alpha_{max} + \alpha_{min}}{2},$$

   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

   $$a = \frac{\alpha_{max} - \alpha_{min}}{\alpha_{min}}\left(\frac{1 + b}{b}\right).$$

There is a second, and partially independent, method of finding the trap density N_t. A plot of the expected relation between ΔI_c and I_e (1.1) is shown in Fig. 5.

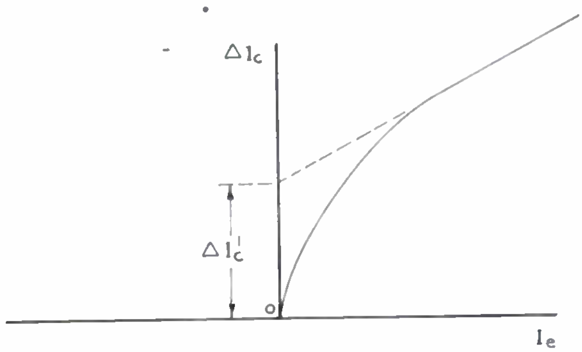

Fig. 5—Theoretical curve for increase in collector current due to emitter current versus emitter current.

For large I_e this curve approaches a straight line which, if extended, intersects the ΔI_c axis at a value $\Delta I_c'$. The current $\Delta I_c'$ 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_c 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 difficult[13] to show, that

$$\frac{\Delta I_c'}{I_c} = \frac{N_t}{N}. \tag{3}$$

Measurement of the conductivity of the germanium, together with $\Delta I_c'$ and I_c on the transistor, permits computation of N_t. The experimental curves of ΔI_c versus I_e have the shape shown in Fig. 5, and $\Delta I_c'$ and I_c 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.

[11] W. Shockley, G. L. Pearson, and J. R. Haynes, "Hole injection in germanium—quantitative studies and filamentary transistors," *Bell Sys. Tech. Jour.*, vol. 28, p. 344; 1949.

[12] J. B. Brown, "Magnetically biased transistor," *Phys. Rev.*, vol. 76, pp. 1736–1737; 1949.

[13] For the filamentary transistor; if the assumption of space-charge stabilization applies, then the filamentary analysis applies to the type A, also, as discussed above.

The remaining problem is to find the trapping energy. In Appendix I it is shown that

$$a = \frac{N_t}{N_v} e^{-E_b/kT}. \tag{4}$$

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_v,[14] we have

$$a = \frac{N_t}{10^{19}} e^{-E_b/kT}. \tag{4.1}$$

One can then evaluate E_b from a single measurement of trapping ratio.

III. Experimental Results

Equipment was constructed for presenting α 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 α down to very low values of I_e. Means of changing the temperature of the transistor under study were provided, also, provision for presenting ΔI_c versus I_e on the oscilloscope.

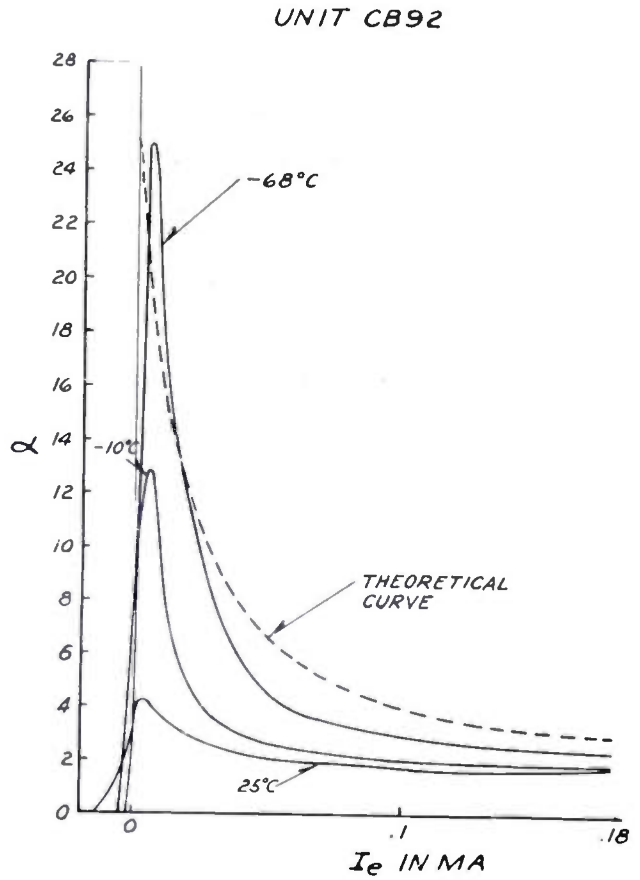

Fig. 6—Alpha versus emitter current at three temperatures with a comparison to the theoretical curve.

[14] The effective density of states in the valence band (N_v) is known from semiconductor theory to be

$$N_v = \left(\frac{2\pi m^* kT}{h^2}\right)^{3/2} \simeq 10^{19}\ \text{cm}^{-3}.$$

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 α. 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 = one intermediate point) by choice of the parameters γ, α, 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 I

	Unit	CB92	CB84
$T = 298K°$	α_{max}	4.4	3.2
	a	2.0	1.0
	N_t in cm^{-3}	7.2×10^{12}	6.7×10^{12}
	E_b in ev	0.31	0.31
$T = 274K°$	α_{max}	6.0	7.0
	a	3.8	2.6
	N_t	9.2×10^{12}	9.6×10^{12}
	E_b	0.35	0.33
$T = 258K°$	α_{max}	13.0	9.0
	a	8.2	3.3
	N_t	2.9×10^{13}	1.9×10^{13}
	E_b	0.30	0.27
$T = 237K°$	α_{max}	19.0	15.4
	a	16.3	10.0
	N_t	7.7×10^{13}	7.3×10^{13}
	E_b	0.30	0.29
	E_b^*	0.28	0.28

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_t 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 α 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 α 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,

$$\frac{p_t}{N_t} = \frac{1}{1 + e^{E_f - E_t/kT}} \simeq e^{E_t - E_f/kT} \tag{1}$$

and

$$\frac{p}{N_v} = \frac{1}{1 + e^{(E_f - E_v)/kT}} \simeq e^{E_v - E_f/kT}, \tag{2}$$

where E is defined in Fig. 4.

N_t = density of hole traps

N_v = effective density of states in valence band.

The simplification is valid since $E_f - E_t$ and $E_f - E_v \gg kT$. Combining (1) and (2), we have

$$a = \frac{p_t}{p} = \frac{N_t}{N_v} e^{E_t - E_v/kT}.$$

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

$$\text{rate of trapping} = Ap(N_t - p_t), \tag{1}$$

where A is a constant.

The rate of release of holes is expected to be proportional to p_t,

$$\text{rate of emission of holes} = Bp_t. \tag{2}$$

The steady-state requires

$$Ap(N_t - p_t) = Bp_t$$

or

$$p_t = N_t \frac{1}{1 + \dfrac{B}{Ap}}. \tag{3}$$

By manipulation of (1) of Appendix I, it can be shown that $B/A = (N_t/a)$, so that (3) becomes

$$\frac{p_t}{N_t} = \frac{1}{1 + \dfrac{N_t}{ap}}, \tag{4}$$

rearranging

$$\frac{p_t}{p} = \frac{a}{1 + \dfrac{ap}{N_t}}. \tag{5}$$

We now need to find the effect of trapped holes on the mobility. The presence of an injected charge density p will induce an added electron charge density p, giving rise to the added electron-current density.

$$q\mu_n p\overline{E} = qb\mu_p p\overline{E} \quad \text{since} \quad b = \frac{\mu_n}{\mu_p}. \tag{6}$$

If P_t of the injected holes are trapped per cm³, electrical neutrality indicates the electron current will be

$$q\mu_p b(p + p_t)\overline{E} \tag{7}$$

as though the mobility ratio were not b but b' where

$$b' = b\frac{(p + p_t)}{p}. \tag{8}$$

Since the value of α in the type-A transistor is

$$\alpha = (1 + b)\gamma \tag{9}$$

(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 α to a new value, shown by use of b' from (8).

$$\alpha = (1 + b')\gamma = \left(1 + b\left(1 + \frac{p_t}{p}\right)\right)\gamma. \tag{10}$$

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),

$$\Delta I_c = -(1+b')\gamma I_e$$

$$= \left[1 + b\left[1 + \frac{a}{1 + \dfrac{ap}{N_t}}\right]\right]\gamma I_e. \quad (11)$$

The problem now is to express p in terms of easily observable quantities. This is obtained from the conductivity expression

$$\gamma I_e = \frac{V_c}{L}(q\mu_p p)A, \quad (12)$$

where

γI_e = hole current to collector
$V_c/L \simeq$ field at the collector
A = area of contact.

Then,

$$\frac{ap}{N_t} = \frac{a}{N_t}\frac{L\gamma I_e}{q\mu_p A V_c} = G' I_e, \quad (13)$$

where

$$G' \equiv \frac{\gamma}{A\left(q\mu_p \dfrac{N_t}{a}\right)\dfrac{V_c}{L}}.$$

Substituting into (11), we find the increase in collector current to be

$$\Delta I_c = -\left(1 + b + \frac{ab}{1 + G' I_e}\right)\gamma I_e. \quad (14)$$

A Scanner for Rapid Measurement of Envelope Delay Distortion*

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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 millimicrosecond 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.[1] More recently, automatic equipment has been developed which, within a few minutes, records the transmission characteristic of a video system on a paper strip.[2] However, for the lineup 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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[1] D. H. Ring, "The measurement of delay distortion in microwave repeaters," *Bell Sys. Tech. Jour.*, Vol. 27, pp. 247–264; April, 1948.

[2] H. A. Etheridge, "Automatic delay and gain recorder," unpublished memorandum.

The frequency range chosen for the equipment is the intermediate frequency band common to all channels of the TD-2 radio-relay system.[3] 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.[4] 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.

[3] 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 coast.

[4] H. Nyquist and S. Brand, "Measurement of phase distortion," *Bell Sys. Tech. Jour.*, vol. 9, pp. 522–549; July, 1930.

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 2×10^{-2} 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

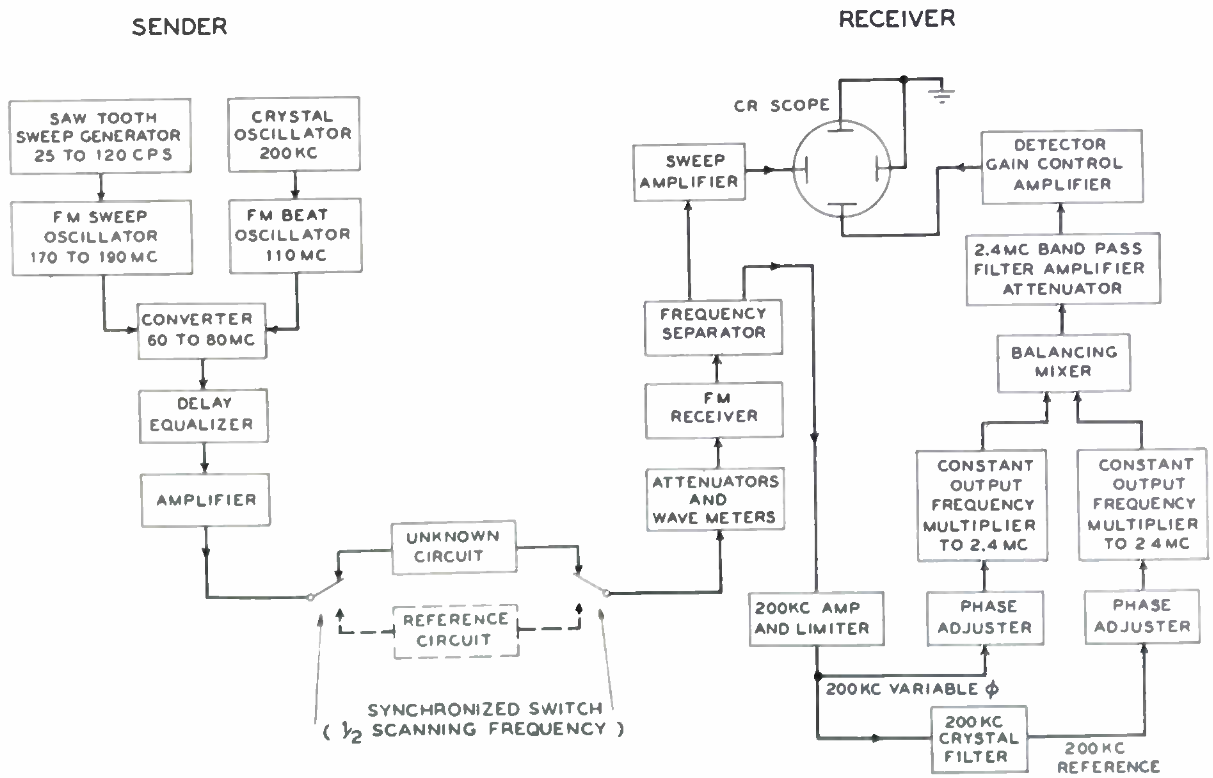


Fig. 1—Delay-distortion scanner block schematic.

and heterodyned down to the 60- to 80-mc range. Internal delay distortion of the equipment is equalized and the power amplified.[5] 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.[6]

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 twelvefold, 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 twelvefold 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-

[5] 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.

[6] F. R. Dennis and E. P. Felch, "Reactance tube modulation of phase shift oscillators," *Bell Sys. Tech. Jour.*; October, 1949.

quency of zero angle, as shown on Fig. 2. If the two vector amplitudes are exactly equal, the reversal shows a sharp break; its sharpness serves as a check of amplitude equality. If one knows which part of the characteristic corresponds to positive angles, the positive and negative branches can be combined with corrected polarities to

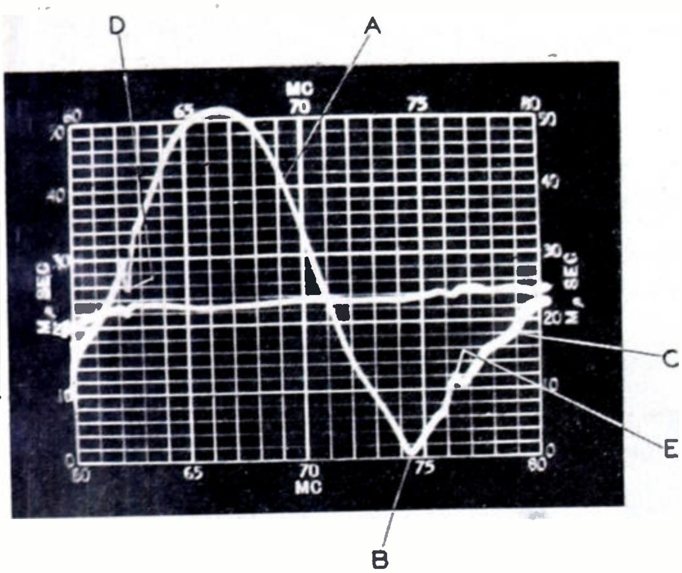


Fig. 2—Folded trace of large delay distortion. *A*—Upright delay trace. *B*—Folding point. *C*—Inverted delay trace. *D*—Upright wave-meter notch. *E*—Inverted wave-meter notch.

obtain an undistorted measuring range of 100 millimicroseconds. This range is indicated on Fig. 3, which shows the vertical elongation as a function of the phase angle between the two 2.4-mc vectors.

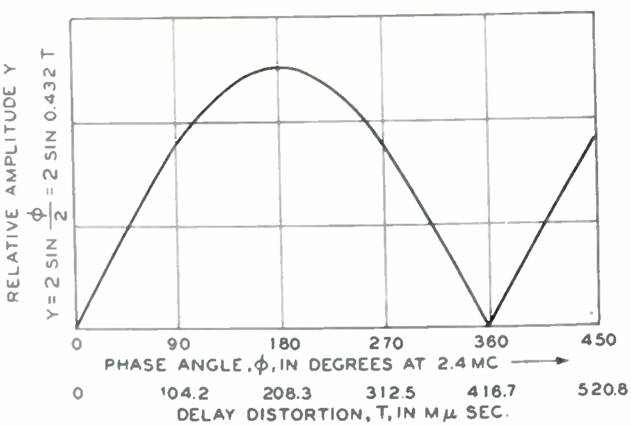


Fig. 3—Calibrating curve for large delay distortion.

This knowledge of polarity together with an indication of the exact frequencies scanned is obtained by means of two wavemeters loosely coupled to the 60- to 80-mc transmission circuit which absorb a small amount of power over a very narrow frequency range. The absorption produces a small reduction of the envelope delay visible as a narrow notch approximately 400 kc wide, in the delay characteristic. At positive-polarities this frequency marker notch points downward. If the polarity is reversed because of zero shift, the notch becomes an upward peak, as shown in Fig. 2.

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

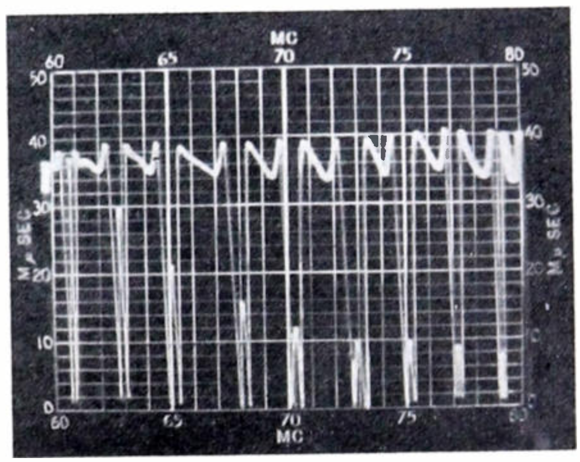


Fig. 4—Calibrating delay trace of mismatched spur cable. Echo delay = 0.46 millimicrosecond. The peak-to-peak excursion of the phase vector is 180°, corresponding to 208 millimicroseconds on a scale reduced by 10 db. This covers 40 scale divisions.

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 $2/\pi \cdot 208 = 133$ 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 function, 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 ϕ, preferably between 30 and 45 degrees. The amplitude ratio of the received to the reference vector is made equal to cos ϕ. 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).

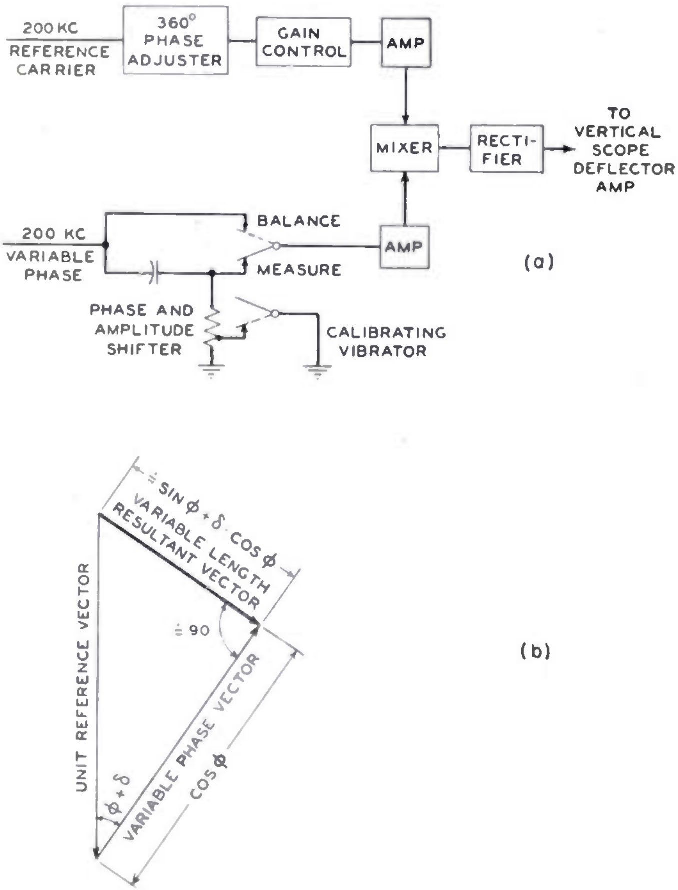


Fig. 5—Simplified phase indicator. ϕ = reference phase angle. δ = small variations of phase angle.

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.

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 saw-tooth 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 synchronism 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.

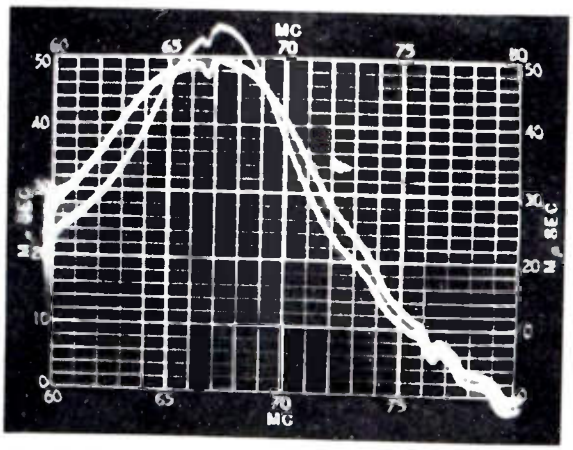


Fig. 6—Superimposed characteristics of two equalizers.

The delay scanner can be used for the testing and adjustment of impedance matches as follows:

In order to match a network, such as an amplifier or equalizer, to the line impedance of 75 ohms, it is connected in series with a long 75-ohm transmission line having a fixed delay, for instance, $T = 0.25$ microsecond, and its delay characteristic is observed. A small-known

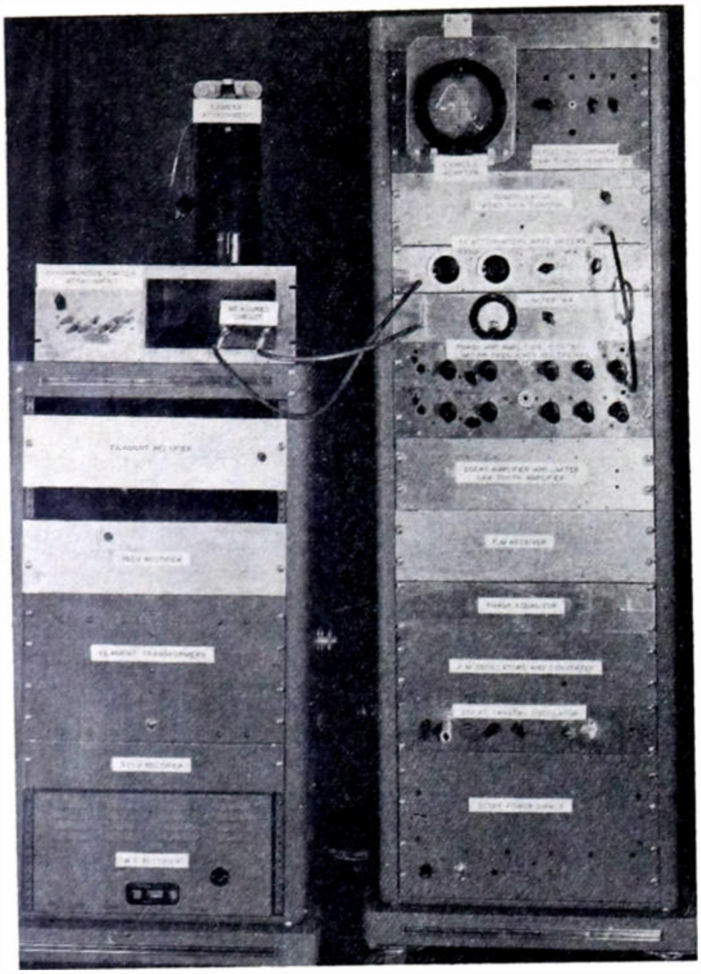


Fig. 7—The first model of the delay scanner as developed at the Deal Laboratories.

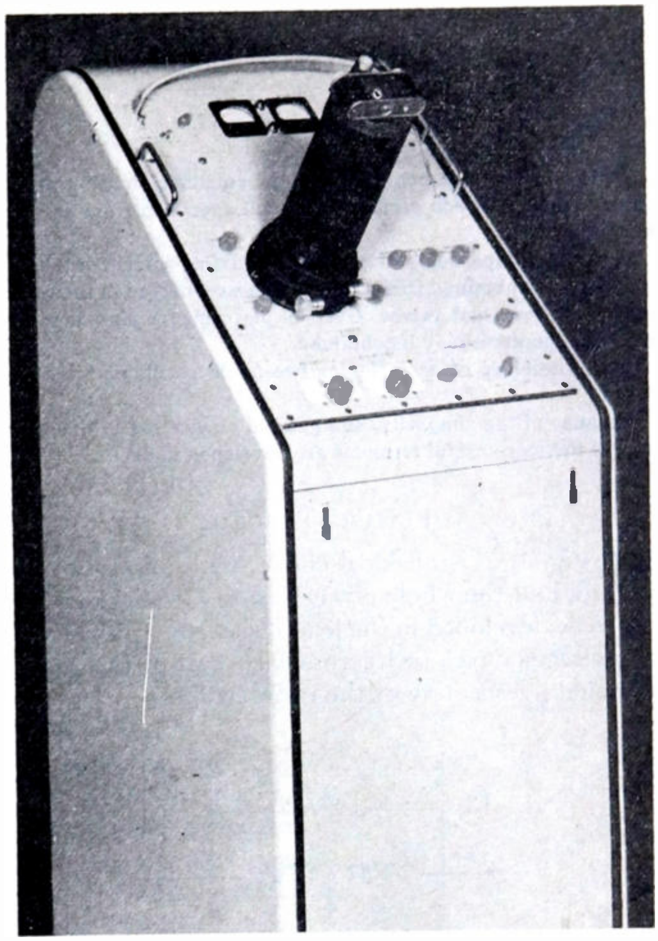


Fig. 8—The delay meter redesigned for commercial use.

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 $1/2T=2$ mc 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

$$Y_{\omega 0}L_1 = 1 + \frac{Q_2(1-x^2m)}{Q_1} - x^2m + j\left[Q_2x(1-x^2m) + \frac{xm}{Q_1} + Q_2\left(x - \frac{1}{x}\right)\right] \Big/ Q_2(1-x^2m)+jxm.$$

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 resister R. In such a case the voltages developed across each half of the winding are equal irrespective of the ratio I_1/I_2.

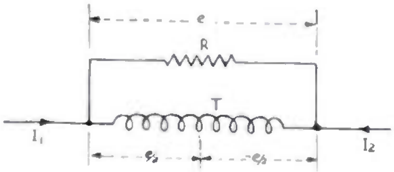


Fig. 1—Basic circuit.

Let R_1 = effective resistance offered current I_1
R_2 = effective resistance offered current I_2.
$I_1/I_2 = Y$.

We have

$$e^2/R = eI_1/2 - eI_2/2$$

$$2e/R = I_1 - I_2 \tag{1}$$

$$I_1/R_1 = I_2/R_2 = e/2 \tag{2}$$

$$I_1/I_2 = R_2/R_1 = Y. \tag{3}$$

Substituting in (1),

$$4/R = 1/R_1 - 1/R_2, \tag{4}$$

whence

$$R_1 = R(Y - 1)/4Y \tag{5}$$

$$R_2 = R(Y - 1)/4. \tag{6}$$

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_3 is applied to the grid of valve 2 in the correct phase, the resister R being varied to obtain ac plate-current balance.

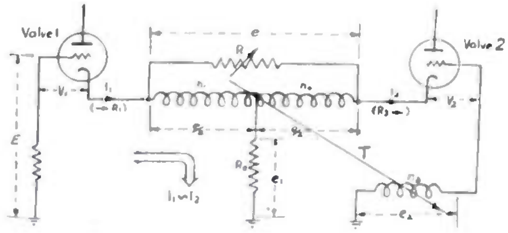


Fig. 2—Basic circuit applied to two valves. An unbalanced voltage E causes push-pull operation by virtue of the transformer T.

Let

$$N_3/(N_1 + N_2) = T = e_2/e \tag{7}$$

G_1 = mutual conductance of valve 1

G_2 = mutual conductance of valve 2.

Also assume negligible distortion and that T is an ideal transformer. In Fig. 2

$$\left.\begin{aligned} I_1 &= V_1G_1 \\ I_2 &= V_2G_2 \end{aligned}\right\} \tag{8}$$

and

$$V_1G_1/V_2G_2 = Y. \tag{9}$$

From (2),

$$V_1\cdot G_1\cdot R_1 = V_2G_2R_2 = e/2. \tag{10}$$

For equilibrium conditions

$$V_2 = e_2 + e_1 - e/2, \tag{11}$$

where

$$e_1 = (I_1 - I_2)\cdot R_0 \tag{12}$$

and using (2)

$$e_1 = \frac{e\cdot R_0}{2}\cdot\left(\frac{1}{R_1} - \frac{1}{R_2}\right).$$

From (5) and (6), with due regard to the sign of I_2,

$$e_1 = \frac{2e\cdot R_0}{R}\left(\frac{Y-1}{Y+1}\right). \tag{13}$$

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)

$$2G_2R_1\left(T - 1/2 + \frac{2R_0(Y-1)}{R(Y+1)}\right) = \frac{V_2G_2}{V_1G_1} = \frac{1}{Y}. \tag{14}$$

* Decimal classification: R363.222. Reprinted from the *Proceedings of the Institution of Radio Engineers, Australia*, vol. II, pp. 199–204, August, 1950, by the courtesy of the Institution of Radio Engineers, Australia.

† Lister Research Co., 333 George St., Sydney, Australia.

If the system is balanced (true push-pull), $Y=1$ and (14) reduces to

$$T = \frac{1 + G_2R/2}{G_2\, R}, \tag{15}$$

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_1 from (5), we can write

$$Y = \frac{1 - G_2'\cdot(T - 1/2 - 2R_0/R')R'/2}{G_2'\cdot(T - 1/2 + 2R_0/R')R'/2}, \tag{16}$$

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 $G_2'R'/G_2R = K \neq 1$.

Using this relation and substituting (15) in (16),

$$Y = \frac{1 - \dfrac{K\, G_2\cdot R}{2}\left(\dfrac{1 + G_2\cdot R/2}{G_2\cdot R} - 1/2 - 2R_0/R'\right)}{\dfrac{KG_2R}{2}\left(\dfrac{1 + G_2R/2}{G_2\, R} - 1/2 + 2R_0/R'\right)}$$

Simplifying,

$$Y = 1 + \frac{2(1 - K)}{K\left(\dfrac{2R_0G_2R}{R'} + 1\right)}. \tag{17}$$

Thus R_0 helps to reduce unbalance. Generally for the simpler circuits $2R_0G_2 \equiv 1$; and if R is nearly equal to R', (17) becomes approximately

$$Y = 1/K. \tag{18}$$

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 $e/2 \ll V_1$, and $e2=0$ (Ro 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_r is zero, and $E \equiv V_1$.

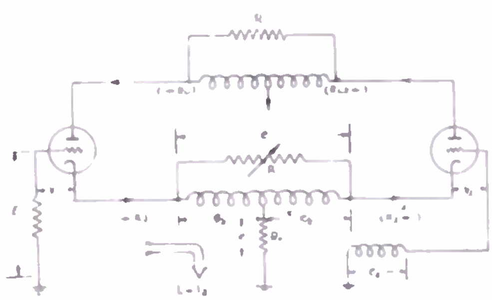


Fig. 3—Complete basic circuit, R_L is the plate load. Power supply circuits are omitted for clarity.

The power in the load R_L may be estimated in the manner used for Fig. 1. Thus let

W_1 = power developed in R_L when $I_1 = I_2$
W_2 = power developed in R_L when $I_1 \neq I_2$
R_{L1} = effective resistance offered I_1
R_{L2} = effective resistance offered I_2.

Then

$$W_1 = (I_1)^2\cdot R_{L1} + (I_2)^2 R_{L2} \text{ as in equation (1)}$$
$$= (I_1)^2\cdot R_L \text{ since } I_1 = I_2$$
$$W_2 = (I_1)^2\cdot R_{L1} + (I_2)^2 R_{L2}$$
$$W_2 = (I_1)^2\cdot R_{L1}\left(1 + \frac{1}{Y}\right) \text{ from equation (3);}$$

and using (5) (allowing for the sign of I_2),

$$\frac{W_1}{W_2} = \left(\frac{2Y}{Y + 1}\right)^2. \tag{19}$$

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_2R 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).

Eliminating R_1 by means of (5) (allowing for the sign of I_2),

$$V_1 = \frac{E}{1 + G_1\left\{\frac{R(Y+1)}{4Y} + \left(\frac{Y-1}{Y}\right)R_0\right\}}. \tag{20}$$

Let V_1' = grid-cathode voltage for the particular case when $Y=1$. Then from (20),

$$V_1' = \frac{E}{1 + G_1 \cdot R/2}, \tag{21}$$

so that using the same nomenclature as before

$$W_1 = (I_1)^2 R_L = (G_1 V_1')^2 R_L. \tag{22}$$

From (19)

$$W_2 = (I_1)^2 \cdot R_L \left(\frac{1+Y}{2Y}\right)^2;$$

and since in this case I_1 is produced by V_1 of (20),

$$W_2 = (G_1 V_1)^2 \cdot R_L \left(\frac{1+Y}{2Y}\right)^2. \tag{23}$$

Substituting (20) and (21) in (22) and (23),

$$\frac{W_1}{W_2} = \left\{\frac{4Y + G_1[R(Y+1) + 4(Y-1)R_0]}{(1+Y)(2+G_1R)}\right\}^2. \tag{24}$$

For $Y=1.1$, $2R_0G \equiv 1$, $G_1R = 0.4$ (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 was >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

$$e_2 = V_2 + e/2 + (I_2 - I_1)R_0, \tag{25}$$

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)

$$Te = V_2 + V_2 \cdot G_2 \cdot R_2 + V_2 \cdot G_2 \cdot R_0(1-Y).$$

Thus

$$2TG_2R_2 = 1 + G_2R_2 + G_2 \cdot R_0(1-Y).$$

Using (15) and (6) (allowing for the sign of I_2),

$$\left(\frac{1+G_2R/2}{R}\right)\frac{R'(Y+1)}{2} = 1 + G_2\left\{\frac{R'(Y+1)}{2} + R_0(1-Y)\right\}. \tag{26}$$

Now the current I_1 in this case is produced by the voltages $e/2$ and e_1. Hence,

$$I_1 = G_1(e_1 - e/2)$$
$$= G_1[G_2 \cdot V_2(1-Y) \cdot R_0 - G_2 \cdot V_2 \cdot R_2]$$

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).

$$\frac{I_1}{G_2V_2} = G_1\left\{(1-Y)R_0 - \frac{R'(1+Y)}{4}\right\}$$

$$Y = \frac{G_1(4R_0 - R')}{4 + G_1(4R_0 + R')}. \tag{27}$$

Substituting for Y in (26), we have

$$\frac{2(1+G_2R/2)(R'(1+2G_1 \cdot R_0))}{R} = 4 + G_1(4R_0 + R') + G_2[R'(1+2G_1R_0) + R_0(4+2G_1R')];$$

and when $G_1 = G_2$, this simplifies to

$$R' = \frac{2R}{1 - G_1 \cdot R/2} \tag{28}$$

$$= R(2T-1)/(T-1) \text{ by using (15).} \tag{29}$$

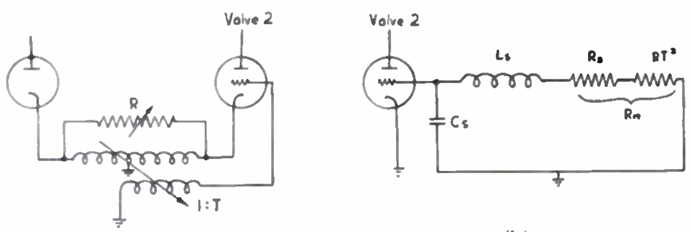
Perfect stability results when $G_1R = 2(T=1)$. The value of R_0 does not affect the stability. Note that it is impossible for oscillation to occur at or near balance. For if $R=R'$, (29) gives $-G_1R=2$, which is impossible. If G_1R is negligibly small, then $R'=2R$, which is well removed from R. If valve 1 is removed, $Y=0$; and from (26),

$$R' = 2R(1 + G_2 \cdot R_0). \tag{30}$$

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



(a) (b)

Fig. 4—The equivalent of circuit (a) at high frequencies is shown in (b). *Cs* is stray capacity, *Ls* leakage inductance, and *Rs* secondary resistance.

network comprising leakage inductance *Ls*, self-capacity *Cs*, and effective secondary resistance *Rs*.

$$R_n = (Rs + T^2R),$$

where *Rs* is the secondary resistance. The impedance of this circuit near resonance is $Ls/Cs \cdot Rn$ so that if *Rn* is sufficiently small and *Ls* large a high impedance may result. Feedback from other parts of the circuit, principally the anodes, can, therefore, produce oscillation. Since $Ls/Cs \cdot Rn$ 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

$$T/(T-1/2). \tag{31}$$

VII. Balance for Noises Originating in the Power Supply

Fig. 5 is the circuit for examination of this aspect of operation. Let

R_{p1} = plate resistance valve 1
R_{p2} = plate resistance valve 2
E_n = noise voltage in high-voltage supply.

We have

$$V_1 = -(e/2 + e_r)$$
$$V_2 = Te - (e/2 + e_r)$$
$$I_1 = E_n/R_{p1} - G_1(e/2 + e_r) \tag{32}$$
$$I_2 = E_n/R_{p2} - G_2(e/2 + e_r) + TeG_2. \tag{33}$$

From (2) and (6)

$$Te = 1/2 \cdot [TI_2R(Y - 1)].$$

If $R_{p1} = R_{p2}$ and $G_1 = G_2$,

$$I_1 - I_2 = -1/2 \cdot [TI_2RG_2(Y - 1)]$$

from (32) and (33). Hence,

$$Y - 1 = 1/2 \cdot [TR(1 - Y) - G_2] \tag{34}$$

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.

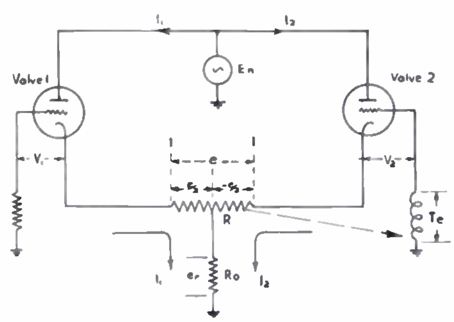


Fig. 5—Equivalent circuit for the examination of noise voltage E_n originating in the high-tension power supply.

VIII. Distortion

The ac plate currents of the valves may be expressed by the usual series,

$$I_1 = aV_1 + bV_1^2 + cV_1^3 + \tag{35}$$
$$I_2 = -a'V_2 + b'V_2^2 - c'V_2^3 + . \tag{36}$$

The total circulating current is the difference between these currents. Usually it is assumed that the coefficients of the two valves are equal ($a=a'$, $b=b'$, 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

$I_{n1} = WV_1^n$ *n*th component for valve 1
$I_{n2} = W(-V_2)^n$ *n*th component for valve 2.

The total circulating current for any particular coefficient will depend on the feedback voltages e, e_r, and Te (Fig. 6), occurring for that particular component.

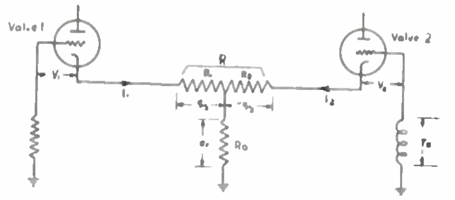


Fig. 6—Basic circuit used for discussion on distortion.

Thus

$$I_{n1} = WV_1^n - (e/2 + e_r)a$$
$$I_{n2} = W(-V_2)^n + (-1)^n(-e/2 + e_r + Te)a$$

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

$$I_{n1} - I_{n2} = W(V_1^n - (-V_2)^n - ea + Tea, \quad (37)$$

where n is an odd number. From (1)

$$e = (I_{n1} - I_{n2})R/2. \quad (38)$$

Substituting in (37) and using (15), we obtain

$$I_{n1} - I_{n2} = W\{V_1^n - (-V_2)^n\}\frac{(2T - 1)}{T}. \quad (39)$$

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_1R 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), $V \propto (1/K)$; from (16), $K \propto G_2'/G_2$. Since $G_2 \propto E$, it follows that $V \propto E$ (Fig. 2). Thus to obtain maximum power [(24) $V=1$], 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 $V=1$, $V_1 \neq V_2$. 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 $V_1 = V$, if $a \neq a'$, $V \neq 1$, and the maximum possible output would be slightly less than obtained with $V=1$.

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.

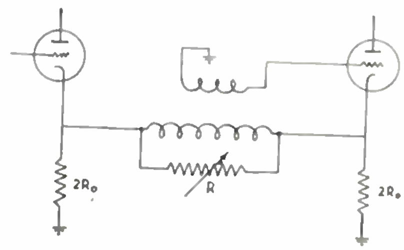


Fig. 7—An interesting modification.

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

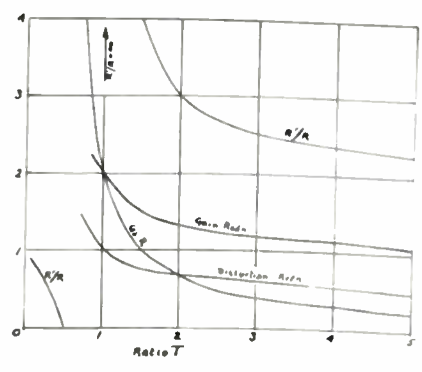


Fig. 8—Showing the relation between the various formulas, and the transformation-ratio T.

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.)

XI. ACKNOWLEDGMENTS

The author is indebted to Ferguson Transformers Pty. Ltd. for the use of their laboratory in investigating this circuit; also to Mr. R. Edwards, who assisted in the initial draft paper.

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.[1] 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.

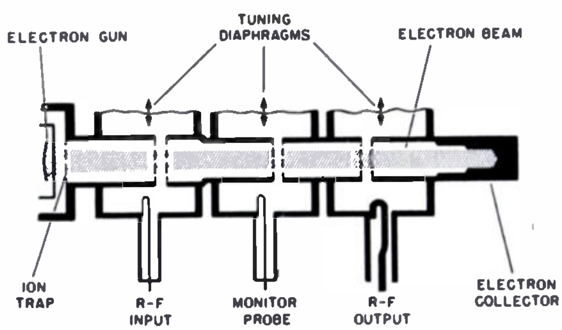

Fig. 1(a)—Example of ion-focused beam in a three-cavity amplifier with gridded gaps. The tube is the SAS-28 with 250-watts output at 2,600 mc and 30 db gain.

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

* Decimal classification: R355.912.3. Original manuscript received by the Institute, April 30, 1951; revised manuscript received, November 2, 1951.
† Sperry Gyroscope Company, Great Neck, L. I., N. Y.

[1] C. C. Wang, "Electron beams in axially symmetric electric and magnetic fields," PROC. I.R.E., vol. 38, pp. 135–148; February, 1950.

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.

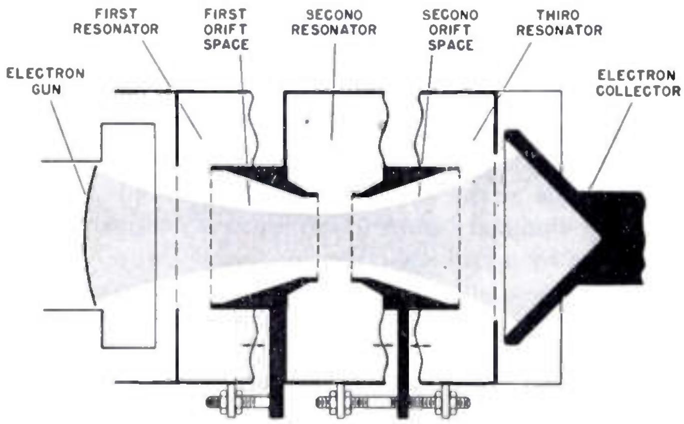

Fig. 1(b)—Example of space-charge focused beam in a three-cavity amplifier with gridded gaps. The tube is the pulse type SAL-39 with an output of 20 kw at 1,000 mc and one-per cent duty cycle.

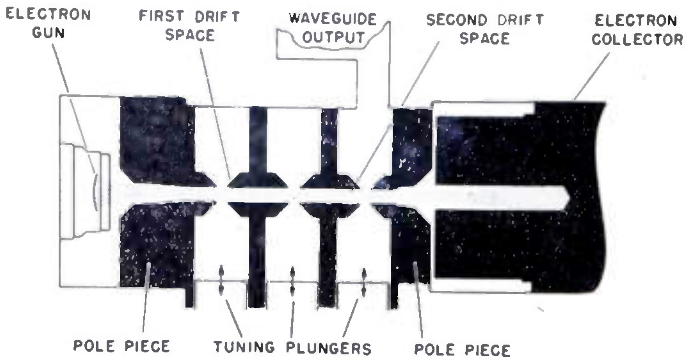

Fig. 1(c)—Example of magnetically focused beam in a three-cavity amplifier with gridless gaps. The tube is the cw or pulsed SAC-33 with 500 watts output at 5,000 mc and 25 to 30 db gain.

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.

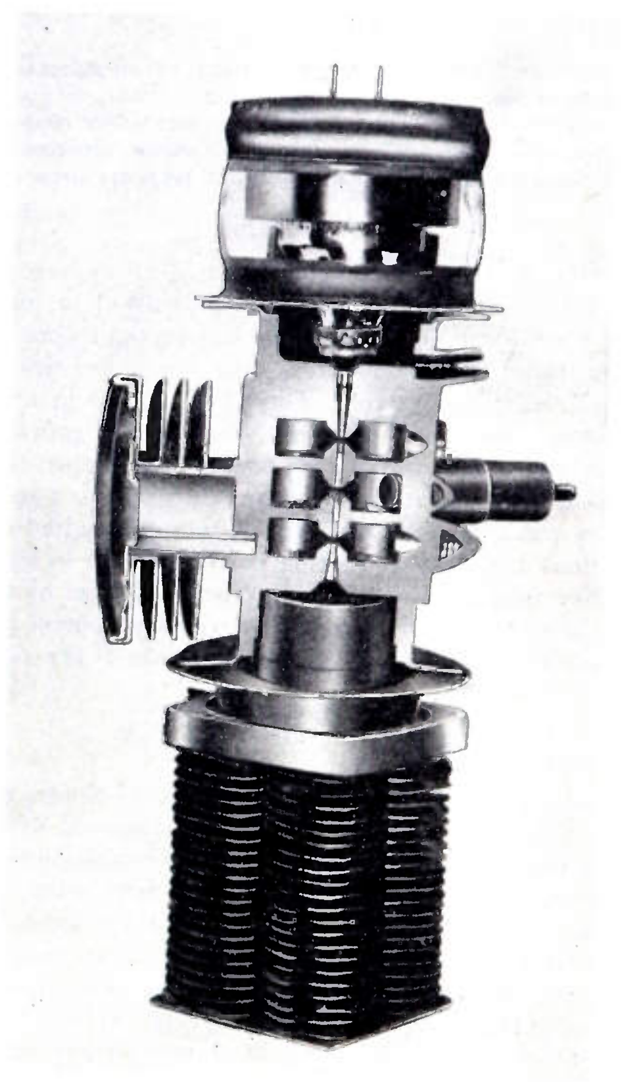

Fig. 2—Photograph of cutaway SAC-33 showing typical construction of a magnetically focused power klystron.

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.

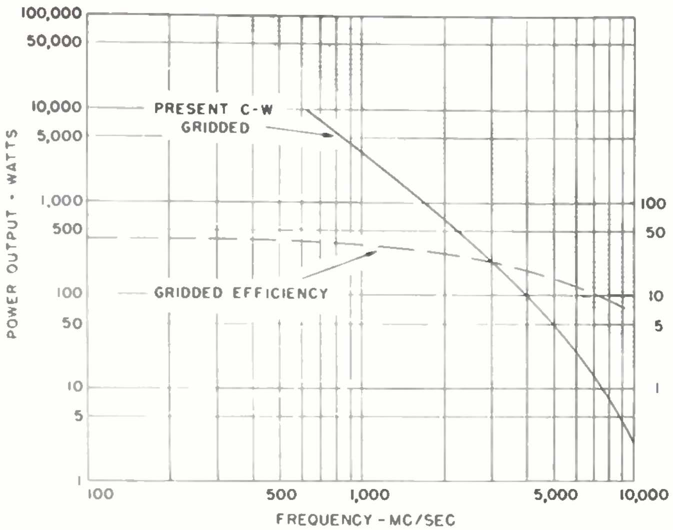

Fig. 3—Approximate ultimate power data for klystrons. The solid line is for gridded tubes and the shaded region the average power for pulsed tubes.

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[1] 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[2] 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, $h_1 = 35$ feet, while Fig. 2 is for $h_1 = 115$ 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 μv across a 50-ohm input impedance, i.e., a received radio-frequency signal of 0.18 $\mu\mu v$ is assumed to provide satisfactory intelligibility. 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 $\epsilon = 15$ and a conductivity $\sigma = 0.01$ mhos/meter which corresponds to land of good conductivity. If the propagation were over either fresh water or sea water

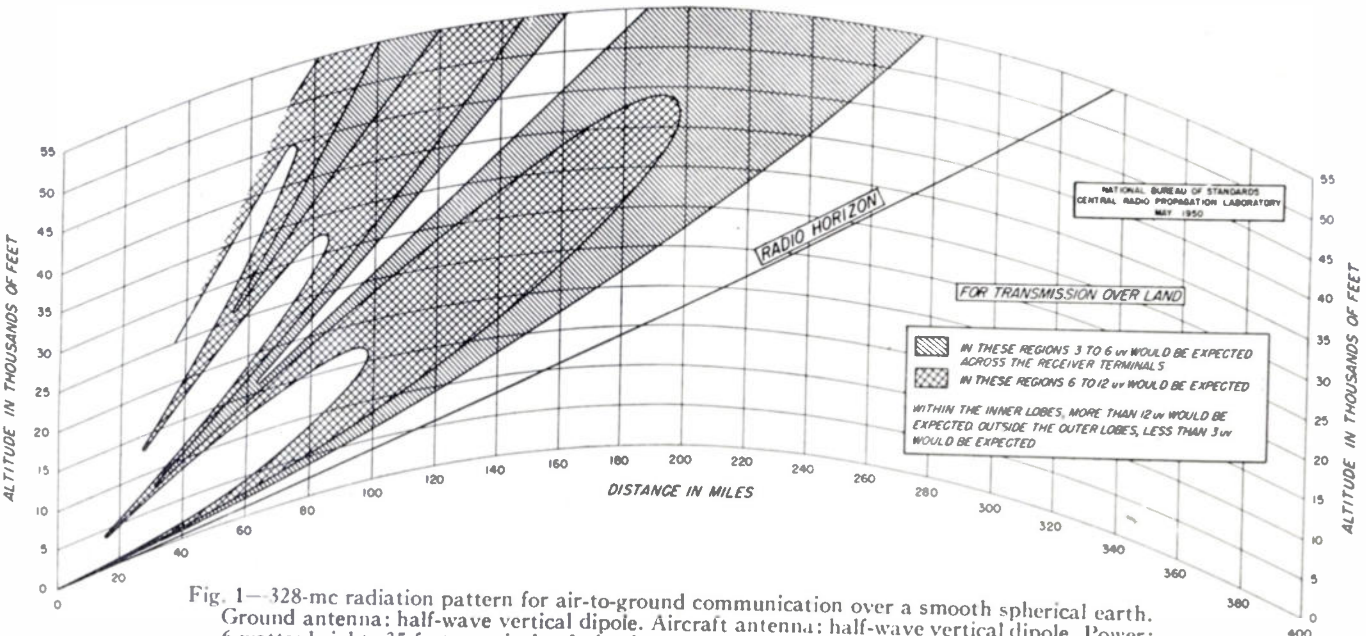

Fig. 1—328-mc radiation pattern for air-to-ground communication over a smooth spherical earth. Ground antenna: half-wave vertical dipole. Aircraft antenna: half-wave vertical dipole. Power: 6 watts; height: 35 feet; vertical polarization. Assumed communication-system loss: 6 db.

* Decimal classification: R523×R528. Original manuscript received by the Institute, April 2, 1951.

† Central Radio Propagation Laboratory, National Bureau of Standards, Washington 25, D. C.

[1] R. S. Kirby, J. W. Herbstreit, and K. A. Norton, "Service Range for Air-to-Ground Communications at Frequencies Above 50 Mc," National Bureau of Standards, Central Radio Propagation Laboratory, October 6, 1950 (in preparation).

[2] "Ultra-High-Frequency Propagation Tests Over Land and Water," Appendices A, B, and G, Project No. TED No. PTR EL 929, U. S. Naval Air Test Center, Patuxent River, Md.; December, 1949.

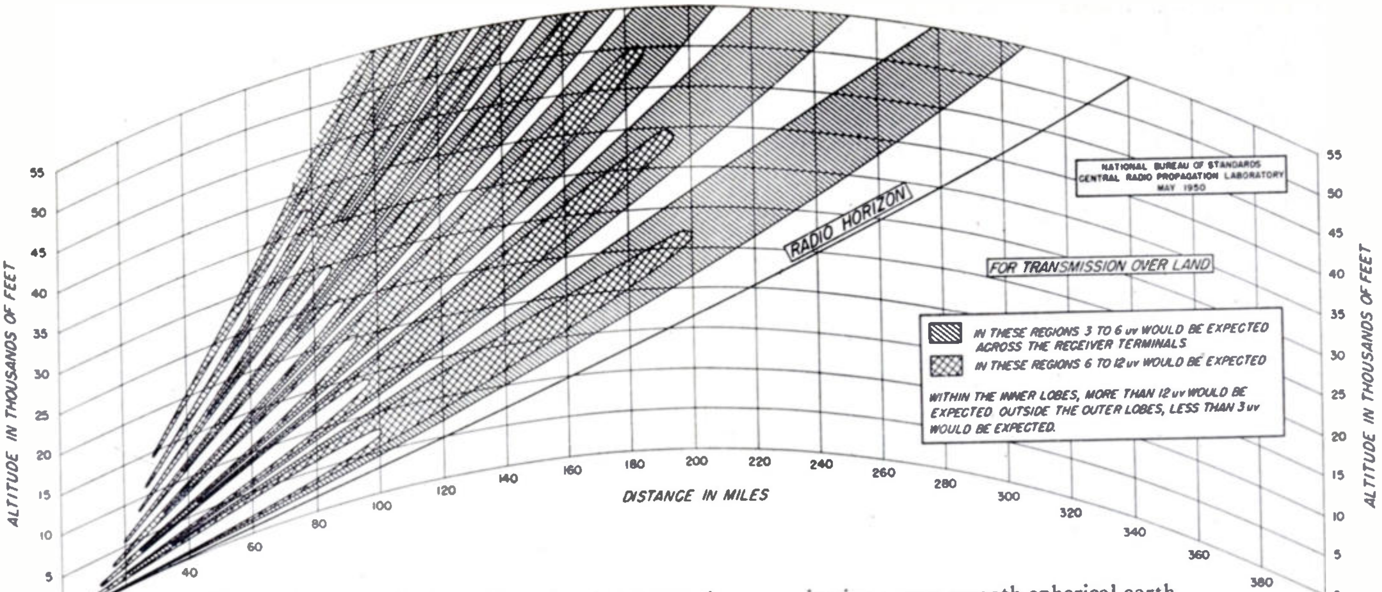

Fig. 2—328-mc radiation pattern for air-to-ground communication over a smooth spherical earth. Ground antenna: half-wave vertical dipole. Aircraft antenna: half-wave vertical dipole. Power: 6 watts; height: 115 feet; vertical polarization. Assumed communication system loss: 6 db.

(see Table I), 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 μv 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 μv 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-μv 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_{1m}, 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_{1m} 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 I

COMPARISON OF h_{1m} EXPRESSED IN FEET FOR PROPAGATION AT 328 MC OVER GOOD GROUND AND OVER SEA WATER

	σ mhos/meter	ϵ	Brewster's angle milliradians	System loss = 6 db			System loss = 12 db		
				H_m = 10,000′	25,000′	40,000′	10,000′	25,000′	40,000′
Good ground	0.01	15	252	45.7′	27.7′	21.2′	30.3′	18.0′	13.8′
Sea water	4.64	81	61.2	93.8′	54.8′	41.0′	57.4′	31.9′	15.9′

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 on frequencies less than 150 mc and using ground-station antenna heights less than 50 feet, we see by Fig. 1 that no problem 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.

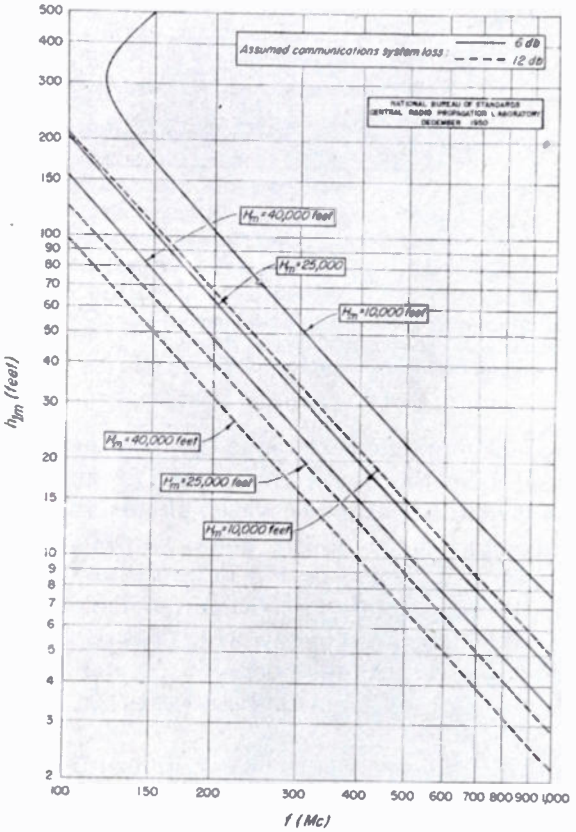

Fig. 3—The maximum ground-station antenna height, h_{1m}, for gapless over land air-to-ground communications up to the altitude, H_m calculated for a smooth spherical earth and the average atmosphere at Washington, D. C. Aircraft transmitter power 6 watts; ground-station receiver sensitivity 0.18 $\mu\mu$w. Aircraft and ground-station antennas: half-wave vertical dipoles.

The solid curves on Figs. 4, 5, 6, 7, 8, and 9 show the maximum-distance range for satisfactory communications at selected aircraft altitudes, $h_{2m} = 1{,}000$, 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_{1m}, corresponding to the selected value of the maximum required altitude, H_m. 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_{1m} 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_{1m}, 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.

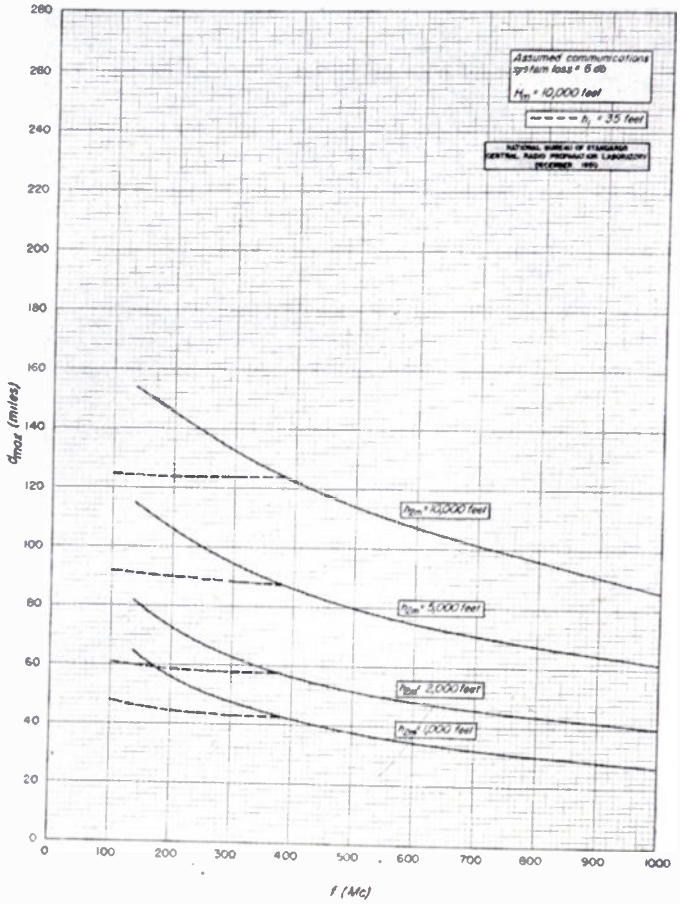

Fig. 4—The maximum-distance range for gapless over land air-to-ground communications calculated for a smooth spherical earth and the average atmosphere at Washington, D. C. Aircraft transmitter power 6 watts; ground-station receiver sensitivity 0.18 $\mu\mu$w. Aircraft and ground-station antennas: half-wave 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.[1] Throughout this paper the optimum values of antenna height were computed by determining values of h_{1m} for which the electrical path-length difference, $\theta - c$ (See footnote reference[1]), is equal to 360° at the maximum height, H_m, 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_{1m} determined in this way are actually a little high at 1,000 mc. These differences are small in this case and are com-

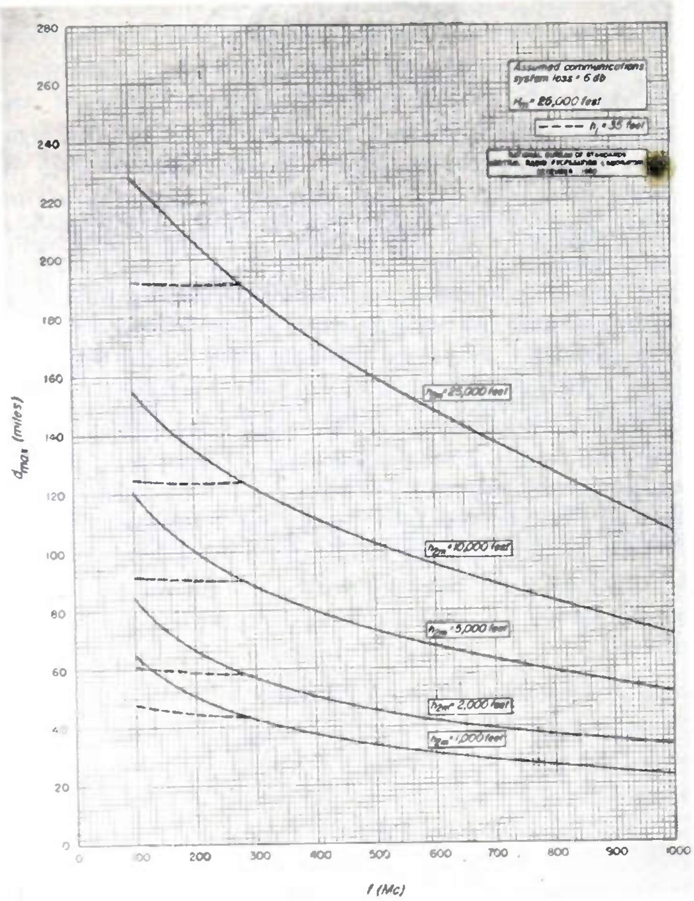

Fig. 5—See caption of Fig. 4.

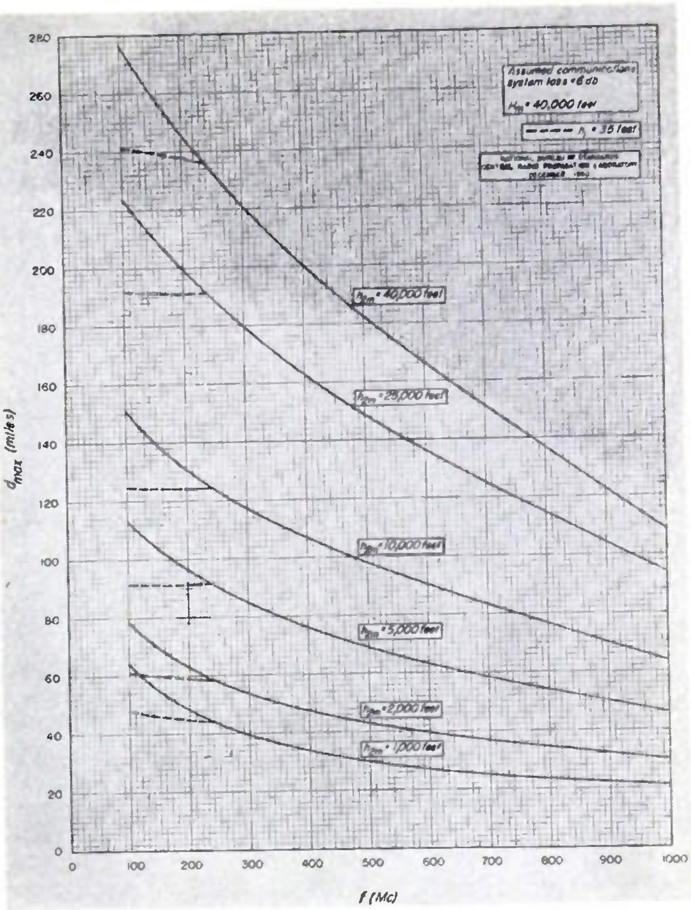

Fig. 6—See caption of Fig. 4.

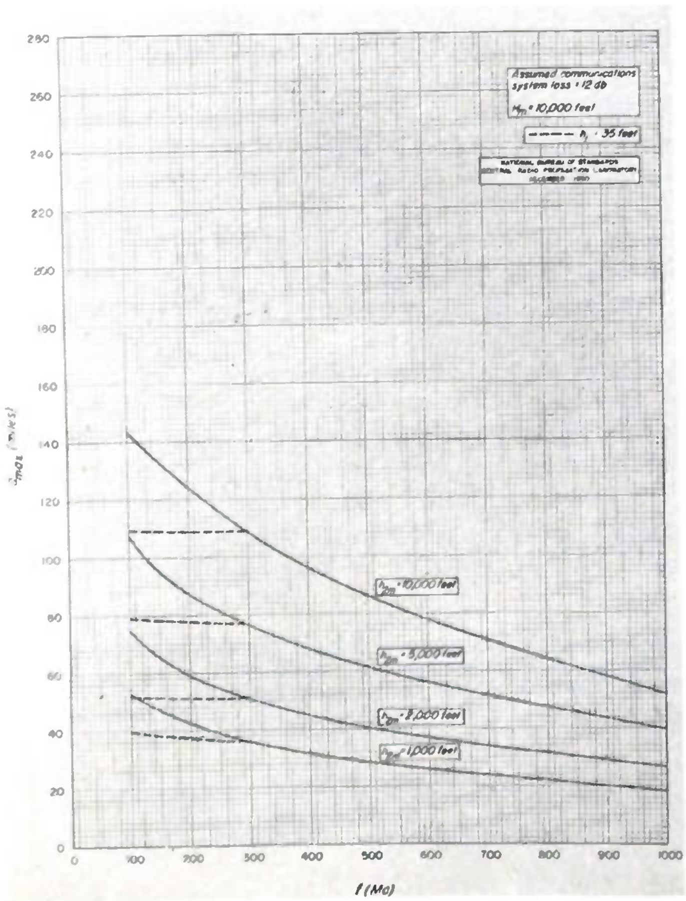

Fig. 7—See caption of Fig. 4.

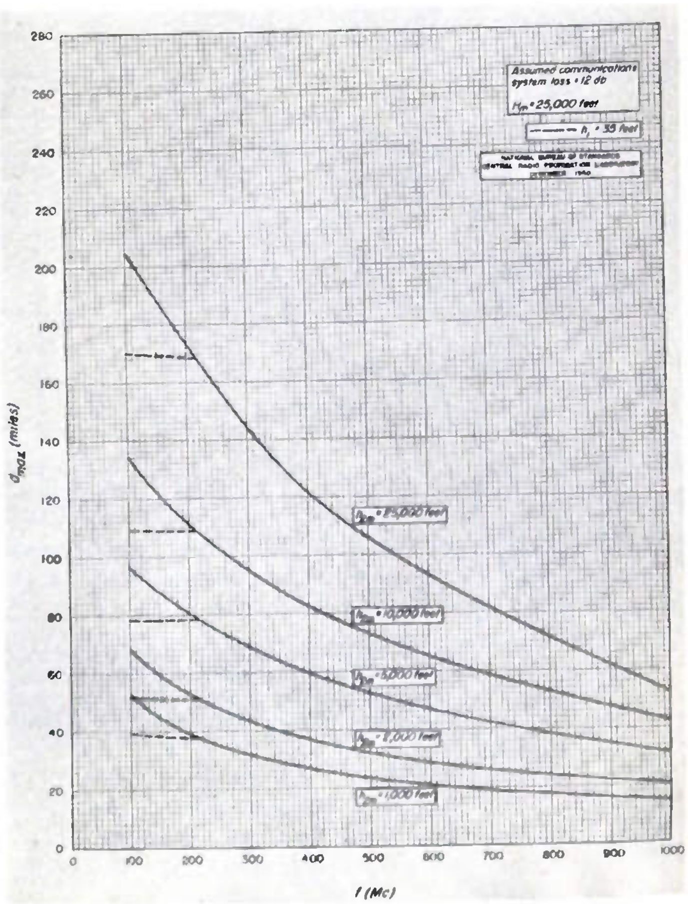

Fig. 8—See caption of Fig. 4.

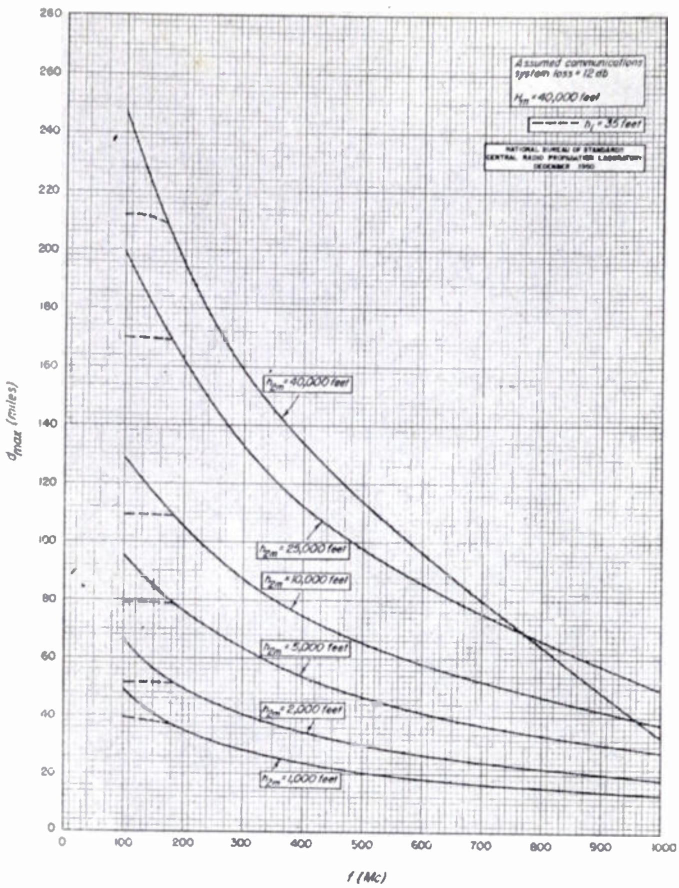

Fig. 9—See caption of Fig. 4.

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,[1] 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.

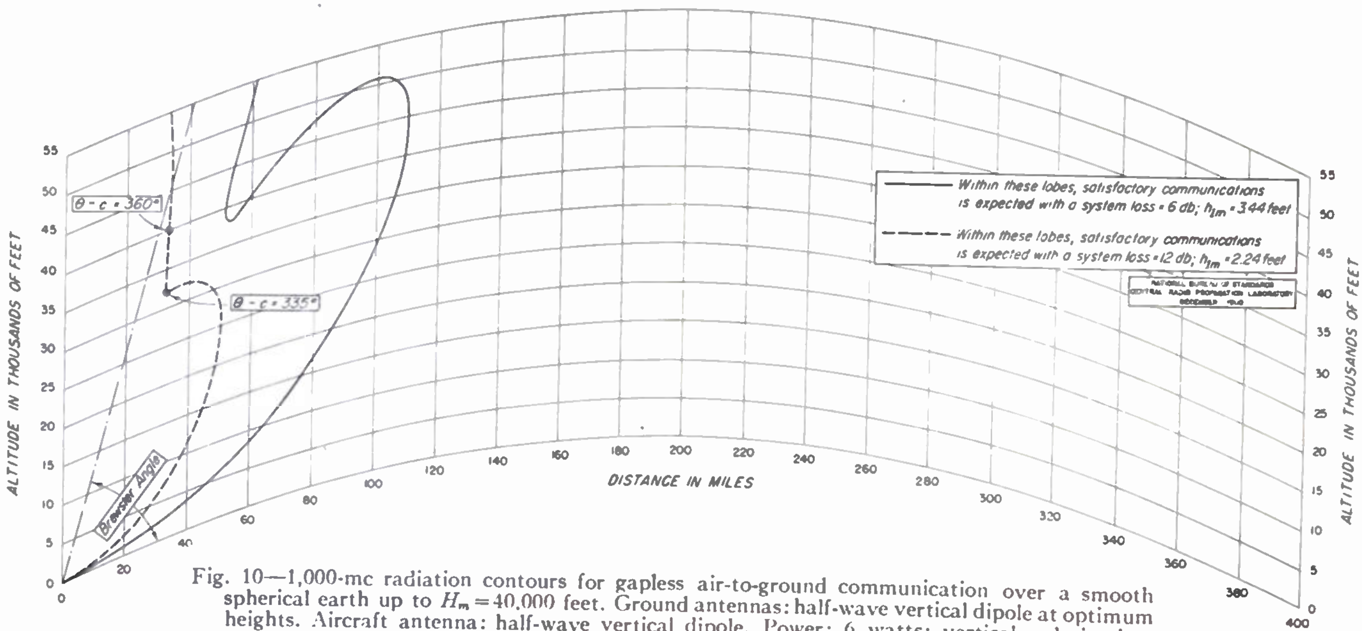

Fig. 10—1,000-mc radiation contours for gapless air-to-ground communication over a smooth spherical earth up to H_m = 40,000 feet. Ground antennas: half-wave vertical dipole at optimum heights. Aircraft antenna: half-wave vertical dipole. Power: 6 watts; vertical polarization. Ground-station receiver sensitivity: 0.18$\mu\mu$w.

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 coincidentally 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.

Introduction

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.[1] 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.

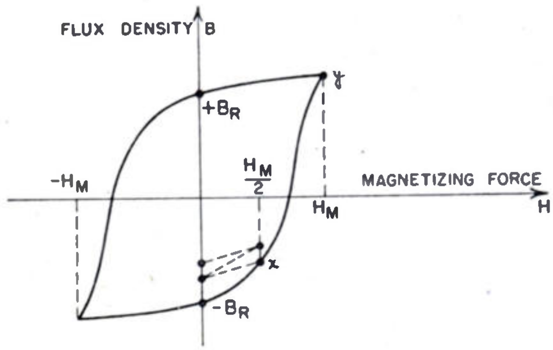

Fig. 1—Paths of operation of a magnetic memory unit.

Two- and Three-Dimensional Selection

If nine such cores are arranged in a two-dimensional array, as in Fig. 2, and currents of magnitude $I_M/2$

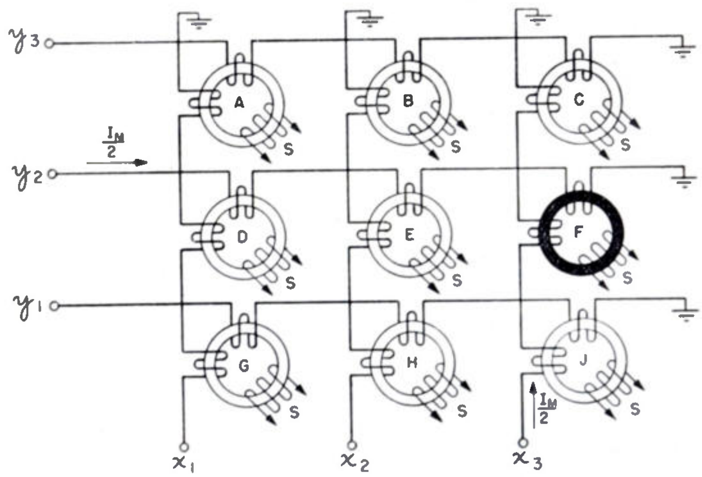

Fig. 2—A two-dimensional array of cores.

(where I_M results in a magnetizing force of H_M per core) are caused to flow coincidentally in selected lines x_3 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

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† Digital Computer Laboratory, Department of Electrical Engineering, Massachusetts Institute of Technology, Cambridge, Mass.

[1] J. W. Forrester, "Digital information storage in three dimensions using magnetic cores," *Jour. Appl. Phys.*, vol. 22, pp. 44–48; January, 1951.

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 *minus* $H_M/2$ 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;[2,3] 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 "undistured 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-ONE 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.

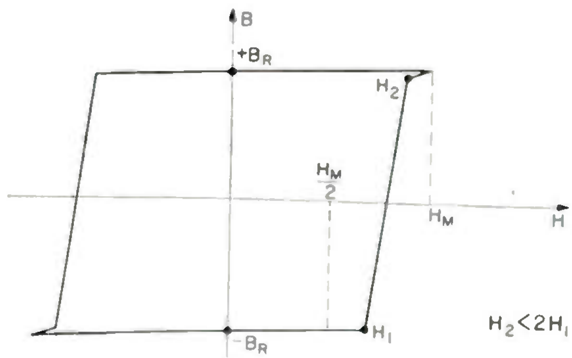

Fig. 3—An idealization of a B-H loop.

From the idealized hysteresis loop of Fig. 3, some necessary conditions for coincident-current operation

[2] "Ferromagnetic and Ferroelectric Cores," Summary Report No. 26, Section 3.4, Digital Computer Laboratory, M.I.T., Cambridge, Mass.; Second Quarter, 1951.

[3] R. R. Everett, "Selection Systems for Magnetic Core Storage," Engineering Note E-413, an internal document of the Digital Computer Laboratory, M.I.T., Cambridge, Mass.; August 7, 1951.

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_1 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* con-

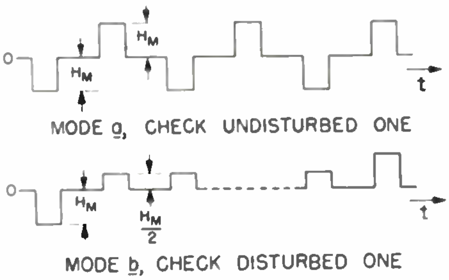

Fig. 4—Core-testing pulse patterns of H.

sists 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-H 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 "Silectron" 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

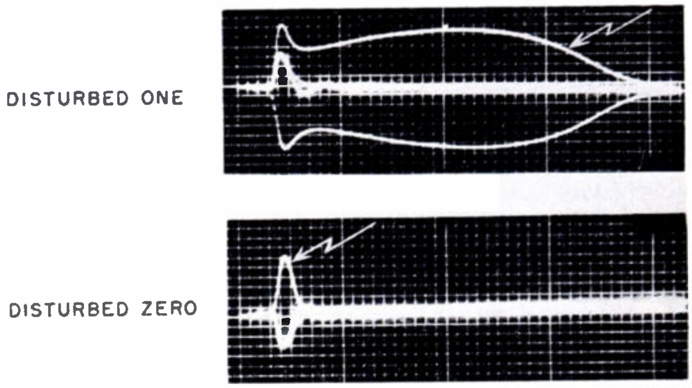

Fig. 5—Coincident-current test results, best metallic core.

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.

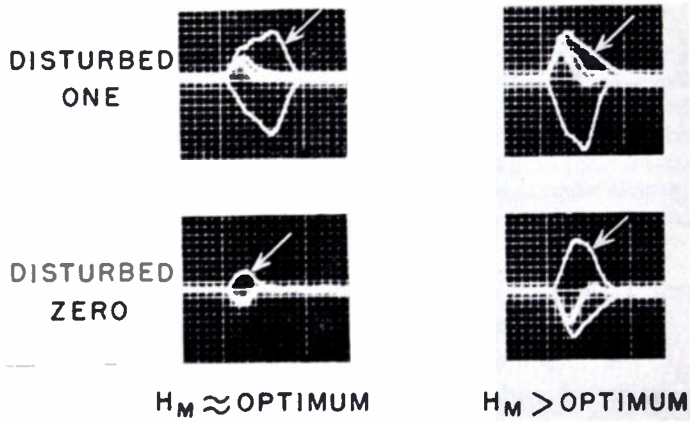

Fig. 6—Coincident-current test results, best ferritic core.

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-ONE output. This led to an unsatisfactory disturbed-signal ratio close to one in value.

CORE CRITERIA	BEST METALLIC CORE	BEST FERRITIC CORE	IDEAL
DISTURBED-SIGNAL RATIO	13	6	$\rightarrow \infty$
NON-SELECTING SIGNAL RATIO	16	$3\frac{1}{2}$	$\rightarrow \infty$
RESPONSE TIME	25 μ SEC	$\frac{1}{2}$ μ SEC	$\rightarrow 0$

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[1] can be divided into two classes on the basis of the feedback arrangement. Field[2] 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,[3,4] 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[4] has shown that an electromagnetic wave traveling along a conducting structure, such as a helix,

* Decimal classification: R339.2×R355.912. Original manuscript received by the Institute, November 22, 1950; revised manuscript received, November 23, 1951.

† Engineering Department, Stanford Research Institute, Stanford, California.

[1] E. M. T. Jones, "Traveling Wave Tube Oscillators," Stanford Technological Report No. 28, prepared under Contract No. N6-ONR-251, Consolidated Task No. 7; August, 1950.

[2] L. M. Field, "Initial Studies of a Harmonic Output Wide-Tuning Range Traveling-Wave Tube Oscillator," Stanford Technical Report No. 20, prepared under Contract No. N6-ONR-251, Consolidated Task No. 7; September, 1949.

[3] J. H. Tillotson, "Explicit Forms of the Propagation Functions of a Traveling-Wave Tube," Stanford Technical Report No. 13, prepared under Contract No. N6-ONR-251, Consolidated Task No. 7; April, 1949.

[4] J. R. Pierce, "Theory of the beam type traveling wave tube," PROC. I.R.E., vol. 35, pp. 112–123; February, 1947.

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[5] for velocity of propagation.

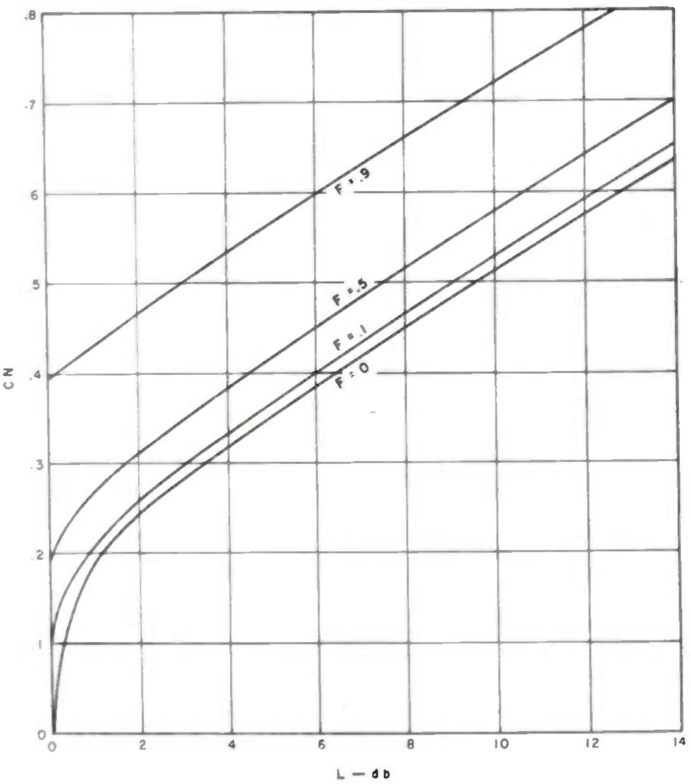

Fig. 1—CN for the start of oscillation, proportional to the one-third power of the beam current, as a function of the loss L of the interaction structure (assumed uniformly distributed) for various fractions F of the available power coupled out of the cavity.

Expressed mathematically, the gain condition is

$$G - L' = -10 \log_{10} [1 - F], \qquad (1)$$

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[5] 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 Tillotson's[3] three-wave approximation to the curves of Pierce,[4] 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[6] 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 Δf across a mode of oscillation is given by[1]

$$\Delta f = \frac{1}{2\left[\dfrac{v_\phi}{f} - \dfrac{\partial v_\phi}{\partial f}\right]} \int_{v_{e1}}^{v_{e2}} \frac{\partial v_f}{\partial v_e} dv_e, \qquad (2)$$

where

v_{e1} = beam velocity (cm per second) corresponding to the low-frequency oscillation limit of the mode

v_{e2} = 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

[5] J. R. Pierce, "Traveling Wave Tubes," D. Van Nostrand Co., New York, N. Y.; 1950.

[6] J. R. Pierce, "Circuits for traveling wave tubes," Proc. I.R.E., vol. 37, pp. 510-515; May, 1949.

v_ϕ = 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 $\partial v_f/\partial v_e$ was very small. The total electronic tuning on one mode was found to be less than 8 mg 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[3] 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 δV, divided by the average voltage V, is[1]

$$\frac{\delta V}{V} = 2\left\{\left[\frac{0.55}{N} - 0.0213\,\frac{CL}{N}\right]^2 - 1.02\,\frac{CL}{N} - 7.28\,\frac{C}{N} + 36C^2 - \frac{0.071L}{N^2} - 7.54\,\frac{C}{N}\log_{10}\left[1-F\right]\right\}^{1/2}. \quad (3)$$

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.

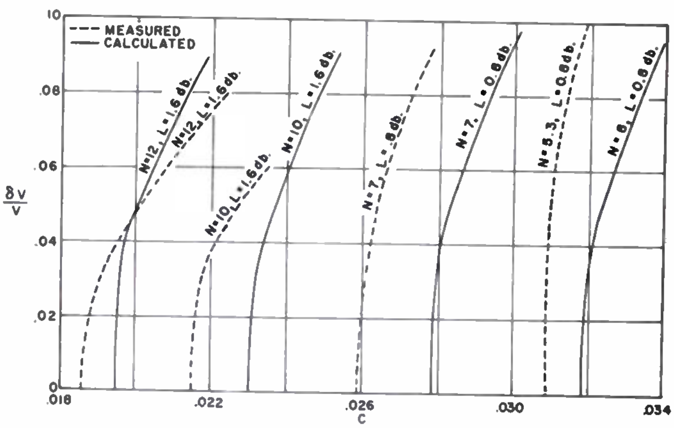

Fig. 2—Fractional voltage width of mode of oscillation $\delta V/V$, as a function of C, with F very small.

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.

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 ΔV, divided by the beam voltage, V, is[1]

$$\frac{\Delta V}{V} \sim \frac{\dfrac{2}{n+1}}{1 - \dfrac{\Delta f}{\Delta v_\phi}\,\dfrac{v_\phi}{f}}. \quad (4)$$

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

$$\frac{\Delta f}{\Delta v_\phi}\,\frac{v_\phi}{f}$$

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

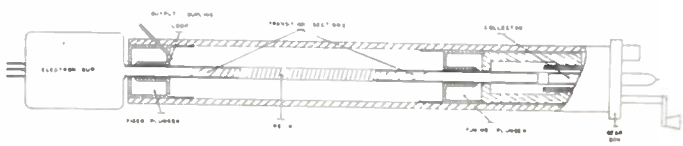

Fig. 3—Longitudinal section of an internal feedback traveling-wave-tube oscillator.

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.[7] 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

[7] C. O. Lund, "A broadband transition from coaxial line to helix," *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.

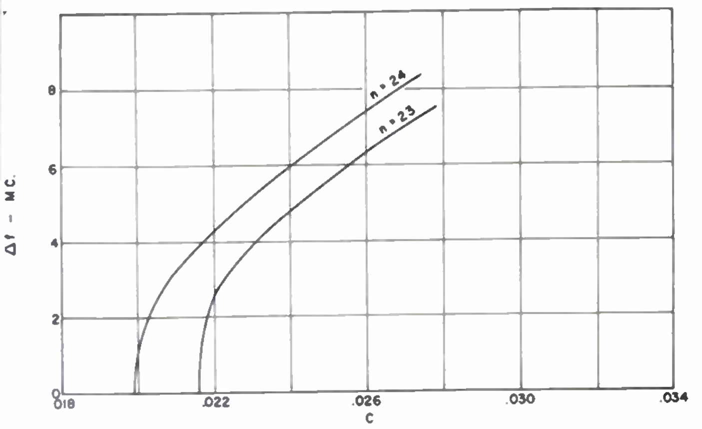

Fig. 4—Typical measured frequency width of modes of oscillation Δf, as a function of C, for various numbers n of wavelengths around the feedback loop.

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.

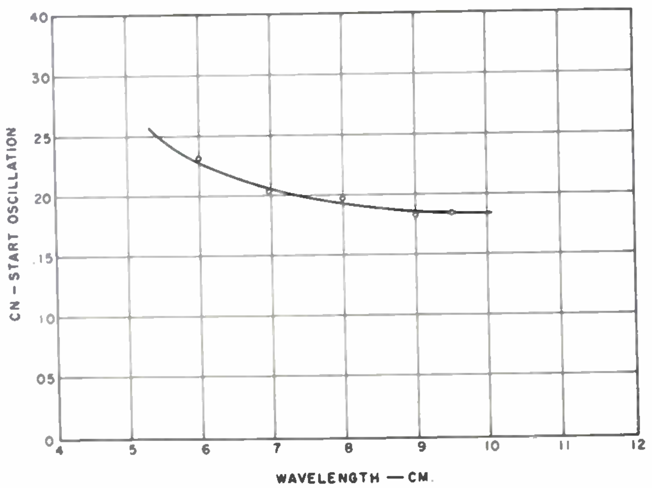

Fig. 5—Experimentally determined CN for the start of oscillation as a function of wavelength.

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

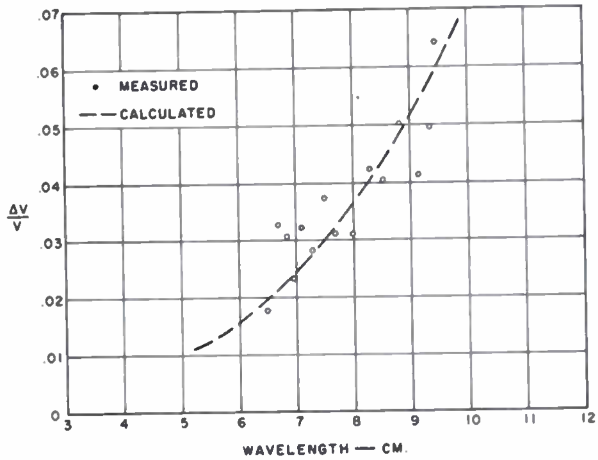

Fig. 6—Fractional voltage separation between modes of oscillation $\Delta V/V$ as a function of wavelength.

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[6] 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 $v_{\phi s}$ is related to the dominant mode phase velocity v_ϕ by the expression[8]

$$v_{\phi s} = \frac{v_\phi}{\frac{s v_\phi}{d} + 1} \quad (s = 0, \pm 1, \pm 2, \cdots), \tag{5}$$

where

d = spacing between loading elements
s = 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

$$v_{\phi s} = \frac{v_\phi}{\frac{s v_\phi}{fd} - 1} \quad (s = 1, 2, \cdots). \tag{6}$$

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.

[8] J. R. Pierce, "Traveling Wave Tubes," D. Van Nostrand Co., New York, N. Y., p. 72, eq. 4.61; 1950.

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.

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 worth while to point out the details involved and to illustrate these with a numerical example.**

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In a paper recently presented at the 1951 IRE Convention, entitled "Transfer Ratio Synthesis by RC Networks," the authors John T. Fleck and Philip F. Ordung appear to be unaware of a simple procedure for obtaining ladder realizations that parallels a well-known technique commonly applied to LC networks. Although adaptation of the method to RC networks follows a rather obvious pattern, it would seem worth while to discuss it briefly and to illustrate with a numerical example since many engineers are apparently unacquainted with this useful tool, and its porticular 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 impedance is

$$Z_{12} = \frac{E_2}{I_1} = \frac{z_{12}}{1 + z_{22}}, \tag{1}$$

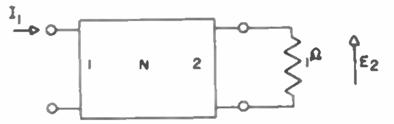

Fig. 1—A relevant physical network arrangement.

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 found[1] from a specified Z_{12}, 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 construct it from the pair of functions z_{22} and z_{12}, or the pair y_{22} and y_{12}. (The driving-point function y_{11} or z_{11} 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 unbalanced ladder (Fig. 2). It is necessary to know how this

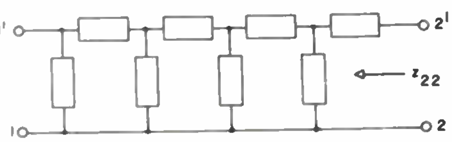

Fig. 2—Geometry of the desired development.

ladder development may be carried out so that the two-terminal-pair network which results when a pair of terminals 1-1′ are placed at the far end of the ladder, also realizes the transfer function z_{12} (resp. y_{12}).

The poles of the functions z_{22} and z_{12} are the complex natural frequencies of the network when both terminal pairs are open. Therefore, the ladder development of z_{22} automatically yields a network with a z_{12} function having the proper poles (except in degenerate cases which are easily avoided). It is only necessary to know how one can produce the proper zeros of z_{12}. 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 produce 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 illustrated 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 ladder may be made to have infinite or zero impedance for any point on the j axis of the complex frequency plane (the 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 relevant only to RC synthesis where the zeros of transmission 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. Guillemin, (*Jour. Math. Phys.*, vol. 28, p. 22), or as pointed out by Fleck and Ordung 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

$$y_{22} = \frac{(s+1)(s+3)(s+5)}{(s+2)(s+4)(s+6)}$$

$$y_{12} = \frac{(s+2.5)^2(s+7)}{(s+2)(s+4)(s+6)}. \tag{2}$$

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 situation can easily be remedied, however.

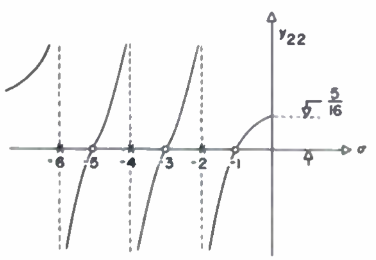

Fig. 3—The input admittance versus negative real values of the complex frequency variable.

[1] For a detailed discussion of how this is done see "A Summary of Modern Methods of Network Synthesis," by E. A. Guillemin, "Advances in Electronics," Academic Press, Inc., New York, N. Y., vol. III, pp. 261–303; 1951.

First it is necessary to compute the value of y_{22} for $s=-2.5$, which is readily found to be

$$y_{22}(-2.5) = \frac{5}{7}. \quad (3)$$

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

$$y_1 = \frac{k_1 s}{s+2}; \quad (4)$$

and so we find the k_1 value for which

$$y_{22}(-2.5) - \left(\frac{k_1 s}{s+2}\right)_{s=-2.5} = \frac{5}{7} - 5k_1 = 0, \quad (5)$$

when $k_1=1/7$, and the appropriate admittance 4 is

$$y_1 = \frac{(1/7)s}{s+2}. \quad (6)$$

Thus the development of y_{22} is begun through constructing a shunt branch having the admittance y_1, and computing the remaining admittance function

$$y' = y_{22} - y_1 = \frac{(6s^2+38s+42)(s+2.5)}{7(s+2)(s+4)(s+6)} = \frac{1}{z'}. \quad (7)$$

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_{12} 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

$$z_2 = \frac{1.185}{s+2.5}, \quad (8)$$

leaving the remainder

$$z'' = \frac{7s^2+59.39s+114.45}{6s^2+38s+42} = \frac{7(s+2.958)(s+5.526)}{6(s+1.427)(s+4.907)}. \quad (9)$$

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 one 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

$$y''(-2.5) = -1.596. \quad (10)$$

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 $s=\sigma+j0$ 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

$$y_3 = \frac{k_3 s}{s+2.958}, \quad (11)$$

with k_3 determined by the condition

$$y''(-2.5) - \left(\frac{k_3 s}{s + 2.958}\right)_{s=-2.5}$$

$$= -1.596 + \frac{2.5k_3}{0.458} = 0, \qquad (12)$$

when $k_3 = 0.2925$ and the appropriate admittance 11 is

$$y_3 = \frac{0.2925s}{s + 2.958}. \qquad (13)$$

Construction of a shunt branch having this admittance is equivalent to subtraction of y_3 from y'', leaving

$$y''' = \frac{(3.952s + 16.8)(s + 2.5)}{7(s + 2.958)(s + 5.526)} = \frac{1}{z'''}. \qquad (14)$$

The residue of z''' in its pole at $s = -2.5$ is found to be 1.401, so that the term representing this pole is

$$z_4 = \frac{1.401}{s + 2.5}, \qquad (15)$$

from which the next series branch is constructed. The remainder $z^{iv} = z''' - z_4$ is found to be

$$z^{iv} = \frac{7s + 36.35}{3.952s + 16.8} = \frac{1.77(s + 5.193)}{(s + 4.25)} = \frac{1}{y^{iv}}. \qquad (16)$$

This completes the second cycle in the development procedure.

Sketches of y^{iv} and z^{iv} are shown in parts (a) and (b), respectively, of Fig. 4, from which we observe that there

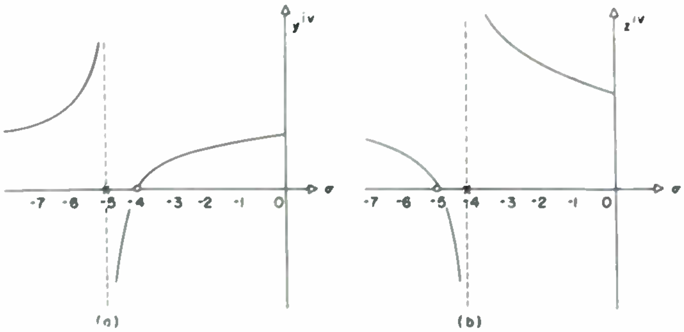

Fig. 4—General character of the remainder functions (16).

is no possibility of shifting a zero of y^{iv} to the point $s = -7$ (the remaining point at which y_{12} is to be zero), but that z^{iv} can be made to have a zero at $s = -7$ through subtracting a positive constant (resistance). That is,

$$z^{iv}(-7) = 1.163, \qquad (17)$$

and this is less than $z^{iv}(\infty) = 1.77$, which is the minimum of its real part for $s = j\omega$.

So we can next remove a series resistance

$$z_5 = R_5 = 1.163 \qquad (18)$$

and leave

$$z^v = z^{iv} - 1.163 = \frac{0.607(s + 7)}{(s + 4.25)} = \frac{1}{y^v}. \qquad (19)$$

Since

$$y^v = \frac{0.648s}{s + 7} + 1, \qquad (20)$$

we see that the next shunt branch is given by

$$y_6 = \frac{0.648s}{s + 7}, \qquad (21)$$

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

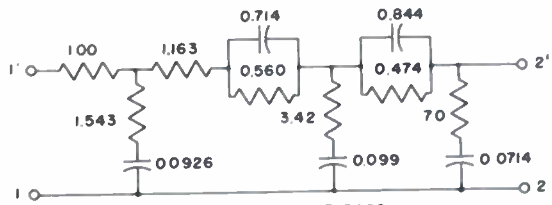

Fig. 5—A two-terminal-pair network realizing the functions given by (2).

component in the left-hand shunt branch (y_6 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.

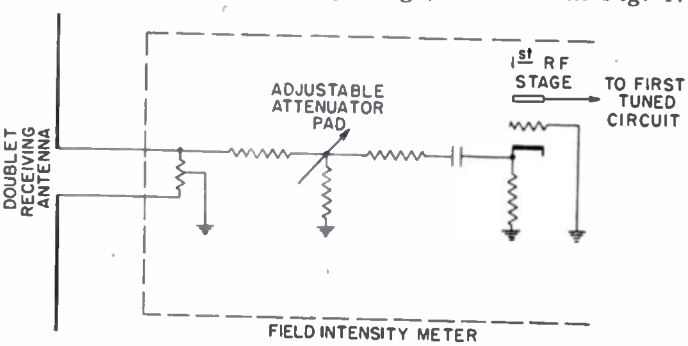

Fig. 1—A typical untuned grounded-grid rf input circuit similar to that used in some commercial types of vhf field-intensity meters at the present time.

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.

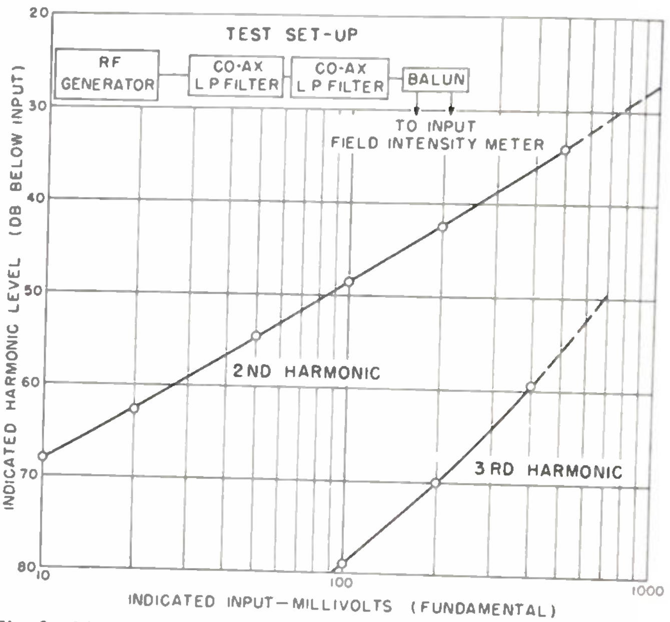

Fig. 2—Measured harmonic levels generated internally as a function of the applied rf input voltage for a receiver employing the type of input circuit shown in Fig. 1.

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-

* Decimal classification: R271. Original manuscript received by the Institute, March 27, 1950; revised manuscript received, October 22, 1951.

† 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 I
Effect of Intermodulation

(1) mv	(2) mv	(3) mv	(4) error per cent
10	100	10.0	0
10	1,000	9.5	5
10	10,000	3.3	67
100	1,000	100	0
100	10,000	95	5

(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:[1] 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.

World War II and security restrictions are partly responsible for the fact that some earlier work was not published. A report[2] 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.[3]

* S. M. Kaplan and R. W. McFall, "The statistical properties of noise applied to radar-range performance," Proc. I.R.E., vol. 39, pp. 56–60; January, 1951.

[1] Naval Research Laboratory, Washington 25, D. C.

[2] D. O. North, "An Analysis of the Factors Which Determine Signal/Noise Discrimination in Pulsed Carrier Systems," RCA Laboratories Report PTR-6C; 1943.

[3] J. L. Lawson and G. E. Uhlenbeck, "Threshold Signals," M.I.T. Radiation Laboratory Series, McGraw-Hill Book Co., Inc., New York, N. Y., vol. 24; 1950.

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 θ in the direction of scanning, with the angular scanning speed ω 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 θ/ω 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.[4]

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.[5] 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.[6] 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 opportune 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[7] 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

[4] For a very good introduction to this subject, see L. N. Ridenour *et al.*, "Radar System Engineering," M.I.T. Radiation Laboratory Series, McGraw-Hill Book Co., Inc., New York, N. Y., vol. 1, pp. 35–45; 1947. For a more complete discussion, see footnote reference 3.

[5] See footnote reference *.

[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.

[7] Chandler, Iams, and Wilkinson, "Minimum Discernible Radar Signal with B- and C-Type Presentation," RCA Engineering Memorandum PEM-58; 1947.

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 Haeff, 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 Haeff, 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.

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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, 1898. 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.

E. A. GUILLEMIN

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.

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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.

F. M. GREENE

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, he 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.

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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.

J. W. HORTON

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 now 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.

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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.

LOYD E. HUNT

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.

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Edward M. T. Jones (S'46–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 radar officer 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.

EDWARD M. T. JONES

He is a member of Sigma Tau and Sigma Xi.

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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 1938, after which he spent two years in the engineering department of the McClatchey Broadcasting 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.

V. R. LEARNED

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.

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K. A. Norton

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 1929, 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.

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W. N. Papian

W. N. Papian 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. Papian 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.

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C. A. Parry

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.

For some years he was a Radio Service Engineer, becoming a foundation member of the Australian Radio Servicemen's Institute.

Mr. Parry joined the developmental staff of Kriesler (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 Institution of Radio Engineers, Australia, and is at present a member of the Examinations Board.

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Philip L. Rice

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 a 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. Wilmotte, 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.

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W. R. Sittner

W. R. Sittner (M'52) was born in Cape Girardeau, Mo., on August 21, 1919. 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.

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L. B. Valdes

L. B. Valdes (A'46) was born in Marianao, 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 three 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.

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Carol Veronda

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.

Institute News and Radio Notes

Technical Committee Notes

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. Dietzold 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 he 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 Dalke, met on November 15, 1951. It was decided that the IRE would cancel 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. Rudd 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. Dalke 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 Committee members.

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 as co-sponsor of the Conference on Semiconductor Devices. R. M. Ryder 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 Electron 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 portions 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 to 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

Radio and Television Show, Manchester, England, April 23–May 3

IRE Cincinnati Section, Spring Technical Conference, Cincinnati Engineering Societies Building, Cincinnati, Ohio, April 19

URSI-IRE Spring Meeting, National Bureau of Standards, Washington, D. C., April 21–24

IEE Television Convention, London, England, April 28–May 3

Association for Computing Machinery Meeting, Mellon Institute, Pittsburgh, Pa., May 2–3

IRE-AIEE-RTMA Symposium on Progress in Quality Electronic Components, Washington, D. C., May 5–7

IRE New England Radio Engineering Meeting, 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 19–20

1952 IRE Western Convention, Municipal Auditorium, Long Beach, Calif., August 27–29

National Electronics Conference, Sherman Hotel, Chicago, Ill., September 29–October 1

IRE-RTMA Radio Fall Meeting, Syracuse, N. Y., October 20–22

Professional Group News

Airborne 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 six consecutive issues of the IRE-PGA 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 Programming and Coding. 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 Symposia

The following Professional Groups sponsored symposia at the 1952 IRE National Convention: Airborne Electronics, Antennas and Propagation, Audio, Broadcast and Television Receivers, Broadcast Transmission Systems, Circuit Theory, Electron Devices, Electronic Computers, Engineering Management, Industrial Electronics, Information Theory, Instrumentation, Quality Control, Radio Telemetry and Remote Control, and Vehicular Communications.

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 radio-electronic 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.

Instruments: Instruments, Incorporated, O. W. Graham, "Radioactive Liquid Level Measurements"; Leeds and Northrup, A. J. Williams, Jr., "DC Amplifier Developments"; Berkely Scientific Corporation, Merle C. Burns, "Nuclear Instruments in the Petroleum Industry"; Humble Oil and Refining Corporation, F. J. Feagin, "A Continuously Recording Dielectric Meter."

Geophysics: Magnolia Petroleum Company, F. J. McDonal, "An Electronic Fourier Analyzer."

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. Campbel, Jr., "Transistors."

Ham Engineering: Eimac Company, John Reinartz, "TVI."

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

Chairman, Symposium Committee, J. G. Reid, Jr., National Bureau of Standards, Washington, D. C.

Session I

ELECTRONICS TODAY

Chairman, A. V. Astrin, Acting Director, National Bureau of Standards, Washington, D. C.

"Electronic Production Requirements from Industry's Viewpoint," Glen McDaniel, President, Radio Television Manufacturers Association.

"Electronics in the Defense Production Program," J. A. Milling, Chairman, Electronics Production Board, Defense Production Administration, Washington, D. C.

"Some Factors in Today's Electronics Production," Rawson Bennett, U. S. Navy, Bureau of Ships, Washington, D. C.

"Reliability of Military Electronics," E. A. Speakman, Vice Chairman, Research and Development Board, Department of Defense, Washington, D. C.

"Electronic Components in Continental Europe," C. B. Lindstrand, U. S. Air Force, Electronics Production Resources Agency, Department of Defense, Washington, D. C.

"Electronic Components in Great Britain," W. A. G. Dummer, Telecommunications Research Establishment, (England).

"Electronic Components in Soviet Russia," G. W. King, U. S. Air Force, Air Technical Information Center, Wright-Patterson Air Force Base, Dayton, Ohio.

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.

"Metallic Refractories, New Materials for the Electrical Industry," Robert Steinitz, American Electro Metal Corp., Yonkers, N. Y.

"Some Fluorochemicals for Electrical Applications," N. M. Bashara, Minnesota Mining and Manufacturing Co., St. Paul, Minn.

"Manufacture of Mica Paper for Insulation," R. L. Griffeth and E. R. Younglove, Mica Insulator Co., Schenectady, N. Y.

"Progress in the Use of Teflon, Including Soldering and Cementing," M. A. Rudner, U. S. Gasket Co., Camden, N. Y.

Session II—Part B

ADVANCES IN MINIATURIZATION

Chairman, Cledo Brunetti, Stanford Research Institute, Palo Alto, Calif.

"Compact Assembly Methods," S. T. Danko, Signal Corps Engineering Laboratories, Fort Monmouth, N. J.

"Reproducibility of Printed Components," W. H. Hannahs and J. Eng, Sylvania Electric Products, Inc., Bayside, L. I., N. Y.

"Miniaturized Components for Transistor Application," P. S. Darnell, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

Tuesday Morning, May 6

Session III—Part A

PROGRESS IN BASIC COMPONENTS

Chairman, Ernst Weber, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.

"Adhesive Tape Resistors," R. L. Davis, National Bureau of Standards, Washington, D. C.

"Metallic Film Resistors," C. T. Graham, Polytechnic Research and Development Co., Brooklyn, N. Y.

"E-C Glass Resistors," J. K. Davis, Corning Glass Works, Corning, N. Y.

"Stability of Standard Component Resistors," C. K. Hooper, Westinghouse Electric Corp., Baltimore, Md.

"Progress in the Field of Resistors," Jesse Marsten, International Resistance Co., Philadelphia, Pa.

Session III—Part B

CAPACITORS

Chairman, R. C. Sprague, Sprague Electric Co., North Adams, Mass.

"Capacitors for High Temperature Operation," J. W. Schell, Erie Resistor Corp., Erie, Pa.

"Expected Performance of Glass Capacitors," Gail Smith, Corning Glass Works, Corning, N. Y.

"Tantalytic Capacitors," L. W. Foster, General Electric Co., Hudson Falls, N. Y.

Session III—Part C

COILS, INDUCTORS, AND TRANSFORMERS

Chairman, R. C. Sprague

"Progress in Size and Performance of Transformers," G. E. Wilson, General Electric Co., Fort Wayne, Ind.

"Ferrite Inductor Cores," W. W. Stifler, Jr., Ferroxcube Corp. of America, Saugerties, N. Y.

Tuesday Afternoon, May 6

Session IV—Part A

MISCELLANEOUS COMPONENTS

Chairman, J. H. Miller, Weston Electrical Instrument Corp., Newark, N. J.

"Selection of Fuse Protection for Electronic Circuits," E. V. Sundt, Littlefuse Inc., Chicago, Ill.

"Design Factors Influencing the Reliability of Relays," J. R. Fry, Bell Telephone Laboratories, Inc., New York, N. Y.

"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," F. M. Oberlander, RCA, Camden, N. J.

"Teflon Wire," C. E. Dodge, Jr., Warren Wire Co., Pownal, Vt.

Session IV—Part B

DESIGN AND PRODUCTION METHODS

Chairman, M. R. Briggs, Westinghouse Electric Corp., Baltimore, Md.

"Unitized Packaging by the Laminar Method," D. G. Heitert, Emerson Electric Manufacturing Co., St. Louis, Mo.

"Heat Transfer from Electronic Components," Walter Robinson, Ohio State University Research Foundation, Columbus, Ohio.

"Packaging Principles Employing Plastics and Printed Wiring to Improve Reliability," W. J. Clarke and N. J. Eich, Bell Telephone Laboratories, Inc., Murray Hill, N. J.

Tuesday Evening, May 6

Session V—Part A

AN EVENING WITH TRANSISTORS

Chairman, (to be announced)

"The Transistor Development Status at Bell Telephone Laboratories," (with demonstration), W. R. Sittner, Bell Telephone Laboratories, Inc. Allentown, Pa.

"Transistor Power Amplifiers," (with demonstration), R. F. Shea, General Electric Co., Syracuse, N. Y.

"Availability of Transistors," W. F. Starr, U. S. Army, Electronics Production Resources Agency, Department of Defense, Washington, D. C.

Wednesday Morning, May 7

Session VI

ASPECTS OF RELIABILITY

Chairman, J. A. Chambers, Motorola, Inc., Phoenix, Ariz.

"Electronic Failure Prediction," J. H. Muncy, National Bureau of Standards, Washington, D. C.

"Part Failure Problem in Navy Electronics Equipment," M. M. Tall, Vitro Corp. of America, Silver Springs, Md.

"How Can the Reliability of Electronic Systems Be Improved Now?" W. Wagenseil, Hughes Aircraft Co., Culver City, Calif.

"Component Part Specifications," D. E. Brown, Vitro Corp. of America, Silver Springs, Md.

"A Component Manufacturer Looks at Reliability," Leon Podolsky, Sprague Electric Co., North Adams, Mass.

(To be announced)

Wednesday Afternoon, May 7

Session VII

ELECTRON TUBES

Chairman, C. R. Banks, Aeronautical Radio, Inc., Washington, D. C.

"Sealed-in-Glass Germanium Diodes," J. W. Dawson, Sylvania Electric Products, Inc., Boston, Mass.

"Reliability of Premium Subminiature Tubes," P. T. Weeks, Raytheon Manufacturing Co., Newton, Mass.

"Method for Achieving Maximum Reliability in Vacuum Tube Applications," R. L. Kelly, RCA Tube Department, Harrison, N. J.

"Failure of Vacuum Tubes from Interface Formation," W. H. Kliever, Minneapolis-Honeywell Regulator Co., Minneapolis, Minn.

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.

G. H. BROWN

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.

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 "radiocite," 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 Electrotechnics 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. STRUTT

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, he 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 Electrotechnical Society at Zurich, the Physical Society of Zurich, and the Swiss Society of Sciences at Berne.

A. G. Jensen (A'23–M'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.

A. G. JENSEN

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 Cliftwood, 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 shortwave 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.

Mr. Jensen has served on many IRE Committees, including, Audio and Video Techniques, 1948; Co-ordination for International Technical Organizations, Chairman, 1950–1951; Instruments and Measurements, 1949–1950; IRE, RTMA, SMPTE Television Co-ordinating Committee, Chairman, 1950–1951; Standards, 1948, Vice Chairman, 1949–1950, Chairman, 1951; Television, 1939–1947, Chairman, 1948; Television and Facsimile, 1938; and Television Systems, Chairman, 1949–1951.

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–M'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.

E. W. HEROLD

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.

E. C. HOMER

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 telegram 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 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 Worth Brothers Steel Company in Coatsville, 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.

M. C. TURKISH

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 Saginaw Dynamatic 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 amateur radio station W8MGK.

⁘

Merril F. Distad (J'31–A'31–SM'45) formerly of the Naval Research Laboratory, has joined the staff of the Ordnance Development Division of the National Bureau of Standards to work in electronic ordnance.

M. F. DISTAD

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, trigonometry, 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

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NOTE: The Institute of Radio Engineers does not have available copies of the publications mentioned in these pages, nor does it have reprints of the articles abstracted. Correspondence regarding these articles and requests for their procurement should be addressed to the individual publications, not to the IRE.

The Annual Index to these Abstracts and References, covering those published in the PROC. I.R.E. from February, 1951, through January, 1952, may be obtained for 2s.8d. postage included from the *Wireless Engineer*, Dorset House, Stamford St., London S.E., England. This index includes a list of the journals abstracted together with the addresses of their publishers.

The number in heavy type at the upper left of each Abstract is its Universal Decimal Classification number and is not to be confused with the Decimal Classification used by the United States National Bureau of Standards. The number in heavy type at the top right is the serial number of the Abstract. DC numbers marked with a dagger (†) must be regarded as provisional.

ACOUSTICS AND AUDIO FREQUENCIES

534.321.9 562
Making Ultrasonic Waves Visible—R. Hanel. (*Radio Tech.* (Vienna), vol. 27, pp. 325–329; August, 1951.) Description of simple schlieren equipment developed at the Technische Hochschule, Vienna.

534.321.9-14 563
Ultrasonic Measurements on Liquids—C. E. Mulders. (*Tijdschr. ned. Radiogenoot.*, vol. 16, pp. 155–169; July, 1951.) Review of methods of investigation.

534.41:534.78 564
The Sound-Film Spectrograph—an Instrument for the Acoustic Analysis of Speech and Other Rapidly Changing Sounds—B. H. Edgardh. (*IVA* (Stockholm), vol. 22, no. 5, pp. 134–153; 1951. In German.) The sound to be analyzed 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.

534.84 565
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 stroboscopic ripple-tank method for the theatres at Orange and Vaison, France.

534.844.5 566
The Use of Artificial Reverberation in the Theatre—A. Moles. (*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.

534.846 567
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 interpreting 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.

534.861.1 568
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 feet³ such resonances may occur in the range 50 to 150 cps. Wall constructions and treatments for absorbing excess energy over various frequency ranges are described, with numerical detail.

534.861.1 569
Broadcasting Studios with Sound-Diffusing Walls—C. Tutino and G. Sacerdote. (*Poste 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 semicylindrical 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 arrangements on the acoustic properties of the rooms; experiments are still in progress.

534.874.1+621.396.621]:519.241.1 570
Perturbation and Correlation Methods for Enhancing the Space Resolution of Directional Receivers—Hunt. (*See* 790.)

621.395.61/.62 571
Reciprocity Relations for Electroacoustic Transducers and their Universal Electrical Equivalents—F. A. Fischer. (*Arch. elekt. Übertragung*, vol. 5, pp. 382–384; August, 1951.)

621.395.623.8 572
Speech-Reinforcement System Evaluation—L. L. Beranek, W. H. Radford, J. A. Kessler and J. B. Wiesner. (PROC. I.R.E., vol. 39, pp. 1401–1408; November, 1951.) Assessment 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.

621.395.623.8 573
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*) twin circular groups, and (*d*) combinations of circular and twin groups. Practical combinations for directional and all-round transmission are discussed.

621.396.611.21:621.317.382 574
Power Measurements on Ultrasonic Quartz Oscillators—Schmitz and Waldick. (*See* 734.)

ANTENNAS AND TRANSMISSION LINES

621.315.212.011.2/.3 575
Effective Resistance and Effective Inductance of Current-Carrying Conductors at High Frequencies—W. Taeger. (*Funk u. Ton*, vol. 5, 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.

[621.392+621.396.67]:621.397.5 576
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

radio emission and propagation and of the manner of operation of antennas and transmission lines. Various types of antenna and array useful for television reception 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. 1408–1412; 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. elekt. 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 used in the af range are typical *RC* lines. Lines characterized mainly by *L* and *G* are of little practical importance, but are nevertheless of interest since coils and transformers with iron cores have an *LG* line as circuit equivalent. Use of the error integral in conjunction with operational calculus enables formulas to be derived permitting numerical calculation of signal transmission along both types 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 line without coil loading, which can be regarded as an *RC* line.

621.392.09 579
Cylindrical Surface-Wave Transmission Lines—H. M. Schmidt. (*Z. angew. Phys.*, vol. 3, pp. 272–279; July, 1951.) A comprehensive analysis of the theory, principles and characteristics of dielectric-covered transmission lines. The results of other workers in the field are summarized and 31 references are given.

621.392.26†:621.317.329 580
Determination of Aperture Parameters by Electrolytic-Tank Measurements—Cohn. (*See* 725.)

621.392.26†:621.39.09 581
Propagation of U.H.F. Electromagnetic Waves in Waveguides of Circular Cross-Section: Part 2—H. Frühauf. (*Elektrotech.* (Berlin), vol. 5, pp. 315–321; July, 1951.) Formulas analogous to those for rectangular waveguides (35 of February) are here derived for circular waveguides.

621.392.26†:621.396.611.39 582
Directional-Coupler Errors—F. A. Benson. (*Wireless Eng.*, vol. 28, pp. 371–372; December, 1951.) In the type of coupler using two windows a $\lambda/4$ apart, errors in measurements of voltage swr or power may result from reflections 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.

621.396.67 583
Distribution of Radiation Resistance along a Rod Aerial: Aerial as Coil Line with Transformer Coupling—O. Zinke. (*Funk u. Ton*, vol. 5, pp. 393–399; August, 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 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.

621.396.67 584
Plane Aerials of Small Width—S. Zisler. (*Ann. Télécommun.*, 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. Kirshhoff's equations are applied and 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.

621.396.67:621.317.336 585
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 coaxial cavity of variable length. Resonance-curve 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. Excellent agreement is obtained with the impedance values for the same antenna when base-driven through the slotted section. Both sets of measurements are in good agreement with the King-Middleton second-order theory.

621.396.67.011.21 586
The Impedance of an Antenna over a Large Circular Screen—J. E. Storer. (*Jour. Appl. Phys.*, vol. 22, pp. 1058–1066; August, 1951.) ". . . treats the problem of an antenna erected vertically in the center of a circular 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."

621.396.67.011.21 587
Influence of a Plane Reflector on the Input Impedance of a Thick Cylinder—S. Zisler. (*Ann. Télécommun.*, 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).

621.396.67.011.21 588
Mutual Impedance of Wire Aerials—L. Lewin. (*Wireless Eng.*, vol. 28, pp. 352–355; December, 1951.) For the general case of two straight wire antennas carrying sinusoidal currents it is possible to evaluate the mutual impedance in terms of the Si and Ci functions. A demonstration of the method for the case of two coplanar $\lambda/2$ dipoles is given. The special cases of dipoles parallel or forming an *X* or *V* are studied. See also 589 below (Medhurst), 1932 "Abstracts," p. 585 (Carter) and 1933 "Abstracts," p. 214 (Murray).

621.396.67.011.21 589
Dipole Aerials in Close Proximity—R. G. Medhurst. (*Wireless Eng.*, vol. 28, pp. 356–358; December, 1951.) A treatment of the problem of finding the 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 *V* and *X* 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 1933 "Abstracts," p. 214 (Murray).

621.396.67.018.424† 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 model studies 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 range and a maximum power loss of 18.5 per cent, due to mismatch when connected to a 52-Ω line.

621.396.671+621.396.11 591
Application of the Compensation Theorem to Certain Radiation and Propagation Problems—C. D. Monteath. (*Proc. I.E.E.* (London), Part IV, vol. 98, pp. 23–30; October, 1951.) Summary abstracted in 2648 of 1951.

621.396.671 592
Current and Charge Distributions on Antennas and Open-Wire Lines—D. J. Angelakos. (*Jour. Appl. Phys.*, vol. 22, pp. 910–915; July, 1951.) Results of measurements on cylindrical antennas and their feeders are shown graphically. 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.

621.396.676 593
The Design of an Omni-directional Aerial System for the Frequency Range 225–400 Mc/s—F. A. Kitchen. (*Proc. I.E.E.* (London), Part III, vol. 98, pp. 409–415. Discussion, pp. 465–470; November, 1951.) Description of the development of a double-conical monopole antenna with counterpoise skirt suitable for installation on the yard-arm of a naval vessel. The antenna dimensions were finally adjusted after a series of measurements of impedance at frequencies within the operating range. Experimental data indicated that the semi-perimeter of the antenna in any vertical plane should be approximately one wavelength at 300 mc, the mid-band second-order-resonance frequency. Results are given of measurements of the variation of terminal impedance, voltage SWR and radiation pattern with frequency. A coaxial 72-Ω feeder is connected directly to the two radiating elements, no matching transformer being necessary.

621.396.676.001.57:621.317.336 594
The Use of Complementary Slots in Aircraft-Antenna Impedance Measurements—J. T. Bolljahn and J. V. N. Granger. (*Proc. I.R.E.* (London), vol. 39, pp. 1445–1448; November, 1951.) Description of a method for eliminating the effect of the feeder cable in measurements of wing-cap and tail-cap antenna impedances with the aid of models. The method gives greater measurement accuracy than that obtainable with conventional techniques, but its use is restricted to simple types of antenna. Typical measurement results are given.

621.396.677 595
A Vertical Nonrotating Directional Antenna System—J. K. 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 elevations on all three working frequency bands. A considerable saving in mast height relative to a horizontal antenna is claimed.

621.396.677 596

Radiation Field of Helical Antennas with Sinusoidal Current—E. T. Kornhauser. (*Jour. Appl. Phys.*, vol. 22, pp. 887–891; July, 1951.) A rigorous formula for the radiation field of a helical antenna is derived, assuming a current distribution determined experimentally by Kraus (3033 of 1947). For a helix of several turns this formula yields results very nearly the same as those obtained by Kraus's approximate method (1860 of 1949), but computation is simpler and the formula is applicable to helixes with a nonintegral number of turns.

621.396.677:621.317.335.3† 597

Artificial Dielectrics for Microwaves—Sharpless. (*See* 727.)

621.396.677.6.029.6†:621.396.931/.933].2 598

Rotating H-Type Adcock Direction-Finders for Metre and Decimetre Wavelengths—H. G. Hopkins and F. Horner. (*Proc. IEE* (London), Part IV, vol. 98, pp. 112–126; October, 1951.) "Instruments of high precision for the range 26–600 mc (0.5–12 m wavelength) are described and details of their performance are given. The direction-finders at the lower end of this frequency range are of high sensitivity and have seen considerable practical service. Development has proceeded largely on empirical lines, but from this work a fair appreciation has now been obtained of the fundamental factors affecting performance and of the practical means for taking them into account. Some progress has been made, for example, in understanding the cause of polarization errors, which are of importance in some—but not all—df applications at these frequencies."

538.566+621.396.67 599

Electromagnetic Waves and Radiating Systems [Book Review]—E. C. Jordan. Publishers: Prentice-Hall, New York, N. Y., 710 pp., 32s. 6d. (*Brit. Jour. Appl. Phys.*, vol. 2, pp. 205–206; July, 1951.) A comprehensive treatise of an introductory character, but not oversimplified; vector analysis is used as the basis of the treatment.

621.392.26† 600

Advanced Theory of Waveguides [Book Review]—L. Lewin. Publishers: Iliffe & Sons, (London), 192 pp., 30s. (*Wireless Eng.*, vol. 28, p. 374; December, 1951.) "Covers posts, diaphragms, windows, steps, tapers and T-junctions in waveguides. Radiation from waveguides is treated as well as propagation in loaded and corrugated guides."

CIRCUITS AND CIRCUIT ELEMENTS

621.3.012.8 601

Electrical-Equivalent Circuits—K. Kupfmüller. (*Fernmeldetech. Z.*, vol. 4, pp. 337–346; August, 1951.) Detailed review of their application in the representation of electrodynamic, physical and physico-chemical phenomena.

621.3.013.5:621.3.011.23:621.314.2.045 602

The Calculation of the Magnetic Field of Rectangular Conductors in a Closed 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 four walls of the slot. A 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 by 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 considerable simplification without undue loss of accuracy."

621.3.015.7†:621.387.4† 603

A Sweep-Type Differential and Integral Discriminator—E. Fairstein. (*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 of rise time ≧ 0.1 μs and output limited to 100V.

621.3.015.7†:621.387.4† 604

A High-Precision Pulse-Height Analyzer of Moderately High Speed—G. W. Hutchinson and G. G. Scarrott. (*Phil. Mag.*, vol. 42, pp. 792–806; July, 1951.) Designed for nuclear research work. Information is stored in an ultrasonic delay line and displayed on a cr 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 10^6 pulses each, 80 channels of up to 3×10^4 pulses each, or 120 channels of up to 1,023 pulses each, with a maximum counting rate of 1,600 per second.

621.314.2+621.318.4 605

Winding Space Determination—N. H. Crowhurst. (*Electronic Eng.* (London), vol. 23, pp. 302–306; August, 1951.) The factors controlling the choice of wire gauge, insulation and winding methods for transformers and chokes are briefly summarized. The use of abacs for simplifying the calculations involved is described with examples.

621.314.2 606

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 *E-I* stampings. A numerical example is worked out.

621.314.58 607

The Magnetic Modulator—R. Feinberg. (*Radio Tech. Dig.* (France), vol. 5, nos. 4 and 5, pp. 217–226 and 281–287; 1951.) French version of 338 of March.

621.316.726.078.3:621.3.015.3 608

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 afc 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 nearly critical damping. 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.

621.318.423:621.3.011.22 609

The Resistance of Round-Wire Single-Layer Inductance Coils—A. H. M. Arnold. (*Proc. IEE*, 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 appearing in the formula are given in tables. 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)."

621.318.572 610

A Comprehensive Counting System for Nuclear Physics Research—N. F. Moody, W. D. Howell, W. J. Battell and R. H. Taplin. (*Rev. Sci. Instr.*, vol. 22, pp. 439–461; July, 1951.) A method of constructing counting systems from a number of standardized 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. The synthesis of various instruments from these sub-units is described. Further sections of the survey to be published later will deal with amplitude analyzers.

621.319.53:621.316.729 611

The Controlled Tripping of High-Voltage Impulse Generators—A. S. Husbands and J. B. Higham. (*Jour. Sci. Instrum.*, vol. 28, pp. 242–245; August, 1951.) A triggered spark-gap and associated circuits are described which enable a generator to be discharged in synchronism with measuring equipment such as a cro 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.

621.319.53:621.396.619 612

High-Power Pulse Generator with Controlled Spark-Gap—E. Prokott. (*Fernmeldetech. Z.*, vol. 4, pp. 347–351; August, 1951.) Description of a compressed-air spark generator with repetition frequency 8–18 kc, and investigation of its suitability as a modulator for telecommunication purposes.

621.392:517.433 613

Operational Approach to Nonlinear Circuit Analysis—G. H. Cohen. (*Jour. Frank. Inst.*, vol. 252, p. 63; July, 1951.) Correction to paper noted in 3077 of 1949.

621.392:517.544.2 614

The One-Sided Green's Function—Miller. (*See* 711.)

621.392:621.317.3.083.4 615

Double-T Networks for Null Measurements at High Frequency—Samal. (*See* 724.)

621.392.43 616

High-Frequency Matching Transformer—F. Steiner. (*Öst. Z. Telegr. Teleph. Funk Fernsehtech.*, vol. 5, pp. 93–100; July/August, 1951.) In a tuned wide-band matching transformer, reactance developed in the damped parallel-tuned secondary circuit at frequencies away from resonance gives rise to large variations of apparent input impedance. Design formulas are derived for a transformer in which the series-tuned primary circuit partially compensates for these variations.

621.392.5 617

Application of Matrices to Four-Terminal-Network Problems—H. P. 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.

621.392.5:621.3.015.3 618

Transient Response. Conditions for Monotonic Characteristics—I. F. Macdiarmid. (*Wireless Eng.*, vol. 28, pp. 330–334; November, 1951.) The necessary and sufficient conditions for a monotonic transient response are considered for the case of a network to which a unit current-step is applied. The location of the zeros of the impedance function on the complex-frequency plane is shown to be as important 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 of a compensated anode load fed by a triode valve.

621.392.5:621.3.015.7†:621.3.018.7 619

Pulse Distortion—S. H. Moss. (*Proc IEE*, Part IV, vol. 98, pp. 37–42; October, 1951.) "For wave forms of simple shapes certain features may be defined: content, epoch, spread, skewness, squatness, etc., which are affected in a very simple way by passage 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 invariants for the pulses and for the system correspond to the cumulants used to describe statistical distributions."

621.392.5:681.142 620

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 *Hg* delay line, for use in an electronic memory unit, giving a delay of 1.2 ms with a bandwidth of several mc.

621.392.5.001.8 621

Linear Elctromechanical Quadripoles—U. John. (*Frequenz*, 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.

621.392.52 622

Design of Electric Wave Filters with the Aid of the Electrolytic Tank—A. R. Boothroyd. (*Proc IEE* (London), Part IV, vol. 98, pp. 65–93; October, 1951. Summary, *ibid.*, Part III, vol. 98, pp. 486–492; November, 1951.) The 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, Cherry and Makar (2743 of 1949). A transformation is developed by means of which the approximation problem can be solved for a specified low-pass-filter insertion loss, the poles and zeros of the insertion modulus function of the filter being accurately determined by simple measurements in the electrolyte tank.

621.392.52 623

The Multisection RC Filter Network Problem—L. Storch. (PROC. I.R.E., 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 Tschudi (1622 of 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.

621.392.52:538.221 624

Ferrites as Magnetostrictive Resonators and their Application as Electrical Filter Elements—C. W. Diethelm. (*Tech. Mitt. schweiz. Telegr.-TelephVerw.*, vol. 29, pp. 281–297; 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 magnetostriction effect and relatively high permeability with 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.

621.392.52:621.396.611.4 625

Microwave Filters employing a Single Cavity Excited in 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 terminals and with an infinite number of possible modes of oscillation. In some cavities of special shape, several degenerate modes with identical natural frequencies can occur. In a single cavity, these degenerate modes can be coupled together to form a chain of coupled circuits by perturbation of the otherwise ideal geometrical configuration of the cavity. The filter characteristics 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.

621.392.52:621.397.61 626

The Vestigal-Sideband Filter for the Sutton Coldfield Television Station—E. C. Cork (*Proc. IEE* (London), Part III, vol. 98, pp. 460–464. Discussion, pp. 465–470; November, 1951.) The specification of the filter is outlined and the reason for the choice of a complementary constant-resistance network filter of the Norton type is explained. The basic design formulas relevant to the chosen network are given, with information on the inversion and replacement 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.

621.392.52.072.6 627

Alignment and Adjustment by Synchronously Tuned Multiple-Resonant-Circuit Filters—M. Dishal. (PROC. I.R.E., vol. 39, pp. 1448–1455; 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.

621.396.6+621.385 628

New Radio Components in the World Market—M. Alixant. (*Radio Tech. Dig.* (France), vol. 5, nos. 1–3, pp. 3–61, 67–89 and 170–177; 1951.) Classified review giving details of new components and apparatus now available in Europe and America; tables of valve characteristics are included.

621.396.6:655.3 629

Practical Assembly of Printed Circuits—R. Singer. (*Électronique* (Paris), pp. 18–20 and 13–17; May and June, 1951.)

621.396.611.1 630

Some Sawtooth Oscillations—T. Vogel. (*Ann. Télécommun.*, 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 sawtooth being represented by a mathematical discontinuity of a certain order. Starting with the multivibrator as a particular example, generalized equations are developed; the periodic solutions found satisfactorily represent the operation of the circuit.

621.396.611.34/.35:621.3.015.7† 631

RC-Coupling Network for Pulse Transmission. Criteria for Maximum Pulse Sharpness—H. Moss. (*Wireless Eng.*, vol. 28, pp. 345–349; November, 1951.) Analysis for a *RC* differentiator circuit acting in conjunction with a normal intervalve-coupling network leads to expressions defining the conditions for maximum pulse sharpness. Experimental results confirm the theory.

621.396.611.4 632

On the Influence of Circular Holes in Electromagnetic Cavity Resonators—W. Klein. (*Z. angew. Phys.*, vol. 3, pp. 253–259; July, 1951.) Experimental investigation at wavelengths of 10 and 25 cm of the alteration of resonance wavelength and damping due to apertures in a cavity wall. The limits of application of theory are determined by examination of the experimental results. Two or more cavity resonators with an aperture in the common wall constitute a system of coupled circuits for which a theory is developed for determination of the coupling factor. 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.

621.396.615.17/.18 633

Arrangement for Division and Multiplication of Frequencies and Frequency Bands—H. Wüstner. (*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.

621.396.615.17 634

Synchronizer for 100-kc/s Square-Wave Generator—L. C. Hedrick. (*Rev. Sci. Instr.*, vol. 22, p. 537; July, 1951.) The generators previously described (851 of 1950) have been found defective owing to lack of stability in the synchronizer. A new synchronizer is here described which has proved entirely satisfactory, one unit having been run continuously for a week without loss of synchronism.

621.396.615.17 635

A Generator for Pulses of Variable Length—A. Gilardini. (*Poste e Telecomunicazioni*, vol. 19, pp. 401–406; August, 1951.) Analysis of May's circuit (853 of 1950) and suggested modification by connection of one of the diodes of a 6AL5 valve across the terminals of the grid resistor of one valve, the other diode being applied to the input of the following amplifier stage as ordinary dc restorer. This results in perfect linearity of the pulse length characteristic, and constant pulse amplitude as the pulse length is varied.

621.396.615.17.029.64 636

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 and fifth harmonics of 900- and 400-mc oscillators respectively. The available power falls from about 60 mw at 500 mc to 2mw at 2,000 mc for Type-1N34A diodes. Circuit data are given. The maximum power output from Si crystals is only about 30 per cent of that from Ge crystals in the range 400–1,000 mc.

621.396.645 637

Design of Input Circuit of a Capacitor-Microphone Amplifier—U. Kirschner. (*Arch. elekt. Übertragung*, vol. 5, pp. 385–391; August, 1951.) The reaction of the acoustical-mechanical system of a capacitor microphone on the electrical system results in a complex internal impedance. Amplifier design is discussed with special reference to this and to polarization voltage, distortion and the input resistance of the valve used. See also 18 of February.

621.396.645:621.317.3 638
Degree of Amplification of Amplifiers for Electrical Measurements—P. Moller. (*Arch. tech. Messen*, pp. T94–T95; August, 1951.) Review of the characteristics of the various types of amplifier, with 29 references.

621.396.645:621.385.3/.4:546.289 639
Transistor Amplifiers: Part 1—Operation and Characteristics—H. Fricke. (*Arch. tech. Messen*, pp. T80–T81; July, 1951.) Review with 24 references.

621.396.645:621.385.3/.4:546.289 640
Transistor Amplifiers: Part 2—Circuits and Construction Types—H. Fricke. (*Arch. tech. Messen*, pp. T82–T83; July, 1951.) Review with 18 references.

621.396.645.012.8 641
Network Representation of Input and Output Admittances of Amplifiers—F. W. Smith. (Proc. I.R.E., vol. 39, p. 1331; October, 1951.) Correction to 2392 of 1951.

621.396.645.371 642
Negative Feedback Amplifiers with Desired Amplitude-Frequency Characteristics—V. J. Cooper. (*Jour. Telev. Soc.*, vol. 6, pp. 233–245; April/June, 1951.) Four types of feedback which provide flat characteristics are defined. An analysis of single- and two-stage amplifiers indicates how the required characteristics may be achieved. Response curves obtained experimentally with amplifiers of up to three stages support the theoretical conclusions and demonstrate the advantages of two of the types of feedback considered.

621.396.822:519.2 643
Expected Number of Crossings of Axis by Linearly Increasing Function plus Noise—Lehan. (*See* 715.)

GENERAL PHYSICS

530.145:51 644
Mathematical Aspects of the Quantum Theory of Fields: Parts 1 and 2—K. O. Friedrichs. (*Commun. pure appl. Math.*, vol. 4, pp. 161–224; August, 1951.) The introduction sets out the ground to be covered, with remarks about functional and spectral representation. Part 1 is concerned with field operators under the headings: simultaneous spectral representation of infinitely many operators; commutation rules and improper operators; the differential equations; the energy interval; motivation of the configuration space representation. Part 2 deals with particle representation as follows: biquantization; occupation number representation; annihilation and creation operators; time variation of these operators and representation of field operators; trace operators; oscillators; Hermite functionals and integration over the Hilbert space. Parts 3–6 to follow.

534.372 645
On the Damping of Vibrating Cylindrical Rods by the Surrounding Medium—H. O. Kneser. (*Z. angew. Phys.*, vol. 3, pp. 113–117; March/April, 1951.)

535.13 646
An Asymptotic Solution of Maxwell's Equations—M. Kline. (*Commun. pure appl. Math.*, vol. 4, pp. 225–262; August, 1951.) The electromagnetic field due to an arbitrary charge distribution with harmonic time behavior is related to the pulse field produced by the same distribution suddenly placed in space at time $t=0$. Asymptotic expansions for the field in the harmonic case can be obtained if certain discontinuities in the pulse solution are known. A method is given whereby the required discontinuities can be determined without finding the complete pulse solution. The asymptotic expansions give the geometrical-optics approximation to the time harmonic field in the limit when the wavelength approaches zero. The theory can be applied to the problem of the field created by a dipole in an inhomogeneous medium and it may be possible to extend it to deal with more elaborate situations.

The form of the asymptotic expansion given and its derivation from Duhamel's principle are due to the work of the late R. K. Luneberg, who also commenced work on the derivation of the ordinary differential equations for the coefficients of the expansion from discontinuity conditions. The portions of this paper which repeat Luneberg's work are included for completeness, as the material was not published before his death.

535.37:621.32 647
Luminous Capacitors: a New Light Source Based on Electro-Luminescence—(*Elec. Times*, vol. 120, pp. 100–105; July 19, 1951.) See 1341 of 1951 (Payne, Mager and Jerome).

536.49:621.319.4 648
On the Thermo-Dielectric Effect—J. C. Ribeiro. (*An. Acad. brasil. Cienc.*, vol. 22, pp. 325–348; September 30, 1950. In English.) Description and discussion of an effect observed in a capacitor whose dielectric is partly in the solid and partly in the liquid state, one of the plates being in contact with the solid and the other with the liquid phase; when solidification or melting occurs at the interface, an electric current is produced. The effect may be responsible for certain phenomena of atmospheric electricity.

537.311.31 649
Metallic Conduction—The 'Internal Size Effect.'—D. K. C. Macdonald. (*Phil. Mag.*, vol. 42, pp. 756–761; July, 1951.) The effect of internal structural discontinuities in limiting the electron mean free path in metals is considered as an explanation of the anomalous resistance and magnetoresistance of gold and other metals at low temperatures and of the anomalous magnetoresistance of ferromagnetic metals.

537.523.4. 650
Observations on the Electrical Breakdown of Gases at 2,800 Mc/s—W. A. Prowse and W. Jasinski. (*Proc. IEE* (London), Part IV, pp. 101–111; October, 1951.) "Electrical discharges at 2,800 mc are produced in a nosed-in cavity type of resonator by energizing it from a pulsed magnetron. Individual pulses of various durations in the range 0.25 μs to 2.5 μs are employed. Electrons are provided in mid gap by the short ultraviolet radiation from an auxiliary dc spark actuated from the circuit used to trigger the power pulse."

538.525.6 651
Dielectric Constant and Electron Density in a Gas Discharge—R. E. B. Makinson, P. C. Thonemann, R. B. King and J. V. Ramsay. (*Proc. Phys. Soc.* (London), vol. 64, pp. 665–670; August 1, 1951.) Measurements at frequencies of the order of 1 kc were made of the impedance of a coaxial transmission line terminating in a small electrode immersed in the plasma of a low-pressure discharge in Hg vapor. The possible use of such impedance measurements to determine electron density is discussed.

537.525.6 652
Plasma Oscillations—D. Gabor. (*Brit. Jour. Appl. Phys.*, vol. 2, pp. 209–218; August, 1951.) A comprehensive review of plasma oscillations and of electronic oscillations determined by the internal dynamics of a discharge rather than by the outer circuit. A new mathematical formulation is given for oscillations in irrotational streams. Research is needed particularly on the following: electronic processes in magnetrons; theory of vortex motion; and the establishment of a satisfactory model for radiating stellar atmospheres.

537.525.6:537.562 653
Measurement of the Electron Density in Ionized Gases by Microwave Techniques—M. A. Biondi. (*Rev. sci. Instrum.*, vol. 22, pp. 500–502; July, 1951.) Measurements are made during the period following a discharge through the gas, the electron-density changes being determined from the detuning of a cavity resonator. Densities from 10^8 to 10^{10} electrons per cm^3 can be measured.

537.525.6:538.56 654
On Oscillations in Electron Streams—R. Q. Twiss. (*Proc. Phys. Soc.* (London), vol. 64, pp. 654–665; August 1, 1951.) The substitution method of determining the possibility of oscillation in electron streams, in which the dispersion equation is examined for complex roots of ω in terms of the propagation vector k, is critically discussed. This method of analysis does not have physical meaning unless the boundary and initial conditions are taken into account. In the infinite plasma treated by Bohm and Gross (88 and 89 of 1950) it is not possible to distinguish formally between amplification and instability; this ambiguity may be resolved by postulating boundary and initial conditions, e.g. those of the two planes $z=0$ and $z=d$. A two-velocity electron stream is discussed in detail, the analysis using the Laplace transform being given in an appendix. It is concluded that in the unidimensional case the longitudinal plasma oscillation can only become unstable if feedback arises from a reverse electron beam, or from a wave reflected from a surface of discontinuity or boundary of the plasma.

537.525.6:538.56]:523.5 655
Plasma Oscillations in Meteor Trails—J. A. Clegg and R. L. Closs. (*Proc. Phys. Soc.* (London), vol. 64, pp. 718–719; August 1, 1951.) An account of radar observations on $\lambda/4$ m of the columns of ionization produced during the Geminid shower of December 1948. Antennas with orthogonal polarizations were adjustable so that the electric vector was along or transverse to the trail. The echoes were classified as of short (<0.15 second) or long (>0.15 second) duration. The ratio transverse/longitudinal polarization amplitude exceeded unity but decreased during the lifetime of the larger echoes. The observations are regarded as evidence of plasma resonance in the majority of trails observed.

537.533.8 656
Fundamentals of Secondary-Electron Emission—M. A. Pomerantz and J. F. Marshall. (Proc. I.R.E., vol. 39, pp. 1367–1373; November, 1951.) Review of basic phenomena and of various theories, none of which appear entirely satisfactory.

537.566:538.566 657
The Ionization and Luminescence of Flames—P. Goercke, E. Saenger and I. Bredt. (*Ann. Télécommun.*, vol. 6, pp. 250–260; August/September, 1951.) Measurements of the reflection of electromagnetic waves from the exhaust gases of rockets show that the degree of ionization is much higher than hitherto assumed. Theory in accordance with these findings is developed by taking account of the fact that the gas is not in an equilibrium state.

537.568 658
Concerning the Mechanism of Electron-Ion Recombination—M. A. Biondi and T. Holstein. (*Phys. Rev.*, vol. 82, pp. 962–963) June 15, 1951.) Discussion of investigations by various workers.

537.71 659
An Introduction to the Rationalized M.K.S. System of Units—G. F. Nicholson. (*Brit.*

Jour. Appl. Phys., vol. 2, pp. 177–182; July, 1951.)

538.311:621.318.423:513.647.1 660
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 solution 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 one coordinate constant. Maxwell's equations and the em 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 on 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.

538.566 661
Propagation in the Non-homogeneous Atmosphere—B. Friedman. (*Commun. pure appl. Math.*, vol. 4, pp. 317–350; August, 1951.) A new exposition of the theory of propagation over a spherical earth where the dielectric constant of the atmosphere varies radially from the earth's center. The methods and results are similar to those of Watson, van der Pol, Bremmer and Rydbeck, with some novelties as follows: (*a*) the dielectric constant is taken as a single function of position instead of having different functions in different regions; (*b*) the contour integral for the Hertz potential is carefully examined; this integral vanishes over the infinite semi-circle, even for an arbitrary atmosphere; the potential may then be expressed as a sum of residues plus an integral which vanishes identically for a perfectly conducting earth, and is small compared with the first term of the residue series when the complex dielectric constant of the earth is much larger than that of the atmosphere; (*c*) it is emphasized that the propagation problem reduces to the eigenvalue problem for an ordinary differential equation, so that the W.K.B. method should be applied; (*d*) the degree of accuracy of the flat-earth theory as an approximation of the exact spherical-earth theory is considered; (*e*) a new approach is made to the case of tropospheric propagation in the presence of a duct, and the solution is expressed in terms of Hankel functions of order one-quarter.

538.566 662
Electric Waves along a Dielectric Cylinder surrounded by a Dielectric, One or Both of the Media being Plasma—W. O. Schumann. (*Z. Naturf.*, vol. 5a, pp. 181–191; April, 1950.) The following cases are analyzed: (*a*) dielectric cylinder in plasma atmosphere, (*b*) plasma cylinder in dielectric atmosphere, (*c*) plasma cylinder in plasma atmosphere. The stationary waves formed between two plane conducting sheets perpendicular to the cylinder axis are also investigated. In consequence of the dispersion of the dielectric constant of a plasma and since it can have a negative value, many types of wave are possible. In most cases propagation is possible only within a limited frequency range. The phase velocity may increase or decrease considerably with the frequency. Surface waves, with low phase and group velocities and strong energy concentration close to the surface of the cylinder, are possible in all cases.

538.566:535.13 663
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 em field produced by prescribed sources 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 functions. In this way Maxwell's equations are transformed so that the solution is reduced to that of scalar equations for guided waves along the r or θ directions. The problem thus becomes that of the solution, as a function of the mode index, of an ordinary second-order inhomogeneous equation. A procedure for the solution of the eigenvalue problem set by this equation is described; the use of the δ function is involved. Complete sets of mode functions for use in typical problems are derived. The application of the results obtained to practical problems in terrestrial radio wave propagation is pointed out.

538.566:535.312 664
Reflection of Electromagnetic Waves from Slightly Rough Surfaces—S. O. Rice. (*Commun. pure appl. Math.*, vol. 4, pp. 351–378; August, 1951.) Theoretical treatment of reflection from a perfectly conducting surface which has small random deviations from a plane. From expressions for the field components average values are found in order to obtain the reflection coefficient, which is found to depend on polarization in a way similar to that of an almost perfectly conducting plane. A modified form of the reflection analysis is used to study propagation along the surface. Reflection from an imperfectly conducting rough surface is also considered briefly.

621.3.064.43 665
Arcing at Electrical Contacts on Closure: Part 1—Dependence upon Surface Conditions and Circuit Parameters—L. H. Germer. (*Jour. Appl. Phys.*, vol. 22, pp. 955–964; July, 1951.)

538.114+538.221 666
Ferromagnetism [Book Review]—R. M. Bozorth. Publishers: D. Van Nostrand Co., New York, 1951, 968 pp., $17.50. (*Jour. Frank. Inst.*, vol. 252, p. 93; July, 1951.) "It is a book . . . that will be useful to the physicist interested in the fundamentals of ferromagnetism, to the metallurgist working with magnetic materials, and to the design engineer adapting new methods and materials to apparatus needs . . . extremely valuable as a survey of the field and as a source for further references."

GEOPHYSICAL AND EXTRATERRESTRIAL PHENOMENA

523.7 667
The Possible Nature and Electromagnetic Origin of the Observed Pulsations of the Diameter of the Sun—L. Gialanella. (*Rend. Accad. naz. Lincei*, vol. 11, pp. 60–62; July/August, 1951.)

523.72+523.8]:621.396.822 668
Radio Astronomy—J. S. Hey. (*Sci. Progr.*, vol. 39, pp. 427–448; July, 1951.) An outline of the general principles of extraterrestrial radio noise reception, illustrated by examples from recent work.

550 669
Transactions of Oslo Meeting [of the International Union of Geodesy and Geophysics] August 19–28, 1948—J. W. Joyce, Ed. (*Int. Ass. terr. Mag. Elec. Bull.*, No. 13, 568 pp., 1950.) These Transactions include national reports on research done up to 1947 on terrestrial magnetism, atmospheric electricity, the ionosphere and related subjects, together with the text or title of numerous papers presented at the meeting.

550.384 670
Typical Daily Variations of the Geomagnetic Field Components at Potsdam, and their Interpretation—J. Bartels. (*Z. Met.*, vol. 5, pp. 236–239; July/August, 1951.) The mean daily curves were calculated for the solstice periods, for quiet days with zero and with high relative sunspot number, and for uniformly disturbed days. An unexpectedly strong variation with sunspot number is found for the quiet-day curves in winter. This indicates that the physical nature of the solar W radiation varies with solar activity; the height of the ionosphere layers ionized by the W radiation varies inversely as the sunspot number.

550.384.3 671
The Analysis of the Geomagnetic Secular Variation—F. J. Lowes and S. K. Runcorn. (*Philos. Trans. A*, vol. 243, pp. 525–546; August 16, 1951.) The analysis shows that the major part of the secular variation field for epoch 1922–1925 is explained by about twelve vertical dipoles below the surface of the earth's core. "The depth of the dipoles confirms that the origin of the secular variation must lie in the core of the earth; because of the high electrical conductivity of the core material it must in fact be due to a thin current sheet at the surface of the core, and this interpretation also gives an explanation for the existence of only vertical sources. The presence of only vertical sources, and in particular the presence of several near the equator, does not support the existence of the toroidal field, which is an essential step in Bullard's dynamo theory of the main field."

551.510.535 672
Note on Triple Splitting in the Ionosphere—W. Becker. (*Z. angew. Phys.*, vol. 3, pp. 83–88; March/April, 1951.) Marked variation of the polarization coefficient with height can occur if the collision frequency approaches a critical value, even when the ionization gradient is small. This value defines the region of transition from quasitransverse to quasilongitudinal propagation. Conditions for reflection and absorption of the ordinary and extraordinary waves are determined from a short mathematical analysis. The sharpness of the trace of the third component observed in echo-sounding at variable frequency is explained by the fact that such echoes can only be received in the direction of the earth's magnetic field.

551.510.535 673
Notes on the Height Fluctuation of the Ionosphere F_2 Layer—R. Eyfrig. (*Z. angew. Phys.*, vol. 3, pp. 96–103; March/April, 1951.) Analysis of data from numerous stations relative to the dependence of the (M 3,000) F_2-layer factor on the relative sunspot number. The running 12-monthly means for 1944–1947 show a nearly linear relation for almost all stations. After the solar-cycle peak the muf factor rises sharply for one group of stations and decreases further for a second group. The stations of both groups appear to be distributed geographically at random. Huancayo is an exception; monthly means show the highest linear correlation, -0.966 for midday and -0.961 for midnight values (see also 890 of 1950). For midday values the magnetic equator represents a line of symmetry; for midnight values the effect of geographical latitude is predominant.

551.510.535:621.3.087.4 674
Echo Sounding of the Ionosphere at Oblique Incidence—W. Dieminger. (*Z. angew. Phys.*, vol. 3, pp. 90–96; March/April, 1951.) Review of methods of synchronizing transmitter and receiver for fixed- and variable-frequency working. Traces recorded using quartz-clock synchronization for pulse reception and receiver tuning are shown, and results are briefly discussed.

551.510.535:621.396.11 675
Spectral Representation of Space-Wave Reception and the Ionosphere—Spork. (*See* 780.)

551.510.535(98) 676
Thickness of Winter F Layer in Polar Regions—M. W. Jones. (*Trans. Amer. Geophys. Union*, vol. 31, Part 1, pp. 187–190; April, 1950.) The half-thickness t of the F layer, as calculated by the Booker-Seaton method, for the winter months at College, Alaska, decreased from a monthly mean of 24 km for 1941–1942 to 13 km for 1943–1944. This decrease coincides with the decrease in total sunspot number. For the period October–December 1948 the mean value of t was 60 km and the 5-fold increase is believed to correspond with increase in sunspot number. Contour graphs show the mean diurnal variations of t for each month of the above-mentioned periods.

551.594 677
New Electric Effect in Icing by Sleet Formation in Naturally Supercooled Mists—H. Lueder. (*Z. angew. Phys.*, vol. 3, pp. 247–253; July, 1951.) Measurements were made of the charge acquired by ice forming on an earthed metal rod rotating in a supercooled mist on a mountain peak. This charge is negative. Results indicate that particles of vapor settle only partly as ice, the remainder rebounding in liquid form with a positive charge.

551.594.6 678
A Note on the Similarity of Certain Atmospherics Waveforms—W. F. Zetrouer and W. J. Kessler. (*Jour. Frank. Inst.*, vol. 252, pp. 137–141; August, 1951.) Photographic records of atmospherics associated with particular thunderstorms observed in Florida are discussed. Of 104 night-time wave forms identifiable with a surface cold front extending over the midwestern states, 55 per cent had similar fine structure. Of 520 day-time wave forms associated with a surface cold front moving over the edge of the Gulf Stream 41 per cent were of similar type.

551.594.6:621.3.018.7.087.4/.5 679
Automatic Atmospherics-Waveform Recorder—C. Clarke and D. E. Mortimer. (*Wireless Eng.*, vol. 28, pp. 359–370; December, 1951.) A description of equipment for recording the changes in electric field constituting the atmospherics due to lightning discharges. The amplifier is aperiodic and covers the range 100 cps–100 kcps. At maximum gain, an input signal of 8mv is required to give full-scale deflection on a 6-inch cr tube. The wave form appears on two cr tubes simultaneously, linear single-stroke timebases of short and long duration respectively serving to display on one tube the initial hf portion of the wave, and on the other the lf "tail" associated with distant atmospherics. The timebases are triggered by the atmospheric. After each exposure on the two 35-mm-film cameras, the film is automatically moved on to the next frame, 40 exposures per minute being possible. Provision is made for synchronization with the Meteorological Office network of cr direction finders so that the origin of each recorded atmospheric may be determined.

LOCATION AND AIDS TO NAVIGATION

621.396.9:551.578.1/.4 680
A Quantitative Study of the 'Bright Band' in Radar Precipitation Echoes—P. A. Austin and A. C. Bemis. (*Jour. Met.*, vol. 7, pp. 145–151; April, 1950.) Observations and measurements of the bright band are presented and discussed. The theory attributing the phenomenon to the coalescence and melting of snowflakes affords an adequate explanation.

621.396.9:551.578.1 681
Vertical Recording of Rain by Radar—S. K. H. Forsgren and O. F. Perers. (*Acta Polyt.* (Stockholm), no. 87, 19 pp.; 1951.) Report of observations with radar equipment operated on a wavelength of 3.2 cm with output power of 7.5 kw, pulse duration 0.5 μs and repetition rate 300 per second. Anomalous echo patterns are illustrated and discussed. A record showing a triple echo is in good agreement with theoretical curves for multiple reflections from a scattering layer.

621.396.933 682
The American Plan for Air Traffic Control: A Description of SC31—D. O. Fraser. (*Jour. Inst. Nav.*, vol. 4, pp. 213–231. Discussion, pp. 232–236; July, 1951.) Summary of a report by the Radio Technical Commission for Aeronautics which outlines a comprehensive scheme for the development of control facilities during the next 15 years. The functions of the various ground and airborne units of equipment are described briefly and an example of the use of the facilities is given.

621.396.933 683
Modern Aircraft Safety Equipment—K. Witmer. (*Bull. schweiz. elektrotech. Ver.*, vol. 42, pp. 125–135; March 10, 1951. In German.) A review of the principles and operation of radio communication equipment, radio beacons, df systems, radar navigation aids, air traffic control systems, and aids to landing in bad weather conditions.

MATERIALS AND SUBSIDIARY TECHNIQUES

533.5 684
Molecular Flow in Connected Tubes—W. Harries. (*Z. angew. Phys.*, vol. 3, pp. 296–300; August, 1951.) Probability theory is used in an analysis of molecular flow problems encountered in vacuum technique.

535.37:539.234 685
Transparent Luminescent Films—F. J. Studer, D. A. Cusano and A. H. Young. (*Jour. Opt. Soc. Amer.*, vol. 41, p. 559; August, 1951.) Two methods of producing such films are described. In the first, a clear film of the phosphor is deposited on a heated glass surface by the reaction of appropriate vaporized materials. The second method consists in evaporating a film of ZnF_2 onto a glass surface and then converting it to ZnS by heating in a stream of H_2S. The best films, made by the first method, are Mn-activated ZnS films. They have approximately half the brightness of conventional television phosphors and have orange-yellow luminescence.

535.37:621.385.832 686
Phosphors for Cathode-Ray Tubes—L. Levy and D. W. West. (*Jour. Telev. Soc.*, vol. 6, pp. 178–183; January/March 1951.) The properties of various phosphors are discussed critically in relation to the characteristics of cr tube screens for direct-viewing and projection television, also for certain radar applications.

537.226.2 687
A General Law including as Particular Cases the Various Empirical Formulae proposed by Various Authors to represent the Variation of Dielectric Constant of a Solvent as a Function of Temperature—T. Erben. (*Bull. tech. Univ. Istanbul*, vol. 3, no. 1, pp. 45–60; 1950. In French.)

537.312.6:621.315.592† 688
Manufacture, Regulating Action and Applications of Thermistors—E. Meyer-Hartwig and H. Federspiel. (*Bull. schweiz. elektrotech. Ver.*, vol. 42, pp. 135–142; March 10, 1951. In French.) The physical properties of the materials used in thermistors are described, manufacturing processes are outlined for low-power and high-power units, and examples of their use are illustrated.

538.221 689
Magnetic Materials and Ferromagnetism—A. E. de Barr. (*Research* (London), vol. 4, pp. 366–371; August, 1951.) A survey paper discussing the properties of modern magnetic materials in the light of domain theory of ferromagnetism.

538.221 690
On the Dielectric and Magnetic Properties of some Ferrites at High Frequency—F. Wagenknecht. (*Frequenz*, vol. 5, pp. 145–155 and 186–190; June and July, 1951.) Report of investigations of ferrites of Mg, Mn, Fe, Ni, Cu, Pb and CuPb in the frequency range 170–3,285 mc. The system FeO-Fe_2O_3 was specially dealt with. Preparation of the samples is described; their properties and factors influencing them are tabulated and discussed in relation to molecular structure.

538.221 691
Resistance Anomalies in a High-Permeability Nickel-Iron-Molybdenum Alloy—F. Assmus and F. Pfeifer. (*Z. Metallk.*, vol. 42, pp. 294–299; October, 1951.) Variations of permeability and resistance of supermalloy subjected to additional tempering are investigated. As well as the expected increase of permeability, increase of cold resistance is observed, together with dependence of hot resistance on rate of cooling. These effects differ from those observed in permalloy but are similar to those observed in other alloys, e.g. Ni-Cr.

538.221:669.15 692
Iron-Silicon Alloys Heat Treated in a Magnetic Field—M. Goertz. (*Jour. Appl. Phys.*, vol. 22, pp. 964–965; July, 1951.) Heat treatment of Fe–Si alloys in a magnetic field results in much improved magnetic properties, the highest maximum permeability being obtained in an alloy with about 6.5 per cent Si. For a single crystal of this composition, magnetic annealing nearly closed the hysteresis loop and increased the maximum permeability from 5×10^4 to 3.8×10^6, the highest value yet reported.

539.234:546.57:537.312 693
Temperature Variation of the Electrical Properties of Films containing Cavities—J. P. Borel. (*C. R. Acad. Sci., Paris*, vol. 233, pp. 296–297; July 23, 1951.) The electrical resistance of Ag films of thickness less than 10 mμ does not obey Ohm's Law; such films are lacunary in character. The voltage/current ratio increases irreversibly with temperature in the range 15°C–150°C. For films of thickness 11–12 mμ the corresponding variation is reversible.

539.234:546.57:537.312 694
Variation of the Resistivity of Thin Metal Films as a Function of Thickness and Temperature—J. P. Borel. (*Helv. Phys. Acta*, vol. 24, pp. 389–400; September 20, 1951. In French.) See 693 above.

546.212:621.3.011.5 695
The Dielectric Behaviour of Water in Water-Dioxan Mixtures—H. F. Cook. (*Trans. Faraday Soc.*, vol. 47, pp. 751–755; July, 1951.) Report of investigation at microwave frequencies. The experimentally derived static dielectric constants of mixtures are analyzed in terms of Kirkwood's theory for liquid dielectrics. The relaxation time of water in water-dioxan mixtures is greater than the value in pure water by a factor of approximately 2 at the greatest concentrations investigated.

546.23:537.311.33 696
Conductivity and Hall Effect of Microcrystalline Selenium containing Iodine Impurities—K. W. Plessner. (*Proc. Phys. Soc.* (London), vol. 64, pp. 681–690; August 1, 1951.) The increase in conductivity arising from increased iodine content is due not to an

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 temperature, in agreement with X-ray diffraction evidence of greater crystal perfection at higher temperatures.

546.23:548.55:537.311.33 697
Conductivity, Hall Effect and Thermoelectric Power of Selenium Single Crystals—K. W. Plessner. (*Proc. Phys. Soc.*, vol. 64, pp. 671–681; August 1, 1951.) Single crystals were grown from the vapor phase. Conductivity obeys the law $\sigma = \sigma_0 \exp(-eE/kt)$ with $eE = 0.13$ eV. Ohm's Law is not obeyed for applied fields >5V/cm. Both thermoelectric power and Hall effect rise slightly with increasing temperature, indicating a decreasing concentration of current carriers (positive holes). The evidence points to the existence of intergranular barriers in single crystals.

546.23:548.55:537.311.33 698
Electrical Properties of Selenium: Part 1—Single Crystals—H. W. Henkels. (*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 application of field. The large values found for thermoelectric power indicate hole conduction with a hole density of the order of 10^{14}/cm^3, the density decreasing with temperature increase above room temperature. Mobilities and activation energies were also determined.

546.47-31:537.311.33 699
Some Electrical Properties of Zinc Oxide Semiconductor—E. E. Hahn. (*Jour. Appl. Phys.*, vol. 22, pp. 855–863; July, 1951.) Results and discussion of conductivity and Hall-coefficient measurements.

546.48-31+546.74-31 700
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 and 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.

546.74:548.55 701
Some New Bitter Patterns on a Single Crystal of Nickel—L. F. Bates and G. W. Wilson. (*Proc. Phys. Soc.*, vol. 64, pp. 691–695; August 1, 1951.) An investigation of domain magnetization processes using the experimental technique originated by Bitter.

546.814.221 702
The Conductivity/Temperature Characteristics of Lead Sulphide: The Influence of Oxygen and of the Rate of Heating—W. Ehrenberg and J. Hirsch. (*Proc. Phys. Soc.*, vol. 64, pp. 700–706; August 1, 1951.) Equipment is described for recording conductivity/temperature curves at heating rates up to 5,000°C per second, and the results of extensive measurements on PbS in an oxygen atmosphere are discussed.

546.817.221:535.61-15:535.345.1 703
Infrared Transmission of Galena—W. Paul, D. A. Jones and R. V. Jones. (*Proc. Phys. Soc.*, vol. 64, pp. 528–529; June 1, 1951.) Single crystals of galena were found to be sensibly opaque up to about 3μ, beyond which the transmission rose sharply to a maximum at about 4.5μ, then falling more slowly to a low value at 10μ. The rise of transmission beyond 3μ 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.

548.0:537.228.1 704
Piezoelectric Behaviour of Partially Plated Square Plates Vibrating in Contour Modes—R. Bechmann and P. L. Parsons. (*Proc. Phys. Soc.*, vol. 64, pp. 706–712; August 1, 1951.) A continuation of work described previously [2208 of 1951 (Bechmann)]. Measurements on square crystals are used to check the theoretical solution for the motion. For the longitudinal mode-2 described by Ekstein (423 of 1945) a particularly sensitive test of the theory is possible. Experiment confirms that with a critical size of electrodes the piezoelectric excitation vanishes.

548.0:549.514.51:539.37 705
Piezocrescence—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 lengthwise temperature gradient, is explained in terms of a reversible phenomenon, the growth of one crystallographic orientation out of another under the influence of stress, for which the term 'piezocrescence' is proposed. Piezocrescence may also be expected in other crystals such as titanates, felspars and boracite.

621.314.63 706
Effect of Temperature on the Height of Potential Barriers and on the Breakdown Voltage of Contact Rectifiers—E. Billig. (*Proc. Phys. Soc.*, vol. 64, pp. 752–753; August 1, 1951.) Measurements of the contact resistance of standard Se, Ge and Si rectifiers indicate a barrier of constant 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. Se) the breakdown voltage is lowered by a decrease in temperature, while 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. (*Jour. 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 σ. Thus a maximum value of tan δ can occur at some frequency without resonance absorption. It is suggested that the σ/frequency curve be used as a criterion of resonance.

621.315.612.4 708
Properties of Beryllium-Barium Titanate Dielectrics—E. N. Bunting, G. R. Shelton, A. S. Creamer and B. Jaffe. (*Bur. Stand. J. Res.*, vol. 47, pp. 15–24; July, 1951.) Dielectrics having compositions in the system BeO-$BaTiO_3$-TiO_2 were matured at 1,240°–1,525°C. Data are given for the composition, heat treatment, absorption and shrinkage. The dielectric constant (K) and the reciprocal of the power factor (Q) were determined at various temperatures from −60° to 200°C; measurement frequencies used were 50 kc, 130 kc, 1 mc, 20 mc 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 decreased in some cases by a factor of 10^6 over a few days; for specimens of some compositions K and Q changed with time. Results are tabulated.

537.525 709
Dielectric Breakdown of Solids [Book Review]—S. Whitehead. Publishers: Oxford University Press, London, 271 pp., 25s. (*Elec. Rev.* (London), vol. 149, p. 208; July 27, 1951.) An account of theoretical and experimental work carried out by the Electrical Research Association.

MATHEMATICS

512.972 710
Practical Transformation Methods for Tensors of the Third and Fourth Orders—R. Bechmann. (*Arch. elekt. Übertragung*, vol. 5, pp. 360–362; August, 1951.) Methods useful in treatment of the elastic and piezoelectric properties of crystals.

517.544.2:621.392 711
The One-Sided Green's Function—K. S. Miller. (*Jour. Appl. Phys.*, vol. 22, pp. 1054–1057; August, 1951.) Discussion of the properties of the function and of its relation to the impulsive response of a linear network.

517.63 712
The Solution of Boundary-Value Problems by Multiple Laplace Transformations—T. A. Estrin and T. J. Higgins. (*Jour. Frank. Inst.*, vol. 252, pp. 153–167; August, 1951.)

517.944 713
Solutions of Some Partial Differential Equations (with Tables)—L. Weinberg. (*Jour. Frank. Inst.*, vol. 252, pp. 43–62; July, 1951.) Discussion, exemplification and tabulation of the solutions of Laplace's equation, Poisson's equation, the diffusion equation, the wave equation, the damped-wave equation and Helmholtz's equation.

518.3 714
Construction of Three-Dimensional Nomographs—W. H. Burrows. (*Indus. Eng. Chem.*, vol. 43, pp. 1823–1826; August, 1951.) A simple theoretical approach is presented, applicable to all formulas capable of representation in a nomogram with a planar index surface; the construction is made on a hyperbolic co-ordinate system.

519.2:621.396.822 715
Expected Number of Crossings of Axis by Linearly Increasing Function plus Noise—F. W. Lehan. (*Jour. Appl. Phys.*, vol. 22, pp. 1067–1069; August, 1951.) "The expected number of times the function $e(t) = at + e_N(t)$ crosses the t axis in a positive direction prior to any given time is calculated, where $e_N(t)$ is a random noise function of arbitrary power spectrum. The solution is given as the product of two functions. Curves are presented for the two functions."

517:621.3.015.3:621.3 716
Transient Analysis in Electrical Engineering [Book Review]—S. Fich. Publishers: Prentice-Hall, New York, 1951, 306 pp., $5.50. (*Jour. Frank. Inst.*, vol. 252, p. 208; August, 1951.) "Designed for a stiff undergraduate course." Differential equations and operational methods are used.

MEASUREMENTS AND TEST GEAR

620.178.16:621.315.3 717
The Testing of Fine Wires for Telecommunication Apparatus—R. C. Woods and J. K. Martin. (*Proc. IEE*, Part II, vol. 98, pp. 529–536. Discussion, pp. 536–538; August, 1951.) Existing acceptance and quality tests are discussed, abrasion and electrical breakdown are considered in greater detail and the need for new tests and for appreciation of the limitations of existing ones is stressed.

621.3.018.41(083.74) 718
Standard Frequency Transmissions—(*Wireless World*, vol. 57, p. 378; September, 1951.) Details are given of the four standard-frequency signals radiated by the B.B.C. The 200-kc signal is particularly useful; guaranteed accuracy is to within 1 part in 10^6 of the

nominal frequency, actual accuracy even greater. The frequency stability of the B.B.C.'s ordinary transmissions is also discussed briefly.

621.3.087.4:551.510.535 719
A 16-kw Panoramic Ionospheric Recorder—R. Lindquist. (*Acta Polyt.* (Stockholm), No. 85, 41 pp.; 1951.) For another account see 1425 of 1951.

621.3.087.6:[621-526:621.396.615 720
A Servo Drive for Heterodyne Oscillators—T. Slonczewski. (*Elec. Eng.*, vol. 70, p. 683; August, 1951.) Summary of A.I.E.E. 1951 Summer General Meeting paper. A method for sweeping a test oscillator through its frequency range while some characteristic of the device under test is being recorded. 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. Ton*, vol. 5, pp. 337–343; July, 1951.) Equipment is described which gives, in the frequency range 1c–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 source; the thermal noise in the range 50 90 kc is aperiodically amplified and then transposed to the desired range by means of a ring modulator, using an auxiliary frequency of 70 kc. The power-supply unit includes a Steinlein stabilization system. Full circuit details of both generator and supply unit are given.

621.317.3:621.396.611.21.011 722
New Methods for the Determination of Electric Constants of Vibrating Piezo-electric Crystals—P. G. Ventouratos. (*Beama Jour.*, vol. 58, pp. 227–230; August, 1951.) The effective Q and R of a quartz-crystal resonator are determined (*a*) from cro measurements 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 easily calculated from simple formulas.

621.317.3:621.396.645 723
Degree of Amplification of Amplifiers for Electrical Measurements—F. Moeller. (*Arch. tech. Messen*, pp. T94–T95; August, 1951.) Review of the characteristics of the various types of amplifier, with 29 references.

621.317.3.083.4:621.392 724
Double-T Networks for Null Measurements at High Frequency—E. Samal. (*Arch. tech. Messen*, p. T86; 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 specially suitable for R, L or C null measurements at frequencies up to about 60 mc are described and their particular advantages enumerated.

621.317.329:621.392.26† 725
Determination of Aperture Parameters by Electrolytic-Tank Measurements—S. B. Cohn. (Proc. I.R.E., vol. 39, pp. 1416–1421; November, 1951.) Results of measurements of magnetic polarizability are given for rectangular apertures and for slot, cross-, rosette-, dumbbell-, and H-shaped apertures with slot ends rounded.

621.317.331 726
Methods for the Measurement of Very High Electrical Resistances and Low Capacitances—H. Tellez Plasencia. (*Rev. gén. élect.*, vol. 60, pp. 209–221; May, 1951.) A method for measuring resistances of the order of $10^{12}\,\Omega$ 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.

621.317.335.3:621.396.677 727
Artificial Dielectrics for Microwaves—W. M. Sharpless. (Proc. I.R.E., vol. 39, pp. 1389–1393; November, 1951.) Description of a procedure for measuring the permittivity and loss factor for metal-strip-loaded pseudo-dielectrics, making use of a short-circuited coaxial line. Formulas based on transmission-line theory are provided for determining approximately the dielectric properties of certain loading configurations.

621.317.336 728
A Precise Sweep-Frequency Method of Vector Impedance Measurement—D. A. Alsberg. (Proc. I.R.E., vol. 39, p. 1393; November, 1951.) An impedance is determined from the insertion loss and phase shift which result when it is inserted in a transmission line terminated at both ends by its characteristic impedance. Insertion loss and phase shift can be converted directly to impedance by use of special charts, whose derivation is outlined. Equipment previously described (2836 of 1949) has been modified and sweep-frequency measurements from 50 kc to 20 mc can now be made with a possible accuracy to within ±0.05 per cent for impedances of about 75 Ω.

621.317.336:621.396.67 729
The Measurement of Antenna Impedance using a Receiving Antenna—Hartig, King, Morita and Wilson. (See 585.)

621.317.336:621.396.676.001.57 730
The Use of Complementary Slots in Aircraft-Antenna Impedance Measurements—Bolljahn and Granger. (See 594.)

621.317.353 731
A New Measurement Apparatus for Mains-Voltage Overtones—W. Wilshaus. (*Elektrotech. Z.*, vol. 72, pp. 408–410; July 1, 1951.) An overtone-meter is described, in which the deflection of a wattmeter indicates the instantaneous amplitude of the overtones. The error may be calculated from curves or may be balanced out; in the latter case its magnitude is reduced to <1 per cent of the measured value.

621.317.361 732
Frequency Measurement by the Capacitor Charge Method—H. Weidemann. (*Arch. tech. Messen*, pp. T87–T88; August, 1951.) Detailed description of the method in which an incoming sine wave, whose frequency is to be determined, is transformed into a rectangular wave by means of a multistage amplifier. This rectangular wave is differentiated, at the point where its value is zero, by an RC circuit whose time constant corresponds to the highest measurement frequency. The dc mean value of the capacitor charging current is then proportional to the measurement frequency. The accuracy of the method is discussed.

621.317.382:621.3.015.7† 733
Measurement of Power at the Peaks of Periodic High-Frequency Pulses—W. Hasselbeck. (*Funk u. Ton*, vol. 5, pp. 344–350; July, 1951.) Peak pulse power is derived from mean power by use of a form factor whose physical significance is explained and for which a method of measurement is described.

621.317.382:621.396.611.21 734
Power Measurements on Ultrasonic Quartz Oscillators—W. Schmitz and L. Waldick. (*Z. angew. Phys.*, vol. 3, pp. 281–288; August, 1951.) So that the measurements can be made during normal operation without disturbing the radiation field, an electrical method is used. This is based on a development of the equivalent circuit of the crystal, in which its equivalent resistance is decomposed into three measurable components, viz., (*a*) internal resistance, (*b*) resistance due to holder, and (*c*) radiation resistance. Results are presented and discussed.

621.317.71/.72 735
New Moving-Coil Standard Instrument—(*Arch. tech. Messen*, p. F1; July, 1951.) Improvements in the AEG instrument include an Alni magnet giving a much stronger field in the gap (3,500–5,000 gauss) and a new coil system. Temperature compensation is provided. At 20°C the reading error at any point of the uniform scale in no case exceeds 0.1–0.2 per cent of the full-scale reading.

621.317.725 736
Linear Diode Voltmeter. Response to Randomly Recurrent Impulses—R. E. Burgess. (*Wireless Eng.*, vol. 28, pp. 342–344; November, 1951.) "The response of an ideal linear diode voltmeter to randomly recurrent impulses is evaluated in terms of the parameters of the impulses and the time constants of the voltmeter. The rectification efficiency is shown to be slightly greater than that for regularly recurrent impulses of the same average recurrence frequency."

621.317.733:621.317.335.3† 737
A Bridge for the Measurement of the Dielectric Constants of Gases—W. F. Lovering and L. Wiltshire.) *Proc. IEE*, Part II, vol. 98, pp. 557–563; August, 1951.) The criteria of sensitivity and stability required for the determination of the dielectric constants of gases are discussed; these can be met by the use of an ac bridge, a suitable design of which is described. Results of measurements on several gases and on water vapor are given.

621.317.755 738
Oscillograph with Electronic Commutator for Four Recordings—B. Bladier. (*Rev. gén. élect.*, vol. 60, pp. 195–203; May, 1951.) A cro using a time-division system.

621.317.755 739
A Fiftyfold Momentary Beam Intensification for a High-Voltage Cold-Cathode Oscillograph—J. H. Park. (*Bur. Stand. Jour. Res.*, vol. 47, pp. 87–93; August, 1951.) Circuit devices are described for superposing steeply rising voltage pulses on the steady direct voltage of 50 kv normally applied to the discharge tube producing the electron beam. The beam intensity is momentarily increased up to fiftyfold, and legible traces are obtained with writing speeds as high as 9,100 inches/μs. For a shorter account see *Tech. Bull. Nat. Bur. Stand.*, vol. 35, pp. 148–150; October, 1951.

621.317.755.621.3.012.2 740
Circle-Diagram Recorder for the Audio-Frequency Range—O. Schäfer and H. Eberhardt. (*Arch. elekt. Übertragung*, vol. 5, pp. 377–382; August, 1951.) The apparatus described comprises an af generator, preamplifier, ring modulator and low-pass filter, final amplifier and cr tube. This enables complex impedances, conductances and transformation ratios to be measured in the range 50c–10kc. By continuous variation of a parameter, generally the frequency, the circle diagram can be displayed, compared with a standard curve and photographed. Parts of the equipment are suitable for measurements on complex impedances or can be used as a complex compensator.

621.317.755:621.397.5 741
Oscillographic Representation of Television Signals—K. R. Sturley. (*Radio Tech. Dig.*, Édn (France), vol. 5, pp. 227–235 and 289–292; 1951.) French version of 447 of February.

621.317.757 742
Results of Measurements on the Rounded-Signal [radiotelephony] Transmitter at Lyon-la-Doua—A. Tchernicheff. (*Ann. Télécommun.*, vol. 6, pp. 191–196; July, 1951.) Measurements were made with the spectrometer previously described (3056 of 1951) (*a*) 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.

621.317.761 743
Accurate Direct-Reading Frequency-Measurement Equipment, 30c/s–30Mc/s—L. R. M. Vos de Wael. (*Tijdschr. ned. Radiogenoot.*, vol. 16, pp. 171–184; 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 29 mc, a mixing circuit, and an electronic 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 10^7, ± 1 c.

621.317.763.029.64 744
Design of Cavity-Resonator Wavemeters for Cm Waves—M. L. Toppinga. (*Tijdschr. ned. Radiogenoot.*, vol. 16, pp. 185–207; July, 1951.) A graphical method of deriving design data is described and is applied to the design of a cavity wavemeter 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.

621.396.621:621.396.619.13 745
A New Method for Predicting the Adjacent-Channel Performance of Mobile Radio Equipments by Graphical Analysis—T. S. Eader. (*FM-TV*, vol. 11, pp. 21–24, 39; September, 1951.) Various methods of testing the selectivity of fm communication receivers are discussed; 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 adjustably spaced from the first. To determine for a given receiver whether interference will be caused first by (*a*) break-through of adjacent-channel modulation, (*b*) desensitization produced by the adjacent-channel carrier or (*c*) on-frequency noise produced by the adjacent-channel transmitter, a three-stage graphical procedure is developed comprising (*a*) preparation of transmitter sideband distribution curves, (*b*) preparation of receiver interference characteristics and (*c*) graphical application of curves (*a*) to curves (*b*). Methods are also given for the measurement of bandwidth, which should be specified separately from selectivity.

621.317.3.029.5/.6 746
High-Frequency Measurements [Book Review]—A. Hund. Publishers: McGraw-Hill, New York, 2nd ed. 1951, 631 pp., $10.00. (Proc. I.R.E., vol. 39, p. 1472; November, 1951.) "This second edition . . . has been revised extensively . . . 'high frequency' now is interpreted to include all frequencies above 20 kilocycles per second up to super high frequencies (microwaves) . . . . With this timely revision, the book will retain its leadership in the frequency range of greatest interest to practical radio engineers."

OTHER APPLICATIONS OF RADIO AND ELECTRONICS

531.768:546.431.824-31 747
Miniature Piezoelectric Accelerometer—(*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 testing the frequency response of vibration generators. The pickup comprises a $BaTiO_3$ disk of thickness 1/16 inch and diameter ⅜ inch, stacked between a base and a metal loading block; it weighs <0.1 ounce. The response curve is flat within 20 per cent between 50 c and 6 kc, and rises to a slight peak between 10 and 18 kc.

531.768:546.431.824-31 748
Self-Generating Accelerometers—G. K. Guttwein and A. I. Dranetz. (*Electronics*, vol. 24, pp. 120–123; October, 1951.) The characteristics and advantages are discussed of compression and bending types of accelerometer using piezoelectric $BaTiO_3$ ceramic elements. The useful range of a typical unit is from 0.022 *g* to 600*g*; the corresponding output-voltage range of 1 mv–27 v can be measured with normal equipment. Readings are hardly affected by temperature or humidity.

538.569.2.047 749
Dielectric Behaviour of Human Blood at Microwave Frequencies—H. F. Cook. (*Nature* (London), vol. 168, pp. 247–248; August 11, 1951.) Measurements of the dielectric constant of human blood over the frequency range $1.78\times10^9 - 2.36\times10^{10}$ c are reported; coaxial-line and waveguide methods were used. Experimental results are discussed in relation to dielectric theory.

620.178.3 750
Electrically Excited Resonant-Type Fatigue Testing Equipment—T. J. Dolan. (*ASTM Bull.*, pp. 60–68; July, 1951.) An application of a valve-maintained tuning-fork circuit, with electronic calibration and control.

620.179.16 751
Supersonic Flaw Detection—(*Overseas Eng.*, vol. 25, pp. 32–34; August, 1951.) Description of two British commercial equipments, with details of the various probes available.

621.315.612.4:546.431.824-31 752
An 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 the necessary conditions for inscribing and erasing electrostatic preorientation in $BaTiO_3$ ceramics at a temperature somewhat below the Curie point. The results suggest the possibility of a memory device that can be operated in the range of audio-frequencies or higher.

621.317.755:612.82 753
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 spaced signal sources, e.g. the brain, are visually displayed on a system of 22 cr tubes arranged to represent a simple 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 electrical responses evoked by photic stimulation.

621.317.755:621.4 754
The Standard-Sunbury Engine Indicator 'Mark 6'—E. S. L. Beale and R. Stansfield. (*Engineer* (London), vol. 142, pp. 215–217 and 246–248; August 17 and 24, 1951.) A detailed description of an improved cro engine indicator. The pickup heads are of an electromagnetic type with good high-frequency response. The timing errors introduced by the crankshaft degree-marker wheel and by the amplifier response have been reduced to <0.1° at 6,000 rpm. Switching between different pickups and the degree marker is instantaneous, with no float of the base line.

621.365.54/.55† 755
Radio Frequency Heating in Industry—R. 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.

621.365.54/.55† 756
Matching Problem, Efficiency and Recent Applications of High-Frequency Heating—R. Wälchli. (*Bull. schweiz. elektrotech. Ver.*, vol. 42, pp. 525–531; July 28, 1951. In German.) A simple formula for the efficiency of the inductive heating of metals is derived and the calculation of the matching of the work to the hf generator is explained. From the formula the effect of the various factors concerned in the design of the work coil is discussed. Examples of resent applications of both inductive and capacitive heating are described.

621.365.54/.55† 757
Application of Tubes in Heating Equipment—H. J. Dailey and C. H. Scullin. (*Electronics*, vol. 24, pp. 216, 240; October, 1951.) Discussion of the physical and electrical factors concerned in obtaining maximum service from tubes used in hf-heating generators.

621.38.001.8 758
Applied Electronics—C. A. Taylor. (*Nature* (London), vol. 168, pp. 283–284; August 18, 1951.) Brief description of wide variety of electronic devices exhibited at Manchester College of Technology, July, 1951.

621.384.6†:621.313.291 759
Pulsed Air Core Series Disk Generator for Production of High Magnetic Fields—R. I. Strough and E. F. Shrader. (*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 convert it rapidly into useful electromagnetic energy by using the rotating mass as the armature of a series-wound homopolar generator. When operated under short-circuit conditions, a current pulse of 56 ka maximum is obtained in the single-turn series field coil. Generators of this type may be useful as sources of magnetic field for air-core betatrons and synchrotrons.

621.384.6:621.316.721 760
Magnet Current Stabilizer—H. S. Sommers, Jr., P. R. Weiss and W. Halpern. (*Rev. Sci. Instr.*, vol. 22, pp. 612–618; August, 1951.) Design and performance of a feedback amplifier for controlling the current of a 40-kw electromagnet are described; fluctuations at frequencies $>10^{-3}$c are kept below 1 part in 10^6.

621.384.611.2† 761
Forced Betatron Oscillation in a Synchrotron with Straight Sections—N. M. Blachman. (*Rev. Sci. Instr.*, vol. 22, pp. 569–571; August, 1951.)

621.384.612.1† 762
A Dee Biasing System for a Frequency Modulated Cyclotron—L. L. Davenport, L. Lavetelli, R. A. Mack, A. J. Pote and N. F. Ramsey. (*Rev. Sci. Instr.*, vol. 22, pp. 601–604; August, 1951.)

621.385.833 763
Spherical-Aberration Correction of Electron Lenses by means of Image-Forming Elements without Rotational Symmetry—R. Seeliger. (*Optik*, vol. 8, pp. 311–317; July, 1951.)

621.385.833 764
55-kV Electron Microscope—(*Engineer* (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 lense 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 attained. The specified resolving power of the Type-EM4 is better than 100 Å.

621.387.4† 765
Radiation and Particle Detectors in Modern Nucleonic Instruments—D. Taylor. (*Jour. Brit. 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 stabilities. A typical process-control instrument is described which has an accuracy to within ±1 per cent over long periods, for the continuous routine control of α particles in solutions.

621.387.424† 766
The Slow Discharge in a Non-Self-Quenching Geiger-Mueller Counter—W. E. Ramsey. (*Jour. Frank. Inst.*, vol. 252, pp. 143–151; August, 1951.)

621.387.424† 767
The Gas Filling and some Characteristics of Bromine-Quenched Geiger-Müller Counters—D. H. Le Croissette and J. Yarwood. (*Jour. Sci. Instr.*, vol. 28, pp. 225–228; August, 1951.)

621.387.424† 768
A Toroidal Geiger Counter—C. P. Haigh. (*Nature* (London), vol. 168, pp. 246–247; August 11, 1951.) Description of an experimental counter constructed to give sensitivity nearly independent of source position over a limited region.

621.387.462† 769
Ionization Pulses and Charge Transport Mechanism in Diamond—H. Ess and J. Rossel. (*Helv. Phys. Acta.*, vol. 24, pp. 247–278; July 10, 1951. In French.)

621.398 770
Radio Telearchics—(*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 for 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).

621.398:621.396.712 771
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, with detailed circuit diagrams, of a system in use at Winchester, Va., for controlling and monitoring an unattended broadcasting transmitter over 20 miles away. Six tones in the range 18–30 kc, 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 not >5 per cent. A special receiver in the studio is tuned to the subcarrier to derive all meter readings.

621.791.3:535.61-1 772
Electronic Control of Soldering Temperatures by Infra-red Radiation—Déribéré and J. C. Stern. (*Électronique* (Paris), pp. 4–7; August/September, 1951.) The radiation from the work pieces is interrupted by the teeth of a rotating wheel and then falls on a compensated bolometer. The resulting modulated signal is amplified and used to control the heating system.

PROPAGATION OF WAVES

538.566 773
The Zenneck Ground Wave—G. Goubau. (*Z. angew. Phys.*, vol. 3, pp. 103–107; March/April, 1951.) Analysis showing that the Zenneck wave is physically possible; the problem is analogous to that of the excitation of an open waveguide. There is an orthogonal relation between the ground wave and the space wave, from which the amplitude of the former can be calculated.

538.566 774
Propagation in a Non-homogeneous Atmosphere—Friedman. (See 661.)

538.566:535.13 775
Field Representations in Spherically Stratified Regions.—Marcuvitz. (See 663.)

621.396.11+621.396.671 776
Application of the Compensation Theorem to Certain Radiation and Propagation Problems—Monteath. (See 591.)

621.396.11:538.566 777
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 main reason for 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 quantitative indication of range of the wave in free space, is determined for the whole of the field.

621.396.11+538.566]:550.38 778
The Effect of the Earth's Magnetic Field on Short Wave Communication by the Ionosphere—G. Millington. (*Proc. IEE*, Part IV, vol. 98, pp. 1–14; October, 1951.) Summary abstracted in 2805 of 1951.

621.396.11:551.510.535 779
Scattering of Radio Waves and Undulation in the Ionosphere—S. S. Banerjee, R. R. 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.

621.396.11:551.510.535 780
Spectral Representation of Space-Wave Reception and the Ionosphere—A. Spork. (*Ost. Z. Telegr. Teleph. Funk Fernsehtech.*, vol. 5, pp. 100–110; July/August, 1951.) An account of the formation and structure of the ionosphere and its influence on radio propagation, illustrated by records of reception obtained with wide-band apparatus developed by Herzan.

621.396.11:551.510.535 781
Influence of the Earth's Magnetic Field on Group Velocity and Propagation Time of Radio Waves in the Ionosphere—II. 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, assuring a plane ionosphere 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.

621.396.11:551.510.535 782
Some Calculations of Ray Paths in the Ionosphere—S. K. H. Forsgren. (*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 form. With the aid of a graphic method due to Poeverlein (2875 of 1950), ray paths have been calculated for vertical incidence, zero losses, and a parabolic electron-density distribution. Approximate formulas are given for the horizontal deviation of the ordinary and extraordinary rays for vertical incidence. Maximum deviation occurs for frequencies near the critical frequency of the layer and may be large enough to make any determination of gyrofrequency from critical-frequency measurements unreliable.

621.396.11:551.510.553(98) 783
Polar Blackouts recorded at the Kiruna Observatory—R. Lindquist. (*Acta polyt.* (Stockholm), no. 85, 25 pp; 1951.) Report and discussion of observations, beginning in October 1948, with a panoramic recorder covering the 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^2-layer ionization frequently 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.

621.396.11:621.317.087.4 784
Notes on the Analysis of Radio-Propagation Data—R. P. Decker. (PROC. I.R.E., 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 preselected signal levels were exceeded is described.

621.396.11:621.317.353.3† 785
Ionospheric Cross-Modulation—I. 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 measurement of the amplitude and phase of the modulation transferred to the wanted carrier is described and details of the equipment are given. From measurements using several pairs of B.B.C. stations, a value for the collision frequency was derived. Experimental confirmation was obtained of the laws of variation of cross modulation with (*a*) modulation frequency, (*b*) radio frequency, (*c*) power, and (*d*) modulation depth of the disturbing wave. Variations at sunrise were contrary to expectations. Self-distortion due to the frequency-

dependent absorption of energy by the ionosphere is also discussed.

621.396.11.029.45 786
The Reflection of Very-Low-Frequency Radio Waves at the Surface of a Sharply Bounded Ionosphere with Superimposed Magnetic Field—K. G. Budden. (*Phil. Mag.*, vol. 42, pp. 833–850; August, 1951.) A homogeneous ionosphere is assumed. The quasilongitudinal approximation to the magneto-ionic theory [3306 of 1935 (Booker)] is used, the reflection coefficients being then independent of the horizontal direction of the transmission path. Values derived 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 above, but the theory is likely to be most useful for investigating propagation at frequencies of 10 kc and below, used in studying atmospherics.

621.396.11.029.62 787
Radio Propagation Experiments carried out between Monte Serpeddì (Cagliari) and Monte Cavo (Rome) on Metre Wavelengths during the Period January–May 1949—A. Ascione and C. Micheletta. (*Poste e Telecomun.*, vol. 19, pp. 251–262; May, 1951.) A full description is given of the transmitting and receiving gear 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 path is 392 km long, almost entirely over sea, and 170 km of it lies outside the optical range. The recording program 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 weather; (*c*) rapidly and irregularly fluctuating, during or immediately preceding and following showers of hail or snow. Anticyclones 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 2061 of 1948 (Smith-Rose and Stickland), while wind always adversely affected the signal. In general the practical results obtained were very much better than those expected from theoretical calculations. The experiments are being continued.

621.396.11.029.63 788
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 at 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 and distance. Antenna tests were made to show the effects of antenna height at large distance. Graphs are provided which show the effects of distance, terrain, antenna height, and time upon the field strength. The practical significance of the results in the broadcast and communication fields is indicated."

621.396.11.029.64 789
Microwave Propagation in the Optical Range—O. F. Perers, B. K. E. Stjernberg and S. K. H. Forsgren. (*Acta polyt.* (Stockholm), no. 87, 20 pp; 1951.) A report of observations of transmissions from Mosseberg, Gothenburg, on wavelengths of 10, 3 and 1 cm. The transmitter 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:[534.874.1+621.396.621 790
Perturbation and Correlation Methods for Enhancing the Space Resolution of Directional Receivers—F. V. Hunt. (PROC. I.R.E., vol. 39, p. 840; July, 1951.) An assessment is made of the application of techniques for for correlation with respect to space variables as well as with respect to the time variable. A simple example illustrates the use of the technique.

621.396./397].6 791
40th Paris Fair—(*Radio prof.* (Paris), pp. 17–27; May, 1951.) Illustrated description of radio and television receivers exhibited. For other accounts see *T.S.F. pour Tous*, vol. 27, pp. 213–217; June, 1951, and *Toute la Radio*, pp. 168–170; June, 1951.

621.396.621:621.396.619.13 792
A New Method for Predicting the Adjacent-Channel Performance of Mobile Radio Equipments by Graphical Analysis—Eader. (See 745)

621.396.621.029.63 793
Receivers for Use at 460 Mc/s—E. G. Hamer and L. J. Herbst. (*Wireless Eng.*, vol. 28, pp. 323–329; November, 1951.) A discussion of design considerations with particular reference to receiver signal/noise ratio. The performance of tubes and circuits both as rf and if amplifiers is discussed. Circuits are shown of (*a*) a low-noise if amplifier used for determining noise-factor data (tabulated for various tube types), (*b*) a typical receiver comprising earthed-grid rf amplifier and earthed-grid mixer.

621.396.621.53 794
Gated-Beam Mixer—S. Rubin and G. E. Boggs. (*Electronics*, vol. 24, pp. 196, 212; October, 1951.) Discussion of the use of a Type-6BN6 tube as a mixer, preferably with outer-grid injection, the oscillator being connected to the third grid. Performance is satisfactory, in view of high transconductance, low space-charge coupling and low capacitance between control grids.

621.396.622 795
The Relative Advantages of Coherent and Incoherent Detectors: A Study of their Output Noise Spectra under Various Conditions—R. A. Smith. (*Proc. IEE*, Part IV, vol. 98, pp. 43–54;, October, 1951.) Summary abstracted in 255 of February.

621.396.822:519.272.119 796
Study of Some Statistical Patterns relative to Problems of Background Noise—A. Blanc-Lapierre. (*Rev. Sci.* (Paris), vol. 89, pp. 139–150; May/June, 1951.) The identity of the variable ν in the integral expressing the theorem of Loève with the physical concept of frequency is noted. Spectral 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, and two main spectra are identified; these are associated with flicker effect and with shot effect.

STATIONS AND COMMUNICATION SYSTEMS

621.39.001.11 797
Time and Frequency Uncertainty in Waveform Analysis—P. M. Woodward (*Phil. Mag.*, vol. 42, pp. 883–891; August, 1951.) "The concept of a structural time-constant is introduced by considering the time auto-correlation function of any wave form, 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 χ, an absolute time-frequency constant is obtained. Its value is always unity, and it is suggested that this expresses time and frequency uncertainty more precisely than the relation $\delta t \delta f \geq \frac{1}{4}\pi$. To illustrate the function χ, two special wave forms are considered, namely, the complex Gaussian pulse and the real Gaussian pulse-train."

621.395.97 798
An 8-Channel Transmitter for an Experimental Carrier Wire-Broadcasting System—R. G. Kitchen. (*Jour. Brit. IRE*, 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 evenly spaced 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. Test equipment, audio and visual monitoring facilities, and power supplies are incorporated. A selective alarm system in conjunction with unit construction facilitates maintenance. Circuit and performance details are given.

621.396.324 799
Transmitter Diversity Applied to Machine Telegraph Radio Circuits—G. E. Hansell. (*Telegr. Teleph. Age*, vol. 69, pp. 12–14,27; August, 1951.) Tests have shown that transmitter diversity is as effective in overcoming fading effects as receiver diversity. The system described used two transmitting antennas 1,500 feet apart, radiating at 15.49 mc, the respective carriers being separated by 200 cps; frequency-shift modulation was applied. Arrangements were made for having both transmitters, or one only, operative 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 impracticable or uneconomical.

621.396.4 800
Some Trends in Development in the Transmission of Information—H. F. Mayer and E. Hölzler. (*Frequenz*, vol. 5, pp. 156–166; June, 1951.) Review of wide-band carrier-current and directional radio systems and of the applications of vhf and uhf techniques in multi-channel communication.

621.396.44:621.315.052.63]+621.317.083.7 801
Single-Sideband Equipment and High-Speed Cyclic Telemetry for Carrier-Current Operation on High-Voltage Lines—H. Bloch. (*Tech. Mitt. schweiz. Telegr.-Teleph Verw.*, vol. 29, pp. 298–305; August, 1, 1951. In French and in German.) Description of Brown Boveri equipment exhibited at the 1951 Swiss Fair in Basle.

621.396.619.11+621.396.619.13 802
The Distribution of Energy in Randomly Modulated Waves—D. Middleton. (*Phil. Mag.*, vol. 42, pp. 689–707; July, 1951.) The theory of fm and phm by normal random noise is developed, as a model for speech-modulated carriers. The effect of spectral shape of the modulating noise on the intensity distribution 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 very slow 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.

621.396.65.029.621.63 803
The Turin-Piacenza Experimental Radio Link—L. Pivano. (*Poste e Telecomun.*, 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:—Turin-Rocca di Stradella, 160 and 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.

621.396.65.029.63 804
The Parameters of a Decimetre-Wave System with Pulse-Time Modulation (Pulse-Phase Modulation)—K. O. Schmidt. (*Fernmeldetech. Z.*, vol. 4, pp. 362–368; August, 1951.) A diagram based on resistance noise shows necessary signal levels throughout the communication chain. The attainment of these values in a pm 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.

621.396.7(45) 805
Present and Planned on Broadcasting Service for Italy—G. Provenza. (*Poste e Telecomun.*, vol. 19, pp. 343–346; July, 1951.)

621.396.712:621.396.66 806
Automatic Broadcast Program Monitor—A. A. McK. (*Electronics*, vol. 24, pp. 124–127; October, 1951.) See also 1491 of 1951 (Rantzen, Peachey and Gunn-Russell).

621.396.712:621.396.66 807
A Supervisory Instrument for Standard Broadcast Stations—E. D. Cook and H. R. Summerhayes, Jr. (*Gen. Elect. 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.

621.396.712:621.398 808
Remote-Control System for F.M. Broadcast Stations—Whitney. (See 771.)

621.396.712(083.81) 809
Guide to Broadcasting Stations. [Book Notice]—Publishers: *Wireless World*, Dorset House, Stamford Street, London SE 1, 6th ed., 94 pp., 2s. (*Wireless Eng.*, vol. 28, p. 349; November, 1951.) Includes frequencies and other details of European stations and of sw broadcasting stations in 117 countries.

SUBSIDIARY APPARATUS

621-526 810
Combination Open-Cycle Closed-Cycle control Systems—J. R. Moore. (Proc. I.R.E., vol. 39, pp. 1421–1432; November, 1951.

621-526 811
A General Theory of Sampling Servo Systems—D. F. Lawden (*Proc. IEE*, Part IV, vol. 98, pp. 31–36; October, 1951.)

621.314.263 812
Study of Harmonic Power Generation—P. E. Russell and H. A. Peterson. (*Elect. 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 derived harmonic. Such a circuit has been analyzed on a differential analyzer.

621.314.634 813
Recovery of Selenium Rectifiers 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. Increase of recovery speed under illumination indicates that the process is electronic and not ionic.

621.316.722 814
General Theory of Voltage Stabilizers—J. J. Gilvarry 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 stabilizer for which the approximations of the three-parameter theory are considerably in error.

621.316.933.3 815
Latest Developments in the Design of Resorbit Arresters—W. Zoller. (*Brown Boveri Rev.*, vol. 38, pp. 105–114; April, 1951.) Arresters are now produced with a rated discharge capacity of 5 to 10 ka and a maximum discharge capacity 20 times greater, and the Resorbit resistance material can now cope with low 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.

621-526 816
Servomechanisms and Regulating System Design [Book Review]—H. Chestnut and R. Mayer. Publishers. J. Wiley & Sons, New York, 1951, 505 pp., $7.75. (*Jour. Frank. Inst.*, vol. 252, p. 96; July, 1951.) "This book . . . is intended for the training of design and application engineers in the principles of feedback control."

TELEVISION AND PHOTOTELEGRAPHY

621.396./397].6 817
40th Paris Fair—(See 791.)

621.397 818
Phototelegraphy by Wire—V. Castell. (*Tech. Mitt. schweiz. Telegr.-Teleph Verw.*, vol. 29, pp. 309–312; August 1, 1951.) French version of paper abstracted in 3123 of 1951.

621.397.2:621.396.65 819
The Paris-Lille Television Radio-Relay Link—(*Radio franç.*, no. 5, pp. 6–10; May, 1951. *Telev. Franç.*, no. 71, pp. 7–10, 15; June, 1951.) Brief illustrated description of the system. The 210-km path is covered in three stages. The Eiffel Tower transmitter radiates the fm video signal on 945 mc$\pm$15 mc from a dipole with parabolic reflector. The reradiated frequencies at the two relay stations are respectively 910 and 945 mc, an if of 85 mc serving for signal amplification prior to retransmission at the higher frequency.

621.397.2:621.396.65 820
The London-Birmingham Television Radio-Relay Link—R. J. Clayton, D. C. Espley, G. W. S. Griffith and J. M. C. Pinkham. (*Proc. IEE*, Part I, vol. 98, pp. 204–223; July, 1951. Discussion, pp. 224–227; Summary, *ibid.*, Part III, vol. 98, pp. 472–476; July, 1951.) A comprehensive account of the complete system and its operation. See also 2026 of 1950 (Mumford and Booth) and back reference.

621.397.24/.26 821
Television from Calais—W. D. Richardson and W. N. Anderson. (*Jour. Telev. Soc.*, vol. 6, pp. 214–218; April/June, 1951.) A general description of preliminary tests and of the equipment used for linking Calais with London. See also 459 of 1951 (Pulling).

621.397.24 822
The Transmission of Television Signals on Telephone Lines—T. Kilvington. (*Jour. Telev. Soc.*, vol. 6, pp. 197–203; January/March, 1951.) Due to the widely varying impedance characteristics of telephone circuits, 64 constant-impedance, non-resonant equalizer sections, with fixed half-loss frequencies ranging from 15 kc to 4.67 mc and fixed zero-frequency loss from ½ to 3 db, are needed in each repeater unit for B.B.C. outside-broadcasts transmissions over ordinary telephone lines, in order to equalize the gain over the frequency range 50 cps to 3 mc. See also 2552 of 1951 (Bridgewater).

621.397.5 823
Velocity-Modulation in Television-Image Reproduction—A. B. Thomas. (Proc. I.R.E., vol. 39, p. 1341; October, 1951.) Comment on paper abstracted in 2296 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.'

621.397.5:535.62 824
Alternative Approaches to Color Television—D. G. Fink. (Proc. I.R.E., vol. 39, pp. 1124–1134; October, 1951.) Review of principles, capabilities and limitations of the field-sequential and color-subcarrier systems of color television.

621.397.5:535.62 825
Color Television and Colorimetry—W. T. Wintringham. (Proc. I.R.E., vol. 39, pp. 1135–1172; October, 1951.) An outline of modern 3-color theory, with discussion of its application to the problems of color television. 67 references.

621.397.5:535.623 826
Recent Improvements in Band-Shared Simultaneous Color-Television Systems—B. D. Loughlin. (Proc. I.R.E., vol. 39, pp. 1264–1279; October, 1951.) The "dot-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.

621.397.5:535.623 827
Analysis of Dot-Sequential Color Television—N. Marchand, H. R. Holloway and M. Leifer. (Proc. I.R.E., vol. 39, pp. 1280–1287; October, 1951.) (See 465 of 1951.)

621.397.5:535.623 828
A New Technique for Improving the Sharpness of Television Pictures—P. C. Goldmark and J. M. Hollywood—(Proc. I.R.E., vol. 39, pp. 1314–1322; October, 1951.) In a band-

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 circuit arrangements. Methods of doing this are discussed and results achieved are described.

621.397.5:535.623 829
Spectrum Utilization in Color Television—R. B. Dome. (PROC. I.R.E., vol. 39, pp. 1323–1331; October, 1951.) The frequency spectrum of the 6-mc channel, now 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 images. The three sets of data associated with color television systems may be transmitted by time-division multiplex, by frequency-division multiplex, or by combinations of these two methods. One of the latter methods, called "alternating lows," is discussed in some detail, and some of the working circuits for this method are presented. See also 3131 of 1951.

621.397.5:535.623 830
Subjective Sharpness of Additive Color Pictures—M. W. Baldwin, Jr. (PROC. I.R.E., vol. 39, pp. 1173–1176; October, 1951.) 1951 I.R.E. National Convention paper. Description of tests which indicated that an observer's sensitivity to lack of sharpness in color pictures is greatest for the green component and least for the blue. In monochrome (white, red, green or blue) the sensitivity is equal to that for the green component in color pictures.

621.397.5:535.623](083.74) 831
Color Television—U.S.A. Standard—P. 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 discusses their 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."

621.397.5:621.317.755 832
Oscillographic Representation of Television Signals—Sturley. (See 741.)

621.397.5(083.74) 833
Video Levels in TV Broadcasting—J. H. Roe. (*Tele-Tech.*, vol. 10, pp. 45–47, 64; August, 1951.) A review of progress made in standardizing and measuring the levels of the components of television signals with the object of improving performance and of facilitating the exchange of programs via land-line networks.

621.397.61 834
The Vision Transmitter for the Sutton Coldfield Television Station—E. A. Nind and E. McP. Leyton. (*Proc. IEE*, Part III, vol. 98, pp. 442–459. Discussion, pp. 465–470; November, 1951.) A general description, with additional details of novel parts of the equipment. Aspects of design that are discussed include the general arrangement of the transmitter, the rf and modulation amplifiers and associated circuits, special features of the power-supply, control, monitoring and supervisory facilities, and testing equipment.

621.397.61 835
Automatic Synchronizing Generator for TV—C. Ellis. (*TV Eng.*, vol. 2, pp. 20–22, 25 and 22–23; August and September, 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 different required pulse widths are produced by using delay lines.

621.397.61:621.326 836
Blue *TV* Lamp Design Report—R. D. Chipp. (*TV Eng.* vol. 2, pp. 16–17, 29; August, 1951.) An incandescent lamp partially enclosed in a translucent blue reflector, and mounted inside an ordinary reflector, provides light with a spectrum suitable for television studio use.

621.397.61:621.392.52 837
The Vestigial-Sideband Filter for the Sutton Coldfield Television Station—Cork. (See 626.)

621.397.611.21 838
Practical Use of Iconoscopes and Image Orthicons as Film Pickup Devices—K. B. Benson and A. Ettlinger. (*Jour. Soc. Mot. Pict. & Telev. Eng.*, vol. 57, pp. 9–14; July, 1951.) Problems involved in current practice are discussed in relation to fundamental theory.

621.397.62 839
The English Electric [Co.] Television Receiver—D. J. Fewings. (*Jour. Telev. Soc.*, vol. 6, pp. 184–192; January–March, 1951.) The circuit design is fully described.

621.397.62:621.385.832 840
The 'Ion Spot' Problem in Television—L. Chrétien. (*T.S.F. pour Tous*, vol. 27, pp. 221–225; June, 1951.) The mechanism causing staining of the screen in cr tubes is discussed, and known remedies are described.

621.397.62:621.396.615.17 841
Timebase for Television Receivers—E. Kinne. (*Funk u. Ton.* vol. 5, pp. 429–434; July, 1951.)

621.397.621.2 842
The Design and Operation of Television Cathode-Ray Tubes—L. S. Allard. (*Electronic Eng.*, vol. 23, pp. 292–297; August, 1951.) Discussion with special reference to electron guns and deflection systems.

621.397.621.2:535.623 843
Methods Suitable for Television Color Kinescopes—E. W. Herold. (PROC. I.R.E., vol. 39, pp. 1177–1185; October, 1951. *RCA Rev.*, vol. 12, Part II, pp. 445–465; September, 1951.) A brief description of various practical systems involving excitation of suitable phosphors by an electron beam is given under the following headings: accurate beam-scanning method; signal control by scanning-beam position; adjacent image method; multiple-color phosphor screen; beam control at phosphor screen for changing color; and direction-sensitive color screens.

621.397.621.2:535.623 844
A Three-Gun Shadow-Mask Color Kinescope—H. B. Law. (PROC. I.R.E., vol. 39, pp. 1186–1194; October, 1951. *RCA Rev.*, vol. 12, Part II, pp. 466–486; September, 1951.) The three phosphor colors are arranged in groups of three dots forming an equilateral triangle, and each dot is illuminated by one only of the beams from three electron guns. A thin perforated metal sheet close to the screen has one hole for each trio of phosphor dots; the electron beams are inclined to one another so that each beam as it scans falls on only one dot of the trio. The design geometry of the mask and screen arrangements for maximum efficiency of operation are considered. Construction details of the assembly are given. Experimental tubes have been demonstrated successfully.

621.397.621.2:535.62 845
A One-Gun Shadow-Mask Color Kinescope—R. 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 accomplished 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 may be shared in time sequence or continuously between the three primary colors. The chief problems associated with this system are in the design of the electron-optical system for deflecting the beam into different color positions and, for sequential presentation, in the blanking-off of the beam between different color positions. Practical solutions of these and other problems are described.

621.397.621.2:535.623 846
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 single electron beam scans, at an angle of incidence of 45°, the back of a perforated metal plate which is coated with red, green and blue phosphor strips on the front. It is mounted parallel to a glass plate coated with a transparent conducting film. The electrons passing through the slots are reflected back on to the phosphors by an electric field applied between the plates, and variation of this field shifts the beam from one color phosphor to another. Features of this system and its variants are simplicity of screen construction, small color-switching power required, and automatic registry of the three colors. Good results have been obtained with experimental tubes.

621.397.621.2:535.623 847
A Grid-Controlled Color Kinescope—S. V. Forgue. (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 construction are considered. Two- and three-color experimental tubes have been operated with the R.C.A. color-system signal.

621.397.621.2:535.623 848
Development and Operation of a Line-Screen Color Kinescope—D. S. Bond, F. H. 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, a stepped deflection voltage being 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 deriving control information from secondary-emission-signal areas on the screen. Tubes of 16-inch envelope diameter have given pictures of high horizontal definition and adequate color purity.

621.397.621.2:535.623 849
Phosphor-Screen Application in Color Kinescopes—N. S. Freedman and K. M. McLaughlin. (PROC. I.R.E., vol 39, pp. 1230–1236; October, 1951. *RCA Rev.*, vol. 12, Part II, pp. 568–582; September, 1951.) Describes the technique of preparing cr tube screens composed of dots or lines of three different

color phosphors. The pattern for each color is produced by forcing the phosphor, suspended in a lacquer, through a gelatine stencil supported by a steel mesh; it is located to an accuracy of better than 0.001 inch over the entire screen.

621.397.621.2:535.623 850
Three-Beam Guns for Color Kinescopes—H. C. Moodey and D. D. Van Ormer. (Proc. I.R.E., vol. 39, pp. 1236–1240; October, 1951. *RCA Rev.*, vol. 12, Part II, pp. 583–592; September, 1951.) The gun principally described consists of three guns aligned with axes parallel, equidistant from the assembly axis, and evenly spaced round it. Separate leads are provided for cathodes and grids 1 and 2 of each gun; the potentials of grids 3 and 4 may be varied to maintain beam focus and convergence during scanning. Construction details of this gun are given, and also of certain other types.

621.397.621.2:535.623 851
Mechanical Design of Aperture-Mask Tri-color Kinescopes—B. E. Barnes and R. D. Faulkner. (Proc. I.R.E., vol. 39, pp. 1241–1245; October, 1951. *RCA Rev.*, vol. 12, Part II, pp. 593–602; September, 1951.

621.397.621.2:535.623 852
Effects of Screen Tolerances on Operating Characteristics of Aperture-Mask Tri-color Kinescopes—D. D. Van Ormer and D. C. Ballard. (Proc. I.R.E., vol. 39, pp. 1245–1249; October, 1951. *RCA Rev.*, vol. 12, Part II, pp. 603–611; September, 1951.)

621.397.621.2:535.623 853
Deflection and Convergence in Color Kinescopes—A. W. Friend. (Proc. I.R.E., vol. 39, pp. 1249–1263; October, 1951. *RCA Rev.*, vol. 12, Part II, pp. 612–644; September, 1951.) A method is described for obtaining deflection with satisfactory convergence of the beam when a shadow-mask color kinescope is used. The convergence at each point of the screen was studied with the aid of a conical scan produced by a rotating magnetic field; it could be corrected by adjustments of the deflection yoke or of the convergence lens. A method applicable to single-beam line-screen color kinescopes is also described briefly.

621.397.7 854
The Sutton Coldfield Television Broadcasting Station—P. A. T. Bevan and H. Page (*Proc. IEE*, Part III, vol. 98, pp. 416–441. Discussion, pp. 465–470; November, 1951.) A description is given of the design, construction and service performance of the station, which operates on sound and vision carrier frequencies of 58.25 mc and 61.75 respectively. The relation of the operating channel to the frequency allocation plan for the United Kingdom and the reasons for using vestigial-sideband vision transmission are discussed. The choice of site, the sources of power and the layout of the buildings are considered.

The vision transmitter is of the high-power modulated type giving a peak-white power output of 42kw, and the amplitude/frequency characteristic is shaped by means of a vestigial-sideband filter. The sound transmitter has a final stage of the earthed-grid coaxial-line power-amplifier type capable of being tuned over the band 41–68 mc and giving a power output of 12 kw. The control and cooling equipment and the measured performance characteristics for both transmitters are described.

The vision and sound signals are supplied by separate transmission lines to a combining diplexer at the top of a 750 foot mast and are radiated from the same antenna system. This consists of two rings of vertical folded dipoles, each ring having four units, the phase changing progressively round the rings in steps of 90°. The method of obtaining this phase relation and of adjusting the admittance/frequency characteristic of the complete system to give a voltage swr of better than 0.96 over the required band is described. A field-strength map of the service area is included.

621.397.82 855
Observer Reaction to Low-Frequency Interference in Television Pictures—A. D. Fowler. (Proc. I.R.E., vol. 39, pp. 1332–1336; October, 1951.) Report of tests to determine how much low-frequency interference can be tolerated in black-and white television pictures. See also 751 of 1951 (Mertz et al.).

621.397.828 856
The Overtone Crystal Oscillator against TVI—E. J. Pearcey. (*Short Wave Mag.*, vol. 9, pp. 278–282; July, 1951.) Consideration of the choice of fundamental frequency of the crystal in a hf or vhf amateur transmitter and the use of overtone operation to minimize interference with television reception from the British stations.

TRANSMISSION

621.396.619:621.319.53 857
High-Power Pulse Generator with Controlled Spark-Cap—Prokott. (See 612).

TUBES AND THERMIONICS

621.383.2 858
Lithium-Antimony Photoelectric Cathodes—N. Schaetti 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.

621.383.2.032.21:537.312.5 859
Photoconductivity of Composite Photoemissive Cathodes—S. Pakswer and W. O. Reed. (*Jour. Appl. Phys.*, vol. 22, pp. 987–988; July, 1951.) Discussion of investigations on semitransparent photoemissive coatings of Ag-O-Cs, Sb-Cs, and PbS-Cs.

621.383.4:546.817.241 860
Photoconductivity in the Infrared Region of the Spectrum: Part 1—The Preparation and Properties of Photoconductive Films of Lead Telluride—O. Simpson and G. B. B. M. Sutherland. (*Phil. Trans.*, *Ser. A*, vol. 243, pp. 547–564; August 16, 1951.) "The method of preparation of photoconductive films of lead telluride is described. Details are given of the construction of cells suitable for infrared detection in spectroscopic applications. Lead telluride is not photosensitive at room temperature, but is strongly photoconductive at temperatures in the region of −190°C. The conductivity of lead telluride as a function of the applied voltage, and the wavelength and intensity of illumination has been investigated, for seven films of widely different conductivity, at liquid-air temperature. The application of the photoconductive effect to infrared detection is discussed, and attention is drawn to the effect of any background of thermal radiation on the performance of a cooled photoconductor."

621.383.4:546.817.241 861
Photoconductivity in the Infrared Region of the Spectrum: Part 2—The Mechanism of Photoconductivity in Lead Telluride—O. Simpson. (*Phil. Trans.*, *Ser. A*, vol. 243, pp. 564–584; August 16, 1951.) "A method is described by which thin semi-conducting films of nearly stoichiometric lead telluride can be prepared by evaporation, in a sequence with increasing impurity of lead. The conductivity and infrared photoconductivity of the specimens has been investigated as 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 oxygen at room temperature is equivalent to the removal of excess lead; the presence of oxygen is not a requirement for the appearance of photoconductivity. These observations are used to draw conclusions concerning the mechanism of the photoconductivity. It is shown that all the phenomena can be explained by a single lattice model, without recourse to internal potential barriers or inhomogeneities in the composition of the samples."

621.385+621.396.6 862
New Radio Components in the World Market—Alixant. (See 628.)

621.385 863
The JETEC Approach to the Tube-Reliability Problem.—J. R. Steen (Proc. I.R.E., vol. 39, pp. 998–1000; September, 1951.) An outline of statistical methods of assessing reliability and of procedures considered by the Joint Electron-Tube Engineering Council as necessary for the production of more reliable types of tube.

621.385.011 864
On the Rigorous Calculation of the Transconductance of Planar Systems on the Basis of Potential Theory.—O. Heymann. (*Frequenz*, vol. 5, pp. 57–62 and 97–107; March and April, 1951.) The method developed avoids mathematical difficulties of the image techniques. 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.

621.385.012.6 865
Electron-Tube Performance with Large Applied Voltages—A. E. S. Mostafa. (Proc. I.R.E., vol. 39, p. 1432; November, 1951.) Correction to paper abstracted in 1517 of 1951.

621.385.029.62/.63 866
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/.63 867
Traveling-Wave Amplification by means of Coupled Transmission Lines—W. E. Mathews. (Proc. I.R.E., vol. 39, pp. 1044–1051; September, 1951.) The theory of interaction between coupled transmission lines moving relative to each other is developed, and conditions yielding waves increasing exponentially with distance are found. The case of lossless lines, one 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, so that when the translational 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 translational 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 traveling-wave oscillator has been built; this was demonstrated at the I.R.E. Conference on Electron Devices. Princeton, June 1949.

621.385.032.216 868
On the Initial Decay of Oxide-Coated Cathodes—T. Hibi and K. Ishikawa. (*Jour. Appl. Phys.*, vol. 22, pp. 986–987; July, 1951.) Investigation of the effect produced on the decay by heating getter deposits in tubes.

621.385.032.216:546.841.3 869
Conductivity and Other Electrical Properties of Thoria in Vacuo—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 thoria. 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 of 1951 (Mesnard).

621.385.3:546.289:621.396.822 870
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.

621.385.3:621.396.615.14 871
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. Yamanaka. (*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.

621.385.38 872
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.

621.385.38 873
A New Amplifier Arrangement—R. Besson. (*Toute 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)

621.385.38 874
A High-Current Thyratron—A. W. Coolidge Jr. (*Elect. Eng.*, vol. 70, pp. 698–699; August, 1951.) 1951 A.I.E.E. Winter General Meeting paper. Description of the thyratron Type GL-5855, with peak and average current ratings of 150 and 12.5A respectively, a 2.5-V cathode and an anode voltage rating of 1,500 V. Construction details are given, one feature being the use of rigid strap connections instead of a tube base.

621.385.38 875
The Thyratron Grid Spike—M. P. Givens. (*Rev. Sci. Instr.*, vol. 22, pp. 533–534; July, 1951.) When a thyratron 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.

621.385.832 876
An Electrostatic-Tube Storage System—A. J. Lephakis. (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 $3.3+10^4$ per second and $7+10^4$ per second for the storage of pulsesand for supplying stored pulses.

621.396.615.141.2 877
The Magnetron in the Condition of Static Space Charge: Magnetrons with Axial Anode—J. L. Delcroix. (*C. R. Acad. Sci.* (Paris), vol. 233, pp. 546–547; August 20, 1951.) The study of the bidromic 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.

621.396.615.142.2 878
The Effects of Grid Mesh on the Performance Characteristics of Klystrons—S. Uda and J. Ikeuchi. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. B*, vol. 1/2, pp. 105–116; January, 1951.)

621.396.615.142.2 879
Electron Oscillation of the Reflex Klystron—M. Ishida and Y. Ibaraki. (*Sci. Rep. Res. Inst. Tohoku Univ., Ser. B*, vol. 1/2, pp. 327–336; March, 1951.) An electron oscillation, independent of the cavity, is obtained with the parallel-plane electrode structure of a reflex klystron. The characteristics of this oscillation are studied theoretically and experimentally and compared with the velocity-modulation oscillation.

MISCELLANEOUS

001.891:621.396 880
University Research in Physics: Part 2—Research in Physics at Cambridge University. Radio Research—J. A. Teegan. (*Beama Jour.*, 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.

001.891:621.396.029.6 881
Study Centre for Microwave Physics: Activities during 1950—N. Carrara. (*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.